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Render/Cast Stone Analysis
Wythenshawe Bus Garage

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Contact: Andrew Burns
Atelier MB

www.lincolnconservation.co.uk
info@lincolnconservation.co.uk
01522 835055

Investigator Team: Dr Sumit Konar (Solid Materials Instrument Scientist)
Dr Steve Prior (Senior Instrument Scientist)
Dr Peter Eaton (Microscopy Instrument Scientist)
Dr Nicholas Riess (Senior Project Scientist)

Lead Project Scientist: Dr Nicholas Riess (Project Scientist)

Address: The Bridge Advanced Engineering R&D Centre
Joseph Banks Laboratory
University of Lincoln
Green Lane
Lincoln
LN6 7DL

Client: Craig Mansfield Perry
Cardinal Global Logistics
Leestone Road
Sharston Industrial Estate
Manchester
M22 4RB

Site Address: Wythenshawe Bus Garage
Bradnor Road
Sharston
Wythenshawe
Manchester
M22 4TE

1.0: Introduction

2no. render/cast stone samples were sent to us by Andrew Burns of Atelier MB from Wythenshawe Bus Garage with sample locations recorded in figure 1. The samples were analysed with a view to understanding the composition of the render/cast stone. To achieve this, aggregate and binder portions were physically separated and analysed by powder X-ray diffractometry (PXRD). The resulting diffraction patterns were cross-referenced against a database to determine the dominant and minor phases present.

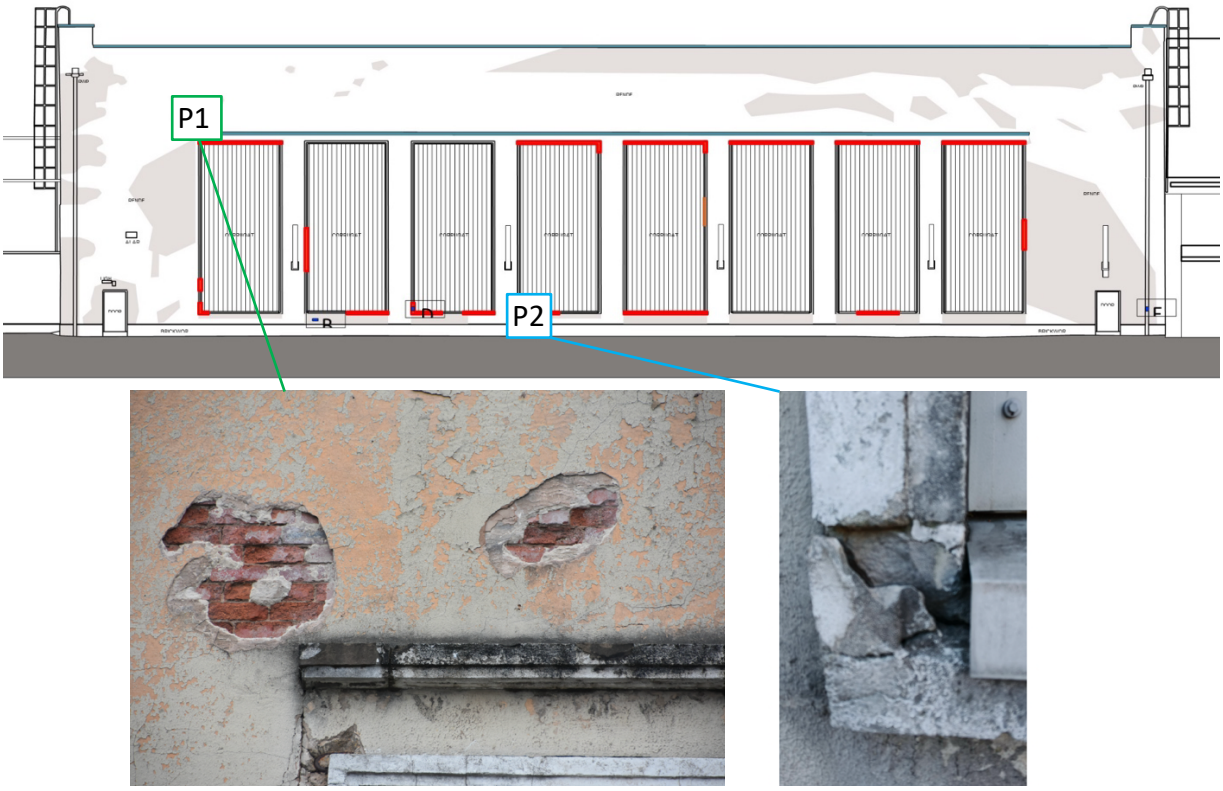


Figure 1: Harling Road elevation of the former Wythenshawe Bus Garage, showing sample locations, with photograph of render (P1) and cast stone (P2). (Image courtesy Paul Lodge, Atelier MB).

2.0: Methodology

2.1: Light Microscopy and PXRD

Each sample was ground, separately, by hand to an even powder. A portion of the powder (~5g) was sieved, initially through a 1.7mm sieve to remove any unbroken mortar and then through 0.140 mm and 0.045 mm sieves respectively. For the purposes of PXRD analysis that fraction of the sample which was retained by the 0.140 mm sieve was designated aggregate whilst that fraction passing through the 0.045 mm sieve was determined to be binder. For the determination of aggregate and binder masses, that fraction which was >0.045mm was designated aggregate whilst material < 0.045 mm was determined to be binder.

The two fractions were imaged at x20 magnification using a Stemi 508 light microscope coupled to an Axiocam 208 digital camera (Zeiss). The sieved aggregate/binder fractions were then analysed using powder X-Ray diffraction. *X*-Ray diffraction data were collected with a Bruker D8 Discover operating in with parallel beam geometry with Cu-Kα radiation (λ = 1.5406 Å). Data were collected with Coupled TwoTheta/Theta scans in the 2 θ-range 3-90° with dwell time of 0.4s for each 0.015° increment. Data were merged for analysis.

3.0: Results

3.1: General Observations / Aggregate:Binder ratios

Photomicrographs of the broken down and separated mortar sample components are shown below in Figure 2.

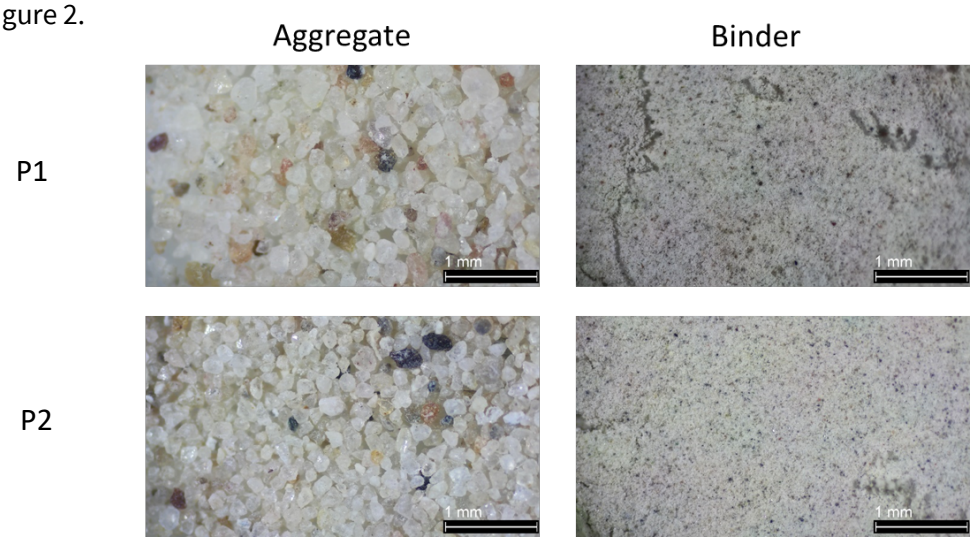


Figure 2: Micrographs of the ground render/cast stone samples P1 and P2.

The samples appeared similar to each other with each consisting of a fine-grained, pale aggregate fraction and binder comprising an off-white powder interspersed with dark specks.

The relative proportions of aggregate to binder for each sample are summarised below in Table 2 together with the aggregate to binder ratios. Sample P1 had a more varied aggregate fraction whilst sample 002 appeared more fine-grained. There were glass-like fragments apparent in both aggregates and distinct green layers observed on particles in the P1 aggregate. Both binders were pale powders with multi-coloured flecks dispersed throughout, likely remnants of the aggregate fraction.

Sample	***Aggregate***		***Binder***		***Aggregate:Binder***		***Aggregate Grain Size***
	(g)	***(cm³)***	***(g)***	***(cm³)***	***By weight***	***By volume***	***(mm)***
BLPr_00352_001	*2.50*	*2.08*	*1.27*	*0.97*	*2.0:1*	*2.2:1*	*<0.5*
BLPr_00352_002	*2.59*	*2.16*	*1.65*	*1.26*	*1.6:1*	*1.7:1*	*<0.5*

Table 1: Approximate aggregate:binder ratios for each sample by weight and volume.

3.2: Mortar Mineralogy

The results (mineral phases) from the powder X-ray diffraction analysis are summarised in Table 3 and the findings for each sample are summarised in turn below.

Sample	Fraction	Calcite	Quartz	Alite	Larnite	Gypsum	Portlandite
P1	Aggregate	++	+++++				
	Binder	+++	+++++		++	+	++
P2	Aggregate	+++	+++++				
	Binder	+++++	+++++		++		

+++++ dominant
++++ major
+++ minor
++ trace
+ possible

Table2: Mineral phases present in samples

Sample P1 (External render)

Aggregate

Quartz was the dominant phase present with calcite present as a trace phase.

Binder

Quartz was again dominant with calcite now present as a minor phase. In addition, larnite (or belite) and Portlandite were present as trace-level phases. Gypsum was also tentatively identified.

Summary

Based on the mineralogy and appearance the aggregate appears to be sand (quartz) based. The presence of calcite and larnite/ belite, coupled with the absence of alite, indicate that the mortar is a **hydraulic lime mortar** (or natural hydraulic lime mortar). Portlandite was also observed (this is non-carbonated lime), indicating that a portion of the lime mortar has not fully cured. The presence of significant gypsum in the binder, suggests either the addition of gypsum, to speed up the setting process, or from the sulphation of calcite by sulphur in the environment (e.g. exposure to urban atmosphere).

Sample P2 (External cast stone)

Aggregate

Quartz was the dominant phase present with calcite present as a minor phase.

Binder

Both quartz and calcite were present as dominant phases with larnite (or belite) present as a trace phase.

Summary

Based on the mineralogy and appearance the aggregate appears to be sand (quartz) based. The presence of calcite and larnite/ belite, coupled with the absence of alite, indicate that the material is formed of a **hydraulic lime mortar** (or natural hydraulic lime mortar).