Material Conditions Series

This Series of Blog Posts was originally published on verticalaccessllc.wordpress.com.

Each post in the series provides an in-depth look at one of the standard conditions we encounter and document during inspections of buildings and civil structures.

Part 1: Cracks and Crack Systems in Masonry

Cracks of varying degrees of severity are almost always found during investigations of stone, brick, concrete and terra cotta building materials.

Crack system through joints in brick

Crack system through units in granite

Severe crack through a terra cotta unit

Materials
Stone, brick, concrete and terra cotta

Also known as
Crack systems that follow the masonry joint diagonally are often called “step cracks”.

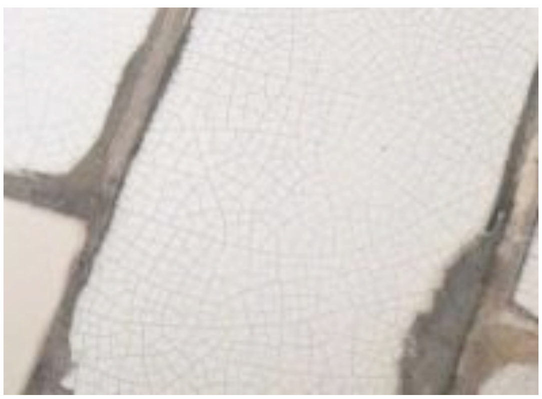
Distinctions
Cracks can be limited to a single masonry unit, or can occur as crack systems through multiple units, through the mortar joints only, or through both units and joints. Severe crack systems can reach horizontally across entire facades, or can extend vertically for many floors.

What causes cracks?
The forces that cause cracking in masonry and concrete have a variety of causes, including thermal expansion, water infiltration and freeze-thaw stresses, faulty design or installation, inappropriate repairs and repointing, and settlement. Patterns and directions of cracking can give clues to the underlying causes. Repair in the near future is recommended for most cracks and crack systems.

Part 2: Crazing

Crazing is a pattern of fine hairline cracks along the surface of a material, sometimes appearing in a net-like or web-like pattern.

Crazing in concrete



Crazing in a glazed terra cotta tile

Materials
Concrete, terra cotta

Also known as
Crazing in concrete is sometimes called "map cracking" or "alligatoring".

What causes crazing?
Crazing can occur when the surface of cast or poured concrete cures or dries more quickly than the interior. In glazed terra cotta, crazing can be a result of manufacturing defects and glaze/body incompatibility, or in response to water infiltration after installation. Crazing does not usually require a repair treatment.

Part 3: Spalls

Spalling is the mechanism by which shear stresses within masonry or concrete force pieces of the material to break away. The resulting piece of loose material is called a spall.

Incipient spall in concrete

Bonded brick spall held in place by sealant

Materials Brick, stone, concrete, terra cotta

Also known as Bursting

Distinctions *Incipient spalls* are not yet fully-formed. *Bonded spalls* are fully formed, but remain attached to the surrounding masonry, typically by mortar or sealant. *Missing spalls* may expose metal anchors or other ferrous embedments.

Cramp spall in limestone due to rusted steel anchor

What causes spalling?
Spalling is a mechanical action that can have various root causes. Water infiltration causes spalling through the destructive action of freeze-thaw cycles. The use of inappropriate repair materials or mortars can cause spalling by introducing a material with a different rate of thermal expansion than the adjacent material. When reinforcing steel, metal anchors, lintels or embedments are exposed to moisture, the rust that forms expands in volume, forcing apart the masonry or concrete in which it is located. Natural flaws in stone; manufacturing defects in brick, concrete or terra cotta; poor design (for example, too-narrow masonry joints); or improper installation (such as wood shims left in place) can also contribute to spalling.

Part 4: Efflorescence and Leached Salts

Efflorescence is a soft white deposit on the surface of masonry caused by water moving through the material and bringing dissolved minerals to the surface. The term *leached salts* refers to hard encrustations of salts deposited at the surface of masonry, often at joints or cracks. In extreme cases, leached salts can form stalactites.


Leached salts in terra cotta


Efflorescence in cast stone

Materials
Efflorescence and leached salts can occur in brick, stone, concrete, or terra cotta, or at the mortar joints of masonry construction.

Also known as
Leached salts are also known as "salt crusts"


Leached salts at mortar joints in brick

What causes leached salts and efflorescence?
As water moves through stone, concrete, terra cotta, and mortars, it dissolves naturally-occuring salts and minerals, which are deposited at the surface of the material as the water evaporates. This usually results from water infiltration into otherwise-sound masonry. Efflorescence can also form as a result of concrete curing, as water and dissolved salts are driven out of the finished product. Poor concrete curing practices, inappropriate concrete mixtures, poor quality brick, and inappropriate mortars can contribute to the problem.

Part 5: Surface Loss

Surface loss describes the disappearance of material at the outer faces of masonry units or concrete.


Delaminated sandstone


Exfoliated granite


Face-spalled brick, above


Eroded limestone

Materials
Brick, stone, concrete, and terra cotta.

Distinctions
Erosion, delamination, exfoliation, chipping, glaze loss and *face spalling*. Surface loss can lead to the material becoming *friable*.

Also known as
Exfoliation may be referred to as blistering.

What causes surface loss?
Erosion of concrete and masonry materials can occur due to scouring by wind and water, or abrasion by other materials. *Delamination* applies only to natural stone, and results from the separation of layers along bedding planes. *Exfoliation* is the loss of the outer surface of a material in thin layers. Water infiltration is a major cause of delamination and exfoliation. *Chipping* refers to shallow surface loss, typically at the edge of a masonry unit. *Glaze loss* applies only to terra cotta, resulting from water infiltration or poor glaze-body "fit". *Face spalling* generally applies only to brick, and can result from thermal expansion forces resisted by inappropriately-hard mortars. A material is described as *friable* when a loss of cohesion within the unit or concrete, caused by water infiltration, has rendered it powdery or crumbly.

Inappropriate surface treatments or cleaning techniques can contribute to several types of surface loss.

Part 6: Failed Joints in Masonry

Failed masonry joints occur when the mortar or sealant material between masonry units or between a masonry unit and an adjacent material has broken down and is no longer providing a weathertight seal.


Missing mortar in brick masonry


Caulked mortar joints in brick masonry

Materials
Failed masonry joints occur in brick, stone, terra cotta, cast stone, and precast concrete. Failed sealant joints can also occur adjacent to areas of cast-in-place concrete.

Distinctions
Failed mortar occurs where mortar has cracked, eroded, or separated from the adjacent masonry units. When this deterioration process has continued for a long enough period of time, the result is *missing mortar*. *Failed sealant* occurs at joints between masonry and another material, such as wood or metal window assemblies, or at expansion joints. It is distinguished from *caulked mortar joints* and *failed caulked mortar joints*, where caulk has been applied as a repair material to an already-failing masonry joint.


Failed mortar in cast stone masonry

What causes failed masonry joints?
Because mortar is sacrificial by design, all masonry joints are expected to fail eventually. A well-made masonry wall that is adequately protected from water infiltration should be expected to last 50 to 100 years before needing repointing, but some factors contribute to mortar joints deteriorating before their time. Poor design can be a cause, as when a too-narrow joint does not contain enough mortar to resist thermal expansion and

freeze stresses. Lack of weatherproofing or failure to maintain copings and roofing elements leads to water infiltration, and joint failure along with other types of deterioration. Repointing with inappropriate

Failed Joints in Masonry, continued

Failed sealant at an expansion joint in precast concrete panels

mortar can cause failure of mortar joints and can severely damage the surrounding masonry units.

The service life of sealants and caulk is much shorter than that of mortar; these materials deteriorate relatively quickly and must be replaced as part of regular building maintenance.

Part 7: Atmospheric Soiling and Black Crusts

Atmospheric soiling is a discolored build-up of airborne pollutants. *Black crusts* are accumulations of gypsum deposited at the surface of masonry materials and discolored by airborne pollutants.

Atmospheric soiling on brick

Black crusts on granite

Materials

Atmospheric soiling can build up on all materials, but this discussion focuses on its effects on masonry and concrete. Black crusts only form on brick, stone and concrete.

What causes atmospheric soiling and black crusts?

Atmospheric soiling results from airborne pollutants - usually soot, soil particles, and fly ash - accumulating on the surface of a building material. Porous and rough-textured materials, such as brick and stone, are more susceptible to atmospheric soiling than metals and painted surfaces. Some types of atmospheric pollution contribute to the deterioration of masonry materials via acid rain. Black crusts are accumulations of insoluble gypsum formed by the reaction of particulate pollutants within the masonry material, and darkened by atmospheric soiling. Black crusts typically form in sheltered areas, where moist air delivers a high concentration of dissolved pollutants.

Part 8: Biological Growth

Biological growth refers to the accumulation of living organisms on the surface of building materials. This can include fungi, algae, lichens, mosses, and vascular plants.

Unintended "living walls": vascular plant growth in terra cotta

Microbiological plant growth on limestone

Materials
Biological growth can occur on all building materials where moisture can accumulate and linger.

Distinctions
When investigating wood building components, we distinguish between *fungi* (including molds and mildews), *lower plants* (non-vascular), and *higher plants* (vascular).

Also known as
The term *biological colonization* may be used to refer to microorganism and plant growth, as well as colonization by animals. The term *biofilm* is sometimes used to describe areas of microbial growth.

What causes biological growth?
Plants and fungi require water in order to survive. Thus, unwanted biological growth often occurs in sheltered areas that do not dry out quickly. Higher plant forms appear where poor drainage or surface features allow dirt and debris to build up. Some biological growth may be tolerated as simply a cosmetic nuisance, but other forms may cause or contribute to deterioration. For example, lichens secrete oxalic acid, which dissolves some types of stone, and the roots and tendrils of vascular plants have a mechanically-destructive effect on building materials.

Part 9: Guano

Guano refers to the excrement of birds and bats. Most of the guano we encounter during building investigations is produced by birds, but both bird and bat guano can be present in interior building spaces.

Guano accumulations on marble

Guano accumulations on granite

Materials
Guano can accumulate on any building material that presents a horizontal or near-horizontal surface.

Why is guano a problem?
The occasional bird dropping is not of concern, but large deposits of guano can produce chemical reactions that break down building materials. The presence of bat and bird droppings in significant quantities can be a health hazard for people accessing the affected areas of a building or structure. Hazardous buildups of guano must be removed following appropriate precautions. Anti-roosting installations are often used to prevent birds from landing and perching on skyward-facing surfaces of buildings and structures.

Part 10: Pack Rust

Pack rust refers to the expansive corrosion of cast or wrought iron and steel. This powerful mechanical force can break apart adjacent concrete and masonry.

Pack rust in a relieving angle causing adjacent brick to spall

Pack rust between steel plates of a bridge truss

Materials

Pack rust occurs only in ferrous metals. Pack-rusted fasteners and structural elements can cause the deterioration of adjacent brick, stone, terra cotta, and concrete. In structural iron and steel, pack rust leads to overall structural weakening.

What causes pack rust?

Iron oxidizes in the presence of oxygen and water, and exposure to salt can accelerate the process. Iron expands rapidly as it corrodes. When exposed surfaces rust, the brittle corrosion product weathers away, but when rust occurs within a confined space - for example, within reinforced concrete or between two plates of a bridge truss - the rapidly expanding corrosion product forces apart surrounding materials. Where iron and steel fasteners were designed to be protected from the elements, this action causes more water to enter, creating a positive-feedback cycle of deterioration.

Part 11: Displacement

Displacement refers to the shifting of masonry units out of their as-built position.

Horizontal and vertical displacement in limestone

Horizontal and vertical displacement in brick

Materials
Brick, stone, terra cotta, and concrete (cast stone or pre-cast panels).

Distinctions
Displacement can be in the *vertical* plane, *horizontal* plane, or both.

What causes displacement?
Displacement occurs when the fasteners or mortar holding a masonry unit in place can no longer resist movement from thermal expansion, frost heave, seismic events, gravity, or other forces. Displacement is therefore a symptom of several different modes of failure and deterioration, such as water infiltration, pack rust formation, or failed mortar.

Part 12: Hollow Areas

Hollow areas appear to have a void behind an intact surface, based upon sounding with a mallet.

Hammer-sounding a Guastavino tile ceiling

Materials
Hollow areas can occur in brick, stone, concrete and cast stone, terra cotta, plaster, stucco, architectural metal, and wood.

Why are hollow areas a problem?
Although the surface is intact, hammer-sounding as part of a hands-on investigation can reveal material failures that are otherwise hidden. This can include failed fasteners in masonry and terra cotta, deterioration of back-up masonry, subflorescence in masonry, detachment from the substrate in plaster and stucco, and fastener failure or rot in wood.

Part 13: Failed Coatings

Failed coatings include paints, sealants, and other surface treatments that exhibit blistering, peeling, wrinkling, crazing, checking, alligatoring, chalking, staining, discoloration, pinholes, or other types of deterioration.


Failed paint coating on wood


Failed paint coating on sheet metal

What causes coating failure?
Coating failure - especially paint failure - has numerous causes. These can include: poor surface preparation, weathering, use of inappropriate or incompatible treatments, poor bonding between layers of coatings, ultraviolet degradation, atmospheric or biological soiling, improper application, and more. Coating failure can be both a symptom and a cause of water infiltration.

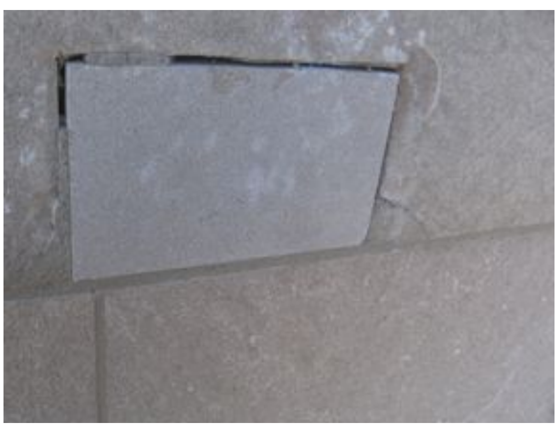
Part 14: Previous Repairs

Previous repairs are prior attempts to remedy building material failures. Failed repairs may be due to inappropriate repair materials or poor installation, or they may indicate ongoing problems such as water infiltration, thermal movement, etc.


Sound crack repair in precast concrete


Replacement repair in brick

Materials
Repairs can be made with a wide variety of materials. Repairs to masonry may include cementitious mortars and patches, epoxies, replacement of units or portions of units with in-kind materials, or replacement with composite materials such as glass fiber reinforced concrete. Metal repairs may be soldered, welded or attached mechanically. Stucco and plaster repairs are usually made in-kind, however plaster moldings and other decorative details are sometimes cast with composite materials. Repairs to wood typically include dutchmen, epoxies, or replacement of entire members with new wood or with composite materials.


Failed dutchman repair in limestone


Sound patch repair in sheet metal

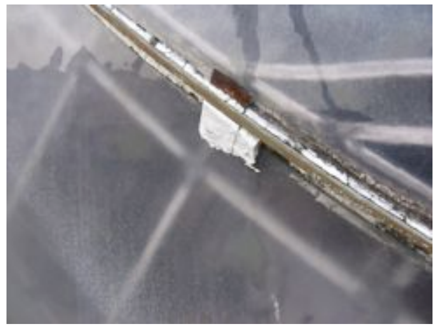
Distinctions: We distinguish between *sound repairs* and *failed repairs*. We document *crack repairs*, *patch repairs, dutchmen*, and *replacements.*

Why document sound repairs?
Documenting both failed and sound repairs can reveal underlying causes of deterioration and chronic problem areas, and can provide information about how a structure has been maintained over time.

Part 15: Glass Conditions

Architectural uses of glass include window glazing, glass block, curtain wall panels, and even structural glass. Window glazing may include clear glass, stained glass, faceted or textured glass, and wire-reinforced glass.

Bulged glass panes in a multi-light window



Putty failure in window glass

Conditions

Typical failure conditions in glass or window assemblies include *cracks, putty failure, sealant failure, missing* or *unsecured glass*, and *bulging panes* (found in multi-light window configurations held in place with metal came, such as stained glass and art glass).

Cracked, loose and missing glass in a multi-light window

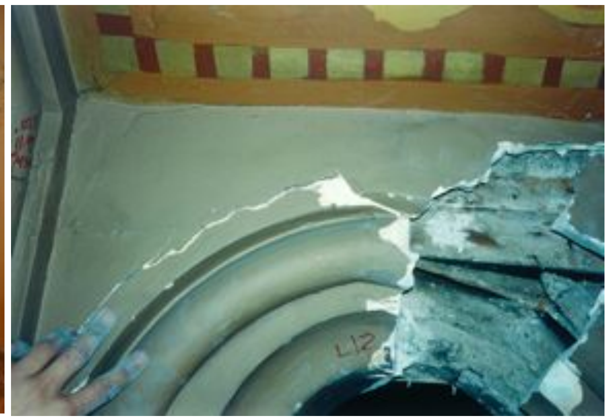
What causes glass deterioration?

Some components of glass window and curtain wall assemblies - putty and sealant - degrade over time and can be expected to need repair or replacement as part of regular maintenance. Glass itself is resistant to decay, so conditions like cracked or loose pieces of glass are usually caused by the failure of surrounding materials, impact forces, or weather events.

Part 16: Plaster Conditions

Plaster is a finish material used principally for interior walls and ceilings. Ubiquitous in buildings of all types until well into the 20th century, plaster's low cost and ease of workability made it a natural choice for creating interior finishes ranging from simple to ornate. Historically, flat plaster was applied to walls and ceilings in two or three coats over a wood lath substrate. Decorative moldings, coffered ceilings, and ceiling medallions were either formed on-site or cast in molds. Plaster may have a variety of finish treatments, including surface textures, wallpapers and decorative painting, sometimes in imitation wood or stone.

Unsecured plaster medallion



Water-damaged plaster that has separated from the substrate

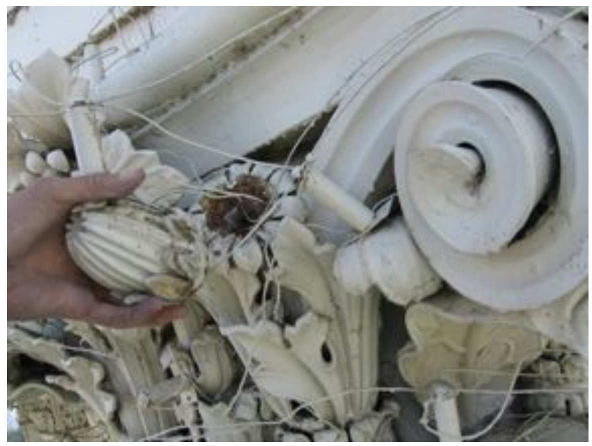
Conditions
We document *failed coatings*; *cracks*; *sound* and *failed crack* and *patch repairs*; *failed lath*; *replacement repairs*; *water damage* and *water staining*; and *unsecured* plaster.

What causes plaster deterioration?
Structural movement and vibrations from vehicle traffic or construction activity can cause plaster to crack, often at the corners of rooms or at the corners of windows and doors. Water staining is usually indicative of roof or plumbing leaks, which can eventually lead to significant deterioration and cracking, separation from the substrate, and failure. Substrate failure may occur due to rusting fasteners or other modes of deterioration. Plaster keys (the plaster that oozes between the lath, forming a mechanical bond) can be damaged or broken by inappropriate treatment - for example, a plaster ceiling in an exposed attic space may be carelessly walked on. Later building modifications, such as retrofitted mechanical systems and interior reconfigurations, often result in substantial damage to plaster walls and ceilings.

Part 17: Metal Conditions

Metals used in the construction of buildings and civil structures include cast and wrought iron, steel, aluminum, copper, lead, zinc, tin, nickel, and various alloys. We document conditions for *architectural metal* (structural members, windows, spandrel panels, railings, sculpture and cast ornament, fasteners, etc.) and *sheet metal* (thin metal typically used as cladding for roofs and cupolas, flashing, and as ornament.)

Dented sheet metal grotesque



Unsecured cast iron ornament

Conditions

Metal conditions include *failed coatings*; *failed fasteners*; *corroded fasteners*; *prior repairs*; various types of *soiling*; *failed sealant; dented* metal; and *unsecured* metal. We distinguish among three types of corrosion conditions: *surface corrosion*, *pitted corrosion*, and *perforated corrosion*. Some conditions affect only architectural metal: *cracks, bent* metal, *failed flange connections* and *failed welds*; and several conditions affect only sheet metals: *failed folded seams*, *failed soldered seams*, *puncture damage* and *tearing*.

What causes metal deterioration?

Corrosion (and failure of fasteners through corrosion) is the principal mode of failure for architectural and sheet metals, especially iron and its alloys. Corrosion is accelerated when dissimilar metals are placed in contact with each other (galvanic corrosion). Corrosion of sheet metal roofing and cladding is accelerated by contact with atmospheric contaminants. When designed for exterior applications, cast and wrought iron were often protected with paint coatings. Loss of protective coatings (paint, plating, or galvanizing) leads to rapid corrosion of iron-based sheet metals. Some metals, such as copper and aluminum, are resistant to corrosion except by galvanic action. Sheet metals are also susceptible to impact damage, fatigue, and tearing.

Part 18: Wood Conditions

Wood is one of the oldest architectural materials. In historic and modern exterior applications, wood may be used in the form of structural timbers or dimensional lumber, roof and wall cladding or underlayment, carved or turned decoration, as a component in door and window assemblies, and in balustrades and railings.


Weathered wood louvers


Checked structural wood member

Conditions
Wood conditions include *biological growth*, which includes both *lower plants* (fungi, lichens, algae) and *higher* (vascular) plants; *sound* and *failed coatings* such as paint; *cracking* and *checking*; *infestation* by *insects* or *mammals*; *abrasion, weathering*, and *rot*; *sealant failure*; *sound* and *failed patch repairs* and *dutchman repairs*; various types of *soiling*; and *unsecured* wood due to *failed fasteners*.


Structural wood members exhibiting biological growth (algae) and rot

What causes wood deterioration?
As a plant-based material, wood is subject to some types of deterioration that do not affect other building components, such as rot and insect damage. Rot, which is a type of fungal attack, requires moisture and often occurs when wood elements aren't adequately protected from the elements by paint coatings or weatherproofing details. Abrasion is wear on the surface of wood from foot traffic, handling, or contact with moving parts such as hardware. Weathering occurs due to exposure to wind-blown dusts, water and ultraviolet light, resulting in discoloration and/or surface loss. Often, the wood's softer seasonal growth is lost at a greater rate than the denser seasonal growth, resulting in an uneven surface texture. Cracking occurs when wood yields to external stresses, often as a result of weakening by other forms of deterioration. Checking, on the other hand, is splitting along the wood grain caused by drying, and does not typically affect the strength of the wood.

Part 19: Slate Conditions

Slate is a metamorphic rock that is easily split along its layers and dressed, yielding an attractive, durable roof tile. In the U.S. slate is quarried in Pennsylvania, Virginia, New York, Maine and Vermont. Natural color variations in slate - including gray, green, purple, and red - are often combined for architectural effect.


Failed fasteners and missing slates


Cracked and missing slates

Conditions
Slate conditions include *failed fasteners*; *cracks*; various types of *soiling*; and *unsecured* slate


Loose slate resulting from a failed fastener

What causes slate deterioration?
Slate roof tiles are generally very durable, with a well-designed slate roof having a service life of at least 60 years, and often 100 years or longer. Slates with greater amounts of impurities are subject to destructive weathering with wetting and thermal cycles. Weathered slates lose strength, becoming more prone to cracks. Steeply-pitched roofs shed water more efficiently, reducing weathering and resulting in substantially longer service life. Metal fasteners are prone to corrosion and eventual failure, leaving loose or unsecured slates. When only a few roofing slates are deteriorated, a roof that is in otherwise good condition can be easily repaired by a skilled roofer.

Part 20: Stucco Conditions

Stucco is a cementitious coating applied to masonry, wood, or metal lath as a watertight exterior finish. Historically, stucco was sometimes colored and scored to imitate stone.

Cracks through stucco scored to imitate stone masonry

Failed crack and patch repairs in stucco

Conditions

Stucco conditions include *cracks*; *sound* and *failed coatings*; *ferrous embedments*; *failed sealant*; prior *patch, crack,* and *replacement repairs*; various types of *soiling*; and areas of *unsecured* or *hollow* stucco.

Unsecured stucco separating from the brick substrate

What causes stucco deterioration?

Stucco is particularly susceptible to water damage; historically, stucco was often whitewashed or coated with other protective finishes to prevent water infiltration. Water damage from improper detailing, poor foundation drainage, or other sources can lead to rotten wood lath or corroded metal lath and fasteners, causing stucco to separate from the substrate. Cracking due to settlement is another common stucco condition.