Terra Cotta Manufacturing Issues

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Architectural Terra Cotta

Architectural terra cotta refers to a fired mixture of clay, grog (fired clay particles) and water that can be used in a non-structural, semi-structural, or structural capacity on the exterior or interior of a building. Terra cotta translates from Latin as "baked earth". Terra cotta can be unglazed, slip glazed, or glazed.

Ceramic Engineering

The technology that involves the design and manufacture of ceramic products. Ceramics are inorganic, nonmetallic materials that have been hardened by firing at high temperatures.

-New World Encyclopedia

Cause and Manifestation

- Design
  - Ceramic
  - Glaze
  - Geometry
- Manufacturing
  - QA/QC
- Installation
  - Detailing
  - Ancillary Components
- Maintenance

Historically

- More than 30 manufacturers prior to 1930s
- Clays were sourced locally for proximity to fabrication
- Grog from recycled terra cotta/clay materials
- Early glazes often ‘proprietary’ and used many toxic metals and other toxic additives
- Professional organizations
  - National Terra Cotta Society: 1900s through 1920s
  - American Ceramic Society: 1900s through today, but no efforts related to architectural terra cotta
- Faulty material likely has long been removed or replaced

American Ceramic Society

- Established in 1899 and Included Architectural Terra Cotta Subcommittee
- 1922 Publication-Regarding Defect Causes
  - Plaster used for molds
  - Materials used for the clay body
  - Processes of preparing the clay
  - Glaze performance
  - Patching
  - Service problems

ACS: Proper Pressing Techniques (1922)

- One homogeneous mass, misconceptions:
  - Not just an ornamental impression of the face of a unit
  - Inherent characteristics of the clay caused all clay to easily bond together
- No thumb pressing (concentrations), but rather using side of hand or fist
  - Rolls of clay recommended
  - Lower shrinkage clay used for webs

Current Manufacturers

- Gladding McBean, Lincoln California
- Boston Valley, Orchard Park, New York
- Darwen, Devinshire, England
- Others

Current Standards for Terra Cotta

- Compression Strength (ASTM C39M)
- 24-hour Cold Water Absorption (ASTM C67)
- 5-hour Boil Absorption (ASTM C67)
- Saturation Coefficient (ASTM C67)
- Initial Rate of Absorption (Suction) (ASTM C67)
- Efflorescence (ASTM C67)
- Freeze-Thaw Resistance (ASTM C67)

Current Standards, cont.

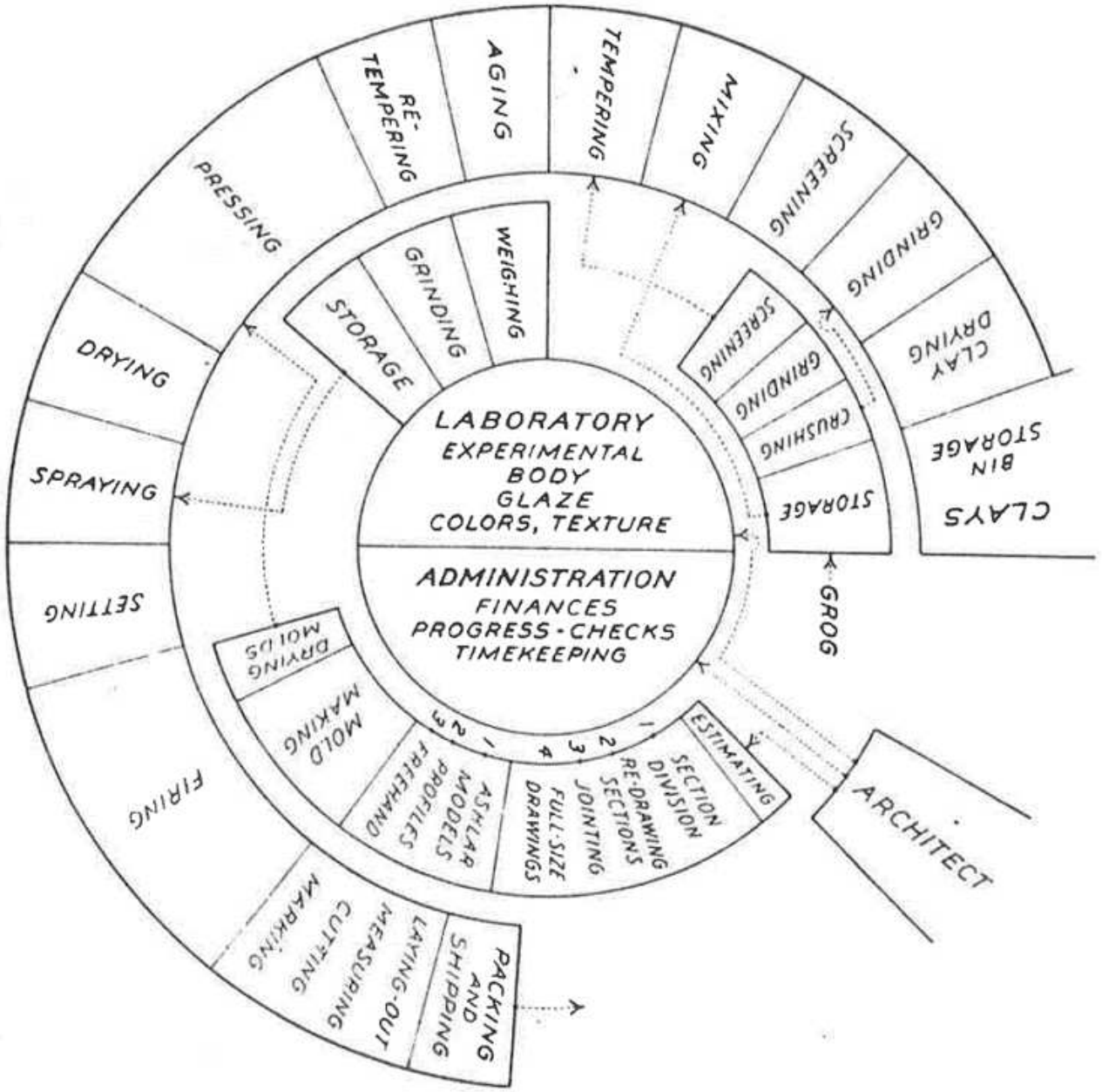
- Resistance to Crazing (ASTM C126)
- Imperviousness (ASTM C126)
- Resistance to Fading - Chemical resistance test (ASTM C126)
- Color (ASTM D1729)

Non-standardized

- Glaze Permeability
- Glaze Adhesion
- Others

Issues: General

- Material Properties
- Manufacturer's QA/QC
- Unit Geometry
- Glaze Properties
- Exposure Considerations
- Durability



Issues: Specific

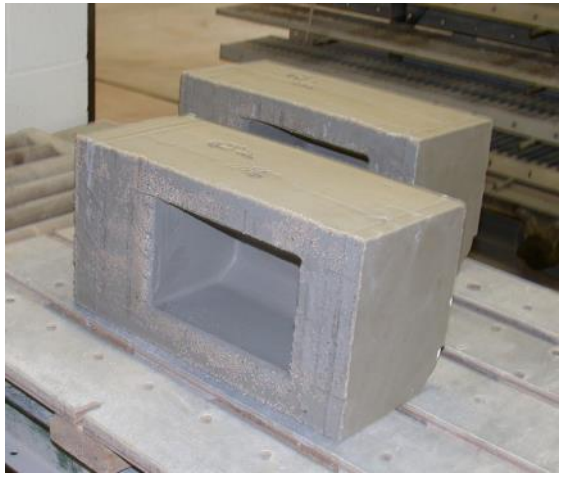
- Schedule Issues
- Substitute Material Competition
- Unit Geometry
  - Extruded Units
  - Notches
- Filling Units
- Glaze Spalling
- Regional Differences
  - Climate
  - Seismic

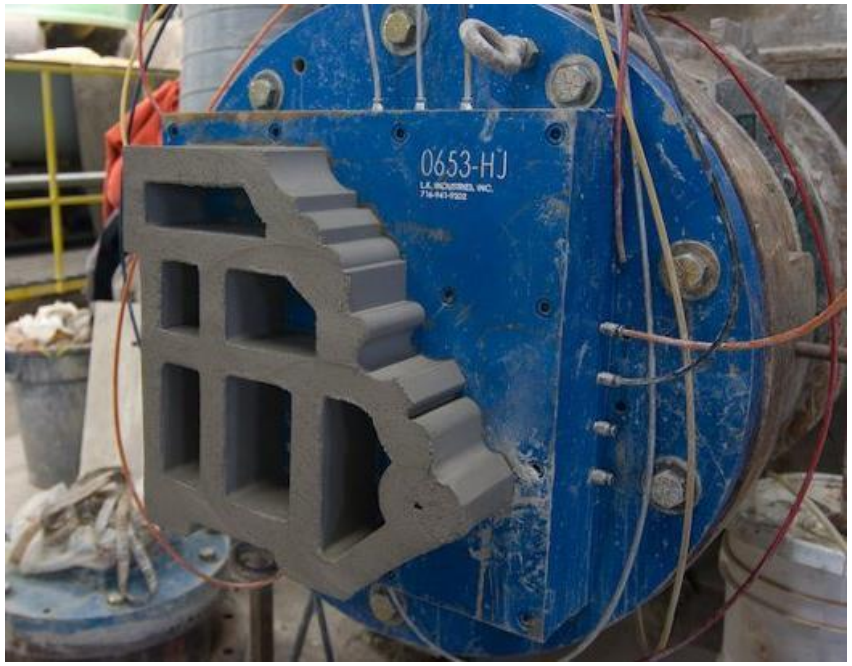
Manufacturing Methods

- Hand Pressed
- Extruded
- Slip Cast
- Ram Pressed
- Sculpted

Hand-pressing and Sculpting

Molds and Dies



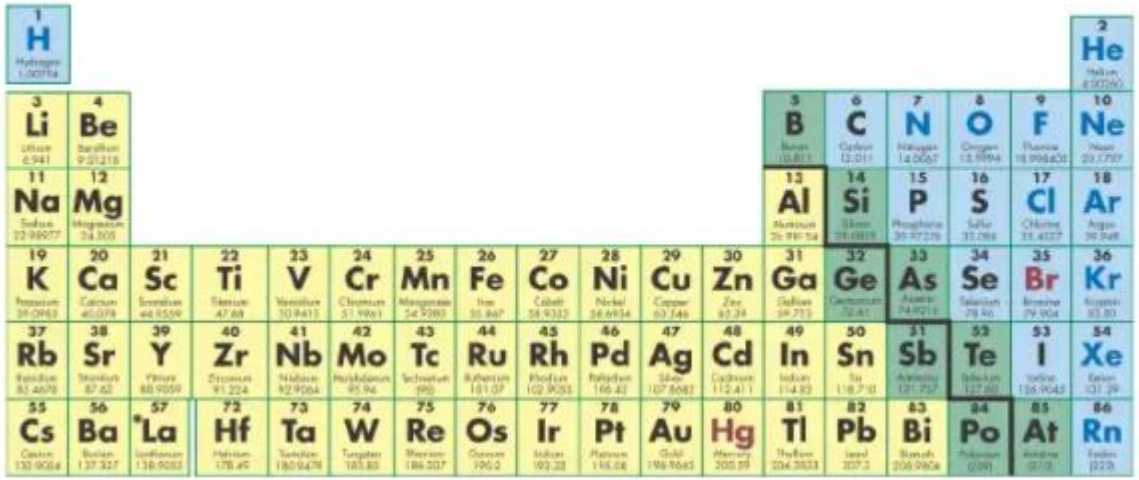


Material Properties: Comparison

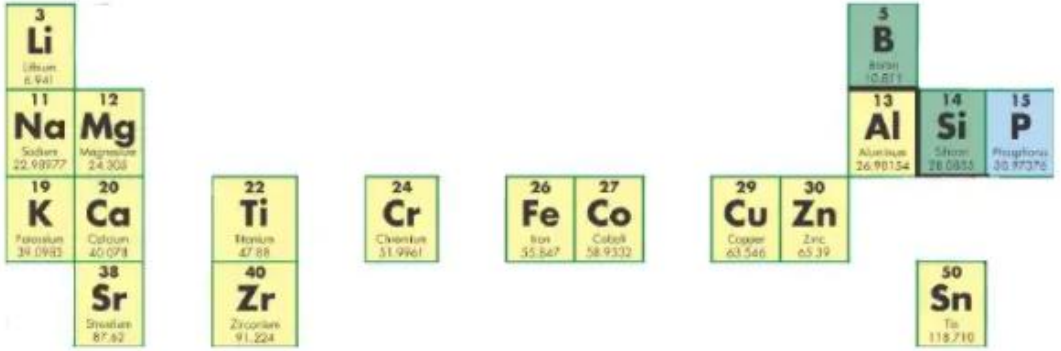
Material Properties (ASMT C67)	Historic Properties	Mfg. Specified Limits (Current)	Actual Testing Hand Pressed (Current)	Actual Tested Extruded (Current)	Guild Specs
Comp. Strength (psi)	5,000 to 12,000	6,000 to 8,000	9,500 to 14,500+	10,000 to 15,000+	6,000 12,000 max
Absorption 24 hr. soak (%)	6 to 10*	7.5 to 7.9	4.7 to 6 (BVTC) 6.5 to 7.5 (GMB)	4.0 to 5.5 (BVTC) 6.5 to 7 (GMB)	9.0 max
Absorption 5 hr. boil (%)	10 to 15*	11.5 to 11.9	6.5 to 8 (BVTC) 9.5 to 11 (GMB)	6.0 to 7.5 (BVTC) 9.5 to 10.5 (GMB)	-
Saturation Coefficient (c/b)	0.80+*	0.69	0.63 to 0.70 up to 0.80		0.68 avg/ 0.70 max
Autoclave	-	150 psi	150 psi	150 psi	150 psi

Ceramic Glazes: Issues

Periodic Table of the Elements



Elements we use in the current set of studio glazes



Glaze Defects: Crazing

- Moisture crazing
- Delayed crazing:
- Crazing is the most common defect, and normally the easiest to correct. In both crazing and shivering the thermal expansion characteristics of both body and glaze should match.

Controlling Crazing: Testing

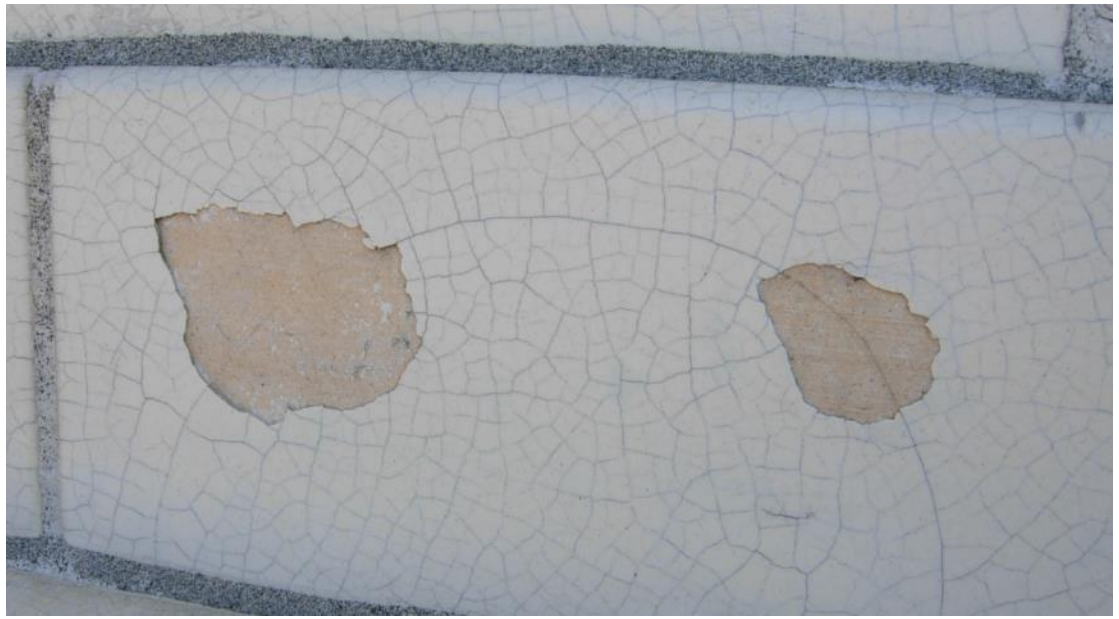
- Autoclave Testing: 1930s
  - Steam pressure (150 psi) for 1 hour
  - Absorption: 10 percent w/variable soak/boil durations
- Autoclave Testing: 1970
  - Steam pressure (75 psi)
  - Absorption:

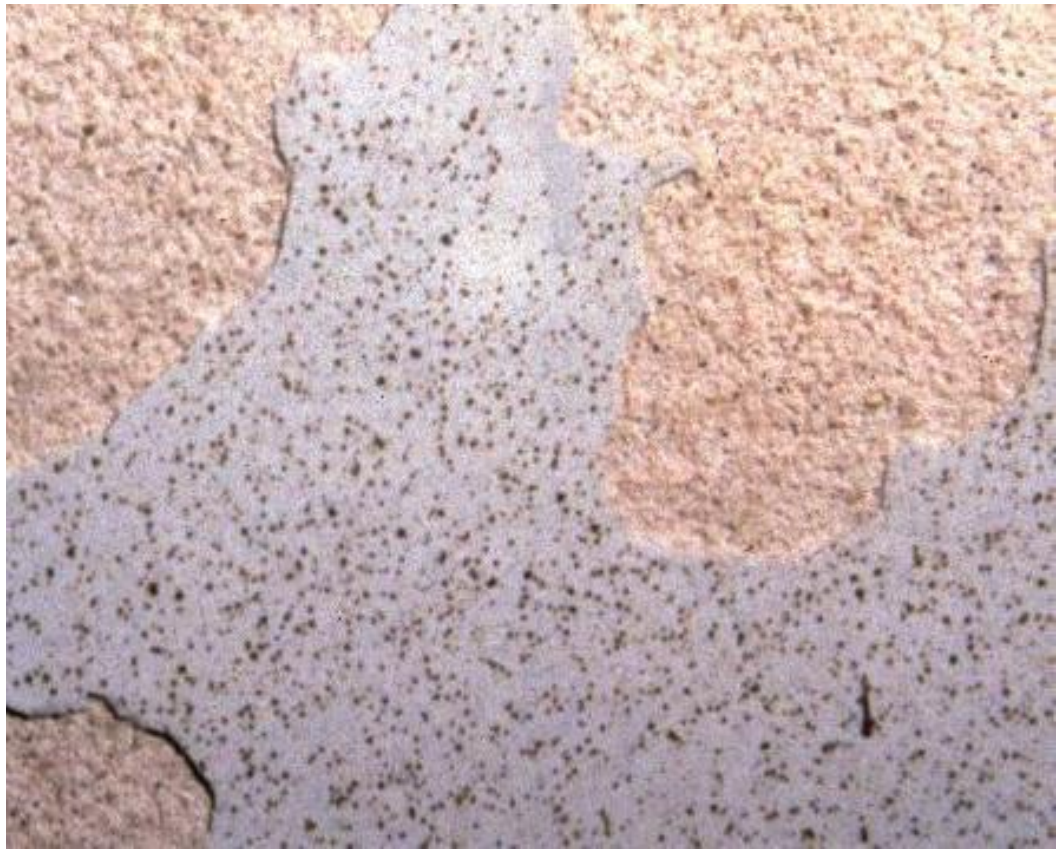
Glaze Defects: Shivering

- Shivering is the reverse of crazing
- Most glazes are as much as 10x stronger in compression than tension, thus shivering is rarer than crazing

Glaze Defects: Debonding

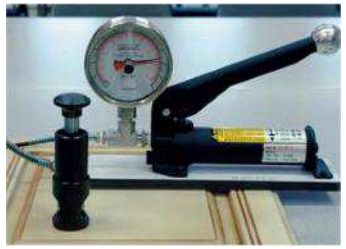
- Poor initial bond with thermal cycles
- Glaze formulation
- Clay body compatibility





Debonding: Testing

- Glaze adhesion testing



Glaze Defects: Crawling

- Occurs during firing resulting in “islands” of glaze forming as it crawls, leaving bare patches of body
- Surface tension in the glaze. Adhesion problems, often caused by bad application
- Occurs when one glaze is applied over another, particularly if the first is allowed to dry out completely before the second application

Glaze Defects: Pitting and Pin-holing

- Poor control during firing cycle, the glaze composition, or can originate within the body, particularly highly grogged clay bodies
  - Rapid firing cycle
  - Apply the glaze less thickly
  - Improper glaze formulation
  - Increase the maturing temperature of the glaze
  - Increase hold time in kiln at the glaze maturing temperature
  - Cool the kiln slowly

Glaze Defects: Blisters

- Excessively thick application of glaze
- Incomplete clay preparation, wedging, blunging, etc.
- Overfiring or to the use of soluble fluxes in the glazes

Clay Body Issues

- Warping
- Improper drying
- Inadequate firing
- Improper cooling
- Poor body mix
- Air inclusions in clay

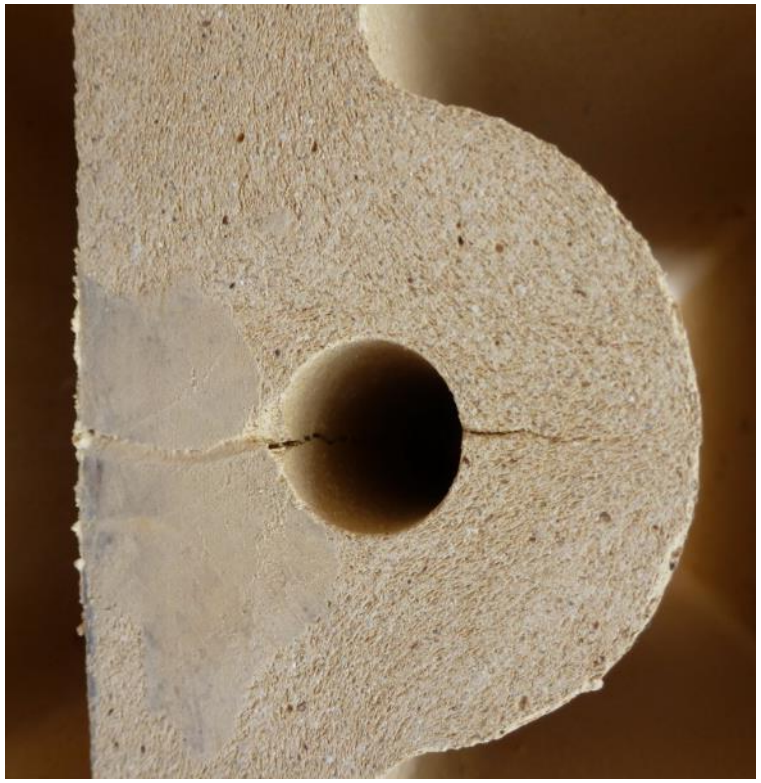
Dunting

- Cooling cracks in the clay body
- Grog size potentially contributes
- Type of clay/clay formulation

Pressing Issues

Geometry: Notching

Geometry: Extrusion Issues



Questions to Consider

- Are there ways to improve scheduling issues from the designer's and manufacturer's end?
- Are substitute materials unavoidable if the industry doesn't adjust?
- Is there a need to substantially modify the existing industry standards for terra cotta?
- Is the material currently being manufactured a long-term durable material?