Lime binder aggregate interface for Indigenous Scottish sands: a preliminary investigation
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Abstract: Indigenous Scottish natural aggregates are currently underutilised in conservation mortars. The variability and provenance of aggregates can be considered, owing to the variability of Scotland's geological history, however aggregates can be broadly characterised by region into granitic and siliceous forms. Aggregates with differing physico-chemical properties have been associated with variable performance therefore some behavioural uncertainty exists. It is also widely accepted that an important aspect of all mortars' durability, is the binder-aggregate interface. The area of direct contact and the progressive region extending typically between 10 – 65 μm are together known as the Interface Transition Zone (ITZ), typified in PC by lower density and is a known 'weak' point in the materials. To what extent mineralogical variation within Scottish aggregates affects the ITZ in lime mortars is unknown. Research into the binder-aggregate interface and the broader ITZ in lime mortars is in its infancy, when coupled with an assessed understanding of, and work in this area would fill a collective gap in our knowledge.

Introduction

Lime is a frequently occurring material, chiefly associated with the historic built environment through to contemporary conservation and environmental construction. Historically, localised manufacture sustained and facilitated the widespread use of lime in construction (Arts, 2012) giving rise to regional practices and foresight regarding regional and locally specific lime and aggregates (Allen et al., 2003). The prevalence of lime use decreased with the invention of OPC. Patented in 1824 OPC was quickly adopted on the basis of its reliability primarily a factor of its consistent manufacture (Bleazard, 1998). However with manifestly different physical properties than limes.

Project Outline

The benefits of using lime mortars for repair and restoration purposes are well supported in the scientific literature (Lanas et al., 2004; Pavia & Toomey, 2007; Forster & Carter, 2011; Margalha et al., 2013). However, many fundamental characteristics of lime mortars remain unresolved. It is the aim of the study to investigate interactions between binder and aggregate by examining the performance of two distinct natural aggregates and natural stone types. Aggregates with differing physico-chemical properties have been investigated with varied results (Lanas et al. 2004; Pavia & Toomey, 2007) regarding their influence on the properties, performance and durability of mortars. This project aims to build upon previous research and evaluate the properties of Scottish aggregates, specifically the role they play on ITZ development and resultant structure. Often cited as a site of inherent weakness, the aggregate/binder interface transition zone (ITZ), is of particular importance to the durability of composite materials such as mortars (Tasong et al. 1998b; Tasong et al. 1999).

Scottish Aggregates

If economic and energy inputs are to be considered: natural sand and gravel aggregates in a virgin state are most cost effective. Artificial grading via selective sieving may filter out finer, coarser or undesirable components from an aggregate. This system can be used to filter out specific mineralogies, e.g. clays, which may affect aggregate performance. The effects of dosage may prove to either enhance or inhibit the performance of specific aggregate types. Tasong et al (1998a-b) has shown inherent geochemical and physical characteristics of an aggregate affect the interface between cement paste and aggregates. This study has been designed to investigate the performance of quartz rich and granitic derived aggregates types which are prevalent in Scotland. Figure 1 displays the aggregates chosen and the location of origin.

Figure 1: Geological map of Scotland. Geological diversity in Scotland accommodates a range of aggregate types. This study will utilise the following as drug aggregates: 1. Cleddach, 2. Park WICS, paired respectively with the following stone types 3. Hazledene Sandstone 4. Craighenog Granite

Experimental Methodology

The study program has been designed to examine the structure of the ITZ between St Aster NNL 5 lime paste and aggregate/stone representative of the Scottish geology. The work will be carried out in 3 work packages, listed below:

i. Physical testing of binder paste / natural stone interface as a proxy mortar aggregate interface – based on previous tests from the cement literature, Tasong et al (1998a) and Tasong et al (1999) - see Figure 3 a. Specimens will be tested at 28 and 100 days.

ii. Sorptivity testing of mortars and by extrapolation the attainment of binder aggregate interface performance. A method of evaluating relative moisture transfer, following work by Wong et al (2009) with complementary AC impedance. Measurements will also be taken of compressive and flexural strength performance at 28 and 100 days.

iii. Materials Interface surface studies: Microscopic work on samples will be conducted via petrographic and ESEM (with EDX) analyses. Fracture surfaces from physical testing will be scanned and modelled in high resolution 3D using an Alicona Infinite Focus (Figure 3 b, c and d).

Working Hypothesis

The inherent physical and chemical characteristics of an aggregate (roughness, grading, shape, mineralogy) influence the nature of the ITZ between both aggregate and binder. Failure within the ITZ itself will vary in nature depending upon these characteristics. These are major factors affect the performance of lime mortars.

Research Objectives and Outcomes

i) Investigation into the properties of Scottish aggregate resources: Granite, sandstone and naturally occurring counterparts. The multiphase experimental procedures outlined above have been designed to ascertain information pertaining to the ITZ of NHL and overall mortar performance. Ultimately, observations will result in an enhanced understanding of how mineralogically and physically distinct aggregates perform in hydraulic lime mortars. This will offer insights into how NHL mortars mixed with certain aggregates will perform and how durability may be affected.

ii) Research will enable a contribution of data to on-going debates in the relevant literature. The first regarding the broadly applicable debate of calcite v.s. siliceous aggregates and secondly, the utilisation of local aggregates as part of a more sustainable outlook on conservation work and building design.

References


