# REFURBISHMENT CASE STUDY 26

## BLACK BULL CLOSE DUNBAR

HOT-MIXED LIME MORTAR TRIALS

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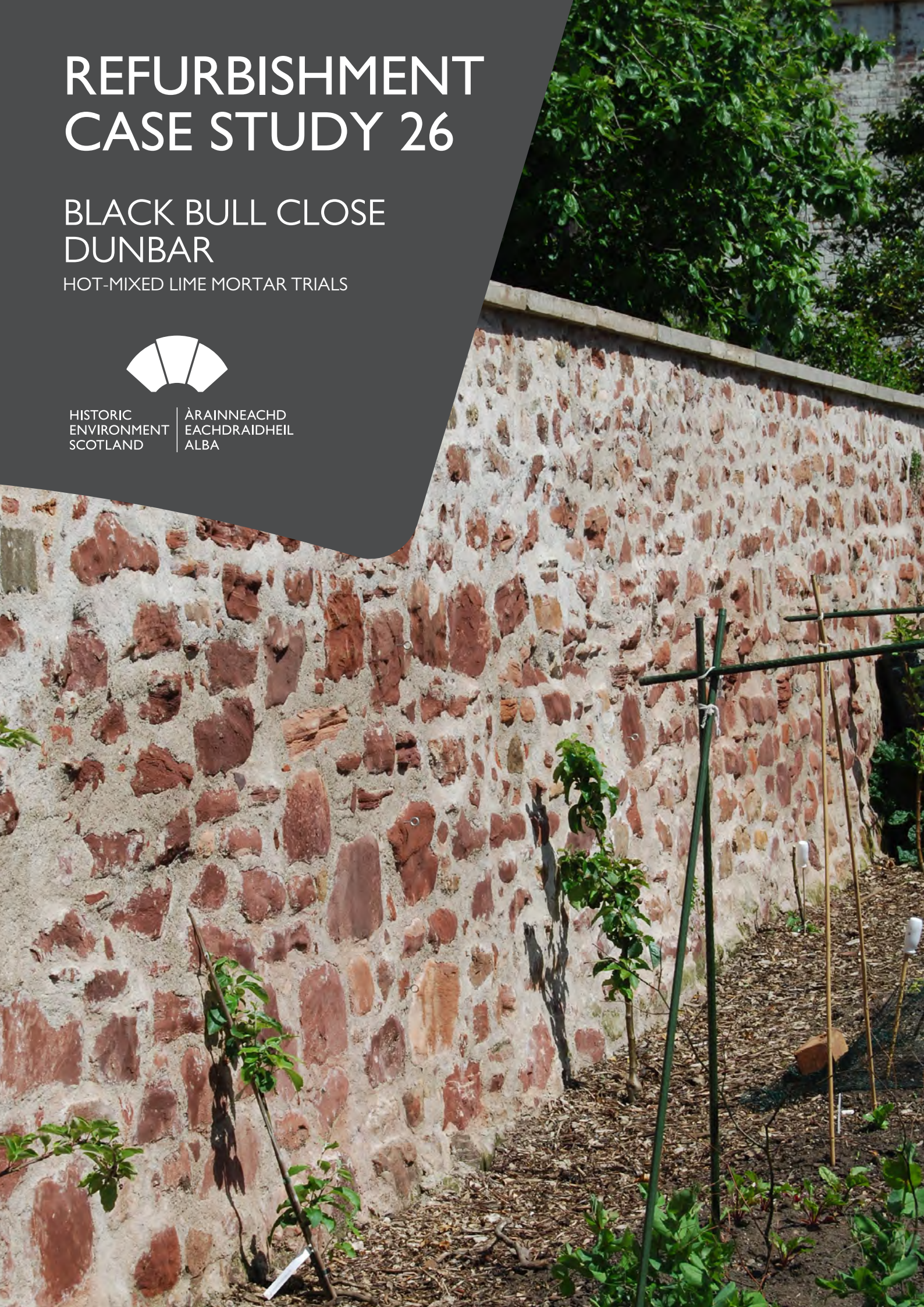

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## HOT-MIXED LIME MORTAR TRIALS

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Acknowledgements:

With thanks to The Ridge CIC

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# 1. INTRODUCTION

This case study describes a trial project which aimed to test how hot-mixed lime mortars can be used in the repair and rebuilding of a traditional Scottish boundary wall. A hot-mixed lime mortar is made by mixing quicklime with aggregate and water, with which it reacts to generate heat. This technique contrasts with modern practice, which typically employs pre-slaked bagged dry-hydrate natural hydraulic lime mortars.

The Ridge at Dunbar is one of a series of site trials sponsored by Historic Environment Scotland (HES) to assess the feasibility of the preparation and use of hot-mixed mortars on-site, and to test their practicality and durability. The work contributes to the evidence being gathered by HES on the preparation and use of traditional mortars. It also supports a broader knowledge exchange amongst the Hot-Mixed Mortars Collaboration, a partnership between conservation agencies in the UK and Ireland.

Analysis of historic lime mortars held by the Scottish Lime Centre Trust indicates that historic mortars tended to be lime rich, mostly feebly to moderately hydraulic and prepared from quicklime[1]. A current series of HES Technical Papers on hot-mixed lime mortars explores both the evidence for use of hot-mixed lime mortars in the past, and applications for its current use, particularly within a conservation context[2].

This trial was supported by HES and delivered by The Ridge, a Community Interest Company (CIC). The work used local labour and materials and was managed by The Ridge. The trial assisted The Ridge with its objectives to restore a garden plot for community use and train local tradespeople and volunteers in the use of traditional lime and rubble building techniques. These objectives were fully achieved, with contractors at the end of the project confident in the use of traditional mortars and The Ridge staff and volunteers able to continue with small areas of masonry repair using a hot-mixed lime mortar.

# 2. THE SITE

Black Bull Close in Dunbar is a type of landholding called a 'burgage plot', part of a common medieval town layout characterised by narrow strips of land extending at right angles from a high street in a 'herringbone' pattern.

[1] Research undertaken on behalf of HES by Ann Schmidt, *Analysis of the SLCT Mortars Database,* pending publication.
[2] *Technical Paper 27: Hot-Mixed Lime Mortars: Microstructure and Functional Performance*; *Technical Paper 28: Specifying Hot-Mixed Lime Mortars*; *Technical Paper 29: Review of Hot-Mixed External Lime Coatings in Scotland 1997-2016*; *Technical Paper 25: Traditional Lime Mortars and How They Were Made*, pending publication; *Technical Paper 26: Historic External Lime Finishes in Scotland*, pending publication.

The boundary walls of this plot form the subject of this study and are shown outlined in red, with the initial work area marked with a star on Figure 1. Commonly referred to as ‘backlands,’ these areas were generally used for horticulture of some type, although orchards, stables, byres and even light industry are all known to have been present at various sites, often in combination with each other. Dunbar is a good surviving example of these multifunctional ‘gardens,’ situated off the high street along what are probably the medieval boundaries.

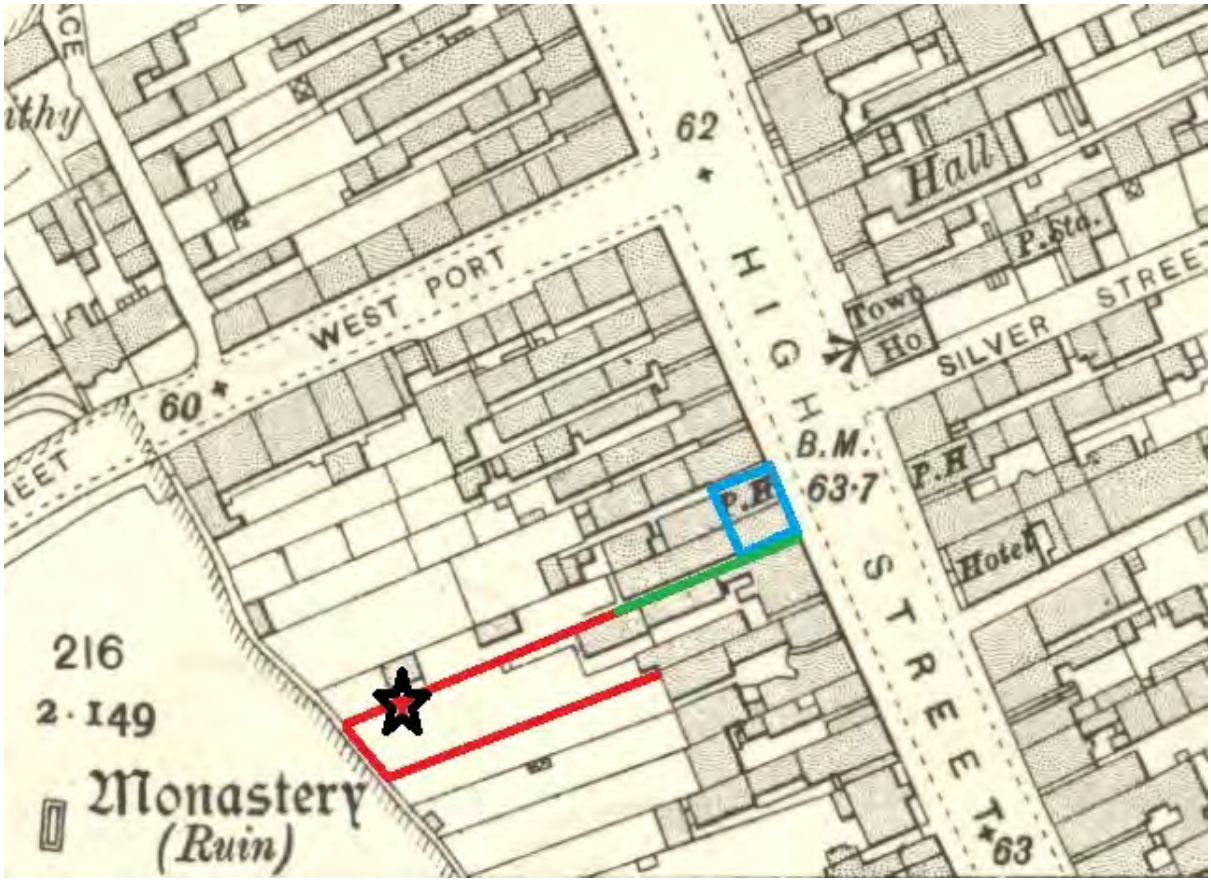


Figure 1. The location of the garden and its boundary walls in Dunbar, outlined in red. The boundary wall area discussed in this study is marked by the star. Black Bull Close is marked in green running along the south-east elevation out to the ‘backlands’. The blue square marks the Black Bull Inn. This map extract is the Second Edition of the Ordinance Survey of Scotland dated 1907, courtesy of the National Library of Scotland.

As its name suggests, Black Bull Close was the side or back entrance to the Black Bull Inn, marked in blue on Figure 1. Either side of the alleyway or close, marked in green, were several small dwellings extending back into the plot. These date from the late 16th century and, while not the subject of this study, are notable for the survival of their early harl and limewash finishes (Figure 2). Such traditional finishes, once typical of masonry structures across Scotland, have been largely lost, often deliberately removed or replaced, but early examples survive in neglected backyard

areas such as this[3]. The departure of residents and the absence of any interventions or maintenance over the years means that surface finishes survive on the masonry walls of many of the buildings in Black Bull Close.

Figure 2. Surviving historic harling finished with limewash in Black Bull Close, Dunbar.

Black Bull Close passed into the hands of the local authority in the mid-20th century, and they have recently leased it to The Ridge for training in horticulture and masonry. The site and its history were investigated by a community group guided by staff from 'Scotland's Urban Past', a HES-led national project supporting the investigation, understanding and dissemination of the history of Scotland's towns and villages. This research work gave an indication of how the burgage plots had been divided up, their subsequent uses and habitation patterns, and assisted interpretation of the remaining boundary walls that enclosed the plot.

## 3. THE BOUNDARY WALLS

The rectangular plot is enclosed by boundary walls on three sides, with the repair of the wall on the west side the subject of this study (Figure 3). The rubble walls were typical in their construction and detail, consisting of a local red sandstone and a lime rich mortar prepared from beach

[3] HES *Technical Paper 26: Historic External Lime Finishes in Scotland*, pending publication.

aggregates; the site is only a few hundred metres from the coast. Various repairs at different times had resulted in a heterogeneous mixture of masonry styles. In some areas on the south-west wall entire sections had been taken down and the stone removed. The Ridge wished to rebuild these sections to restore the garden boundary and provide support for the growing of fruit. The growth of ivy has caused structural instability in some areas of upstanding walls at the street end of the plot, which will be addressed in a future programme of works.

Figure 3. View of the garden plot and the boundary wall before the works. Phase 1 started with rebuilding the collapsed section on the far right.

## 4. PROJECT OBJECTIVES

### Trial hot-mixed lime mortar

Following dialogue with The Ridge, HES agreed to contribute funds to support the rebuilding of a section of the boundary wall back to full height. A hot-mixed lime mortar was to be used, in order to assess its ease of preparation and use with inexperienced contractors, and test its durability.

### Use of traditional materials

Locally sourced sand containing added crushed shell was used as an aggregate in the mortar. The quicklime was purchased from a lime producer in Cumbria, as no local sources are available. As most of the

stone from the largely demolished west wall had been removed, additional stone was procured from a dismantled structure on the site.

### Trial winter working

Due to the timescales for procuring funding, and to test the durability of the material and its use in harsher conditions, it was agreed that the work would be carried out over the winter. Protection of the finished masonry was an important aspect of the plan of works.

### Use of local contractors and volunteers

The Ridge wished to use local labour, and to train volunteers in aspects of traditional masonry work. Although the contractor had not used a hot-mixed lime mortar before, they were familiar with traditional masonry and modern lime mortar practice.

### Assess traditional additives

Evidence from recent lime practice and historic sources[4] indicates that in some cases additional materials were added to mortars to speed up the setting process. Such additives included the type of aggregate, and the addition of crushed brick and wood ash. The mortar used to rebuild the wall had an additive of wood ash to impart a weak pozzolanic set.

### Demonstrate traditional pointing finishes

Modern masonry practice often differs from what was done in the past. Pointing styles change over time, and using a different technique can change the appearance of traditional and historic buildings.  For this project, the existing original pointing style was replicated; a 'flush point' where the mortar is used generously to fill the joints and bring the finished surface level with the plane of the wall.

### Protection of the finished wallhead

The project did not have the funds required for the 50 linear metres of new natural stone cope required, and various alternatives to new-cut stone were discussed. Reclaimed stone suitable for copes was available, but not in the quantities required, and flat paving slabs or natural stone from abroad were both visually unsatisfactory and too costly. Therefore, as a pragmatic solution, second-hand concrete slabs were used as a wall cope. These were available at no cost, were visually unobtrusive, and could be easily cut to size and assembled on site.

[4] HES *Technical Paper 25: Traditional Lime Mortars and How They Were Made*, pending publication.

## 5. DEVELOPING AND TESTING OF MIXES

### Mortar analysis

While scientific mortar analysis was considered, the surviving mortar in this fairly thin wall was highly washed-out following exposure to the weather, and unlikely to be indicative of what was originally prepared and used. Visual analysis of mortar from other areas of the wall showed a relatively lime-rich mortar, easily broken by hand, and light grey/buff in colour with a shelly aggregate. The new mortar mix was prepared using aggregate to match the original, likely sourced from the beach nearby.

### Mixing equipment

At project inception the hiring of a forced action mixer was considered, but issues of cost, storage and provision of electrical power meant that this would have been impractical. Therefore a traditional mortar trough was constructed from scaffold battens and 4 inch nails (Figure 4) and was used for all mortar preparation during the project. Although basic, it proved ideal for use by the volunteers, who enjoyed the direct contact with the materials, and easily produced the mortar needed by the two stonemasons engaged in the rubble building (see section on health and safety below). While hand-batching is suitable for smaller projects, for larger work a forced action mixer is generally recommended for best results.

Figure 4. Hand-batching the sand and quicklime. This mortar bath was used to prepare the mortar for the test mortar and the rest of the project.

### Basic mortar mix

The mix ratio used for the works was 1 part un-slaked quicklime to 2 parts sharp sand and 1 part building sand; this was referred to as the ‘standard

mix'. This mix was the first to be used on a square metre of masonry at the base of the west wall.

### Trial mortar mixes

Three trial mixes, all variations on the standard mix, were also tested in square metre areas next to the standard mix. The first substituted crushed shell for the building sand, the second substituted the locally sourced aggregate for the building sand, and the third added ½ part of wood ash to the standard mix. These mixes were used in the first two days of the project, in early December 2015. The trial mixes showed no significant variation in curing time. All the mortar in the different areas appeared to cure at about the same rate: very slowly, with a set only taking place after three weeks. This might have been due to the low temperatures (around 10°C with some frost at night), which greatly slows the carbonation rate. There was also no discernible difference in curing time between the trial mixes and the standard mix.

Following the trials in November the test areas were evaluated. While the different additives did not appear to affect curing times, the use of crushed shell gave a good texture and appearance once scraped back. Therefore the standard mix (1 part quicklime, 2 parts sharp sand and 1 part building sand) was used with ½ a measure of crushed shell for the rest of the works. This also gave a better visual match with the existing mortar in other walls, where there was clearly a shell component.

## 6. HEALTH AND SAFETY

Like all lime and cement materials, quicklime is a hazardous material and requires the use of appropriate Personal Protective Equipment (PPE) and safe working practices. Skin exposure and inhalation of lime can cause harm, but with the right measures in place the risks can be managed at a safe level. Gloves and eye protection must be worn at all times, and dust masks when batching. Dust produced during batching can be reduced by the use of quicklime that is ground to a consistency of fine gravel, often called 'kibbled' quicklime. Further information about safety precautions can be found in HES's publications: *INFORM: Hot-Mixed Lime Mortars* and *Short Guide: Lime Mortars in Traditional Buildings.*

## 7. THE WORKS

### 7.1 Phase 1

Following the mortar trials, site work started in November 2016, with consolidation and rebuilding of the western end of the north wall

concluding in mid-December. This period was characterised by low temperatures but generally dry weather. The rubble work was taken up in 12 inch lifts, extending in a more or less horizontal line. Care was taken to ensure that the wall core was through bonded with stones. The mortar was batched fairly stiff, but just wet enough to allow easy positioning of the stones, and the mortar was left slightly proud of the wall (Figure 5).

Figure 5. The wall head protection in place at the end of Phase 1 in December 2016. This mortar has yet to take a set and be scraped back.

## 7.2 Phase 2

The second period of work, beginning in February 2017, took the south-west length of the wall up to full height by March 2017 (Figure 6). As the wall rose in height a single lift system scaffold was required to give a more effective working height, especially when handling heavy stones. The mortar from Phase 1 was scraped back just proud of the faces of the stones, giving a generally smooth surface.

During Phase 2 the sharp sand content of the standard mix was increased to 3 parts, and the building sand component was removed. This was to simplify batching and determine if removing the finer aggregate made any difference. This simplified mix was functional, but more difficult to work, and was described as ‘too sticky’. When cured it had a lighter colour than the standard mix, which was noticeable at the south-west end of the wall, which was shaded. It was concluded that the original standard mix containing building sand produced better results. The concrete slabs, selected as the cope, were also bedded in.

Figure 6. The rebuilt boundary wall at the end of Phase 2 in March 2017, with the flush pointing finish clear. The upper quarter of the wall has yet to take a set and be scraped back.

## 7.3 Phase 3

The final stage of the project began in April 2017 and completed the middle section of the north wall. As Phase 3 progressed, it was decided to set up a cover over the scaffold to allow work to progress during periods of rain. This significantly improved site availability and the working conditions for the masons. The mortar in Phase 3 cured much quicker than in earlier phases, and was ready to be scraped back after only three days (Figure 7). This quicker set was due to higher ambient temperatures as the spring progressed. For all phases, the wall head was protected during and after the works with hessian and polythene until the mortar had fully cured. Misting and re-hydrating the finished mortar was not required due to the quantity of water within the wall from the new mortar and the generally slow drying.

Figure 7. The rebuilt middle section of the boundary wall following scraping back towards the end of Phase 3 in April 2017.

## 7.4 Mortar performance

Only one small area of mortar failure was noticed, occurring where the new work met the existing wall at the south-west end. In this location the existing historic mortar, being very absorptive, drew the water from the new mortar. This caused drying, rather than the desired curing or carbonation, of the lime binder. It resulted in a whitish bright and friable mortar, visually different from the cured mortar elsewhere. This failed mortar was removed and replaced; careful dampening down resulted in a proper cure with the repaired section.

Figure 9. The finished walls from Phases 1 to 3 can be seen middle-right. The hessian protection is still covering the repaired upper masonry and new copes on the right.

## 8. ASSESSMENT AND LONG TERM MONITORING

Representatives from the Hot-Mixed Mortars Collaboration visited the site in April 2017, as Phase 2 was being completed. They examined the mortar preparation, the building techniques and how the mortar was finished and scraped. There were no identified issues; the effects of the crushed shell in the curing of the mortar generated discussion. In order to assess the process of carbonation, and better understand mortar strength over time, samples of mortar will continue to be taken from the wall core and analysed by HES over a period of years. The finished wall continued to dry out in the summer of 2017, and by August appeared to be largely dry and cured.

## 9. FUNDING

The works were supported by HES as part of a hot-mixed lime mortar research project, and part of the trial was to establish rates and costs for this type of building work. The contractor, by keeping careful records of time spent and materials used, was able to give a general rate for the

rebuilding of a rubble wall. The labour costs for the rubble building work were approximately £100 per square metre, but were not affected by the use of a hot-mixed lime mortar. If anything, productivity was increased due to the excellent workability of the mortar. The cost of the quicklime component in the mortar worked out around four times cheaper than commercially available hydraulic limes.

## 10. USE OF VOLUNTEERS

A significant part of The Ridge's garden enterprise is the retraining of people from all backgrounds in a range of horticultural and land management practices. The volunteers were able to assist in the rebuilding of the walls, and contributed with batching up the mortar, wall preparation and pointing, and assisting with the final scraping back. They found working with the hot-mixed lime mortar very satisfying, and gained a good perspective on the masonry work by being involved with the process from the very beginning. When the contractors were away the volunteers were able to continue with the preparation and pointing of some sections unsupervised. Further instruction will introduce rubble building and stone preparation. The results in terms of personal development for the trainees was noteworthy. To quote from the Managing Director of The Ridge:

*"The impact of this high quality training has been really exciting - the improvement in the state of the walls is both highly visible and highly rated across the community. We see the huge impact this response has on… those involved [and] the belief that they can make a highly valued contribution to their community, and the realisation that they are acquiring highly marketable and valued practical skills. Working as a close-knit team under steady supervision, they have also learned invaluable personal and workplace skills. It would be hard to over-state the positive effect this has had…"*

Figure 10. The contractors and volunteers by the Phase 2 finished wall on 9 August 2017.

## 11. CONCLUSION

This project demonstrated that hot-mixed lime mortars can be specified, prepared and used by competent tradespeople and others with the appropriate supervision.

The trial has shown that traditional mixes based on existing mortar samples are found to perform well. Curing times were undoubtedly longer during periods of low temperature, and on a more commercially driven site this might have restricted progress. However, with the right site practices and wall protection there does not seem to be a long term effect on the quality and finish of the mortar.

Locally procured aggregates and commercial quicklime proved to give a consistent mortar and resulted in a good visual match with the existing wall mortar of the boundary walls. However, due to physical site constraints, limited storage of materials and difficulty of access prevented bulk deliveries, and added time to the works.

While the contractor had not used a hot-mixed lime mortar before, all those involved quickly learnt and appreciated the working qualities of the mortar. A particular success with this project was the learning and development of the volunteers and trainees. From a position of modest masonry knowledge they were able to capably batch up hot-mixed lime mortar and carry out successful re-building and pointing work.

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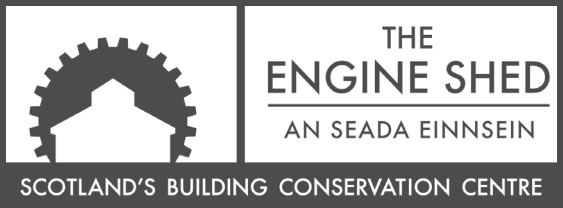

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