

Mortar Analysis Report

Project: Ayscoughfee Hall War Memorial

Client: Mark Hamblin

Sample Type: Render

Location: External

Analysis Date: May /2024

Conducted By: Mark Hamblin MSc BSc

1. Introduction

This report presents the results of the mortar analysis conducted on six samples collected from the Ayscoughfee Hall War Memorial, Hall of Remembrance. The samples were examined to determine their composition, texture, particle size distribution, and overall material characteristics, with a particular focus on distinguishing the properties of the top and bottom layers of the render. One of the samples was sent to an independent laboratory, Ty Mawr for third party testing, their results can be found in Appendices 1 and 2

2. Visual and Microscopic Analysis

2.1 Top Layer Analysis

Microscopic Observation at 40x Magnification:

- **Texture and Composition:**

The top layer of the mortar presents a fine and compact texture with a smooth appearance. This layer is characterized by a homogeneous distribution of fine particles and binder, indicative of a well-mixed, refined finish coat. The surface appears smooth with minimal surface irregularities, suggesting that this layer was applied with the intention of achieving a uniform finish suitable for painting or decorative work.
- **Particle Size and Distribution:**

The aggregates in this layer are fine, with no visible large particles. This fine aggregate size indicates that the mortar mix was carefully sieved to exclude larger particles, resulting in a smooth and even finish. The fine particles are well-integrated within the binder matrix, contributing to the layer's overall homogeneity.
- **Material Characteristics:**

The top layer is lighter in colour, suggesting a higher content of lime or a similar fine binder, mixed with a fine lighter coloured sand. This composition is typical of a finishing coat, designed to provide a smooth, aesthetically pleasing surface.
- **Porosity and Inclusions:**

The top layer exhibits some porosity, with small, rounded voids scattered throughout the matrix. This porosity is consistent with a lime containing mortar, which require breathability to allow moisture to escape, thereby preventing damage to historic masonry. The presence of tiny, irregular inclusions, fine sand grains or mineral particles, indicates a well-mixed composition that has been carefully applied.

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2.2 Bottom Layer Analysis

Microscopic Observation:

- **Texture and Composition:**
The bottom layer displays a much coarser and irregular texture compared to the top layer. The surface is uneven with visible protrusions and recesses, indicative of a rougher composition. This layer appears to be a structural base coat, designed primarily for strength and adherence rather than for aesthetic purposes.
- **Particle Size and Distribution:**
The bottom layer contains a varied mix of aggregate sizes, ranging from medium to coarse. The visible presence of larger aggregates suggests a less refined mix, typical of a base coat intended to provide structural support and effective bonding to the underlying masonry.
- **Material Characteristics:**
This layer has a more varied colour palette, with both light and dark areas. The darker areas may indicate denser materials or more concentrated binder regions, while lighter areas could represent different minerals or voids. The binder is unevenly distributed, possibly indicating a lime or cement-based mortar mixed with sand and larger stone particles.
- **Porosity and Inclusions:**
The bottom layer exhibits greater porosity, with visible gaps and voids between the aggregates. This characteristic suggests that the mortar mix is somewhat permeable, allowing moisture to move through the wall, which is essential for maintaining the structural integrity of historic buildings. The inclusions observed range from fine sand grains to larger stone fragments, well-embedded within the binder.

3. Comparison of Top and Bottom Layers

- **Purpose and Functionality:**
 - **Top Layer:** Serves as a finishing coat, providing a smooth, even surface intended for aesthetic finishing, such as painting or decorative applications. The finer texture and uniform particle size indicate a carefully prepared mortar mix for a refined appearance.
 - **Bottom Layer:** Functions as a structural base coat, designed to provide strength and adhesion to the substrate. The coarser texture and varied aggregate sizes suggest a robust mixture focused on mechanical bonding and durability rather than appearance.
- **Material Composition:**
 - **Top Layer:** Likely composed of a high lime and fine cement binder, mixed with fine aggregates to achieve a smooth, polished finish.
 - **Bottom Layer:** Contains a mix of larger aggregates and potentially different binders, such as lime, cement and brick pozzolans, to enhance structural support and provide a strong bond with the masonry.

- **Porosity and Permeability:**

- **Top Layer:** Exhibits some porosity, allowing for breathability and moisture management, which is crucial in historic buildings to prevent moisture retention and associated damage.
- **Bottom Layer:** Shows greater porosity, which facilitates moisture movement through the wall, reducing the risk of moisture entrapment and promoting the longevity of the masonry.

4. Conclusion

The mortar analysis reveals that the render from the Ayscoughfee Hall War Memorial consists of two distinct layers, each serving different purposes. The top layer is a fine, smooth finishing coat designed for aesthetic purposes, while the bottom layer is a coarse, structural base coat intended for strength and durability. Both layers exhibit characteristics typical of historic masonry practices, emphasizing the importance of material compatibility and moisture management in the preservation of historic structures.

5. Recommendations

Based on the analysis, it is recommended that any restoration work should carefully consider the material composition and function of each mortar layer to ensure compatibility with the existing structure. Using a similar mortar composition, particularly focusing on breathability and structural integrity, will help preserve the historic value and longevity of the Ayscoughfee Hall War Memorial.

We would suggest using a hybrid mix of Roman cement, hydraulic lime, and a fatty lime as the matrix and a well graded blended sand 5 mm down for the base coat. For the topcoat we would recommend a white formulation of hydraulic lime possibly including Roman cement mixed with a fine well graded sand in 1:1 ratio. The Roman cement which is not a modern cement would add durability and breathability to the mix. For the paint we would recommend something like Graphenstone's Biosphere or a silicate paint which should prove breathable and durable.

For further guidance or specific material recommendations, please contact Mark Hamblin.

Mark Hamblin

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30/8/24

Appendix 1

Email from Jon Paish TyMawr

Based on your description and the analysis of the mortar sample provided, it appears that the existing mortar consists of several layers with varying compositions. The base coat seems to be a type of lime mortar, though it's notably hard, which suggests it might have a high density or possibly some added materials that contribute to its rigidity. The presence of brick fragments attached to the base coat further suggests a robust bond, characteristic of a harder lime mortar.

The white layer on top, likely a lime plaster, also exhibits considerable hardness. This could indicate the presence of cement or another hardening additive, but this cannot be confirmed without further analysis. Additionally, some of the sample pieces have an extra white layer, which I suspect is a modern repair. This repair layer seems to be made from a cement-based product similar to Polyfilla and has a coating of what appears to be acrylic paint.

Given these observations, I do not recommend replicating the current render's composition. The existing render's hardness, lack of flexibility, and impermeability could be detrimental to the structure's long-term health, especially for historic buildings that require breathable materials to prevent moisture buildup and damage.

Instead, I suggest using an NHL 2 lime render, or potentially NHL 3.5, depending on the required strength and the specific conditions of the building. For the scratch and float coats (base coats), a coarse sharp sand, like our Shropshire sand, would be suitable. For the top coat, a moderately fine sand, such as our London or Fine Cumbrian sand, would be more appropriate.

The mix ratios I recommend are as follows:

- Base coats: 2.5 parts aggregate to 1 part lime binder (by volume).
- Top coat: 3 parts aggregate to 1 part lime binder (by volume).

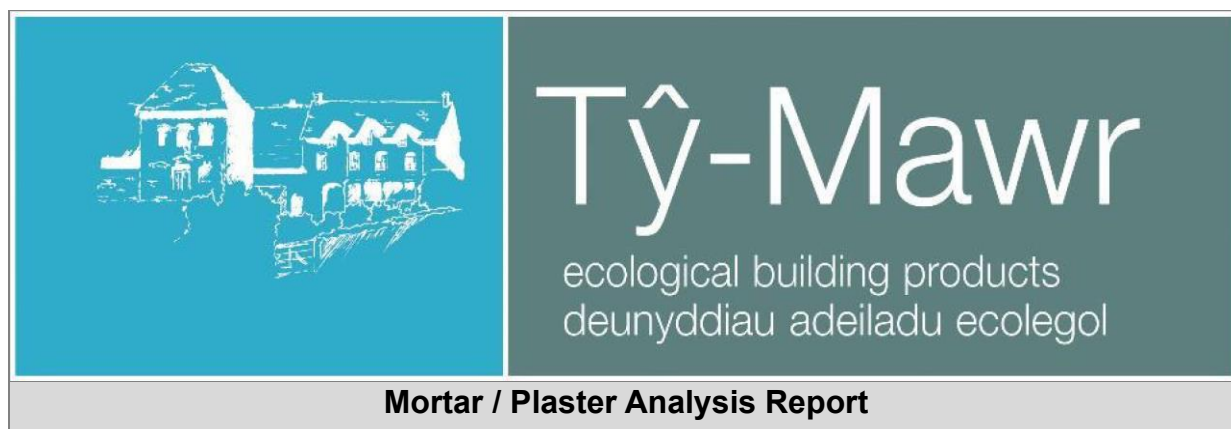
Since the render will eventually be painted, the colour of the render itself is not crucial. However, it's essential to use a suitable vapor-permeable paint, such as Graphenstone Biosphere, to maintain breathability. Ideally, any existing impermeable acrylic paints should be removed before applying the new render to ensure optimal performance and durability of the lime render.

I hope this guidance helps in selecting the appropriate materials and methods for your project.

Best regards.

Appendix 2

Acid dissolution report from TyMawr



Job Details	
Client name	Mark Hamblin
Sample no.	Sample 1
Site	Ayscoughfee Hall War Memorial
Sample type	Render
Location in building	External
Analysis date	11/07/2024
Analysis carried out by	Jon Paish

Visual Analysis

The sample received was in large, hard aggregated pieces, visually consisting of three separate layers of mortar as well as layers of paint and what appears to be a proprietary filler.

The base layer of approx. 5mm and second layer of approx. 10mm appeared to be formed from the same material consisting of buff coloured coarse aggregate within the binder. The top layer of approx. 3mm was formed from much finer aggregate of pale grey colour.

It proved impossible to separate the layers for individual dissolution, so they were dissolved as a single piece.

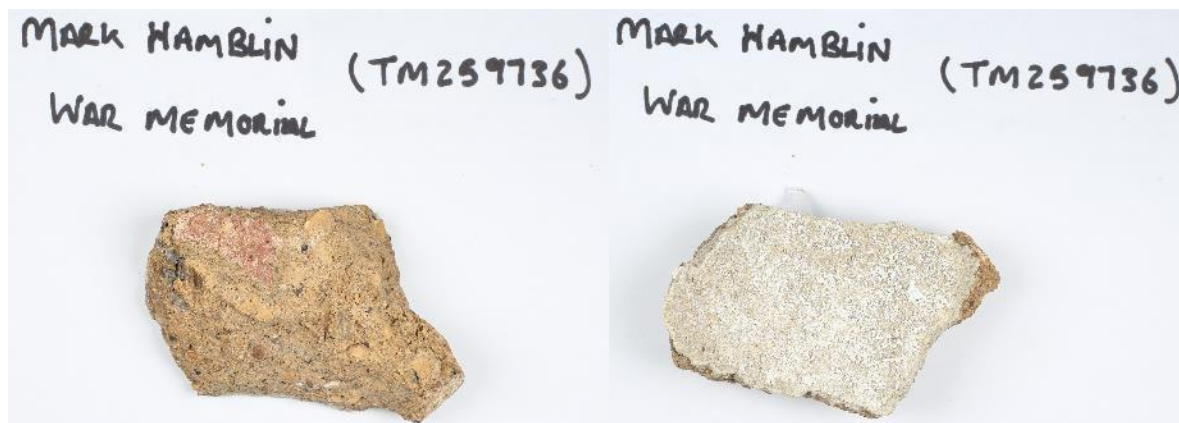


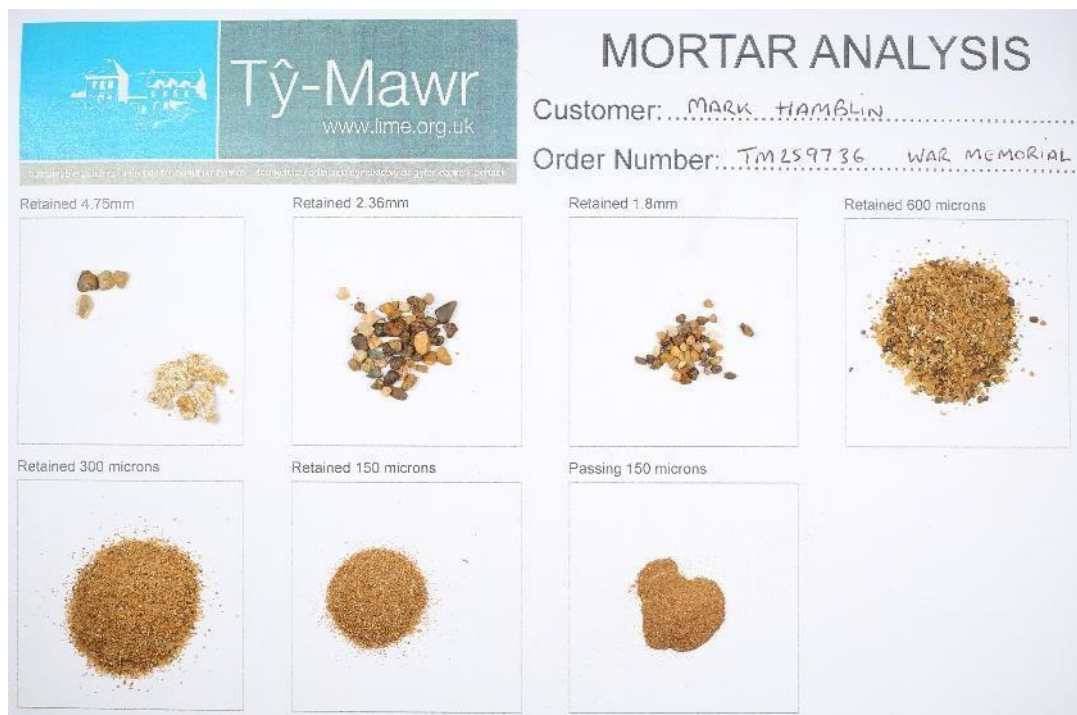
Photo of Sample Received

Acid Dissolution and Particulate Size Analysis

Dissolution in acid produced only a sluggish reaction, which slowed further after 30 minutes and continued to slow until it ceased after 55 minutes. The base layer dissolved faster than the top layer, its binder becoming fully dissolved after 35 minutes.

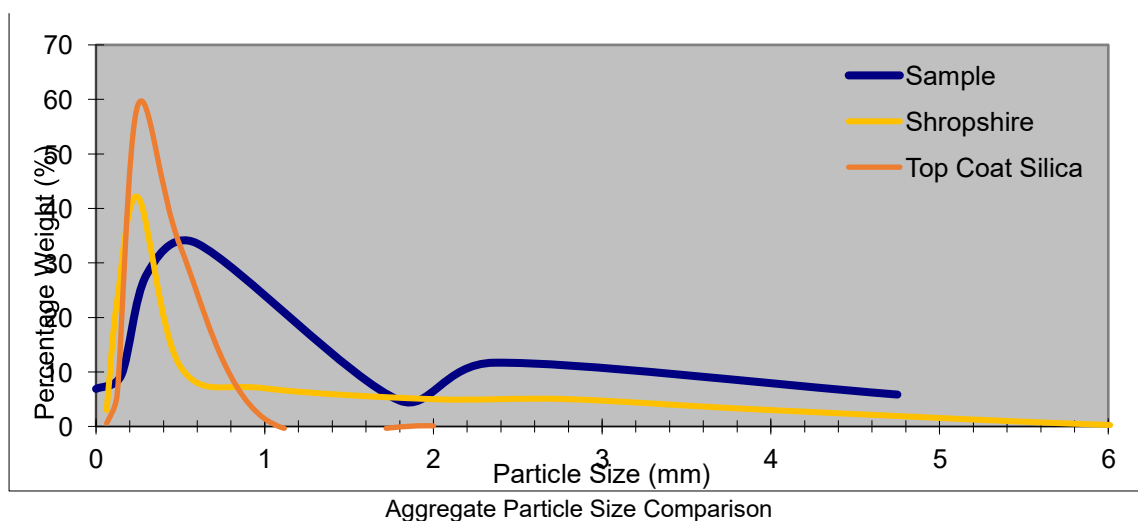
There was some of the top layer remaining undissolved at the end of the reaction.

The acid dissolution removed approx 52% of the sample, suggesting a mix ratio of about 1 part aggregate to 1 part binder.



Sieve Analysis of Aggregate Particle Size

The aggregate consisted of a wide range of sizes from over 4.75mm to under 0.15mm. However, since the sample was unable to be separated into top coat and base coats, further analysis is fairly meaningless, as it is unknown which particles came from which layer of the sample.



Conclusions

The sluggish nature, and very long duration, of the reaction with acid, together with the hard, brittle nature of the mortar and inability to separate the layers of render are highly suggestive of this being a cement-based mortar. It is possible that it was made using an eminently hydraulic lime (NHL 5), but this is unlikely since the early 20th Century saw a massive rise in the use of Ordinary Portland Cement (OPC), and Natural Hydraulic Limes did not have widespread use outside of military and civil engineering construction until the 1990s.

Replacement Material Recommendation

The use of OPC mortars and renders in solid wall constructions has been shown to be potentially extremely detrimental to the fabric, so a like for like replacement is not recommended. Since the render is from a structure open to the elements on all elevations, vapour permeability is not of prime concern. In my opinion, the main requirement is to have a mortar that will withstand the weathering it is likely to receive, whilst remaining sufficiently soft and flexible to care for the masonry substrate. It is important that the mortar should be softer/more permeable than the masonry in order to act as a sacrificial layer.

In this instance, I would suggest that renders based on NHL 2 lime are likely to be appropriate, although a non-NHL Fat Lime could also be considered. Since the render will be decorated (and needs to be decorated with a vapour permeable limewash or paint) the colour of the render is of no great significance. I would suggest that base coats using Shropshire sand and reinforcement fibres and a top coat using the finer Cumbrian sand (without fibres) would give a highly appropriate finish.

Generally, the choice of mortar is made on the basis of the hardness of the masonry and the exposure of the elevation. The choice needs to be agreed between the architect, client and contractor.

The method of finish affects texture and tone enormously, a pointing iron struck lightly onto the mortar surface will create a bland, smooth surface. Brushing, scraping or sponging will impart texture and character to the finished pointing by revealing the shapes and colours of the aggregate.

Please note that mortar colour, texture and finish may also need to be agreed with the relevant local planning authority.

NOTE: It is not recommended to use lime products (lime mortars, renders and limewashes) when temperatures are liable to fall below 5°C (41°F) for several weeks/months after the products has been used, this is especially true for Non-Hydraulic/Fat-Limes/Air Limes and the weaker Natural Hydraulic Limes (NHLs)

The information provided in this report is provided in good faith after receipt of samples. It is suggested that you satisfy yourself with the technical characteristics of the suggested products for the specific applications (see published technical sheets – copies available on www.lime.org.uk) and if necessary ask the contractor to produce samples so that the suitability, timescales and finish can be checked and agreed.

This report is not an engineer's report. It is based on our professional experience of assessing historic buildings and mortars over many years. Ty-Mawr Lime Ltd are committed to providing the highest level of support to ensure a successful job, if you have any concerns at any stage of the project, email us on tymawr@lime.org.uk

Synopsis of Ty Mawr Report:

Based on the "Mortar & Plaster Analysis Report" for the Ayscoughfee Hall War Memorial, here are the key findings and recommendations:

Key Findings:

1. Composition and Layers:

- The sample consisted of large, hard, aggregated pieces with three distinct layers of mortar, along with paint and a proprietary filler.
- **Base Layer:** Approximately 5mm thick, composed of buff-coloured coarse aggregate.
- **Second Layer:** Approximately 10mm thick, appeared similar in material to the base layer.
- **Top Layer:** Approximately 3mm thick, made from much finer, pale grey aggregate.

2. Acid Dissolution and Particle Analysis:

- The mortar's reaction to acid was slow, taking up to 55 minutes to fully react, indicating a hard, cement-based composition.
- The base layer dissolved faster than the top layer, with complete dissolution occurring in 35 minutes.
- About 52% of the sample was dissolved in acid, suggesting a mix ratio of roughly 1 part aggregate to 1 part binder.
- Due to the inability to separate the layers, the particle size analysis did not yield detailed layer-specific data.

3. Nature of the Mortar:

- The mortar's hardness, brittleness, and slow dissolution in acid strongly suggest a cement-based composition, potentially Ordinary Portland Cement (OPC). The presence of an eminently hydraulic lime (NHL 5) is possible but unlikely given historical trends.

Recommendations:

1. Replacement Mortar:

- A like-for-like replacement using cement-based mortar is not recommended, as OPC mortars can be detrimental to solid wall constructions.
- **Suggested Mortar:** Use NHL 2 lime-based renders, which are more appropriate for historic structures. A non-NHL fat lime could also be considered for areas where softer and more permeable materials are needed.

2. Application:

- For base coats, use Shropshire sand with reinforcement fibres.
- For the topcoat, use finer Cumbrian sand without fibres.
- Ensure the chosen mortar is softer and more permeable than the masonry to function as a sacrificial layer and protect the underlying structure.

3. Finishing and Compliance:

- The finishing technique will significantly affect the mortar's texture and tone; methods like brushing, scraping, or sponging can reveal the aggregate's texture and colour.
- Consider the requirements of the local planning authority regarding mortar colour, texture, and finish.
- Lime products should not be used if temperatures are expected to fall below 5°C (41°F) for extended periods, particularly for non-hydraulic or weaker NHL limes.

4. Decoration:

- The render should be decorated with a vapour-permeable limewash or silicate paint to maintain breathability.

Additional Notes:

- The report provides guidance based on professional experience and is not an engineer's report. It is advisable to review technical characteristics and agree on samples with the contractor before proceeding with the work.

Appendix 3

Visual analysis of whole sample



Description of Each Layer:

1. Top Layer (Lighter Coloured Layer):

- **Texture:** The top layer has a finer, smoother texture compared to the underlying layer. The surface appears more homogenous and less coarse, indicating a more refined mixture with smaller aggregate sizes.
- **Particle Size:** The aggregates in this layer seem to be much finer and more uniformly distributed. There are no visible large particles, which suggests the use of a finely graded sand or filler material.
- **Colour and Composition:** This layer is lighter in colour, suggesting a different binder or a different mix ratio, possibly indicating a lime-based render. The lighter colour and smoother finish typically indicate it was intended as a finishing coat, designed to provide a smooth surface for painting or decorative work.

2. Bottom Layer (Darker Coloured Layer):

- **Texture:** The bottom layer appears rougher and more uneven. The texture is coarser, with larger, more angular aggregates visibly protruding from the surface.
- **Particle Size:** This layer contains a mix of aggregate sizes, including some larger, coarse particles. This varied particle size suggests it was designed for strength and structural integrity rather than for a fine finish.
- **Colour and Composition:** The darker colour and presence of larger aggregates indicate a different composition, possibly a more robust lime or cement-based mortar. This layer appears to be a base coat, providing a solid foundation for the finer topcoat.

Comparison and Contrast:

• Purpose:

- **Top Layer:** The finer, smoother texture and lighter colour of the top layer suggest it was used as a finishing coat. Its purpose is primarily aesthetic, providing a uniform surface that can be painted or decorated. The use of finer materials likely aimed at achieving a smooth finish.
- **Bottom Layer:** The coarser texture and varied aggregate size indicate this is a base coat. Its primary function is structural, providing strength and bonding capacity to support the upper layers and protect the underlying masonry.

• Material Characteristics:

- **Top Layer:** Composed of finer aggregates and possibly a higher lime content and other fine cement binders, this layer is hard and robust.

- **Bottom Layer:** Made with coarser aggregates and possibly a different binder mix, this layer is designed for durability and strength. The use of larger particles helps with mechanical bonding to the substrate, making it ideal for the base coat.
- **Historical Construction Practices:**
 - **Top Layer:** Reflects the common practice of applying a finer finishing coat over a coarser base. This was done to achieve a smooth, aesthetically pleasing surface while ensuring that the underlying structure was adequately supported.
 - **Bottom Layer:** Represents the more functional aspect of historic mortar work, providing the necessary strength and adhesion. This layer is typically mixed to a consistency that supports the overall stability of the construction.

Conclusion:

The two layers in this mortar sample serve different but complementary functions. The bottom layer provides strength and support, while the top layer ensures a smooth, finished appearance. This layering technique is typical of historic construction methods, where the focus was on both durability and aesthetic quality. The differences in texture, particle size, and colour reflect the distinct roles each layer plays in the overall mortar composition.

Appendix 4



A 40x magnification of the top layer of the mortar sample, here are our observations:

Texture and Composition:

- **Overall Texture:** The image reveals a relatively fine and compact texture with a smooth appearance, characteristic of a finishing layer in a mortar application. The surface seems to have a fairly uniform distribution of fine particles and binder, indicating that this layer was likely applied to provide a smooth, even finish.
- **Particle Size and Distribution:** The aggregates visible in the image appear to be small, mostly fine particles. There are no large, coarse aggregates, suggesting that the mortar mix for this top layer was well-sieved to exclude larger particles, resulting in a finer finish. The particles are well-embedded within the matrix, which contributes to the overall smooth texture.
- **Material Characteristics:** The light colour and relatively homogenous appearance suggest that the top layer may have a high content of lime or fine cement binders, possibly mixed with a very fine sand or filler material. The presence of these materials

would make the layer suitable for creating a smooth, polished finish typical of a plaster or a fine mortar.

- **Binder:** The binder in the image appears to be finely distributed around the aggregates, holding them together in a cohesive matrix. This fine distribution is indicative of a mortar that was carefully mixed to ensure even coating and adhesion of the binder to the aggregates.

Microscopic Features:

- **Porosity:** There appear to be small, rounded voids or pores scattered throughout the matrix. These pores suggest that the mortar layer is somewhat porous, which is typical for mortars containing lime that need to allow moisture to pass through for breathability in historic buildings.
- **Inclusions:** There are tiny, irregularly shaped inclusions visible, possibly fine sand grains or other mineral particles. These inclusions are well-integrated into the binder matrix, indicating a good mix and suggesting that the top layer was applied carefully to achieve a uniform finish.
- **Surface Quality:** The surface under magnification does not show significant cracks or fissures, indicating that the top layer is relatively intact and has maintained its structural integrity.

Conclusion:

The microscopic image of the top layer shows a fine, smooth mortar with small aggregate sizes and a homogenous appearance. The characteristics suggest this is a finishing layer, likely intended to provide a smooth, even surface that could be painted or otherwise finished. The fine distribution of the binder and the small, evenly mixed aggregates indicate a high-quality application, suitable for the final surface coat in historic masonry work. The presence of some porosity suggests breathability, which is essential for allowing moisture to escape and preventing damage in traditional building materials.



A 40x microscopic image of the bottom layer, here are our observations:

Texture and Composition:

- **Overall Texture:** The bottom layer shows a much coarser and irregular texture compared to the top layer. The surface is uneven, with visible protrusions and recesses, indicating a rougher composition. This texture suggests that the bottom layer is a structural base coat designed for strength rather than a smooth finish.
- **Particle Size and Distribution:** The image reveals a mix of larger aggregates and finer particles. The aggregates are visibly more prominent and varied in size, ranging from medium to coarse. This suggests a less refined mixture, typical of a base coat meant to provide structural support and adherence rather than aesthetics.
- **Material Characteristics:** The colour in this layer is more varied, with a mixture of light and dark areas. This variation indicates distinct types of materials or minerals used in the aggregate mix. The darker areas could be denser materials or areas with more concentrated binder content, while lighter areas may represent different minerals or voids.
- **Binder and Matrix:** The binder is unevenly distributed, possibly indicating a lime or cement-based mortar mixed with sand and larger stone particles. The presence of

larger aggregates suggests that the mix was intended to create a solid foundation, providing mechanical strength and bonding to the structure.

Microscopic Features:

- **Inclusions:** The image shows a variety of inclusions, ranging from fine sand grains to larger, stone fragments and brick. These inclusions are embedded in the binder, which has varying degrees of density and distribution.
- **Porosity:** There seems to be a relatively higher level of porosity in this layer, with visible gaps and voids between the aggregates. This porosity indicates that the mortar mix allows for some permeability, which is crucial for the structural integrity of historic buildings as it permits moisture to move through the wall, reducing the risk of trapped moisture and associated damage.
- **Surface Quality:** The coarse and varied surface quality suggests that this layer has not been finished to a smooth texture and is likely intended to act as a base or intermediate layer that supports subsequent finer coats.

Conclusion:

The bottom layer, as observed under the microscope, is characterized by a coarse, heterogeneous mixture of aggregates and binder. The varied particle sizes and rough texture indicate a robust structural layer, designed to provide strong adhesion to the substrate and support for the finer top layers. This layer's composition, with larger inclusions and visible voids, suggests a focus on mechanical strength and flexibility, rather than achieving a smooth finish. This kind of mortar is typical in historic construction, where a base coat needs to be both durable and compatible with the masonry substrate to accommodate movement and prevent cracking.

Appendix 6:

Our own acid digestion results can be found below:

Five samples were digested three whole and two crushed. Although we managed to separate the top and bottom layers, we were unable to separate the paint coating from the top layer.

The bottom layer and paint layer reacted to the acid more quickly than the top layer.

Bottom Layer



Analysis of the Base Layer Sample After Acid Dissolution

1. Aggregate Composition and Characteristics:

- **Aggregate Size and Distribution:** The aggregates visible in the sample are primarily coarse, with a noticeable range of particle sizes. The particles vary from small to medium-sized grains, suggesting a heterogeneous mixture. Most of the particles appear to be angular, which is typical for crushed stone or sharp sand, and some are rounded, indicating natural weathering or river-sourced aggregates.
- **Colour and Material Composition:** The colour of the aggregates ranges from light tan to darker brown shades, which indicate different types of minerals or stones. This colour variation suggests a diverse source of materials, likely including quartz, feldspar, and other common sand and gravel minerals. The darker particles could be fragments of denser rock types or brick may contain iron oxide.

2. Absence of Binder:

- **Effect of Acid Dissolution:** The acid dissolution process removes the binder material, typically lime or cement, leaving behind the aggregate. The absence of a finer, powdery residue in the sample suggests that the binder was fully dissolved, which is consistent with a well-reacted lime or cement-based mortar. This process allows for a clearer examination of the aggregate itself without interference from the binder.

3. Observations on Aggregate Characteristics:

- **Texture and Surface Quality:** The aggregates have a rough, gritty texture, typical of materials used for the base layer in mortar applications. This roughness aids in mechanical bonding within the mortar matrix, providing structural stability and durability. The angular nature of many particles indicates good interlocking potential, enhancing the mortar's overall strength.
- **Inclusions and Impurities:** There are visible impurities or inclusions among the aggregates, which could include small fragments of other materials or contaminants. These inclusions are normal in natural sand and gravel sources and generally do not affect the performance of the mortar unless present in excessive quantities.

4. Implications for Mortar Functionality:

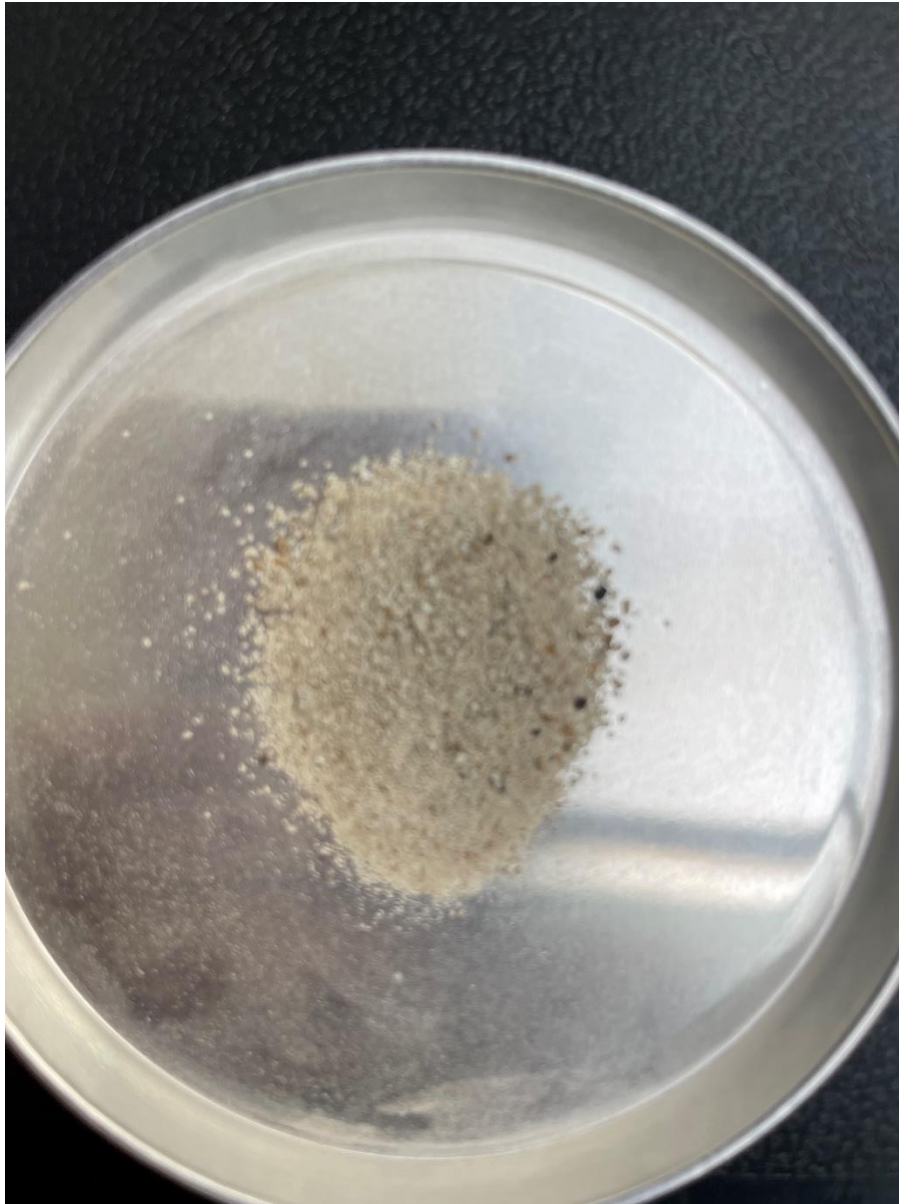
- **Structural Role:** The coarse, varied aggregate composition suggests that this mortar was intended for use as a base or scratch coat, providing a robust foundation for subsequent layers. The range of particle sizes and the angularity of the aggregates are ideal for creating a strong, adhesive layer that binds well to masonry substrates.
- **Durability and Compatibility:** The diverse aggregate mix, with its good mechanical interlocking properties, would contribute to the mortar's durability, especially in an external application where exposure to weathering and moisture is a concern. The presence of natural, weather-resistant stone particles would further enhance the mortar's longevity and compatibility with historic masonry.

Conclusion:

The sample analysed post-acid dissolution reveals a coarse, varied aggregate composition typical of a base mortar layer. The aggregate size and texture suggest that the mortar was

designed for structural purposes, providing a solid foundation and good adhesion for the top layers. The mixture's diverse mineral content indicates a durable and weather-resistant composition, suitable for historic preservation work. This analysis supports the mortar's role in ensuring the longevity and structural integrity of the Ayscoughfee Hall War Memorial.

Top Layer



Analysis of the Top Layer Sample After Acid Dissolution

1. Aggregate Composition and Characteristics:

- **Aggregate Size and Distribution:** The aggregates visible in this sample are primarily fine, with a very uniform particle size distribution. The grains are much smaller and more consistent in size compared to the base layer sample, indicating a carefully graded fine

aggregate. This uniformity suggests that the top layer was designed to provide a smooth finish, typical of a plaster or finishing coat in mortar applications.

- **Colour and Material Composition:** The colour of the aggregates is predominantly light, ranging from off-white to light beige. This lighter colouration indicates a higher likelihood of fine sand, possibly mixed with crushed stone or other light minerals. The uniform light colour also suggests minimal contamination or presence of darker minerals, which aligns with the intent to create a smooth, aesthetically pleasing surface.

2. Absence of Binder:

- **Effect of Acid Dissolution:** The acid dissolution process removes the binder material, which in the case of the top layer is likely a lime and fine cement binder. The absence of any visible larger residue in the sample suggests that the binder was fully dissolved, confirming the binder's susceptibility to acid, which is typical of lime-based mortars.

3. Observations on Aggregate Characteristics:

- **Texture and Surface Quality:** The aggregates have a fine, granular texture, which indicates that the mortar mix was designed to provide a smooth finish. The fine aggregates would help in achieving a polished surface, reducing the roughness and enhancing the appearance of the finished wall.
- **Inclusions and Impurities:** There are minimal visible impurities or inclusions among the aggregates, which supports the use of a fine and clean sand or filler material. The lack of darker or varied-coloured particles suggests that the mix was carefully screened and selected for purity and consistency.

4. Implications for Mortar Functionality:

- **Surface Finish Role:** The fine, uniform aggregate composition suggests that this mortar was intended for use as a finishing or topcoat. The small particle sizes would allow for a smooth application, creating an even and visually appealing surface suitable for painting or decorative finishes.
- **Durability and Compatibility:** The fine aggregate mix would ensure that the top layer is compatible with the base layer, bonding well while providing a smoother finish. The homogeneity and light colour of the aggregates also indicate a mortar that is less likely to cause discolouration or visual inconsistency in the final finish.

Conclusion:

The sample analysed post-acid dissolution reveals a fine, uniform aggregate composition typical of a top mortar layer. The fine grain size and light colour suggest that the mortar was designed to provide a smooth, aesthetically pleasing finish. The mixture's consistency and lack of impurities indicate a high-quality finish suitable for historic preservation work, ensuring both aesthetic value and functional compatibility with underlying layers. This analysis supports the mortar's role in achieving a refined, durable finish for the Ayscoughfee Hall War Memorial.



Observations of the Top Layer Mortar in Acid Solution:

1. Colour of the Solution:

- The acid solution has taken on a yellow hue. This indicates a chemical reaction between the acid and the components of the mortar. The yellow colouration could result from the dissolution of certain minerals or the presence of specific compounds in the mortar, such as iron oxides or other metal oxides, which can impart a yellowish colour to the solution.

2. Precipitate Formation:

- There is a significant amount of fine, suspended particulate matter in the solution. This precipitate is likely composed of undissolved particles from the mortar, such as fine aggregates or other insoluble materials. The presence of a fine precipitate suggests that some components of the mortar do not dissolve

readily in acid, which could be indicative of silica sand or other non-reactive minerals commonly found in mortar.

3. Layer of Sediment:

- A layer of sediment has formed at the bottom of the container. This sediment is the heavier particles or aggregates that were not dissolved by the acid. The sediment indicates that while the acid has dissolved some of the lime or carbonate-based binder, the aggregate particles remain intact.

4. No Vigorous Effervescence:

- There is no visible vigorous bubbling or effervescence, which would typically be observed if a strong reaction were occurring between the acid and a carbonate material (like lime). This shows that the initial reaction has already taken place, and the solution has reached a more stable state, or that the top layer has a lower carbonate content compared to what would be expected in a lime-rich mortar.

Analysis of Chemical Reaction:

- **Mortar Composition:**

- The yellow colouration and lack of vigorous bubbling suggest that the top layer may contain compounds that are not predominantly carbonates or that the carbonate content is lower. The presence of a fine precipitate and sediment aligns with a mortar that includes fine aggregates or fillers, likely designed for a smooth finish.

- **Reaction State:**

- The absence of active bubbling indicates that the reactive components, such as any carbonates in the mortar, have already been consumed, and were not present in large quantities to begin with. The reaction between the acid and the mortar has reached completion or a near-stable state, where most soluble materials have been dissolved, leaving behind only insoluble components.

Conclusion:

The top layer mortar in the acid solution provides insight into the chemical composition and properties of the mortar. The yellow hue and fine precipitate suggest that the mortar includes components such as fine aggregates and possibly some metal oxides, which are less reactive with hydrochloric acid. The lack of vigorous effervescence indicates either a low carbonate content and that the reaction has reached a stable state, highlighting the possible use of cement-based materials and a low-lime formulation in the top layer mortar.



Observations of Whole Sample of Mortar in Hydrochloric Acid Solution:

1. Colour of the Solution:

- The hydrochloric acid solution has turned a deep yellow to orange-brown colour. This colour change indicates that a significant chemical reaction has occurred between the acid and the mortar materials. The colour suggests the presence of iron compounds or organic materials, which can impart a yellow to brown hue when dissolved in an acidic environment.

2. Formation of Bubbles and Effervescence:

- The image shows noticeable bubbling and effervescence on the surface of the solution. This bubbling is a typical reaction when hydrochloric acid reacts with carbonates, such as lime (calcium carbonate) in the mortar. The reaction produces carbon dioxide gas, which forms bubbles as it escapes from the

solution. The vigorous bubbling suggests that there is a considerable amount of carbonate material in the mortar layers.

3. Presence of Foam:

- There is a visible layer of foam forming on the surface of the solution. This foam could be due to the reaction between the acid and any organic materials or impurities present in the mortar. The formation of foam can also indicate the presence of specific components in the mortar that react strongly with hydrochloric acid.

4. Sediment and Particles:

- There appear to be small particles or sediments suspended in the solution and possibly settling at the bottom. These particles likely consist of undissolved aggregates, such as sand, or other insoluble components of the mortar that do not react with hydrochloric acid.

Analysis of Chemical Reaction:

- **Reactivity of Mortar Components:**

- The bubbling and effervescence indicate an active reaction between the hydrochloric acid and the carbonate materials in the mortar. This is typical for lime-based mortars, where calcium carbonate reacts with hydrochloric acid to form calcium chloride, water, and carbon dioxide gas. The reaction is evidence of the presence of lime or similar carbonate-based components in both the top and bottom mortar layers.

- **Possible Presence of Iron or Organic Compounds:**

- The yellow to orange-brown colouration suggests the possible presence of iron compounds or organic materials within the mortar. Iron oxides or hydroxides can dissolve in acidic solutions, producing yellow-brown colours. Organic compounds, if present, can also contribute to colouration and foam formation.

- **Differential Reaction Between Layers:**

- If both layers are reacting in the same solution, the differences in reaction intensity and the components being released into the acid could indicate variations in the composition of the top and bottom layers. The top layer may have finer particles and less carbonate material, while the bottom layer, typically being more structural, may have a higher carbonate content.

Conclusion:

The observed reaction of the mortar samples with hydrochloric acid provides insights into the composition of the mortar layers. The vigorous effervescence and bubble formation confirm the presence of carbonate materials, such as lime, which are common in historic mortars. The yellow to orange-brown colour change indicates that iron compounds or organic materials may also be present, affecting the mortar's appearance and durability.



Observations of the Mortar Sample Remnants from the Sample Above:

1. Visible Remnants and Layer Characteristics:

- The image shows three distinct pieces of material remaining after the acid dissolution process. These remnants are portions of the top layer that have survived the acid bath after an hour, indicating that the top layer has a different chemical composition or a higher resistance to acid compared to the bottom layer.

2. Texture and Surface Appearance:

- The remnants are relatively flat and thin, indicating they are fragments of the top finishing coat. The surface of these pieces is relatively smooth and lacks the coarse texture that might be expected from a more aggregate-rich, structural

layer. This further supports the conclusion that these pieces are from the top layer, which is designed for a smoother, more refined finish.

3. Colour and Material Composition:

- The remnants have a consistent light brown to beige grey colour, with slight variations. This uniformity suggests that the top layer is composed of a homogeneous mixture of fine aggregates and binder, likely lime and cement, which was not entirely dissolved by the dilute hydrochloric acid. The absence of darker aggregates or inclusions further indicates a refined mortar mix intended for aesthetic purposes.

4. Effectiveness of Acid Dissolution:

- The dissolution of the bottom layer and the survival of the top layer remnants indicate a significant difference in their respective compositions. The bottom layer, likely cement/ lime-based with a high carbonate content, has dissolved completely in the acid. In contrast, the top layer remnants show resistance, suggesting a cement binder with a reduced carbonate content.

5. Potential for Layer Separation:

- The remnants' intactness suggests that while the bottom layer was vulnerable to acid dissolution, the top layer was bonded well enough to remain as separate pieces after the lower material dissolved away. This indicates that the top layer was applied as a finishing coat over a structurally different and chemically more reactive base layer.

Analysis of Chemical Resistance and Composition:

• **Differential Chemical Composition:**

- The remnants' resistance to acid suggests that the top layer may contain less lime or other acid-reactive materials than the bottom layer. This layer might have been formulated with additives or components that enhance its durability and resistance to environmental factors, including acids.

Conclusion:

The image of the mortar sample remnants after acid dissolution reveals that the top layer has distinct characteristics that differentiate it from the more reactive bottom layer. The resistance of the top layer to hydrochloric acid dissolution suggests a formulation designed for a smooth finish and durability, incorporating materials that are less reactive with acids.