APPENDIX H: Alternate Preparation of Hot Lime Mortars: Outline Method Statement

Hot Lime Mortar: Hand Mixing

Storage of Materials:
Quicklime stored in sealed containers in a container or shed, Aggregate stored covered to prevent ingress of organic matter.

Plant / Materials / Equipment to be used:
Buckets, shovels, hoe, water supply, wheelbarrow, tarpaulins/insulation. Trowels

Certification / test details:
NA

Significant risks:
Burns, lime burns, damage to eyes, inhalation of lime dust, , manual handling.

Proposed sequence of works:
Hot Lime mixing by hand

Before starting work ensure all PPE is in place, barrier cream has been applied and that nitrile gloves are worn below standard work gloves

1. Prepare mixing area (area to be covered and protected from inclement weather).
2. Place ply sheets on ground to provide clean level mixing area or use concrete base.
3. Measure out required quantity of quick lime, water and aggregate using batching boxes or appropriately sized buckets, *Ensure that separate buckets are used for each material and that the quick lime bucket is kept dry, ensure that only small quantities of quick lime are taken from the store as required and that the lid is replaced on the container when not in use. Ensure buckets do not contain more than 15kg of quicklime or sand*
4. Mix dry aggregate and quicklime together by turning over with the shovel or hoe to ensure the materials are thoroughly blended.
5. Make a well in the centre of the lime and aggregate mix and carefully add the water.
6. Using a long handled hoe or shovel start to draw the aggregate into the water, keep moving the mix in to the water to ensure all the water is incorporated through the aggregate and quicklime .
7. Alternatively, instead of 5. & 6. Above, the dry mix can be spread out over the mixing area and wetted using a water hose with a spray attachment, constantly turning over the mix with the shovel or hoe until it is the required consistency.
8. It is not sufficient to simply turn the materials over with a shovel or a hoe, they need to be worked together physically with either the back of the shovel or the push and pull action of the hoe.

Please note that good trade practice will prevent many of the risks associated with hot-lime mixing, working cleanly and using the tools in a controlled manner is essential. The material becomes VERY hot during the mixing/slaking process and is caustic, great care is needed during all process involving hot-lime.

PPE to be worn:
Hard hat, hi visability vest, safety glasses, gloves, safety boots, half face respirator *(not paper)* barrier cream

Hot Lime Mortar: Mixing in a Mixer (drum or pan)

Storage of Materials:
Quicklime stored in sealed containers in a container or shed, Aggregate stored covered to

prevent ingress of water and debris.

Plant / Materials / Equipment to be used:
Pan or drum mixer, buckets, shovels, hoe, water supply, wheelbarrow, tarpaulins. trowels

Certification / test details:
NA

Significant risks:
Burns, lime burns, damage to eyes, inhalation of lime dust, electric shock, manual handling, power tools

Proposed sequence of works:

Hot Lime mixing in a mixer (drum or pan)

Before starting work ensure all PPE is in place, barrier cream has been applied and that nitrile gloves are worn below standard work gloves

1. Prepare mixing area (area to be covered and protected from inclement weather).
2. Measure out required quantity of quick lime, water and aggregate using batching boxes or appropriately sized buckets, *Ensure that separate buckets are used for each material and that the quick lime bucket is kept dry, ensure that only small quantities of quick lime are taken from the store as required and that the lid is replaced on the container when not in use.*
3. Add half the water and half the sand to the running mixer.
4. Add half the quick lime to the mix and allow to run for about 5 mins. *Take care when adding the quick lime to ensure that the minimum amount of dust is created*, *please note that careful and efficient use of all tools will result in a safer process. Keep tool handles clean and do not allow materials to be thrown into the mixer or dropped into the buckets from a height.* Do not stand in front of the drum mixer or look directly into the drum while mixing.
5. During this time keep a careful watch on the slaking lime to ensure the mix is not too dry should the mix start to dry out add additional water to control the slaking process. *Only add small quantities at a time in order to avoid drowning the lime also note that a wet mix will splash*.
6. Add the remaining aggregate and quicklime this allows you to control the mix and reduces the chance of over watering the mix.
7. Again control the slaking process by adding small quantities of water. *Depending on the type of quicklime the reaction can be very rapid with the mixture drying out and choking the mixer (particularly drum type mixers) should this happen the mixer should be stopped and the mixture loosened up with a long handled hoe.*
8. Allow the mix to run until all traces of quicklime have broken down and the mix is of the desired consistency.
9. Empty the mix out into a barrow or tub taking care to avoid splashes, Should smaller quantities be required at a time (pointing) the mix can be left in the mixer and the required quantity trowelled out. This allows the mix to be knocked up by running the mixer should it start to stiffen up.

Please note that good trade practice will prevent many of the risks associated with hot-lime mixing, working cleanly and using the tools in a controlled manner is essential. The material becomes VERY hot during the mixing/slaking process and is caustic, great care is needed during all process involving hot-lime

APPENDIX I: Preparation of Hot Lime Mortars: Outline Risk Assessment

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when ?	Done
Slips and trips	*Staff and visitors may be injured if they trip over objects or slip on spillages and waste*	*Carry out general good housekeeping. All areas are well lit including stairs. There are no trailing leads or cables. Keep work areas clear, Wear appropriate footwear and refuse access to site for visitors who do not have correct footwear*	*Monitoring of process and adaptation if different methods or tools are used*	*Supervisor*	*on-going*	*on-going*
Burns (caustic and heat)	*Staff and visitors may be injured if they come into contact with hot lime*	*Carry out general good trade practice. Appropriate tools and equipment are used for the process. Protective clothing and gloves are worn during mixing operations. Barrier cream is applied before use. Tool handles kept clean and free of lime*	*Monitoring of process and adaptation if different methods or tools are used*		*on-going*	*on-going*
Manual Handling	*Staff*	*Materials to be mixed are supplied in 25kg tubs or bags and are moved using barrows, when mixing materials are placed in batching tubs to reduce weight*	*Monitoring of process and adaptation if different methods or tools are used*	*Supervisor*	*on-going*	*on-going*
Damage to eyes	*Staff and visitors may be injured if they come into contact with hot lime*	*Good trade practice, eye protection worn during Hot Lime mixing, clear segregation of mixing area, no visitors allowed near mixing area without correct PPE*	*Monitoring of process and adaptation if different methods or tools are used*	*Supervisor*	*on-going*	*on-going*
Inhalation of dust	*Staff and visitors may be injured if they come into contact with dust produced during hot lime mixing*	*Good trade practice, P3 Half Face Respirator worn during Hot Lime mixing, clear segregation of mixing area, no visitors allowed near mixing area without correct PPE*	*Monitoring of process and adaptation if different methods or tools are used*	*Supervisor*	*on-going*	*on-going*
Use of power tools	*Staff and visitors*	*Power tools visually inspected before use*	*Monitoring of process and*	*Supervisor*	*on-going*	*on-going*

What are the hazards?	Who might be harmed and how?	What are you already doing?	Do you need to do anything else to manage this risk?	Action by whom?	Action by when ?	Done
	may be injured by coming into contact with moving parts or by electric shock	*(daily) , regular testing and maintenance for all power tools, ensure all guards are in place, ensure all staff using tools are trained by a competent person and are familiar with their use.*	*adaptation if different methods or tools are used*			

APPENDIX J: HLM PROJECT – SUPPLEMENTARY INFORMATION FROM LABORATORY TESTING (90 DAYS)

An assessment of the depth of carbonation was determined on both the cast prisms and on the mortar in the test panels. This was determined on a number of samples from each mix using a phenolphthalein indicator solution to indicate reduced pH, which was taken, in this instance, to infer that carbonation had occurred.
The following samples were obtained from the test panels constructed during the workshop at Portumna Castle on the 8th & 9th July 2014.

The samples received for assessment were as follows:

Mix No. 1 (Quicklime/sand at 1:4)

1 sample from Pointing panel

1 sample from Harl panel

1 sample from wall panel

Mix No. 2 (Quicklime/sand at 1:4 + 10% shell by volume of lime)

1 sample from Pointing panel

1 sample from Harl panel

1 sample from wall panel

Mix No 3 (Quicklime/ NHL3.5 – St. Astier/sand at 1:1:6)

1 sample from Pointing panel

1 sample from Harl panel

1 sample from wall panel

Mix No. 4 (Quicklime/ NHL3.5 – Roundtower/sand at 1:1:6)

1 sample from Pointing panel

1 sample from Harl panel

1 sample from wall panel

The mean results of the carbonation tests are reported below, along with the results of site tests carried out on the actual panels, at a mortar age of 90 days. Depths are in millimetres measured from the outer surface.

Table i: Depth of carbonation (Phenolphthalein Test) depths: site measurements

Mix	Pointing	Harling	Wall Panel
1	Nil to 10mm	4 to 6mm	Nil to 5mm
2	20mm to full depth	6mm	Nil to <1mm
3	9mm	8 to 10mm	Nil to <1mm
4	4 to 8mm	4 to 6mm	Nil to <1mm

Table ii: Laboratory Measurements on site samples & cube specimen

Mix	Pointing	Harling	Wall Panel	Cube Sample
1	Surface <1mm	2.2 to 6.0mm	Nil to 5.4mm	0.2 to 1.3
2	8.4mm to full depth	Nil to 5.2mm	Nil	0.2 to 2.1
3	4.0 to 8.1mm	Surface <1mm	Nil to 3.0mm	0.4 to 2.2
4	Patchy- 3.8mm	Surface <1mm	Nil to <1mm	0.3 to 1.8

A sample from each mix was also digested in dilute hydrochloric acid to allow the mix composition to be checked, with a sample of the sand also treated in the same manner to allow for the correction of any acid soluble components in the sand.

Aggregate
Acid Soluble content: 0.93% by dry mass of aggregate

Table iii: Mix composition - as mixed, corrected for acid soluble in aggregate.

Mix proportions by volume				
Mix no.	**1**	**2**	**3**	**4**
Quicklime	1.0	1.0	1.0	1.0
NHL	-	-	0.86	0.92
Sand	3.90	3.50 (shell content approx 0.40)	5.31	5.22
Design mix	1: 4	1:4	1: 1: 6	1: 1: 6

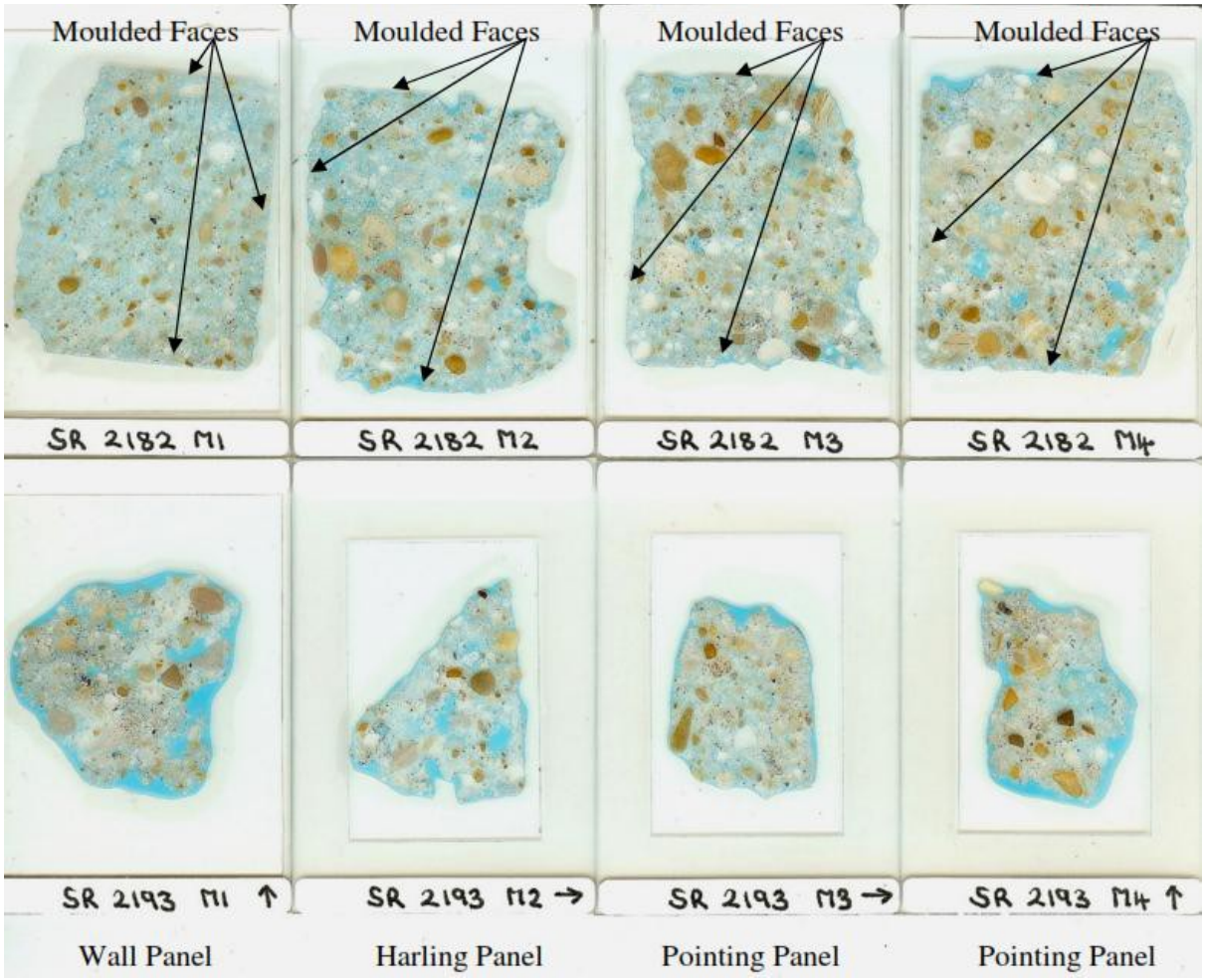
Thin Section Examination
Thin sections were prepared from one 50mm cube from each of the four mixes, plus one representative sample from each of the mortar samples obtained from site. All were resin impregnated, with a blue dyed resin, and mounted on 50 x 75mm slides for examination in the polarised light microscope. The thin sections were made from the following:

Sample Cubes: sample reference SR2182 M1 to M4
Mix No. 1 – 90 Day cube sample
Mix No. 2 – 90 Day cube sample
Mix No. 3 – 90 Day cube sample
Mix No. 4 – 90 Day cube sample

With the following samples from the site sampled material: sample reference SR2193 M1 to M4
Mix No. 1 – Wall panel mortar
Mix No. 2 – Harl mortar
Mix No. 3 – Pointing mortar
Mix No. 4 – Pointing mortar

Initial observations from thin section examination are as follows:
Plates are shown in both Plane polarised light (ppl) and Cross polarised light (xpl) to highlight specific features.
These show that all of the mortars have behaved in the same manner as high calcium limes (non-hydraulic lime mortars) in that initial stiffening due is due to drying of the paste with the formation of early drying shrinkage cracks, with these forming as a network of micro-cracks. Resulting in a high microporosity, with well connected channel ways, indicating that the mortar will be both porous and permeable with a high vapour permeability. The porosity as determined from modal analysis was found to be in the region of that determined by measurement, albeit slightly lower, as the micropores that will be present are below the resolution of the microscope.

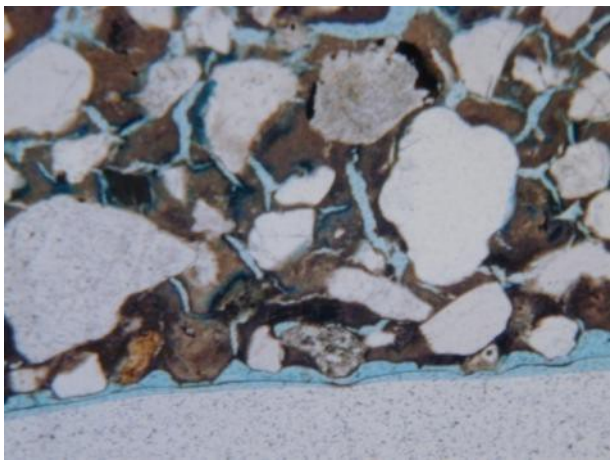
An indication of the porosity can be gained from an examination of the scanned images of the slides, see below, where the porous condition of the mortar is highlighted by the presence of the blue dye included in the encapsulation resin; see the colour of the slides below.

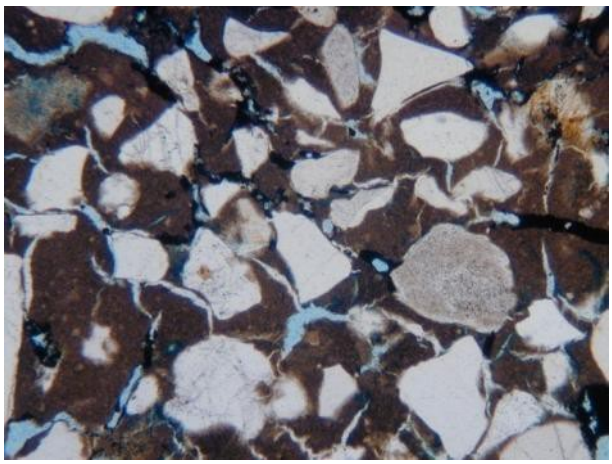


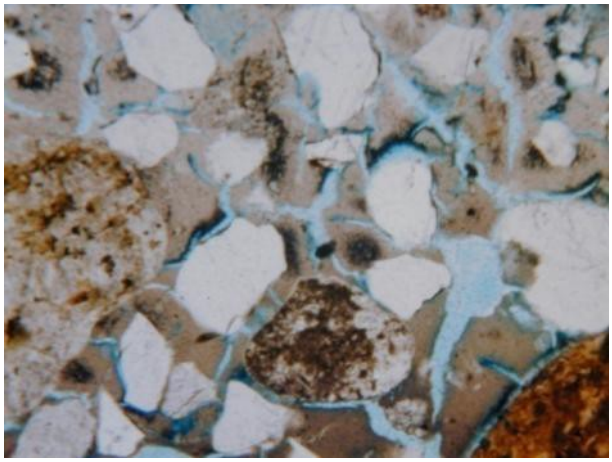
Thin sections prepared from cube specimens used in the measurement of density, water absorption and porosity (upper four samples) and those prepared from samples of mortar taken from the test panels after they had matured for a period in excess of 90 days (lower four samples).

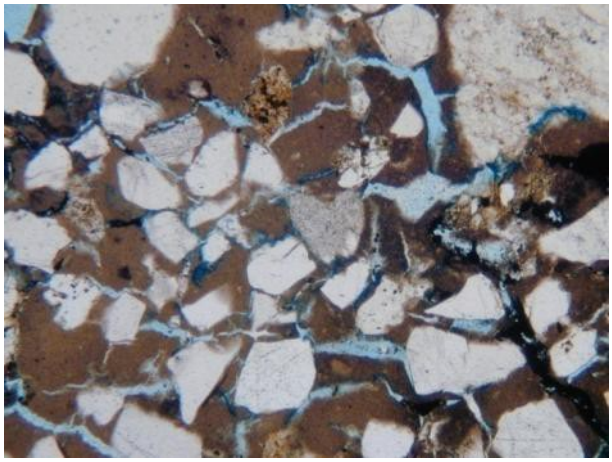
The following series of thin section images illustrate, side-by-side, each of the mixes, for ease of comparison. The left hand images are of the 90 day cube samples and the right hand images are the site samples from the wall panels.

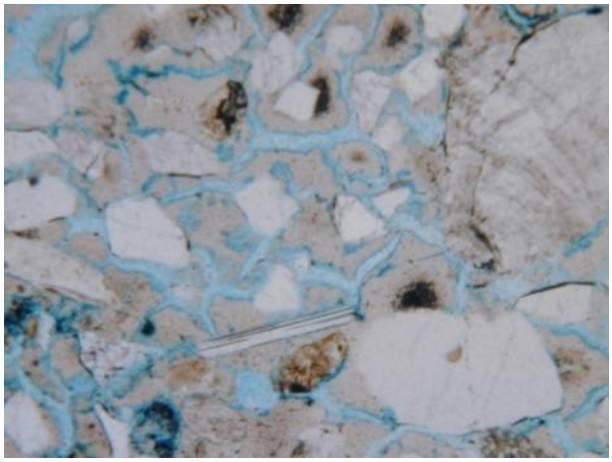
Mix No. 1 – 90 Day cube sample **Mix No. 1 – Site sample from Wall panel**

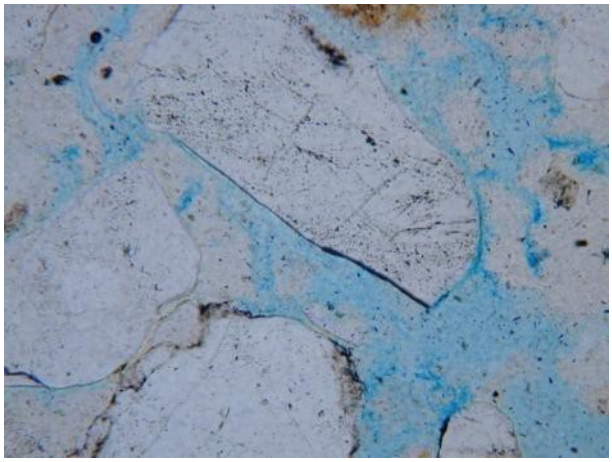


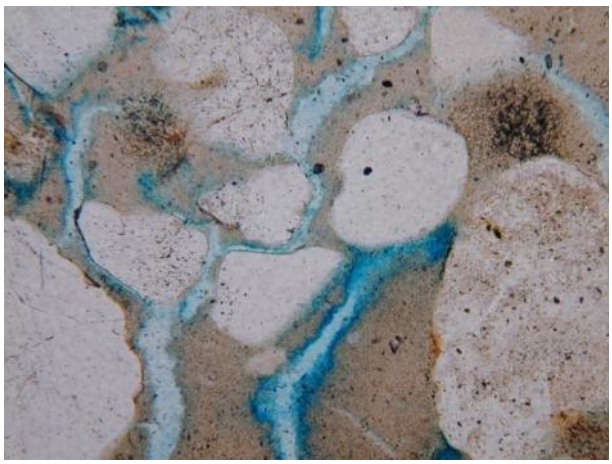


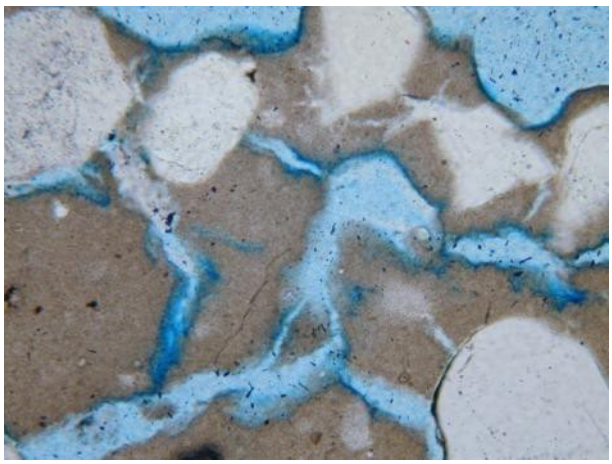


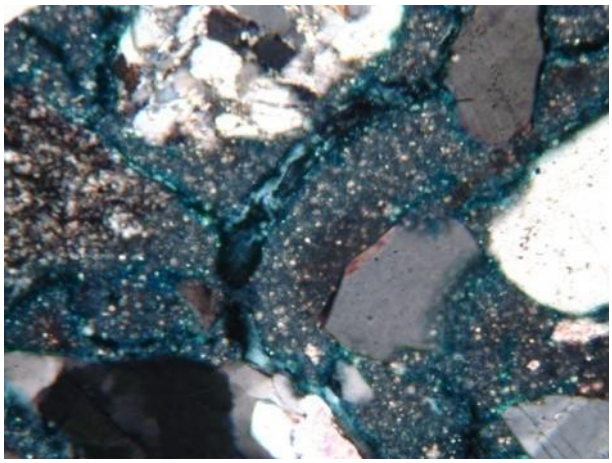


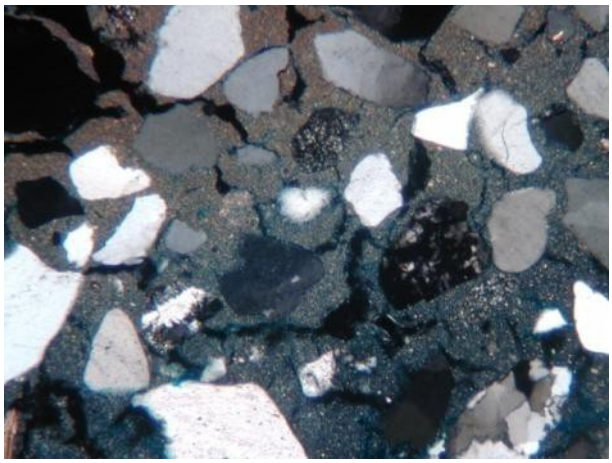


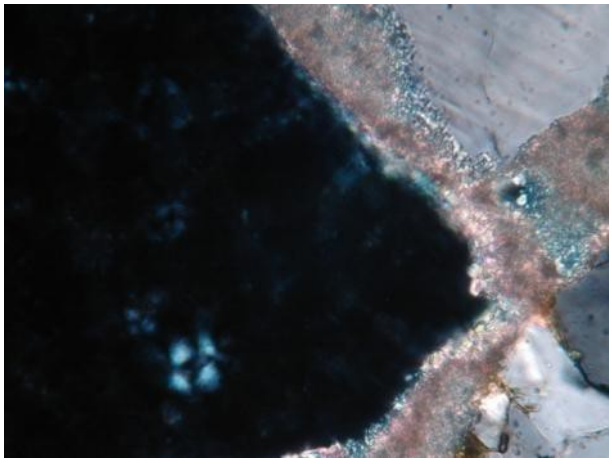


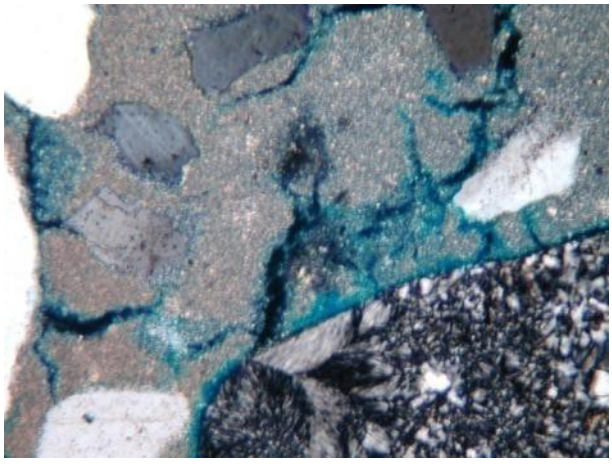






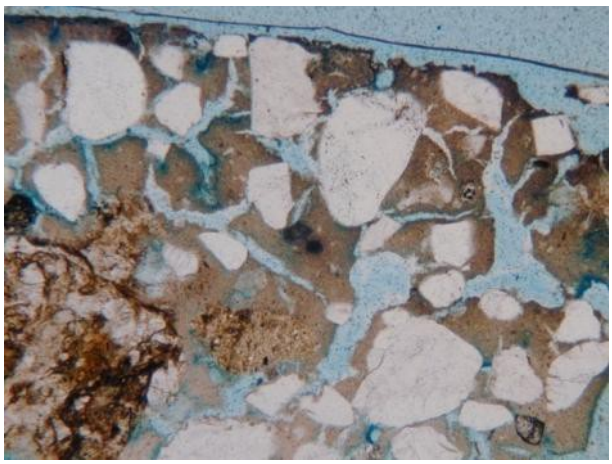


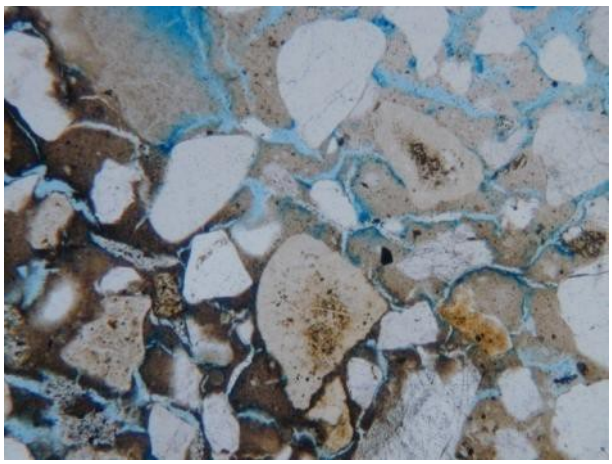


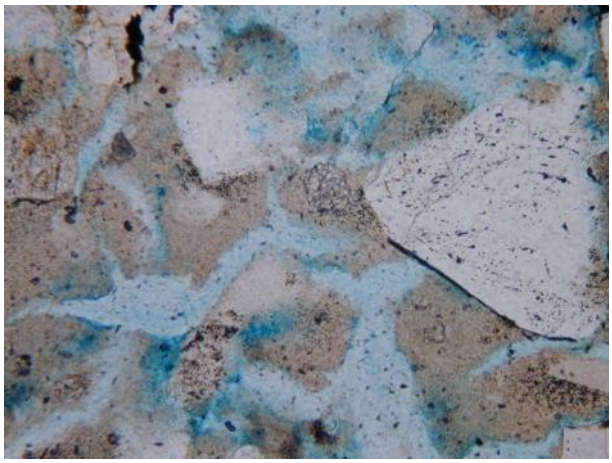


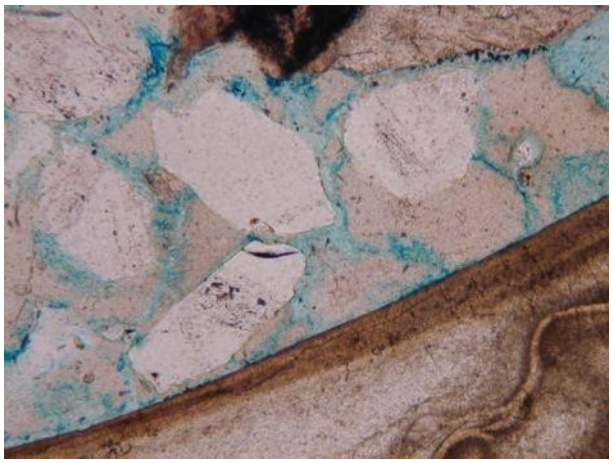
Mix No.2 – 90 Day cube sample

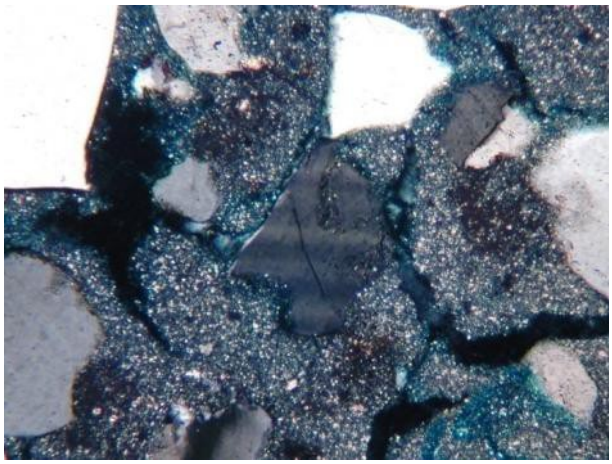
Mix No. 2 – Site sample from Harl panel

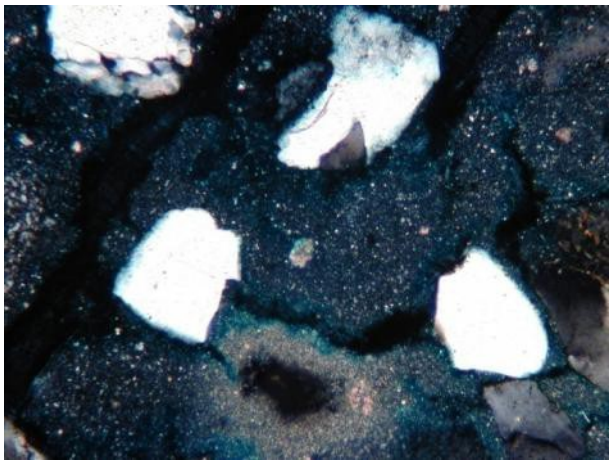


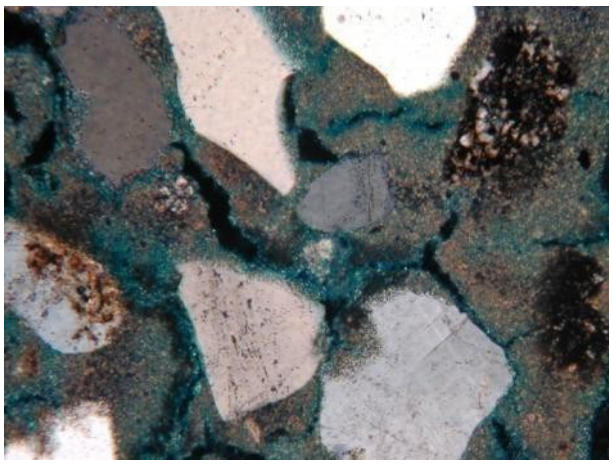


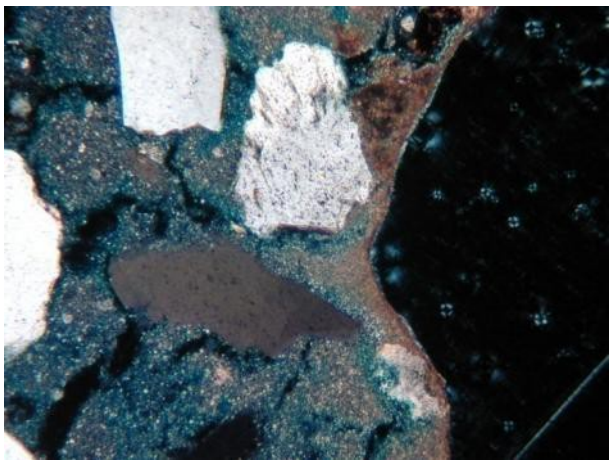




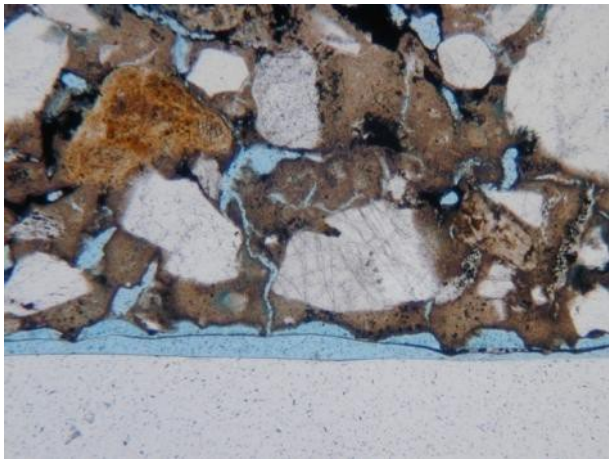




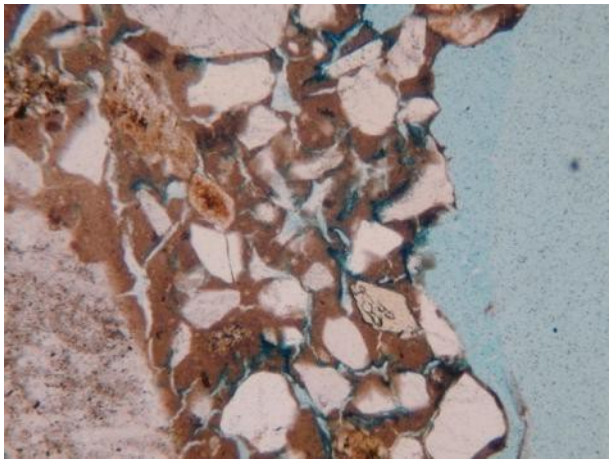


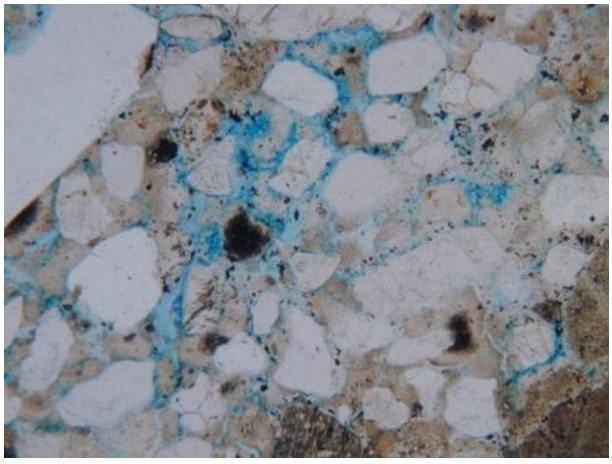


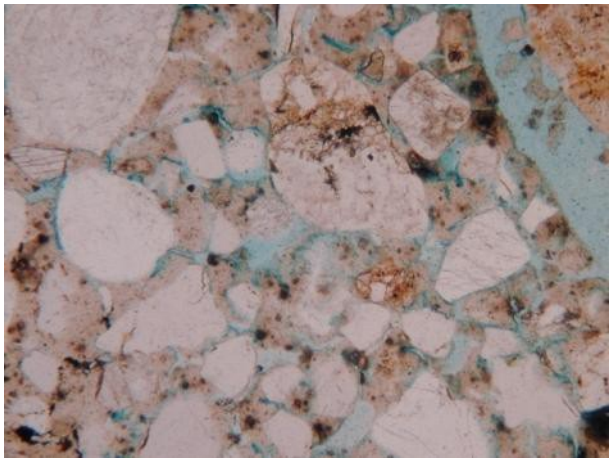
Mix No.3 – 90 Day cube sample

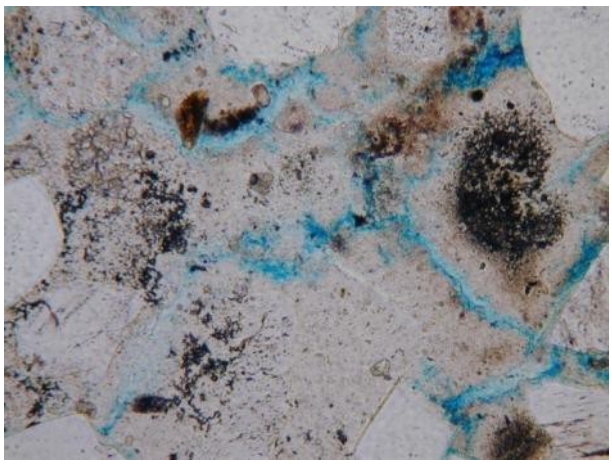


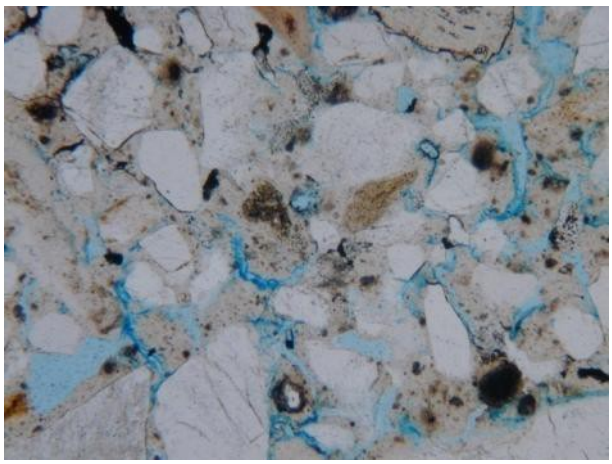
Mix No. 3 – Site sample from Pointing panel

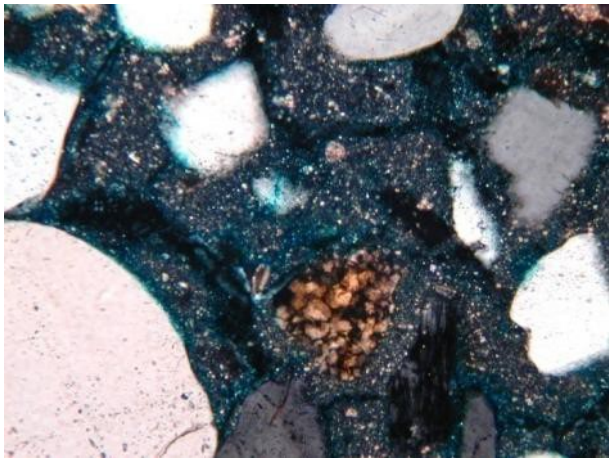


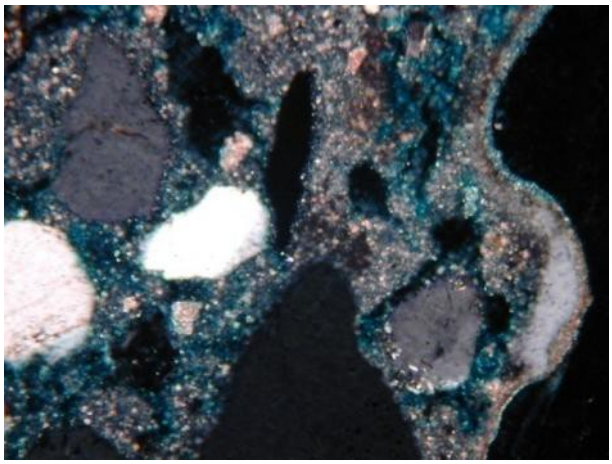


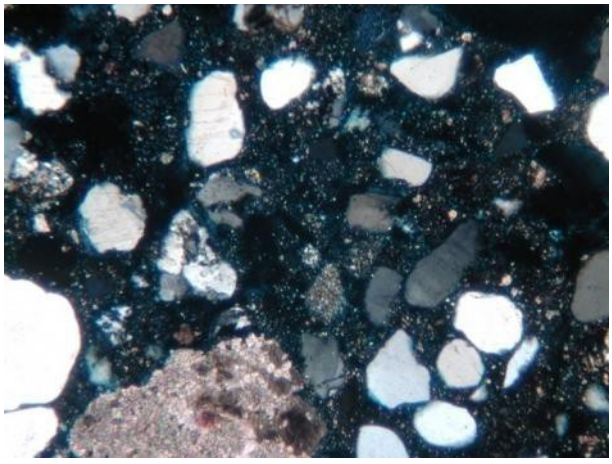


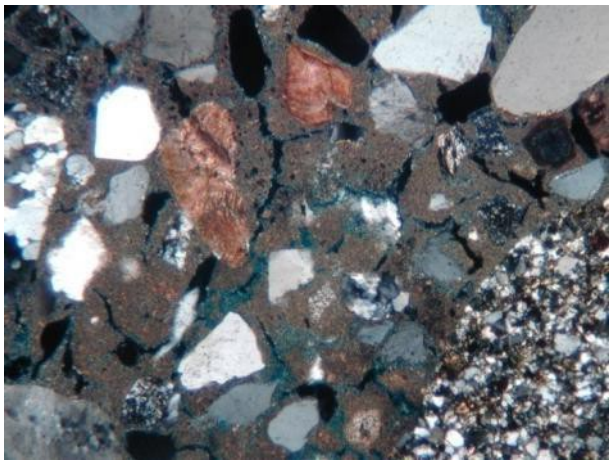






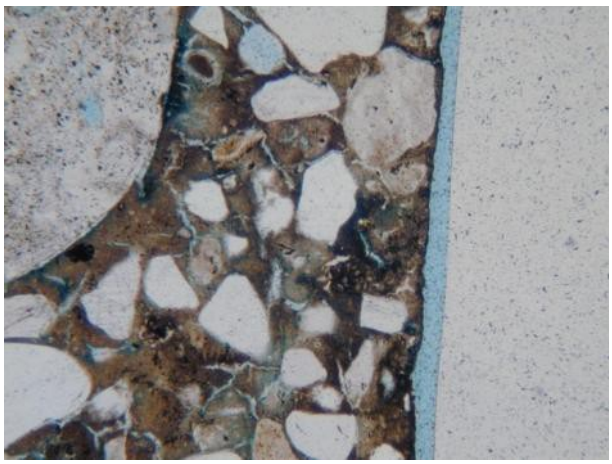


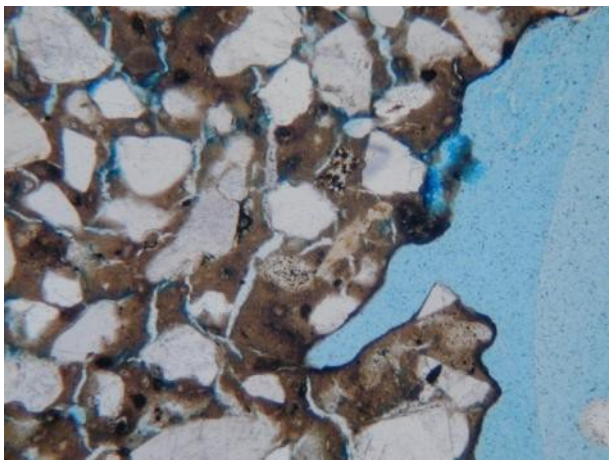


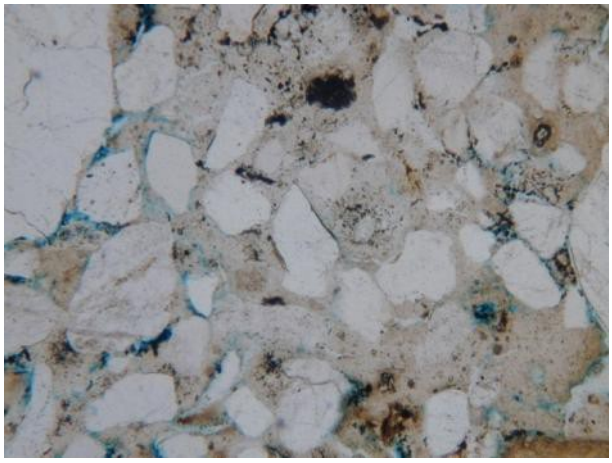


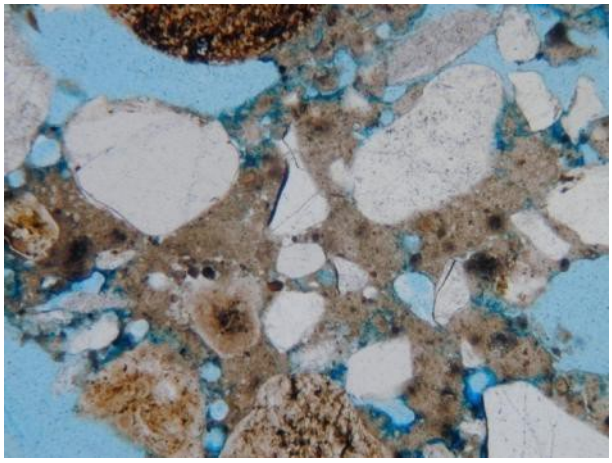
Mix No.4 – 90 Day cube sample

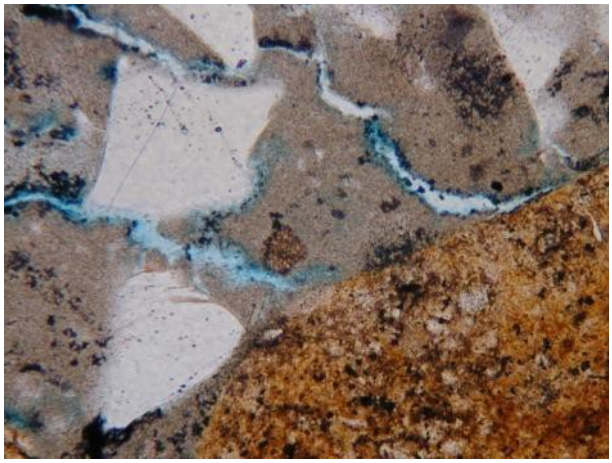
Mix No. 4 – Site sample from Pointing panel

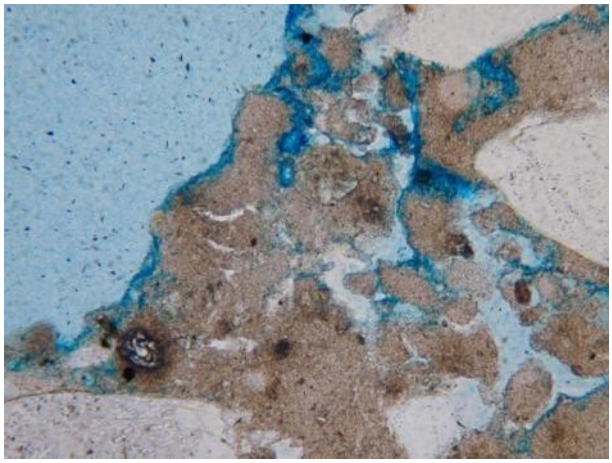


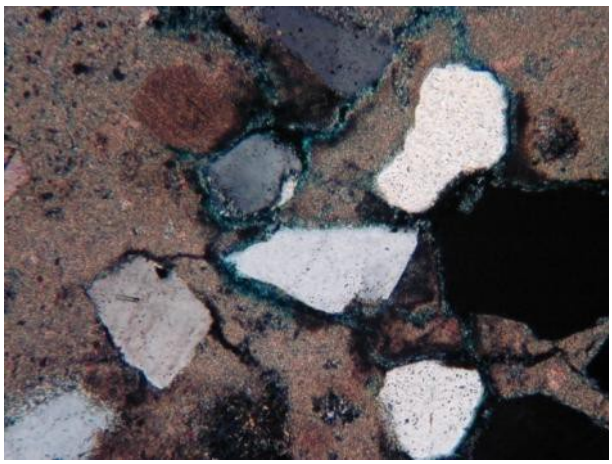


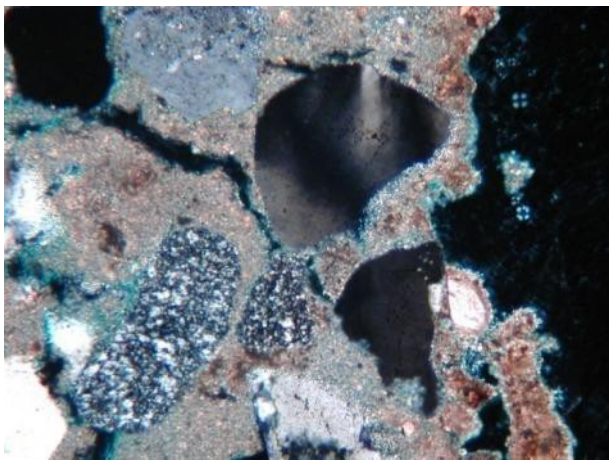












APPENDIX K: Associated Projects

The Restoration of the Lime Kiln at Russborough House, Co Wicklow.

Lisa Edden, Patrick McAfee & others.

Key personnel

Russborough	Eric Blatchford CEO
Architect + PSDP	James Howley of Howley Hayes Architects
Project Coordinator and Engineer	Lisa Edden Consulting Structural Engineer
Stonemason	Patrick McAfee
Kiln Consultant	Stafford Holmes Architect
Construction managers + PSCS	Henry Snell + Alan McGrath
Restoration	Conservation and
Mortar mix design & analysis	Craig Frew, Ivor McElveen, Hugh Dorrian, plus Bill Revie

Lime Kiln 2007

After excavation works April 2013

The project has been sponsored by Russborough (The Alfred Beit Foundation) and The Building Limes Forum Ireland.

Materials supplied so far by Clogrennane – CRH / Traditional Lime Company / Lochplace / Irish Pebble Co / Lime Store / Limeworx

After enabling and preparation works the restoration of the kiln commenced with a Hot Mix Workshop 1st and 2nd May 2013 with a gathering of stonemasons; drystone wallers; plasterers; brick layers; architects and engineers some of whom had travelled from France; Co. Clare; Wexford; Tipperary; Belfast and London.
Craig Frew from Scotland and the rest of the HLM Project Team were present to give a hand, as well as Stafford Holmes from Warwickshire, who has much experience in repairing and commissioning historic kilns.

There were further Workshops in June, July and September to progress the works.

The 2014 Workshop and lecture, 14th -17th July, had the attendance and participation of students studying under the Society for the Protection of Ancient Buildings (SPAB) Fellowship and Scholarship Programme. Work concentrated on daubing out the pot with clays dug from Russborough, setting cobbles in the same clay and pointing with an NHL mortar. Wall building and pointing in the lower draw area of the Kiln continued using hot-lime mortar gauged with hydraulic lime.

Further works were carried out in September when Kirwan Masonry Services voluntary helped to complete the south draw wall – again all using Hot Lime Mortars.

Over a 100 volunteer stonemasons and others have turned their hands to mixing both hot-lime and clay mortars, shifting & laying stones; repairing arches etc, devoting many hours to this worthwhile project.

The kiln smoking for the first time in 70 years. July 17th 2014

Early Mortared Masonry and the Mortar Mill at the Irish National Heritage Park, Ferycarrig, Co Wexford.

Patrick Hickey & Ronan O'Flaherty

Lime mortars make their first appearance in Ireland in the Early Medieval period, apparently used exclusively for the construction of religious buildings, such as churches and round towers.

It is estimated that around 1100AD, mortared masonry started to spread into secular military fortification, but it remains the case that it is in the religious arena that mortar predominates. The ability to work with mortar was critical to the appearance of what was to become the iconic symbol of early medieval Ireland, the Round Tower. Standing up to 30m tall these structures only became possible when the art of mortared masonry had been mastered.

The quantity of mortar being used in these towers, as well as in some of the early churches is the strongest indication that some sort of mechanical production must have been involved. In the later period, and particularly the post-Norman period with the construction of great abbeys and castles, there was clearly a need for mortar production on an industrial level. Fortunately, from excavations further afield we can hazard a guess at how that might have been achieved. Excavations at some 37 sites across Europe have produced evidence for use of a machine which archaeologists with unusual clarity have simply described as 'mortar mixers' (Hüglin, 2011). They date mainly from the eighth and ninth centuries but seem to have continued in use right up to the sixteenth century. None have yet been found in Ireland, but five examples are known from Britain and it is highly likely that these machines were also used here, perhaps even in the pre-Norman period, but have just not been recognised in the archaeological record.

An experimental archaeology project is now under way in Wexford, where researchers are testing a full-scale reconstruction of one of these medieval mortar mixers, led by local stonemason Pat Hickey, who has a long standing interest in traditional limes and mortars, as well as in traditional building techniques. Archaeologist Ronan O'Flaherty, who is a director of the Irish National Heritage Park, is providing archaeological research and other support. While there has been some study into the composition of medieval mortars themselves – notably by Jason Bolton – the process by which they were produced and the implications in terms of expertise and 'site management' has barely been touched at all. The purpose of the Wexford project is to try to shed some light on these questions, by exploring the mechanics and productivity of these mortar-mixers, as well as looking at the implications for the use of hot-lime mixes.

The project is in its very early stages at present but has already produced some very practical insights into the operation and efficiency of these machines. The mechanism seems easily transportable and can be set up quite quickly onsite, and has proved very effective in mixing large quantities of mortar. The archaeological signature would be quite limited, however, confined to the remains of a circular pit about 2.5m wide, with mortar remains at the base, and in all likelihood located outside the constructed area, which in turn may explain why remains are so rarely found. It is also considered that a study of techniques and mixes might provide some useful pointers to the *sources* of the overseas influence on Ireland and from where it was drawing its technical expertise. A short initial paper is nearing completion at time of writing. In the meantime, plans are underway to move activities to the Irish National Heritage Park in 2014 for further experimentation.

Hüglin, S. 2011 Medieval Mortar Mixers revisited: Basle and beyond. *Zeitschrift für Archäologie des Mittelalter*, Jahrgang **39,** 189-212

Mixing hot-lime mortar.

Medieval serfs at work.

APPENDIX L: Testimonials

Testimonials:

ST CANICE'S STEPS & ARCH, Kilkenny

Structural repair to 17th century collapsed arch and steps with the consolidation of adjacent limestone random rubble walls.

Mix ratio 1: 1: 5.0 NHL 3.5 (Roundtower Grey): Quicklime/sand, plus 10% aggregate 1/4" pea gravel

Other mix formulations were used in specific locations for testing which are being kept under observation.

Testimonial:

- Mix in small quantities by hand; use hot - within 1 -3 hour.
- Easy to use and had excellent adhesion to the applied surface.
- It was ideal for working in adverse weather conditions.
- Cost effective as reduction in amount of NHL lime with better bulking.
- Now prefer this material to any alternative mixes being used for stonework.

Tallis & Co, Kilkenny.

Finished arch & steps with hot-lime harling to facing wall.

View looking down steps on completion.

RUSSBOROUGH, Co. Wicklow

Restoration of 19th century lime kiln.

Mix Ratio 1:1:5:0.5 NHL 5 (St Astier): Quicklime: coarse sand: Limestone dust.

Testimomial:
Cleaner work with no runs of mortar down the face and better quality of work with increased production as well as:

- More solid full joints
- Allowed the wall to be built higher than normal without leaks and mortar slump
- Prevented leaching from the face of the work where the stones and sand are wet
- Allow wet stones to be laid and stabilised
- Very wet sand could be used without adverse effects on the final consistency of the mix because of the massive absorption of water by the quicklime
- Arch Centres can be removed from arches and arch barrels the same day resulting in fewer forms being required.

- Allows surface finishing of mortar joints the same day.

Less water in the mix means reduced vulnerability to cold weather and frost and when gauged with NHL and other hydraulic materials the heat created in the hot mix accelerates setting times of those hydraulic materials.

Pat McAfee, Mason, Instructor & Author.

Before reconstruction after clearance

After completion with kiln cover.

CASTLEBORO HOUSE, Coach Yard Entrance Stabling, Co Wexford

Replacing covered (concealed) vertical slate cladding of 1815.

Mix Ratio: 1: 1.5: 5. NHL 3.5 (Roundtower Grey): Quicklime: Course sand + 10% lime dust

Testimomial:

- Main feature was '*stick ability*' and very easy to work with in awkward situations.
- Also the expansive nature of the warm mortar was conducive to compression in setting.

Patrick Hickey, Mason.

Prior to repairs showing exposed slates.

Render on completion over concealed slate cladding.

BOUNDARY WALL Humewood, Co Wicklow.

Restoration, including re-build of 1,500 metres length of 2 metre high masonry estate boundary wall.

Mix Ratio: 1: 1: 5 NHL 5 St Astier: Quicklime: Gravel 12mm dn

Testimonial:

- Forced action paddle mixer.
- Placed in mortar bins when hot and moved using a teleporter to the wall where immediately used.
- The wall is covered when still warm with poly frost rain shield.
- The mortar itself is very workable and the feedback from the masons is positive.

Kirwan Masonry Services

Fixing stones, note bulking of hot-lime mortar prior to beating back & winter protection.

Finished wall.

ST MARY'S FUNERARY MONUMENTS, Kilkenny.

Repair and rebuilt of barrel vault roof on mausoleum.

Mix Ratio: **1: 1: 5. NHL 5 (St Astier) : Quicklime: sharp sand with 10% pea gravel.**

Testimonial:

- **Ease of application and workability with expansion of warm mortar most effective in filling voids with tight joints.**
- **In all my 35 years as a mason have not worked with a better mortar.**

Patrick Hickey, Mason.

Arch dome roof repair with site salvage bricks

General view of mausoleum

APPENDIX M: Acknowledgements

Thank You

The BLFI wishes to acknowledge and thank the following for making the HLM Project possible with financial and other appreciated assistance:-

Department of Arts, Heritage and the Galetacht
The Heritage Council
Office of Public Works
Clogrennane Lime

Kilkenny Borough Council
Wexford County Council

The HLM Project Team would like to thank the following for their counsel and other assistance during the course of the project. The views and opinions expressed in this report, however, are not necessarily shared by those mentioned.

Kevin Blackwood, Jason Bolton, Eugene Butler, John Cahill, Kevin Carrigan, Martin Codd,
Nigel Copsey, Seamus Davis, Ian Doyle, Lisa Edden, Alan Forster, Frank Geraghty, Michael Halpenny, Pat Hickey, Stafford Holmes, Joe Kirwan, John Kirwan, Paul Livesey, Gerard Lynch, Eoin Madigan, Liam Mannix, Paul McMahon, Anna Meenan, Una Ni Mhearain, Ronan O'Flaherty, Jerry O'Sullivan, Chris Pennock, James Powell, Paul Tallis, Brian Walsh, Amanda Wilton.

The HLM Project Team would also like to thank the Committee of the BLFI for its financial support and good counsel, and also the Technical & Standards Committee for its support and contribution during the course of the project.

Lastly, the Convenor wishes to acknowledge and thank all the members of the Project team for their dedication and commitment which expanded far beyond its original remit, and for the many additional hours of consultations and meetings during the previous ten months.

In particular, special mention should be made of the Scottish team led by Craig Frew, who was unstinted in sharing his considerable experience with building limes, and in guiding the project to its completion, and to Bill Revie, who was instrumental in the provision of sound technical knowledge and essential backup to the many issues faced. Andy Bradley is also to be thanked for his practical inputs and know-how, and in demonstrating the craft of the mason.

Lastly, to Pat McAfee without whose knowledge and counsel the HLM Project would not have been possibly; to Robert Howard whose insights were most valuable, and who contributed much in both masonry work and laboratory testing; to Joe Connolly who was always forthcoming with technical advice and assistance and; to Yvonne Doyle who showed sublime patience and gave much support.

My thanks to you all.

Ivor

APPENDIX N:

Historic Scotland

INFORM

Information for Historic Building Owners

Hot-Mixed Lime Mortars.