Precast Concrete Repair: Material and Procedure Selection

Todd Spindler, Sika Corporation

PRECAST CONCRETE REPAIR

Objective
- 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

PRECAST CONCRETE REPAIR

Agenda
- 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

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Root Cause Analysis
- 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?

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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.
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

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?

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?

PRECAST CONCRETE REPAIR
Service Requirements

Special Finishes:
• Exposed surfaces
  – Specified coatings that require small bug holes to be filled

PRECAST CONCRETE REPAIR
Service Requirements

Service requirements to consider for determining the type of repair and product
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

PRECAST CONCRETE REPAIR
Service Requirements

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

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

PRECAST CONCRETE REPAIR
Surface Defects

- Voids
- Honey Comb (Surface)

PRECAST CONCRETE REPAIR
Surface Defects

- Bug Holes
- Surface Spalling
PRECAST CONCRETE REPAIR
Surface Defects
- Surface Cracks
  - Plastic Shrinkage
- Scaling

PRECAST CONCRETE REPAIR
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

PRECAST CONCRETE REPAIR
Structural Defects
- Transverse Cracks
  - Exposed reinforcement
- Major Spalling

PRECAST CONCRETE REPAIR
Structural Defects
- Rock Pockets (no binder)
PRECAST CONCRETE REPAIR
Structural Defects

- Product handling and storage

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

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

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
**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – Material Properties**

- Strength (compressive, flexural, tensile, bond)
- Modulus of elasticity
- Coefficient of thermal expansion
- Permeability
- Freeze/thaw resistance
- Shrinkage
- Thickness
- Set/cure time
- Application method
- Color

**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – Material Properties**

- 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.?

**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – MOE**

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

**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs**

**Material Selection**

- Cement based
- Cement based with mineral additives
- Polymer-modified cement based
- Epoxy modified, cement-based
- Epoxy mortar
### PRECAST CONCRETE REPAIR
Structural Spall Repairs – Material Selection

#### Cement Based

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Compatible with concrete</td>
<td>• Critical water:cement ratio</td>
</tr>
<tr>
<td>• Economical</td>
<td>• Shrinkage, curing</td>
</tr>
<tr>
<td>• Mix with water, easy cleanup</td>
<td>• Slow reactions</td>
</tr>
<tr>
<td>• Resist high temperatures</td>
<td>• Low tensile, flexural, bond strengths</td>
</tr>
<tr>
<td></td>
<td>• Surface preparation</td>
</tr>
</tbody>
</table>

#### Cement Based with Mineral Additives

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improved adhesion</td>
<td>• Workability problems</td>
</tr>
<tr>
<td>• High strengths</td>
<td>• Finishing (sticky)</td>
</tr>
<tr>
<td>• Low permeability</td>
<td>• Curing is critical</td>
</tr>
<tr>
<td>• Abrasion, impact resistance</td>
<td>• Mixing is critical</td>
</tr>
<tr>
<td>• Improved durability</td>
<td>• Higher cost</td>
</tr>
</tbody>
</table>

#### Epoxy Modified Cement Based

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Excellent adhesion</td>
<td>• Three components (typically)</td>
</tr>
<tr>
<td>• Adhesion on damp concrete</td>
<td>• Ratios are critical</td>
</tr>
<tr>
<td>• Very low permeability</td>
<td>• Must not freeze</td>
</tr>
<tr>
<td>• Corrosion protection</td>
<td>• Finishing difficulties</td>
</tr>
<tr>
<td>• Chemical resistance</td>
<td>• Higher cost</td>
</tr>
</tbody>
</table>

#### Epoxy Mortar

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Impervious to moisture and de-icing salts</td>
<td>• Mixing is critical</td>
</tr>
<tr>
<td>• High abrasion, skid resistance</td>
<td>• Vapor barrier</td>
</tr>
<tr>
<td>• Minimal added dead weight</td>
<td>• Thermally incompatible</td>
</tr>
<tr>
<td>• Rapid turnaround - open to traffic in 4 - 6 hours</td>
<td>• Creep</td>
</tr>
<tr>
<td></td>
<td>• Higher cost</td>
</tr>
<tr>
<td></td>
<td>• Solvents needed for cleanup</td>
</tr>
</tbody>
</table>

#### Polymer Modified Cement Based

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Adhesion</td>
<td>• Proper latex</td>
</tr>
<tr>
<td>• Low permeability</td>
<td>• Application time</td>
</tr>
<tr>
<td>• Increased flexural strengths</td>
<td>• 45°F (vs. 40°F) and rising</td>
</tr>
<tr>
<td>• Increased abrasion resistance</td>
<td>• Preconditioned material</td>
</tr>
<tr>
<td>• Lower modulus</td>
<td>• Finishing</td>
</tr>
<tr>
<td></td>
<td>• Moderate cost</td>
</tr>
</tbody>
</table>

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

### PRECAST CONCRETE REPAIR
Structural Spall Repairs – Material Selection

#### 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
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

**PRECAST CONCRETE REPAIR**
Structural Spall Repairs – Material Selection

**PRECAST CONCRETE REPAIR**
Structural Spall Repairs – Application
- Horizontal, Vertical, Overhead
- Hand Applied
- Form and Pour
  - Form and Pump
  - Machine Applied

**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

**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
PRECAST CONCRETE REPAIR
Structural Spall Repairs – Removal Geometry

Boundary of loose and delaminated concrete
Recommended Layout

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Removal Geometry

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Removal Geometry

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Surface Profile

• Open Pore
  – Clean
  – Sound
  – Typical for coatings

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

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Surface Profile

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Surface Profile

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

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Reinforcement

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Reinforcement

PRECAST CONCRETE REPAIR
Structural Spall Repairs – SSD

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

PRECAST CONCRETE REPAIR
Structural Spall Repairs – SSD

PRECAST CONCRETE REPAIR
Structural Spall Repairs – SSD

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Tools

Tools

PRECAST CONCRETE REPAIR
Structural Spall Repairs – Tools
**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

**PRECAST CONCRETE REPAIR**
Structural Spall Repairs - **Mixing**

- 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

**PRECAST CONCRETE REPAIR**
Structural Spall Repairs – **Bonding Agents**

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
• 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

• 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

Learning points: overfilling, shaving, bellying, blistering
Learning points: proper surface preparation
**PRECAST CONCRETE REPAIR**
Structural Spall Repairs – Form and Pour

- 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

**PRECAST CONCRETE REPAIR**
Structural Spall Repairs – Form and Pour

- Concrete or repair material?
- Why?
**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – Form and Pour**

- Scrub coat
- Pour in to wet
- Screed to level

**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – Curing**

- 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

**PRECAST CONCRETE REPAIR**

**Structural Spall Repairs – Summary**

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

**PRECAST CONCRETE REPAIR**

**Structural Cracks**

Things to avoid:

- Feather edges
- Abrupt changes in width or depth
- High length/width ratio
- Undercutting
- Poor surface
- Temperature extremes
- Over finishing
**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

**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

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**Examples, Root Cause Analysis**

- Detail

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**Examples, Root Cause Analysis**

- Detail

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**Examples, Root Cause Analysis**

- Detail
PRECAST CONCRETE REPAIR
Structural Cracks – Causes

Concrete cracking problems
• Cracking due to loading
• Cracking in the absence of loading

PRECAST CONCRETE REPAIR
Cracks – Causes

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

PRECAST CONCRETE REPAIR
Cracks – Causes

Plastic Shrinkage

Causes
• Rapid drying
• Excessive rate of hydration
• High slump, bleeding
• Wind
• Low humidity
• Dry forms
• Premature finishing

Prevention
• Protect concrete, moist cure
• Lower concrete temperature
• Dampen aggregate
• Reduce slump
• Erect wind shades
• Misting, fogging
• Dampen forms
• Proper finishing techniques
• Fibers

PRECAST CONCRETE REPAIR
Cracks – Causes

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.

PRECAST CONCRETE REPAIR
Structural Cracks – Causes

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)
PRECAST CONCRETE REPAIR
Cracks – Causes

Drying Shrinkage
Causes
• Inadequate curing
• Improper jointing
• Form temperature
• Reinforcing steel temperature

Prevention

Thermal Cracking
Causes
• Temperature differentials
• Excessive heat of hydration
• Ambient temperature variations

Prevention

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

Prevention

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>0.016</td>
</tr>
<tr>
<td>Humidity, moist air, soil</td>
<td>0.012</td>
</tr>
<tr>
<td>Deicing chemicals</td>
<td>0.007</td>
</tr>
<tr>
<td>Seawater and Seawater spray, wetting and drying</td>
<td>0.006</td>
</tr>
<tr>
<td>Water-retaining structures</td>
<td>0.004</td>
</tr>
</tbody>
</table>
The Precast Show

PRECAST CONCRETE REPAIR
Structural Cracks – Allowable Crack Width

PRECAST CONCRETE REPAIR
Structural Cracks – Epoxy Resins

• 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

PRECAST CONCRETE REPAIR
Structural Cracks – Epoxy Resins

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

PRECAST CONCRETE REPAIR
Structural Cracks – ASTMC881

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

PRECAST CONCRETE REPAIR
Structural Cracks – ASTMC881 Type

• 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
**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"

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**PRECAST CONCRETE REPAIR**
Structural Cracks – ASTM C881 Class

- A, B, & C are defined for Types I – V
- D, E, & F are defined for Types VI & VII

<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>
</tr>
<tr>
<td>B</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>C</td>
<td>60</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>40</td>
<td>65</td>
</tr>
<tr>
<td>E</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>F</td>
<td>75</td>
<td>90</td>
</tr>
</tbody>
</table>

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**PRECAST CONCRETE REPAIR**
Structural Cracks – Epoxy Resins

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

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**PRECAST CONCRETE REPAIR**
Structural Cracks – Surface Preparation

- Remove contaminates
  - Surface
  - Cracks
- Do not contaminate crack
  - Grinding
  - Drilling
  - Flushing

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**PRECAST CONCRETE REPAIR**
Structural Cracks – Application Overview

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

**PRECAST CONCRETE REPAIR**

**Structural Cracks – Gravity Feed**

**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

**PRECAST CONCRETE REPAIR**

**Structural Cracks – Gravity Feed**

**Application**

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

**PRECAST CONCRETE REPAIR**

**Structural Cracks – Gravity Feed**

- Small volume cartridges

**PRECAST CONCRETE REPAIR**

**Structural Cracks – Gravity Feed**

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

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 (economical, duration, better penetration)
  – High Pressure (best performance, travel, penetration)
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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 caps seal
- Verify

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Structural Cracks – Surface Preparation

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

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Structural Cracks – Surface Preparation

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

- Port Spacing - How far apart?

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Structural Cracks – Surface Mount Ports

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Structural Cracks – Surface Mount Ports
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Structural Cracks – Corner Ports

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Structural Cracks – Corner Ports

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Structural Cracks – Insertion (packer) Ports

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Structural Cracks – Insertion (packer) Ports

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Structural Cracks – Direct Insertion ¼” Tubing

- 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

The purpose is to contain the injection

- Proper capseal dimensions
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**Structural Cracks – Capseal**

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

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**Structural Cracks – Capseal Application**

Mistakes:
- Capseal applied too thin
- Improper mixing of epoxy paste
- Insufficient cure time
- Poor material selection
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### Structural Cracks – Capseal Mistakes
- Improper mixing ratio

### Structural Cracks – Capseal Solutions
- Full unit batching (too much volume?)
- Metered equipment
- Prepackaged cartridges
- Proper tools

### Structural Cracks – Capseal Complete

**Now What?**
- Means and Methods of injection
- Where do we start to inject?
- How long do we inject?
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Structural Cracks – Inject Resin

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Structural Cracks – Shutoff Ports

• Crimping
• Closing
• Locking
• Capping

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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

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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

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Structural Cracks – Hand Injection (Cartridges)
PRECAST CONCRETE REPAIR
Structural Cracks – Hand Injection (Kits)

Everything needed for one repair
- Epoxy injection resin
- Epoxy cap seal
- Mixing nozzles
- Injection ports
- Gloves
- Application tool separate

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Structural Cracks – Hand Injection

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

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Structural Cracks – Pressure Injection

- Fine cracks require duration and consistent pressure
- 4-12 minutes typical

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Structural Cracks – Low Pressure Injection
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Structural Cracks – High Pressure Injection

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Structural Cracks – Clean Up

- Remove ports
  - Optional
  - Grinding
  - Heating and scraping

- Restore surface as necessary
- Verification
  - Coring

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Structural Cracks – Clean Up

- Heat gun
- Torch
- Scraper

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Structural Cracks – Clean Up

- 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
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

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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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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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

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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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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
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)

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

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

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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**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

**PRECAST CONCRETE REPAIR**

**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