Repair is the process of treating an imperfection in the concrete so that the product’s service life will not be impacted.

Repair requires 2 elements:
- **Skill:** The art of making the repair
- **Knowledge:** Knowing how to do it right

Our goal is to educate those that perform or manage the repair process of precast products:
- Identify repair problems
- Determine the root cause for corrective action
- Determine the repair process based on the type of repair needed
- Establish the repair procedure
- Address approval process by QC, governing agency, and/or specifying authority
- Deliver quality product to the customer

**CP1 – PRECAST CONCRETE REPAIR**

**Objective**
- Determine repair strategy
  - Service conditions
  - Structural vs. Non Structural (cosmetic) repairs
- Repair Methods
  - Material selection
  - Application conditions
  - Surface preparation
  - Material placement
  - Equipment
- Focus on precast production
  - In plant, erection
  - WRT causes, applications, and methods

**Agenda**
- Take a picture to use with your repair analysis
- Define what the problem is and why (if known)
- Determine when the damage was caused
  - Production issue?
  - Handling?

**Root Cause Analysis**
- Analyze costs
- Wasted profits
  - $18 - $45 for bag of repair material
  - Multiplication factor to apply
  - $80 per bag at 10 bags a week = $800 wk., $40,000 yr.
- Develop a metric to measure repair costs
  - What doesn’t get measured doesn’t improve
  - Bag of repair material per day/week/month
  - Bag of repair material per yard of concrete poured
  - etc.
**CP1 – PRECAST CONCRETE REPAIR**

**Root Cause Analysis**

**Corners are spalling or cracking**
- Is it caused by improper handling with impacts on the edges?
- Does the form bind up when stripping? Is there an indentation in the form?
- Is concrete bleeding into the form joints?
- Is the form coating providing sufficient release?

**Handling issues – you can control**

**CP1 – PRECAST CONCRETE REPAIR**

**Root Cause Analysis**

**Corners are spalling or cracking**
- Do you need reinforcement?
- Form joints tight?
- Form coating – sticky leaves concrete build-up
- Costs money to clean forms and repair products

**Damaged concrete around chamfer area**
- Improper vibration?
- Did the forms yield while the concrete was in the plastic state?

**CP1 – PRECAST CONCRETE REPAIR**

**Root Cause Analysis**

**Honey combing or voids**
- Vibration inadequate?
- Concrete not placed properly?
- Steel shifted or not in proper location?
- Concrete mix design too stiff?
- Concrete flash set creating placement problem?
- Delayed placement of concrete?
- Design issue with too much reinforcement congestion?

**CP1 – PRECAST CONCRETE REPAIR**

**Root Cause Analysis**

**Determine what needs to change to ...**

*... Prevent this problem from occurring again*

- Decide on corrective actions based on where the problem occurred.
- Is it a production issue, handling, or design problem?
- Should your QC procedures be revised to address these problems?

**CP1 – PRECAST CONCRETE REPAIR**

**Root Cause Analysis**

**Service Requirements**

**Special Finishes:**

- Exposed surfaces
  - Specified coatings that require small bug holes to be filled
CP1 – PRECAST CONCRETE REPAIR  
Service Requirements

Special Finishes:
- Determine requirements based on type of construction
  - Form finish
  - Architectural
  - Surface details, colors, or textures must be consistent
- The CHALLENGE is to repair without making the repair obvious

CP1 – PRECAST CONCRETE REPAIR  
Non Structural vs. Structural Repair

Surface Defects
- Bug holes
- Scaling
- Voids
- Honey combs
- Surface spalls
- Surface cracks
- Architectural repairs

Structural Defects
- Deep spalling
- Exposed reinforcement
- Rock pockets
- Cracking
  - Transverse
  - Full depth
- Under strength
- Capacity impaired

CP1 – PRECAST CONCRETE REPAIR  
Structural Definition

- Affects the concrete’s performance
  - Loads
  - Protection and connection to reinforcement (significantly exposed)
- Repair area engages live or dead loads
  - Including lifting points
- Loss of structure cross section
- Weakening of constituent materials
- Necessary to reestablish structural capacity
  - Determined by structural engineer

CP1 – PRECAST CONCRETE REPAIR  
Surface Defects

- Voids
- Honey Comb (Surface)
**Surface Defects**

- Surface Cracks
  - Plastic Shrinkage
- Scaling

**Structural Defects**

- Transverse Cracks
  - Exposed reinforcement
- Major Spalling

**Structural vs. Non Structural Repairs**

- Similar substrates and material components
- Increased service requirements
  - Loads
  - Exposure
  - Environmental conditions
  - Wet / dry cycles
  - Freeze thaw
  - Water
  - Chlorides
  - Corrosion

- Require different methods and materials

**Examples, Root Cause analysis**

- Detail
  - Rock Pockets (no binder)
**CP1 – PRECAST CONCRETE REPAIR**

**Structural Defects**

- Product handling and storage

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Spall Repairs**

Identify structural spall:
- Load bearing
- Transfers load
- Exposed steel reinforcement
- Deep / full depth
- Significant stresses are likely to develop in or immediately around the patch material due to service loads

Determine service conditions:
- Mild: Interior
- Moderate: Wet / dry cycles
- Severe: Freeze thaw, water, chlorides

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Spall Repairs**

Overview
- Select orientation
  - Horizontal, vertical, overhead
- Select application method
  - Hand applied, form & pour, form & pump, low pressure spray, high pressure shotcrete
- Select appropriate repair mortar
  - Cementitious, polymer modified, silica fume enhanced, fiber reinforced, air entrained, corrosion inhibitor enhanced, accelerated or non-accelerated

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Defects**

Causes
- Poor form construction
- Difficult / rough removal from forms
- Early removal, low strengths
- Structure design
  - Concrete mix
  - Reinforcement
- Thermal shock (forms, environment)
- Poor handling methods
- Improper storage
Strength (compressive, flexural, tensile, bond)
Modulus of elasticity
Coefficient of thermal expansion
Permeability
Freeze/thaw resistance
Shrinkage
Thickness
Set/cure time
Application method
Color

Select repair material to best match/meet host concrete properties
Why not use original concrete?
- Thickness (aggregates)
- Set time
- Bond
- Orientation
What’s the big deal about M.O.E.?

Modulus of Elasticity is important:
- The concrete and the repair material must react similarly to loads
  - When an external load (compressive or tensile) is applied parallel to the bond line, low modulus materials deform more than the high modulus materials
  - Loads will be transferred from low modulus materials to high modulus materials
  - Stress concentration may cause failure of the high modulus materials

Generally, match MOE for similar performance
- Lower MOE attracts less of the load
- Higher MOE absorbs more of the load

Compared to host concrete, faster setting, higher strength repair materials (for application convenience) are offset by a lowered MOE (polymers) and greater bond strengths (load transfer) to closely match substrate concrete performance

Material selection process is one of informed compromises

Material Selection
- Cement based
- Cement based with mineral additives
- Polymer-modified cement based
- Epoxy modified, cement-based
- Epoxy mortar

Color is generally not a determining factor for structural repair material selection
Sometimes worth consideration
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CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Material Selection

Cement Based

**Advantages**
- Compatible with concrete
- Economical
- Mix with water, easy cleanup
- Resist high temperatures

**Limitations**
- Critical water:cement ratio
- Shrinkage, curing
- Slow reactions
- Low tensile, flexural, bond strengths
- Surface preparation

Epoxy Modified Cement Based

**Advantages**
- Excellent adhesion
- Adhesion on damp concrete
- Very low permeability
- Corrosion protection
- Chemical resistance

**Limitations**
- Three components (typically)
- Ratios are critical
- Must not freeze
- Finishing difficulties
- Higher cost

Epoxy Mortar

**Advantages**
- Impervious to moisture and de-icing salts
- High abrasion, skid resistance
- Minimal added dead weight
- Rapid turnaround - open to traffic in 4 - 6 hours

**Limitations**
- Mixing is critical
- Vapor barrier
- Thermally incompatible
- Creep
- Higher cost
- Solvents needed for cleanup

Polymer Modified Cement Based

**Advantages**
- Adhesion
- Low permeability
- Increased flexural strengths
- Increased abrasion resistance
- Lower modulus

**Limitations**
- Proper latex
- Application time
- 45°F (vs. 40°F) and rising
- Preconditioned material
- Finishing
- Moderate cost

Best mix of properties, speed, and economy for STRUCTURAL REPAIRS

Polymer Modified Cement Based

- The use of a water-dispersed polymer as a secondary adhesive in Portland cement concrete or mortar
- 1 or 2 component
  - Liquid polymer added
  - Powdered polymer included

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Material Selection

Cement Based with Mineral Additives

**Advantages**
- Improved adhesion
- High strengths
- Low permeability
- Abrasion, impact resistance
- Improved durability

**Limitations**
- Workability problems
- Finishing (sticky)
- Curing is critical
- Mixing is critical
- Higher cost

Epoxy Modified Cement Based

**Advantages**
- Impervious to moisture
- High abrasion, skid resistance
- Minimal added dead weight
- Rapid turnaround - open to traffic in 4 - 6 hours

**Limitations**
- Mixing is critical
- Vapor barrier
- Thermally incompatible
- Creep
- Higher cost
- Solvents needed for cleanup
CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Material Selection

With or without a corrosion inhibitor?
- Owners goal
- Owners budget
- Physical condition of structure
- Sensitivity to loss of use
- Ease of installation
- Durability
- Ease of maintenance

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Application

- Horizontal, Vertical, Overhead
- Hand Applied
- Form and Pour
  - Form and Pump
  - Machine Applied

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs
Application

- Remove unsound concrete
- Surface preparation for repair material
- Expose and clean reinforcement
- Prime reinforcement and substrate with an anti-corrosion coating or bonding agent
- Place repair mortar and cure
  - Mitigate active corrosion with inhibitor
  - Protect from future chlorides, carbonation and freeze-thaw cycles
  - Monitor overall corrosion activity

Two key ingredients of a successful repair job:
- 5% Material
- 95% Surface Prep

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Surface Preparation

- Detailed technical guidelines
- ICRI - International Concrete Repair Institute
- www.icri.org
- Industry standards
- Useful guides include
  - Guide # 310.2 (03732) - Surface Prep Methods
  - Guide # 310.1R (03730) - Geometry-Rebar

- Geometry: “square”
- Perimeter: saw cut edges
- Depth: uniform
- Profile: fractured aggregate
- Reinforcement: clean and accessible
- SSD: saturated surface dry
CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Removal Geometry

- Open Pore
  - Clean
  - Sound
  - Typical for coatings

- Fractured-Aggregate
  - Stone breaks before it pops out
  - Typical for spall repair

For cementitious repairs:
- Saturated Surface Dry
- Moisture drive
- Prevents drying at glue line
- Less than 4%
- Frost awareness

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Surface Profile

CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs – Reinforcement

- Remove concrete around corroded reinforcement
- Perimeter should be cut 90 degrees to surface
- Remove concrete a minimum of ¾” underneath reinforcement
- Steel should be brushed to white finish to remove any corrosion
- Rebar coatings
CP1 – PRECAST CONCRETE REPAIR
Structural Spall Repairs - Tools

- Proper trowels
  - Mag floats for placing polymer mortars
  - Wood or sponge floats
  - May steel trowel after set
  - Blisters!
- Mixing
  - "WC" ratio
  - Shear paddle
  - Mix time
  - Pot life

Tools

- Always consult manufacturer data sheets
- Specialty materials have specialty requirements (for special results!)
- Mix mechanically with low speed drill (400-600 rpm) and mixing paddle or mortar mixer if allowed
- Start mixing by adding most of liquid (3/4 - 7/8) to a clean pail
- Add powder slowly, ensuring all powder wets out
- Adjust liquid dosage if necessary to achieve desired consistency
- Mix to uniform consistency, generally 3 minutes per manufacturer

Precautions

- Are bonding agents absolutely required
  - Not necessarily
    - Vibration may be used when feasible
    - Pumping into forms under pressure
    - Machine application particularly at high pressure
  - Why use a bonding agent?
    - Increases opportunity to succeed, especially for hand-applied projects
    - Helps ensures consistent, well bonded repairs
    - Material forced into pore structure
    - Increase total bonded surface area and mechanical interlock
    - Serves as a 'primer' to prepare the substrate to receive the topping
    - Protect reinforcement
  - Not insurance

Recommended for:

- Low slump mixes
- No slump mixes

Acceptable bonding agents

- Polymer liquids
  - Not all polymers equal, generic term
  - Basic performance
- Proper scrubcoat
  - SSD substrate, no dilution
- Epoxies
  - Wet on wet
- Epoxy cements
  - Extended open times
**CP1 – PRECAST CONCRETE REPAIR**  
Structural Spall Repairs – Scrub Coat

- Substrate should be SSD before application begins  
- Mixed material should be scrubbed into substrate, filling all pores and voids  
- Force material against edge of repair area working to the center and compacting around exposed reinforcement

**Learning points:** overfilling, shaving, bellying, blistering

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**CP1 – PRECAST CONCRETE REPAIR**  
Structural Spall Repairs – Vertical Overhead

- After filling repair, consolidate and screed  
- Finish with steel, magnesium, wood, plastic floats, or damp sponges depending on desired surface texture  
- For multiple lifts, score top surface on each lift to produce a roughed substrate for the next lift.  
- If previous layers are more than 6 hrs old, mechanically prepare

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Learning points: proper surface preparation
For horizontal and vertical applications
Material chosen should be low shrinkage and provide sufficient flow
Ensure depth appropriate for material
Extend with SSD aggregate as allowed
Vibrators can be used to coax material into hard to fill areas
Rodding material from access points aids in consolidation

Concrete or repair material?
Why?
Scrub coat
Pour in to wet
Screed to level

Accelerated materials mean accelerated need for curing!
Cure with as much diligence as you would your own pieces!
Wet, burlap, poly, compounds
Complete coverage
Consistent curing

Surface Preparation
Clean Concrete
Saturated Surface Dry Condition
Scrub coat / bonding agent
Aggregate used for extension- saturated
Temperature limitations
Curing

Things to avoid:
Feather edges
Abrupt changes in width or depth
High length/width ratio
Undercutting
Poor surface
Temperature extremes
Over finishing
CP1 – PRECAST CONCRETE REPAIR
Structural or Non Structural

Will we:
• Improve appearance of the concrete surface
• Provide watertightness
• Restore or increase strength
• Restore or increase stiffness
• Improve functional performance
• Improve durability
• Prevent development of a corrosive environment at reinforcement

CP1 – PRECAST CONCRETE REPAIR
Structural or Non Structural

Will we:
• Improve appearance of the concrete surface
• Provide watertightness
• Restore or increase strength
• Restore or increase stiffness
• Improve functional performance
• Improve durability
• Prevent development of a corrosive environment at reinforcement

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Static or Dynamic

• Non-moving cracks
  – Repair with epoxy resin adhesive
  – Gravity feed or epoxy injection
  – Used for static cracks
  – Can repair horizontal, vertical and overhead cracks
  – If substrate is dynamic, crack will reopen or translate elsewhere in the member

• Moving cracks
  – Repair by routing and filling with flexible sealant
Concrete cracking problems
- Cracking due to loading
- Cracking in the absence of loading

Cracking due to loading
- Early release, low strengths
- Overstressing
- Improper design / configuration
- Construction movements
- Erection tolerance
- Subgrade movement (installation)
- Settlement (installation)
- Soft soils (installation)
- Backfilling (installation)

Cracking in the absence of loading
- Plastic shrinkage
- Drying shrinkage
- Thermal changes
- Humidity
- Expansion
  - Aggregates
  - Corrosion

Plastic Shrinkage
- Cracking that develops in the surface soon after it has been placed and while still in a plastic state
- Plastic shrinkage cracks are generally parallel to one another and perpendicular to the direction of the wind

Drying Shrinkage
- Concrete is typically "restrained" so changes in volume result in cracks because concrete is weak in tensile
- Volume changes occur due to chemical and autogenous shrinkage – both a result of hydration
  - Chemical: Absolute reduction in volume of solids & liquids
  - Autogenous: Macroscopic volume reduction of cement paste
- Concrete can shrink 1/8" in 20 ft.
### Drying Shrinkage

**Causes**
- Inadequate curing
- Improper jointing
- Form temperature
- Reinforcing steel temperature

**Prevention**
- Protect concrete
- Moisture cure 5-7 days
- Joint spacing & depth
- Dampen/cool forms
- Reduce temperature
- Fibers

### Thermal Cracking

**Causes**
- Temperature differentials
- Excessive heat of hydration
- Ambient temperature variations

**Prevention**
- Reduce concrete temperature
- Delay cooling
- Control cooling, heating rate
- Utilize SCM’s
- Increase tensile PSI

### Crazing

**Causes**
- Excessive finishing
- Finishing with bleed water
- Sprinkling cement on surface to control bleed
- Overly wet mixes
- Weather conditions
- Improper curing

**Prevention**
- Finish at the proper time
- Cure Concrete
- Use moderate w/c to reduce bleed
- Use wind barriers or evaporation reducers

### Structural Cracks – Allowable Crack Width

**ACI 224R-Table 4.1: Guide to reasonable crack widths, reinforced concrete under service loads**

<table>
<thead>
<tr>
<th>Exposure condition</th>
<th>Crack width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry air or protective membrane</td>
<td>0.16 in.</td>
</tr>
<tr>
<td>Humidity, moist air, soil</td>
<td>0.012 in.</td>
</tr>
<tr>
<td>Deicing chemicals</td>
<td>0.007 in.</td>
</tr>
<tr>
<td>Seawater and Seawater spray, wetting and drying</td>
<td>0.006 in.</td>
</tr>
<tr>
<td>Water-retaining structures</td>
<td>0.004 in.</td>
</tr>
</tbody>
</table>
CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Allowable Crack Width

- Low viscosity – easy to pour
- Low surface tension
- Fills cracks easily
- Easy and safe to mix and apply
- High bond strength to concrete
- Bonds well to damp concrete

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Epoxy Resins

- Epoxy bond strength > Concrete tensile strength
- Allows for solid, structural repair

- Use (ASTM Type)
- Viscosity (ASTM Grade)
- Temperature (ASTM Class)
- Moisture tolerance
- Set time
- Packaging

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – ASTM C881

• Type I
  - Non-load bearing; hardened concrete to hardened concrete
• Type II
  - Non-load bearing; fresh concrete to hardened concrete
• Type III
  - Skid resistant material to hardened concrete; binder for mortars used in traffic applications
• Type IV
  - Load bearing; hardened concrete to hardened concrete; binder for mortars
• Type V
  - Load bearing; fresh concrete to hardened concrete
• Type VI
  - Bonding and sealing segmental precast w/ internal tendons; span-by-span erection
• Type VII
  - Non stress carrying sealer segmental precast; NOT span-by-span

System for classifying 2-component, epoxy-resin bonding systems for application to Portland-cement concrete

- Physical requirements
  - Type I, II, III, IV, V, VI, & VII
- Flow characteristics
  - Grade 1, 2, & 3
- Suitable temperatures
  - Class A, B, C, D, E, & F
- Color
  - Pigmented or non
CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – ASTM C881 Grade

- Grade 1 – Low Viscosity
  - Very fluid
  - Max 20 Poise
- Grade 2 – Medium Viscosity
  - Oil or paint consistency
  - Min 20 Poise; Max 100 Poise
- Grade 3 – Non-sagging consistency
  - Peanut butter
  - Consistency at ¼"

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Epoxy Resins

- Exothermic reaction!
- Mass dependent!
- Produce heat – mixing time and dispersal critical

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Surface Preparation

- It does not have to be complicated
  - Wire brush
  - Abrasive grinding disc

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Application Overview

- Gravity feed
- Hand injection
- Low pressure injection
- High pressure injection
- Verification

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – ASTM C881 Class

<table>
<thead>
<tr>
<th>Class</th>
<th>Min</th>
<th>Max</th>
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<tbody>
<tr>
<td>A</td>
<td>-</td>
<td>40</td>
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<tr>
<td>B</td>
<td>40</td>
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<td>C</td>
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<tr>
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<td>75</td>
<td>90</td>
</tr>
</tbody>
</table>
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CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Gravity Feed

- Repair cracks on horizontal surface
- Use gravity to fill crack with resin and structurally bond the concrete
- Pressure is not used to drive the resin
- Gravity pushes the resin in the crack
- Keeps out water, salt and other aggressive elements
- Effective method but has its limitations

Equipment

- For smaller projects:
  - Grinder and air compressor
  - Mixing buckets, drills, mixing paddles
  - Flat rubber squeegees, brooms, or rollers
  - Small cans or squeeze bottles
- For large projects:
  - Mixing tanks with spray bar

Application

- Prep
- Apply dams
  - Plumbers putty
  - Basic silicone
- Mix resin
- Pour
- Distribute
- Inspect
- Remove excess
- Apply sand
- Finish smooth (if desirable)

Small volume cartridges

Squeeze bottles
**Caution!**
- What about the bottom?
- Leaks
  - Plumbers putty
  - Basic silicone
  - Epoxy paste

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Pressure Injection**

**Benefits**
- Permanent fix
- Fills the void rather than bridging it
- High bond and tensile strengths of the epoxies prevent yawning and elongation of the crack
- Injected resin is not vulnerable to ultra violet rays, weathering, traffic or vandalism.

**Methods:**
- Hand (easy set up, economical)
- Low Pressure (economic, duration, better penetration)
- High Pressure (best performance, travel, penetration)
**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Injection Overview**

- Clean concrete surface
- Remove foreign debris from cracks
- Mount injection port to cracks - either surface or socket mounted
- Surface seal the cracks and injection ports
- Mix epoxy in proper ratios
- Inject resin
- Remove capseal
- Verify

---

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Surface Preparation**

- It does not have to be complicated
  - Wire brush
  - Abrasive grinding disc
  - Attention to surface

---

**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Surface Preparation**

- Types of Ports
  - Surface Mount
  - Corner Ports
  - Insertion Ports

- Port Spacing - How far apart?

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**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Surface Mount Ports**

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**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Surface Mount Ports**
• Vacuum bit to avoid impaction
How far apart do we space the ports?

- General guidelines
  - Project dependent
  - Crack width, depth, profile
- As far apart as possible
- Typically 6 – 12 inches
- 1 - 2 times concrete thickness

**Purpose**

- Dimensions
- Material selection
- Application
- Common mistakes

**The purpose is to contain the injection**

**Proper capseal dimensions**
CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Capsel

Material Selection
- Strength
- Moisture tolerance
- Odor
- Dispensability
- Cure time
- Thermal compatibility
- Ease of removal
- Cost

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Capsel Application

Mistakes:
- Capsel applied too thin
- Improper mixing of epoxy paste
- Insufficient cure time
- Poor material selection

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Capsel Application

• Capsel applied too thin
**CP1 – PRECAST CONCRETE REPAIR**

Structural Cracks – Capseal Mistakes

- Improper mixing ratio

- Improper mixing equipment

**CP1 – PRECAST CONCRETE REPAIR**

Structural Cracks – Capseal Solutions

- Full unit batching (too much volume?)
- Metered equipment
- Prepackaged cartridges
- Proper tools

**Now What?**

- Means and Methods of injection
- Where do we start to inject?
- How long do we inject?
CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Inject Resin

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Inject Resin

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Injection Methods
- Hand injection
  - Easy
  - Inexpensive
- Low pressure equipment
  - Economical
  - Offers duration
- High pressure equipment
  - Most reliable
  - Most expensive
  - Most complicated
  - Pressure and duration

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Hand Injection (Bulk)
- Individual components or kits
- Not interested in buying a kit
- Fast, easy, lowest cost
- Economical for infrequent repairs, but still requires technical competence
Everything needed for one repair

- Epoxy injection resin
- Epoxy cap seal
- Mixing nozzles
- Injection ports
- Gloves
- Application tool separate

**Caution!**
- Not done yet!
- Force material into substrate
- Leaks!

- Fine cracks require duration and consistent pressure
- 4-12 minutes typical
CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – High Pressure Injection

Remove ports
- Optional
- Grinding
- Heating and scraping

Restore surface as necessary
- Verification
- Coring

CP1 – PRECAST CONCRETE REPAIR
Structural Cracks – Clean Up

- Heat gun
- Torch
- Scraper

- Penetration - core samples
  - Fine Cracks - Epoxy glows under black light
  - Structural compressive & tensile (ASTM C42)

- Non-destructive
  - Impact echo
  - Ultrasonic pulse velocity
  - Spectral analysis of surface waves
**CP1 – PRECAST CONCRETE REPAIR**

**Structural Cracks – Injection Tips**
- Start at the widest point (versus bottom to top)
- Use duration rather than pressure
- Don’t rely on hand pressure for very fine cracks
- Use trained workers

**CP1 – PRECAST CONCRETE REPAIR**

**Non Structural Repairs**

**The purpose of the repair is to preserve the aesthetic look and protect the surface from further deterioration**
- Similar methods and materials, different criteria
  - Block outs that require some finishing to provide a smooth finished opening
  - Surface defects where steel is not exposed and color need to be similar
  - Does not affect structural integrity or intended service life of product
  - Applications under 1 ½” to 2”, cut in to sides to provide a 3/8” lip for bond

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**Non Structural Repairs**

**Overview**
- Similar methodology to structural spall repairs
  - Root cause analysis, QC procedure, approvals
  - Orientation of the repair
  - Surface preparation
  - Application conditions: wind, humidity, temperatures
  - Bond development: SSD, scrub coat, bonding agent
  - Finishing and curing
- Materials
  - Service and appearance driven, rather than loads

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**Non Structural Repairs**

**Color**
- Color of repair needs to be similar to the host concrete
- Matching repair surface with a repair materials is a challenge because the ingredients and proportions are different
  - Concrete has aggregate & sand with around 25% cement content vs. a packaged repair material that is up to 50% cement with only fine aggregate
  - Different manufacturers of cement will influence color
  - Different curing conditions affect color
  - Change in water cement ratio affects color

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**Non Structural Repairs**

**Color – Curing Conditions**
- Temperature
  - Hot sets faster and will be lighter
  - Cold sets slower and may be darker
- Finishing of the surface affects the color
  - Rough sand finish vs. tight steel trowel
- When the repair surface is wet the color will be different from the concrete because of a different absorption rate due to the density of the product
- You may need to coat the product for color uniformity

**CP1 – PRECAST CONCRETE REPAIR**

**Non Structural Repairs**

**Repair material options**
- Job mixing
- Pre-bagged patching cement products

**Critical point: How does the product accelerate set?**
- Internal acceleration
  - Achieve high early set using cement chemistry
- External acceleration
  - Forces cement to hydrate faster
  - Non-Chloride: changes PH of the mix for faster cement hardening
  - Chloride: does the same with potential issues for corrosion
  - Gypsum: will accelerate the mix but may re-emulsify when exposed to moisture
**Patching is different than placing concrete**
- The repair is very thin vs. concrete at 6-12 inches thick
- Does not generate heat when curing like concrete does
- More vulnerable to swings in temperature
- Requires more protection during initial set
- Precondition (warm) materials for a minimum of 24 hours
- Keep the substrate temperature above minimum application temperature
- Use warm water to raise the mixing temperature, cool water to lower it

**Problems:**
- Material placement
  - Material composition is important
  - Too coarse will bridge small cavities
  - Won’t penetrate into small cavities if sticky

**Surface preparation**
- Open bug holes by removing any cement laitance covering them
- Wet surfaces to develop uniform suction

**Sand and cement option**
- With water or bonding agent
- Sticky mix requires over working to force in bug holes. Result is shrinkage and unsightly
- No strength after set – no filler
- Poor consistency requires too much dilution
- End result, the product can be scratched out with a finger nail
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Non Structural Repairs – Bug Holes

Repair mortars are not designed for this application
• Set time forces over working of the product
• Sand in the mix bridges over the bug hole instead of penetrating
• Consistency required exceeds the no-slump consistency of the mortar
• Product may shrink around the perimeter of the bug hole without the filler (sand)

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Non Structural Repairs – Bug Holes

Newer Materials:
Pre-Engineered Cements
• Designed for filling bug holes
• Very fine aggregate filler
• High polymer loading for bond and workability
• Open set time allows for ease of placement
• Light weight product easier to work with
• Expansive additive to reduce shrinkage
• High workability with low WC ratio

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Non Structural Repairs – Architectural

Color Considerations
• Dry powder is approximate color you will get when patch is cured
• Amount of water can alter final color
• Conduct test patches to verify color
• Repair materials come in shades of gray, some in white, some specialty
• Repairs will rarely be exact color
• Finish texture influences color

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Non Structural Repairs – Architectural

Materials:
• Site batching with your own ingredients
• Pigment repair materials
  – % of cement
  – Use white based patching cement
• Pigmented prepackaged patching cement

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Non Structural Repairs – Architectural

Consistent mix required each time
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Documentation

- Per Incident
- Standard Repair Manual
  - Decision makers
  - Inspection process
  - Engineering approval

Analysis
- Pictures (before repair)
- Root cause
- Cost
- Corrective action
- Objectives
- Approvals

Repair strategy
- Service / exposure
- Conditions
- Materials
  - TDS / SDS
- Surface preparation
- Method
- Equipment

Report
- Verification / Testing
- Final Pictures

Summary

- Repair strategy
  - Root cause & cost analysis
  - Structural vs. Non Structural (Cosmetic)

- Structural Spall Repair
  - Materials, Methods

- Structural Crack Repair
  - Moving vs. Non-Moving
  - Materials, Methods

- Non Structural (Cosmetic) Repair
  - Spalls, Bug Holes, Architectural
  - Materials, Methods

- Documentation