Repair of Architectural Terra Cotta

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THE BEST REPAIRS ARE HARD TO FIND
Things We Should Know About Terra Cotta

- Manufactured Clay Masonry
  - High Temperature Firing
- Composite Material
  - May or May Not be Glazed
    - Slip Glaze vs. Vitreous Glaze
  - Vitreous Glaze Is Of A Different Composition Than Clay Body or “Bisque”
  - Near Zero Permeability When Glaze Is Intact
- Low Coefficient of Thermal Expansion
  - Expands & Contracts Less Than Other Materials As Temperature Changes
  - Complicates Repair &/or Replacement
- “Grows” Over Time

Polychrome Glaze
90 West Street, NYC 1910

Unglazed or Slip Glaze
700 Broadway, NYC 1891
Common Causes of Terra Cotta Failure

Material Issues
- Growth Over Time
- Poor Original Glaze Fit

Assembly & Exposure Issues
- Poor Detailing
- Poor Maintenance
- Moisture Entrapment
- Steel Corrosion
- Structural Movement

- Glaze Crazing
- Glaze Spalling
- Joint Failure
- Displacement
Approaches to Intervention

- Preservation/Stabilization
- Restoration
  - Repair, Protection, Maintenance
  - Retention of Historic Fabric
  - Limited Unit Replacement
- Reconstruction
  - Disassembly
  - Replace Unsalvageable Units
  - Necessary If Structural Steel Needs Replacement
Repair of Architectural Terra Cotta

- Replacement w/Substitute
- In-Kind Replacement
- Repair & Coating
How Long Can Repairs Last?

Former Penn Station
Pittsburgh, PA
Repaired 1986

30+ Years Later
Repairs to Withstand the Test of Time...

- For Repairs To Last:
  - Underlying Causes of Deterioration Must Be Comprehensively Addressed
  - Must Use Good Practices and Workmanship
  - Must Use Compatible, Durable Materials
Terra Cotta Repair Challenges

• Thermal Incompatibility of Most Repair Systems

![Bar chart showing Linear Coefficient of Thermal Expansion (LCTE) for different materials.]

- Failed Epoxy-Based Resurfacing Mortar
Terra Cotta Repair Challenges

• Thin-Section Glaze Spalls are Most Common
  • Nominally 1/16”
• Most Repair Systems Perform Poorly in Thin Sections
• Repair Systems Designed for this Specific Application Have Proven Durable and Effective
Terra Cotta Repair Challenges

• Damaged TC Assemblies Tend to be Wet
• Most Repair Systems Perform Poorly in Applications to Wet Masonry
  • Dynamic Moisture Hinders Repair Applications
  • Recent Research Supports Use of Moisture-Insensitive Barrier Primer
• Few Projects Allow Time for Drying
  • Drying Can Take Many Years

Biological Growth in Wet Bisque Beneath Spalling Glaze
Repair System Options

• Very Small Number of Commercial Systems Designed Specifically for Terra Cotta Repair

• Proprietary Formulations
  - Typically Cement-Based
  - Latex-Modified vs. Unmodified

• Multi-Step Repairs
  - Thin Patch (<1/4”)
  - Deep Patch (>1/4”)
  - Coatings to Match Glaze
Latex-Modified Cement Technology

Why Do We Use It?

- **Increases Adhesion**
  - Typically 2x – 4x Higher

- **Improves Flexibility**
  - Typically 2x – 3x Flexural Strength
  - Lower Modulus of Elasticity

- **Lowers Shrinkage**
  - Up to 70% Reduction
  - Eliminates Shrinkage Cracking

- **Reduces Curing Requirements**
  - 0 – 24 hrs (max.)
  - Wet Curing

- **Does Not Impair Permeability**
  - NOTE: TC with Intact Glaze is Impermeable

MICROPHOTOGRAPH: PORTLAND CEMENT IN EARLY STAGE OF HYDRATION

MICROPHOTOGRAPH: LATEX MODIFIED MORTAR AFTER ACID DIGESTION

NOTE: TC with Intact Glaze is Impermeable
Glaze Spall Repair: Thin Patching

- Do You Really Have To Cut Out ½” of Sound Terra Cotta Bisque?
  - Causing More Damage Than Original Problem
- Thin Section Patches May Be Used at 1/4” or Less
Skip Thin Glaze Spall Repair?

- You *Can* Just Coat the Bisque, But it Looks Like _____....

Coating Over Glaze Spalls Without Patching
Thin Patch Custom Multi-Step Glaze-Matched Coating System
Large & Deep Repairs

- With Low-Shrinkage Repair Material, There Is No Limit to Patch Size
- Example: Terra Cotta Bracket Repairs at 230 Park Avenue, NYC
  - Cast In Place Patches Up to 1000 lbs./14” Thick
230 Park Avenue: 2010

30 OF THE 32 BRACKETS WERE FAILING, REQUIRING REPLACEMENT
230 Park Avenue: Repair

- 14” Thick Castings Poured in Terra Cotta Patching Compound After Anchor Installation
- Individual Castings Weighed Up to 1000 lbs.
- Repair Cost <5% of Replacement Cost
230 Park Avenue: After
Ten years later...
Terra Cotta Replacement

• In-Kind, New TC Units
  • 3 Current Manufacturers
• Substitute Materials
  • Precast Concrete
  • GFRC
  • FRP
  • Limestone
  • Proprietary, Cementitious
• Proprietary, Resinous
In-Kind Replacement

- PRO's
  - Maximum Compatibility
  - Historically Accurate
  - Highly Durable
  - Fireproof
  - No Joint or Anchoring Redesign

- CON's
  - Costly
  - Long Lead Times
Precast Concrete

• PRO’s
  • Low Cost
  • Rapid Production

• CON’s:
  • Poor Weathering
  • Thermal Expansion Mismatch
  • High Density
  • Potential Steel Corrosion
  • Anchoring Redesign

Woolworth Building
New York
GFRC

**PRO's**
- Lightweight
- Moderate Cost
- Rapid Production
- Good Initial Esthetics

**CON's**
- Thermal Expansion Mismatch
- Requires Redesigned Anchoring & Joints
- May Tend to Weather Poorly

Nordstrom Flagship Store
Seattle
Resinous - Proprietary

• PRO's
  • Rapid Production
  • Good Initial Esthetics

• CON's
  • Large Thermal Mismatch
    • Requires Joint Redesign & Sealants
  • Mortar & Sealant Bonding Issues
  • Potential Fire Issues
  • Some Systems Demonstrate Poor Long-Term Esthetics
While Some Units Could Be Patched, Many Shattered

Replacements Cast On Site Using Custom Terra Cotta Repair Mortar
COMPLETED CASTINGS
Cementitious - Proprietary

• PRO’s
  • Hollow, Lightweight Units
  • Excellent Thermal Compatibility
  • Drop-In, One-for-One Replacement
    • No Anchoring Changes
    • No Joint Redesign or Sealants
    • Partial-Depth Replacement Possible
  • Rapid Production
  • No Mortar/Sealant Bonding Issues
  • Castings Are Non-Combustible
  • Easily Repairable if Needed

• CON’s
  • It’s Not Terra Cotta
  • Glazes Matched with Durable Coatings
    • Eventual Maintenance
Glaze Replication Challenges

- Bond to Existing Glaze
- Broad Range of Glaze Colors
- Complex Finishes
- “Depth” of Vitreous Glazes
- Durability
GLAZING MATCHING 1: Polyurethane

- Waterborne Aliphatic Polyurethane
- Thin Film
- Can be Clear, Translucent or Opaque
- Can be Gloss, Satin or Flat
- Depth: Clear Coats over Color Coats
- Detail: Can Layer & Sponge-Apply Multiple Colors

New York State Education Building
Albany, NY
POLYURETHANE GLAZE COATING
GLAZE MATCHING 2: Acrylic

- Matte Finish
- High Permeability
- Crack Bridging & Weather-Proofing
- Opaque
- Surface Tolerant
- Can Also Use As Base Coat for Polyurethane Top Coat

Lucas Theater, Savannah, GA
ACRYLIC GLAZE COATING

- Matte Finish Glaze Coating
- Requires No Primer
- Good Detail Retention
- Durable

Omni William Penn Hotel
Pittsburgh, PA
California State Library
California State Library
California State Library
CUSTOM SPECKLE COATING
OVER CUSTOM GREY COATING
SPECKLE REPRODUCTION

- Color Flakes Suspended in Clear Binder
- May Be Controlled for Size, Concentration & Color
Wet Terra Cotta
Building Challenges

Union Station
Worcester, MA
1997
DRYING PLAN 1998

1. STABILIZE
   a. New Roof
   b. Parapet Flashings & Joints
   c. Seal Openings
   d. New Heating System

2. Install Test Areas

3. STOP!
DRYING PLAN 1999

1. BREATHE!
   a. Open All Joints
   b. Scale Loose Glaze
   c. Drill 10,000 Holes
   d. Apply Permeable Primer

2. STOP & TEST
BREATHABLE COATING TEST AREA ON SATURATED WATER TABLE
- Multi-Disciplinary Restoration Team
- Comprehensive Specs and Mock-Ups
- Carefully Planned Work Sequence
  - Envelope Stabilization Prior to TC Repair
  - Carefully Implemented Drying Plan
  - TIME!
- 5-Year Follow-Up/Touch-Up
Ritz Carlton Hotel
San Francisco, CA
Ritz Carlton Hotel
2009: 5 YEARS AFTER
Deep Patch
Thin Patch
Custom Coating
20,000 Repairs
ALL BLOCKS HEAVILY REPAIRED WITH THIN PATCH & COATED WITH 4 SHADES OF POLYURETHANE
VENTURA CITY HALL
2009: 5 YEARS AFTER

THIN REPAIRS
POLYURETHANE GLAZE
10,000 REPAIRED UNITS
VENTURA CITY HALL
Wet TC Buildings

- Follow-Up
  - Wet Buildings May Take Years To Stabilize

- Sequence of Work is Critical
  - Stabilization
  - Drying
  - Time!
  - Finishes

- Plan For Ongoing Maintenance
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Kronenberger & Sons Restoration
Nault Architects
Hawaiian Dredging
Pullman Services
Works In Stone, Inc.
Con-Spec Associates, Inc./CastCotta

Questions?

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