Introduction to the Stone Cycle and the Conservation of Historic Buildings


¹Department of the Built Heritage, Faculty for the Built Environment, University of Malta, Msida MSD 2080, Malta
²Transport Research Laboratory (TRL), 13 Swanston Steading, 109 Swanston Road, Edinburgh EH10 7DS, UK
³40 Kingsdown Avenue, London W13 9PT, UK
⁴Formerly Kingston University, Kingston upon Thames KT1 2EE, UK
⁵Sheffield University, Dept of Civil & Structural Engineering, Krototo Research Institute, Broad Lane, Sheffield, UK
⁶School of Engineering and Computing Sciences, Durham University, South Road, Durham DH1 3LE, UK
⁷School of Earth and Environmental Sciences, University of Portsmouth, Burnaby Building, Burnaby Road, Portsmouth PO1 3QL, UK
⁸British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG, UK

*Corresponding author (e-mail: joann.cassar@um.edu.mt)

This Thematic Set of papers relating to the life cycle of building stone was initiated by a call for papers in order to better recognize the contribution that the disciplines, and practitioners, of engineering geology and hydrogeology make to the conservation of historical buildings, which is intrinsically multidisciplinary. The call for papers particularly focused upon the issues of different stone types used in historical buildings, as well as the performance, durability and conservation of stone in historical settings.

The response was overwhelming, with many more abstracts submitted than could possibly be published in the Quarterly Journal of Engineering Geology and Hydrogeology (QJEGH). Accordingly, the papers were divided into two sets, with one set destined to appear in QJEGH as described herein and the second set to appear in a Geological Society Special Publication (Cassar et al. 2014). The presence of a particular paper in one set or the other is not a reflection on quality, but merely a reflection of the need to divide the papers into two sets each of which reflects subtly differing themes.

History has been written in stone, from prehistoric monuments to modern-day buildings, and all types of stone, limestones and sandstones, granites and marbles, have been utilized to build, to clad, and to decorate. The buildings that are symbols of a city, a region, or a country are mostly built of stone. We immediately think of England when we see an image of Stonehenge; the Acropolis symbolizes Athens; the Coliseum Rome; Machu Picchu Peru; and the Taj Mahal India.

The immense varieties and diverse properties of building stone, its workability and its (im)permanence have been observed and studied since time immemorial. Vitruvius, in the first century BC, writing in the Ten Books on Architecture, Chapter VII (Stone), says the following: ‘The stone in quarries is found to be of different and unlike qualities. In some it is soft … in others, it is medium … in still others it is hard … All these soft kinds have the advantage that they can be easily worked as soon as they have been taken from the quarries. Under cover they play their part well; but in open and exposed situations the frost and rime make them crumble, and they go to pieces. On the seacoast, too, the salt eats away and dissolves them’ (Morgan et al. 1914).

The judicious selection of stone, for building and for replacement, as well as its efficient use, are important also in ensuring the sustainable use of geological resources. Not only must the primary materials be extracted and processed in such a fashion as to ensure that maximum and best use is made of the stone, but the life of the structures that it forms must be maximized by effective construction, detailing, use and maintenance. Subsequently, when the structure is decommissioned, maximum reuse must be made of the component materials and the opportunity should be taken for discarded materials to fulfill potential future uses, which currently may not be envisaged or be technically feasible. Of particular interest in the context of building stone is the potential for the direct reuse of materials such as decorative stonework in other buildings (usually newly built, but at times also older buildings).

Figure 1 illustrates the life cycle of building stone from extraction to disposal. This is adapted from that presented for aggregates (Winter & Henderson 2001; Winter 2002) to account for the specific attributes of the building stone life cycle; in particular, a reverse loop to recognize the improved service life that is a consequence of effective maintenance is introduced. The life cycle for aggregates was a development of that presented by Kennedy (1999) and included a loop to allow for future landfill mining.

The papers in this issue cover a number of themes relating to the ‘stone cycle’. In her invited paper Viles (2013) approaches the topic of durability from various angles and tries to answer the age-old questions: What is durability? Why should we be concerned with durability? How do we quantify or estimate (and thus predict) durability from readily measurable parameters? In addressing these questions, Viles reviews the extensive literature on this topic and thus covers a considerable variety of techniques. These include the examination of past performance, as well as the use of laboratory-based and site-based tools to study deterioration processes, patterns and rates. The ultimate aim is to try to find one or more methods to improve predictions of the performance of stone in different circumstances.

Přikryl (2013) reinforces many of these observations. He points out that durability is not a fundamental property and cannot be measured in the laboratory by any single or simple test. A deep understanding of composition, previous processes and physical properties is required. Quarrying methods and processing and finishing may influence behaviour, and the effects of complex and abruptly changing environmental factors also need to be understood. Cleaning and consolidation (in this field ‘consolidation’ refers to the treatment of deteriorated stone with a chemical to strengthen it) during conservation, insertion of inappropriate stone or incorrect use of replacement mortars also may have negative
impacts. Overall, the response of stone to weathering or decay factors reflects a complex, dynamic but metastable system. Přikryl notes that in situ observation of weathering or decay patterns on historical structures is needed to accompany laboratory tests when extrapolating the durability or service life of stone.

The theme is furthered by Smith et al. (2013), who focus their analysis on Northern Ireland, which has a great heritage of using stone for building. Ensuring the preservation of buildings, monuments, stone walls and bridges requires great attention to detail in the selection of appropriate materials for replacement, repair and refurbishment. Even small changes in, for example, the influence of mineral-rich groundwater in a quarry can result in significant differences in performance and durability. The authors highlight the need to develop a better understanding of stone specification issues and propose an identification process of the threats to, and condition of, the stone-built heritage so that a scientific rationale for repairs can be achieved. This staging system survey approach was applied to 1800 historical buildings and 300 monuments, and this now forms a comprehensive geographic information system (GIS)-based baseline assessment of the historical building stock of Northern Ireland, allowing a proactive approach to appropriate heritage preservation. Smith et al. identify those performance indicators of the stone type ‘in use’ on a building or monument that are most important to allow specification of stone for replacement and repair.

Sourcing stone for the conservation and repair of historical buildings requires knowledge of the stone, either from documentary evidence or from tests on the stone itself, and of the available resources. Focusing on Britain, Lott (2013) documents the wide variety of quarried stone that has been used in buildings, and the current and many former quarries that made up a once important industry. This information is now available in a national database. In this overview the former extent of the building stone resources are described along with the current problems of indigenous stone supply.

Fort et al. (2013) report how the types of stone used in building construction have evolved over time. These changes were in response not only to changing tastes and fashions in terms of construction and stone colour, but also to the development of the transport network, which made a greater variety of stone types accessible. The overriding theme is one of a change from proximity, accessibility and availability determining the type of stone used in historical times, to quality and durability becoming key determinants in more recent times.

Many countries traditionally build and restore with locally quarried stone but the Netherlands generally lacks indigenous sources and has relied on imports. Identical material is often not available and restorers have had to use alternative approaches for choosing suitable stone. Quist et al. (2013) discuss the historical aspects of replacement stone choice in the Netherlands. In the late 19th century the emphasis was on using hard homogeneous rock types, but this changed in the 1920s–1930s to focus on aesthetics and history. By the 1980s, the preferred materials were the most durable. Subsequently, an approach that balances these competing requirements has been adopted. These circumstances have led to unexpected combinations of original and restoration material in proximity that would probably not have been chosen on the basis of composition and origin. Quist et al. argue that a study of the conservation history of listed buildings, the durability and compatibility of various stone types, and relative performances of original and replacement stones provides valuable information for choosing future replacement material.

This theme is also taken up by Siedel (2013), who has systematically recorded types of building stone used on façades in the cities of Dresden, Leipzig and Chemnitz and related the patterns of use to local geology, historical development and economic factors. Local building stones dominated in all three until the middle of the 19th century, when urban growth and industrial and infrastructure development allowed the use of stone from further away. Functional aspects and technical properties played a part but the
economic background and political restrictions (for example, during the separation of East and West Germany) were also influential. Observation of the use of types and qualities of stone over time, especially those with exposure on dated buildings, provides a basis for comparative assessment of long-term behaviour and weathering resistance to supplement laboratory test results. A similar approach in other areas might be beneficial in assessing long-term behaviour and durability.

Erkal et al. (2013) report on moisture conditions in the stone masonry walls of Odda’s Chapel in Gloucestershire, England. This chapel, built in 1056, is a Grade I listed building of great historical significance and one of the most complete surviving Saxon churches. The walls were constructed using Blue Lias Limestone and lime mortar. The paper describes a system for measuring temperature and relative humidity within the walls and also provides data on rainfall, wind-driven rain and runoff rain measurements. High relative humidities were recorded within the walls, with values exceeding 75% for 90% of the monitoring period (October 2011–May 2012). Relative humidity values of over 95% were observed on external wall surfaces after a wind-driven rain event. The high in-wall relative humidities indicate high water contents in the stone and mortar. Biological growth on the internal walls could also be attributed to high indoor relative humidity values of greater than 80%.

Stone decay is a complex problem and probable causes, such as a lack of durability, incorrect placement of the stone and incorrect restoration measures, can be accelerated by external environmental factors. Zurakowska & Hughes (2013) attempt to develop a method to test whether the cleaning of stone causes or speeds up stone decay. Sandstone on cleaned and non-cleaned buildings in Paisley and Glasgow, Scotland, previously surveyed in 1998, was re-examined. Areas with window ornaments and blocks in contact with the ground, which have a higher risk of decay, were avoided. Qualitative evaluation showed that stone decay observed in selected buildings can differ significantly from that in other buildings with similar stone. Buildings were generally repaired during cleaning, helping to protect them, whereas non-cleaned buildings showed more maintenance problems and appeared to be more susceptible to decay owing to detachment of large fragments of stone. Further surveys and visual inspections of a larger number of cleaned and non-cleaned buildings would improve these tentative observations.

Of all external factors affecting stone, moisture has a major influence on stone decay. McCabe et al. (2013) discuss the widely but inconsistently used term ‘time of wetness’, essentially the duration of wetness. This varies depending on weather conditions and time of year, and differs at the surface and in the interior of a block. Therefore McCabe et al. define ‘time of deep wetness’, the penetration of moisture into the stone interior beyond the direct reach of anything but seasonal environmental cycling at the surface, as distinct from time of wetness at the surface. This has implications for decay and weathering processes and for biological attack. Future work should examine the way in which deep wetness in building stone induces decay. This would require a better understanding of the meteorological controls on moisture at depth, such as the changing frequency and persistence of rainfall, and quantification of geographical variations in time of deep wetness.

In their paper Alves et al. (2013) present insights on the relationships between specific surface area (SSA) and salt weathering in a variety of Portuguese limestones, including calcilucite grainstones and travertine. SSA varies with grain size and the effects of lithological heterogeneity are postulated to influence the potential for solute movement, and salt weathering. The results of laboratory experiments on travertine, containing terrigenous matter, were found to be the most useful diagnostic tool, and the authors propose that SSA may be a useful measure of salt weathering potential, alongside other measurements.

Calia et al. (2013) in their paper on the historical building materials employed in the Sicilian town of Syracuse (Southern Italy), discuss an extensive survey of the soft and porous calcarenites used in this town. In a study of the main decay morphologies identified, a study which was supported by detailed laboratory analyses. The decay phenomena seen in these stones are typical of a Mediterranean context, with sea spray as the main cause of decay, together with water and wind. This information has proved to be of great use in the planning of conservation works.

There are, perhaps, two themes that are particularly striking in this set of papers. The first is the difficulty of defining, let alone determining, durability in a consistent manner that is likely to be agreed across a range of researchers with different objectives and purposes. The second is the degree to which the development through history of the use of different stones depends upon not only technological developments in quarrying and processing, and understanding and measurement of stone properties and characteristics, but also the improvement in mobility as the transport infrastructure develops. This thematic set thus reinforces the philosophy accepted by conservation professionals worldwide, that the science and technology of stone conservation needs to be substantiated by both environmental studies and historical studies, including knowing about the quarries where the material was extracted and the conservation history of the building.

References


Received 2 July 2013; accepted 1 August 2013.