



**A systematic approach to restoring
natural stone**

Natural stone – a building material with history

**Constructions with
natural stone –
state of the art since
thousands of years**

Natural stone has been an important building material since the time of Ancient Egypt, a fact borne out, for example, by the pyramids and the sphinx of Giza made from limestone, obelisks from granite or the statues of Ramses from Nubian sandstone. A contemporary of Ramses wrote: "The whole of Egypt is nothing more than a gigantic stonemason's yard."

In antiquity, apart from being used in the construction of temples, baths and stadia, natural stone was also used for sculptures and as a building material for civil and hydraulic engineering. One example of such architecture is the Colosseum in Rome, which is built of travertine.

With the exception of the High Gothic period, from the Middle Ages until the modern era natural stone was primarily reserved for the construction of religious buildings, monasteries, castles, town halls, mansions, town houses, merchants' houses and town fortifications. In the Romanesque period, ashlar masonry was the principal method of construction. When it came to selecting materials, little distinction was drawn between

stone for masonry and that for sculpture. mainly due to the limited availability of stone, which had to be obtained from local quarries. In the Gothic period, greater thought began to be put into the selection of materials, due to the greater demands placed on the natural stone by the large proportion of filigree and complex workpieces, leading to a preference for lighter stones, such as calcareous tufa. The Renaissance, Baroque and Rococo periods are characterized by a previously unknown profusion of decorative features (columns, statues, ornamental figures). There was a willingness to select the best stone for sculptures, but there was a sharp decline in the use of natural stone in masonry. At this time, buildings were generally rendered. In the second half of the 19th century, many facades were removed in the course of restoration and conversion work – the Romantic fashion was to expose the "natural" (unfinished) facade. The masonry which had until then been protected for centuries by render was now exposed to weathering, which meant that many of these buildings have, due to the action of atmospheric pollutants, required constant renovation during the 20th century.

Weathering processes

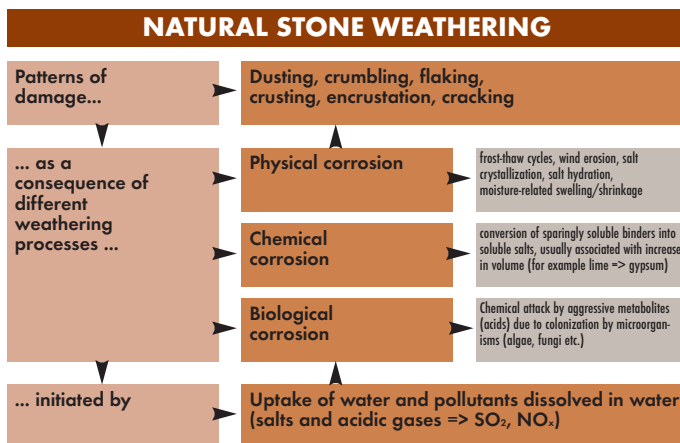
What you need to know about the weathering of natural stone

From time immemorial, sun, wind, rain and frost have been natural factors which act on natural stone and, depending on the type of natural stone, lead to different weathering processes. The onset of industrialization brought with it additional harmful man-made factors.

Weathering processes may fundamentally be divided into three major groups: physical, chemical and biological corrosion.

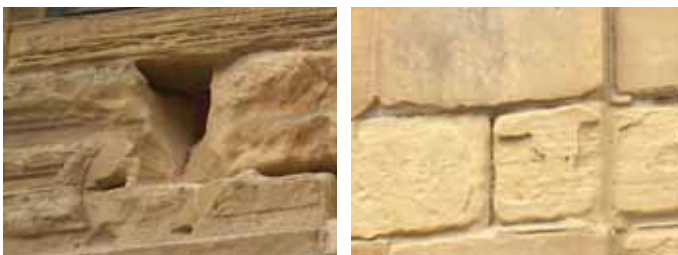
The wide variation in the composition, structure and pore volume of natural stone is reflected in the variety of their weathering processes and profiles. Restoring damaged natural stone requires appropriate materials and methods in order as far as possible to retain and protect the original fabric of the stone and to reproduce its original appearance as well as possible.

Options for restoring natural stone



THE MOST IMPORTANT MEASURES IN OVERVIEW

Stone consolidation	Making good loss of strength by targeted addition of binder	preservative
Stone reinstatement	Reinstating missing areas or parts of stone with suitable restoration mortars.	restorative
Stone replacement	Replacement of entire stones or workpieces	restorative
Water repellent finish	Reducing absorption of water and pollutants as preventive corrosion protection	preservative/preventive
Coating	Recreating original appearance Protection from weathering Protection from water absorption	restorative/preventive



Natural stone restoration encompasses a whole range of different measures and processes which may have a preservative, restorative and/or preventive action.

The essential cause of weathering is most usually water or the harmful salts transported by water.

The various weathering processes or types of corrosion ultimately result in a loss of strength, which may occur in surface zones or also in deeper zones. This results in patterns of damage such as dusting or crumbling, flaking, encrustation, crusting or cracking.



Stone consolidation



Silicate-based consolidation of natural stone

Stone consolidation is a restorative stone preservation measure. Weathering of natural stone results in an increase in the pore volume in the stone's structure with simultaneous weakening of surface zones.

Targeted addition of binder is intended to reconsolidate the matrix of the building material which has been damaged, i.e. whose mechanical stability has been impaired.

Silicate-based products have long been used successfully for stone consolidation. On reaction with water, they produce silica gel deposits, which have a strengthening action, while simultaneously retaining the capillarity and water vapor permea-

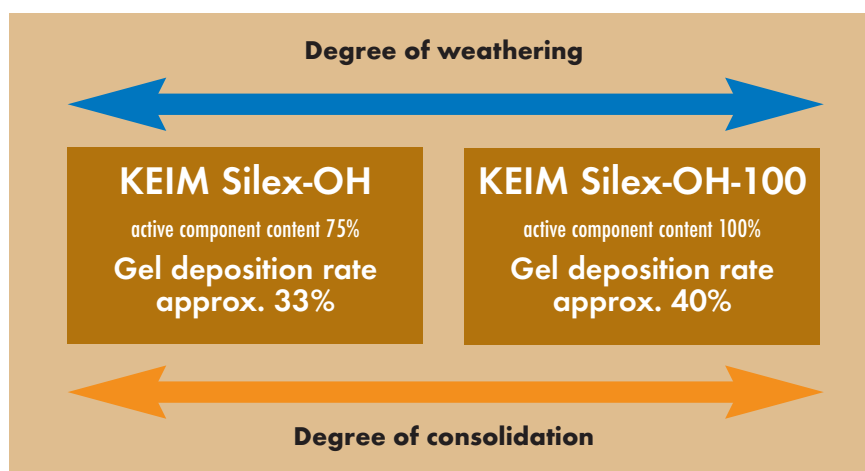
bility of the material being consolidated.

The aim of successful stone consolidation is to recreate the original strength of the material. KEIM's Silex-OH stone consolidation products are accordingly available in two different variants with different gel deposition rates.

If optimum stone consolidation is to be achieved, the weathered zone of the stone must be completely saturated down to the unweathered core, which means that the consolidant is best applied by repeated wet on wet flooding until the material is saturated.

Picture left:
Still brilliant and bright after decades:
Detail of KEIMFARBEN coated facades of the harbour administration in Bilbao, Spain

Picture right:
Monastery of Pelayo in Oviedo, Spain





Water repellent impregnation



Water repellent impregnation as a classic stone preservation method

Most weathering processes in natural stone are caused or promoted by the presence of water. Accordingly, protection from water or moisture is among the classic stone preservation methods.

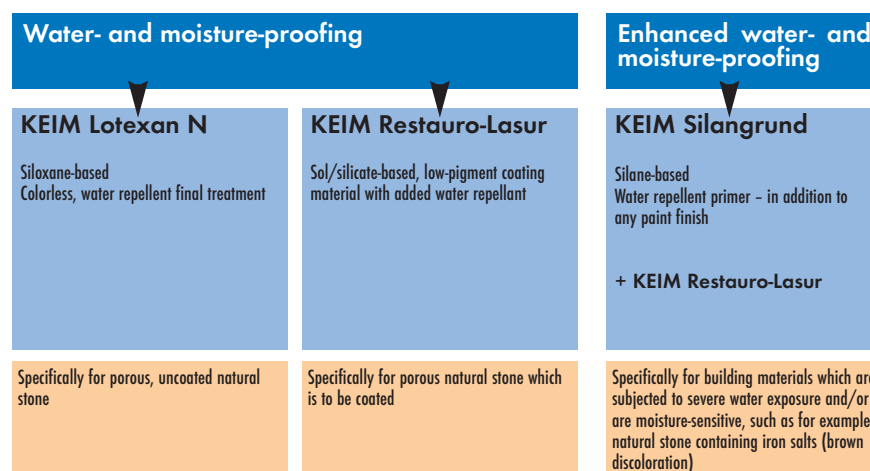
On impregnation, water repellents penetrate into the surface of the building material, so imparting water-repellency. Organosilicon compounds such as siloxanes or silanes are today principally used for this purpose. Coatings with added water-repellants, however, by themselves provide adequate weathering protection. The first step, however, is always to check the natural stone in question and its state in order to establish whether water repellent treatment is actually possible or sen-

sible. There are types of natural stone, for example basalt, granite or marble, which are so impervious that it is difficult or impossible to provide a water repellent finish. It is also better not to provide a water repellent finish on natural stone types with a high salt content, as a high concentration of salts may arise behind the treated layer which may in turn lead to encrustation and consequently flaking. Providing a water repellent finish on types of stone containing clay minerals is also problematic.

The KEIM Restauro range offers various options for providing a water repellent finish on natural stone surfaces with the aim of reducing absorption of water and pollutants:

Picture left: Water tower in Mannheim, Germany

Picture right: Monastery of Pelayo in Oviedo, Spain





Stone replacement

Reinstating natural stone and special applications with restoration mortars

Stone replacement mortars have been used since the 16th century for reconstructing lost portions of the fabric of the stone. Despite the enormous progress which has been made in building materials technology and the greater knowledge of the processes involved in natural stone degradation or weathering, reinstating natural stone with suitable restoration mortars still remains today a real challenge to anyone involved in the restoration of natural stone facades and monuments.

Today there is a much greater emphasis on retaining and protecting the original fabric of the stone to the greatest possible extent than there was in the past. In

this respect, preventive measures to avoid damage to natural stone parts ultimately leading to replacement of the original fabric have become increasingly significant. Stone reinstatement mortars nevertheless still play a major role in the restoration of natural stone.

KEIM's Restauro range of dry bagged, mineral-based restoration mortars provide a large number of options for properly making good any damage to natural stone parts:

Product Property	KEIM Restauro-Grund	KEIM Restauro-Top	KEIM Restauro-Fuge	KEIM Restauro-Gieß
Use	For lining deep areas of damage (> 2 cm) and as a core material for open form casting	Stone replacement for surface zones, including in open moulds	Joint replacement material, especially for natural stone masonry, but also for clinker or sand-lime bricks	For reproducing ornamental figures and parts by casting in moulds
Grain size	< 3,2 mm	< 0,7 mm	< 1,6 mm	< 0,6 mm
Strength N/mm ²	25 - 30	approx. 9	ca. 8	35 - 45
Color shades	brown	color swatch or matching original	color swatch or matching original	color swatch or matching original



Protective coatings

Unique and flawless – protection and coloring of natural stone with KEIM Restauro products using sol/silicate technology

Picture:
Parliament house
Navarra, Pamplona

Today, retaining and protecting the original fabric of the stone is the first priority in the conservation of cultural heritage and quite rightly so. Only in this way is it possible largely to avoid damage to natural stone leading to replacement of the original fabric.

The low-pigment products from KEIM's Restauro range provide ideal and, to date unique, solutions:

Using a sol/silicate-based binder formulation specifically adjusted to the requirements of natural stone, KEIM Restauro-Lasur is ideally suitable in every respect for providing optimum protection for the delicate and valuable material, natural stone.

Being a mineral-bound product, KEIM Restauro-Lasur is ideally "tailored" to the mineral properties of natural stone – the

specific sol/silicate binder in the form used here ensures controlled setting without unwanted introduction of binder, with its consolidating action, into the substrate.

Moreover, with its sd-value of 0.02 m, KEIM Restauro-Lasur is highly vapor permeable and is much less of a barrier to the moisture present in natural stone than are silicone resinbound systems.

The distinctly higher UV stability of the pigments and binder in KEIM's Restauro products also make them ideal protective coatings on natural stone.

Since it is a classic "sacrificial" layer, Restauro protective coatings enable simple renovation in a way which is gentle on the fabric of the stone. In contrast, in the case of systems bound with synthetic or silicone resins, residues of organic binders from damaged, destroyed or weathered coatings must first be removed using chemical or abrasive methods before a new protective coating can be installed.

Thanks to its water repellency, KEIM Restauro-Lasur, the "classic" sol/silicate-based, low-pigment coating for natural stone, protects natural stone by preventing the absorption of water and pollutants. Depending on the level of dilution with KEIM Restauro-Fixativ, Restauro-Lasur can provide an opaque to low-pigment finish and so permits individual natural stone coloring or also unobtrusive color matching of repairs.

KEIM Restauro-Lasur

Overview of product features

KEIM Restauro-Lasur
"classic" low-pigment coating for natural stone

KEIM Restauro-Fixativ
diluent for KEIM Restauro-Lasur

- ultra vapor permeable
- all components UV stable
- low susceptibility to soiling

- microporous
- weathering resistant
- controlled setting

- low stress
- acid resistant
- easy application



The KEIM Restauro range:

A systematic approach to restoring natural stone

Cleaning	Steinreiniger-N	Neutral, biodegradable cleaning concentrate for gentle cleaning of natural stone and clinker brick facades.
	Algicid-Plus	Remediating and cleaning agent for mineral surfaces colonized with algae, fungi and lichens, in particular natural stone with sensitivity to chemicals.
Consolidating	Silex-OH	Silicate-based stone consolidant, gel deposition rate approx. 33%
	Silex-OH-100	Silicate-based stone consolidant, gel deposition rate approx. 40%
Reinstating	Restauro-Grund	Dry bagged mineral restoration mortar for lining deep areas of damage
	Restauro-Top	Dry bagged mineral restoration mortar for replacing natural stone in surface zones
	Restauro-Fuge	Dry bagged mineral joint mortar as joint replacement material, in particular for natural stone masonry
	Restauro-Gieß	Dry bagged mineral restoration mortar for casting in open and closed moulds
Water repellent impregnation	Lotexan-N	Colorless, water repellent final treatment for providing a protective water repellent finish, specifically for uncoated, porous natural stone. Siloxane-based
	Silangrund	Colorless, water repellent primer for additional water-repellent treatment (in addition to coating) and for pretreating natural stone containing iron salts. Silane-based
Coating	Restauro-Lasur Restauro-Fixativ	Sol/silicate-based, thin layer coating for providing a low-pigment finish on sandstone surfaces, for example for color matching repairs to the original fabric

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