Authors: Dr Nicholas Riess &
Dr Andrew C. Gill

Contacts: nriess@lincoln.ac.uk
angill@lincoln.ac.uk

www.jblscience.org

Application Note: Analysis of Building Mortars and Cements for Restoration

Background and Approach

Often, builders and conservators are asked to repair buildings so that they are structurally sound but also in keeping with the immediate surroundings and using materials that are as close as possible to those used previously. Understanding how a building was originally constructed is a necessity in order to perform such restoration projects, so that a suitable, compatible material can be used to perform the restoration.

JBL Science have an established track record in analysing building materials, from palaces, and cathedrals to town halls or mills. By coupling our knowledge of building material mineralogy with our extensive analytical capabilities we can determine the nature and origin of most materials. For example, we can distinguish hydraulic and non-hydraulic lime mortars from more modern Portland cement-based materials as well as Pozzolans.

We initially break the material down into its constituent aggregate and binder fractions. The ratio of these imparts key physical properties to the material so characterising this ratio is a critical first step to understanding the original mixture used during preparation. The aggregate and binder are imaged to check they are separated and to enable a rough characterisation of grain size. Finally, the aggregate and binder are analysed by powder X-Ray diffraction (PXRD) to determine the mineralogies present. Here we present the approach outlined as applied to two render samples removed from an English church during the restoration process.

Figure 1. Preparation of mortar sample for analysis: subsamples are removed from the initial lump of mortar, ground using a mortar and pestle and sieved through filters of various mesh sizes.

Methodologies

Sample Preparation

The samples were initially ground to an even powder by hand using a validated method to ensure separation of the aggregate and binder fractions (Figures 1 & 2). A portion of the resulting powder (~5g) was then sieved through 0.140 mm and 0.045 mm sieves respectively. That fraction of the sample which is retained by the 0.140 mm sieve is designated aggregate whilst the fraction passing through the 0.045 mm sieve is determined to be binder. For the purposes of aggregate : binder ratio determination, the fraction which is retained on the 0.140mm sieve is designated as aggregate.

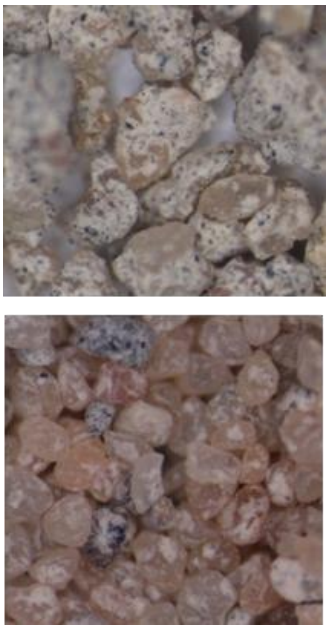

Figure 2. Partially separated (top) and completely separated (bottom) aggregate samples.

Light Microscopy

The aggregate and binder fractions were imaged using a Discover.V8 light stereo microscope (Zeiss) at x40 magnification with a scale bar placed alongside for estimation of grain size.

PXRD

The sieved aggregate/ binder fractions were analysed in triplicate using a Bruker D8 Discover powder X-Ray diffractometer with a UMC150 HTS stage in transmission mode. Cu K-alpha radiation X-ray generator at 40K V and 40 mA. Measurements were taken from 4 to 80 degrees 2-Theta with a step size of 0.02 degrees and a time per step of 0.5 sec.

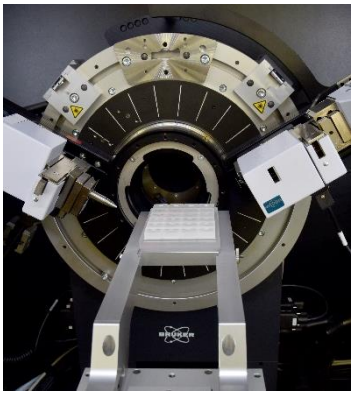

Figure 3. Bruker D8 Discover powder X-Ray diffractometer.

Findings

Determination of Aggregate : Binder Ratio

Both render samples were found to be comprised of aggregate and binder in a 3 : 1 ratio (by weight) which is typical for a mortar rather than a render which contains less cement (typically around 6 : 1) (see Table 1).

Sample	Aggregate		Binder		Aggregate : Binder		Aggregate Grain Size (mm)
	(g)	(cm^3)	(g)	(cm^3)	By weight	By volume	
Sample A	3.64	3.04	1.45	1.10	3:1	3:1	0.2-0.4
Sample B	4.60	3.84	1.38	1.05	3:1	4:1	0.2-0.4

Table 1. Indicative aggregate : binder ratios by weight and by volume (note: assumptions are made about binder density, using bulk densities for quartz sand – 1.20 g/cm^3; and powdered calcite – 1.31 g/cm^3). Aggregate grain-size is given as observed in the ground sample.

Determination of Mineralogy

Cross-referencing the diffraction patterns obtained from the render aggregates and binders revealed that both aggregates were comprised predominantly of quartz and calcite (Figure 4).The binder fractions also consisted of calcite and quartz with Portlandite, with naturally-occurring calcium hydroxide, and gypsum (calcium sulphate) also found at lower levels. In addition, clay (orthoclase) was also observed in sample A.

Summary and Potential Further Work

The high abundance of calcite and portlandite and lack of silicates associated with ordinary Portland cement (OPC) indicate that the material tested is a lime mortar. The presence of gypsum in the binder, suggests either the addition of gypsum, to speed up the setting process (usually observed in plasters, not mortars), or from the sulphation of calcite by sulphur in the environment (e.g. exposure to urban atmospheres, or internally, from close proximity to fireplaces. Orthoclase (feldspar) is an abundant mineral in the earth's crust which may be present as a mining artefact, of lime for example.

To summarise, using a standardised, validated methodology we were able to fully characterise a building sample (render) determining the relative amounts of constituents. In this way we were able to demonstrate the nature of the building material (lime mortar). This comprehensive analysis enables the client to understand the origins of the building material as well as informing and facilitating any future restoration. Our approach represents a general method to characterise building materials, but further supporting information can be derived using our analytical facility. For example, the presence of gypsum, or indeed other minerals, may be further supported by Raman imaging. Our solid materials and cultural heritage experts combine to offer a fully comprehensive service for building materials analysis.

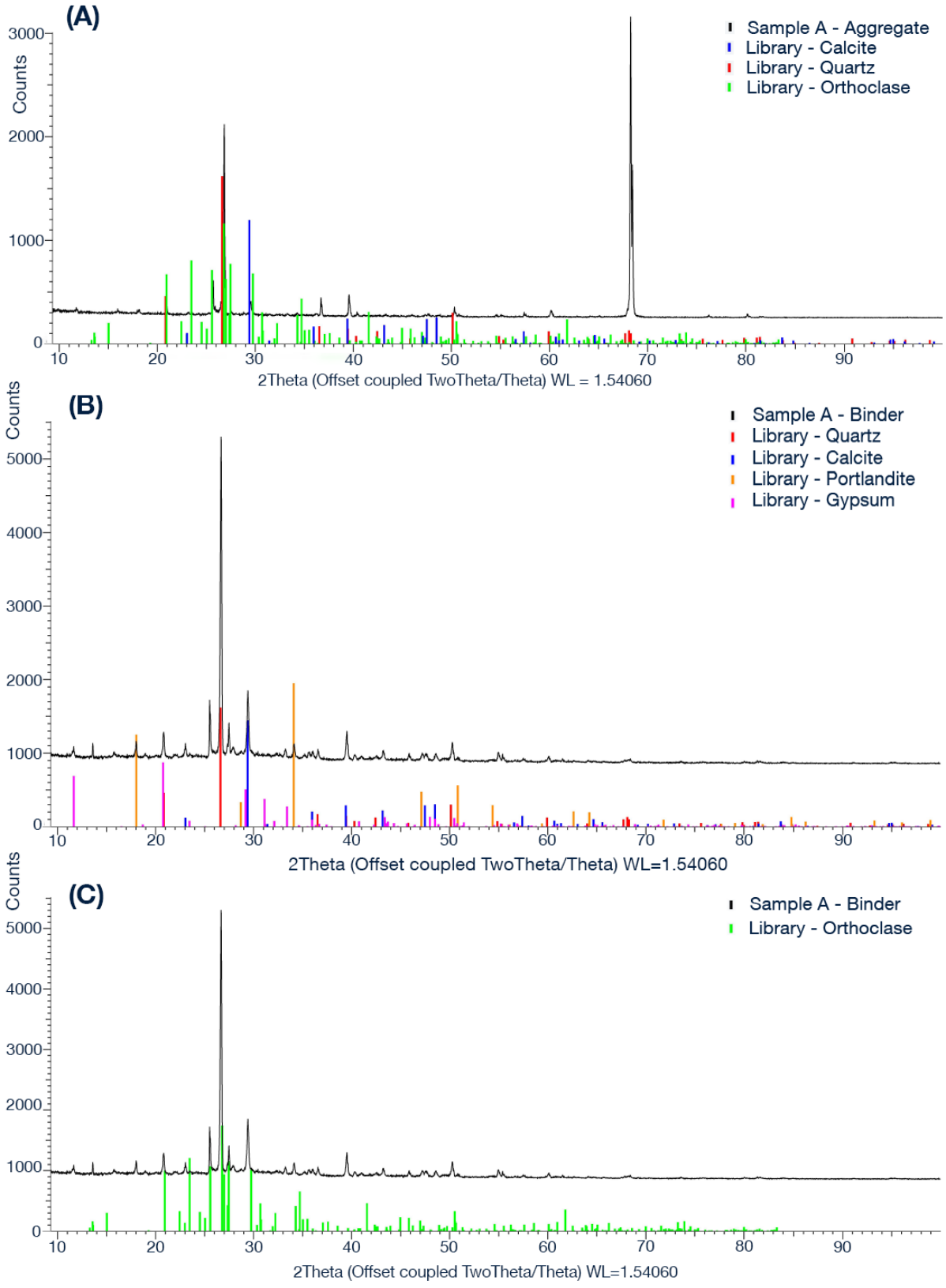

Figure 4. Diffractogram obtained from render samples A. A= aggregate fraction and B/C = binder fraction. Peaks from identified components are shown for comparison.

Web address: www.jblscience.org
Telephone us on: +44 (0)1522 835 258
Email us on: enquiries@jblscience.org

Find us on:
Twitter: @jbl_science
Facebook: @UoLJBLScience
LinkedIn: www.linkedin.com/company/jbl-science

University of Lincoln
Brayford Pool
Lincoln
LN6 7TS

Telephone: +44 (0)1522 886644
Fax: +44 (0)1522 886974
Email: enquiries@lincoln.ac.uk
www.lincoln.ac.uk

UNIVERSITY OF LINCOLN