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Assessing the Performance of Metal Trim for Ceramic & Stone Tile Installations

by

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The use of metal and plastic trim in the tile industry has become extremely popular. This type of trim is specified both as an aesthetic and functional solution to the common problems of protective edge terminations, material transitions, and forming movement joints in ceramic and stone tile installations.

While metal trim accessories have been used for many years in the terrazzo industry, new products being marketed for ceramic and stone tile installations require careful assessment of the factors which affect performance of this type of product. Durability of metal trim is of particular importance, especially when the trim products are embedded in cementitious materials and/or exposed to unusual environments or conditions.

Ceramic and stone tile trim is available in a range of materials and finishes. Aluminum (anodized and mill finish) has become the most popular material, followed by PVC plastic. Other materials such as brass, zinc and stainless steel are also available, but these materials are often considered cost prohibitive compared to aluminum or plastic, even though they constitute a small percentage of overall tile or stone installation costs. Brass, zinc or stainless steel are typically more durable and problem-free, and therefore have a lower life-cycle cost.

Trim pieces are usually embedded in either a cement based thin-set adhesive mortar (containing a dry polymer or liquid latex additive), or a thick cement mortar bed. Occasionally, tile trim is installed and embedded in resinous (epoxy) thin-set mortar, which, in the case of most products, does not contain any cement or water. In most commercial installations, ceramic or stone tile is usually being installed over concrete slabs or cementitious backer board.

Fundamentals of the Metal Corrosion Process

In most ceramic and stone tile installations, trim is embedded in a cement -based mortar. Wet concrete and other cementitious materials are naturally highly alkaline materials with a pH of between 12-13 when wet and 11 when dry (pH is a measure of acidity or alkalinity of a material on a logarithmic scale of 1-14, 1 being highly acidic, 14 being highly alkaline, and 7 being neutral). The high alkalinity of wet cementitious materials actually promotes the formation of a protective film of oxidation on embedded metals such as aluminum or steel, which prevents galvanic action corrosion. Anodized coatings on aluminum provide additional corrosion resistance. However, the benefits of protective oxidation or anodization can be marginal given the thin sections typical of tile trim products and potential for continuous exposure to high alkalinity. Once wet concrete cures, the pH level is reduced. But prolonged exposure to moisture can solubilize alkali ions and can create a continuously high alkaline environment.

Galvanic action corrosion occurs when electrochemical currents are set up in moist cementitious materials (an electrolyte), and flow between metal components (anode and cathode). Disruption of the protective film on aluminum, together with exposure to oxygen, can result in corrosion. In the case of steel, the oxidation produces rust, which in turn causes damaging expansive forces. In the case of aluminum, the protective film can be disrupted by a chemical reaction which releases hydrogen gas and increases porosity of the aluminum, allowing the electrochemical currents to flow, resulting in oxidation and corrosion of the aluminum.

The metal corrosion process can be accelerated if there are two dissimilar metals embedded in the cementitious materials. This is a common and often overlooked design detail. Corrosion could also be accelerated if there is increased exposure to carbon dioxide, such as in a vehicular tunnel or an industrial facility.

When dissimilar metals are embedded in cementitious materials, each metal has a different tendency to promote electrochemical activity. When two dissimilar metals are embedded in a moist cementitious material (electrolyte), the less "active" metal is sacrificed and corrodes (*Figure 1*). Embedded aluminum will be sacrificed and corrode in the presence of embedded steel; steel is almost always present in structural concrete reinforcement bars or steel wire fabric used in mortar beds. In the case of ceramic tile facades, galvanic action could occur between underlying steel stud structure and screw fasteners, and aluminum trim by way of wet cementitious backer board and adhesive acting as the electrolyte.

1. Zinc	7. Lead
2. Aluminum	8. Brass
3. Steel	9. Copper
4. Iron	10. Bronze
5. Nickel	11. Stainless Steel
6. Tin	12. Gold

Figure 1 - Galvanic activity of metals
(in order of increased electrochemical activity)

Carbonation is a chemical reaction which can occur when unusually high levels of carbon dioxide in the air diffuse into cementitious materials and react with dissolved calcium hydroxide contained in moist cementitious materials to form calcium carbonate (this reaction is also known as efflorescence). The carbonation process reduces the alkalinity of a cementitious material to a pH of about 10, resulting in a loss of the protective oxidation film described above. Corrosion caused by carbonation is typically a long term process that requires frequent wetting-drying cycles to allow the formation of calcium carbonate.

The problem of corrosion and deterioration of ceramic and stone tile trim is of special concern, as this process can occur rapidly, exacerbated by the thin sections of the trim. Deterioration of trim can result in a range of problems, from loss of aesthetic and functional value, to adhesion failure of the tile.

Water - The Common Denominator

Water is the common denominator required to initiate corrosion of materials. Aside from corrosive chemicals such as acids, water must be present to initiate and promote the corrosion process. There are some obvious as well as some less obvious sources of water in ceramic and stone tile installations.
Sources of water which can affect the durability of ceramic and stone tile trim are:

- vapor transmission or absorption (damp sub-grades, atmospheric, condensation)
- water exposure from leaks, rain / snow
- maintenance
- residual construction moisture (concrete, mortar beds)

Exterior ceramic or stone tile installations are exposed to rain or snow in most climates, so there is increased potential for corrosion of aluminum and other metals embedded in cement, especially due to the effect of trapped water in cooler climates.

In interior environments, frequent exposure to maintenance water and moisture vapor transmission through concrete slabs on grade are often overlooked sources of moisture. In one such case, rain water collected in the "blotter" layer of gravel placed above a vapor retarder in a slab on grade prior to placement of the concrete. After enclosure and conditioning of the building, moisture vapor transmission to the dry interior air promoted galvanic action and alkali attack of aluminum expansion joint trim used in a ceramic tile floor installation. Investigation of loose and broken tile adjacent to the expansion joint trim revealed that the trim was completely corroded and oxidized only several months after completion of the tile installation.

Residual excess moisture contained in relatively new concrete could also provide enough moisture alone to promote galvanic action. The normal internal service moisture level of a concrete slab is 80 % relative humidity (75% RH is considered dry). Studies have indicated that even normal moisture levels may be sufficient to cause galvanic action in metals embedded in cementitious materials.

Similarly, it may take months or years for a concrete slab to reach this safe moisture level. Residual moisture in concrete slabs and mortar beds, depending on the configuration and type of construction, may exist and promote corrosion for up to 1-2 years after initial installation.

Other Compatibility Issues

There are several other compatibility issues affecting metal and plastic trim is embedded in cementitious materials.

Thermal movement compatibility between trim and ceramic and stone tile can become a factor in exterior installations or interior areas exposed to significant thermal changes. One of the reasons why steel is used as an embedded reinforcement in concrete and other cementitious materials is the thermal compatibility of both the materials (both have a thermal coefficient of expansion of approximately 6.5 x 10^{-6} inches/inch/F ^{o}). Aluminum, on the other hand, has a thermal coefficient of 12.9 x 10^{-6} a value twice that of steel. The thermal coefficient of plastics can range from 15 to as high as 45 x 10^{-6}, or several times the thermal expansion rate of cementitious materials ! In environments with significant thermal cycles, aluminium or plastic trim could be considered thermally incompatible when embedded in cementitious materials, while stainless steel would have compatible movement characteristics.

Summary

As a result of the recent popularity of new ceramic and stone tile trim products and materials, architects and specifiers do not have the benefit of any significant empirical experience to assess the performance and durability of these products. As with any new technology or building material application, it would be prudent for the design professional to request accelerated or simulated durability test results from the manufacturer, as well as the manufacturer's reference experience on similar projects. Together with proven materials science analysis and diligence, the design professional can specify these products with confidence.

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