REFURBISHMENT CASE STUDY 36

KINNEIL HOUSE BO'NESS

REBUILDING OF THE ORCHARD WALL WITH HOT-MIXED MORTAR

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

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HISTORIC ENVIRONMENT SCOTLAND REFURBISHMENT CASE STUDY 36

KINNEIL HOUSE, BO'NESS

REBUILDING OF THE ORCHARD WALL WITH HOT-MIXED MORTAR

ROGER CURTIS

CONTENTS

1. INTRODUCTION

This project was part of the Historic Environment Scotland (HES) hot-mixed mortars trial programme that began in 2015. The work consisted of five sponsored projects involving hot-mixed mortars and is part of a wider programme carried out together with the home nations, called the Hot-Mixed Mortars Project (HMMP). Co-ordinated by HES, it intended to progress knowledge of hot lime mortars in historic and traditionally built structures. There were several strands to the project: gathering historic evidence of lime practice; assessing and recording extant areas of historic lime materials; assessing more recent work with hot-mixed mortars; and describing in detail the special physical properties of a hot-mixed quicklime based mortar. The HMMP project aimed to test the practicality, durability and above all the authenticity of using a quicklime based mortar; reflecting mortar types that were used historically. Conservation principles state very clearly that repairs should be carried out with like-for-like traditional materials; not only those with similar visual properties, but those with similar or the same physical properties. Generally, for masonry work in building conservation, this means mortars that are vapour and capillary-open. Recent research and the publication of Technical Paper 27 show these properties very clearly and that many modern lime based products demonstrate these to a much lesser degree.[1]

The site trials varied in scale and complexity; several were very small with a few operatives and simple work around re-pointing and re-building. The work at Kinneil is by contrast a much larger and more extensive project on a structure of national significance; it is within a scheduled monument area, forms part of a listed building, and is also in the care of Scottish Ministers. The extent of the work was considerable; approximately 40m of retaining wall was dismantled and re-built. While the workforce was well-versed in building conservation work and historic masonry, most had not used a hot-mixed mortar before.

In the finishing of the masonry work, or rather the style of the finished pointing, a different approach was taken from that which is usually encountered on such monuments, one which reflected the evidence found on parts of the wall. The mortar was flush pointed, making a much smoother and flatter looking wall, with a brighter, lighter colour visually, due to the increased surface area of lime. This is in contrast to what visitors to a monument often experience; i.e. recessed pointing where the stone is dominant

As with other trial projects, this learning process using a different type of lime mortar proved to be an important part of the project as well as the nature of the protection to the wall once the building work was completed.

[1] Wiggins, D. (2018) *Technical Paper 27: Hot-mixed Lime Mortars: Microstructure and Functional Performance*. Edinburgh: Historic Environment Scotland.

2. THE SITE

2.1 Kinneil House and its development

Kinneil House is a substantial mansion on the edge of Bo'ness in central Scotland. The building has a long and complex history dating back to the middle ages. Its present form takes that of an 'L' shaped plan, with a late 16th - early 17th century rectangular palace block as the principal elevation. The tower to the north is believed to date mainly from the 16th century (Figure 1). The boundary wall probably dates from the 17th century. Over the early 20th century, the building and its grounds gradually fell into disrepair, and by the 1930's the building was being gradually demolished. The discovery of high quality wall paintings in the north range fortunately stopped this work and the building was passed into State Care, although still owned by Falkirk Council. Over time, the Ministry of Works, latterly Historic Scotland and now Historic Environment Scotland, have re-instated roofs to protect the building fabric that survived, although most of the interiors are large areas of void space with no floors. This multi-layered history and its partial exposure make the building a very important one as a way of understanding traditional construction technology (worthy of a separate study). As with many establishments of this size and status, it comprised more than a single structure; close around the mansion would have been an interlinked complex of storehouses, stables, brewing sheds and gardens. The subject of this case study is a substantial wall to the northeast of the principal buildings, running parallel to the main approach axis, which is believed to have bound the former orchard. In recent years, this orchard has been re-planted.

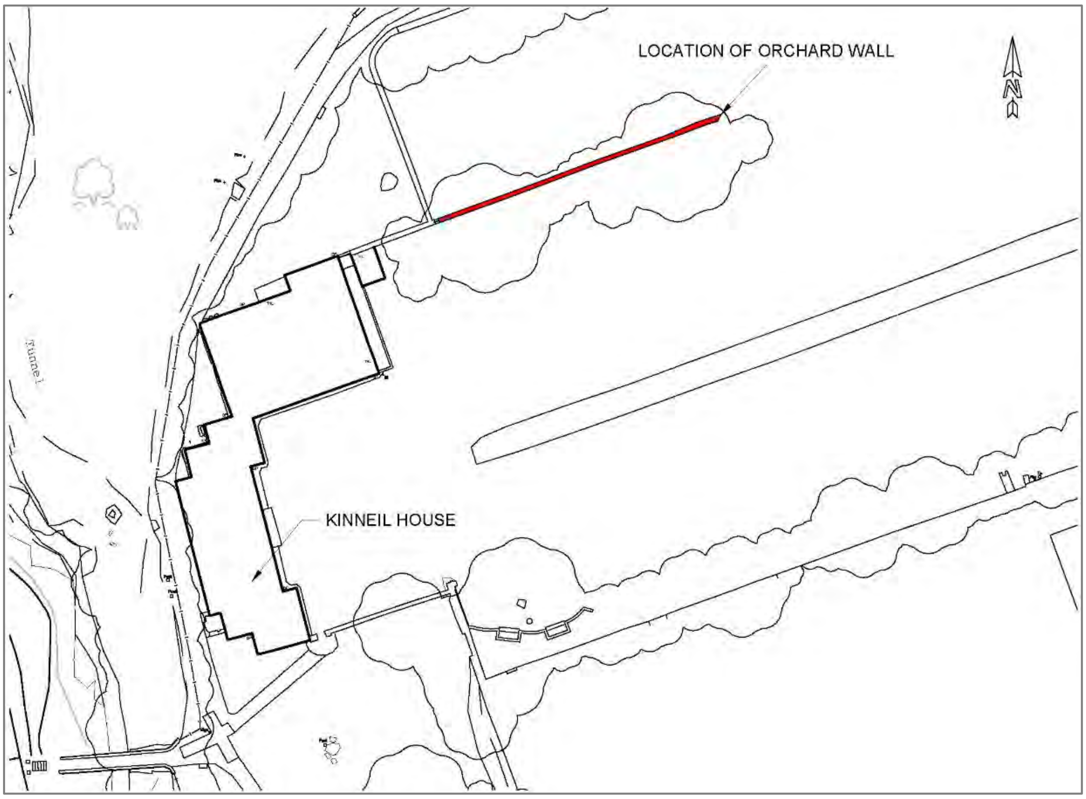

Figure 1. The layout of the Kinneil Buildings.

2.2 The orchard wall

The subject of this study is the remains of the former orchard wall. The wall is 2.44m high on the lower side and 38m in length. It is 0.65m in thickness and is lime bonded. 1.3m of its height is a retaining wall (Figure 2). The masonry construction is a sandstone rubble with ample pinnings. The nature of the mortar remaining on the faces of the stone suggest that the wall was flush pointed and lime washed, possibly with a thin layer of render. The top of the wall was protected by a stone cope formed of cut rectangular sandstone slabs. Approximately 45 years ago, a line of conifers had been planted on the south side of the orchard wall and these had reached full height. The wall was showing significant deflection of the masonry off the vertical along many parts of its length and, if left unattended, this was likely to have led to areas of localised collapse in the future.

Figure 2. The orchard wall prior to the works. Note the trees very close to the upper side which contributed to its instability.

2.3 Reasons for the structural problems

The movement of the wall is probably due to a combination of factors. Retaining walls have been built in rubble for hundreds of years, and many remain in good condition to this day, holding back significant quantities and weights of earth and other materials. However, in the case of the Kinneil wall, the following conditions came together to give an unstable situation: once the trees reached full height, their movement destabilised the earth on the higher side and the tree roots were also exerting outward pressure on the wall. The rubble used in the wall construction varied in size and quality; many stones were entirely decayed. Trial pits dug by HES showed that there was no foundation as such, and certainly no wider masonry plinth onto which most traditional walls are normally constructed. Without this wider footing, it would have been harder for the wall to resist the outward forces from the earth behind. In addition, the well-documented increased rainfall since the 1960s can lead to softer soils with greater weight and plasticity. At Kinneil, the wall is the lowest point along the approach road and water running off the ground to the south will invariably concentrate there. Such land drainage as there was on the ground to the south will have had little attention and the ground would have been wetter. The absence of weep holes may also have contributed to a build-up of pore pressure. As a result of the combination of these factors, the wall was leaning significantly in several places (Figure 3). At its most extreme, towards the east end of the wall, it was 9 degrees off the vertical.

Figure 3. One of the areas of movement on the orchard wall.

2.4 Options for repair

In most situations with scheduled monuments in the Care of Scottish Ministers, the retention of original fabric is the main priority to ensure the authenticity of the structure. The Society for the Protection of Ancient Building's principle 'the minimum necessary but the maximum required' concisely expresses this view. In the case of Kinneil, the engineer's assessment was that the wall would shortly become unsafe without significant works and, as such, would be a danger to the public. Such works would have to consist of rebuilding works, buttresses, and underpinning works, significantly changing the appearance of the wall. The alternative was to dismantle the wall and re-build it to the same dimensions, but with some improvements for structural stability. These options were discussed by the relevant HES staff; the District Architect, Cultural Resources staff, and Structural Engineer.

2.5 Survey and archaeology

Regardless of the approach taken, a full recording of the wall was carried out before and following the removal of the trees. This was photographic in nature, with images stitched together to allow a complete record. Two small pits were dug along the base of the wall to assess the footings and establish if there was any evidence of previous structures or activity. The examination of the wall did not yield any clues as to its exact date and how it fitted into the development of the mansion and its policies. There were indications of a small structure at the west end with plaster indicating a pitched roof.

2.6 Consents

The wall was at that time included in a scheduled area, which comprised the remains of the Roman-era defensive frontier, known as Antonine Wall (this scheduling has now been revised and excludes the ground where the wall is situated). Scheduled Monument Consent (SMC) was, therefore, required for the works. This obliged a series of plans and descriptions outlining what was intended and an assessment of the potential impact of the works on any archaeology or remains that may be encountered on this historic site. SMC dictated that the wall be rebuilt on a like for like basis, using traditional materials and techniques. It also required an archaeological investigation into the foot of the wall and a watching brief during the dismantling phase.

The conifers that had been planted along the top were causing damage, and although already large, were expected to grow even larger. Therefore, it was decided that these trees, not part of a historic planting scheme, should be removed. While consent for this was not required, the Local Authority was informed.

3. THE DESIGN

3.1 Foundations

When considering the re-build of the wall, there were two options – a modern concrete strip foundation or a more traditional one, albeit with some improvements due to site conditions. To keep close to a like for like re-build, it was decided to progress designs for a masonry foundation, which would be more in keeping with the history of the site and the wall, and also demonstrate that modification of traditional details is as successful as modern measures and materials. The structural engineer at HES prepared indicative drawings to show how the wall would be re-built with minor adjustments for additional structural stability. It was agreed that the redesigned foundation would comprise large sandstone rubble pieces, built in stepped layers with a depth of 600mm and total width of 1,250mm at its base. The stones were then stepped at 150mm in four courses beneath the main wall structure.

3.2 Drainage

As saturated ground may have contributed to the instability of the wall, it was agreed that there needed to be provision for drainage to allow water from behind the wall to pass through the structure. Therefore, a land drain was to be set close to the base of the wall on the retaining side to take away some of the run-off water. Weep holes were also specified to allow water to pass though pre-made gaps. This would prevent any water build up at the wall foot from leeching through the masonry and mortar, progressively dissolving the lime binder.

3.3 The mortar mix

A mortar analysis of the mortar on the wall was carried out, which showed that the original mortar was a lime rich mix, probably in a final ratio of 3 sand to 1 quicklime. The mix is believed to have been feebly hydraulic; this hydraulicity was likely due to silicates or other trace elements in the original limestone. For the new work, two types of mortar were specified. The first, for the foundation plinth was mainly hydraulic in character, with a small amount of quicklime for workability. As this mortar would be below ground, it needed to be able to set in wet or moist conditions. The mortar for the wall above ground, including the retaining wall levels, was to be a quicklime based, hot-mixed mortar with traditional additives to improve the speed of setting and durability of the mortar, mixed to replicate the original. To give the new mortar the feebly hydraulic characteristics of the original, crushed shell and crushed brick were identified as being suitable additives to speed up the curing and carbonation process; such additives are called ‘pozzolans’. This would build on previous successful hot-mixed mortar trials at Dunbar[2] and Shetland.[3]

3.4 Binder costs

While the reasons in 3.3 above are sufficient in themselves to justify the use of a hot-mixed mortar, there is another factor, that of cost. Hydraulic lime mortars, normally supplied as bagged dry hydrates, are expensive, at around £20.00 per 25kg or £800.00 per ton. By contrast, a ton of quicklime costs significantly less. This must be one of the few situations where the traditional or conservation material is cheaper than the modern partial alternative.

3.5 Movement joints

In many new walls of any construction type made with modern binders, movement joints are required if elevations exceed 4m to absorb movement and prevent cracking. By contrast, this is not necessary for the use of lime binders in traditional construction. Walls constructed with lime mortars are actually flexible; they can absorb movement without cracking. Therefore, movement joints were not required in the new wall.

3.6 Source of quicklime

For a project of this size a considerable amount of un-slaked quicklime would be required. Procuring it through a retail route in 20 litre tubs would be very expensive indeed, so it was decided to use a Shap kibbled quicklime, supplied in 1-ton bags. This quicklime is a high calcium quicklime, produced very pure for use in the steel industry. The supplier was keen to diversify their sales network, and customers in construction were actively sought. It was acknowledged that mortar from this quicklime would have no hydraulic component and, therefore, the mortar design described above would take this into account. The same source of quicklime was used to make the mortar for the rebuilding works at Dunbar and the results were good, even during periods of low temperature.

4. DELIVERING THE PROJECT

4.1 Mortar trials

In the early spring of 2017, some practical mortar trials were carried out at the nearby HES yard at Blackness Castle. This involved demonstrations and batching up of several mortars for use on a trial wall (Figure 4), and for the

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[2] Curtis, R. (2018) *Refurbishment Case Study 26: Black Bull Close, Dunbar: Hot-Mixed Lime Mortar Trials*. Edinburgh: Historic Environment Scotland.
[3] Hunnisett-Snow, J. (2017) *Refurbishment Case Study 25: Haa of Sand, Shetland.* Edinburgh: Historic Environment Scotland.

repointing of an existing boundary wall. Following the guidance given in the mortar analysis for a new mortar, and described above, this was batched up in a 20 litre electrically powered forced action mixer. Operatives were encouraged to try mixing and building in order to allow an understanding of the hot-mixed mortar. Crushed shell and crushed brick were added to the mixes to assess their effects on the feel and the curing of the mortar. The ratios were 1 kibbled quicklime (unslaked) to 2 ½ measures of concrete sand and ½ a measure of shell or brick dust. The mortars were pressed back and given the required aftercare over the subsequent weeks. In terms of workability, the crushed shell seemed to give a good mix, but the crushed brick much less so. Following the curing and scraping back of the sample areas at Blackness, it was decided that the crushed shell mix made the best mortar and would be used for the wall works at Kinneil.

Figure 4. A small area of trial mortar in a new section of rubble wall in the HES yard at Blackness Castle.

4.2 Site set-up

The site was set up to follow standard industry practice with the work area enclosed by a heras fence. Welfare facilities were already in place within the north range of the house and supplemented by additional facilities located in the neighbouring walled garden. Scaffolding was not required in the early stages. The mixers were placed on a level piece of ground about

50m from the wall. The sand and aggregates were delivered to this area, minimising the movement when mixing started. The quicklime, in its 1-ton bags, was stored in a shipping container.

4.3 Training and engagement

Following the first mortar trials off-site and the establishment of the working site at Kinneil, a further training session was held with members of the Hot-Mixed Mortars Project. Explanations were given regarding hot limes, including various practical demonstrations. Engagement with the HES Monument Conservation Unit (MCU) was important, if the principles of hot-mixed mortars were to be understood, as these are very different from the procedures used with modern hydraulic lime mortars. A half-day session was held at Kinneil with MCU staff from several HES Depots and instructions delivered by contractors and consultants from the Hot-Mixed Mortars Project team. This included demonstration of slaking, discussion on mixing techniques and consideration on the use of additives, such as crushed shell.

Figure 5. Training session on hot-mixed mortars.

4.4 Downtakings

As the wall was of considerable size and length, it was obvious that the dismantling alone would be a task in itself. The required archaeological oversight would also oblige a considerable degree of care in the process.

The downtakings were planned to start in the autumn of 2016 and continue through to the spring of 2017, when the weather and the day length would be conductive to building work. To allow an assessment of how long it might take, two masons and one labourer were allocated to dismantle a trial area at the east end in the summer of 2016. It took longer than expected; while the stones came away easily enough, removing the old mortar, stacking the stones to be re-used and disposing of the decayed ones took a substantial amount of time. In addition, arrangements were needed to allow accessible storage for the stone; a large heap of stone at one end of the site would not have been suitable. The masons needed a range of stone sizes to be visible and available along the entire length, in order to be able to select the best stone for the location. This was achieved with the stones laid on pallets. These in turn were stored above the ground on a simple platform made from scaffold tubes and boards. Before the downtakings began, a mechanical excavator was used to remove the soil and material from behind the retaining wall. This allowed the masons to work on both sides of the wall during the downtakings.

4.5 Archaeological oversight

An archaeologist was in attendance during the work with the digger and the downtakings. There was little to report from this work, and although all were watching for carved or reworked stones, only three were found. These comprised of two former rybits and one distinctive and interesting piece; the substantial part of a parapet drain spout (Figure 6). It was not possible to determine its origin, although tempting to consider it might have been part of the parapet from the tower house that formed the core of the north range. As a conclusion to the downtakings, a trench was dug on the line of the dismantled wall to take the new foundation. Again, during this work there was no evidence of any archaeological material or layers; the ground was ‘clean’.

Figure 6. The drain spout found during the dismantling of the wall.

4.6 Sourcing additional stone

From the condition of the stone on initial assessment and from what was able to be set aside for re-use, it was obvious that there was going to be a shortfall in good rubble. A local supplier at Drumhead Quarry was approached and some suitable blond sandstone rubble was identified. A truckload (approximately 18 tons) was delivered on the site. Fortunately, the dry spring of 2017 meant that the lorry could reverse close to the construction area to be unloaded.

4.7 Building the foundations

After being dug, the trench mentioned above was laid with large, generally flatter stones, configured to sit about 100mm wide off the wall base (Figure 7). This layer was about 400mm deep. To bind this layer of stones, a wetter lime mortar was used, with the lime binder made up of 50% quicklime and 50% NHL5. This hydraulic component was added to ensure that the foundation mortar set in the damp conditions of the wall base.

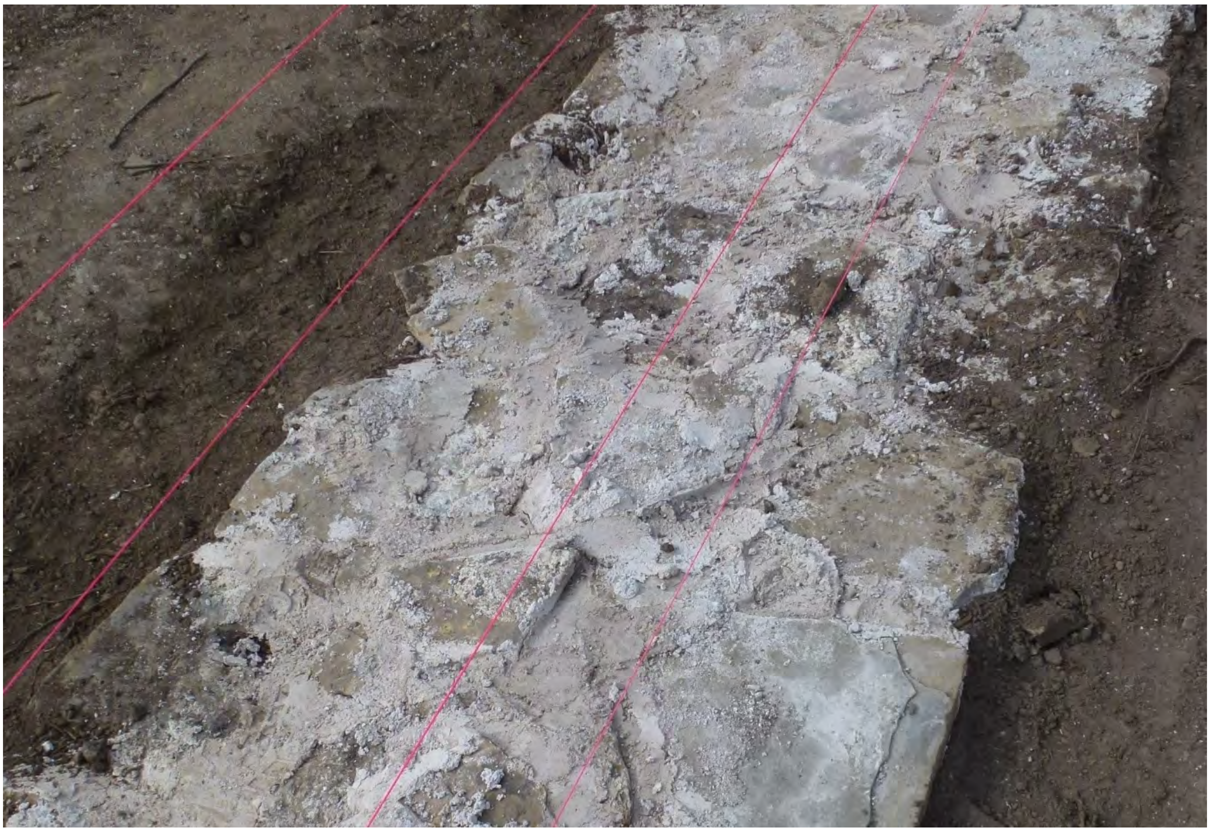

Figure 7. The foundation layer laid with a hydraulic lime mortar. The red lines are the setting out strings for the line of the new wall masonry.

4.8 Setting out and commencing the build

With the foundation layer complete, string lines were set out between four points to allow the base of the wall to be started on the new foundation (Figures 7 & 8), set 200mm wider than the new wall width. The new wall thickness was the same as the original, and the mortar was changed from a gauged quicklime mix (one with hydraulic lime added) to a simple quicklime-based mortar. The foundation mortar had a hydraulic component to ensure that the mortar would set in the damp conditions below ground level. When building a long wall, it is good masonry practice to start work at intervals along the wall; this is called 'stooling' and is a way of minimising sighting errors. It also allows several work squads to build at the same time along the wall.

Figure 8. The string lines set up along the length of the new wall.

4.9 Building the wall

Construction of the wall began in April 2017, with three squads working on site. The wall building technique was standard rubble construction, with an emphasis on stones reaching back into the wall. At regular intervals, a tie stone was placed, i.e. one that went through the whole thickness of the wall.

The building of rubble walls is not as common as it once was in Scotland and many modern versions of this masonry style are poor in terms of appearance and strength. It is common for these to be built as two external skins, with many voids and loose debris in the centre. In a desire to build quickly many flat stones are placed 'on end' giving an appearance that is sometimes pejoratively called 'vertical crazy paving'. At Kinneil there was obviously an obligation to re-build the wall in the style and manner of the original and this was largely achieved. The re-used stones were laid so that the faces were aligned as they were originally; in places this allowed original mortar and limewash fragments to be still visible (Figure 9).

Figure 9. The reused stones in the new wall. Note the original mortar and lime wash still showing on the surface of the re-used stones.

4.10 Mortar supply - site practice and procedure

Batches were prepared with two forced action mixers feeding three masonry squads at different parts of the wall. While the mix ratios were fairly set, the amount of water added required to be judged quite carefully. Bedding mortar made too stiff makes it hard for the mortar to be poured from the mixer in the wheelbarrow. It also makes it harder for the masons to bed the stones quickly. Made too wet, the mortar will shrink and crack as it cures. As the mortar was mixed hot, a further judgement was needed to get the material to the work area before it stiffened up. As the wall rose in height, provision of a working platform was required, and a scaffold was put up to allow completion of the higher levels. As the quantities of mortar and stone were significant, configuration of the scaffold for wheelbarrow access was important.

4.11 Adjustment of the mortar mix

During the work it was noticed that the hot-mixed mortar was showing shrinkage cracking as it cooled and stiffened up with the masonry in place. Understanding that this was likely due to too much water in the mix, the water content was reduced, not by adding less water as such, but by adding an amount of finer sand that would better fill the voids in the aggregate particles. The addition of the sand was indeed successful in reducing the initial shrinkage cracks and, as in the case of the previous trial at Dunbar, it showed that the grading of the sand or the particle size distribution is important for a good mortar. This understanding of the mortar by the operatives and their informed actions to address observed mortar behaviour is exactly what the HMMP is trying to achieve: to return the understanding and configuration of mortars to the masons themselves.

4.12 Matching up with the remaining existing wall

The project generally progressed as planned and the speed of work was as expected. Where there were delays, these were due to external factors such as availability of labour and weather. However, there was one area of note: Where the rebuilt wall connected with the end of the original wall at the west end, the latter still retained a significant lean, the true extent of the lean only being really appreciated when the new wall came within 1m. It was decided that rather than have an odd mismatch at the junction of the old and new sections of wall it was better to leave a designed gap between the two at the upper level, where it is intended to add some interpretation on the history of the garden.

4.13 The pointing and finish of the wall surface

Modern masonry practice encourages sometimes elaborate pointing styles and finishes. With rubble walls, historically, this was not the case; rubble work was quick and simple, and largely intended not to be seen. As such, the pointing finish on older walls was normally a 'flush point', filling the points between the stones to give a relatively smooth undulating surface. There was evidence for such an original finish at Kinneil, with a covering lime wash (Figure 10). The 2017 work sought to replicate this.

Figure 10. An area of historic masonry finish at the base of the orchard wall prior to the works.

In an additional contrast to modern practice, a single type of mortar was used, the bedding mortar extended through the joints, and was scraped off just proud of the masonry plane as the wall was built. This was not only quicker but technically better, there was no discontinuity in layers, and provided a continuation of the vapour and capillary route through the wall.

The work took place in the spring, with day temperatures in the 15 – 18 °C. As a result of this and the nature of the hot-mix, the mortar cured firm in a few days and was scraped back flush with the plane of the wall (Figure 11). The wall was taken up to the original height to provide a level base onto which the copes could be bedded. As is common in the procurement of dimension stone, there was a delay in its arrival on site, and this had implications in the finishing of the project and the curing of the mortar – there was no cope in place over the winter.

Figure 11. Detail of the completed wall awaiting the cope stones. The pointing on the left-hand side still needs to be scraped back.

4.14 Protection and aftercare

When building a new wall there is less burden on protection from drying too fast, as the mortar within the wall has a significant reserve of moisture within. However, good practice requires protection to the wall head from rain. Just as drying out too quickly will spoil pointing, so will too much water; it results in slow setting and carbonation, and in extreme situations the leaching of un-carbonated or free lime from within the wall. Due to the timing and resourcing of the project, the wall was up to full height by July 2017, and while delivery of the new copes was awaited, the wall head was covered with hessian and polythene. It was realised in hindsight that this protection was too enclosing and resulted in the wall not being well ventilated. In addition, the tarpaulins used to cover the wall heads were worn and had many holes, so that water was able to penetrate the covering during the wet autumn of 2017, but not being able to dry out again. The cold weather with frequent frost which followed in December and January caused extensive surface damage to the outer layers of mortar. The situation would have been better if the copes had been in place over the winter. This emphasises the importance of weathering details on exposed wall heads, especially with newly laid mortars

4.15 The new cope

All masonry structures must shed water from the higher levels. Traditional boundary walls achieved this with a stone covering or ‘cope’; the details of this varied but could be a flat slab (a flagstone) or a more crudely worked semicircle of flat stone. The Kinneil wall had a flat flagstone cope, however, many of the stones were missing and what remained had split or broken in many places. In addition, the long length of the wall (38m) meant that ad hoc collection of pieces from various sources was not going to be possible, even if such pieces could be found – they would differ in thickness, size and colour. Therefore, it was decided that a new batch of copes would be procured from the local quarry, ensuring consistency in texture and appearance. Due to issues with extraction of the stones from the quarry, the delivery of the copes was delayed, and they did not go onto the wall until Spring 2018. These were then bedded in the standard mortar mix and the joints between the stones were closed with an ashlar pointing mix. The stone coping was given a very shallow tilt back to the road side, to run the water back in one direction; this is sometimes called a ‘wash’ (Figure 12).

Figure 12. The new sandstone cope with frost damage on the mortar. Note the slight slope, or the ‘wash’ of the cope.

With the new cope in place the scaffold was taken down and the ground landscaped to its previous levels (Figure 13). The pointing damaged by the winter frost was brushed down, and the wall will be re-pointed as resources permit.

Figure 13. View of the completed wall, with the copes in place, summer 2018.

5. MONITORING

5.1 The curing of the mortar

There is still much discussion over the exact time of curing of lime rich quicklime-based mortars. To give some evidence of how this process progresses, regular core sampling of the lime will be carried out. The wall is of modest thickness and it is anticipated that this curing will take two to three years for full carbonation.

5.2 Structural stability

With additional foundation, no trees and improved drainage, there is no reason why the wall should not perform and retain the earth bank better than the original. One of the properties of lime binders is their ability to give flexibility to the structure, such that settlement or movement can be absorbed by the new mortar. Additionally, any small crack will self-heal through the movement of free lime into the cracks. The stability of the wall will be monitored to establish if there is any settlement or movement. Initial observations indicate there has been no observable movement.

5.3 Performance of the drainage arrangements

The end of the new field drain, set at the base of new wall on the retaining side will be monitored to see how much water, if any, has made its way along the base, or if the weep holes, built at intervals along the wall, also drain liquid water.

6. CONCLUSION

The project has been successful in showcasing that it is relatively straight forward to build masonry walls in the same way as they were historically, using traditional materials. When using quicklime-based mortars, however, it should be borne in mind that not every labourer will be experienced in using them and it will most likely require prior training. As seen in this case with HES MCU staff, the learning process appeared to be very productive and, once the use of the hot-mixed mortar was explained and demonstrated, operatives felt comfortable and confident using it. During the project, masons were able to appreciate how it behaved and make subtle adjustments to the ingredients accordingly, which meant putting the knowledge and control of the mortar back in the hands of those doing the building.

The use of a hot-mixed mortar did not create any problems with site processes or safety either, but there needed to be a better appreciation of the nature of the protection needed, and the importance of having all built details in place. The frost damage to the pointing in the first winter could have been prevented by putting a temporary cope and using more suitable protection. The finished results were very satisfactory in terms of appearance, their authenticity, and the curing and carbonation of the mortar. However, continuing long-term monitoring will be important in giving full information on the speed of carbonation and how the material performs overall.

In Scotland, there are many miles of boundary walls and their repair or re-build will soon be a significant challenge as they decay or face damage. For retaining walls, simple traditional construction techniques will be sufficient in most situations and it is hoped that the results at Kinneil will encourage others to procure similar work in planned and reactive maintenance, using traditional materials and methods.

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HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

Historic Environment Scotland is the lead public body established to investigate, care for and promote Scotland's historic environment.

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