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Impact of aggregate type on air lime mortar properties

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Abstract

In recent years, the need for low energy materials has become increasingly recognised. Government targets aim to achieve a decrease in carbon emissions by 80% before 2050. With the construction industry being responsible for approximately 50% of UK carbon emissions, an increased use of low energy materials could go a long way to achieving this target. With this in mind, it is also important that materials still have adequate properties to fit their purpose. For this study, four limestone aggregates were compared with a silicate aggregate in order to assess the impact of the aggregate type on the properties of air lime mortar (CL90). The primary focus was to assess the differences in compressive strength, and investigate reasons behind the measured differences. Without exception, the mortars made with limestone aggregate have higher compressive strengths than those made with silicate sand. Phenolphthalein staining shows slight differences in carbonation levels at 28 days, which could help to explain the strength differences observed. Furthermore, SEM analysis has revealed differences at the binder/aggregate interface between limestone aggregate mortars and silicate sand mortars.

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Keywords: limestone aggregate; silicate sand; air lime; compressive strength; scanning electron microscopy (SEM)

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1. Introduction

Lime mortar has been used for centuries in masonry construction. The past few decades have seen an increase in restoration work on old structures, where the compatibility of old and new materials is of paramount importance. This means that cement-based materials are inappropriate as a repair material due to the significantly higher strengths they reach over lime-based materials; a mortar with a higher strength than the original masonry would lead to more damage due to having less ability to accommodate movement. As a result, a build-up of stresses would cause the masonry to fail (Mosquera et al. 2002) [1].

Lime mortars are inherently weak in compression, and research has shown that higher strengths can be obtained with use of limestone aggregate over silicate aggregate (Lawrence, 2006) [2]. Since low strengths are synonymous with poor durability, higher strengths could lead to longer-lasting mortars. The higher strengths obtained are still much lower than cement mortar strengths so should not have a detrimental effect on existing masonry. Aggregates are primarily used to provide structure to a mortar (Farey et al., 2003) [3] and their role in mortar strength has been largely underestimated. Despite various studies concluding that limestone aggregates can produce higher strength air lime mortars (Lawrence, 2006; Lanas and Alvarez, 2003; Arizzi and Cultrone, 2012) [2,4,5], little is known about the reasons why. Additionally, while adequate strength is required for durability of a mortar, it is also vital to ensure other characteristics are sufficient; porosity, water retentivity and plasticity are just a few of the important properties. In the current climate, it is becoming increasingly recognized that carbon emissions need to be reduced; as the construction industry is responsible for around 50% of the UK's emissions (BIS, 2010) [6], the use of low energy materials can contribute to this reduction. Air lime is a low energy binder due to the fact that during curing, almost all of the CO_2 that was emitted during the manufacturing process is reabsorbed during carbonation (limetechnology, accessed 2013) [7]. Carbonation gives a mortar strength through the transformation of $Ca(OH)_2$ into $CaCO_3$. It is the primary chemical reaction that occurs during setting of air lime mortar, and is a self-limiting process. This is due to the formation of calcite crystals around the calcium hydroxide particles, which block CO_2 penetration and subsequently some portlandite ($Ca(OH)_2$) always remains uncarbonated (Houst and Wittmann, 2002) [8].

The research originated due to lack of knowledge surrounding the effect of aggregate type on mortar properties, particularly compressive strength. Consequently, four limestone aggregates were compared against a silicate sand (CEN Standard sand) to determine firstly the compressive strengths, and secondly whether there were any differences at a microstructural level for the different mixes. Scanning electron microscopy (SEM) was used for this analysis.

Nomenclature

SEM	scanning electron microscopy
$Ca(OH)_2$	position of
$CaCO_3$	calcium carbonate
$CaMg(CO_3)_2$	calcium magnesium carbonate (dolomite)
SiO_2	silicon dioxide
B/Ag	binder/aggregate

2. Effects of aggregate type

Several aspects relating to aggregates can have an impact on the strength of the mortar. The most commonly used aggregate is silicate aggregate, which is hard and chemically inert. Limestone aggregates can be calcitic or dolomitic; calcitic aggregates are in the form $CaCO_3$ whereas dolomitic aggregates are $CaMg(CO_3)_2$. Calcitic aggregates are used in the current study (as well as silica sand) and can either compose of angular or rounded grains. Differences in the porosity of aggregates can have an impact on overall mortar strength, due to differences in the diffusion of CO_2 through the sample. Aggregates with a higher porosity would allow a quicker rate of CO_2 diffusion,