

# Terra Cotta Manufacturing Issues

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**The Masonry Society**

# 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.

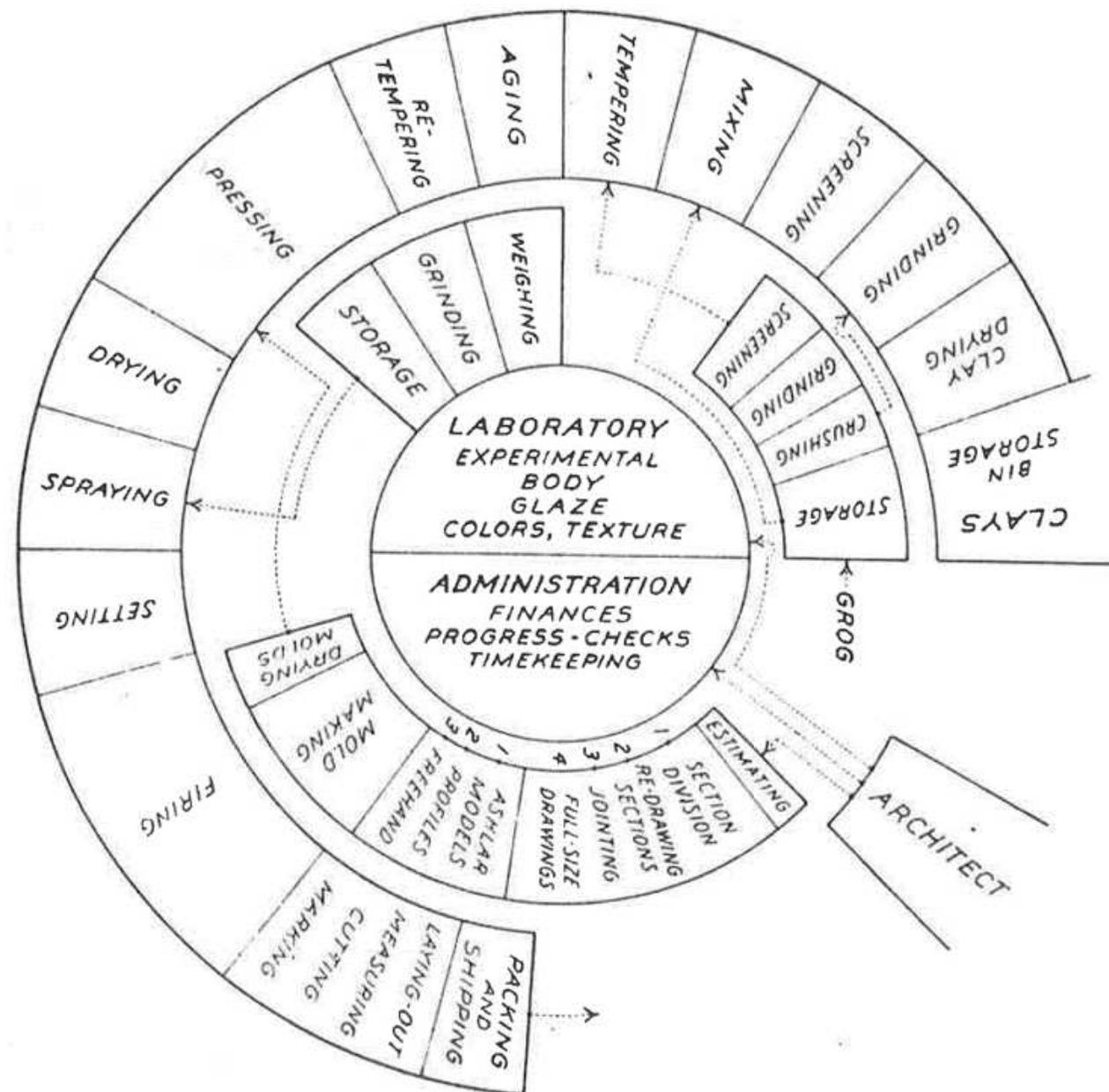
- Resistance to Crazing (ASTM C126)
- Imperviousness (ASTM C126)
- Resistance to Fading - Chemical resistance test (ASTM C126)
- Color (ASTM D1729)

## 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

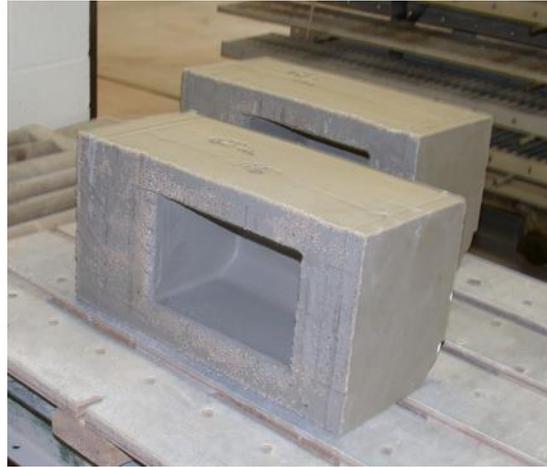
- Hand Pressed
- Extruded
- Slip Cast
- Ram Pressed
- Sculpted



# 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

1 H Hydrogen 1.00794																	2 He Helium 4.002602
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.0064	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.98976928	12 Mg Magnesium 24.305											13 Al Aluminum 26.9815385	14 Si Silicon 28.0855	15 P Phosphorus 30.973761998	16 S Sulfur 32.06	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.9559122	22 Ti Titanium 47.88	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938044	26 Fe Iron 55.845	27 Co Cobalt 58.933194	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.9216	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.9055	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.757	52 Te Tellurium 127.6	53 I Iodine 126.90545	54 Xe Xenon 131.29
55 Cs Cesium 132.90545196	56 Ba Barium 137.327	57 La Lanthanum 138.90547	72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.222	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.9804	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)

## Elements we use in the current set of studio glazes

3 Li Lithium 6.941																	5 B Boron 10.811
11 Na Sodium 22.98976928	12 Mg Magnesium 24.305											13 Al Aluminum 26.9815385	14 Si Silicon 28.0855	15 P Phosphorus 30.973761998			
19 K Potassium 39.0983	20 Ca Calcium 40.078											22 Ti Titanium 47.88	24 Cr Chromium 51.9961	26 Fe Iron 55.845	27 Co Cobalt 58.9332	29 Cu Copper 63.546	30 Zn Zinc 65.38
																	50 Sn Tin 118.710

# Glaze Defects: Crazeing

- Moisture crazing
- Delayed crazing:
- Crazeing 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



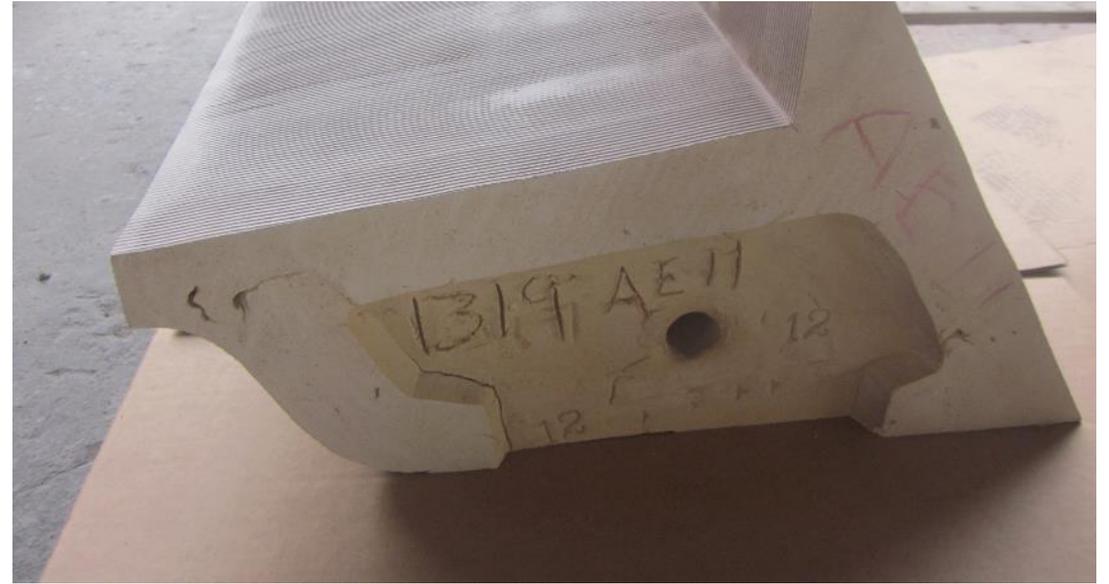
# Clay Body Issues

- 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



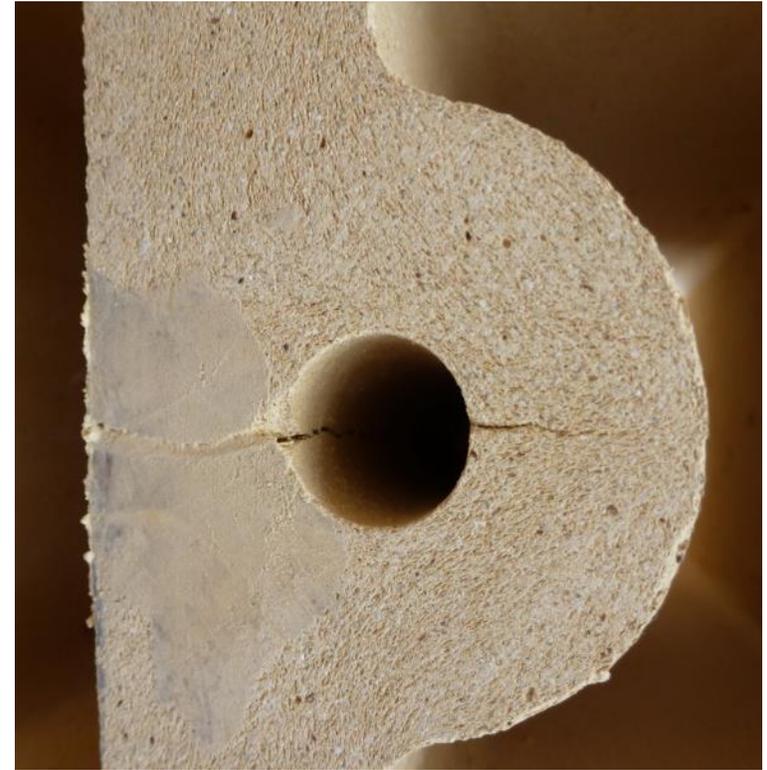
# Pressing Issues



# 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?