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THE TESTING OF A LIME-POZZOLAN MORTAR: USING THE RIGHT CURING REGIME.

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Abstract

The masonry building construction style in Mexico ranges from traditional (local materials) to modern (distant production and distribution). Locally available lime-sand mortars are beginning to be displaced by distributed Portland cement-sand mortars because of a perceived need for early and high strength gain. The opportunity exists, however, to find middle ground in terms of using local materials and achieving the wanted properties by investigating lime-pozzolan mortars. The challenge is to provide an adequate characterization of the mortar. This paper gives a brief summary of the approach taken to investigate 1) the test method to determine the potential for the pozzolanic reaction of volcanic ash to be used in a lime-pozzolan mortar, and 2) the strength gain of lime-pozzolan mortar using different curing regimes.

Key Words

Lime, pozzolan, mortar, sustainability

1 Introduction

The masonry building construction style in Mexico ranges from traditional (local materials) to modern (distant production and distribution). Locally available lime-sand mortars are beginning to be displaced by distributed Portland cement-sand mortars because of a perceived need for early and high strength gain. The opportunity exists, however, to find middle ground in terms of using local materials and achieving the wanted properties by investigating lime-pozzolan mortars.

Since the time of the Romans, lime in combination with pozzolanic materials has been used to create masonry mortars which are able to set under water, or are hydraulic (Vitruvius, ca 27 BC). Malhotra & Mehta (1996) define a pozzolan as: "… a siliceous or siliceous and aluminous material which in itself possesses little or no cementing property, but will in a finely divided form and in the presence of moisture chemically react with calcium hydroxide (lime) at ordinary temperatures to form compounds

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possessing cementitious properties." Common pozzolans include flyash, blast furnace slag, diatomaceous earth, opaline shale, silica fume, rice hull ash, sugar cane straw by-products and volcanic ash. Volcanic ash is one of the most abundant, and historically, most commonly used pozzolan. Central Mexico has extensive deposits of siliceous volcanic ash (Figure 1) creating the possibility, if the ash is sufficiently pozzolanic, to make a lime-pozzolan (hydraulic) masonry mortar.

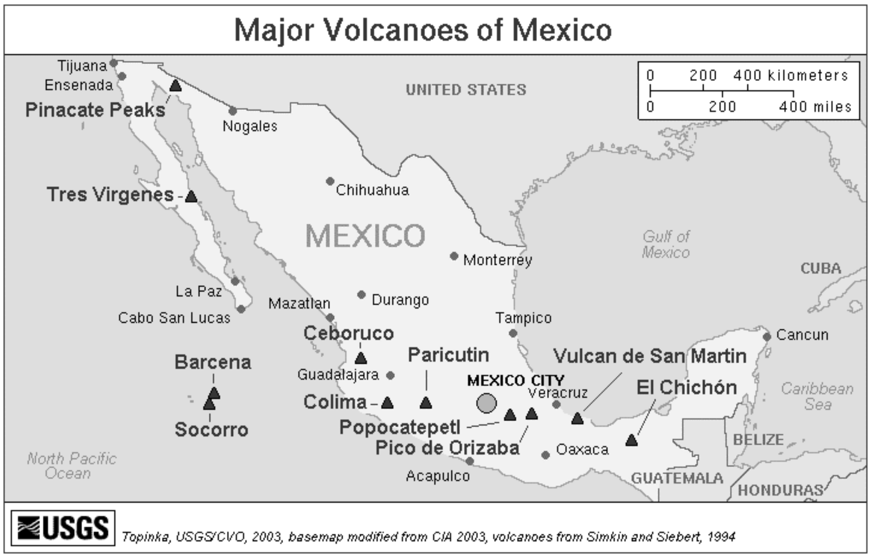

Figure 1. Major Volcanoes of Mexico (Ferrari et al., 1997)

Once the pozzolan is chosen, the challenge comes in assessing the properties of the mortar by using currently accepted engineering practices. The standard protocol for testing compressive strength of Portland cement-based (ASTM C270) or hydrated hydraulic lime mortars (ASTM C141) uses a curing regime of 28 days in saturated lime-water or 100% relative humidity (RH) which promotes the reaction of the cement minerals to form calcium-silica-hydrate (CSH) a primary phase for strength gain (Taylor,1998). However, the strength gain from carbonation of the calcium hydroxide (lime) portion is not tested as carbonation does not occur at 100% RH, but rather in a RH range of 50% to 85%. Current standard test methods, therefore, limits the potential strength gain of a lime-pozzolan mortar to the pozzolanic reaction alone. Through 30 years of investigation, Binda & Baronio (*eg.* 1999) have recognized the role carbonation plays in strength gain of lime-based mortars characteristic of historic masonry. In their research they use a curing regime of 20°C and 65% RH for testing of repair mortars

This paper gives a brief summary of the approach taken to investigate 1) the potential of the pozzolanic reaction of volcanic ash to be used in a lime-pozzolan mortar, and 2) the strength gain of lime-pozzolan mortar using different curing regimes.

2 Mortar Materials

The testing of the mortars was conducted in the United States, at the laboratory of Chemical Lime Company in Henderson, Nevada. Grupo Calider, S.A. de C.V, provided the volcanic ash samples to Chemical Lime Company.

2.1 Volcanic Ash

The initial investigation looked a suite of 6 volcanic ash samples from operating quarries or pits in the western portion of Mexico. One of the volcanic ash samples (Ash A) is overburden on a working limestone quarry currently used for the production of quicklime and hydrated lime. The chemical analysis volcanic Ash A was completed using chemical dissolution and ICP analysis (Table 1).

*Table 1. Major Oxide Chemical Analysis of Volcanic Ash A**

Major Oxide	Weight %
CaO	3.97
MgO	1.07
SiO_2	61.24
Al_2O_3	22.01
Fe_2O_3	7.81
Na_2O	2.24
K_2O	1.22
total	99.77

ICP Leeman Model PS1000

To investigate the potential pozzolanicity of the ash the samples were tested using the methodology described in EN 196-5 (Fig. 2). The samples were screened to pass 180 µm mesh openings. The pozzolanicity is assessed by comparing the quantity of calcium hydroxide in the aqueous solution in contact with the pozzolan (after 7 days for this test), with the quantity of calcium hydroxide capable of saturating a solution of the same alkalinity -- calcium and hydroxide are being consumed by the reaction. The test result is considered positive if the concentration of calcium hydroxide in the solution is lower than the saturated concentration. Two samples of ash chosen for further investigation were Ashes A and B because of potential for pozzolanicity and their proximity to the Mexican lime source.

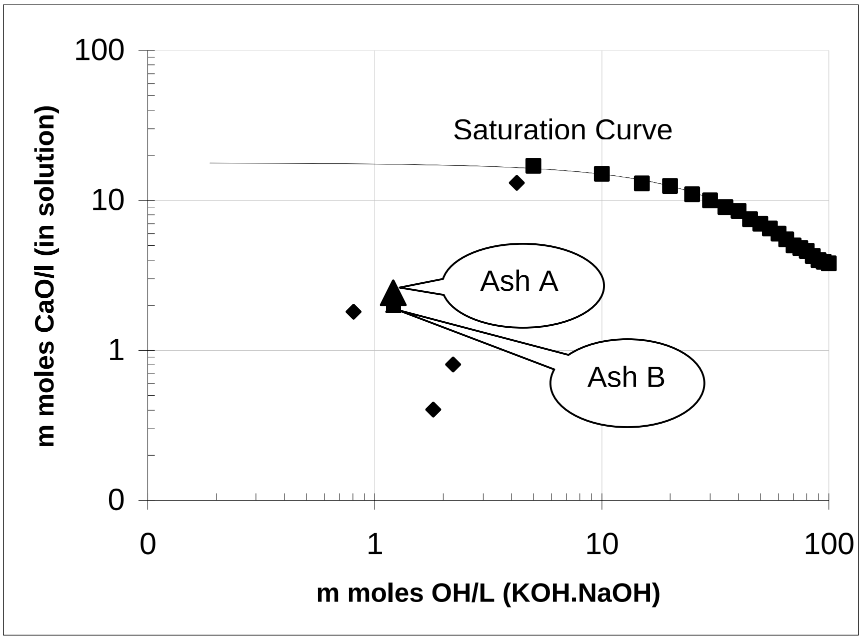

Figure 2. Seven day test data for volcanic ash samples. Data plotting below the calcium hydroxide saturation line shows potential for pozzolanic reactivity.

2.2 Lime and Aggregate

Type S hydrated lime conforming to ASTM C 207 was used. Two aggregates were used: a masonry sand local to the Las Vegas, Nevada region conforming to ASTM C144 and standard (Ottawa) sand conforming to ASTM C778.

3 Lime-Pozzolan Mortar

The volcanic ashes were combined with the hydrated lime in a proprietary proportion and combined with sand at a volume ratio of 1 part binder to 3 parts sand. The mortars were mixed following the standard methods outlined in ASTM C305 and 50 mm cubes were molded following ASTM C109. The mortar filled molds remained in low-permeable plastic bags for 72 hours to allow the mortar to become firm enough to demold. On set of cubes was transferred to a 100% relative humidity cabinet and the second set were transferred to a 50% relative humidity room. Both curing regimes were maintained at 20°C.

Plastic properties of the mortars are summarized in Table 2.

*Table 2. Plastic Properties of Mortars Mixed**

Binder:sand 1:3 (by volume)	H_2O (mL)	Flow (%)	Water Retention (%)
A-ash - local sand – 100 RH	825.0	105.0	75.2
A-ash - local sand – 50 % RH	825.0	105.0	75.2
B-ash - local sand - 100 RH	815.0	108.0	69.4
B-ash - local sand - 50 % RH	815.0	108.0	69.4
A-ash - standard sand - 100 RH	610.0	110.0	72.7
A-ash - standard sand - 50 % RH	610.0	110.0	72.7
B-ash - standard sand - 100 RH	590.0	105.0	61.0
B-ash - standard sand - 50 % RH	590.0	105.0	61.0

*mixing and measurement following ASTM C305 and ASTM C109.

The compressive strength testing apparatus used in this study is a Tinius Olsen Super L Hydraulic Universal Testing Machine with Model 290 display system, model 496 controller and pressure transducer weighing system. A set of three cubes was tested at 7 and 35 days with additional tests, where samples were available, at 86 and 791 days (Fig. 3).

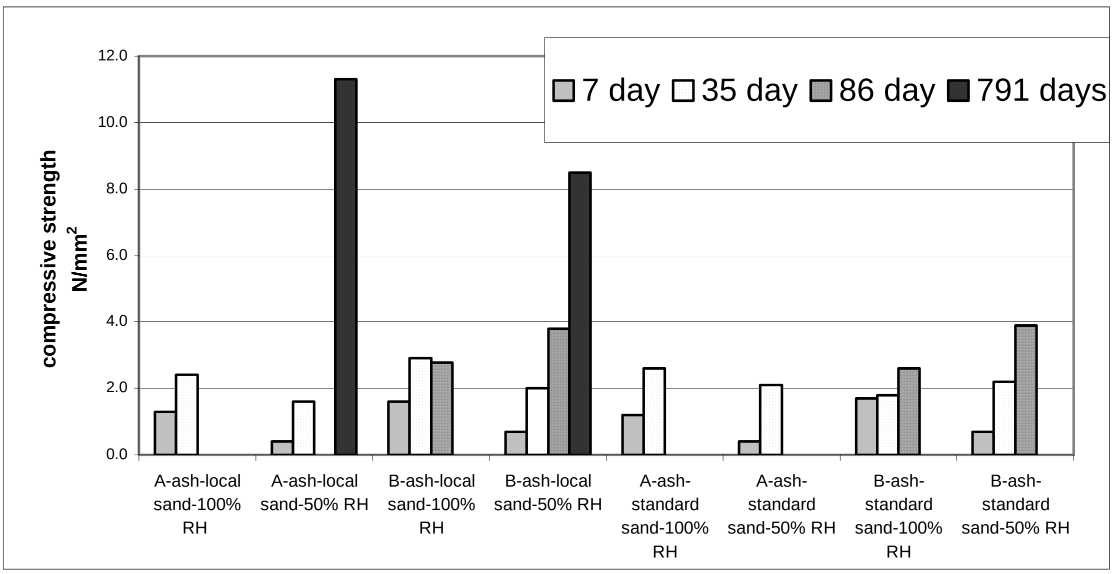

Figure 3. Compressive Strength values for Mortars

4 Discussion

4.1 Curing Regime

Lime-pozzolan mortars harden by the interaction of lime with the soluble silica to form calcium-silica-hydrate. They also harden, however, by the interaction of atmospheric CO_2 gas with soluble calcium hydroxide to form calcium carbonate. The lime-pozzolan mortars cured in 100% RH show relatively early strength gain and lower long-term strength gain. In comparison the same mortars cured in 50% RH show much lower early strength gain, but higher long-term strength gain. Interestingly, there is a linear relationship between strength gain plotted against the square root of time (Fig. 4). Diffusion is the most common process that is governed by square root of time function, and this is consistent with carbonation.

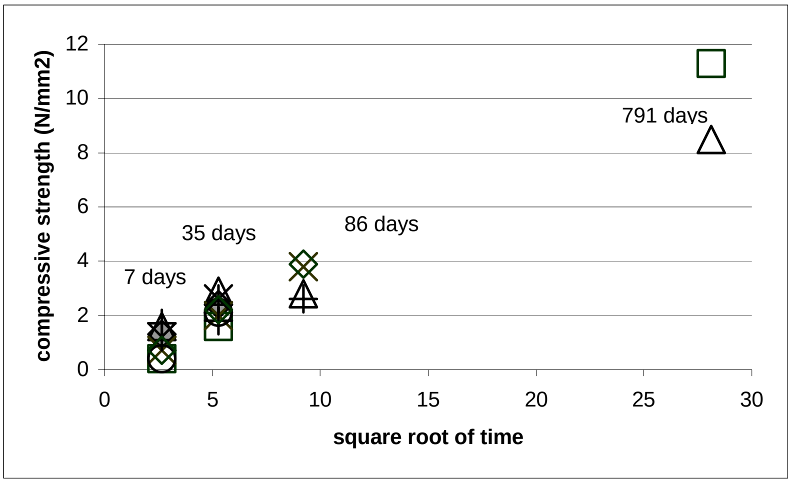

Figure 4. , Compressive strength data from Figure 3 of all the samples plotted against square root of time (days).

5 Conclusions

This work is not intended to provide the solution to problem, but rather to point out that there is a problem. The opportunity to investigate the use of local pozzolans for masonry mortars in regions rich in the resource is potentially hampered by the test methodologies that determine their properties. This points to the need to validate test methodologies at a rigorous level in order to provide a degree of comfort for the use of lime-pozzolan mortars in the Mexican marketplace.

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