Analysis, Design & Strategy of Repair

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Analysis, Design & Strategy of Repair
Anatomy of Surface Repairs
Repair and Analysis Strategy
Performance Requirement

EVALUATE

REPAIR ANALYSIS

REPAIR STRATEGY

Surface Repair

Yes

Protection/ Appearance (Cosmetic)

Barrier to Unwanted Environment

Aesthetic

Wear Resistant

Live Loads

Impact Loads

Dead Loads

Yes

Both

Load Carrying (Structural)
Structural Needs

- A concrete surface repair must
  - replace damage concrete,
  - Restore required structural function
  - Protect from aggressive environment and
  - Restore any lost user performance requirement

- It is important to analyze all possible stresses in the repair material and at the interface and the existing substrate

- Full load relief must be provided during surface repair process
Types of Stresses Acting on Repairs

- Shear Bond
- Composite Overlay
- Settlement
- Shrinkage or Thermal Effect
Types of Stresses Acting on Repairs

- Tensile Bond
- Overlay
- Slab
- Uplift Due to Temperature or Shrinkage Effects
- Flexural Bond
- Uneven Support
Repair Methodology

Symptoms or observations of a deficiency must be differentiated from the actual cause of the deficiency, and it is imperative that *causes and not symptoms* be addressed in repairs. (e.g. cracking)

General procedure:

- *Evaluation.*
- *Relating observations to causes.*
- *Selecting methods and materials.*
  - Prerepair adjustments
  - Constraints.
  - Repair Performance.
  - Repair materials and methods
  - Quality Assurance
Repair Problem

Effect

Primary
- Reinforcing Steel
- Corrosion

Secondary
- Cracking
- Delamination
- Spalling

Cause

Primary
- Chlorides From External

Secondary
- Moisture
- Cracking
- Insufficient Bar Cover
- High Permeability Concrete

Structural Assessment & Repair
Structural Assessment & Repair

Repair Solution

Surface Repair

Minimize Cl flow into slab

OverLay

Chloride Removal

Minimize Moisture Flow into Slab.

Elastomeric Membrane

Sealer

Prevent Rebar Corrosion

Coating

Crack Sealant

Cathodic Protection

Coating Rebar ?
Strategies to provide durable surface repair

- **Strategy 1**
  - Place durable repair material of a quality somewhat better than existing
  - Place reinforcing steel protective system (?)

- **Strategy 2**
  - Place durable repair material of a quality somewhat higher better than existing
  - Place protective surface sealer, membrane, coating, coating on surface

- **Strategy 3**
  - Place enhanced repair material of a quality significantly higher better than the original
Strategy 4
- Place enhanced repair material of a significantly higher quality than the original
- Place protective sealer, membrane, coating on surface

Strategy 5
- Place enhanced repair material of a significantly higher quality than the original
- Place protective sealer, membrane, coating on surface
- Place reinforcing steel protective system (?)
Structure Repair

Physical Methods

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Surface Preparation

- Surface repair involves the process of conditioning the existing concrete to receive repair materials.
- Conditioning is required to remove deteriorated, contaminated or damaged concrete to provide surfaces that will promote bonding of the repair materials.
- Surface preparation process is the most critical phases of site work.
General Surface Preparation

- Locate area to be repaired.
- Design and install temporary support
• Remove deteriorated concrete
• Bar damage by removal operation or have significant section loss may require repair
• Prepare surface repair boundaries to prevent feather edged conditions
• Clean the surface of reinforcement
When Corroded Reinforcement Is Encountered

Surface after loose concrete is removed.

Top bar is heavily corroded.

Perimeter of repair area is cut by saw or other methods approximately 90° angle to surface, less than 1/2" deep.

Concrete is removed to expose bar.

Concrete is removed a minimum of 3/4" under corroded bar.

Steel and concrete surfaces are cleaned.
Recommended Layout

Layouts should be made as simple as possible.

Boundary of Loose and Delaminated Concrete

Recommended Layout

Recommended Layout
Recommended Layout

Boundary of Loose and Delaminated Concrete

Recommended Layout

Recommended Layout
Recommended Removal
Geometry
Recommended Removal
Geometry

Section

Elevation

Beam or Rib
Placement Methods
Physical Repair Analysis

- Placement Methods
  - Material Selection
  - Structural Support Design
  - Placement Method Selection
  - Layout
  - Shoring
  - General Removals
  - Concrete Surface Conditioning
  - Edge conditioning
  - Undercutting of bars
  - Reinforcing Steel Cleaning
  - Reinforcing Steel Repair
  - Bonding New to Old
  - Installation of Repair
  - Protection
  - Bonding Steel Reinforcement
  - Installation of Repair Materials
  - Reinforcing Steel Protection
Introduction to Placement Methods

- Selection of a surface repair placement method includes the following important steps:
  - Selection of a repair material that best reconstitutes the strength, integrity and performance required by the structure’s original design and current situation
  - Selection of a method of placement that will successfully deliver the repair material onto the prepared concrete substrate
  - Checking the constructability of the selected repair material and installation method
  - Adjusting the material and installation methods to provide a constructible repair
Important Considerations

• The placement technique must deliver the selected repair material to the prepared substrate with specified results (satisfactory bonding)
• Repair material to remain uniform during placement (no segregation of repair components)
• Complete filling of the surface cavity
• Long-term engineering and durability performance
• Constructability
Constructability

- Can the repair be built within the constraints specified by engineers and owners?
- Will the necessary equipment be accessible to the repair area?
- Will the specified installation allow the repaired structure to be placed in service within the time specified?
- Is the working environment conducive to a particular installation technique?
- Are there experienced contractors available for the project?

If the answers to these questions are ‘may be’ or ‘no’, then the repair material and installation method need to be reassessed.
Quality Assurance and Control

• Many problems can arise unless proper quality assurance and routine quality assurance are exercised
• Select reputable contractor/s
• During the repair project, develop routine feedback as to the engineering requirements
• Physical properties can be verified by sampling and testing
• Bond strengths can be verified by coring through the repair and into the substrate
• Apply tensile test to the core
Summary of Methods

• Dry Pack
• Form and Cast-in-Place
• Form and Pump
• Dry Shotcrete
• Wet Shotcrete
• Hand-Applied
• Full Depth Repair
• Grouted Preplaced Aggregate
• Overlays  Horizontal Techniques
Dry Packing

- Dry packing is a method of placing zero-slump, or near zero slump, mortar or concrete, by ramming into surface cavities
- The consistency of dry pack mortar must be such that it can be molded into a ball without excessive bleeding
- Compaction densifies the mortar and provides the necessary intimate contact with the existing concrete for achieving bond
- Can be used in all locations: overhead, vertical and flat
- Best for small cavities: tie holes, small honeycomb or rib bottom
- Curing is accomplished with a continuous 7-day moist cure
Form and Cast-in-Place

- Common vertical surface repair method
- Repair material must be of low shrinkage and provide necessary flowability.
- Placed into the top of form and free falls into the prepared cavity
- Internal and external vibration is necessary to remove air and provide intimate contact with the existing surface
- Use dry packing technique to complete the work
Form and Pump

- Common vertical surface and overhead repair method
- A two-step process of constructing formwork and pumping repair material into cavity confined by formwork and existing concrete
- Allows the use of mixed repair materials
- Sequence of pumping is from low points to high points; from one extremity to the other.
- Can use almost any repair material
- Not limited by depth or by size or density of exposed reinforcement
- Pressurisation process consolidates the repair material, providing full encapsulation of exposed reinforcement
- Formwork protects repair material during curing process
- Better quality assurance
Form and Cast-in-Place - 2

- Considerations;
  - Surface Preparation
  - Formwork
  - Pumping Equipment
  - Materials
  - Placement
  - Bonding of the New Repair Materials to Existing Concrete
  - Quality Assurance
Grouted Preplaced Aggregate

1. Gap-graded aggregate must be washed, free of fines and bond-inhibiting materials.

2. Washed aggregates are placed into formed cavity.

3. Forms are fitted with pipe nipples and valves for placement of grout.

4. Flowable grout is mixed and placed into pump. Flowable grout is mixed and pumped into formed cavity, filling space between aggregate.
Dry Mix Shotcrete

- Involves the premixing of binder and aggregates, which are fed into a special mechanical feeder metering the premixed material into a hose.
- The material is conveyed through the hose with compressed air to a nozzle which is outfitted with a water ring where additional water is mixed with binder and aggregates.
- The mix is jetted from the nozzle at high velocity onto the prepared concrete surface.
- May be applied in multiple layers.
## Additives for Dry Mix Shotcrete

<table>
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| Silica Fume        | • Increased thickness  
                     • Increased density  
                     • Increased freeze-thaw resistance  
                     • Increased chemical resistance  
                     • Reduced rebound  
                     • Increased adhesion  
                     • Increased flexural and compressive strength |                                                            |
| Accelerators       | • Increase/buildup of layers  
                     • Reduced initial set time  
                     • Increase early strength gain | • Increased drying shrinkage  
                     • Reduced shotcrete strength with age  
                     • Not necessary if silica fume is used |
| Steel Fiber        | • Elimination of shadows and voids which are created with conventional reinforcement  
                     • Improved impact resistance. |                                                            |
| Polypropylene Fibers | • Reduced plastic shrinkage cracking |                                                            |
| Latex              | • Improved flexural, tensile bond strengths  
                     • Increased resistance to freeze-thaw and chemical attack. | • Latex hardened film may occur between layers, causing delamination. |
# Additives for Dry Mix Shotcrete

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Wet Mix Shotcrete

- Involves the premixing of all ingredients (except accelerators) including binder, aggregates, admixtures, and mixing water
- The premixed repair materials are deposited into a pump or pressure vessel which transports the materials to an exit nozzle, where compressed air is introduced
- The repair material is propelled onto the substrate with compressed air
- Admixtures can be used to enhance the shotcrete material
Full Depth Repair

- Suitable for extensive surface damage
- The affected part of the member is removed, then reconstructed using full depth repair
- Careful with drying shrinkage problem (may caused cracking)
- Low shrinkage concrete mixes should be used
Hand Applied

• Suitable for non-sag repair materials on vertical and overhead locations
• Using special blends of cement, finely graded aggregates, non-slag fillers, shrinkage compensating systems, and water
• The mixed material is applied to the prepared surface with either a trowel or by hand
• The applied pressure drives the repair material into the pore structure of exposed concrete.
• The repair material is designed to ‘hang’ in place until subsequent layers are added.
REPAIR OF CORROSION DAMAGED CONCRETE

Patch repair
REPAIR OF CORROSION DAMAGED CONCRETE (Cont.)

Guniting / Shotcreting

Preparing slab for guniting

Shotcreting on R.C. wall
REPAIR OF CORROSION DAMAGED CONCRETE (Cont.)

Pressure grouting

Before  In progress  After
REPAIR OF CORROSION DAMAGED CONCRETE

Another repair options

- Preplaced aggregates & Pressure grouting
- Preventive measures
  - Surface protection
  - Electrochemical methods
- Strengthening
  - Plate bonding (steel, CFRP)
  - Jacketing
  - External prestressing
- Give up – Demolish and rebuild to new & improved specification