STRUCTURAL INTEGRITY RESERVE STUDY ANALYSIS

AT

CASTLE GARDENS 11

4750 NW 22nd CT

LAUDERHILL, FLORIDA 33313

BY

FLORIDA TECHNICAL, INC.

5604 MILEY RD

PLANT CITY, FLORIDA 33565

CA#4455

Florida Technical, Inc.

CONSULTING ENGINEERS **TAMPA – KEY WEST**

September 22, 2025

Castle Gardens 11 Condominium
Assoc.
c/o Roch Pilon, LCAM
Property Manager
Castle Gardens 11
4750 NW 22nd Ct
Lauderhill, FL 33313

Re: Structural Integrity Reserve Study (2026 Calendar Year)

Property Name / Address: CASTLE GARDENS 11
4770 NW 22nd CT
LAUDERHILL, FLORIDA 33313

Dear Rich:

In accordance with your request, attached please find our Reserve Study Analysis for the above referenced condominium building and selected components. Also included for valuation are the requested common element items. The effective date of this report is for the 2026 Budget Year [1/1/2026 – 12/31/2026]. This report is intended for sole use by the Client / Condominium Association to assist with long term budget planning and evaluation.

This report is based on a physical examination and visual observations of exposed areas with no removal of interior finishes. Observations of the structures and related elements were surveyed through accessible areas normally used during routine maintenance. The condition of the buildings and mechanical features represents the present conditions of each, as to the extent reasonably possible. At the request of the client, only a partial list of components was evaluated and included in this study. The remaining components may be added over the upcoming years to provide a complete budget of all reserve items. This will be done at the sole discretion of the Client/Association.

The following pages summarize the budget amounts and life expectancy for each asset that was requested. This report is intended for use by the association as a useful tool for long term budgeting and planning. The actual reserves set aside is done at the sole discretion of the Association and the information in this report is not meant for performing an audit, quality/forensic analyses or background checks of historical records.

It was a pleasure assisting you with this matter. Please feel free to contact me with any questions or concerns.

Sincerely,

Thomas E. Cheever

THOMAS E. CHEEVER, P.E.
President

S.I.R.S. – CASTLE GARDENS 11

A Reserve Study is a valuable tool to help you budget responsibly for your property. This report contains all the information you need to avoid surprise expenses, make informed decisions, save money, and protect property values.

Regardless of the property type, it's a fact of life that the very moment construction is completed, every major building component begins a predictable process of physical deterioration. The operative word is " predictable" because planning for the inevitable is what a Reserve Study by Florida Technical is all about.

Following the Surfside tragedy, the Florida Legislature recently enacted Senate Bill 4-D which established requirements for periodic inspections of structural & electrical elements of residential buildings 3 stories and taller. Inspections are required for buildings 30 years and older (25 years if located within 3 miles of the coast) and at 10 year intervals following the initial inspection.

As defined by the statute:

"Milestone inspection" means a structural inspection of a building, including an inspection of load-bearing walls and the primary structural members and primary structural systems as those terms are defined in s. 627.706, by a licensed architect or engineer authorized to practice in this state for the purposes of attesting to the life safety and adequacy of the structural components of the building and, to the extent reasonably possible, determining the general structural condition of the building as it affects the safety of such building, including a determination of any necessary maintenance, repair, or replacement of any structural component of the building. ***The purpose of such inspection is not to determine if the condition of an existing building is in compliance with the Florida Building Code or the fire safety code.***

The purpose of the Milestone Inspection is to determine the condition and life expectancy of designated components for use in developing the Structural Integrity Reserve Study.

Florida Technical completed the Phase 1 Milestone Inspection. An inspection of the following systems was conducted:

a. Roof.
b. Load-bearing walls or other primary structural members.
c. Floor
d. Foundation.
e. Fireproofing and fire protection systems.
f. Plumbing.
g. Electrical systems.
h. Waterproofing and exterior painting.
i. Windows.
j. Any other item that has a deferred maintenance expense or replacement cost that exceeds $10,000 and the failure to replace or maintain such item negatively affects the systems described in a through i above.

Utilizing the Phase 1 Milestone Inspection, a Structural Integrity Reserve Study is required. "Structural Integrity Reserve Study" means a study of the reserve funds required for future major repairs and replacement of the common areas based on a visual inspection of the common areas.

A structural integrity reserve study may be performed by any person qualified to perform such study. **However, the visual inspection portion of the structural integrity reserve study must be performed by an engineer licensed under chapter 471 or an architect licensed under chapter 481.** At a minimum, a structural integrity reserve study must identify the common areas being visually inspected, state the estimated remaining useful life and the estimated replacement cost or deferred maintenance expense of the common areas being visually inspected, and provide a recommended annual reserve amount that achieves the estimated replacement cost or deferred maintenance expense of each common area being visually inspected by the end of the estimated remaining useful life of each common area.

The amount to be reserved for an item is determined by the association’s most recent structural integrity reserve study that must be completed by December 31, 2025.

This report includes the field inspection report with two key results:

Component List Unique to each property.
The Component List serves as the
foundation of the Reserve Study and details the scope and schedule
of all necessary repairs & replacements.

Reserve Funding Plan
A multi-year funding plan based on current Reserve Fund strength
that allows for component repairs and replacements to be completed
in a timely manner, with an emphasis on fairness and avoiding
"catch-up" funding.

REPORT PROCESS

The purpose of this report is to provide the Castle Gardens 11 with specific information necessary in establishing a capital reserves program for the current budget year beginning January 1, 2026 and ending December 31, 2026, as required by statute.

The process of preparing this report began with an on-site inspection of the Association's property. During this inspection, an initial review was made of past reserve expenditures and the current reserve plan. From there, an inventory was made of the specifically requested items of the common area elements and a reserve component list was developed.

Using this list, a takeoff was then made of each component through a review of available construction drawings, taking pertinent measurements and noting its current observed physical condition. Additional background information on the property was obtained through discussions with various contact personnel.

Using the information gathered during the site inspection, calculations were then performed to determine the correct quantity of each component. From there cost estimates were then prepared based on a combination of local contractor information, any available bid proposals, and our own database of construction costs.

Asset lives have been determined using a combination of published guidelines and our review of the properties climatic conditions and the components observed physical condition noted during our site inspection. It is possible that asset lives may not last as long as projected or may exceed their estimated lives. Outside influences such as weather, improper maintenance, physical / abnormal abuse can drastically alter the projected life and replacement cost.

At the present time Castle Gardens 11 is collecting/accumulating pooled reserves and is projected to have $169,500.00 in reserves on hand as of this date but continue to collect each month.

The Association handles any surplus maintenance issues on a per item, as needed, basis. Any deficit from the operating budget is supplemented via a special assessment.

RESERVE STUDY ACCOUNTING

This reserve study report calculates the annual reserve contribution using the straight-line funding method.

Straight Line Funding Plan:

This plan utilizes straight line accounting formulas. Straight line accounting is based on current costs and neither interest nor inflation is factored into the calculations.

Straight line accounting takes each individual line-item component listed in the reserve schedule breakdown and computes its' annual contribution amount by taking its' unfunded balance (current replacement cost minus projected year end reserve balance) and divides it by the component's remaining life. This is the amount that should be contributed into the reserve’s accounts over the component's remaining life.

Straight line funding does not account for expected maintenance/service costs. Regular maintenance provided ‘as needed’ or via a service contract does not reduce replacement costs, but does extend remaining useful life.

REPORT TERMINOLOGY & DEFINITIONS

RESERVES - Monies set aside for the projected repair and/or replacement of the association’s common elements.

COMPONENT - A specific item or element which is part of the association's common area assets and is considered to require reserve funding.

QUANTITY - The quantity or amount of each reserve component element.

UNITS - The unit of measurement for each quantity.

COST PER UNIT - The estimated cost to replace a reserve component per unit of measurement.

CURRENT COST - The estimated current cost to replace a reserve component.

USEFUL LIFE - The total average estimated life, in years, of a component to maintain its useful purpose.

REMAINING LIFE - The estimated remaining useful life, in years, of a reserve component as of the current budget year.

12/31/2025 BALANCE - A projection of estimated reserve funds at the end of the previous budget year.

UNFUNDED BALANCE - The total remaining amount of reserve funds that are required to fully fund a component. Calculated by subtracting the component's current replacement cost from its' year-end reserve balance.

2026 CONTRIBUTION (Standard) - This is the total annual contribution amount for the current budget year calculated by dividing every component's useful life by its current replacement cost.

2026 CONTRIBUTION (Fully Funded) - This is the total annual contribution amount for the current budget year calculated by dividing every component's unfunded balance by its' remaining life.

Property Description:

Castle Gardens 11 is a multi-story (5 floors) condominium located in Lauderhill, FL, adjacent to the coast. Constructed in 1972 under the requirements of the South Florida Building Code, primary structural components are masonry including post tension cable construction for floors, cast concrete columns and/or beam and CMU block construction for walls.

Buildings Frame Structure & Mechanical Components:

Constructed in 1972, the building is 53 years old. The construction is typical for the period, and appears to be in compliance with the prevailing building code at the time of construction, the South Florida Building Code, which was the active code prior to the Florida Building Code implementation in March, 2002

The inspection conducted was to determine the condition, remaining life and replacement cost of Association owned elements. Typical of condominiums, the unit owner is responsible for all improvements and finishes interior of the drywall paper finish. The assumed life expectancy of Castle Gardens 11 is 70 years,

Overall Condition: The community was originally constructed in 1972, has received adequate routine continual maintenance and is considered to be in overall good condition. This summation is based on a cursory interior/exterior inspection with a very limited sample of the units inspected and should not be considered as a replacement for a more detailed property inspection with testing of the individual components and systems.

Building Maintenance and Component Recapitulation:

An on-site inspection of the property was performed during multiple visits during 2023 to present. At that time, it was reported that since completion there have been no renovations to the building. The roof was installed new in 2008. In 2016 the roof was ‘repaired/refreshed’ to extend the life. In 2025 an additional repair was done to extend the life/warranty period to 2025. Roof maintenance, including leak repairs are regularly completed/addressed.

Unit owners are responsible for maintaining individual fan coil units. Interior painting and miscellaneous touch-ups are performed by association maintenance personnel. Common area flooring is ceramic tile and carpet. Due to the age of the building (53 years), electrical and plumbing are included in anticipation of future repairs / replacement. This figure is a partial estimate as these repairs would be done on an “as needed” basis and an entire replacement would not be done at one time. Recent historical data along with published cost guides were used to determine the current replacement costs and useful life (age span) of each component analyzed in this report.

RESULTS OF INSPECTION

A. ROOF COMPONENT

EXISTING ROOF IS A DEAD LEVEL MODIFIED BITUMIN ROOF MEMBRANE OVER A LIGHTWEIGHT CONCRETE SUBTRATE ON A STRUCRTURAL CONCRETE SLAB.
THE ROOF SHOWS WEAR INDICATIVE OF A 17 YEAR OLD ROOF.

1. AVERAGE AGE OF THE ROOF COMPONENT…SEVENTEEN (17) YEARS

2. **ESTIMATED REMAINING USEFUL LIFE……NINE (9) YEARS**

3. **ESTIMATED CURRENT REPLACEMENT COSTS……$ 400,000.00**

4. SAFETY OF THE ROOF ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE ROOF ELEMENT IS SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL, THE ROOF ELEMENT IS SAFE, FUNCTIONING AND IN ACCEPTABLE CONDITION.

NOTE: WHEN RE-ROOFING CURRENT CODE REQUIRES NEW ROOF MEMBRANE BE PROVIDED WITH A POSITIVE SLOPE TO DRAIN.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE ROOF ELEMENT. THE OPINION THAT THE ROOF ELEMENT IS SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE ROOF ELEMENT PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE ROOF ELEMENT. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE ROOF ELEMENT BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

B. STRUCTURAL COMPONENT

THE BUILDINGS STRUCTURAL ELEMENTS ARE AS FOLLOWS: CAST CONCRETE COLUMNS AND BEAMS SUPPORTING POST TENSION CONCRETE FLOOR SLABS. CONCRETE MASONRY UNIT (CMU) BLOCK WALLS ARE USED AS INFILL AND STRUCTURAL ENVELOPE COMPONENTS. COASTAL PROXIMITY INDICATES CONCRETE DETERIORATION AS THE BUILDING AGES, THE BUILDING IS UNDERGOING A MULTI-YEAR CONCRETE RESTORATION AND PAINTING PROJECT WITH AN ESTIMATED COST OF UP TO $398,000.00. PROJECT COMPLETION IS EXPECTED BY END OF YREAR 2026.

1. AGE OF THE STRUCTURE……...……..FIFTY (53) YEARS

2. ESTIMATED REMAINING LIFE……SEVENTEEN (17) YEARS

3. ESTIMATED CURRENT REPLACEMENT COSTS……$ 5,930,000.00

   NOTE - 5% OF REPL'MT COST IN YEAR 2042 (70 YRS) $ 296,500.00

4. SAFETY OF THE STRUCTURAL ELEMENTS WITH RESPECT TO USE INTENDED:
   IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:
   IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE STRUCTURAL ELEMENTS. THE OPINION THAT THE STRUCTURAL ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE STRUCTURAL SYSTEM PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE STRUCTURAL SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE STRUCTURAL SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

C. FLOOR COMPONENT

THE BUILDING LIVING LEVELS, FLOORS AND ROOF DECK ARE CAST CONCRETE OVER POST TENSION CABLES. LIKE ALL MASONRY STRUCTURES, COASTAL PROXIMITY ACCELERATES CONCRETE DETERIORATION AS THE BUILDING AGES WITH SIGNIFICANT RESTORATION LIKELY OVER THE BUILDIGN LIFE. THERE ARE NO PARKING LEVELS. BUILDING PARKING REQUIREMENTS ARE SATISFIED WITH EXTERIOR, GRADE LEVEL ASPHALT PARKING.

1. AGE OF THE STRUCTURE……...……FIFTY THREE (53) YEARS

2. **ESTIMATED REMAINING LIFE-…….SEVENTEEN (17) YEARS**

3. **MAINTENACEN/BALCONY/WATERPROOFING COSTS…..$ 157,500.00**

4, SAFETY OF THE STRUCTURAL ELEMENTS WITH RESPECT TO USE INTENDED:

IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE FOR THE USE INTENDED.

4. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:
IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE FLOOR ELEMENTS. THE OPINION THAT THE FLOOR ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE FLOOR SYSTEM PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE FLOOR SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE FLOOR SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

D. FOUNDATION COMPONENT

THE BUILDING IS SUPPORTED ON DEEP PILE FOUNDATIONS WITH CAST CONCRETE PILE CAPS. DURING INSPECTION NO EVIDENCE OF DIFFERENTIAL DEFLECTION NOR SETTLEMENT WAS OBSERVED.

1. AGE OF THE STRUCTURE……...……..…..FIFTY THREE (53) YEARS

2. ESTIMATED REMAINING LIFE…..… …SEVENTEEN (17) YEARS

6. ESTIMATED CURRENT REPLACEMENT COSTS……$ 5,930,000.00

   NOTE – MAINTENACE EST'ED AT .5% OF REPLACEMENT IN YEAR 2042 (70 YEARS) ……. $ 29,650.00

4, SAFETY OF THE STRUCTURAL ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE FOR THE USE INTENDED.

3. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:
   IN GENERAL, THE STRUCTURAL ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE FOUNDATION ELEMENTS. THE OPINION THAT THE FOUNDATION ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE FOUNDATION SYSTEM PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.

AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE FOUNDATION SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE FOUNDATION SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

E. FIRE PROOFING & FIRE PROTECTION COMPONENT

THE FIRE ALARM SYSTEM CONCISTS OF ALARMS, PULL STATIONS, FIRE EXTINGUISHERS AND SMOKE DETECTORS. FIRE EXTINGUISHERS ARE LOCATED IN THE BUILDING COMMON AREAS. HARD WIRED SMOKE DETECTORS ARE LOCATED THROUGHOUT THE COMMON AREAS. EACH UNIT IS PROVIDED WITH A SMOKE DETECTOR. A CENTRAL STATION MONITORED FIRE ALARM SYSTEM IS PROVIDED. A CITY FIRE HYDRANT IS LOCATED WITHIN 300 FEET OF THE CASTLE GARDENS 11 ENTRY.

1. AVERAGE AGE OF THE COMPONENT
   SMOKE DETECTORS……...……..(UNKNOWN) YEARS
   FIRE ALARMS…….……..TEN (10) YEARS

2. ESTIMATED REMAINING USEFUL LIFE
   SMOKE DETECTORS……...……(UNKNOWN) YEARS
   FIRE ALARMS…….. SEVENTEEN (17) YEARS

3. ESTIMATED CURRENT REPLACEMENT COSTS
   SMOKE DETECTORS……UNIT OWNERS ARE RESPONSIBLE FOR COST
   FIRE ALARMS…….……..$ 125,000.00

4. SAFETY OF THE FIRE SAFETY ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE FIRE SAFETY ELEMENTS ARE SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL, THE FIRE SAFETY ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE: NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE FIRE SAFETY ELEMENTS. THE OPINION THAT THE FIRE SAFETY ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE ROOF ELEMENT PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.

F. PLUMBING COMPONENT

THE WATER AND SANITARY SEWER ARE PROVIDED BY PUBLIC UTILITIES. THE WATER DISTRIBUTION PIPING WITHIN THE BUILDINGS, WHERE VISIBLE, IS COPPER. THE SANITARY SEWER COLLECTION SYSTEM WITHIN THE BUILDING IS CAST IRON. WHEN LEAKS OR MAINTENANCE IS REQUIRED, CASTLE GARDENS 15 IS REPLACING CAST IRON WITH PVC PIPING. DOMESTIC WATER PUMPS ARE PROVIDED FOR DOMESTIC WATER SERVICE.

1. AGE OF PLUMBING COMPONENT (PIPING)…….FIFTY THREE (53) YEARS

2. **ESTIMATED REMAINING USEFUL LIFE……SEVENTEEN (17) YEARS**

3. **ESTIMATED CURRENT REPLACEMENT COSTS……$ 200,000.00**

4. SAFETY OF THE PLUMBING ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE PLUMBING ELEMENTS ARE SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL, THE PLUMBING (PIPING) ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE PLUMBING ELEMENTS. THE OPINION THAT THE PLUMBING ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE PLUMBING SYSTEM PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE PLUMBING SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE PLUMBING SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

G. ELECTRICAL COMPONENT

THE ELECTRICAL SYSTEM FOR THE BUILDINGS IS 120/208 VOLTS, 4 WIRES, THREE PHASE, UNDERGROUND SERVICE. ELECTRICAL/METER ROOMS ARE LOCATED ON EACH RESIDENTIAL FLOOR THERE IS A SEPARATE METER FOR EACH RESIDENTIAL UNIT. BRANCH CIRCUITS ARE WIRED WITH COPPER CONDUCTORS AND THERE ARE PANELS IN EACH UNIT. THERE IS ALSO METERING AND DISTRIBUTION PANELS FOR THE COMMON ELEMENTS (PARKING, SWIMMING POOL, ETC.) A GENERATOR IS PROVIDED FOR EMERGENCY AND STANDBY USE TO POWER

1. AGE OF ELECTRICAL SYSTEM……..……. FIFTY THREE (53) YEARS

2. **ESTIMATED REMAINING USEFUL LIFE…… SEVENTEEN (17) YEARS**

3. **ESTIMATED CURRENT REPLACEMENT COSTS……$ 222,375.00**

4. AGE OF GENERATOR……..……..……. NOT APPLICABLE

5. **ESTIMATED REMAINING USEFUL LIFE…… NOT APPLICABLE**

6. **ESTIMATED CURRENT REPLACEMENT COSTS……NOT APPLICABLE**

7. SAFETY OF THE ELECTRICAL ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE PLUMBING ELEMENTS ARE SAFE FOR THE USE INTENDED.

8. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL THE ELECTRICAL ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE ELECTRICAL ELEMENTS. THE OPINION THAT THE ELECTRICAL ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, THE ELECTRICAL SYSTEM PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY

AS A GUARANTEE FOR ANY PORTION OF THE ELECTRICAL SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE ELECTRICAL SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

H. WATERPROOFING & EXTERIOR PAINTING COMPONENT

WATER IS THE UNIVERSAL SOLVENT. PROTECTING STRUCTURAL AND OTHER BUILDING COMPONENTS AGAINST WATER/MOISTURE INTRUSION IS ESSENTIAL TO ACHIEVING MAXIMUM LIFE EXPECTANCY OF ALL BUILDING COMPONENTS. PAINTING/WATERPROOFING SHOULD BE APPLIED EVERY 10 TO 12 YEARS. A CONCRFETE RESTORATION AND EXTERIOR PAINTING PROJECT IS UNDERWAY WITH COMP-LETION EXPECTED BY END OF 2025.

1. AGE OF EXISTING EXTERIOR PAINT … (1) YEARS BY 2025 END

2. **ESTIMATED REMAINING USEFUL LIFE……ELEVEN (11) YEARS**

3. **ESTIMATED CURRENT REPLACEMENT COSTS……$ 61,000.00**

4. SAFETY OF THE WATERPROOFING & PAINT ELEMENTS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE WATERPROOFING & PAINTING ELEMENTS ARE SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL, THE WATERPROOFING & PAINTING ELEMENTS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE: NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE WATERPROOFING ELEMENTS. THE OPINION THAT THE WATERPROOFING ELEMENTS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL, WATERPROOFING PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE WATERPROOFING SYSTEM. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE WATERPROOFING SYSTEM BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

I. WINDOWS – COMMON AREA

WINDOWS ARE AN INTEGRAL COMPONENT OF THE BUILDING EXTERIOR COMPONENTS AND CLADDING. CONSTRUCTED PRIOR TO THE IMPLEMENTATION OF THE FLORIDA BUILDING CODE. EXISTING COMMON AREA WINDOWS WERE REPLACED IN 2019 (6 YEARS) NOTE: PER ASSOCIATION BYLAWS, INDIVIDUAL UNIT OWNERS ARE RESPONSIBLE FOR MAINTENANCE AND/OR REPLACEMENT OF UNIT WINDOWS, THERFORE UNIT WINDOWS ARE NOT INCLUDED IN THE RE-CAPITULATION.

1. AGE OF EXISTING EXTERIOR COMMON AREA WINDOWS……SIX (6) YEARS

2. **ESTIMATED REMAINING USEFUL LIFE…SEVENTEEN (17) YEARS**

3. **ESTIMATED CURRENT REPLACEMENT COSTS……$ 12,000.00**

4. SAFETY OF THE COMMON AREA WINDOWS WITH RESPECT TO USE INTENDED:

   IN GENERAL, THE COMMON AREA WINDOWS ARE SAFE FOR THE USE INTENDED.

5. THE STRUCTURAL AND FUNCTIONAL SOUNDNESS OF ELEMENT:

   IN GENERAL THE COMMON AREA WINDOWS ARE SAFE, FUNCTIONING AND IN SOUND CONDITION.

NOTE:NO DESTRUCTIVE METHOD WAS USED TO ASCERTAIN THE CONDITION OF THE COMMON AREA WINDOWS. THE OPINION THAT THE COMMON AREA WINDOWS ARE SAFE, FUNCTIONING AND SOUND IS BASED ON VISUAL OBSERVATIONS. IN GENERAL THE COMMON AREA WINDOWS PRESENTS NO DANGER TO THE PUBLIC AND IS IN SOUND CONDITION FOR THE TYPES OF LOADS NORMALLY ENCOUNTERED IN THIS TYPE OF USE.
AS A ROUTINE MATTER, IN ORDER TO AVOID POSSIBLE MISUNDERSTANDING, NOTHING IN THIS REPORT SHOULD BE CONSTRUED DIRECTLY OR INDIRECTLY AS A GUARANTEE FOR ANY PORTION OF THE COMMON AREA WINDOWS. TO THE BEST OF MY KNOWLEDGE AND ABILITY THIS OPINION REPRESENTS AN ACCURATE APPRAISAL OF THE PRESENT CONDITION OF THE COMMON AREA WINDOWS BASED UPON CAREFUL EVALUATION OF OBSERVED CONDITIONS, TO THE EXTENT REASONABLY POSSIBLE.

RESERVE STUDY - BUDGET YEAR 01/01/2026 - 12/31/2026

			REMAINING	REPLACEMENT	12/31/2024	UNDERFUNDED	2025 ANN.
		AGE	LIFE	OR MAINTENANCE	BALANCE	BALANCE	CONTRIB.
	CATEGORY	(YRS)	(YRS) *	COSTS $ *	$	$	$
A,	ROOF	17	9	$400,000.00	38,000	$ 362,000.00	$ 40,222.22
B.	STRUCTURAL	53	17	$296,500.00	0	$ 296,500.00	$ 17,441.18
C.	FLOOR/PARKING LEVELS, RAMPS, FLOOR AND ROOF DECK	53	17	$157,500.00	0	$ 157,500.00	$ 9,264.71
D.	FOUNDATION	53	17	$29,650.00	0	$29,650.00	$ 1,744.12
E.	FIRE ALARMS	10	17	$ 125,000.00	0	$ 125,000.00	$ 7,352.94
					0		
F.	DOMESTIC PLUMB SYS	53	17	$ 200,000.00	58,000.00	$ 142,000.00	$ 8,352.94
G.	ELECTRICAL	53	17	$ 222,375.00	0	$ 222,375.00	$ 13,080.88
						$ -	
H.	PAINTING / WATERPROOFING	1	11	$ 61,000.00	3,000	$ 58,000.00	$ 5,272.73
I.	WINDOWS	6	17	$ 12,000.00	0	$ 12,000.00	$ 705.88
						TOTAL	**$ 103,437.60**

TOTAL W/O FLOORS & FND 92,428.77

*ASSUMES CONSUMMABLE REPLACEMENT COST NPOT TO EXCEED 1% OF COMPONENT FULL REPLACEMENT VALUE

FOLLOWING THE IMPLEMENTATION OF FL SB4-D THE LEGISLATURI NOW RECOMMENDS RESERVES FOR FLOORS AND FOUNDATION BUT ARE NO LONGER REQUIRED

CERTIFICATE

THIS INSPECTION REPORT IS BASED ON VISUAL INSPECTION OF THE SUBJECT PROPERTY. INSPECTION IS LIMITED TO FULFILLMENT OF THE REQUIREMENTS WITH RESPECT TO THE DISCLOSURE OF CERTAIN COMPONENTS AS TO THEIR AGE, ESTIMATED REMAINING USEFUL LIFE, CURRENT ESTIMATED REPLACEMENT COST, AND STRUCTURAL AND FUNCTIONAL SOUNDNESS OF THE COMPONENT. OTHER THAN AS NOTED HEREIN, NO REVIEW OF THE CONSTRUCTION DOCUMENTS IS INCLUDED AND NO COMMENTS ARE MADE REGARDING CONFORMANCE OR NON-CONFORMANCE TO PLANS AND SPECIFICATIONS AND NO DISCLOSURE AS TO ACTUAL CONDITION OF THE ELEMENTS

I HEREBY CERTIFY THAT I HAVE PERFORMED THE INSPECTIONS AND EVALUATIONS, AND HAVE PREPARED THIS REPORT PERSONALLY ON THE 22ND DAY OF SEPTEMBER 2025, FOR THE ABOVE PROJECT, AND THAT IT IS TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

SIGNED: Thomas E. Cheever

THOMAS E. CHEEVER, P.E. #36054
PRESIDENT
FLORIDA TECHNICAL, INC.
5604 MILEY RD
PLANT CITY, FL 33565

RECERTIFICATION /MILESTONE INSPECTIONS

BUILDING SAFETY ACT - PHASE 1 MILESTONE INSPECTION

AT

CASTLE ELEVEN CONDOMINIUMS 4750 NW 22nd Ct, Lauderhill, FL 33313

BY

FLORIDA TECHNICAL, INC.
114 W. DAVIS BLVD
TAMPA, FLORIDA 33606
CA#4455

Florida Technical, Inc.

CONSULTING ENGINEERS **TAMPA – KEY WEST**

August 12, 2023

Mr. Rafal Kuta, CAM
Castle Eleven Condominiums
4750 NW 22nd Ct
Lauderhill, FL 33313

Re: PHASE 1 BUILDING MILESTONE INSPECTION & STRUCTURAL INTEGRITY RESERVE STUDY @
Castle Eleven Condominiums
4750 NW 22nd Ct
Lauderhill, FL 33313

Dear Mr. Kuta:

My team and I inspected Castle Eleven beginning on July 22nd through July 23rd 2023, pursuant to Florida Senate Bill 4-D which established requirements for periodic inspections of structural & electrical elements of residential buildings 3 stories and taller. Inspections are required for buildings 30 years and older (25 years if located within 3 miles of the coast) and at 10 year intervals following the initial inspection.

The following systems were inspected:

a. Roof.
b. Load-bearing walls or other primary structural members.
c. Floor
d. Foundation.
e. Fireproofing and fire protection systems.
f. Plumbing.
g. Electrical systems.
h. Waterproofing and exterior painting.
i. Windows.
j. Any other item that has a deferred maintenance expense or replacement cost that exceeds $10,000 and the failure to replace or maintain such item negatively affects the systems described in a through i above.

You indicated unit windows at Castle Eleven Condominiums are the responsibility of each individual unit owner. I encourage each owner to install shutters and/or impact rated windows. However, only Association common area windows were inspected and/or will be considered for replacement in the Structural Integrity Reserve Study.

114 W. DAVIS BLVD. TAMPA, FL 33606 * 813-765-0264 * 813-699-8323 (FAX) * THOMAS.FLTECH@GMAIL.COM

ROOF

The existing 'modified roof system' was new in 2009. A maintenance coating was installed in 2016. I am not an advocate of roof coatings. In my experience they are unreliable, expensive and make future re-roofing more difficult. The roof was inspected in October 2021. I noted no significant changes in the last 2 years. Nonetheless, the installed coating does require service to seal multiple penetrations or breaks.


ALLIED

I observed numerous areas that appear to have trapped moisture under the roof coating. Because the roof membrane is installed over a concrete deck, roof leaks into top floor units are minimal. However, the membrane will continue to deteriorate.

Barring further tropical storm activity and, with proper maintenance, the roof has an estimated 3 to 5 year life expectancy before replacement is necessary. NOTE: The base modified roof is approaching 15 years old, the age many insurance companies will require replacement.

NOTE: Beginning with the 2012 Florida Building Code, when replacing existing roofs steps must be taken to ensure a positive slope to drain to achieved. At Castle Eleven Condominiums this will require installing tapered insulation, lightweight concrete or other means to slope roof to north and south edges.

LOAD BEARING WALLS & OTHER PRIMARY STRUCTURAL MEMBERS

Castle Eleven Condominiums is a masonry structure. Walls consist of block CMUs (Concrete Masonry Units), concrete pilasters and cast concrete beams with a stucco exterior finish. The ground floor is a cast slab on grade, upper floors and roof deck are cast concrete slabs.

Exterior structural elements above the ground floor were inspected using a 10X power monocular. Past crack repairs are evident. Many of these repairs most likely occurred when the building was last painted.

NOTE: For observed areas requiring repair and/or remediation see individual building report via Dropbox link.

FLOOR

Raised floors are cast concrete steel reinforced slabs.. Common area floors, electrical rooms, stairwells, etc. were inspected. Additionally, building stairs and hallways were inspected. There was no observed evidence of deterioration.

NOTE: There was no observed evidence of differential deflection indicative of movement or imminent collapse. Cracks should be repaired by a licensed contractor experienced in concrete restoration materials and techniques.

FOUNDATION

Building exterior was inspected for signs of grade level settlement and/or differential deflection. Stair stepping in block construction, cracked window sills, ground level doors out of square can be signs of foundation fatigue.

NOTE: There was no observed evidence of grade level settlement nor differential deflection indicative of movement or imminent collapse.

FIREPROOFING AND FIRE PROTECTION SYSTEMS

The building is not equipped with fire sprinklers. However, fire cabinets with hoses and extinguishers are located on each floor. Fire extinguishers are inspected and certified annually.

Castle 11 has an installed central station fire alarm system with pull stations. The alarm is NOT off site monitored.

NOTE: Each extinguisher inspected indicated 'green' or good charge and were within annual inspection.

PLUMBING

Incoming potable water service was inspected at the meter box. Verified presence of water shutoff valve. Did not operate valve to confirm it is working and functional. No signs of underground pipe leaks were observed.

Observed plumbing cleanouts located adjacent to the structure. Did not open cleanouts to confirm operability.

NOTE: The existing potable water and sanitary sewer system are functional without signs of deterioration.

ELECTRICAL SYSTEM

Castle Eleven Condominiums is provided with a 800 amp and a 1200, 120/208 volt three phase utility electric service. There are electrical rooms on floors 5, 4, 2, and 1. The rooms are directly in the center of each hallway. Each unit is provided electric service via utility 120/208 volt single phase service conductors.


520
MAIN
BREAKER


BREAKER
CATALOG NO.
MC 34
MAIN RATING
800 AMPS
240


MAIN
BREAKER

NOTE: The electric room is accessible and uncluttered. However, disassociated equipment should be removed and stored elsewhere. No FPE Stab-Lok breakers were observed.

WATERPROOFING AND EXTERIOR PAINTING

Information provided indicates the building exterior was painted between 2013. Observations of paint condition aligns with 10 year old paint. Paint is chalking and abraded. Exterior paint is NOT waterproofing but, it does provide the initial barrier against moisture intrusion. Moisture is the universal solvent. Given enough time, moisture will destroy ALL building materials. Wood, concrete, stone, steel, etc. will all lose structural integrity with excessive and prolonged moisture exposure,

NOTE: Building exteriors should be painted at 10 year or less intervals to minimize damage from moisture intrusion to concrete and/or steel structural elements.

WINDOWS

As noted, residential unit windows are the responsibility of individual owners. Castle Eleven Condominiums is responsible for common area windows/glazing at lobby/office, ground floor meeting rooms, and floors 2 through 6 hallway windows/doors.


4750
U-HAUL

Today's high-quality windows can last up to 30 years. Yet, with a proper inspection and maintenance, they can go beyond these figures. This could be the reason many window manufacturers will provide a 30 to 40 year limited warranty for their products.

However, overall the windows are functioning as intended. With proper maintenance, window replacement should be anticipated in 20 to 25 years.

NOTE: Although the existing windows are still functional, the ability for each window to properly seal against wind and moisture has been compromised by age. When replaced due to or otherwise, the replacement window must be impact rated in accordance with the requirements of the Florida Building Code in effect at the time of replacement. The current code is the 2020 Florida Building Code, Seventh Edition.

ANY OTHER ITEM
Nothing observed to report.

If you have any questions concerning the above, or if I can ever be of assistance, please don't hesitate to call. I look forward to speaking with you in the near future.

Sincerely,

Thomas E. Cheever

THOMAS E. CHEEVER, P.E.
President

Attachment

Castle Eleven Condominiums

FLORIDA TECHNICAL MILESTONE INSPECTION

INSPECTOR: RANDOLPH L SCOTT & HEATHER RIVERA

DATE: JULY 22, 2023

500 NUMBERED UNITS

Unit 500-Balcony-Tile-Hollow throughout. Previous repair on main wall. Missing stucco on main wall.

Unit 520-Balcony-Tile. Enclosed. Hollow tile at middle edge 2'x2' area. Previous repair under window.

Unit 501- Balcony-Tile. Hollow area at Right corner 1'x1'.

Unit 519-No Access-No key.

Unit 502-Balcony-Tile. Hollow 2'x2' at Right.

Unit 518-Balcony-Tile. Left at balcony wood wall rotting. Sliding glass door Left A crack at old wall installation.

Unit 503-Balcony-Laminate. Wall are beadboard.

Unit 517-Balcony-Tile. Hollow at sliding glass door and throughout.

Unit 516-Balcony-Carpet over tile. No entry to balcony.

Unit 504- Balcony-Tile. Tile is on the walls and the floor is hollow throughout.

Unit 515-Balcony-Tile. Beadboard walls. Patch from prior leak at upper Right.

Unit 505-Balcony-Tile. Beadboard walls. Tile buckling throughout. Screens and glass are gone. Water appears to be getting in and floor requires

attention.

Unit 506-Balcony-Tile. Beadboard walls.

Unit 514- Balcony-Tile. Wallpaper walls. Hollow tile are 1'x1' at the L front.

Unit 512-Balcony-Tile. Beadboard walls. Tiles appear to be missing proper adhesion.

Unit 507-Balcony-Exposed rebar and spalling throughout. Previous spalling repairs. Walls are ok. Screens missing.

Unit 511-Balcony-Tile. Beadboard walls. Wall L 2' previous patch. Tiles loose & hollow throughout.

Unit 508- Balcony-Tile. Beadboard walls. Tiles loose & hollow throughout.

Unit 509- Balcony-Tile. Upgraded windows. Hollow tile throughout.

Unit 510-Balcony-Tile. Everything ok.
Storage Room-Painted concrete floors. Room in good condition.

Trash Chute Room-Painted concrete. Room in good condition.

Meter Room-800 Amp Breakers. Room in good condition.

400 NUMBERED UNITS

Unit 400-Balcony-tile. FL room panels. 2'x6' CD spall at ceiling front edge and R

Unit 420- Balcony-Tile. Some water intrusion evident. Hollow tiles at edge 4'x3' possibly from not enough adhesion at installation.

Unit 401- Balcony-Tile. Hollow throughout.

Unit 419-Balcony-tile. Wall R furniture marks. 3' BC crack Wall L. Tiles

cracked at sliding glass door. There are also 4 wall penetrations. Note: Window covering found on floor.

Unit 402-Balcony-tile. CD spall L corner of balcony. Post is rotted at the top and bottom. 4' AB crack. 6' BC spall.

Unit 418-No access due to large amount of items stacked throughout unit.

Unit 417-Balcony-Tile. Missing wall sconce.

Unit 403-Balcony-Tile. Upgraded windows. 2 spall L ceiling. Tile hollow throughout possibly from not enough adhesion at installation.

Unit 416-Balcony-No access due to large amount of items stacked throughout.

Unit 404-Balcony-Tile. Missing screens, otherwise balcony ok.

Unit P-4-Balcony-Tile. Hollow throughout, possibly from not enough adhesion at installation.

Unit 405-Balcony-Tile. D spall at R corner. Post is rusted throughout. 2' A crack at upper R corner. Post missing at L and exposed at top corner. Hollow tile throughout.

Unit 415-Balcony-Tile. Upgraded windows.

Unit 414- Balcony-Carpeted. 1' A crack R corner ceiling.

Unit 406-Balcony-Tile. Ok.

Unit 412-Balcony-Tile. 1' A crack at ceiling R. Hollow tile throughout possibly from installation.

Unit 407- Balcony-Tile. Previous repair at ceiling edge. Hollow tile throughout, possibly from installation.

Unit 408- Balcony-Tile. The areas able to access were ok.

Unit 411-No Access-Key not available.

Unit 409-Balcony-Tile. Hollow tile throughout, possibly from installation.

Unit 410- Balcony-Tile. Ok.

Laundry room-Painted concrete floors. Room is in good condition.

Electrical room-Painted concrete floors. Room is in good condition.

Trash room-Painted concrete floors. Room is in good condition.

300 NUMBERED UNITS

Unit 310-Balcony-Tile. 6' prior repair at ceiling.

Unit 309-Balcony-tile. Tile missing at edge. Post at lower R is rusted. 2' A crack at R corner ceiling. Hollow tile at edge of window 1" of tiles.
Note: Door was unlocked and the screen is missing.

Unit 311-Balcony-tile. Beadboard walls. Hollow tile throughout, except at L.

Unit 308-Balcony-Tile. CD spall ceiling L. L post is rusted at the bottom. Hollow tile throughout, possibly due to installation.

Unit 312-Balcony-Carpet. Beadboard walls.

Unit 307-Balcony-Tile. Beadboard walls. Ceiling R 2" hole at post and bracket. 2' CD spall.

Unit 306-Balcony-Concrete. Porch light missing. Post at bottom rusted but covered by shades.

Unit 314-Balcony-Tile. Superficial A crack at sliding glass door, previous repair made.

Unit 305- Balcony-tile. 6' CD spall at ceiling front. 4" AB crack on wall. 4" A crack at balcony wall L. 2' CD spall at ceiling R.

Unit 315-Balcony-Tile. Enclosed. Upgraded windows.

Unit 304-No Access

Unit 316-Balcony-Sliding glass door removed and the living room extended.

Unit 303-Balcony-Tile. Hollow tile throughout.

Unit 317-Balcony-Sliding glass doors removed. Walls are paneled. Hollow tiles at the perimeter.

Unit 302-Balcony-Tile. Paneled walls. Water intrusion in R corner floor. Hollow tiles throughout.

Unit 318-Balcony-Concrete. Spalling throughout post at R rotted.

Unit 319- Balcony-Outdoor carpet. Ok

Unit 301-No Access

Unit 300-Balcony-Tile. 3' hollow area at line near wall.
Note: Door was separated.

Unit 320-Balcony-Tile. Areas that could be tested, ok.

Storage room-Painted concrete. Room is in good condition.

Trash Chute-Painted concrete. Room is in good condition.

200 NUMBERED UNITS

Unit 209- Balcony-Tile. Beadboard on walls. 6' BC spall at ceiling front. 2' CD spall straight to end.

Unit 210- Balcony-No access.

Unit 208-Balcony-Tile. Upgraded windows. Hollow tile throughout.

Unit 211-Balcony-Tile. Beadboard walls.

Unit 212-Balcony-Tile. Ceiling previous repair near edge. Hollow tile throughout.

Unit 207-Balcony-Tile. Beadboard walls. 2’ AB spall at the middle of ceiling edge. Hollow tile throughout.

Unit 206-Balcony-Tile. Beadboard walls. F2’ C spall at ceiling L. Hollow tile throughout, possibly from installation.

Unit 214-Balcony-Tile. No access-Animal on balcony.

Unit 205-Balcony-Tile. Hollow tile at front of sliding glass door. Previous 1’x2’ ceiling spall repair at L ceiling. Hook or possibly rebar at balcony edge.

Unit 215-Balcony-Tile. Sliding glass door removed. Hollow tile throughout, possibly from installation. Beadboard on walls.

Unit P-2-Balcony-Tile. Hollow tile near sliding glass door entry and L side in the middle of balcony.

Unit 216-Balcony-Tile. Hollow tile throughout. Beadboard walls. Above post as A crack (bracket has been covered with stucco).

Unit 204-Balcony-Marble. Hollow area at sliding glass door and front edge, R & L perimeters. C spall L ceiling rear. A crack L front. 1’x3’ BC crack at ceiling R.

Unit 217- Balcony-Tile. 2’ B spall at ceiling edge L.

Unit 203-Balcony-Tile. Ok.

Unit 202-Balcony-Tile. Hollow tile throughout. Post at R is rusted at the bottom. The L is rusted throughout as well. 2’ AB spider crack on wall L.

Unit 218-Balcony-Tile. Hollow tile at front edge & perimeter, the remaining tiles were inaccessible. The area was covered with many items.

Unit 219-Balcony-Tile. Hollow tile throughout.

Unit 201-Balcony-Tile. Hollow tile throughout. Post at R is rusted.

Unit 220-Balcony-Tile. Beadboard on walls. Hook in ceiling R.

Unit 200-Balcony-Tile. Hollow tile near middle L and center, possibly from installation. 2' AB crack, where shades are screwed in. Hook on wall near sliding glass door. Upgraded windows.

Electrical room-Painted concrete floor. 800 AMP service.

Trash room-Painted concrete floor. Room in good condition.

Laundry room-Painted concrete floor. Room in good condition.

100 NUMBERED UNITS

Unit 100-Balcony-Tile. Beadboard on walls. Hooks on main wall.

Unit 120-No Access

Unit 101-Balcony-No access due to hurricane shutters.

Unit 119- Balcony-Tile. Ceiling L C spall. 4'x3', 1', and 2' C spalls.

Unit 102-Balcony-Tile. 2'x3' A crack at front edge and rusting.

Unit 118- Balcony-Tile. 3' A crack in ceiling. Several spider cracks. Stucco missing at corner beam.
Note: Unit under construction.

Unit 117- Balcony-Carpet. Beadboard on walls. 4' A crack on ceiling.

Unit 103-Balcony-Tile. Ok.

Unit 116- Balcony-Tile. Ceiling R post spall at bracket. Old repair above sliding glass door. 3' hook in ceiling.

Unit 104-Balcony-Tile. Shutters.

Unit 115-Balcony-Tile. Beadboard on walls.

Unit 105-Balcony-No access due to shutters.

Unit 106-Balcony-Tile. 2’ CD spall at ceiling R. Paint is peeling around sliding glass door.

Unit 114-Balcony-Tile. Ceiling L at beam and ceiling small 3” crack at plate.

Unit 107-Balcony-Tile. Post on outside is rusted. Shutters.

Unit 112-Balcony-Tile. Beadboard on walls.

Unit 108-Balcony-Tile. Beadboard on walls.

Unit 111-Spider cracks in ceiling, multiple superficial cracks. 3’ CD at R of door.

Unit 110-No access. No key available.

Unit 109-Balcony-Tile. Beadboard on walls.

Trash room-Painted concrete floor. Room in good condition.

Electrical meter-Painted concrete floor. Room in good condition.

Castle 11
Building Exterior

Layout uploaded for identification purposes.

W side entry door-Missing stucco above door.

The rear W side of building on the outside edge of the 10 stack the 2nd and 3rd floor paint is bubbling.

509-Balcony edge has D spall on the W side.

207-Post at top R of balcony has concrete missing from around mounting plate.

507-Balcony edge has deteriorating concrete.

206-Balcony has 3' BC crack along the front edge.

305-Balcony has C spalling along balcony front edge and wrapping around to R side.

505-R corner edge of balcony appears to have paint peeling or possible spall.

504-R corner edge of balcony appears to have paint peeling or possible spall.

404-R corner edge of balcony appears to have paint peeling or possible spall.

304-C Crack throughout balcony front edge.

402-4th floor balcony edge R 3rd floor ceiling R at post has concrete missing around mounting plate.

400-4th floor balcony edge R 3rd floor ceiling R at post has concrete missing around mounting plate.

420-4th floor balcony edge R 3rd floor ceiling R at post has concrete missing around mounting plate.

419-Post has rust damage.

319-3rd floor balcony edge R 2nd floor ceiling R at post has concrete missing around mounting plate.

218-Post has rust damage.

318-Previous concrete repair on R edge.

418- Previous concrete repair on R edge.

217-Post has rust damage.

317-Post has rust damage.

517-Possible B spall.

312-4th floor balcony edge R 3rd floor ceiling R at post has concrete missing around mounting plate.

311-Possible previous concrete repair on L edge.

211-Possible previous concrete repair on L edge.

210-Possible spall near camera.

310-B Crack at R corner.

OBSERVATIONS / PHOTOS

Dropbox links to access photos and field reports of observed spalling damage of the areas listed below will be provided to each responding contractor:

100 Unit Photos
https://www.dropbox.com/scl/fo/oyay4xcmxl8cuqs3qw8ij/h?rlkey=08p6vlz7zwxpfvlemeejk25oi&dl=0

200 Unit Photos
https://www.dropbox.com/scl/fo/2b4i0tlkpkkkw4nlyp13s/h?rlkey=85dml7ralyo03dh94cq6hco2l&dl=0

300 Unit Photos
https://www.dropbox.com/scl/fo/kmiuz57mo9t5k5clop6fy/h?rlkey=wdcp8gxnt44snuyimjksvxzjt&dl=0

400 Unit Photos
https://www.dropbox.com/scl/fo/ga5e4g4hsbgz5yyxvjldz/h?rlkey=ijjzg3rh2d7m41w0eet193xeb&dl=0

500 Unit Photos
https://www.dropbox.com/scl/fo/865nfud2qdua70js9hqqc/h?rlkey=hvxlvi5mpaxznom6yg5j0m2mw&dl=0

Exterior Photos
https://www.dropbox.com/scl/fo/mrool9sn37tcxfcxwsiyj/h?rlkey=1vzkx2xy5lgag5mqxcvl5tvr7&dl=0

SPALLING LEGEND

SPALLING KEY

This report describes each spalling area as either “A”, “B”, “C”, or “D”. The following describes each different condition:

“A” Spalling: This condition is often described as “spider” cracking. An “A” spalling condition will not have any exposed steel, nor will any concrete material be missing or broken. These areas can best be repaired by sealing the crack with an epoxy composite material or approved caulk. “A” areas will require ongoing observations for future maintenance if the area continues to deteriorate.

“B” Spalling: A “B” spalling condition exists where the crack exceeds 1/8” wide. There is no exposed steel and little or no concrete chipping. These areas are the most difficult to repair. It is very difficult to determine the extent of damage without chipping away the “spalled” concrete to expose the steel. It is often necessary to remove concrete far in excess of the original crack to obtain concrete solid enough to accept the patch material.

“C” Spalling: This condition is easy to identify. Concrete material is missing and the reinforcing steel is exposed. “C” spalling is often the latest manifestation of spalling, surrounded by “A” and “B” spalling. The repair method is straight forward. Concrete material must be removed to expose and measure the diameter of the exposed steel. The steel can be either treated or replaced. If replaced, new steel must be epoxied into non-affected concrete. The contractor is to inspect each area of known or noted concrete spalling to determine the extent of damage. “C” type spalling should be repaired as follows:

1. All damaged concrete shall be removed to expose the underlying steel reinforcement. Steel should be exposed a minimum of 20 diameters beyond the area of concrete damage.
2. Once steel is exposed a measurement shall be taken to determine whether or not steel reinforcement has deteriorated more than 10% of cross sectional area. If steel deterioration is excessive the steel reinforcement shall be removed and replaced. Overlap shall be 25 inches minimum.
3. Exposed existing steel shall be treated with an approved material similar to “Cor-seal” in accordance with the manufacturer’s recommendations.

4. The spalled area shall be patched with an approved material similar to the Tamms product line. Such material shall be mixed and installed in strict adherence to the manufacturer's instructions.

5. When completely cured, the affected area shall be sealed with an approved product similar to Bullfrog, Fox or Thompson's masonry sealer.

<u>"D" SPALLING:</u> This is the most severe condition. It is similar to "C" spalling, however the missing concrete and/or exposed steel is noticeably worse. The repair scenario is identical to the "C" repair, except that the reinforcing steel **"MUST"** be replaced. Because the affected area is often times large, it is usually prudent to completely replace the structural element. Site logistics may prevent replacing the element, but it should always be considered. As such, these repairs are the most costly, but also the most necessary to prevent further structural damage.

TECHNICAL GUIDELINES

1. **Guide – Vertical & Overhead Spalling Repair**

2. **Guide for Selecting Application Methods**

3. **REMR Tech Note – Spall Repair**

4. **Surface Repair Using Form & Pump Techniques**

5. **Surface Repair Using Form and Pour Techniques**

6. **Structural Crack Repair Using Epoxy Injection**

7. **Repair Details**
    - **Spall Repair Detail**
    - **Full Depth Slab Repair**
    - **Column Spall Repair**
    - **Spalled Edge Repair**
    - **Ceiling Spall Repair**

ACI RAP Bulletin 6

American Concrete Institute®
Advancing concrete knowledge

FIELD GUIDE TO CONCRETE REPAIR APPLICATION PROCEDURES

Vertical and Overhead Spall Repair by Hand Application

ACI RAP Bulletin 6

(Reapproved 2010)

Field Guide to Concrete Repair Application Procedures

Vertical and Overhead Spall Repair by Hand Application

Reported by ACI Committee E706

David W. Whitmore
Chair

J. Christopher Ball*
Peter H. Emmons
Timothy R. W. Gillespie
H. Peter Golter
Fred R. Goodwin
Bob Joyce
Brian F. Keane
Kenneth M. Lozen
John S. Lund
Kelly M. Page
Jay H. Paul
George I. Taylor
Patrick M. Watson

*Primary author.

ACI Repair Application Procedure 6.

Structural Disclaimer

This document is intended as a voluntary field guide for the Owner, design professional, and concrete repair contractor. It is not intended to relieve the user of this guide of responsibility for a proper condition assessment and structural evaluation of existing conditions, and for the specification of concrete repair methods, materials, or practices by an experienced engineer/designer.

Introduction

One of the most common application methods for repairing concrete is by hand troweling mortars. This method can be used to repair spalled or deteriorated concrete (Fig. 1) or to resurface vertical, overhead, and horizontal concrete surfaces. Applying repair materials by hand does not require significant equipment and is ideal for shallow surface repairs, especially in areas with limited or difficult access. While both portland cement-based and resin-based repair mortars have been used for trowel-applied vertical and overhead repairs, this field guide focuses on the application of portland cement-based repair materials.

Before any concrete repair is initiated, the root cause of the damage should be determined with a thorough condition survey of the structure. Typical causes of concrete damage can include corrosion of embedded metals from exposure to chloride ions from deicing salts or sea spray in coastal areas; disintegration from freezing-and-thawing cycles when the concrete is saturated with water; or deterioration from chemical attack. Understanding the cause of the deterioration, the owner's repair objectives, and the in-service environment of the concrete structure will help in the proper selection of repair materials and application methods.

The technique of hand troweling repair mortars requires the selection of a sag-resistant mortar and attention to detail during application to achieve an adequately consolidated repair that is well-bonded to the concrete substrate. The successful installation is a function of good surface preparation, application techniques, curing procedures, and properties of the repair material selected.

What is the purpose of this repair?

Hand-applied repair mortars replace damaged concrete and are generally recommended for thin repairs that are cosmetic in nature. Thin overlays of mortar can also be applied to renovate deteriorated vertical and overhead concrete surfaces. This technique, when properly executed, improves the appearance of the deteriorated structure and provides additional protection to the concrete surface.

When do I use this method?

Structural repair projects generally require other repair methods such as form and cast-in-place, grouted pre-placed aggregate repair, or shotcrete. Experienced workers using wood floats, sponges, or steel trowels can achieve a variety of finishes with trowel-applied mortars. Hand application has been used to repair vertical and overhead surfaces including walls, columns, beams, soffits, and building facades.

Placement thickness can vary depending on the type of materials selected and the size, depth, and orientation of the repair cavity. Placement thickness can range from 1/8 to 2-3/4 in. (3 to 70 mm) on vertical surfaces, and 1/8 to 1 in. (3 to 25 mm) on overhead surfaces in a single layer. Deeper placements may require repair material to be placed in additional layers.

How do I prepare the surface?

The recommended steps in properly preparing the surface to receive a hand-applied mortar are as follows:

Fig. 1—Concrete delamination.

Fig. 2—Bulk concrete removal.

1. *Bulk concrete removal and edge conditioning*— Loose, delaminated concrete should be removed until the substrate consists of sound concrete (Fig. 2). Where corrosion of the reinforcement exists, continue bulk removal along the reinforcing steel and adjacent areas with evidence of corrosion-induced damage that would inhibit bonding of repair materials. Bulk concrete removal should include undercutting the corroded reinforcing steel by approximately 3/4 in. (19 mm). The shape of the prepared cavity should be kept as simple as possible–generally square or rectangular in shape. The edges of the patches should be sawcut perpendicular to the surface to a depth of 1/2 in. (13 mm) to avoid feather edging the repair material (Fig. 3).

2. *Final surface cleaning*— Use abrasive blasting (Fig. 4) to remove residual dust, debris, fractured concrete, and contaminants that prevent proper bonding. If abrasive blasting is not feasible, pressure washing using a minimum 3000 psi (250 MPa) may be acceptable depending on the bond strength required. Blowing with oil-free compressed air or alternately, the use of a vacuum, may be appropriate if dust is still present after the blasting. The final surface texture should be rough, with approximately a 1/4 in. (6 mm) amplitude (Fig. 5) (Concrete

Fig. 3—Edge conditioning.

Surface Profile [CSP] No. 6 to 9 per ICRI Technical Guideline No. 310.1R-2008);

3. *Treatment of exposed reinforcement*—Bond-inhibiting corrosion should be removed from the reinforcing steel by an abrasive blasting wire wheel or needle scaler. If the cross-sectional area of the reinforcing steel has been significantly reduced, a structural engineer should be consulted. If a reinforcing steel coating has been specified, apply the coating after the reinforcing steel has been cleaned (Fig. 6).

4. *Substrate saturation*—Most portland cement-based materials require the base concrete to be in a saturated, surface dry (SSD) condition prior to application to prevent a rapid loss of moisture from the repair material and into the substrate. An SSD condition is achieved when the body of the concrete is saturated and free surface water and puddles have been removed from the surface of the concrete. An SSD surface is not recommended if a polymer bonding agent is to be used. When using polymer bonding agents, follow the manufacturer's recommended surface preparation requirements. The general recommendations previously given may be influenced by several factors, including:

- Desired roughness profile of the prepared surface (This may be specified by the manufacturer of the repair product);
- Method of surface preparation, including chipping hammers, abrasive blasting, high-pressure water-blasting, or hydrodemolition;
- Possible contamination of the surface by chemicals, oils, or grease; possible carbonation; and methods of removing contaminants or carbonated concrete;
- Repair material manufacturer's recommendations (Ask for technical data sheets and installation bulletins and read the printed instructions on the packaging.); and
- Treatment of existing cracks and joints.

For additional information, consult the recommendations of the International Concrete Repair Institute (ICRI) Guidelines No. 310.2-1997, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Overlays," or No. 310.1R-2008, "Guide for Surface Preparation for Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion."

Fig. 4—Final surface cleaning.

Fig. 5—Properly prepared surface.

How do I select the right material?

Hand- or trowel-applied repair materials are generally proprietary, prepackaged, cementitious products. Portland cement-based materials designed for hand application may also include polymers, silica fume, shrinkage-compensating materials, and other additives for enhanced physical properties and improved handling.

Specifiers, applicators, and owners can consult ACI 546.3R-06, "Guide for the Selection of Materials for the Repair of Concrete," or ICRI Guideline No. 320.2R-2009, "Selecting and Specifying Materials for Repair of Concrete Surfaces," for a useful checklist for prioritizing desired material properties. Manufacturers' technical data sheets should be consulted for material properties.

The physical property requirements such as drying shrinkage, permeability, freezing-and-thawing resistance, and mechanical properties vary from project to project depending on the expected service conditions. The properties critical to the long-term success of the repair should be determined during the evaluation phase and be specified.

Fig. 6—Treatment of exposed reinforcement.

Other factors that may influence the selection of repair materials include desired application thickness, rate of strength gain, ease of application, color, and in-place cost.

For some hand-applied repairs, sealers or decorative or protective coatings may be used to provide additional protection to the base concrete, to enhance aesthetics, or both. When this is the case, confirm the required curing and drying time (or maximum moisture content) with the sealer or coating manufacturer before application commences. For more information, consult ACI 515.1R, "Guide to Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete."

What equipment do I need?

Typical equipment needed for hand-applied repair mortars includes:

- A suitable mixer unit such as a drill/paddle/pail combination for small repairs (Fig. 7), or paddle-type mortar mixers for larger applications;
- Air compressor, sawcutting equipment, blades, abrasive blast equipment;
- Water-measuring device to ensure that proper amounts of mixing water are used; and
- Finishing, handling, and testing tools required by the specification or good concreting practices.

Be sure that necessary equipment and tools are on site and in proper working order. Have backup equipment or alternate methods planned and available.

What are the safety considerations?

Concrete repair mortars are hazardous materials and should be treated as such. Job-site safety practices should include the following where applicable:

- Applicable material safety data sheets (MSDS) should be on hand;
- Machinery and equipment used must have the correct safety guards and warnings in place;
- Workers should wear protective gloves and other clothing needed to prevent skin contact with wet, highly alkaline cementitious materials;

Fig. 7—Typical equipment to mix materials.

- A face shield or safety glasses are needed to provide eye protection;
- Eye wash facilities should be available on the job site.
- Dust masks are needed for workers operating or working near the material mixer and forced-air respirators used for abrasive blasting;
- Hearing protection must reduce sound levels reaching the inner ear to limits that are specified by the United States Occupational Safety and Health Administration (OSHA); and
- Confirm that adequate ventilation is available in closed spaces before operating equipment that emits dangerous exhaust fumes.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives for the owner, engineer, contractor, materials manufacturer, and any other parties needed to explain the means, methods, and materials necessary to achieve the repair objectives. See ICRI Guideline No. 320.2R-2009, "Guide to Selecting and Specifying Materials for Repair of Concrete Surfaces."

Repair procedure

1. *Apply the repair material.*

- Mix the material following the manufacturers' recommendations;
- Scrub a thin bond coat of the repair mortar into the SSD substrate, thus filling pores to ensure intimate contact and to help prevent sloughing or sagging of repair

Fig. 8—Hand application of repair material.

Fig. 9—Spray application of curing compound.

materials on vertical and overhead surfaces. Alternatively, apply a bonding agent if required by the manufacturer or the repair specification;

- Apply the material with adequate pressure before the bond coat dries (Fig. 8). Thoroughly consolidate the repair material into the corners of the patch and around any exposed reinforcement in the repair zone. Full encapsulation of the reinforcement is important for long-term durability; and
- If a second lift is required, thoroughly roughen the surface of the first lift by scoring the soft mortar to achieve an aggressive finish, similar in profile to the prepared concrete substrate. This process will promote additional mechanical bond between lifts. If the second lift will not be immediately applied, keep the first lift moist until application of the second lift. After the first lift has reached final set, moisten the surface of the first lift, scrub in a thin layer of fresh mortar, and apply the second lift of material. Once the desired thickness has been achieved, strike off level with the adjacent concrete.

2. *Finish and cure the repair.*

- Finish the repair material to produce a final finished appearance as required by the project specifications. Because of the nonbleeding, "sticky" nature of many of these materials, the use of an evaporation control film may be helpful; and
- As with all portland cement-based materials, proper curing will provide enhanced physical properties. Good curing procedures prevent rapid moisture loss at early ages. Consult the product manufacturer for curing instructions. Curing will generally be conducted in accordance with ACI 308R, "Guide to Curing Concrete." The use of curing compounds (Fig. 9) that comply with the moisture retention requirements of ASTM C309, or moist curing are common curing methods.

How do I check the repair?

Requirements may include:

- Before and after photos;
- Confirmation of acceptable surface preparation. This may include observing the surface amplitude profile. Alternatively, direct tension testing of the prepared surface will provide quantitative data regarding the level of surface preparation achieved;
- Material testing performed by a qualified testing agency;
- Sounding the cured repair for delaminations;
- In-place direct tensile bond testing of the hardened, cured repair to the base concrete using methods similar to those described in ICRI Technical Guideline No. 210.3-2004, "Guide to Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials," published by the International Concrete Repair Institute. Important observations include maximum stress, expressed in psi or MPa, and failure mode (base concrete, bond line, or cohesive failure of the mortar).

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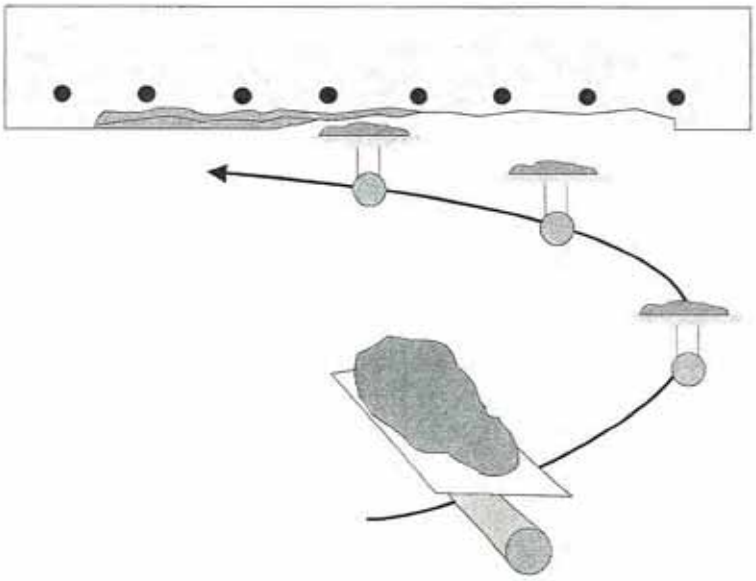
TECHNICAL GUIDELINES

Prepared by the International Concrete Repair Institute
February 1992 (reissued April 1996)



Guideline No. 03731

Guide for Selecting Application Methods for the Repair of Concrete Surfaces

TECHNICAL GUIDELINES

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February 1992

Guide for Selecting Application Methods for the Repair of Concrete Surfaces

Guideline No. 03731

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Selection

The selection of a suitable repair material and application method should proceed in this sequence:

1 Select the repair material providing the strength and durability properties which best restore the integrity of the original design.

2 Select a method of placement which will successfully place the repair material onto the prepared concrete.

3 Review the physical properties and placement requirements for the repair material to ensure the constructibility of the selected repair system.

4 Change the material or application method as needed to provide a constructible repair.

When trade-offs need to be made, the long-term durability of the repair system is far more important than the ease of application.

Quality Assurance and Quality Control

The combination of the working conditions, the repair contractor, the existing concrete material, the structure design, and the repair material, is unique to every project. Much can go wrong without proper quality assurance and routine quality control. Start by selecting a qualified contractor who can demonstrate successful long-term repairs using the intended installation method. If any questions remain unanswered regarding the contractor's qualifications, the repair material, or the installation technique, consider a pilot project.

During the actual repairs, develop a feedback system to verify compliance with the engineering requirements established for the project. Physical properties of the materials can be confirmed by sampling at the time of placement, by in-place testing, or by using core sampling techniques. Bond strengths can be verified by coring through the repair and into the substrate, followed by applying a tensile force to the core.[1] Consolidation of the materials can be verified with visual observations of extracted cores and in-place testing.

[1] Suitable direct tensile test methods are described in ACI 503R "Use of Epoxy Compounds with Concrete," Appendix A–Test Methods, Manual of Concrete Practice.

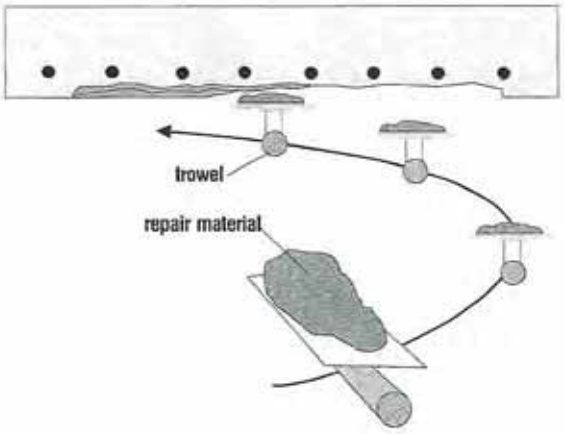
Application Methods

Trowel applied

General description: Repair material is mixed into a trowelable, non-sag consistency. Trowels or other suitable placing tools are used to transport the repair material to the prepared substrate. The repair material is pressed into the substrate to develop intimate contact without voids.

Best application: Surface restoration when reinforcing steel is not encountered.

Material requirements: Fine-grained material easily finished, with non-sag properties to stay in place in vertical or overhead applications.



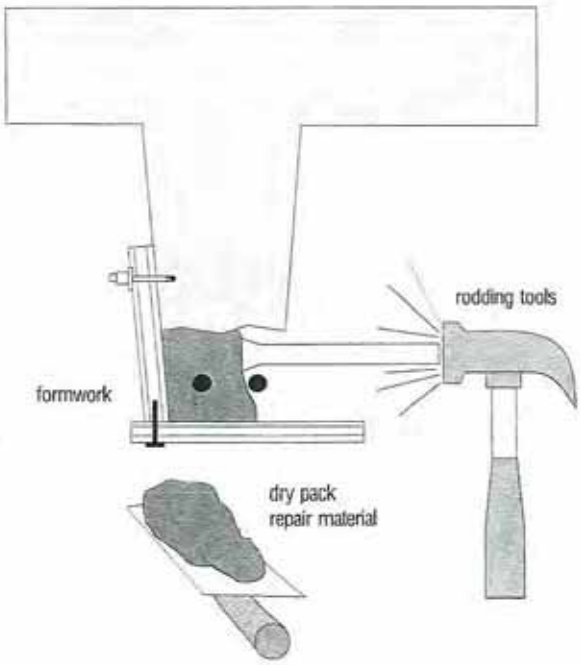
Dry packing

General description: Repair material is mixed into a uniform, cohesive plastic state, then transported to a confined space and compacted with rodding tools to produce a dense repair material.

Best application: Post-tensioning grout pockets; tie holes; pan joist bottoms; waffle pan joists; vertical, overhead and horizontal locations.

Material requirements: Mortar with consistency capable of being molded into a ball without sagging.

Reference: Headquarters, United States Army Corps of Engineers (1995), "Evaluation and Repair of Concrete Structures," EM 1110-2-2002, Washington, D.C.



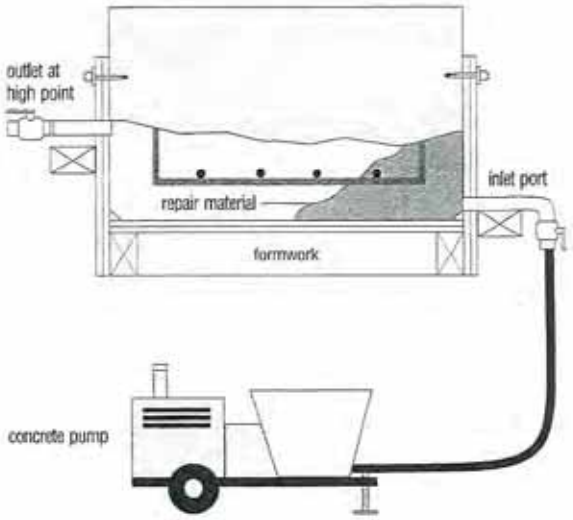
Form and pump

General description: Repair material is mixed and pumped via concrete line connected to the formwork, until the cavity is filled and pressurized. Consolidation and bonding is provided by the internal form pressure.

Best application: Overhead and vertical applications where congested reinforcing is present. Beam bottoms, ribs, slab soffits, or sectionalized areas.

Material requirements: Pumpable, good flow characteristics, self-bonding, aggregate size compatible with size of cavity and space between bars.

Reference: ACI 304.2R, "Placing Concrete by Pumping Methods"



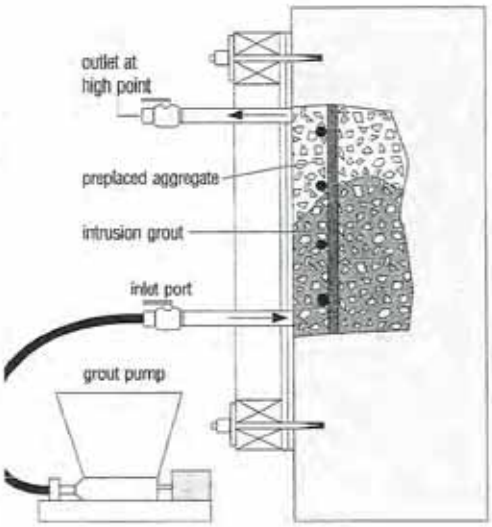
Preplaced aggregate

General description: Gap-graded aggregate is placed into formed cavity. Grout is then pumped into form via grout pump until all voids are filled and pressurized. Shrinkage is minimal because of aggregate contact and volume.

Best application: Vertical and overhead applications where extremely low shrinkage of repair material is required; column enlargements.

Material requirements: Gap-graded aggregate (40-50% void ratio), pumpable grout, self-bonding portland cement or resin-based binder. One inch (25 mm) or larger aggregate typically used in cementitious applications.

Reference: ACI 304.1R, "Guide for the Use of Preplaced Aggregate Concrete for Structural and Mass Concrete Applications"



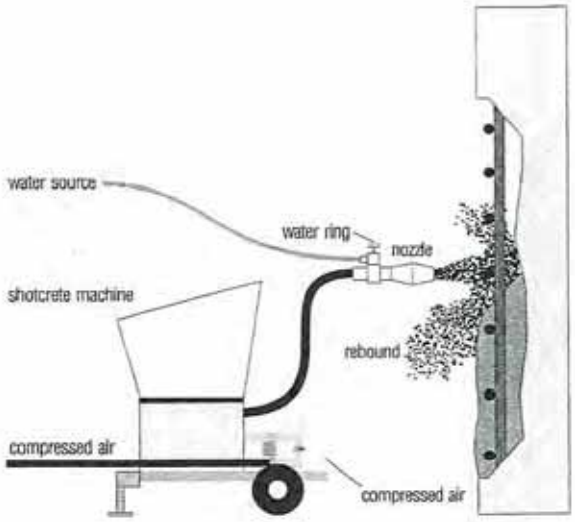
Dry-mix shotcrete

General description: Repair material is placed dry or slightly damp into shotcrete machine and mixed with compressed air. The mixture is transported via hose to the exit nozzle where water and admixtures, if any, are introduced. The ingredients are propelled onto the prepared substrate by the force of the compressed air.

Best application: Large vertical and overhead areas with small bars, No. 6 (19 mm)[3] or less, and minimal congestion of embedded reinforcement.

Material requirements: Well-graded aggregate with necessary binders (usually portland cement). Mixture must be proportioned to compensate for rebound losses. Admixtures are frequently used to shorten set time, and/or to allow thicker layers to be built-up in a single pass.

Reference: ACI 506.2, "Guide to Shotcrete"



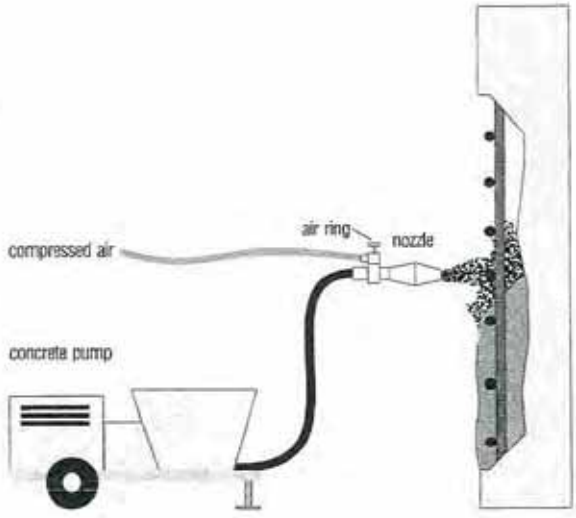
Wet-mix shotcrete

General description: Pre-batched and thoroughly mixed repair material is placed into a concrete pump and transported via pump line to an exit nozzle where compressed air and admixtures, if any, are introduced. The repair material is propelled onto the surface by the compressed air.

Best application: Large vertical areas with small bars, No. 6 (19 mm)[3] or less, and minimal congestion of embedded reinforcement.

Material requirements: Pumpable, low-slump mixture which does not sag when impacted on the prepared substrate.

Reference: ACI 506.2, "Guide to Shotcrete"



[3] As there are presently no generally accepted conversion standards for reinforcing steel, the ASTM A615 #6 has been rounded to the nearest millimeter.

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REMR Technical Note CS-MR-4.5
Spall Repair

Purpose

To provide guidance for repairing concrete spalls.

Overview

A spall in a concrete surface may be the result of localized distress or the symptom of a more widespread distress in the concrete element. In either case, an attempt should be made to determine the cause of the distress prior to selecting a remedy. Causes of spalls include (a) corrosion of reinforcing steel, (b) an inoperative joint resulting from incompressibles in the joint, (c) mis-alignment of joint dowels, (d) impact, (e) freezing and thawing of nonair-entrained concrete in a critically water-saturated condition, (f) freezing and thawing of porous aggregate in a critically water-saturated condition, and (g) alkali-silica reaction.

Repairs of spalls to remedy the symptoms of a more widespread distress are intended to be temporary solutions that extend the service life of a concrete element until a long-term solution can be implemented.

Standard practice for the repair of concrete spalls varies depending on the type of concrete element being repaired, cause and extent of damage, location of the spall, and repair material selected. The repair material selection is typically based on such factors as properties of the repair material, climatic conditions, repair time frame, expected service life, and cost. Properties that influence the selection of repair material include shrinkage, strength, modulus of elasticity, creep, and sag.

The repair process generally includes (a) an inspection to document the extent and details of damage, (b) an evaluation to determine the cause of distress and the as-constructed details for the damaged element, (c) the selection of a repair material, and (d) the application of the repair material in accordance with standard concrete practice for portland cement based concretes or in accordance with the manufacturer's instructions for commercial products.

Concrete Removal

The general procedure for preparing a spalled area for repair is to (a) mark off the area to be repaired using straight lines between corners, (b) make a

normal-to-the-surface cut along the marked boundary, (c) remove all concrete from within the cut perimeter to a near uniform depth, (d) sound the remaining concrete within the repair area for weaknesses and perform removal as needed, and (e) clean all surfaces within the repair area. The marked area should have 90-deg corners with the sides parallel or normal to the direction of the reinforcement. The marked boundaries for the repair area should be a minimum of 50 mm (2 in.) outside the perimeter of the spall. For a single spall at a pavement joint, the repair area should be a minimum of 100 mm (4 in.) wide (measured normal to the joint) and 250 mm (10 in.) long (measured along the joint) (Patel, Mojab, and Romine 1993). If a number of spalls are closely located to each other, these spalls should be included in a single area marked for repair.

A normal-to-the-surface cut along the marked boundary should be made with a diamond blade saw. However, when diamond cutting is not practical, the normal edge can be made with an impact hammer. The depth of cut should be a minimum of 25 mm (1 in.), except for spalls at pavement joints, where a minimum 50-mm (2-in.) deep cut is recommended (Patel, Mojab, and Romine 1993). In situations where the diamond saw could cut into the reinforcing steel due to inadequate concrete cover, the boundary edge should be formed by means of impact hammers. A pachometer can be used to estimate the depth of cover.

Concrete should be removed to produce a near uniform depth for the repair area. For spalls at pavement joints, it is recommended that the depth of repair be a minimum of 50 mm (2 in.) (Patel, Mojab, and Romine 1993). A full-depth repair must be used when dowel bars are reached or when the spall depth is greater than one-third of the thickness of pavement.

Full-depth repairs require that a full-depth saw cut be made at the boundaries. For pavements subject to heavy traffic, dowels will be required for load transfer between the existing pavement and repair and back to the pavement in the direction of traffic (American Concrete Pavement Association 1989). Dowel holes should be made with a gang drill to avoid misalignment of the dowels. The American Concrete Pavement Association recommends that a minimum of four 32-mm (1-1/4-in.) to 38-mm (1-1/2-in.) dowels per wheel path be used.

Impact hammers are typically applicable for smaller and moderate areas of removal and for areas of limited access. Removal should begin at the interior of the repair area and progress toward the boundaries. Removal should be performed using 14-kg (30-lb) hammers for the interior and 6.8-kg (15-lb) hammers for around reinforcing and near boundary edges.

Mechanical milling (single drum, rotary cutter head with tungsten-carbide bits) is applicable for large areas where the concrete cover is to be removed. Care must be taken to avoid contact with the reinforcing steel as both the reinforcing and the cutter drum could be damaged. The front and back edges of removal will be rounded and the other two sides possibly feathered.

Rounded and feathered edges should be cut to form normal-to-the-surface boundaries. For spalls at pavement joints, the orientation of boundaries with rounded edges should be parallel to the direction of traffic (Patel, Mojab, and Romine 1993).

Hydrodemolition (water jet blasting) is applicable for large areas of spall repair where the reinforcing steel is to be exposed and reused in the repair. Waterborne fines deposited on newly exposed concrete and reinforcing surfaces during removal should be removed by low-pressure water blasting before deposits dry. Feathered edges along the removal boundary should be cut to form a normal-to-the-surface boundary.

After removal, exposed surfaces should be visually inspected and sounded for weaknesses and delaminations. If found, additional removal will be required.

Additional help in selecting a removal method can be found in REMR Technical Note CS-MR-1.14.

Surface Preparation

Prior to preparation of concrete surfaces, exposed reinforcing should be inspected for proper exposure, clearance, cross-sectional area, and location. Reinforcing bars must be further exposed if the remaining concrete is debonded from the reinforcing steel. Removal must be continued to completely expose the bar if more than half of a reinforcing bar perimeter has been exposed. For completely exposed reinforcing bars, a minimum clearance of 19 mm (3/4 in.) or nominal maximum size aggregate plus 6 mm (1/4 in.), whichever is greater, must be provided between the reinforcing bar and surrounding concrete. A structural engineer should be consulted if the cross-sectional area of a bar has been reduced by 25 percent or more or if two adjacent bars have been reduced by 20 percent or more. Out-of-plane and loose reinforcing should be secured in its design location.

The general procedure in preparing concrete and reinforcing surfaces for optimum bonding is to sandblast the surfaces and then remove dust and debris by air blasting, low-pressure water blasting, or brooming. If the damage was the result of corrosion, an epoxy coating should be considered to protect the exposed reinforcing steel. Final inspection of the prepared area and remedying of deficiencies should be completed just prior to batching the repair material.

Additional help in preparing concrete and steel reinforcing surfaces for bond can be found in REMR Technical Note CS-MR-2.1.

Formwork

If repairs are to be made to vertical or overhead surfaces and a non-sag material is not to be used, formwork will be required. Prior to installing forms, the concrete surface must be inspected for any surface contours that could result in air being trapped during concrete placement or pumping. If found, concrete must be removed to change the contour, or vent tubes must be installed.

Formwork should be designed to withstand a minimum 0.1 MPa (14 psi) hydrostatic pressure (Emmons 1993). Installed form anchors should be tested for slippage via preloading. Formwork should be secured to the concrete with expansion anchors or standard form ties. Preformed foam gaskets or cast-in-place foam may be required to provide a watertight seal between the concrete and form surfaces.

Repair Materials

Restrained contraction of repair materials, the restraint being provided through bond to the existing concrete substrate, is a major factor that significantly increases the complexity of the repair. Drying shrinkage and thermal gradients are the primary causes of contraction, which often results in cracking of the repair material or debonding of the repair. Therefore, repair materials must be dimensionally compatible with the existing concrete substrate to minimize the potential for cracking and debonding as a result of restrained contraction. Those material properties which influence dimensional compatibility include shrinkage, thermal coefficient of expansion, modulus of elasticity, bond, and creep.

Conventional concretes

Conventional concretes are low-cost, general-purpose repair materials that are typically used where the depth of repair is greater than 50 mm (2 in.). The batched mixtures contain a Type I portland cement with admixtures included as needed to shorten the time of setting, to increase strength gain and improve durability of the hardened concrete, and to inhibit the corrosion of reinforcing steel. Most conventional concretes will obtain a minimum compressive strength in the range of 21 MPa (3,000 psi) to 28 MPa (4,000 psi) at 28-day age.

Rapid-hardening cementitious repair materials

Rapid hardening cementitious repair materials are used to minimize out-of-service time for repairing pavements and bridge decks. Repair depth and volume are usually small due to the high cost and rapid heat generation of the rapid-hardening materials. These materials include concretes made with

Type III portland cement, concretes containing regulated-set portland cement, gypsum-based concrete, magnesium phosphate concrete, and concrete containing high alumina cement.

Most of the rapid-hardening products will obtain a minimum compressive strength of 21 MPa (3,000 psi) at 4-hr age. The high alumina concretes require 6 hr to achieve this minimum compressive strength. Concrete mixtures containing Type III portland cement and an accelerator can obtain a minimum compressive strength of 14 MPa (2,000 psi) at 6-hr age. The regulated-set concrete is a very high early-strength concrete that will obtain a minimum compressive strength of 34 MPa (5,000 psi) at 24-hr age.

Concrete containing high alumina cements will have increases in porosity, permeability, and strength losses with time due to the conversion of hydrated aluminate compounds (Zia, Leming, and Ahmad 1991). This will eliminate the high alumina concretes from consideration for many repair applications.

Additional information regarding rapid hardening cementitious repair materials can be found in REMR Technical Note CS-MR-7.3.

High-performance concretes

High-strength concretes are attractive as a potential repair material for structural concrete because of their high durability and strength while requiring minimal out-of-service time in making the repair. These concretes have a maximum water-cement ratio of 0.35; a minimum Durability Factor of 80 percent (American Society for Testing and Materials (ASTM) C 666-92, Method A); and a minimum compressive strength of 21 MPa (3,000 psi) at 4-hr age, 34 MPa (5,000 psi) at 24-hr age, or 69 MPa (10,000 psi) at 28-day age (Zia, Leming, and Ahmad 1991).

High-performance concretes may be obtained with either specialty cements or Type III portland cement (Zia, Leming, and Ahmad 1991). The Type III portland cement will require an accelerator to achieve the required minimum compressive strength at 24-hr age. High-performance concretes frequently require a retarding admixture to control rapid stiffening in even moderate temperatures due to high cement contents.

Mineral admixtures are sometimes included to produce a high-performance concrete via improving the durability or strength characteristics of a mixture (Zia, Leming, and Ahmad 1991). These admixtures include Class C and Class F fly ashes, ground granulated blast-furnace slag, and silica fume.

Drypack mortars

Drypack mortars are typically used to repair small confined areas and cavities in vertical and overhead surfaces. Conventional drypack mortars typically consist of one part cement, three parts of sand passing a No. 16 sieve, and just enough water so that the mortar will stick together when molded into a ball by hand. To reduce shrinkage, the batched mortar should be allowed to stand for 30 min and remixed before placement. For commercial drypack products, follow the manufacturer's recommendations.

Drypack mortars are hand placed in approximately 10-mm (3/8-in.) thick layers followed by tamping or ramming of the mortar into place. A hardwood stick is used to prevent polishing of the surface of the mortar layers during compaction (Emmons 1993). Because of the low water-cement ratio of the drypack materials, there is little shrinkage, and the repair remains tight and is of good quality with respect to durability, strength, and watertightness.

Additional information regarding drypacking can be found in REMR Technical Note CS-MR-3.8.

Pumpable concretes

Pumpable concretes are commonly used to repair large areas at projects where space for construction equipment is limited or access is difficult. Repairs to overhead surfaces are made by the form and pump method, while repairs to vertical surfaces are made by form and pump or form and cast-in-place methods.

For the form and pump method, concrete is pumped into the formed area through a valved entry port. Located at the highest point of repair is a valved exit port, which is opened to allow the air to escape while it is being displaced by the pumped concrete. When the formed area has filled, the exit port valve is closed and pump pressure exerted to consolidate and force the pumped concrete against the existing concrete surface for better bonding.

For the form and cast-in-place repair method, the top of the form has an offset chimney that extends outside the formed face. The concrete mixture is gravity fed through the chimney and into the form until the top of the chimney is filled. The form is vibrated at 30-min intervals until the concrete hardens and no longer responds (EM 1110-2-2002 (Headquarters, Department of the Army 1986)). A form closure plate can be used to separate the repair from the concrete in the chimney during vibration of the concrete. If not, the projection left by the chimney can be removed the next day via saw cutting with a diamond blade having a recessed hub.

It is common to experience a decrease in air content for the concrete mixture during pumping (EM 1110-2-2000 (Headquarters, Department of the

Army 1994)). Therefore, it may be necessary to entrain a higher air content at the pump in order to obtain the specified air content at the point of placement.

The pump selection is dependent on the mixture design, particularly the nominal maximum size aggregate (Emmons 1993).

Preplaced aggregate concrete

Preplaced aggregate concretes are used for repairing large areas where low volume change is required. For repairs to vertical and overhead surfaces, the surface must be formed and aggregate tightly packed within the form. A valved grout entry port is located at the lowest point of the form, and a valved exit port at the highest point of the other end of the formed area.

The preplaced aggregate is gap graded to exclude fines and typically has a 40- to 50-percent void ratio after the aggregate is packed (Emmons 1993). Care must be taken in preplacing coarse aggregate to avoid breakage and segregation of the aggregate (EM 1110-2-2000). This becomes more difficult as the nominal maximum size aggregate increases and when two or more sizes are blended. The nominal maximum size aggregate is typically 38 mm (1-1/2 in.) to 50 mm (2 in.).

Conventional intrusion grout mixtures are proportioned in accordance with ASTM C 938-80 to obtain the specified consistency, air content, and compressive strength. The ratio of cementitious material to fine aggregate is typically in the range of 0.67 for mass concrete mixtures to 1.00 for structural concrete mixtures (EM 1110-2-2000). A grout fluidifier is commonly used to offset bleeding, to reduce the water-cement ratio and still provide a given consistency, and to retard stiffening so that handling times can be extended. If field testing of grout shows an expansion of less than 2 percent or more than 6 percent, adjustments to the fluidifier should be made to bring the expansion within these limits. A pozzolan is typically used to increase flowability of the grout.

For commercial intrusion grouts, follow the manufacturer's recommendations.

Additional information regarding preplaced aggregate concrete can be found in REMR Technical Note CS-MR-9.4.

Polymer concretes

Polymer concretes are typically used for making shallow repairs in pavements and bridge decks where a fast-curing, high-strength, and low-permeability repair material is required. Repair depths are limited to 50 mm (2 in.) or less due to rapid heat generation (Patel, Mojab, and Romine 1993).

For repairs of greater depth, polymer mixtures must be placed in lifts. The cost for the deeper repairs will likely result in another repair material being selected.

Some of the polymers used to make concrete mixtures include epoxy resins, high molecular weight methacrylates, polyesters, vinyl esters, acrylics, styrenes, and polyurethanes. The applications of these mixtures vary greatly. Some applications require a dry surface, some a moist surface, and some are not sensitive to moisture (American Concrete Institute (ACI) 548.1R-92 1993). Non-sag mixtures are available for making vertical and overhead repairs.

The manufacturer's recommended bonding agent must be used and application instructions followed.

Polymer-modified concretes

Polymer-modified concretes are typically used for making shallow repairs up to 50 mm (2 in.) deep in structural concretes where a less permeable, higher tensile strength material than conventional concretes is required. For repairs of greater depth, the concrete mixture must be placed in lifts.

The polymer-modified concretes are generally normal portland cement mixtures to which a water soluble or emulsified polymer has been added during the mixing process (ACI 548.1R-92 1993). The properties and application of these concretes vary widely depending on the type polymer and dosage rate used in the mixture. Some of the concretes have coefficients of thermal expansion and moduli of elasticity near that for structural concretes. The polymer solids content for optimum performance is typically between 15 and 20 percent by weight of the cement.

After placement and finishing, polymer-modified concretes should be covered promptly with a single layer of clean, wet burlap topped with a preferably white sheet of polyethylene film (ACI 548.1R-92 1993). The surface should wet cured for 24 hr and dry cured for 72 hr before vehicular traffic is permitted on the repair surface.

Numerous commercial concretes are available that have the ingredients prepackaged. For these products, the manufacturer's recommendations must be followed.

Shotcrete

Shotcrete mixtures are typically used to repair large spalled areas in vertical and overhead surfaces where the depth of repair is less than 150 mm (6-in.) (EM 1110-2-2002). Conventional shotcretes are the most widely used shotcrete. They are pneumatically applied using a dry- or wet-mix process

(ACI 506R-90 1993). For the dry-mix process, water is mixed at the nozzle with the premixed portland cement and aggregate. For the wet-mix process, the mixture is batched before entering the pneumatic system. Coarse aggregate can be included in the mixture; however, the shotcrete has higher rebound, is more difficult to finish, and cannot be used in thin layers.

The properties for shotcrete are largely dependent on the conditions under which it was placed, equipment selected, and competence and experience of the application crew. Shotcrete typically has a compressive strength in the range of 20 MPa (3,000 psi) to 48 MPa (7,000 psi) (ACI 506R-90 1993). It is recommended in ACI 506R that strengths higher than 35 MPa (5,000 psi) be specified only for carefully engineered and executed shotcrete work. Drying shrinkage generally falls within the range of 0.06 and 0.10 percent. Chemical accelerators should be avoided where not absolutely necessary as they increase drying shrinkage (Emmons 1993). The coefficient of thermal expansion is near that of steel reinforcing.

Special proprietary shotcrete mixtures are available that contain materials, such as sodium and potassium silicates, magnesium phosphates, polymers, silica fume, and steel or plastic fibers. For these special mixtures, the recommendations of the manufacturer must be followed.

Fiber concretes and shotcretes

Steel fiber-reinforced concretes and shotcretes are used to repair concrete where increased tensile strength and toughness are required (ACI 544.1R-82). The more common steel fiber shapes include straight, crimped, surface-deformed, and hooked ends. The straight steel fibers provide the least toughness for the same volume concentration (EM 1110-2-2000). Steel fibers with hooked ends have basically the same properties as straight fibers of the same aspect ratio using fewer fibers per unit volume. Fibers are usually described by their aspect ratio, which is fiber length to diameter.

Steel fiber-reinforced concretes generally have higher cement and fine aggregate contents and smaller nominal maximum size aggregates than conventional concretes (EM 1110-2-2000). Nominal maximum size aggregate for these concretes is usually 19 mm (3/4 in.) or less. The practical upper limit for most steel fibers is generally considered to be 2 percent by volume of the total concrete mixture. Pozzolans are often used to reduce the cement content in the mixture.

Other fibers have been produced from plastic, glass, and natural materials in various shapes and sizes. Glass fibers are subject to chemical attack by alkalinity of the concrete that causes them to become brittle and lose their effectiveness. Plastic fibers made of nylon, polypropylene, or polyethylene are not subject to chemical attack. Incorporation of plastic fibers into a concrete

mixture can result in small improvements in flexural and tensile strengths, increase in fracture toughness, and decrease in shrinkage.

Bituminous concretes

Bituminous concretes are used to make temporary patches to extend the service life of spalled concrete pavements and bridge decks. These bituminous concretes are fairly inexpensive, widely available, easy to place, and require little cure time. The most effective of the bituminous concretes are the hot mix asphalts. Many commercial bituminous cold mixtures that perform well are also available. The cold mixtures may become sticky and hard to work when ambient temperatures are near upper product limits.

Batching

The volume of material required for repairing a prepared spall area is often small (0.014 to 0.057 m^3 (0.5 to 2.0 ft^3)) (Patel, Mojab, and Romine 1993). Small drum or paddle-type mixers with capacities of 0.17 to 0.23 m^3 (6 to 8 ft^3) and Jiffy mixers are often used. For large repair jobs, equipment of greater capacities may be required.

For portland cement concretes and mortars, the mixture proportions are usually finalized through trial batches. For big jobs, the materials may be weighed and bagged in advance to make the batching process more efficient. Mixture proportions commonly include air-entraining, water-reducing (conventional and high-range), and accelerating admixtures. For pumpable mixtures, pozzolan and fluidifier admixtures are usually included. To limit chloride ion content in the concrete, calcium-chloride accelerators are being replaced with nonchloride accelerators. Nonchloride accelerators containing calcium nitrite and calcium nitrate have generally proven to be effective replacements (Zia, Leming, and Ahmad 1991).

A corrosion inhibitor should be considered for repairs where corrosion is the cause of the spall. The most common inhibitor is a calcium nitrite based admixture (Zia, Leming, and Ahmad 1991). Calcium nitrite is also an accelerating admixture which may cause mixing and placing problems for some jobs.

For commercial repair products, batching must be performed according to the manufacturer's recommendations. The product binder comes prebagged, and for some polymer concretes, the fine and coarse aggregates are also prebagged.

Bonding Agent

The most common bonding agent for portland cement concretes and mortars is made up of equal volumes of portland cement and fine aggregate mixed with enough water to create a slurry having a consistency of a thick cream. For silica fume, polymer-modified, and other cementitious mixtures, the bonding agent is typically the grout portion of the concrete mixture. These cementitious bonding grouts must be worked into the surfaces with a stiff broom or brush. The grouts should not be allowed to dry more than 10 min before the repair material is placed. If allowed to dry, the grout must be removed and the surfaces prepared. Removal of grout is typically accomplished by low-pressure water blasting followed by sandblasting.

Epoxy and other polymer bonding agents are available for cementitious concretes and mortars. If one of these products is selected, the manufacturer's recommendations must be followed.

For polymer concretes and mortars, the bonding agent recommended by the manufacturer must be used and application instructions followed.

Evaluating Repair Performance

It is important that repairs be inspected periodically to document the field performances of different types of repair materials and techniques. Documentation should include techniques, equipment, and materials employed for removal, surface preparations, batching, placing, and curing; repair date and cost; and assessment date and performance. A summary of repair performances grouped by repair material or technique may show trends that will benefit future repair efforts through technology transfer.

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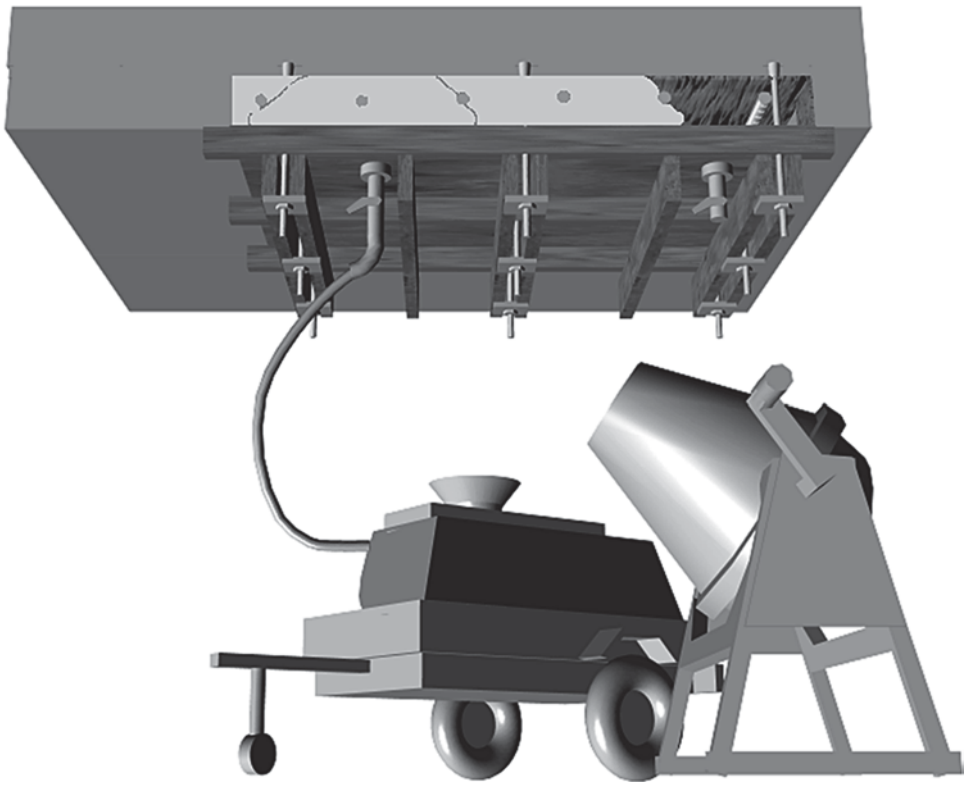
ACI RAP Bulletin 5

FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

Surface Repair Using Form-and-Pump Techniques



Field Guide to Concrete Repair Application Procedures

Surface Repair Using Form-and-Pump Techniques

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Structural Disclaimer

This document is intended as a voluntary field guide for the Owner, design professional, and concrete repair contractor. It is not intended to relieve the user of this guide of responsibility for a proper condition assessment and structural evaluation of existing conditions, and for the specification of concrete repair methods, materials, or practices by an experienced engineer/designer.

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Introduction

The form-and-pump repair technique is a multi-step process of preparing and constructing formwork, and pumping repair material into the cavity confined by formwork and existing concrete. The form-and-pump technique allows the use of many different repair materials. The necessary requirement for material selection is pumpability. Various pumps are used, depending on the mixture design with focus on aggregate size. Prior to construction of formwork, any surfaces that may cause air to become trapped during the pumping process must be trimmed, or vent tubes installed.

Repair materials are mixed and pumped into the confined cavity. The sequence of pumping is from low points to high points and when performed overhead, from one extremity to the other. Large areas may require bulkheading to separate placements into manageable areas. When the cavity is full, pump pressure is exerted on the form, causing the repair material to consolidate and make intimate contact, and effect bonding with existing concrete surfaces. The form-and-pump technique offers many advantages to alternative techniques, such as shotcrete, hand placement, and preplaced aggregate.

Advantages include:

- Placement is not limited by thickness of repair or by size or density of exposed reinforcement;
- Repair materials are premixed and placed to provide a uniform cross section without segregation or intermediate bond lines;
- Sagging or dropouts of freshly placed materials aren't problems; all materials are supported by formwork during the placement and curing process;
- The pressurization process consolidates the repair material, providing for full encapsulation of exposed reinforcing steel;
- The formwork protects the repair material during the curing process;
- The process is less subject to individual operator error; and
- Quality assurance of the in-place repair is easier to provide.

What is the purpose of this repair?

The primary purpose for this type of repair is to restore the structural integrity, concrete cover requirements, or both, for the damaged element.

When do I use this technique?

This technique is commonly used on vertical surfaces such as walls, columns, and other combinations such as beam sides and bottoms. Separate bonding agents such as grouts or epoxy are not commonly used with this technique. It is highly recommended that for each project, a trial installation be performed to verify the preparation, material, and placement technique using quality-control procedures outlined at the end of this document.

How do I prepare the surface?

Regardless of the repair method, surface preparation is essentially the same. Concrete is removed until good quality concrete is located. Exposed bars are undercut, and surfaces are cleaned with high-pressure water or are abrasively blasted. With form-and-pump techniques, it is important to understand how the existing surfaces will permit the repair material to penetrate and flow. Surfaces that might trap air need to be trimmed, or vent pipes may be provided in the formwork. Profile roughness from hand-chipping or hydrodemolition is not generally a problem for entrapping air. Flow of the repair material (while flowing within the formed cavity) will most likely remove air from the profile.

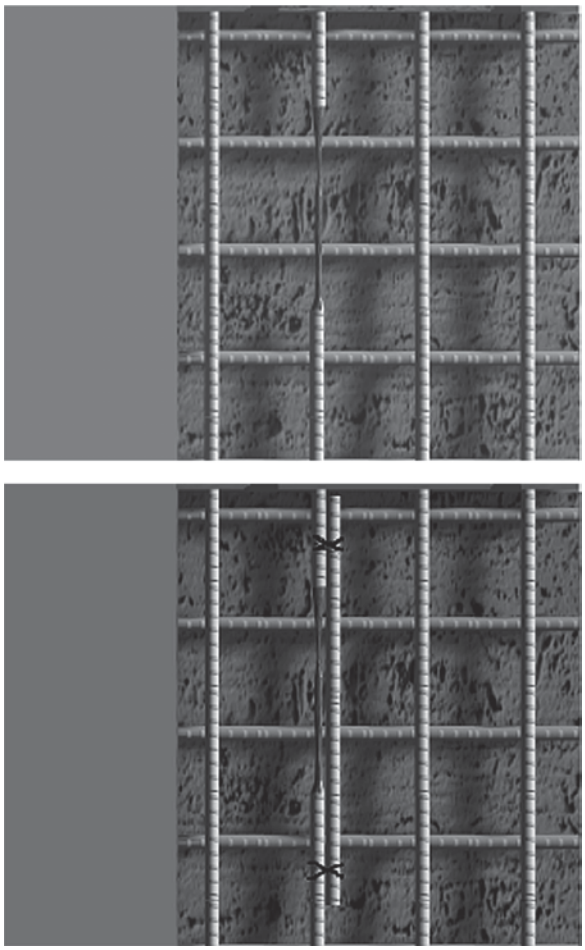


Fig. 1—Lapping of supplemental reinforcement.

Steps in surface preparation include the following:

Step 1—Sounding or other appropriate nondestructive concrete testing to locate areas of delamination.

Step 2—Marking of the perimeter of the repair area. Layout should be simple square or rectangular shapes. There should be no acute angles between boundary lines defining the repair area.

Step 3—Removal of concrete with a 15-lb chipping hammer. Hammers larger than a 15-lb class may cause damage to substrate and reinforcement.

Step 4—Sawcutting perimeter of the repair. Note: sawcut should not be deeper than the cover over the reinforcement.

Step 5—Reinforcement repair. When reinforcing steel is heavily corroded and the diameter is reduced, consult a structural engineer for repair procedures. For many applications, supplemental reinforcement can be lapped to adjacent damaged bars, as shown (see Fig. 1).

Step 6—Cleaning of reinforcing steel and concrete with abrasive blasting.

How do I select the proper repair material?

Constructibility requirements for materials used with the form-and-pump technique are limited only by their ability to be pumped and their flow characteristics. More important than constructibility are the materials' in-place properties, such as low drying shrinkage, compatible strength, thermal and elastic properties, and durability requirements. While constructibility of the repair materials requires good pumpability and flowability, these required characteristics should not sacrifice the requirement of low drying shrinkage. Drying shrinkage can cause cracking, delamination, inability to carry loads, and reduced durability. Pumpability and flowability can be brought to the material with aggregate shape and chemical admixtures that preserve low water-cement ratio, yet provide a pumpable mixture. Prepackaged repair materials, which are designed for pumping and incorporate shrinkage-compensating additives, are appropriate for many applications. Materials should be reviewed for effects on drying shrinkage to find those with low shrinkage.

Shrinkage testing in accordance with ASTM C 157 (modified in accordance with ASTM C 928 and measured over a 120-day period) will provide meaningful and comparable shrinkage properties.

What equipment do I need?

Pumping equipment—Pumping equipment is generally matched to the type of repair material and the size of the repair project. The specified repair material requires pumping through a pump line to the formed cavity. Cementitious repair materials have various aggregate contents and aggregate sizes. Fine-grained repair mixtures with very fine aggregate and little or no coarse aggregate can be pumped with mono-type pumps or piston/ball valve pumps.

Repair materials with large aggregates (larger than 3/8 in. [10 mm]) are best pumped with hydraulic/swing valve

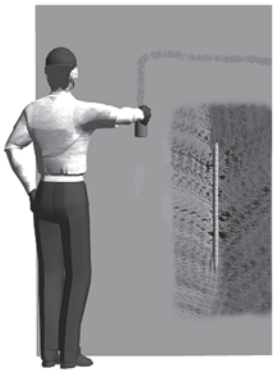
STEP 1

Sounding of concrete to locate areas of delamination.

STEP 2

Unsound concrete removed with 15-lb chipping hammer. Hammers larger than 15-lb class may cause damage to substrate and reinforcement.

STEP 3

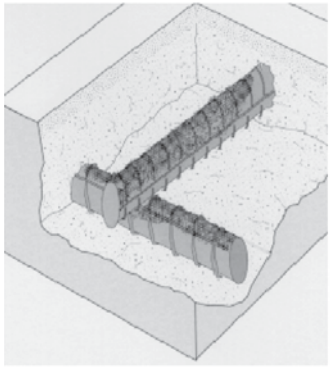


Mark perimeter of repair area. Layout should be simple geometric shapes.

STEP 4

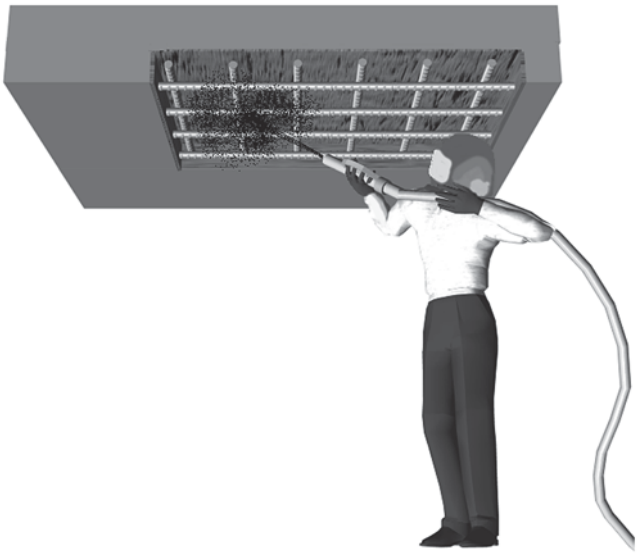
Sawcutting perimeter of repair. Note: sawcut should not be deeper than cover over reinforcement.

***STEP 5:** Reinforcement repair. When reinforcing steel is heavily corroded and the diameter is reduced, consult a structural engineer for repair procedures. For many applications supplemental reinforcement can be lapped to adjacent damaged bars, as shown.*



***Important Note**: If corroded reinforcing bars are encountered in the preparation process, then concrete surrounding the bars must be removed to fully expose the full circumference. Clearance under the bar should not be less than 3/4 in. (19 mm), or 1/4 in. (6 mm) greater than the largest aggregate size of the repair mixture, whichever is greater.*

STEP 6



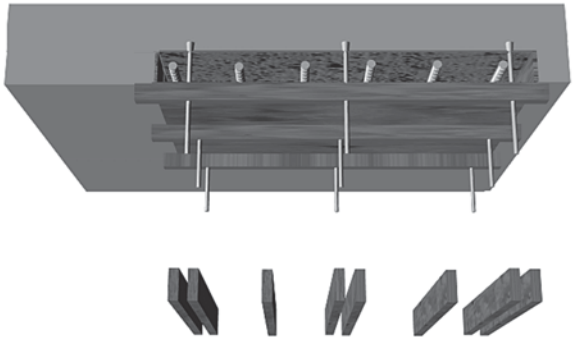
Cleaning of reinforcing steel and concrete with abrasive blast.

pumps. All pumping equipment must have adequate controls to regulate flow rates and pressures.

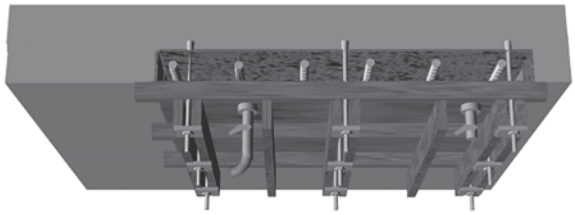
What are the safety considerations?

Job site safety practices include, but are not limited to, the following where applicable:

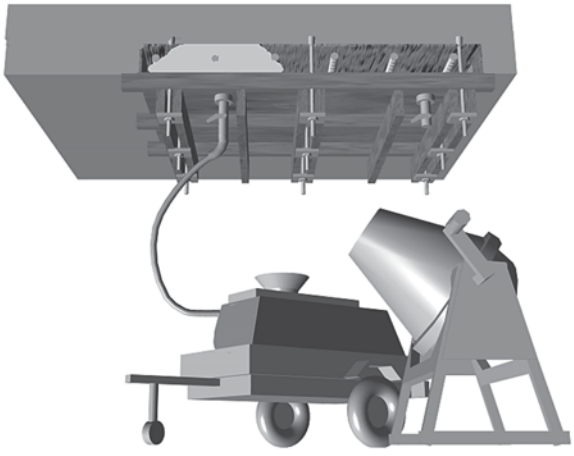
- Material Safety Data Sheets (MSDS) available;
- Protective clothing worn by workers handling or exposed to hazardous materials;
- Use of protective eyewear during pumping and preparation;
- Availability of eye wash facilities; and
- Use of respirators during preparation.



Erection of formwork with embedded anchors supporting formwork

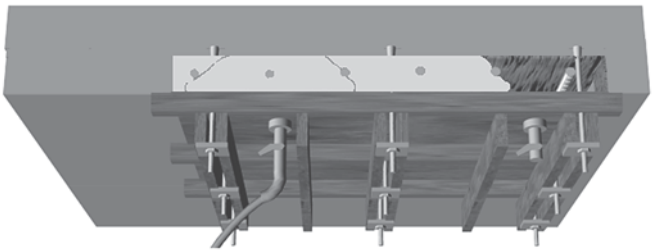


Formwork complete ready for pumpline hookup

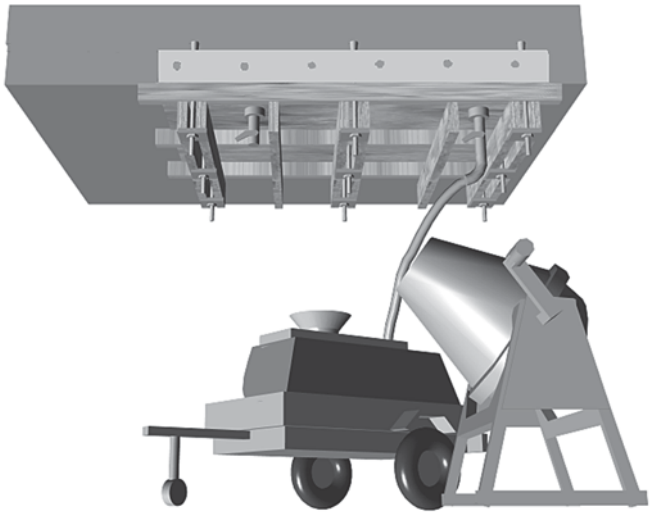


Pumpline hooked to form and pumping of repair material begins

Fig. 2—Pumpline hooked to form and pumping of repair material begins.



Pumping underway. Note flow path radiating from pump line port.



Cavity is filled and pressurized. Pump line is shut down.

Fig. 3.

Fig. 4—Material placement: vertical application.

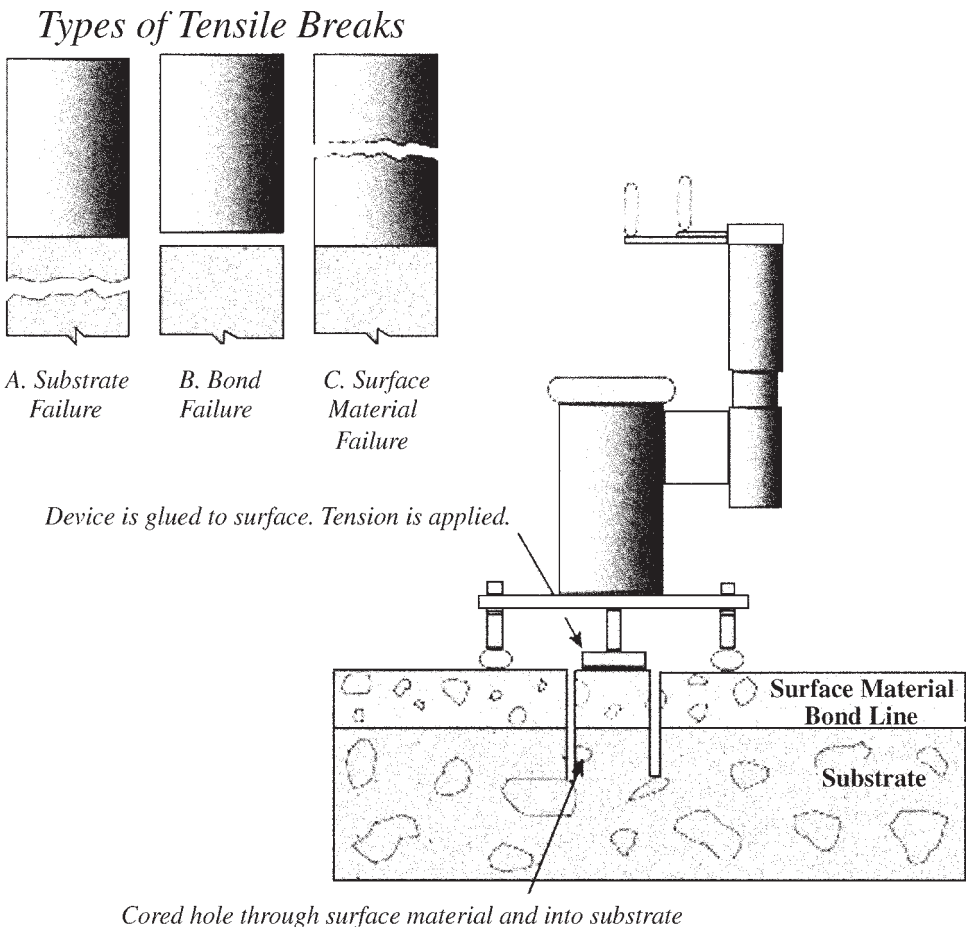


Fig. 5—Test procedure.

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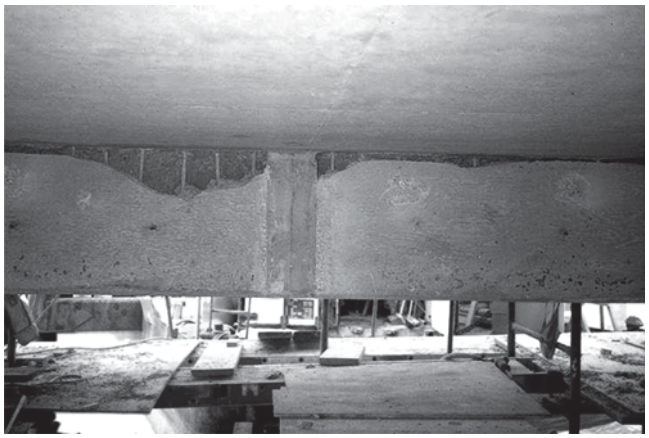
Preconstruction meeting and trial repair

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.), and specifically address the parameters, means, methods, and materials necessary to achieve the repair objectives. Trial repairs using the proposed procedure and materials are highly recommended.

Repair procedure

Formwork construction—Formwork must accommodate the mass and pressure of the repair material. Design of the forms should follow standard practice for cast-in-place concrete construction except for the calculation of form pressure. Form pressure should be designed for a minimum of 14 psi (100 kPa). Maximum pressure exerted on formwork occurs after the formwork cavity is full and pressurized. Formwork is best attached directly to the concrete surface with expansion anchors or standard form ties. All anchors should be preloaded to prevent slippage during placement. In some applications, shoring or scaffolding can be used to support the formwork. Forms should be constructed to fit tightly against existing concrete surfaces. Preformed foam gaskets or cast-in-place foam works well to address difficult-to-match surfaces. Attachment of the pump hose to formwork is achieved with various techniques, including the use of plumbing fittings with flanges and ball valves or the use of a pump-line attachment with hand-held friction fit-insertion followed by wooden plugs.

Pumping procedure—The sequence of material placement into the formed cavity depends on the geometries involved. Vertical surfaces start at the lowest point, filling in a manner that prevents air entrapment. Arrangement of ports for pump line attachments is usually horizontal with spacing of 3 to 4 ft (900 to 1200 mm) in grid form. Pumping continues even after material flow occurs from adjacent ports to expel air. When the flow is without intrusion of air, the pump is temporarily shut off, the port closed off, and the pump line connected to the adjacent port that has seen flow. The sequence is continued until the cavity is filled. In some conditions, the cavity can be pumped from one port. In this situation, each adjacent port is capped off as flow occurs. It is necessary to monitor pump-line pressure to prevent excessive back-pressure when pumping long distances. Once the



Effects of not filling the cavity.

cavity is filled, the full-line pressure is available to pressurize the formed cavity.

Care must be exercised in the final pressurization because the excessive pump-line pressure (hydraulic pumps can exert in excess of 800 psi [5 MPa]) may cause the form to fail. In most applications, pressure gages should be attached to the pump line near the exit port to monitor cavity pressure. If the formwork fails due to overpressurization, the failure will generally occur as a slight movement in a form panel seam or perimeter seal. The failure is not explosive because there is no significant stored energy. Overhead placements are accomplished by starting at an extremity of the surface and proceeding in a fashion similar to vertical placements. Material will flow radially from the injection port to adjacent ports. Repairs involving soffit and vertical faces of members can be combined into one placement. In this case, placement begins at the lowest elevation and follows the procedure detailed above for each orientation. Large areas of repair should be sectionalized utilizing bulkheads. Bulkheads can be constructed of repair material and left in place. Utilizing bulkheads and manageable placement volumes limits the risk of problems associated with large placements and allows pressurization to occur within shorter durations of material mixing.

How do I check the repairs?

After stripping of forms various tests can be performed to confirm the placement of repair material has achieved complete consolidation and intimate contact with the substrate to achieve bond. A uniaxial bond test can be performed by drilling through the repair into the substrate. A bonded plate attached to the core is pulled until rupture occurs. Bond values should exceed 100 psi (0.7 MPa), and in most cases exceed 150 psi (1 MPa). These tests are performed in accordance with ACI 503R Appendix (see Fig. 5).

The complete repair area should also be hammer-sounded or evaluated by other non-destructive methods to determine overall integrity. Any hollow sounds may represent poor bond or voids.

Sources for additional information

1. “Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforced Steel Corrosion,” No. 03730, International Concrete Repair Institute.

2. “Guide for Selecting and Specifying Concrete Repair Materials,” No. 03733, International Concrete Repair Institute.

3. ACI Committee 347, “Guide to Formwork for Concrete (ACI 347-01),” American Concrete Institute, Farmington Hills, Mich., 32 pp.

4. ACI Committee 546, “Concrete Repair Guide (546R-96),” American Concrete Institute, Farmington Hills, Mich., 41 pp.

5. ACI Committee 503, “Use of Epoxy Compounds with Concrete (503R-93 (Reapproved 1998)),” American Concrete Institute, Farmington Hills, Mich., 1998, 28 pp.

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ACI RAP Bulletin 4

FIELD GUIDE TO CONCRETE REPAIR APPLICATION PROCEDURES

Surface Repair Using Form-and-Pour Techniques

ACI RAP Bulletin 4
(Reapproved 2009)

Field Guide to Concrete Repair Application Procedures

Surface Repair Using Form-and-Pour Techniques

Reported by ACI Committee E706

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Introduction

The form-and-pour placement technique is a multistep process of preparation, formwork construction, and placement of repair materials. Repair materials are placed in the cavity between the formwork and the prepared substrate with buckets, pumps, chutes, or buggies. The form-and-pour technique allows the use of many different castable repair materials. Placeability is the primary consideration material selection. Depending on the consistency of the repair material, consolidation is accomplished by vibration, rodding, or when the material has extremely high slump (self consolidating), no additional steps may be required.

What is the purpose of this repair?

The primary purpose of this type of repair is to restore the structural integrity, or concrete cover requirements, or both, for the damaged element.

When do I use this technique?

This technique is commonly used on vertical surfaces such as walls, columns, and other combinations such as beam sides and bottoms. When used to repair slab soffits, the repair material is typically placed through holes or openings cut through the slab. Adhesive bonding agents or grouts are not commonly used with this technique. A trial installation is highly recommended for each project, to verify the preparation, material, and placement technique using quality-control procedures outlined at the end of this document.

The form-and-pour technique offers many advantages:

- Many different types of repair materials can be used;
- Repair material can be placed around reinforcing steel; and
- Formwork protects against early-age drying that promotes cracking.

The primary limitation of the form-and-pour technique is that formwork installation makes it more labor-intensive than alternative placement methods such as shotcrete or hand application (see Fig. 1).

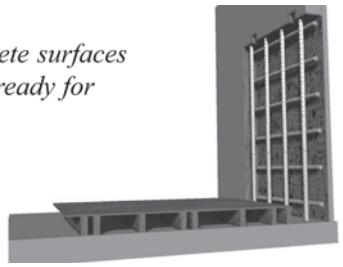
How do I prepare the surface?

Regardless of the repair method, surface preparation is essentially the same. Concrete is removed until sound concrete is located. Exposed bars are undercut, and surfaces are cleaned with high-pressure water, or are abrasively blasted. With form-and-pour techniques, it is important to understand how the existing surfaces will permit the repair material to penetrate and flow. On partial-depth vertical repairs, the upper edges of vertical surfaces should be trimmed to eliminate potential pockets of entrapped air and promote complete filling from the location of the chute. Refer to page 5 for step-by-step preparation procedures.

Step 1—Sound the concrete to locate areas of delamination.

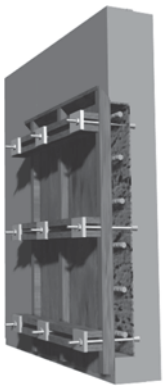
Step 2—Mark the perimeter of the repair area. Layout should be simple square or rectangular shapes.

Step 3—Sawcut the perimeter of the repair. Note: sawcut should not be deeper than the cover over reinforcement.



Prepared concrete surfaces with formwork ready for erection.

Fig. 1(a).



Section view through repair showing formwork and chute at top for placement of repair material.

Fig. 1(b).

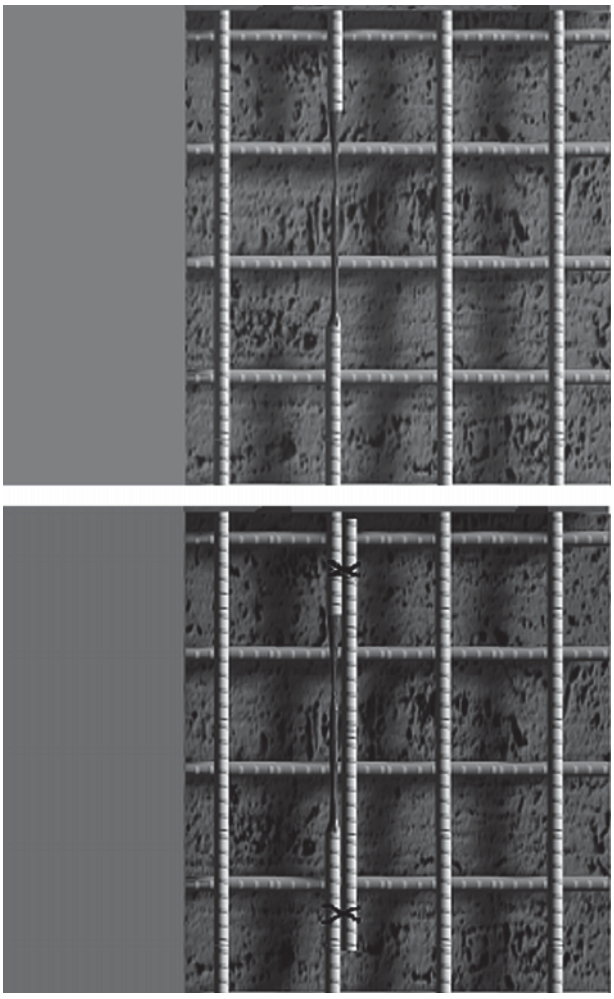


Fig. 2—Lapping of supplemental reinforcement.

Step 4—Remove unsound concrete with a 15-lb chipping hammer. Hammers larger than a 15-lb class may cause damage to the substrate and reinforcement.

Step 5—Repair reinforcement as necessary. When reinforcing steel is heavily corroded and the diameter is reduced, consult a structural engineer for repair procedures. For many applications, supplemental reinforcement can be lapped to adjacent damaged bars, as shown (see Fig. 2).

Step 6—Clean reinforcing steel and concrete with abrasive blasting.

How do I select the proper repair material?

Constructibility requirements for repair materials used with the form-and-pour technique are limited only by their ability to be transported to the formwork cavity. Maximum aggregate size should not exceed 25% of the space between the formwork and the substrate, or 50% of the distance between the reinforcing steel and the substrate—whichever is smaller. In general, the largest practical maximum size aggregate should be used to minimize drying-shrinkage and reduce the potential for cracking of the repair. Mixtures with high flowability (high slump) will make the placement easier; however, do not sacrifice a low water-cement ratio (<0.40) for high slump. Use high-range water-reducing admixtures as necessary. Prepackaged repair materials, which are designed for high-flow placement, include shrinkage-compensating additives, and are appropriate for many applications. All mixture proportions should be optimized to minimize drying shrinkage. Shrinkage testing in accordance with ASTM C 157 measured over a 120-day period is recommended.

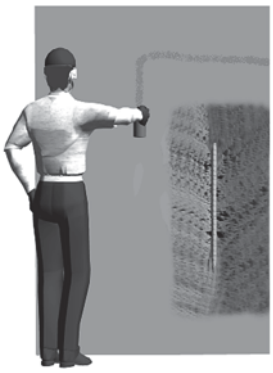
What equipment do I need?

Placement equipment may include either concrete buggies, buckets, or concrete pumps. Concrete pumps should be sized for the type of repair material being placed. If the repair is mixed on site, a portable mixer is required.

STEP 1

Sounding of concrete to locate areas of delamination.

STEP 2



Mark perimeter of repair area. Layout should be simple geometric shapes.

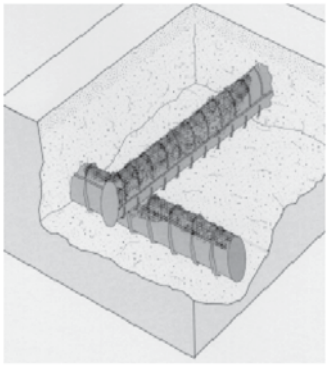
STEP 3

Sawcutting perimeter of repair. Note: sawcut should not be deeper than cover over reinforcement. Remove sound concrete within sawcut area.

STEP 4

Unsound concrete removed with 15-lb chipping hammer. Hammers larger than a 15-lb class may cause damage to substrate and reinforcement.

STEP 5: *Reinforcement repair. When reinforcing steel is heavily corroded and the diameter is reduced, consult a structural engineer for repair procedures. For many applications supplemental reinforcement can be lapped to adjacent damaged bars, as shown.*



***Important Note**: If corroded reinforcing bars are encountered in the preparation process, then concrete surrounding the bars must be removed to fully expose the full circumference. Clearance under the bar should not be less than 3/4 in. (19 mm), or 1/4 in. (6 mm) greater than the largest aggregate size of the repair mixture, whichever is greater.*

STEP 6

Cleaning of reinforcing steel and concrete with abrasive blast.

Check with the manufacturer of the product to determine the recommended type of mixer.

What are the safety considerations?

Job site safety practices include, but are not limited to, the following where applicable:

- Material Safety Data Sheets (MSDS) available;
- Protective clothing worn by workers handling or exposed to hazardous materials;
- Use of protective eyewear during pumping and placement of repair materials;
- Availability of eye wash facilities; and
- Use of respirators and ear protection during demolition.

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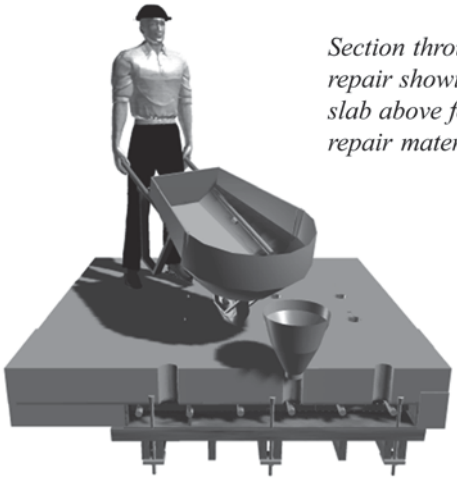
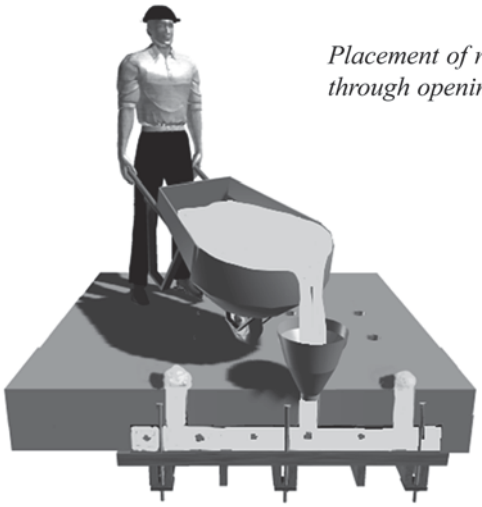
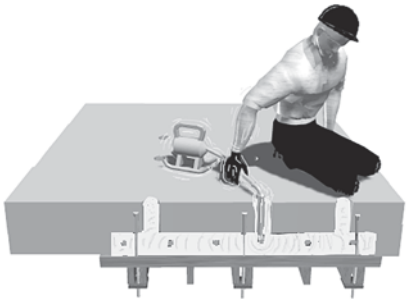


Section through overhead repair showing opening in slab above for placement of repair material.



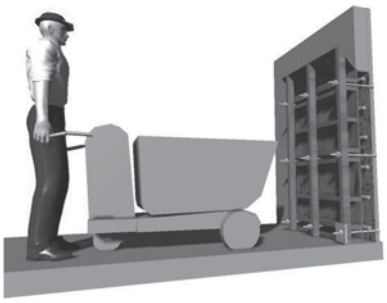
Placement of repair material through opening in slab



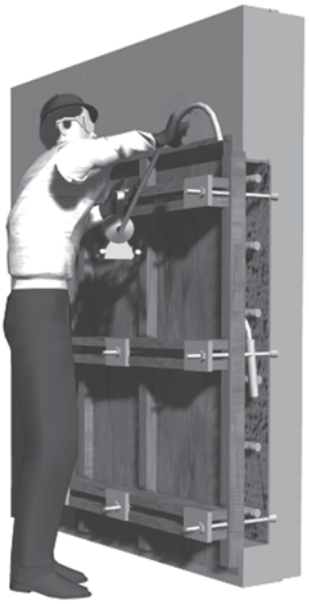
Pencil vibrator is used to consolidate repair material in cavity.

Fig. 3—Material placement: horizontal application.

Repair material is brought to the repair site via concrete buggy or other suitable means. Five-gallon buckets make useful tools to deposit repair material into form.



After the repair material is placed into cavity, vibrators are inserted into placement and consolidated. It is recommended that consolidation be done in lifts of no more than 2 to 3 ft (0.7 to 1 m).



Curing compound is immediately rolled or sprayed onto repaired surfaces after formwork is removed. Proper curing will help ensure repair material does not have premature drying and cracking, and the material develops its full strength.

Fig. 4—Material placement: vertical application.

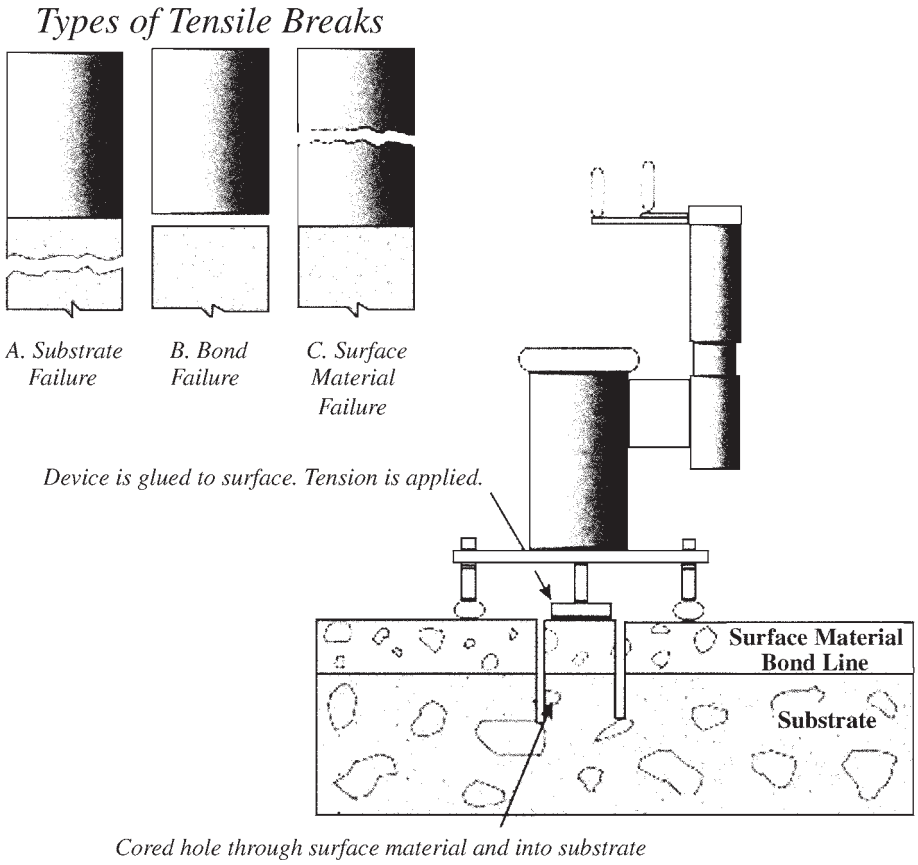


Fig. 5—Test procedure.

the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.), and specifically address the parameters, means, methods, and materials necessary to achieve the repair objectives.

Repair procedure

Formwork construction—Formwork must accommodate the mass and pressure of the repair material. Design of the forms should follow standard practice for cast-in-place concrete construction. Formwork is best attached directly to the concrete surface with expansion anchors or rock anchors designed for coil rod. In cases of repair of slab soffits (underside), scaffold frames or shoring posts can be used to support the formwork tight against the concrete surfaces. When expansion/rock anchors are used, ensure anchors are firmly set in place to prevent slippage under load. Preloading of rock anchors with coil rod can be accomplished with a center-hole jack applying loads to the coil rod with a standoff. Forms should be constructed to fit tightly against existing surfaces. Preformed gaskets or cast-in-place foam work well on difficult-to-match surfaces. Placement openings or chutes are required to place the repair material behind vertical forms. Chutes should be constructed to permit development of a hydraulic head above the prepared upper edges of the concrete surface. This will provide for repair material supply into these upper horizontal zones after concrete is consolidated. For large, vertical surfaces exceeding 10 ft (3 m) in height, multiple lifts should be considered to reduce free-fall segregation and excessive formwork pressures. Formwork for overhead surfaces does not require openings for placement of repair materials. Generally, placement occurs through openings in the slab from above (see Fig. 3).

Material placement—Prior to placement of the repair material, moisture conditioning of the prepared surface should provide for saturated-surface dry conditions. It is important not to overwet the surface. Saturated surfaces will prevent proper bonding because the surface pores are clogged with water, unable to absorb the repair material. Mixed repair material is brought to the formed area via whatever transport technique is appropriate for the situation (see Fig. 4). This may include buckets, pumpline, buggies, or wheelbarrows. For vertical surfaces, material is placed into the chute or opening. External or internal vibration is a must for almost all mixture consistencies. Some self-leveling repair materials, also known as self-consolidating, can be placed without vibration. When the cavity is filled, extra care should be taken to ensure that the uppermost surfaces are filled adjacent to the chute or opening where placement occurs. Rodding or tamping can ensure proper filling. Formwork should be left in place for the prescribed curing period.

After stripping of formwork, any spaces not filled should be trimmed, cleaned, and dry-packed. Placement of a membrane curing compound is recommended immediately after removal of formwork.

How do I check the repairs?

After stripping of forms, various tests can be performed to confirm that the repair material was thoroughly consolidated and that adequate bond to the substrate was achieved. A uniaxial bond test can be performed by drilling through the repair into the substrate. A bonded plate attached to the core is pulled until rupture occurs. The location of the failure should be reviewed. Bond values typically exceed 100 psi (0.7 MPa) and, in most cases, exceed 150 psi (1 MPa). These tests are performed in accordance with ACI 503R Appendix (see Fig. 5).

The complete repair area should also be hammer-sounded to locate voids and delaminations within the top 6 in. (150 mm). Any hollow sounds may indicate poor bond or voids.

Sources for additional information

1. "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," No. 03730, International Concrete Repair Institute, 1995, 5 pp.

2. "Guide for Selecting and Specifying Concrete Repair Materials," No. 03733, International Concrete Repair Institute, 1996, 34 pp.

3. ACI Committee 347, "Guide to Formwork for Concrete (ACI 347-01)," American Concrete Institute, Farmington Hills, Mich., 2001, 32 pp.

4. ACI Committee 546, "Concrete Repair Guide (ACI 546R-96)," American Concrete Institute, Farmington Hills, Mich., 1996, 41 pp.

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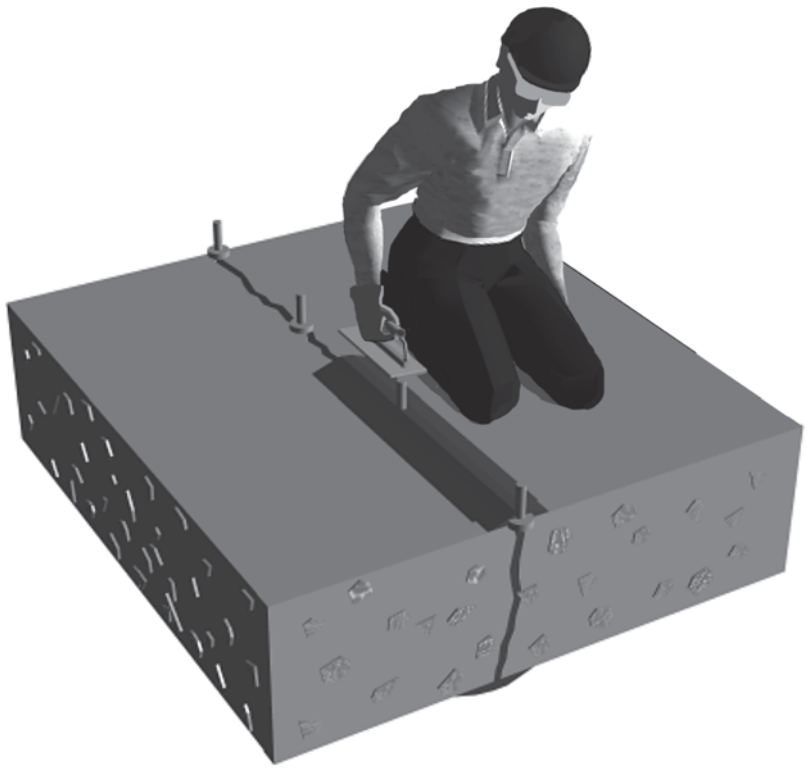
FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

Structural Crack Repair by Epoxy Injection



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Structural Crack Repair by Epoxy Injection

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ACI Repair Application Procedure 1.

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Introduction

Certain things in life are inevitable. Some are said to include death, taxes, and concrete cracks! The latter is subject to volumes of literature on causes and cures. Some of the more typical causes for concrete cracking include:

- Drying shrinkage;
- Thermal contraction or expansion;
- Settlement;
- Lack of appropriate control joints;
- Overload conditions that produce flexural, tensile, or shear cracks in concrete; and
- Restraint of movement

One of the potentially effective repair procedures is to inject epoxy under pressure into the cracks. The injection procedure will vary, subject to the application and location of the crack(s), with horizontal, vertical, and overhead cracks requiring somewhat different approaches. The approach used must also consider accessibility to the cracked surface and the size of the crack.

Cracks can be injected from one or both sides of a concrete member. If access is limited to only one side, installation procedures may include variations in epoxy viscosities, injection equipment, injection pressure, and port spacing to ensure full penetration of epoxy into the crack.

Depending on the specific requirements of the job, crack repair by epoxy injection can restore structural integrity and reduce moisture penetration through concrete cracks 0.002 in. (0.05 mm) in width and greater. However, before any concrete repair is carried out, the cause of the damage must be assessed and corrected and the objective of the repair understood. If the crack is subject to subsequent movement, an epoxy repair may not be applicable.

Note: Horizontal cracks of sufficient width can be filled by gravity-fed epoxies where suitable for the repair (See Crack Repair by Gravity Feed with Resin, RAP-2).

What is the purpose of this repair?

The primary objective for this type of repair is to restore the structural integrity and the resistance to moisture penetration of the concrete element.

When do I use this method?

Injection is typically used on horizontal, vertical, and overhead cracks where conventional repair methods cannot penetrate and deliver the specific repair product into the crack.

Prior to proceeding with a crack repair by epoxy injection, the cause of the crack and the need for a structural repair must be determined. If the crack does not compromise the structural integrity of the structure, injection with polyurethane grouts or other nonstructural materials may be a more suitable choice to fill the crack. When a structural repair is required, conditions that cause the crack must be corrected prior to proceeding with the epoxy injection. If the crack is damp and cannot be dried out, an epoxy tolerant to moisture should be considered. Cracks caused by corroding reinforcing steel should not be repaired by epoxy injection because continuing corrosion will cause new cracks to appear.

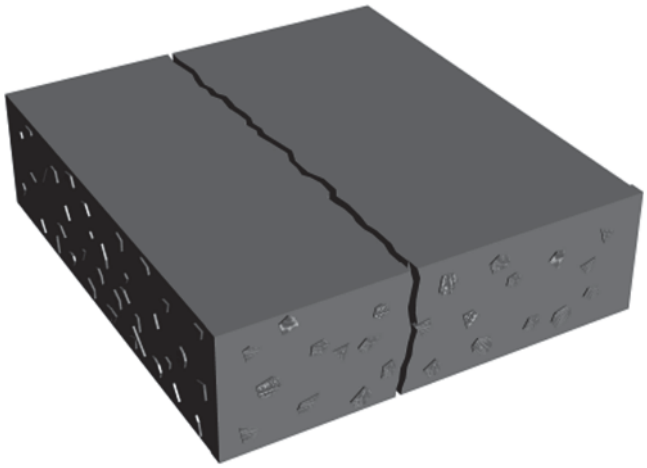

Fig. 1—Cracks must be clean and free of debris.

How do I prepare the surface? (see Fig. 1)

Clean the surface area about 1/2 in. (13 mm) wide on each side of the crack. This is done to ensure that materials used to seal the top of the crack (the cap seal) will bond properly to the concrete. Wire brushing is recommended because mechanical grinders may fill the cracks with unwanted dust. Contaminants can also be removed by high-pressure water, “oil-free” compressed air, or power vacuums. When using water to clean out the crack, blow out the crack with oil-free, compressed or heated air to accelerate drying. Otherwise, allow enough time for natural drying to occur before injecting moisture-sensitive epoxies.

Where concrete surfaces adjacent to the crack are deteriorated, “V”-groove the crack until sound concrete is reached. “V” grooves can also be used when high injection pressures require a stronger cap seal.

How do I select the right material?

The appropriate viscosity of the epoxy will depend on the crack size, thickness of the concrete section, and injection access. For crack widths 0.010 in. (0.3 mm) or smaller, use a low-viscosity epoxy (500 cps or less). For wider cracks, or where injection access is limited to one side, a medium to gel viscosity material may be more suitable.

ASTM C 881, “Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete,” identifies the basic criteria for selecting the grade and class of epoxies (see Table 1).

For concrete sections greater than 12 in. (305 mm), the working time may need to be increased, and the viscosity decreased, as the crack gets smaller.

In addition to the criteria used in Table 1 for epoxy selection, the following product characteristics may also have to be considered:

- Modulus of elasticity (rigidity);
- Working life;
- Moisture tolerance;
- Color; and
- Compressive, flexural, and tensile strengths.

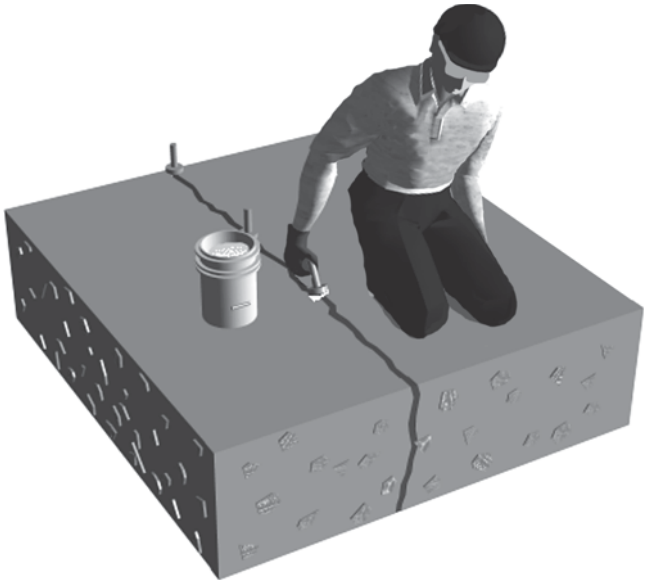

Fig. 2—Installation of entry ports.

What equipment do I need?

Equipment for epoxy injection by high-pressure or low-pressure systems includes:

- Air guns;
- Hand-actuated delivery systems;
- Spring-actuated capsules; and
- Balloon-actuated capsules.

Determine the delivery method that will best suit the repair requirements by considering the size and complexity of the injection repair and the economic limitations of the project.

What are the safety considerations?

Epoxy resins are hazardous materials and must be treated as such. Job-site safety practices should include, but not necessarily be limited to, the following:

- Having Material Safety Data Sheets (MSDS) available on site;
- Wearing protective clothing and protective eyewear where required;
- Wearing rubber gloves or barrier creams for hand protection;
- Having eye wash facilities available;
- Wearing respirators where needed;
- Providing ventilation of closed spaces;
- Secured storage of hazardous materials;
- Having necessary cleaning materials on hand; and
- Notifying occupants of pending repair procedures.

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Table 1—ASTM C 881 requirements for epoxy resins that are used to bond hardened concrete to hardened concrete

	Type I*	Type IV†
Viscosity, centipoise		
Grade 1 (low-viscosity), maximum	2000	2000
Grade 2 (medium-viscosity), minimum	2000	2000
Maximum	10,000	10,000
Consistency, in.		
Grade 3 (non-sagging), maximum	1/4	1/4
Gel time, min.	30	30
Bond strength, minimum, psi		
2 days, moist cure‡	1000	1000
14 days, moist cure	1500	1500
Absorption, 24 h maximum, %	1	1
Heat deflection temperature		
7 days minimum, °F	—	120
Linear coefficient of shrinkage		
On cure, maximum	0.005	0.005
Compressive yield strength		
7 days minimum, psi	8000	10,000
Compression modulus, minimum, psi	150,000	200,000
Tensile strength, 7 days minimum, psi	5000	7000
Elongation at break, minimum, %	1	1

*Type I: for use in non-load-bearing applications.

†Type IV: for use in load-bearing applications.

Source: ASTM C 881, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete.

‡Moist-cured systems should be tested by assembling the sections to be bonded before immersing in water.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.) and specifically address the parameters, means, methods, final appearance, and materials necessary to achieve the repair objectives.

Repair procedure

1. Port installation (see Fig. 2).

Install the entry ports only after proper surface preparation. Two types of entry ports are available for the injection process:

- Surface-mounted; or
- Socket-mounted.

Entry ports (also called port adapters) can be any tubelike device that provides for the successful transfer of the epoxy resin under pressure into the crack. Proprietary injection guns with special gasketed nozzles are also available for use without port adaptors. Port spacing is typically 8 in. (40 mm) on center, with increased spacing at wider cracks. Port spacing may also be a function of the thickness of the concrete element. Surface-mounted entry ports are normally adequate for most cracks, but socket-mounted ports are used when cracks are blocked, such as when calcified concrete is encountered. Entry ports can also be connected by a manifold system when simultaneous injection of multiple port locations is advantageous.

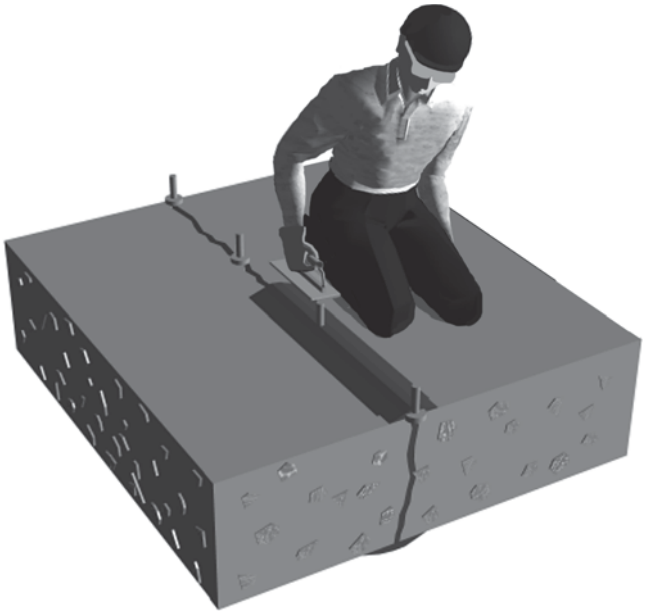

Fig. 3—Installation of seal cap.

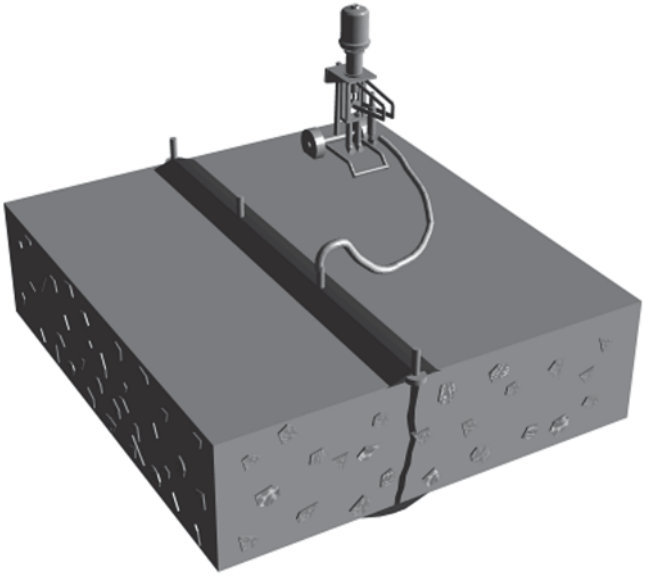

Fig. 4—Start injection at widest segment of the crack.

2. Install the cap seal (see Fig. 3).

Properly installed, the cap seal contains the epoxy as it is injected under pressure into the crack. When cracks penetrate completely through a section, cap seals perform best when installed on both sides of the cracked element, ensuring containment of the epoxy. Cap seals have been successfully installed using epoxies, polyesters, paraffin wax, and silicone caulk. The selection of the cap seal material should consider the following criteria, subject to the type of crack to be repaired:

- Non-sag consistency (for vertical or overhead);
- Moisture-tolerance;
- Working life; and
- Rigidity (modulus of elasticity).

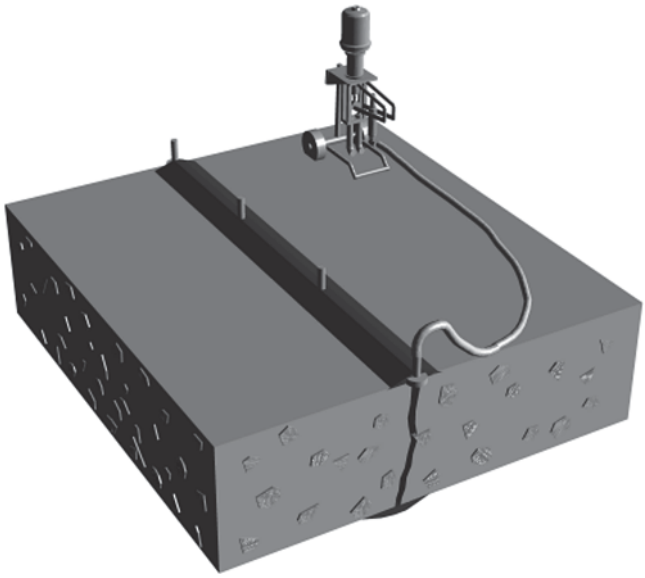

Fig. 5—Continue injection until refusal.

Concrete temperature changes after installation of the cap seal but prior to injection may cause the cap seal to crack. If this occurs, the cap seal must be repaired prior to resin injection.

Prior to proceeding with installation of the cap seal, mark the location of the widest portion of the crack and pay close attention to the following:

- Use only materials that haven't exceeded their shelf life;
- Accurate batching of components;
- Small batches to keep material fresh, and dissipate heat;
- Port spacing; and
- Consistent application of the material (1 in. wide x 3/16 in. thick [25 x 5 mm]) over the length of the crack.

3. Inject the epoxy (see Fig. 4 and 5).

For a successful epoxy injection, start with the proper batching and mixing of the epoxy components in strict accordance with the manufacturer's requirements. Prior to starting the actual injection, be sure that the cap seal and port adapter adhesive have properly cured so they can sustain the injection pressures.

Start the injection at the widest section of a horizontal crack. (Be sure to locate and mark these areas before installing the cap seal.) Vertical cracks are typically injected from the bottom up.

Continue the injection until refusal. If an adjacent port starts bleeding, cap the port being injected and continue injection at the furthest bleeding port. Hairline cracks are sometimes not well suited to "pumping to refusal." In those cases, try injecting the epoxy at increased pressure (approximately 200 psi [1.3 MPa]) for 5 min. Closer port spacing can also be considered. When injection into a port is complete, cap it immediately. Higher pressure can be used for injecting very narrow cracks or increasing the rate of injection. However, the use of higher pressure should be managed with care to prevent a blowout of the cap seal or ports.

4. Remove ports and cap seal (see Fig. 6).

Upon completion of the injection process, remove the ports and cap seal by heat, chipping, or grinding. If the appearance is not objectionable to the client, the cap seal can

Fig. 6—Remove seal cap.

be left in place. If complete removal is required for a subsequent application of a cosmetic coating, prepare the concrete surface by grinding.

How do I check the repair?

To ensure that the injection has been successful, quality assurance measures may include test cores or nondestructive evaluation (NDE).

1. Test cores:

- Core locations should be chosen to avoid cutting reinforcing steel, drilling cores in areas of high stress, or creating core holes below the waterline. The engineer should determine core locations when these types of conditions exist;
- Be sure the epoxy has set before extracting a core;
- Take cores (normally 2 in. [50 mm] diameter) to check that the penetration of the epoxy is adequate;
- Inspect the core visually to determine the penetration of the epoxy into the crack;
- Cores can be further tested for compressive and split tensile strength per ASTM C 42; and
- Subsequently, patch the removed-core area (after proper surface preparation) with an expansive cementitious or epoxy grout compatible with the existing substrate concrete and the surrounding environment.

2. Methods for nondestructive evaluation:

- Impact echo (IE);
- Ultrasonic pulse velocity (UPV); and
- Spectral analysis of surface waves (SASW).

Sources for additional information

ACI Committee 224, 1993, "Causes, Evaluation, and Repairs of Cracks in Concrete Structures (224.1R-93)," American Concrete Institute, Farmington Hills, Mich., 22 pp.

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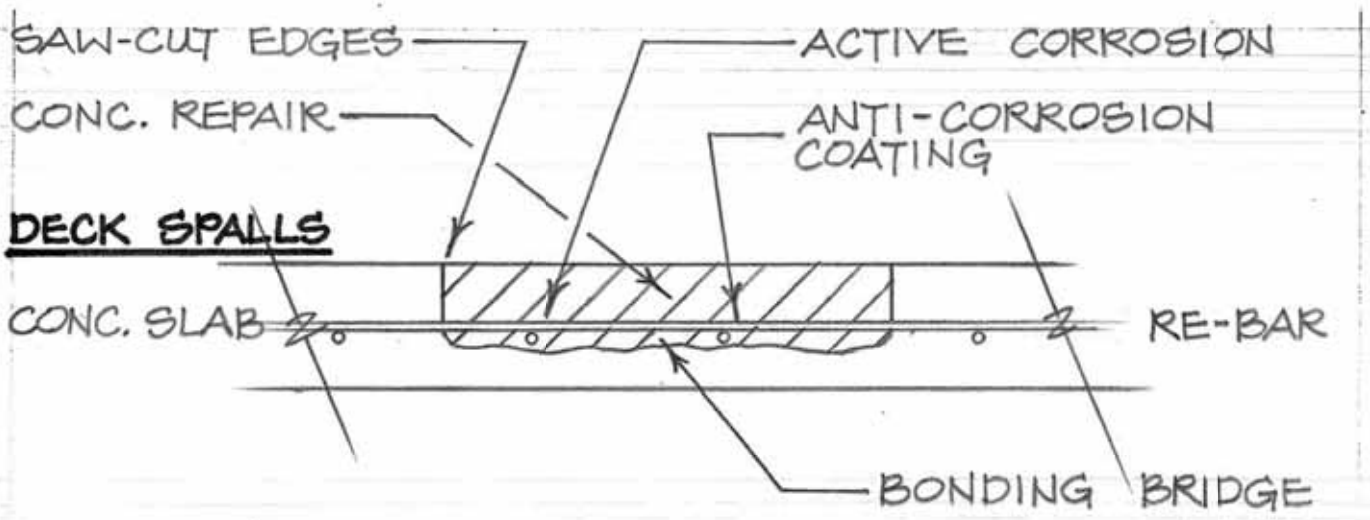

FLOOR SPALL REPAIR DETAIL NOT TO SCALE

REPAIR PROCEDURE

1. Remove all damaged or unsound concrete. Preparation of concrete surface shall be in accordance with ACI 546 R-96 Chapter 2 entitled "Concrete Removal, Preparation and Repair Techniques".
2. Saw cut the perimeter of the repair area, a minimum of 1/2 inch deep all around forming a shoulder perpendicular to the substrate.
3. Chip out the concrete to expose the entire circumference of the rebar. Removal shall continue along the length of the reinforcing steel until at least 6 inches of uncorroded rebar is observed.
4. Sandblast the concrete and exposed rebar. All scale shall be removed from rebar restoring bars to their original "white metal" condition. Surface and existing rebar shall be prepared as per "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" ICRI Guideline No.03730.Insert new bars of equal diameter next to those that have deteriorated by more than 10%. All new steel shall be ASTM A- 615 Grade 60. Lap splices shall be in accordance with ACI 318-02.
5. Coat all new and existing rebar as specified.
6. Repair mortar shall be as described in the specifications.
7. Cure and finish as required in the specifications.

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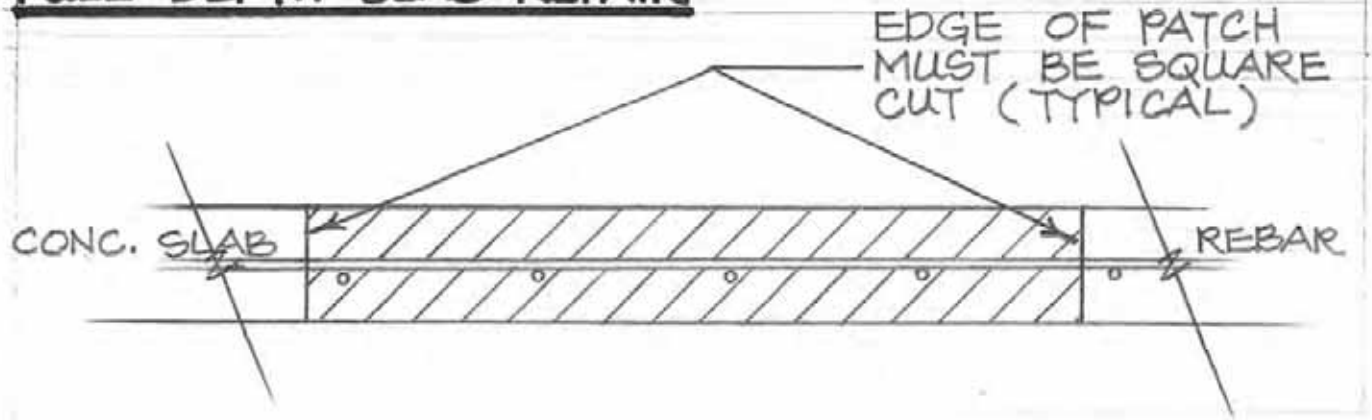
FULL DEPTH SLAB REPAIR



* FOR REBAR DETERIORATED > 10%

SLAB SECTION NOT TO SCALE

REPAIR PROCEDURE

1. Remove all damaged or unsound concrete. Preparation of concrete surface shall be in accordance with ACI 546 R-96 Chapter 2 entitled "Concrete Removal, Preparation and Repair Techniques".
2. Saw cut the perimeter of the repair area, a minimum of 1/2 inch deep all around forming a shoulder perpendicular to the substrate.
3. Chip out the concrete to expose the entire circumference of the rebar. Removal shall continue along the length of the reinforcing steel until at least 6 inches of uncorroded rebar is observed.
4. Sandblast the concrete and exposed rebar. All scale shall be removed from rebar restoring bars to their original "white metal" condition. Surface and existing rebar shall be prepared as per "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" ICRI Guideline No.03730.Insert new bars of equal diameter next to those that have deteriorated by more than 10%. All new steel shall be ASTM A- 615 Grade 60. Lap splices shall be in accordance with ACI 318-02.
5. Coat all new and existing rebar as specified.
6. Repair mortar shall be as described-in the specifications.
7. Cure and finish as required in the specifications.

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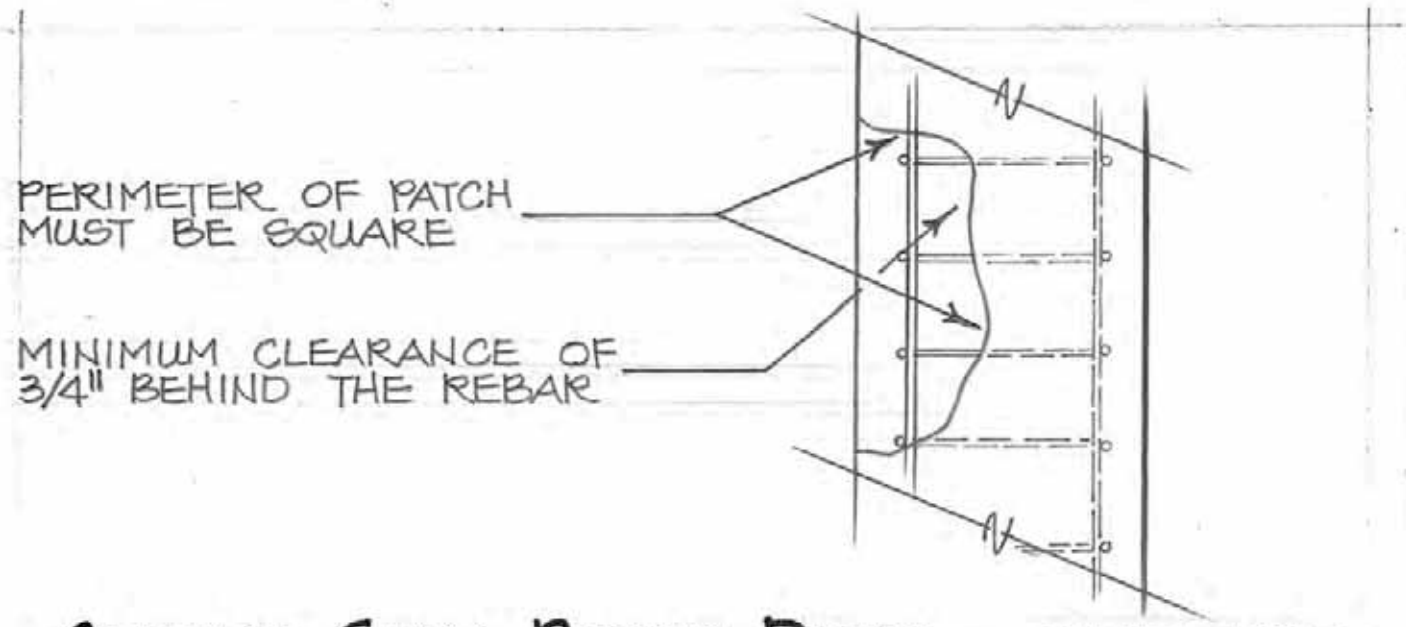

COLUMN SPALL REPAIR DETAIL NOT TO SCALE

REPAIR PROCEDURE

1. Remove all damaged or unsound concrete. Preparation of concrete surface shall be in accordance with ACI 546 R-96 Chapter 2 entitled "Concrete Removal, Preparation and Repair Techniques".
2. Saw cut the perimeter of the repair area, a minimum of 1/2 inch deep all around forming a shoulder perpendicular to the substrate.
3. Chip out the concrete to expose the entire circumference of the rebar. Removal shall continue along the length of the reinforcing steel until at least 6 inches of uncorroded rebar is observed.
4. Sandblast the concrete and exposed rebar. All scale shall be removed from rebar restoring bars to their original "white metal" condition. Surface and existing rebar shall be prepared as per "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" ICRI Guideline No.03730.Insert new bars of equal diameter next to those that have deteriorated by more than 10%. All new steel shall be ASTM A- 615 Grade 60. Lap splices shall be in accordance with ACI 318-02.
5. Coat all new and existing rebar as specified.
6. Repair mortar shall be as described in the specifications.
7. Cure and finish as required in the specifications.

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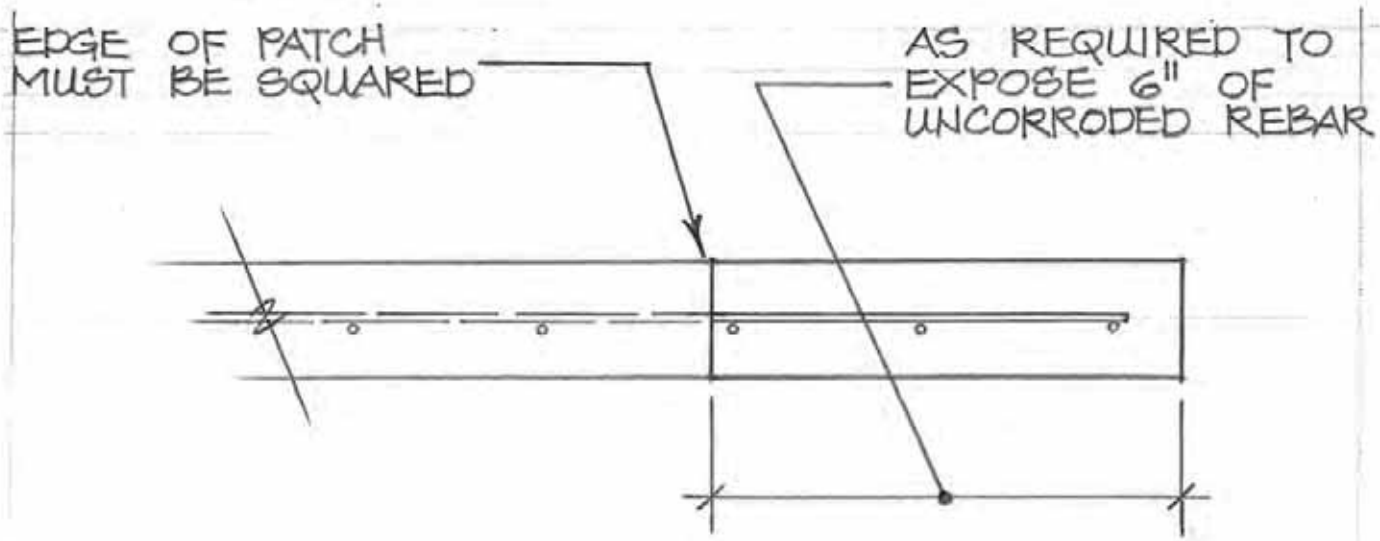

SPALLED EDGE REPAIR DETAIL NOT TO SCALE

REPAIR PROCEDURE

1. Remove all damaged or unsound concrete. Preparation of concrete surface shall be in accordance with ACI 546 R-96 Chapter 2 entitled "Concrete Removal, Preparation and Repair Techniques".
2. Saw cut the perimeter of the repair area, a minimum of 1/2 inch deep all around forming a shoulder perpendicular to the substrate.
3. Chip out the concrete to expose the entire circumference of the rebar. Removal shall continue along the length of the reinforcing steel until at least 6 inches of uncorroded rebar is observed.
4. Sandblast the concrete and exposed rebar. All scale shall be removed from rebar restoring bars to their original "white metal" condition. Surface and existing rebar shall be prepared as per "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" ICRI Guideline No.03730.Insert new bars of equal diameter next to those that have deteriorated by more than 10%. All new steel shall be ASTM A- 615 Grade 60. Lap splices shall be in accordance with ACI 318-02.
5. Coat all new and existing rebar as specified.
6. Repair mortar shall be as described-in the specifications.
7. Cure and finish as required in the specifications.

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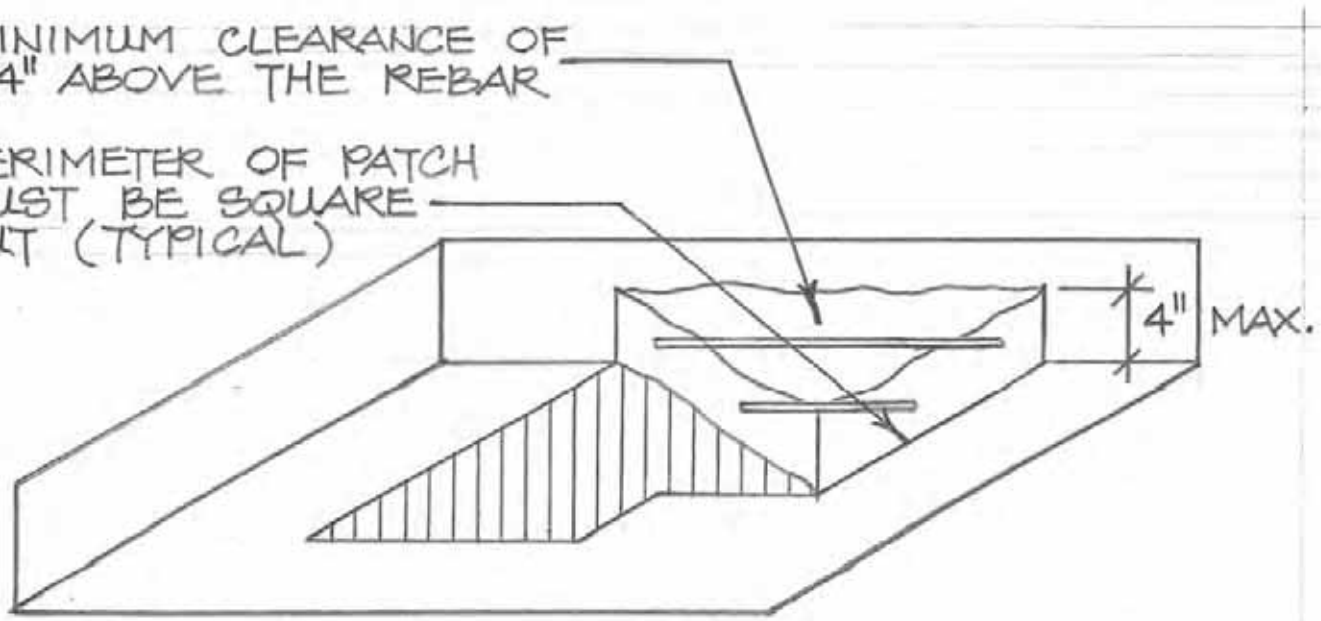

CEILING SPALL REPAIR DETAIL NOT TO SCALE

REPAIR PROCEDURE

1. Saw cut the perimeter of the repair area, a minimum of .5 inch deep all around forming a shoulder perpendicular to the substrate.
2. Chip out the concrete to expose the entire circumference of the rebar. Removal shall continue along the length of the reinforcing steel until at least 6 inches of uncorroded rebar is observed. Preparation of concrete surface shall be in accordance with ACI 546 R-96 Chapter 2 entitled "Concrete Removal, Preparation and Repair Techniques".
3. Sandblast the concrete and exposed rebar. All scale shall be removed from rebar, restoring bars to their original "white metal" condition. Surface and existing rebar shall be prepared as per "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion" ICRI Guideline No.03730. Insert new bars of equal diameter next to those that have deteriorated by more than 10%. All new steel shall be ASTM A- 615 Grade 60. Lap splices shall be in accordance with ACI 318-02.
4. Coat all new and existing rebar as specified.
5. Repair mortar shall be as described in the specifications.
6. Cure and finish as required in the specifications.

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