# The Effect of Water on the Durability of Granitic Materials Consolidated with Ethyl Silicates

# L'Effet de l'Eau sur la Durabilité des Matériaux Granitiques Consolidés avec les Silicates d'Éthyle

Dória Costa, Geologist, Research Officer, Laboratório Nacional de Engenharia Civil, Lisbon, Portugal, phone 351 218443359, drcosta@lnec.pt
José Delgado Rodrigues, Principal Researcher (ret.), Laboratório Nacional de Engenharia Civil, Lisbon, phone 351 218443351, delgado@lnec.pt

## Abstract

The action of water on granitic materials consolidated with ethyl silicates was investigated. Tests were performed in the laboratory and involved three types of actions: cycles of temperature and humidity, long-term water immersion and cycles of absorption followed by drying of liquid water.

Ultrasound measurements were used to monitor changes during the “ageing” processes. The vast experience existing in this field allows us to consider this method one of the best choices for fissured rocks characterization like granites, in particular when used in a comparative basis.

All tests indicate that these ethyl silicates currently used in practice of conservation are sensitive to the action of water. Although this sensitivity is not limited to these products, they are particularly vulnerable, even if the consolidant has a water repellent side effect due to its composition.

## Résumé

Dans ce travail nous avons étudié l'action de l'eau sur les matériaux granitiques consolidés avec différentes formulations commerciales de silicates d'éthyle fréquemment utilisés dans la conservation de la pierre. Les tests de laboratoire comprenaient trois types d'actions: les cycles de température et d'humidité, une immersion prolongée dans l'eau et des cycles d'absorption de l'eau suivie de séchage.

Pour contrôler des processus de vieillissement on a utilisé la vitesse de propagation des ondes élastiques. La vaste expérience de l'utilisation de cette méthode indique qu'elle est l'une des meilleures options pour la caractérisation des roches fissurées, en particulier lorsque le procédé est utilisé dans une perspective comparative.

Tous les tests indiquent que les silicates d'éthyle sont sensibles à l'action de l'eau. Bien que cette sensibilité n'est pas exclusif de ces produits, ils sont particulièrement vulnérables, même si un effet hydrofugeant complémentaire est présente.

## Introduction

Ethyl silicates, as they are known by practitioners or referred in conservation literature, are a large family of products used for a long time as consolidants on several types of materials, namely on stone. Since the very beginning they were extensively used to consolidate limestones, sandstones or marbles and an important number of publications after Laurie and Schaffer (1932) and then Bosch (1972) present results on their behaviour on these types of substrates were published. Their use to consolidate granitic materials is more recent and in some way conditioned by a prejudice involving the inability to consolidate granitic materials, still very current in the 1990s.

Past builders of our monuments often sculpted and shaped already decayed materials extracted from local outcrops used as quarries. The pollution and the systematic use of incompatible materials in modern times introduced other relevant decay agents. The use of incompatible mortars (with some Portland cement incorporated, for instance) is recognized harmful factor for stone. Flaking, contour scaling and granular disintegration are very common in granitic decayed surfaces and responsible for the fast erosion rates observed in practice.

Granitic materials present in monuments are characterized by the existence of fissure-like voids and low porosity, but also by a high variability of mineral composition and textures, where quartz and feldspars are the major components. All these distinctive aspects control the physical and mineralogical characteristics of those materials and are key-parameters in consolidation, namely when alkoxysilanes are involved to achieve a mass consolidation effect.

Generally speaking and despite the great variability of compositions available on the market, ethyl silicate-based products are recognized for their good capability to penetrate deeply into the materials and therefore a bulk consolidation of decayed material can be reached. In fact, the low viscosity and the ability to form Si-O-Si bonds, considered relatively strong and stable, are two properties often cited to justify the use of alkoxysilanes for the consolidation of stone, even when exposed to outdoor conditions. The chemical similarity of these gels with silicate minerals was used to support the idea of great resistance when submitted to weathering; actually, silicate minerals are not always stable phases and these gels are not comparable to them. Nevertheless, the gels formed after hydrolysis and condensation of ethyl silicate-based consolidants are chemically compatible with silicate substrates, fulfilling one important selection criterion for the choice of the product to be used. The information available (Elfving and Jäglid cited in Wheeler 2005, p. 39, 40) indicates the possibility of chemical bonding between the major granite components (quartz and feldspars) and the gels formed.

Some words must be added about the context of this work. In the frame of the "Granitix Project", an European Commission research project (1991-1994) on degradation and conservation of granitic rocks used in megalithic monuments, several types of consolidants were tested in laboratory conditions, including Wacker OH. Later, this subject was pursued using different products and tests involving Rhodia ethyl silicates. More recently, the works of Wheeler (2005) and (2008) on alkoxysilanes used in stone conservation added practical and relevant information about the characteristics, behaviours and diversity of the gels allowing us to better understand our own results, some still unpublished.

For all these reasons, in this paper some information obtained on different “ageing“ tests performed in the laboratory is compiled. Different varieties of granites were treated with some of the most currently used commercial ethyl silicate-based products. The results are presented and discussed, taking into consideration the consequences of their behaviour for the in-practice consolidation of granitic materials.