

Can Sealers help prevent the destructive forces of weathering?

Recently Scott Worthington (Aqua Mix Technical Representative) made a trip to Egypt where the site of their wonderful national monuments was something to behold. However priceless monuments such as the Sphinx and Pyramids are showing signs of decay mainly due to weathering and an ever more aggressive environment. We have often been asked if modern sealer technology can help prevent this type of damage, so this trip kick-started him into addressing this very question. The answer lies in firstly describing the forces at work in the complete weathering process because as you will see the common thread is water. Reduce water ingress and you are more than half way to significantly managing this problem.

Weathering is a complex amalgamation and interaction of chemical, biological and physical processes that together or sometimes individually change the chemistry or structure of the stone. The physical characteristics and properties of stone vary greatly both between different stones and within a single stone or even a single piece. Mineral composition, variation in hardness, pore and stylolitic seam (veins) structure, and textural variation are why stones vary between types and individually as well as being the reason why the same forces of weathering will act differently and unevenly on them.

The minerals that make up the stones composition can be broken down or even changed into new compounds (which can alter the look and performance of the stone) by a number of different processes. These processes of weathering however can be categorised under two broad headings, Mechanical and Chemical. So we now need to look at the processes individually under each category. Bear in mind that in each process you will see the importance of water and the ultimate benefit of managing this water.



Mechanical Weathering Processes

Wet and Dry Cycles: Volume change through wetting and drying cycles is the first major process in mechanical weathering. Stone expands when it absorbs water and then shrinks on drying. These coefficients of expansion and contraction create internal stresses at the grain boundaries which is where the grains are adhered. Sandstone is a good example where the sand particles are bonded with other materials such as calcites. This stress can create surface flaking and delamination as well as damage to veins in stone such as marble.

Thermal Expansion: The different minerals that make up stone expand and contract at different rates. Temperatures of stone can vary between 30% and as much as 50% higher than the ambient temperature. The darker minerals usually absorb more heat than lighter ones and also cool faster. These variations in coefficient of thermal expansion create stresses and small fractures in the minerals further weakening the stone internally. Water makes the process of thermal expansion even more efficient. In fact it is the combination of water and thermal expansion (of the stone and the water) that creates the real damage.

Mechanical Weathering Processes continued...

Frost Damage: this occurs when water absorbed by the stone freezes in the pores. When water freezes it expands between 7-12% by volume. As it expands it exerts a huge amount of pressure on the mineral grains. It has been calculated this force can be up to 500kg per cm². This extreme internal pressure is made worse by continued cycles creating more cracking and deterioration of the internal structure resulting in cracks, flaking and spalling.

Salt or Efflorescence Damage: Soluble salts or efflorescence is one of the most damaging processes in weathering. The most common are those salts that form on the surface of the stone. These can create some surface damage as they expand in the surface texture and pores creating stress and eventually surface damage. However the most damaging salts are those that form just below the surface. These are referred to as sub florescence. These create internal pressure sometimes deep within the stone eventually destroying the core. The type of soluble salt is also a major factor in determining the type of deposit formed as well as the amount of damage created. For example some of the salts when combined with other types form a very hard crystalline efflorescence that is almost impossible to remove. It is this sub florescence that is creating the most damage in the monuments that Scott saw in Egypt, with the Sphinx and Pyramids perfect examples. We all know the story of efflorescence in that the salts form only in the presence of water. So once again water is the catalyst that needs to be controlled.

Chemical Processes

Oxidation: This is often referred to as rusting. It occurs when oxygen combines with iron bearing minerals within the stone. The oxygen is usually transported into the stone in the form of water. Water, high temperatures and humidity accelerate the process of oxidising the iron and magnesium rich minerals in the stone. Iron occurs in stone in three main forms – metallic, ferrous and ferric. During oxidation ferrous converts to ferric oxide which weakens the mineral structure as well as changing the colour of the stone either totally or locally.

Some granites are known to suffer from rust spotting. This is most commonly due to the oxidation of ferrous/magnesium silicate minerals whose conversion can also create structural damage to the stone.

When limestone or marble contain soluble Pyrite – a sulphide – and it undergoes oxidation the ferrous oxide in this compound will create rust staining. The oxidised sulphur component creates sulphuric acid which when dissolved destroys the calcium carbonate (most limestone and marble are composed over more than 50% calcium carbonate). This reaction will create pitting of the surface and loss of polish on polished stone at the very minimum.

Dissolution: This is the process where minerals or part of the minerals composition is attacked and dissolved in water. If the water has an acidic pH then the dissolution of minerals containing calcium, magnesium, sodium and potassium is even worse. The atmosphere has a large part to play in this process. One of the most common gases in the atmosphere is carbon dioxide (CO₂). It is also produced by the burning of fossil fuels and hence is in much greater quantities in the cities and heavily populated areas. When CO₂ is dissolved in water it forms carbonic acid. This reaction makes the water extremely corrosive to stone. Limestone and marble are particularly susceptible to this corrosive mixture as seen in the Pyramids in Cairo. This corrosive water not only effects traditional calcium stones but also those sandstones whose binder is a calcite. It must be remembered that pure rain is actually acidic with a pH around 5.5. However the addition of more dissolved CO₂ and the resulting increase in levels of carbonic acid make this mix an even more damaging process to stone.

Hydration: Hydration happens when a mineral accepts additional water molecules producing in most cases a new compound. This process invariably increases the size of the molecule and in doing so increases the internal pressure of the stone. It happens mostly in localised areas of the stone further creating mineral variations which in turn upset the structural balance of the stone.

Hydrolysis: This process affects the silicates in the granite family and is a dissolution and alteration process. The feldspar silicates in granite are a foundation mineral in the stones structure. These compounds contain significant quantities of sodium, potassium and calcium which are in many cases soluble. When exposed to acidic water (remember the natural ph of rain at 5.5 is made even more acidic in areas of high pollution due to increase of CO₂ and resulting carbonic acid) these important soluble elements are dissolved. This in turn increases the stones permeability exposing even more of the stone to the corrosive water. This process eventually leads to the spalling of the granite surface, loss of polish and eventually the disintegration of the internal structure as the water penetrates deeper into the stone.

Atmosphere: I have already mentioned one aspect of the atmosphere that weathers stone. However along with the increased levels of carbon dioxide found especially in cities and dense population centres, these areas also commonly have high levels of nitrogen and sulphur bearing gases. When these combine with water powerful acidic solutions result. Pure rain water having an acidity of approximately 5.5 (due to the natural conversion of CO₂ and water into carbonic acid) is made even more acidic with the presence of sulphur and nitrogen pollutants. Atmospheric moisture turns the sulphur dioxide into sulphuric acid and the nitrogen oxide into nitric acid greatly intensifying the corrosiveness of the water. This additionally charged water is what we commonly refer to as acid rain, having a pH of about 4.4 more than 10 times stronger

than normal rain. The sulphur and nitrogen gases do not all mix with water, about half the quantities settle back to earth in the form of dry gases and particles commonly referred to as aerosols. These deposits build up between periods of rain and when finally dissolved by water render even higher acidic solutions which are even more corrosive to stone. This particular process along with the process of efflorescence are most damaging ones at work on the monuments around Cairo that Scott visited.

Composition of the Stone: The stones composition helps to determine which of these weathering processes will be most damaging. Granite is the most resistant to the mechanical processes with the exception of efflorescence. Granite is more susceptible to hydrolysis and in some cases oxidation. Limestone and marble are prone to attack from all the processes with salt decay, dissolution, hydration and oxidation being the most destructive. Sandstone is damaged primarily by salt, oxidation and when the binders are calcite the process of dissolution. The other main category of stone, Slate, due to its clay content, is more prone to damage by way of hydration, hydrolysis and oxidation.

Where do sealers fit in? Hopefully by now you will have realised that although there are numerous chemical and mechanical processes at work the common denominator is water.

All of the above processes require water as a catalyst except thermal expansion. However even this process reaches it's most damaging phase when the thermal expansion of the stone and water are combined. Therefore if you can reduce the amount of water that penetrates into a stone you can at the very least significantly reduce and slow down weathering.

Weathering is an impossible process to stop. However slowing or reducing the process not only prolongs the life of the stone and structure but makes any maintenance work easier and more effective. The use of a **breathable penetrating sealer** such as Aqua Mix **Sealers Choice Gold** or **UltraSolv** can achieve this. I have no doubt that sealers will be employed eventually on the monuments in Egypt especially on those around cities such as the Pyramids on the outskirts of Cairo. Proper application of sealers along with other measures such as maintenance, cleaning and better management of moisture flow and ingress, will work together to preserve these stone monuments for future generations.

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