4 Conservation of Stone Artworks

4.1 Introduction [1]

Historical buildings and monuments are a part of the Cultural Heritage of the world. Therefore, countries, unions, national bodies and international bodies should pay attention to their maintenance and preservation to protect them for future generations.

Most of the greatest buildings (as well as many of its architectural gems) of the world are built of stone. Therefore, it is no wonder that the subject of stone conservation continues to arouse great interest among conservation professionals and the general public.

Conservation of historic or culturally significant stone is a relatively recently recognised practice. Previously, damaged architectural stone was replaced or repaired with little regard to the compatibility of materials with stone, matching of appearance, or durability of the treatment, which sometimes led to further damage. Over time, the unsuitability of many treatments encouraged research efforts to develop new materials and procedures for stone preservation.

The science of stone conservation spans over three centuries. The nineteenth century saw attempts to consolidate stone using waxes and barium hydroxide. During the twentieth century, lime-based methods were refined, as well as synthetic consolidants and sophisticated cleaning methods developed. Today, we have at our disposal methods based on advanced laser and poultice cleaning, together with new polymeric materials tailored expressively for the consolidation and protection of stone.

Real progress has been made in many areas of stone conservation. Significant gaps in knowledge have been narrowed substantially, including many of the fundamental aspects related to the mechanisms of stone degradation. In several cases, the descriptive nineteenth-century notions of weathering have probed deeply and quantified, measured in the field, and replicated in laboratory experiments. These insights have, in some cases, led to innovations in the preventive treatment of stone, with advancement of more sophisticated models of damage and more quantitative observations from field measurements and laboratory experiments. However, many questions remain open, concerning: (i) development of new materials and new application procedures;
(ii) evaluation of improvements in stone properties after treatment; (iii) setting up of universally accepted methods for evaluation of the stone properties; (iv) assessment of the long-term durability of each treatment; and (v) effects of climate change and biodeterioration.

Nowadays, multidisciplinary challenges are included in stone conservation, bringing new tools from materials science, polymer chemistry, geotechnical engineering, geology, physics, geochemistry, microbiology, and geomorphology, and adding these to the historic tradition of chemistry at the centre of research in stone conservation.

Many parties play a part in shaping conservation policy: architects, art historians, scientists, archaeologists, conservators, artwork owners, and ultimately, the general public. Scientists may be convinced of the validity and importance of their results, but there are others to be convinced before the results can impact on conservation policy.

### 4.2 Artworks Conservation: General Highlights

Stones have been used for building purposes because of their durability (i.e., their ability to resist degradation through time). However, even these materials are subject to slow (but inexorable) deterioration if exposed continually to weather (see Chapter 3). In general, changes are visible only after centuries of exposure, though in some cases, transformations may be seen in just a few years.

The durability of stone materials is quite variable. In 1892, durability was classified by Salmoiraghi into a general scale and divided into ten classes [2]. On the first level there are the least durable rocks, such as marls and clays which, on average, resist less than 1 year. The most enduring rocks are quartzites and red porphyry.

The alteration and deterioration of stone can be stopped (or at least limited) thanks to a set of well-focused operations of conservation and preservation. As a primary rule, restoration work must conserve the original characteristics of artworks (especially form and appearance) to respect the idea of whoever created it initially. The current philosophy is to ‘conserve as found’: to keep original material and prevent further deterioration as much as is practicable. Once the restoration work has been done, the ideal situation would be to eliminate the causes of deterioration, even if this is generally hard to do because of intrinsic causes linked to manufacture (e.g., problems of rising moisture) or to environmental factors (e.g., air pollution).

The most recent approaches emphasise the relevance of the interrelationships (often nonlinear) among environmental, material and historical variables. A further benefit
is represented by the growing understanding of the behaviour of materials [3] and the maintenance necessary to sustain long-term performance [4].

In general, correct restoration work comprises several stages, not all of which are always necessary:

- **Anamnesis**: Identification and location of artworks; assessment of environmental conditions.

- **Diagnosis**: In-depth study of the artwork: characteristics; history; constituent materials; state of deterioration; types of alteration and decay processes; damage rating; need/urgency of preservation measurements. In this phase, the conception of intervention is assessed.

- **Pre-consolidation** is done only in cases where the material is in a very critical condition. This operation enables improvement of the physical characteristics of the material and to prevent crumbling and break-off during cleaning.

- **Cleaning**: Removal of the layers and products of alteration present on the artworks by chemical, physical or mechanical methods.

- **Consolidation**: Treatment done with specific chemical products (organic or inorganic compounds) which, penetrating deeply, can reach the healthy, intact part of the material, thereby improving the physical–mechanical properties of stone (especially cohesion and adhesion).

- **Surface protection**: Final operation, usually done with hydrophobic products that can limit the effects of water, weather and polluting agents on the artwork surface. This operation may be done in spite of consolidation when the material is well conserved.

- **Maintenance**: Periodic review of the conservation state to ensure that alterations do not become pathologically irreversible. Continual or occasional maintenance also aims at limiting or blocking the sources of decay as well as entailing minor cleaning jobs. Maintenance should also include checking whether protective treatments have remained effective over time and possibly repeating them.

- **Reconstruction**: Done in particular cases if fundamental parts are broken or loosened. In the first case, the parts are reattached with an adhesive. In the second case, they can be obtained, forged from new materials, and then attached. This latter operation is not very common but should be studied carefully because the final result might be more negative than positive, especially from an aesthetic viewpoint.
Recently, there has been an increasing emphasis on doing something not only to the stone itself but also to the environment in which the stone is placed. This reflects a growing awareness of the: importance of preventive conservation; principle of minimum intervention to mitigate some decay processes; need to limit the use of materials that might prove harmful to the stone or the environment [5].

4.3 Preventive Conservation

The fundamental principle of conservation is to alleviate the problems affecting a building or monument in a way that does not detract from its history but promotes its future. This should be done, wherever possible, with the absolute minimum of intervention and in a way that is reversible.

The main goal of preventive conservation is keeping water out of the stone, and controlling the relative humidity and temperature of the air around the stone. This is relatively easy for stone artefacts within a museum, and it may also be feasible for stone masonry that is exposed on the interior of a building [1]. It is less easy for outdoor stonework, although a dramatic example of this approach is provided by the glass envelope constructed over the ruins of Hamar Cathedral in Norway (Figure 4.1).

Figure 4.1 Hamar Cathedral, Hamar, Norway
More modest protective shelters are frequently used on the outside of a building to protect those features that are particularly important. They may be part of the original design (e.g., a canopy protecting a statue in a niche), or they may be a later addition. As an extreme measure, they may enclose the feature altogether. Their purpose is to reduce the amount of rain that reaches the stone and to stabilise the temperature and moisture content of the stone.

The main purpose of the control or buffering of relative humidity is to reduce the damage from salt and moisture cycles. The humidity regimen required to prevent damage in a stone or a wall painting that is contaminated by salts has not been established. As discussed in Chapter 3, the behaviour of salt mixtures is complex, and there are now methodologies to help with selecting appropriate humidity ranges, even for complex mixtures [6, 7].

Making interventions to the stone environment is not simply a matter of temperature and relative humidity. Preventing damage can embrace a very wide range of topics: legislation to protect individual buildings and monuments; control of traffic, pollution or groundwater; visitor management; and disaster planning [8]. Other areas of preventive research on immovable stone heritage include shelters, wind fences, and reburial [9, 10], as well as modelling of interior environments [11].

4.4 Responsible use of Surface Coatings and Polymer-based Consolidants [1]

Thorough assessment of stone damage and examination of all possible options, bearing in mind conservation principles, should precede a decision on whether to carry out repairs or to use some form of consolidant.

Two main aspects of conservation policy must be taken into account during an intervention: (i) responsible use of surface coatings, adhesives, and polymeric consolidants; and (ii) the problems posed by multiple treatments. These issues have a common thread in that no organic treatment can be expected to last forever, i.e., all treatments have a finite life. This has direct implications for conservation policy because a treatment could become an unforeseen problem in the future.

Virtually all research on stone treatment is based on the assumption that treatment must be applied to stone that has never been treated before. Few studies have been done on the effects that one treatment might have on another and upon re-treatability [12, 13].
Any consolidant that blocks the pores of the stone and prevents subsequent application of another consolidant must be regarded with caution. The topic that demands research, however, is the physical and/or chemical interaction of one consolidant with another. The swelling of polymers under the influence of solvents is a well-known phenomenon, but little attention seems to have been paid to the swelling of a consolidant if a second consolidant is applied. Such swelling might cause damage to the stone. Moreover, the second consolidant could be deposited as a coherent layer on top of the previous treatment, forming an intermingled mixture. This is not an appealing prospect, and certainly deserves more attention. Equally, there is a need to ensure that there are no unforeseen consequences of multiple applications of maintenance coatings.

For a long time, conservators paid homage to the principle of reversibility: no treatment should be used unless it can be removed at some future date. In the context of stone conservation, however, reversibility is more idealistic than realistic. It can be extremely difficult, in practice, to remove even the most soluble of treatments. Treatment is irreversible, in practice, but decay through neglect is irreversible too. This dilemma highlights the importance of preventive conservation, but there are instances whereby preventive conservation is not sufficient. Ultimately, it becomes necessary to reach a carefully balanced decision taking into account all aspects of each individual case to decide if treatment is justified.

When talking about stone consolidation one must be clear on the difference between a consolidant and a preservative. The aim of a preservative is to totally preserve the stone in whatever state of weathering it has reached and stop all future decay; this usually means applying a coating to the surface of the stone which totally protects it from the effects of the atmosphere around it. Consolidation should aim to stabilise the friable materials to give them adhesion and cohesion. If considered in this context, consolidation appears to agree with the principles of conservation. However, application of a chemical to a stone is usually considered a more significant intervention.

References


2. F. Salmoiraghi in *Materiali Naturali da Costruzione*, Hoepli, Milano, Italy, 1892.
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