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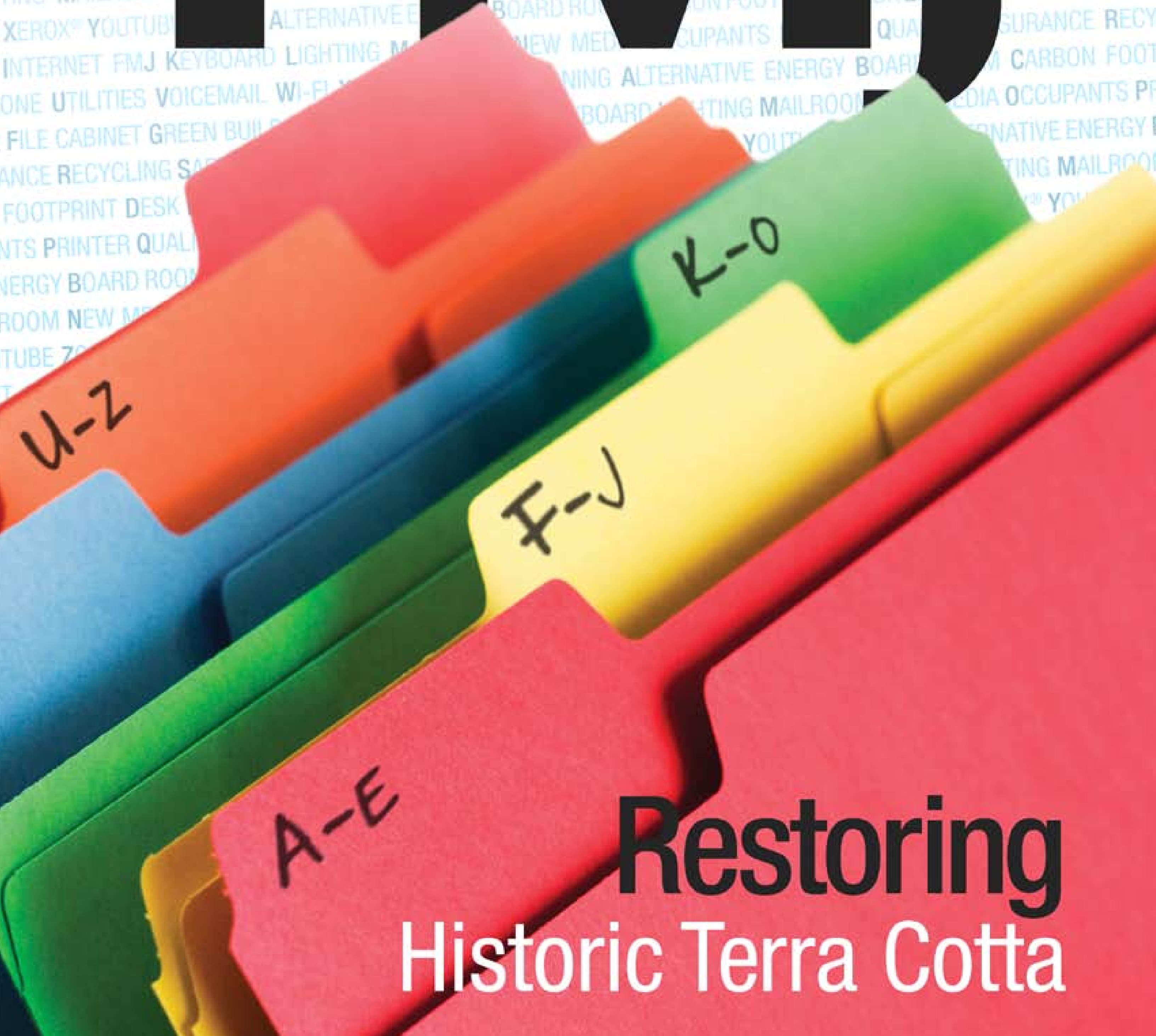

Restoring Historic Terra Cotta

Photo: Series of terra cotta columns.

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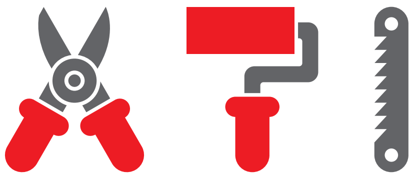
OLGA A. VAYSMAN



Terra cotta:

from Latin "cooked earth."
A ceramic material made from clay forced into negative plaster molds and fired; often glazed in single or many colors; capable of assuming many forms; widely used from 1875 to 1930 as a sheathing material.

Terra cotta cladding and decorative elements can be found on many historic buildings. When building owners and managers are faced with deteriorating terra cotta components, they need to determine appropriate repair methods or consider replacing the terra cotta in kind or with alternate materials. There are various steps that building owners and managers should consider when dealing with failing terra cotta.

History and applications in construction

Though terra cotta dates back to 3200 B.C., its use in North America began in the 1860s and continued through the 1930s. In its early stages, unglazed brown structural terra cotta was prevalent in load-bearing walls and some ornamentation. After the Chicago fire of 1871, fireproof terra cotta (lightweight terra cotta block), was used between floor beams, as sheathing of skeletal iron or steel frames, and as wall partitions. By the 1890s, terra cotta also became an exterior cladding material, consisting of 4-inch hollow units. In the 1920s, the thinner terra cotta veneer became available. However, problems—such as warping and glazing deterioration—contributed to its decline. By the 1930s, terra cotta was primarily used as ornamentation. Deteriorated terra cotta was replaced with other materials and decorative elements were often removed entirely.

Material composition

The body of terra cotta consists of argillaceous rocks, such as marl (mixture of clay and lime), ball clay (kaolin or china clay), fire clay and a grog (ground semivitrified terra cotta from previous firings). If left in its natural unglazed state, terra cotta is a warm red brown color. The slip, or finish, is composed of finely ground colored clays and elutriated clays. The glaze is comprised of common salt, sodium compounds, borax, boric acid and either lead or tin; feldspar could also be added. Colors vary from red and brown to white.

Manufacturing process

The manufacture of terra cotta is tedious—resulting in long lead times for construction. Terra cotta manufacture begins with mixing the ingredients, followed by packing the mixture into a negative plaster mold. To account for the shrinkage that occurs during the drying and firing process, the initial clay model must be slightly larger than the end product. Shrinking of terra cotta is caused by the plaster drawing moisture from the clay. Once the terra cotta is released from the mold, the exposed surfaces are tooled and finished. The next step is air drying, which can last several days to several months. This prepares the terra cotta for the two stages of kiln drying. Prior to the first—or between the first and second kiln drying—the terra cotta is coated with a slip. Some of the units also receive a glaze coating which gives them a glasslike surface. Coatings and glazes must be applied prior to kiln drying so that the body and finishes shrink at the same rate, otherwise the finishes can spall or craze. High heat from kiln drying sparks chemical reactions within the terra cotta and causes shrinkage. If done properly, the terra cotta reaches a "sinter point" where the particles fuse together. Over-firing or under-firing can result in insufficient thermal and strength values.

Deterioration: causes and symptoms

Building use

Terra cotta deterioration often depends on how it is utilized. Terra cotta used as part of a load bearing wall system, where anchorage is limited, typically has greater longevity than terra cotta used for cladding or as a decorative element. In many early cladding applications, terra cotta designs did not incorporate a system of flashings, expansion joints or weeps for the terra cotta—resulting in premature material and system failure.

Water infiltration

Water infiltration is often caused by improper flashing configurations or mortar joint deterioration, resulting in severe defects. One effect of water infiltration is glaze crazing—which occurs when water causes the terra cotta to expand, resulting in tension, leading to glaze crazing. Since the glaze essentially serves as the vapor barrier, crazed glaze allows vapor to penetrate terra cotta. The damage typically starts with staining and spalling and if left untreated, significant material loss and deterioration of the backup masonry and metal anchor system can occur. Extensive deterioration can also result in dislodging of whole units.

Expansion and contraction

Insufficient provision for expansion and contraction mainly occurs through the use of inappropriate hard mortar and lack of soft joints. This is most prevalent in high-rise construction prior to the 1920s and has resulted in stress-related failure of terra cotta, ranging from stress-cracks to complete deterioration. Typically, full deterioration occurs when the stresses on the material are coupled with other elements such as water infiltration.

Manufacturing defects and inappropriate repairs and alterations

Manufacturing defects, inappropriate repairs and damage from alterations also contribute to terra cotta deterioration. Manufacturing defects include insufficient drying times, overdrying or improper finishing applications. Inappropriate repairs range from replacing terra cotta with incompatible materials to installing new terra cotta components improperly.

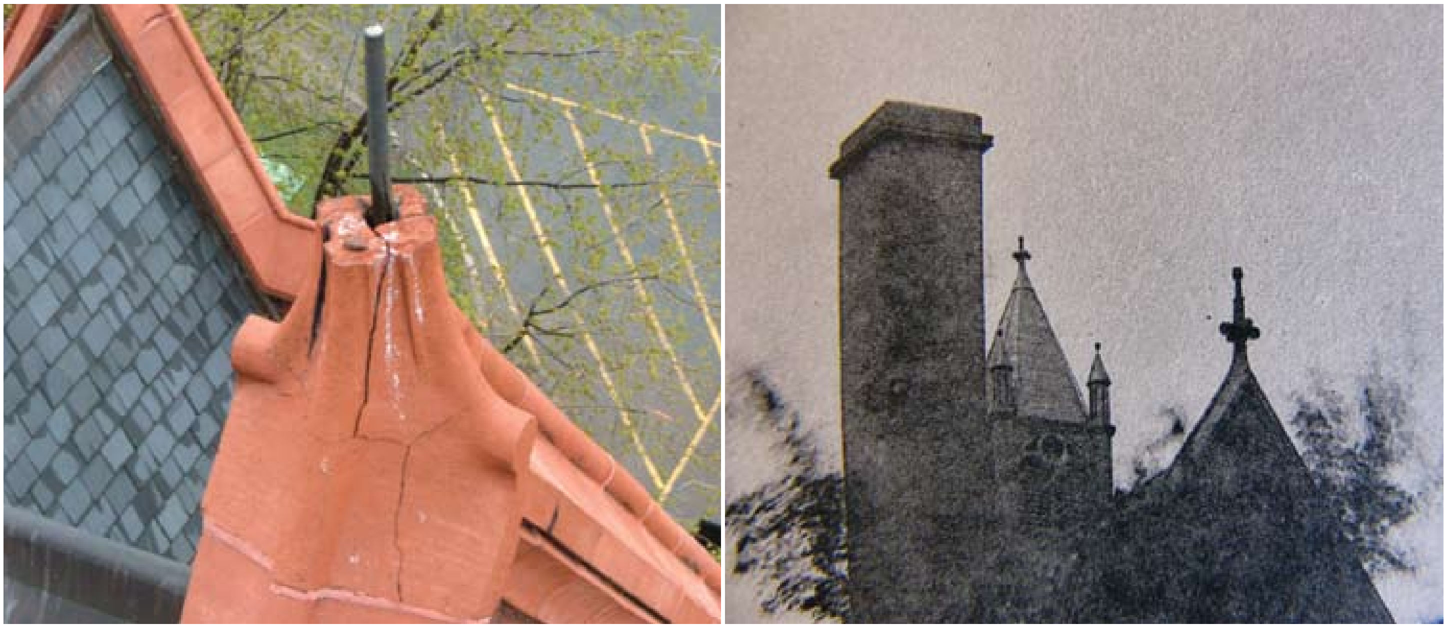
Evaluation and diagnosis

Prior to determining a repair approach, building owners and facility managers need to diagnose the terra cotta's condition by performing a visual evaluation, a non-destructive and a hands-on inspection, and sometimes destructive testing.

Visually inspecting the terra cotta piece-by-piece should be the first step when assessing true conditions. While crazing and spalling are easy to observe, the key is to establish the cause. Design and construction documentation—such as section drawings—will help to understand the assembly, establish potential causes and determine other components affected by deterioration. For example, these documents could show the configurations of the flashings or lack thereof, and illustrate structural elements (i.e. anchors).

Non-destructive approaches, such as sounding (lightly tapping) the terra cotta with a mallet, may indicate which units are delaminated. More technical approaches—such as infrared scanning and sonic testing—can help expose moisture and potential internal deterioration, respectively. Metal detection can locate the structural compo-

Photo: The photo of the current condition (on left) shows the missing finial and cracked base. Historic photos (such as the one on the right) allowed us to see the original profile of the finial so that it could be accurately replicated.



nents to determine possible corrosion and allow as-built information to be compared with original design drawings, if available. Inserting a boroscope into large cracks or mortar joints provides a view inside the terra cotta assembly.

Destructive testing (i.e. removal of a terra cotta section) allows the underlying structure and its conditions to be verified. The extracted terra cotta can then be sent to a laboratory for analysis. Minimal tests should include a porosity test on the body, and absorption, adhesion and permeability tests on the glaze.

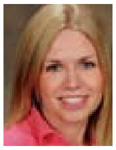
Restoration

Identifying the source(s) of the terra cotta deterioration is vital to establishing the restoration approach. Once the source(s) are identified and repaired, the terra cotta elements can be restored or replaced. As previously described, water typically enters the assembly via defective or non-existent flashings, deteriorated mortar joints or defects in glazing. For complete restoration, there are three types of repairs that need to be performed. The goal is to address the source(s) of material deterioration, repair or replace damaged materials, and reduce the potential of new defects. The three types of repairs include:

1. Repair of the underlying building components (i.e. structural steel and masonry backup). Stabilization of backup masonry can be achieved by rebuilding, grouting, repointing and replacing corroded structural steel elements with stainless steel anchors. It is sometimes prudent to install a through-wall flashing assembly to direct water out of the existing wall assembly.
2. Repair and/or replacement of the damaged terra cotta body and glaze. This will vary, depending on the condition of the terra cotta and the types of repairs that are required.
3. Surface restoration, such as joint repointing, installation of expansion joints, and surface flashings (i.e. reglets). Repair, replacement, or installation of new flashings is case dependent and should be performed when water infiltration is a problem.

Preserving history

Historic terra cotta construction, particularly ornamentation, has largely become a lost art. The time-consuming, painstaking process of manufacturing and building with terra cotta does not coincide with current construction practices and cost concerns. However, terra cotta is often a beautiful architectural element and frequently historically significant. Remaining terra cotta work should not be allowed to deteriorate and every effort should be made to preserve and restore its beauty. FMJ



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