Moisture Compatibility of Portland Stones and other Oolitic Limestones

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Abstract

Approximately 30% of Europe's building stock comprises historic buildings, with the UK having a significant contribution of Portland stone structures. However, difficulties in sourcing the original material have led to the need for compatible material substitutes. Currently, the level of compatibility required between original and substitute material has not been quantified, and the approach has been to evaluate each case separately. This research aims to answer the question of how compatible is compatible enough, specifically in relation to moisture risk, and provide a guiding framework for the heritage conservation sector. The project uses a sensitivity analysis to quantify the compatibility of Portland Stone and other Oolitic limestones, considering porosity and age of the original/substitute stone as sensitive parameters when selecting compatible strategies for repair and reconstruction.
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Keywords: Portland Stone, Oolitic Limestone, stone repair, moisture compatibility, moisture risk, mould growth, freeze-thaw, framework.

1. Introduction

Historic England (HE) has actively supported the need for adaptable frameworks that prioritize sustainable sourcing of stone substitutes for the conservation of historic buildings [1]. The main reason for this need lies in the decline of natural building stones that are being actively quarried. This leads to a clear sourcing problem for the market and an environmental challenge for preservation. Building stone has been used and repaired since Roman times [2], and up to this day the strategy has been a case-per-case approach. The reason is the lack of standards or rules that give a simple answer to the suitability of compared stones for repair. When assessing different cases and their solutions, the question "How compatible is compatible enough?" is often raised. This refers to the justification of the selected material and how it is deemed to be successful in minimizing disruption of the existing fabric. Considering the identified growing need for building reuse over new constructions, a framework for successful substitute finding and material compatibility becomes a priority [1,3]. The topic arises as the industry is in the initial data collection timeframe, with an intention to supply adaptable targets in line with construction principles. In the context of the United Kingdom, this paper addresses the Portland Stone, which has been proposed as a viable "Global Heritage Stone Resource" because of its widespread historical use [2].

The foundations of the approach lie in a series of recommendations from the industry, understood as a methodology to be tested for historical repair. Through the integration of essential building conservation and preservation principles in heritage buildings, the scope spans from the wider context to the specifics of the UK and Portland Stone importance. Furthermore, to understand the steps required in the selection process, HE's document and the industry's continued research provide a baseline for the parameters needed for successful stone repair and conservation [1]. These include stone aesthetics and behaviour: sampling analysis for stone characterization and selection criteria for suitability [1]. Through the understanding of these parameters and the repair challenges as the building ages, it becomes relevant to highlight the importance of moisture and how crucial it is in the failure of material substitutes. While Portland Stone is typically durable, if it has already deteriorated, the extra pore spacing might give more area for moisture absorption, speeding up degradation [4]. Compatibility is assessed through the quantification of moisture risk - a term that refers to the extent of moisture accumulation, and the resulting negative consequences, within the building fabric. The hygrothermal simulation of the interface in the situation can be represented to numerically quantify the effects on the transfer of heat and moisture through building structures, for a selected time period and location. These effects can be represented as moisture risk, through damage such as mould growth and freeze-thaw [5].

The research gap identified is the problem in assessing compatibility for material substitution in stone heritage conservation. A review of the literature proves that, although a holistic approach is imperative, moisture is among the most defining and complex factors that need to be accounted for during the selection of the substitutes. Therefore, the aim of the study is to quantify the compatibility criteria between Portland Stone and other oolitic limestones in the face of moisture risk, as a parameter of mould growth and freeze-thaw. In close consideration of BS EN 15026:2007 and Historic England's recommendations, the following research objectives have been identified: (1) Review of the state of UCL building stones and their deterioration through dating, visual inspection, and numerical comparison; (2) Stone characterization through literature review (including porosity, unit weight, water absorption, and diffusion coefficients) and mineralogy; (3) Laboratory

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investigation of limestone equilibrium moisture contents through Dynamic Vapour Sorption testing, and thermal conductivity testing; (4) Modelling the moisture risk in WUFI 2D software, at positions on the interface of the original Portland Stone and the selected Oolitic limestone samples, using documented and measured attributes; (5) Sensitivity analysis of the defining parameters, as a graphical comparison (mould growth and freeze-thaw events) to obtain a benchmark. The parameters: bulk density, thermal conductivity, water vapour diffusion resistance factor, and porosity and (6) Evaluation of the suitability of the framework: recommendations on the assumptions and limitations for uses in the future search for natural stone substitutes.

2. Methodology and results

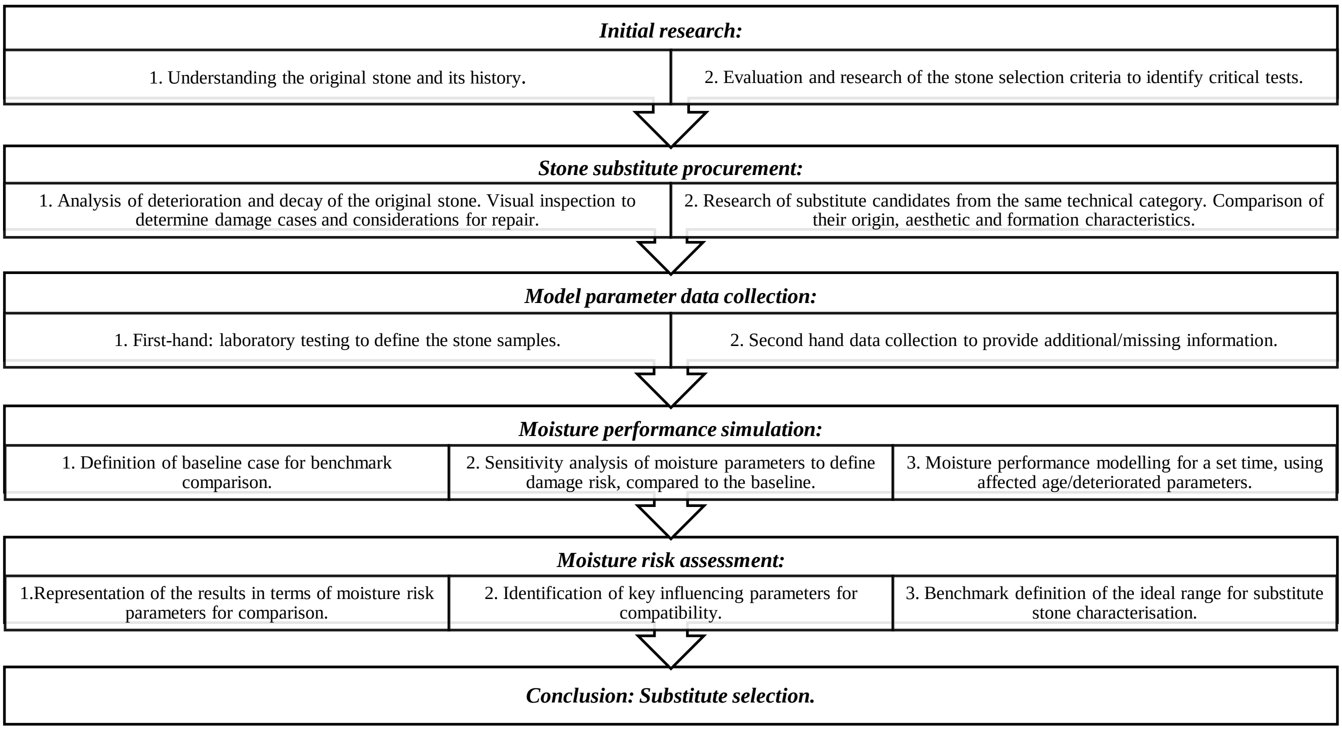

Figure 1: Proposed methodology framework to test for compatible stone substitutes

2.1. Data and laboratory work: The stones used in this study include Portland Stone and alternative Oolitic limestone substitutes (Gloucestershire, Shelly Gloucestershire, and Yorkshire Limestone) procured from the UCL Department of Earth Sciences. Additional data is sourced for the characterization of stones in mineralogy analysis and deterioration. Lab tests are used to carry out porosity, water absorption, and unit weight tests, to describe stones physicomechanically. Through Dynamic Vapour Sorption (DVS) testing, moisture isotherms are generated to determine the equilibrium moisture content. Thermal conductivity characteristics are defined in moisture-dependent and temperature-dependent tests, using a thermal analysis kit.

2.2. Moisture Risk Modelling: The stone characteristics are modelled at the interface where they meet. This is simulated in WUFI2D for hygrothermal modelling, where substitution is placed in the context of the baseline model: a generic building in London. The results are processed to display common moisture risks (mould growth and freeze-thaw). The baseline case and substitute characteristics are graphed together for each risk parameter and for water content, to compare the substitute compatibility with the original.

2.3. Discussion: The method framework and stone categorization developed in this study provides a systematic approach for evaluating the compatibility of stone repair materials with the original facade. The moisture risk modelling and sensitivity analysis allows for the qualitative identification of the most sensitive parameters, with porosity being the most influential. This finding suggests that porosity should be considered as a key criterion for compatibility assessment and that compatibility benchmarks should be based on a range of acceptable porosity. In parallel, the findings illustrate the importance of considering the age of the existing fabric, and how this might impact the moisture properties during the compatibility assessment.

References

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