



Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Low energy pre-blended mortars: Part 1 – Control of the sand drying process using a lime drying technique



D.C. Hughes*, J.M. Illingworth

Bradford Centre for Sustainable Environments, University of Bradford, Bradford, West Yorkshire BD7 1DP, UK

HIGHLIGHTS

- A technique is described for low-energy drying of wet sand to produce pre-blended mortars.
- Quicklime is used as the drying medium.
- The dominant processes are chemical combination and evaporation of free water.
- Four principal process control factors have been identified.
- The drying process produces slaked lime to form a component of the binder phase.

ARTICLE INFO

Article history:

Received 13 May 2015

Received in revised form 19 August 2015

Accepted 14 October 2015

Keywords:

Mortar
Sand drying
Quicklime
Slaking
Process control

ABSTRACT

Production control methods allow factory produced mortars to be supplied to a more consistent formulation than site produced mortars. However, there is scope to enhance their “sustainability” credentials by addressing the methods of drying the wet sand and the use of lower energy hydraulic components. This paper describes the development of a technique in which quicklime is added in controlled quantities to remove free water by both chemical combination and evaporation. The slaked lime so generated is porous and a third mechanism of absorption is suggested which, however, might have adverse effects during storage of the pre-blended mortar. The principal process-control factors are lime addition based upon a ratio of the stoichiometric requirements for complete slaking of the quicklime, free moisture content of the sand, mixing time of the combined sand and quicklime, and storage of the mixed material.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The use of pre-blended dry silo mortars is a relatively new concept in UK construction, but is standard practice throughout mainland Europe. Dry silo (and bagged) mortars are produced in computer controlled facilities which allow accurate gravimetric batching of fine aggregate, binders and appropriate admixtures. Hence, a wide range of site specific mix designs may be created and many of the potential problems arising from ‘on-site’ volumetric batching are eliminated. Further advantages of the pre-mix system include reduced wastage, lower labour costs and cleaner, quieter construction practice [1].

Unfortunately, these advantages are somewhat offset by an increase in the embodied energy of pre-blended mortars. Quarried sands typically contain significant amounts of free water, typically

* Corresponding author at: 10 High Fold Lane, Utley, West Yorkshire BD20 6ES, UK.

E-mail addresses: hughes249@sky.com (D.C. Hughes), jamesillingworth@hotmail.co.uk (J.M. Illingworth).

within the range of 5–10% and this must be removed prior to mixing with the hydraulic binders in order to prevent deleterious hydration reactions occurring during storage. In this paper we take free water to be that in excess of the water required to saturate the pore space within the sand particles and therefore exists both on the surface and between the particles. The drying of the wet aggregate usually takes place in large diesel-fuelled kilns, an energy intensive process which imposes an additional environmental cost upon the material. This is of particular concern in the context of the current drive for greater sustainability in construction materials.

Lime mortars have been used for millennia. One traditional technique for their production is known as ‘hot lime slaking’ in which freshly calcined quicklime is mixed with the wet sand and worked during the slaking period or whilst the material is hot [2]. In this approach the aim is to slake the lime prior to use after a period of several days have elapsed and thus the slaked lime is simply viewed as the binder. However, at the extreme where the contents of water and quicklime are “in balance” the outcome is a fully slaked lime and dry sand. Should it be possible to sensibly achieve this balance under operational conditions, the process

may yield a material which forms the basis for a factory produced mortar to which an additional hydraulic binder component can be added. In this case the lime is both a drying agent and a component of the binder phase.

In the current work the production of 'low-energy' pre-blended mortars using a controlled quicklime drying technique for the aggregate is described. The 'as-received' wet aggregate is mixed with controlled amounts of quicklime and water is removed from the aggregate via the hydration of the quicklime. Further water is removed by evaporation as a consequence of the heat generated by the exothermic hydration reaction; thus, there is no need to utilise the full stoichiometric amount of quicklime to fully combine with the moisture within the sand (i.e. 3.113 g of CaO being required to combine with 1 g water). The 'green' credentials of these mortars may be further enhanced by careful selection of the hydraulic component. Recycled waste materials such as ground granulated blast furnace slag (ggbs) and pulverised fuel ash (PFA) possess far lower embodied energy than the more commonly used Portland cement (PC) or natural hydraulic lime (NHL) [3]. In order to produce a true 'low-energy' pre-blended mortar, this research concentrates primarily on the addition of ggbs as the hydraulic phase and demonstrates that a range of mortars with differing physical properties may be engineered.

The work is reported in two parts. The first describes the control methodology of the drying process itself whilst the second [4] records the properties of ggbs/lime mortars and Roman cement mortars which have been retarded by a pre-hydration technique [5]; both of which utilise the lime-drying process. It is apparent that variations in the as-delivered moisture content of the sand will be accompanied by variations in the amount of quicklime required and, hence, the amount of slaked lime produced. This variation is accounted for in the mix design procedure described in Part 2 of the paper.

Two research projects have been progressed alongside each other but not necessarily contemporaneously. One has been a laboratory investigation whilst the other was based in the commercial premises of Lime Technology Ltd in Didcot, UK where the principal focus has been the application of principles arising from the first project (reported here-in) as they apply to locally sourced materials. Such a factor was deemed important to minimise the carbon footprint of the product. This paper is a combination of data obtained in both projects.

2. Experimental procedures

Nitrogen adsorption-desorption isotherms were determined at 77 K using a Micromeritics ASAP 2000 automated gas adsorption apparatus. The samples were outgassed at 100 °C under vacuum for 18 h prior to analysis. The specific surface area (A_{BET}) of the samples was calculated by the Brunauer, Emmett and Teller (BET) method [6] using adsorption data in the relative pressure (P/P_0) range 0.05–0.25. The total pore volume (V_p) was determined from the volume of adsorbed N_2 at $P/P_0 = 0.99$, assuming a liquid density for N_2 of 0.8081 g/cm³.

Thermogravimetric analysis (TGA) was used to determine the proportion of Ca(OH)₂, CaCO₃ and absorbed water in both the quicklimes and derived slaked limes. The TGA profiles were produced using a Stanton Redcroft TG761 with a heating rate of 20 °C/min under a dry nitrogen flow. The weight loss events at 400–550 and 600–850 °C were used to determine the quantity of Ca(OH)₂ and CaCO₃ respectively whereas the weight loss up to 250 °C was used to determine the moisture content of the sample.

The free lime measurements were obtained by titration using the method described in BS EN 459-2 for the analysis of air limes. The same Standard was used to evaluate the soundness of slaked limes produced during the drying process.

The bulk density of sands, quicklime and slaked lime powders was determined using a Hosokawa Powder Densometer. The values cited in this paper are the average values of the aerated and tap densities. The former is obtained by vibrating the powder through a 0.710 mm sieve into a cylinder of known volume whilst the latter is determined by compacting the powder for 3 min at the standard tap rate.

The absorption of the sands was obtained by first soaking the sand in excess water for 24 h. Then it was gently dried in a frying pan to SSD and weighed. The determination of the SSD condition is made when the finest particles adhere to a metal spatula when rotated vertically but are detached by a gentle tap. The sample was then oven dried and the absorption expressed as a percentage of the oven dry weigh.

An Environmental Scanning Electron Microscope (FEI Quanta 400 E-SEM) was used in back-scattered mode to illustrate the morphology of slaked lime particles.

Unless otherwise stated all oven drying of materials was conducted in a closed system in air at 110 °C circulated through silica gel and soda lime.

3. Sand characterisation

Three silica sands have been used in this work and the results of dry sieve analysis are shown in Table 1. Sand 1 has been previously used by Lime Technology Ltd as a component of their conventional dry silo mortar which uses natural hydraulic lime as the binder. Sand 2 was identified as a more sustainable source being closer to their Didcot factory and was identified following the commencement of the investigation. Sand 3 is an atypical sand with a grading with only minimal overlap in grading with the lime which permitted the physical extraction of lime for analysis with only a small contamination of sand resulting from surface degradation of the sand during the mixing phase. The water absorption values were determined to be 1.5%, 3.1% and 1.0% for sands 1–3 respectively; their densities are 1636, 1671 and 1614 kg/m³ respectively.

4. Lime characterisation

Six powdered quicklimes were sourced for initial evaluation and finally two were selected for mortar production as being indicative of highly reactive and less reactive quicklimes and of commercial interest. In the interest of conciseness only details of these two limes are included here and are detailed in the first column of Table 2. Given the range of suppliers there was no consistency in the measure of reactivity used to classify them. In order to assess their performance as agents for drying sand, mixes have been made using sands 1 and 3 and in all cases only a single mix has been made at each condition; hence, only broad conclusions will be drawn.

In the first series a 1 kg mix of sand 1, pre-soaked to yield free moisture contents of 5%, 7.5%, 10% and 12.5% after allowing for the absorption of the sand, and the quicklimes dosed at 50% of the stoichiometric ratio required for full conversion (i.e. 1.556 g of CaO for 1 g of water) were mixed in a domestic Kenwood Chef (speed 1 – approximately 60 rpm) for a period of 1 h. No account of the purity of the quicklime was taken in determining the weight of material to be added to each mix. A type K thermocouple was secured within the charge and the temperature logged every second. At intervals of 5 min the mixing was momentarily halted and the system weighed so that the weight loss due to evaporation could be determined. In the second series quicklime C1 was used at 40%, 50% and 60% stoichiometry together with sand 1 at free moisture contents of 5% and 10% and similarly evaluated.

In the third series, sand 3 was used to facilitate the separation of the lime from the aggregate following the mixing period, thus allowing a detailed analysis of the resulting slaked limes. Mixes of 1 kg of sand at 5%, 7.5% and 10% free moisture were prepared at 50% stoichiometric ratio and mixed for 20 min. Subsequently, the mixture was dried at 110 °C until constant weight achieved and then placed over a 0.15 mm sieve to separate the sand and

Table 1
Sand gradings.

Mesh size (mm)	1	2	3
4	99.3	95.0	100
2	95.8	83.8	100
1	91.7	67.4	98.4
0.5	74.8	45.6	3.8
0.25	31.3	25.2	0.2
0.125	7.6	13.6	0
0.063	1.9	7.1	0

Download English Version:

<https://daneshyari.com/en/article/256379>

Download Persian Version:

<https://daneshyari.com/article/256379>

[Daneshyari.com](https://daneshyari.com)