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Effect of conservation treatments on heritage stone. Characterisation of decay processes in a case study

M.J. Varas-Muriel [a,b,*], E.M. Pérez-Monserrat [a], C. Vázquez-Calvo [a], R. Fort [a]

[a] Instituto de Geociencias IGEO (CSIC, UCM), C/José Antonio Novais 12, 28040 Madrid, Spain
[b] Facultad Ciencias Geológicas, Universidad Complutense de Madrid (UCM), C/José Antonio Novais 12, 28040 Madrid, Spain

HIGHLIGHTS

- Long-term effectiveness, suitability and durability of conservation treatments.
- Need for preliminary studies to ensure successful restoration.
- Use of petrological techniques to determine treatment mechanisms.
- Unsuitable use of cements and synthetic resins on decayed dolostone.
- Salt-induced loss of restored ornaments.

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ABSTRACT

Preliminary studies are an imperative when determining the impact of conservation treatments on historical materials. The Romanesque apse on a church at Talamanca de Jarama, Madrid, Spain, whose dolostone was severely decayed by rainwater and salts, was treated in the past with substances that ravaged the restored area. Petrological techniques showed that salts leached out of the cement under the roof onto the stone cornice whose surface had been coated with synthetic resins. During evaporation, the salts precipitated in the stone and underneath the resin, inducing blistering, fissuring, flaking, scaling and detachment of part of the restored decorative elements.

1. Introduction

Time and weathering (water, wind, solar radiation, temperature variations, air pollution...) are the chief agents of decay in most stone materials comprising the built heritage. The impact of such decay varies depending on the composition and texture of the materials involved [1–3].

The need to conserve the cultural heritage has driven the appearance on the market of many restoration products, designed and manufactured primarily to retard stone decay and increase its durability [4–7]. These products may be: inorganic (such as "lime wash" – $Ca(OH)_2$ (aq) used in the nineteenth century and presently recovered in the form of nanolime – $Ca(OH)_2$ alcoholic colloidal nanoparticles [8]) or organic, which may in turn be divided into natural (scantly processed animal or plant substances) or synthetic (primarily highly processed petroleum derivatives) compounds. A third group of products, organosiliceous derivatives such as ethyl silicates or alkoxysilanes, combines organic and inorganic compounds. All three groups are designed to: (a) consolidate the internal components of the stone (consolidants); (b) waterproof surfaces (water repellents); or (c) rendering surfaces or fill in joints, cracks, fissures, or gaps in the stone itself (restoration mortars). Further to international recommendations, the use of such restoration products should be limited and controlled, and only applied if they are clearly beneficial, their long-term efficacy is proven and they entail no risk whatsoever for people or the environment [9–11].

Synthetic resin and cement restoration mortars have been used profusely in recent years, for they bond well to the substrate and are highly weatherproof [4–7,12–15]. Nonetheless, several

* Corresponding author at: Instituto de Geociencias IGEO (CSIC, UCM), C/José Antonio Novais 12, 28040 Madrid, Spain.
E-mail address: mjvaras@geo.ucm.es (M.J. Varas-Muriel).

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ICOMOS Charters [9–11] advise against using such restoration mortars in any form unless a detailed study has been conducted of their long-term performance and durability. The rationale for such recommendations may lie in these compounds' possible failure to meet the aims for which they were initially designed (render, infill, restitution of lost material,...): when combined with other construction materials they may respond in unintended ways, even generating undesirable by-products such as salts. The composition of synthetic restoration mortar varies depending on its intended purpose and the construction materials with which it is to be in contact. As a general rule, such mortars comprise a binder (cement, lime/hydraulic lime or gypsum), siliceous or carbonaceous sand aggregate, pigments for colour and admixtures such as polymeric resins, silicone or siloxane resins, acrylic resins, epoxy resins, fluorinated polymers or unsaturated polyesters [12,14,15].

Like decay itself, conservation and restoration products perform differently depending on the type of stone to which they are applied and on environmental conditions. Hence the need for preliminary studies [6,12,16–18], firstly to characterise the composition and texture of the stone substrate. In particular its porosity must be determined (pore percentage, shape, size and distribution) and its condition assessed (forms, causes, processes and agents of decay), paying close heed to local environmental factors or microclimatic conditions inside the building to be conserved [6,7,12,19,20]. That should be followed by a field or/and laboratory study of the restoration products and application techniques to establish their efficacy, their compatibility with and suitability for the stone substrate, and their durability in the prevailing climate [1,7,12–14,16,17,20].

While preliminary studies are called for in international recommendations and protocols for action on world cultural heritage conservation (e.g., Athens 1931, Venice 1964, Restauro 1987 Charters, to name a few; ICOMOS), they are often absent in restoration project design and implementation. The distressing result has been that many interventions in heritage buildings have accelerated decay in the materials they set out to protect [1,12,14,17,21].

Moreover, since the full chemical formulation of market products is normally unknown, preliminary trials provide information from which to more or less accurately predict their possible long-term behaviour [7,16–18,21–23]. This is of particular relevance because the original chemical composition of these products may vary with time, depending on their interaction with the material to be restored and the local environment, and may become irreversible for disposal. In a similar vein, gaining a subsequent understanding of the product applied and the application technique used may be a complex task if no documentary record of the intervention is available [12,14,17].

1.1. San Juan Bautista Church at Talamanca de Jarama, Madrid, Spain: apse construction and restoration

San Juan Bautista Church is located at Talamanca de Jarama, a village 45 km NNE of Madrid, Spain. Characterised by two architectural styles, Romanesque (twelfth-thirteenth centuries) and Renaissance (sixteenth century), the church is made of dolostone, limestone and quartzite ashlars and rubble stones; brick masonry; earthen infills; and mortars, both as jointing and as render. The rectangular presbytery and semi-circular apse (Fig. 1) are all that is left of the original Romanesque dolostone building. The rectangular nave or main body of the church, consisting of three aisles with varying heights, was rebuilt in Renaissance style in the sixteenth century with a wide variety of construction materials (stone, brick and mortars). In 1885, with the church in ruins, the south wall and bell tower were rebuilt. The building was listed

Fig. 1. Twelfth-thirteenth century Romanesque apse on church at Talamanca de Jarama, Madrid, Spain, whose upper stone ashlars are yellow and lower rough ashlars beige dolostone; occasional white limestone cladding. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.).

as a historic-artistic monument in 1931 and has been protected as such ever since.

The semi-circular apse was built around four pilasters that delimit five walls or infills. Its three windows are located in alternate infills (Fig. 1). The stone masonry consists of rough ashlars at the base and more refined ashlars in the upper areas. The floral, geometric and human forms carved out of the stone modillions and cornice, are of significant historic and artistic value (Figs. 2 and 3). The dolostone on the apse, traditionally used in the area, was quarried from nearby Upper Cretaceous geological formations [24].

The two types of dolostone were quarried from different geological strata. One, beige-coloured, compact and scantly porous, is found in the rough ashlars at the base, while the other, a yellowish and more porous stone, is found in the upper walls ashlars, including the decoratively carved modillions and cornice (Figs. 1 and 2). The former is known as *Piedra de Torrelaguna* (*Torrrelaguna stone*) and the latter and more workable, *Piedra de Redueña* (*Redueña stone*) [2]. Some of the stone in the dado and underneath the modillions was replaced (possibly in the 1885 intervention) with the same varieties of dolostone as the original material. The lighter tone cladding visible in the same areas was laid during the 1990 restoration (Fig. 1).

In the late nineteen seventies, the apse was observed to be largely decayed, due primarily to the damp accumulating in the dado, cornice and windows, attributed respectively to capillary moisture rising from the subsoil, rainwater leakage and surface runoff. The main causes of decay in the cornice were the poor condition of the roof and the lack of any means to evacuate rainwater. The