Appendix 1: Historic

This appendix is one of four environment topics covered as part of the NERC funded project report: Naylor, LA., Kippen, H, Coombes, MA., et al. (2017). Greening the Grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report. URL: http://eprints.gla.ac.uk/150672/

Business Case: Historical Innovations

image ©Historic Environment Scotland

This business case assesses the existing evidence of integrated green grey infrastructure (IGGI) measures that can support wider implementation on historic buildings, ruins and sites. It forms part of the NERC funded IGGIframe project outputs (URL: http://eprints.gla.ac.uk/150672/). Costs, benefits and measures of the engineering and ecological performance (called critical success factors) of a range of IGGI alternatives to traditional 'grey' approaches are drawn from operational and research examples across the UK and beyond.

Measures considered involve adding soil and/or vegetation to the tops (CS-H1; AP-H1; AP-H2) and the faces (AP-H3; AP-H4) and reburial of ruins (CS-H2). The business case is aimed at reducing the uncertainties when considering GI innovations, including:

- What are they?
- Where have they been applied?
- What evidence is there to show they work?
- Costs
- What are the benefits over business as usual?
- What measures and solutions are there?
- Where are they suitable?
- What are the risks?
- How can I get approval?
- What are the wider corporate benefits?

What are they?

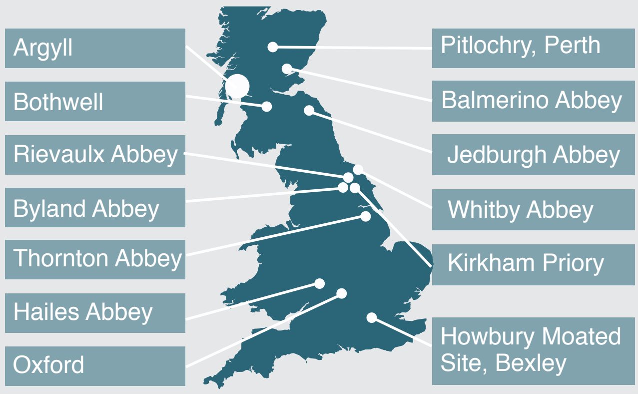
Innovative adaptations to traditional management of historic assets in historic conservation areas including ruined sites and free-standing walls. Most measures involve using nature-based approaches to limit/slow on-going deterioration of historic conservation assets (e.g. soft capping of walls) or alternative management strategies to minimise deterioration (e.g. reburial). Some measures also offer opportunities to support or increase local biodiversity.

When in the design/life of an asset can this be applied?

Methods aimed at slowing deterioration/aiding conservation of existing historic assets may be applied at any point, but may be most cost effective when the current risk of damage/deterioration is high. The measures described here can be used in other historic conservation settings around the UK, and with further study, could be adapted for use on the modern built environment.

For new build schemes within historic areas, possible green measures such as those in the urban, mowing and coastal bundles should be considered as part of strategic or design stages as well as retrospectively or as part of on-going maintenance.

Where has this innovation been tested or applied?



Evidence Summary

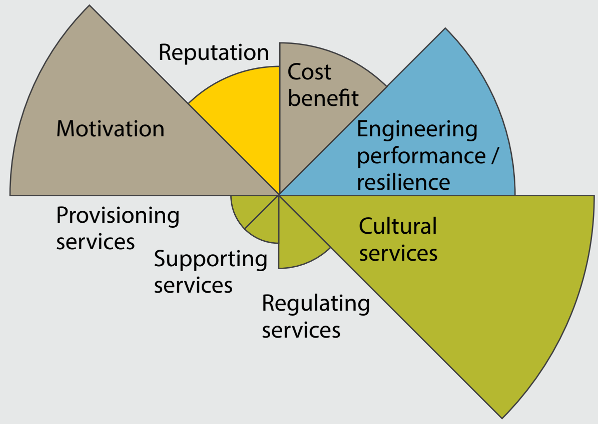
The evidence summary and benefits assessment are a summary of the critical success factors evaluated for all of the coastal case studies and 'Art of the Possible' examples. It is replicated across the four business cases to enable comparison between environmental contexts.

Costs	Ecosystem Services	Engineering	Policy
What do they cost compared to business-as-usual?	What evidence do we have that they deliver ecosystem service benefits?	Are there any risks to design life, inspection or effects on maintenance regimes?	How does it relate to policy and guidance?
Often less expensive to install compared to traditional grey solutions. Generally less expensive in the long-run, sometimes requiring less maintenance and repair.	The primary driver for heritage assets is typically improving resilience. However, in many cases greening approaches bring additional environmental benefits including local biodiversity gains.	Most of the measures are developed to increase design life by improving asset resilience. Altered or new maintenance regimes are required, although this is often less or similar to business as usual in terms of costs and personnel time.	Measures can contribute to wider policy aims and national guidance for historic sites and assets including on-going physical conservation, and reinforcing and enhancing access and presentation of sites for the general public.
LESS OR THE SAME	POSITIVE	POSITIVE	ACHIEVED

Social	Reputation	Asset Resilience	Data Quality
What are the potential additional social benefits?	How have the schemes helped improve public perceptions?	How have the schemes and measures influenced asset resilience to on-going deterioration?	What is the evidence base for IGGI approaches in the historic environment?
The wider benefits beyond cultural ecosystem services have not been assessed, although there may be some aesthetic and educational benefits of GI approaches.	Greening of historical assets is divisive, but there is evidence that the public are generally in favour where this is shown to help conservation.	Some measures can significantly help manage/limit damage to valued historic assets caused by weathering-related deterioration.	Site specific ecological data for each example was typically high, other data types varied.
UNKNOWN	NEUTRAL	POSITIVE	MODERATE - HIGH

Benefits Assessment

The evidence summary presented above is derived from the examples contained in this bundle, each of which have been assessed using the **Critical Success Factors** guidance. The benefits wheels show the benefits of each critical success factor relative to each other. They are a combination of ecosystem services and other important engineering and social considerations necessary to evaluate IGGI measures compared to business as usual. More detailed breakdown of each element can be found below.



Cost
These approaches can provide value for money as a long-term approach to maintenance and conservation. They can contribute to conservation of historic assets with, often, low to moderate installation and maintenance costs, and can maintain opportunities for subsequent research of the asset/site that can help reveal and support heritage values for the general public.

Engineering value
Some approaches have been developed primarily to improve asset resilience (against on-going deterioration) and maintain the long-term cultural value of historic structures, including already ruined sites. The success of these approaches is shown by their increasing application by statutory authorities such as Historic England and Historic Environment Scotland.

Cultural services
Measures that contribute to the on-going conservation of historic assets and sites can help sustain cultural heritage values. This includes the physical protection of materials and structures themselves, but also improving site aesthetics, education and experience for visitors.

Regulating services
There is limited study and evidence of regulating services (for people) from IGGI approaches in historic settings. However, greening measures can support improved air quality at a local scale.

Provisioning services
Likely to be very limited due to the scale and nature of these enhancements.

Supporting services
Introduction of soil and vegetation to historic sites and assets can support local biodiversity, including some rare species. Managing vegetation for primarily heritage conservation reasons can offer opportunities to improve conditions for insects and birds (e.g. ivy growing on historic assets where appropriate). Further evidence is needed.

Motivation
Motivation for the options outlined here is primarily the long-term conservation of historic assets as a heritage resource. This is especially for the case for vulnerable assets that are already at threat from on-going deterioration caused by environmental impacts such as weathering. Existing ('grey') approaches to conservation (e.g. hard capping) may also be inappropriate or ineffective and costly in some cases, with a need to develop and trial new greener and more sustainable solutions.

Policy
Experimental work on historic assets and at test sites are informing practice in the heritage sector, particularly those that have a very strong evidence base such as soft capping. Major guidance documents have been recently produced that outline this evidence, providing practical information for heritage asset managers/owners aiming to adopt some of these measures (see individual Case Studies and Art of the Possible examples for relevant references).

Reputation
Opinion on 'greening' of historic sites and assets is not clear cut. When coupled with adequate education and engagement, the public are often very positive about introducing nature into the historic environment. On the other hand, barriers do exist due to the potential for biodeterioration and issues of perceived neglect/ mismanagement of valuable heritage.

IGGI Measures

The IGGI measures in this bundle are mostly local/site based trials carried out as part of scientific research studies. This includes some work using purpose-built test structures that are more appropriate for testing and developing techniques than using existing heritage assets. Some examples are based at the 'operational' scale, where greening (alongside other 'soft' measures such as reburial) of entire sites/ruins has been undertaken to support wider efforts to conserve historic asset in the long-term.

Most of the measures outlined involve changes to the ways in which vegetation is managed, whether actively introducing it (e.g. soft capping) or altering approaches to its maintenance/removal (e.g. ivy on walls). These approaches aim to capitalise on the ability of vegetation of 'buffer' other factors that can contribute to on-going deterioration of vulnerable historic materials, including temperature and moisture cycles, and frost damage. Reburial of ruined sites and other archaeological remains is also primarily aimed at stabilising environmental conditions to limit further deterioration.

What types of infrastructure?

These measures have been tested or applied to a range of historic assets including freestanding and retaining walls and ruins. We have grouped these into three broad types:
(1) wall face
(2) wall tops
(3) ruins.

Case Studies

Type	Aim of the IGGI	Label	Title
Wall top	Soft capping of historic free-standing walls to improve asset resilience	CS-H1	Soft capping of historic walls, England
Ruin	Reburial of historic ruins to better conserve them	CS-H2	Reburial of historic ruins, Scotland

Art of the Possible

Type	Aim of the IGGI	Label	Title
Wall top	Soft capping of historic free-standing walls to improve asset resilience	AP-H1	Soft capping of historic walls
Wall top	Understanding and managing ivy on walls to reduce deterioration	AP-H2	Ivy on historic walls: bioprotection
Wall face	Understanding and managing ivy on walls to reduce deterioration	AP-H3	Ivy on historic walls: bioprotection
Wall face	Managing ivy on walls to attenuate pollutants and improve asset resilience	AP-H4	Ivy on historic walls: pollution biofilter

Two measures in the coastal bundle have also been applied in historic conservation areas or on historic conservation assets. These include ecological enhancement of a coastal flood alleviation scheme in Shaldon, Devon (CS-C7) and test panels of textured concrete for marine biodiversity (AP-C8) tested on the historic pier at Blackness Castle, Scotland. Other coastal IGGI measures shown to encourage faster colonisation by intertidal species (e.g. AP-C7) may also be applied to historic coastal assets to make repairs blend in more swiftly to improve amenity and habitat provision.

IGGI Solutions

IGGI measures on historic assets and in historic conservation areas can contribute to wider greening approaches to environmental enhancement. Measures are typically very local scale, but can provide elements of 'green' that improve habitat connectivity. In combination with measures in urban and coastal environments, greening of historic assets can form a valuable part of landscape-scale IGGI solutions.


image ©Historic England

What ecological factors need to be considered?

It is important to consider the ecological suitability of the IGGI measures for a given location and for different types of historical assets and their component materials. Timing of application, the kinds of species used and maintenance practices can influence the likely success of greening measures and their ability to support beneficial biodiversity. Similarly, given that the measures described in the bundle are primarily intended to aid conservation of the assets, biodiversity gains are only a secondary aim and may be generally limited, but can be locally significant. Further details of these kinds of considerations are provided on the risks page of this business case.


image ©Historic Environment Scotland


image ©Historic Environment Scotland

How can you get this type of greening approved for your scheme?

The case studies, art of the possible examples and policy links provided here can be used to demonstrate the economic, environmental and social benefits that can be gained from adding IGGI measures to historic conservation projects. They also provide clear evidence of the policies that have been used as statutory climate change (AP-H1) or environmental impact assessment (CS-C7) or non-statutory, organisational strategy (CS-H1, CS-H2) drivers.

Where no statutory mitigation is required, how else can you get this type of greening approved? Many of the examples only require a willingness to innovate, as testing or applying IGGI measures often requires minimal change in behaviour or practice. Some examples illustrate how changes in operational practice (e.g. CS-H1, AP-H1 to AP-H3) can support on-going conservation of culturally valued assets or sites at reduced cost compared to business as usual, and provide some additional local benefits such as increased habitat provision for wildlife and improved asset resilience through pollutant trapping (AP-H4).

Known limitations or risks associated with these IGGI approaches

There is increasing evidence of the value of some greening approaches for helping to conserve vulnerable historic assets and sites, including experimental research at a number of different sites across the UK. There are important limitations that need to be considered however, especially as the assets involved are often valued as national heritage, and recognising that greening will not be appropriate in all cases. Risks associated with the measures described in the bundle include:

Risk Factor	Description and Risk Reduction Strategies
Establishment of soft caps	Establishment of plants can be weather dependant and watering may be required during dry or warm periods post-construction. Birds may remove plug-plants from some soft capping sites.
Geography	Soft capping may not be suitable for very dry or drought-prone sites, or more drought tolerant species would be required.
Biodiversity	As a secondary aim to the conservation of the asset, there is limited data on the ecological benefits of soft capping and ivy on historic assets; further study would be beneficial. However, vertical vegetation, including ivy, is known to be very beneficial for wildlife.
Maintenance	Routine maintenance is needed to remove any woody vegetation from soft caps and to undertake some repair/replacement of damaged areas of capping that may occur over time. Ivy must be monitored and kept away from guttering and roofs, with annual trimming recommended.
Aesthetics	Soft capping of walls may initially look 'unusual' until established, when they appear more naturalistic. Vertical vegetation like ivy is not appropriate where it obscures valued features such as architectural detailing. Vegetation on historic assets can be seen as 'neglectful' by members of the public.

Where to learn more

Coombes, MA, Viles, HA, Cathersides, A. (Forthcoming) Ivy on Walls. Historic England Research Reports Series.

Hanssen, SV, Viles, H. (2014) Can plants keep ruins dry? A quantitative assessment of the effect of soft capping on rainwater flows over ruined walls. Ecological Engineering, 73: 173-179.

Historic England. (2016) Research Strategy. URL: https://content.historicengland.org.uk/images-books/publications/research-strategy/research-strategy.pdf/

Lee, Z, Viles, HA, Wood, CH. (editors). (2009). Soft capping historic walls: A better way of conserving ruins? English Heritage Research Project Report. URL: https://historicengland.org.uk/images-books/publications/soft-capping-historic-walls/

Morton, T. et. al. (2011). Soft capping in Scotland: the content and potential of using plants to protect masonry, Historic Scotland Research Report. URL: https://www.engineshed.org/publications/publication/?publicationId=5a2c8f33-dc6a-4604-9df6-a5af00960d7b

Scottish Government. (2014) Our place in time - The Historic Environment Strategy for Scotland. URL: http://www.gov.scot/Resource/0044/00445046.pdf

Sternberg, T, Viles, H, Cathersides, A, Edwards, M. (2010). Dust particulate absorption by ivy (*Hedera helix L*) on historic walls in urban environments.

How to cite: Naylor, LA., Kippen, H, Coombes, MA., et al. (2017). Greening the Grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report. URL: http://eprints.gla.ac.uk/150672/

Historic Case Studies

Case Study CS-H1:

Soft Capping - Historic England

Summary

Placing soil and grass on the tops of ruined walls to aid conservation offers a viable alternative to traditional hard capping. Eight years of experiments, field trials and monitoring by Historic England and the University of Oxford at multiple historic sites demonstrate how this approach can not only reduce rates of deterioration, but also support biodiversity and reduce costs. Based on this evidence, all of the ruins at Hailes Abbey, Gloucestershire, were soft capped in 2013 and this is proving very successful.

Benefit	MEDIUM
Engineering	MEDIUM
Ecosystem	LOW
Cost	LOW

How does it work?

Ruined and free-standing walls are exposed to rain, thermal fluctuations and frost that cause deterioration over time. Hard caps of stone and mortar have traditionally been used to consolidate wall tops and minimise on-going damage, but these often crack/deteriorate quickly requiring regular maintenance and repair. Using soil and vegetation to cap walls offers an alternative, and there is strong evidence that such soft caps are effective at buffering fluctuations in temperature (including frost) and moisture, and thereby protect the tops of walls from further damage. Soft caps also reduce the amount of rainwater running down the face of walls that can increase the harmful weathering of face stones and cause unsightly surface staining.

Motivation

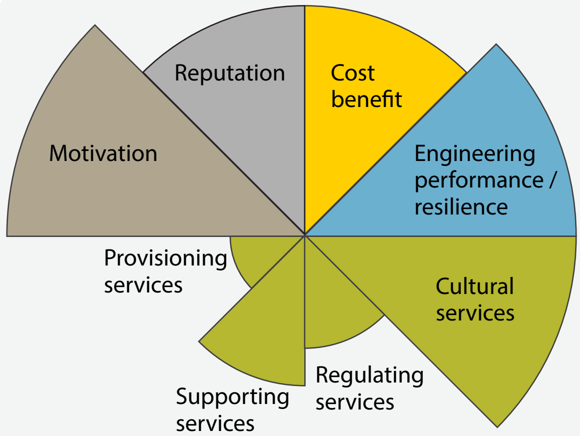
Hailes Abbey suffers from flooding and is situated in a frost hollow and many of the walls were in very poor condition and deteriorating rapidly, requiring frequent and costly repairs to the hard capping in the past. Previous soft capping trials at the site had proved effective, supporting the decision to soft cap the entire monument as a more sustainable and cost-effective way of conserving the ruin.

Design Innovation / Enhancement measure

Hailes Abbey, a 13th Century Cistercian abbey, was the first Scheduled Ancient Monument in England to be entirely soft capped, in 2013. Soft caps were applied on all sections of exposed wall, including at ground level and walls up to 5 m in height. The cap consisted of locally-cut turf with a thickness of c. 10 cm. In some areas small sedum plants were added subsequently to help prevent edge erosion.

Benefits

Although costs can vary (see below) the soft capping method has proven to be a cost effective, low maintenance method of conservation that reduces costly maintenance and repair cycles for asset managers. It also provides a degree of ecological enhancement of value in itself; greening ruins provides some aesthetic appeal and limited regulating (e.g. water attenuation) and supporting (e.g. habitat provision) ecosystem services. Results of preliminary trials here and in Scotland (see AP-H1 and AP-H2) show it can be a useful asset management tool that can achieve desired engineering performance outcomes and provide ecosystem services.



Net Cost

Trial installations of soft capping at three sites (Byland Abbey, Kirkham Priory, Thornton Abbey) were fully costed based on 2005 prices for a research rather than commercial installation. Soft capping costs ranged from £39 to £75 per m^2 (using 10 cm thick soil and turf cut on site). The higher costs in the range largely reflect the need for scaffolding to install capping on higher walls.

Direct cost of intervention

Other costs include labour, materials and equipment (e.g., turf cutter hire). If installed carefully, maintenance costs are minimal.

Cost compared to business-as -usual

Hard capping costs at the same sites were calculated as £567 to £991 per m^2 at 2005 prices using suitable stone and lime mortar. These costs incorporate additional costs of a stonemason, materials, removal and recording of any existing consolidation, salvaging original stonework, and additional time to select and source appropriate replacement stone. Soft caps can be easily installed in a matter of days – hard capping (when done properly) may take considerably longer.

Per meter of wall, soft capping at three fully-costed sites at 2005 prices was around 13 to 15 times less expensive than using hard capping.

Long-term cost

Once a soft cap is established the maintenance costs should be minimal (see following section). Long-term cost savings will be positive given that walls are expected to deteriorate more slowly and require less frequent intervention/ repair. There is currently minimal evidence to indicate the likely scale of these savings over the long term.

Engineering performance, inspection and maintenance

Experimental evidence and site monitoring shows that soft capping will reduce fabric loss from walls by providing a thermal blanket on wall heads, which reduces deterioration caused by freezing events and repeated thermal expansion and contraction. At Hailes Abbey, trial soft capping also led to generally lower levels of moisture and reduced moisture fluctuations in the underlying walls compared to uncapped walls. Soft caps are also more effective at shedding water away from walls than hard caps, reducing the amount of water running down the wall face during heavy rain that can lead to decay and surface staining.

Research has been undertaken to address performance concerns relating to possible damaging effects of vegetation on stone walls. This has shown that a soft cap reduces the amount of water reaching the wall head, and that this water is not acidified and therefore does not enhance chemical degradation of the stonework. Furthermore, grass and sedum roots are not woody and pose little if any risk of enhanced deterioration. Occasionally, woody species may become established in soft caps, and these should be removed immediately once identified.

Installation of soft capping requires careful timing (ideally between October and February), as new caps are very prone to drying out. An initial period of regular watering (around 3 months) is advised to help the cap establish. Exposed edges can be especially prone to drying out and then eroded during heavy rain and this can lead to failure of the caps to establish if not monitored. This can be partially overcome by introducing more drought resilient plants, particularly sedums. These can be inserted as plugs to the edges of turf caps to improve stability.

Once established, soft caps are generally low maintenance and are considered largely self-maintaining, particularly in comparison to hard capping. Where/if growth becomes excessive a cap may benefit from being trimmed back. Assessment of the general condition of the cap, including evidence of edge erosion, should take place every 5 years. Woody species should be identified and removed on an annual/biennial basis.

Ecosystem services

Soft capping functions as additional habitat for plants, insects and birds that hard-capped walls do not provide. Plant communities forming soft caps are dynamic and change naturally over time, and may support locally similar but distinct species assemblages.

Ecological surveys of sections of turf capping originally installed at Hailes Abbey in 2005 were carried out in 2007 and 2011. A comparison was made in an adjacent field site where the turf was sourced. In 2007 the communities both in the field and on the wall were classified as MG6a *Lolium perenne-Cynosurus cristatus* grassland following National Vegetation Classification (NVC). Perennial rye-grass was less common within the soft-cap than the field, whereas Cocksfoot and Red fescue were more abundant. By 2011 considerable changes in the community had occurred, classified as MG11a (*Festuca rubra-Agrostis stolonifera-Potentilla anserine* grassland) Lolium perenne sub-community. The changes likely reflect progressive leaching of nutrients and lack of moisture on the soft cap.

By slowing the deterioration of valued historic assets soft capping provides a cultural service. Many people also place greater aesthetic value in 'natural looking' ruins, and using vegetation to slow deterioration may therefore support broader efforts to engage the public with historic sites (see social value).

Social value

A detailed visitor perception study at Hailes Abbey found that around 78% of visitors has a positive perception of the capping and 16% had a negative view (the remainder were neutral). Those with a negative view were more accepting once educated about the conservation benefits of a soft cap. Based on a choice of photographs, around half of visitors (47%) preferred the ruin after it had been soft capped, 12% preferred it with natural vegetation (based on a 1937 photograph) and 20% indicated preference for no vegetation. There was also a general interest from visitors for more on-site information about soft capping of the ruin, indicating educational opportunities.

Who can apply this intervention / technique?

Soft capping could be applied to any historic freestanding wall or ruin, with appropriate prior consultation but if the structure is listed or scheduled, consent will be needed. In situations where hard capping has been applied but is currently failing, or where unconsolidated walls are rapidly deteriorating, soft capping can be a viable option. Height and composition of walls do not appear to affect success, but thin walls (< 30 cm) may be less suitable to support a healthy soft cap. Drought-tolerant sedums are considered crucial for the success of soft caps on thinner walls. Walls with flat heads will be most suitable for soft capping, whereas rough wall heads may require additional soil to level out the surface.

Scaling up the benefits

Soft capping has been shown to perform well on walls made from a range of materials including limestone, sandstone, brick and flint. Equally, the moderating influence of soft capping has been consistent across a range of climatic settings in England, including Yorkshire, Gloucestershire, Oxfordshire, Norfolk and Greater London. Overall, soft capping is also considered a good interim conservation solution for ruined sites as it can be both installed and removed relatively quickly and easily.

Where left undisturbed and given enough time, walls often acquire a natural ‘soft cap’. There is little research on the possible benefits of these, but they are likely to function in a similar way to installed soft caps. Where conservation of historic fabric is not a key driver, soft capping may still be a viable option for greening of boundary, retaining and other types of free-standing walls, including in urban areas, to support wildlife and create new green space.

Data Quality

The table shows the relative strengths of the Economic, Technical and Environmental data available. They are classified as:

Scheme Specific
part of a PhD or similar detailed research

Expert Judgment
interpretation of the scheme by one or more experts

Wider Supporting Evidence
extrapolated from published work or reports by practitioners.

DATA TYPE	DATA QUALITY / QUANTITY						
	Scheme specific information			Expert judgement		Wider supporting evidence	
	No Data	Limited reported sources	Strong reported sources	Some expert opinion	Multiple experts	Some sources	Multiple sources
COST			●	●			●
ENGINEERING			●	●			●
ECOSYSTEM			●	●		●	

Further information / Contacts

Historic England (Forthcoming) Soft Capping of Ruined Walls. Research Reports Series XXX-XXXX.

Prof. Heather Viles, University of Oxford:
Heather.viles@ouce.ox.ac.uk

Lee, Z, Viles, HA, Wood, CH. (editors). (2009). Soft capping historic walls: A better way of conserving ruins? English Heritage Research Project Report. URL: https://historicengland.org.uk/images-books/publications/soft-capping-historic-walls/

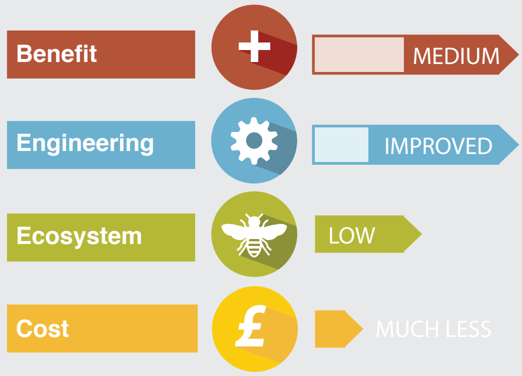
Chris Wood, Historic England:
Chris.wood@historicengland.org.uk

Case Study CS-H2:

Reburial of historic monuments

Summary

Reburial of historic monuments at Jedburgh Abbey, Scottish Borders. An innovative scheme to rebury parts of the masonry at most risk. Vegetation and growing medium were applied to the top of the monuments. Monitoring and assessments of the impacts might prove useful for preserving many other buildings at risk in Scotland and elsewhere.



How does it work?

Thirty years of wetting–drying and frost cycling had damaged the red sandstone masonry on the South Range of Jedburgh Abbey, a ruined Augustinian abbey in the Scottish Borders. Repairs and consolidation with cement-based mortar had exacerbated the damage of the clay rich sandstone. Removal and replacement of the mortar with a lime-based cement would have been damaging, and selective replacement of the most damaged stones would have reduced the detail and appeared incongruous. Reburial was deemed most preferable, least damaging option. In November 2015 the masonry was covered with an isolating layer of geotextile, and a protective (soft) capping of puddle clay tempered with sand was created, at least 100 mm thick, topped with two layers of turf.

Motivation

Exposed historic masonry is at risk from a number of factors including physical and chemical weathering from pollution and climate change. The site at Jedburgh presented opportunities to test innovative reburial techniques, and monitor the temperature and humidity changes over a relatively lengthy period using remote sensors.

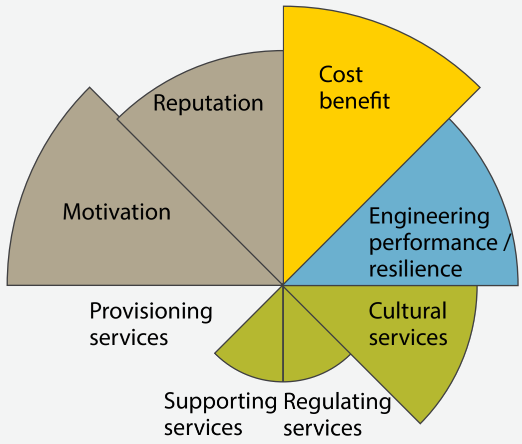
Design Innovation / Enhancement measure

The wall head of historic ruins was protected using a combination of the geotextile and clay/ sand mix topped with turf. The design enabled conservation of vulnerable masonry by maintaining a relatively stable temperature, humidity and pH. Monitoring was incorporated into the activities, by burying iButton sensors at different depths within the reburial material (at 20 mm, 70 mm and 150 mm depths, and between the masonry and membrane).

image ©Historic Environment Scotland

Benefits

The technique appears to provide a stabilising option that can drastically limit the rate of degradation of important social, cultural, historic and economic historic conservation structures. This could be a useful and cost effective way to preserve cultural and historically significant buildings in the long term. It also has the potential (as yet unmeasured) to improve climate change resilience of the assets and through improved rainfall attenuation, as well as improve habitat for wildlife. Modern scanning and mapping technologies can create detailed 3D images of the structures for analysis and public engagement, and if required, the capping can simply be removed later.



Net Cost

The net cost of the intervention is expected to be very similar to the direct cost of the reburial construction costs, as on-going inspection and maintenance is expected to be low and the turfed areas to have a long (> 25 year) design life. For this trial, there are additional monitoring costs to evaluate the effects of reburial on the risk of subsurface deterioration. These increase the net cost of reburial in this instance.

Cost compared to business-as -usual

The direct cost of the intervention was £22,000 (2015 costs) compared to £120,000 for consolidation repairs to the historic asset, which was the second option considered during the options appraisal. This represents an 82% savings for design and construction compared to business-as-usual, a savings of £1151 per m^2.

Direct cost of intervention

The direct cost of the intervention was £22,000 (2015 costs) of which £18,000 was labour and £4000 was material costs, including VAT for the design and installation of 66m^2 of reburial works. The cost per m^2 is £667.

Long-term cost

The long-term asset maintenance costs of reburial are unknown but are expected to be low. Historic Environment Scotland are monitoring the reburial to measure the effects of reburial on soil moisture fluxes and thus risk of asset deterioration, which is incurring a modest cost.

Engineering performance, inspection and maintenance

The reburial/capping provides a stable environment relatively free from damaging influences. The dense materials provide thermal stability, insulating the masonry from temperature extremes, intense and chronic exposure to radiation, storms and other extreme weather events.

The Jedburgh work included the use of iButtons – remote sensors that monitor the environmental conditions. Data from the iButtons will be analysed for changes in environmental conditions like thermal variation and humidity changes.

Ecosystem services

The vegetation capping the reburial will provide a modest amount of habitat that can be mowed or left to develop into more mature grassland. There are opportunities to plant wild flower meadow species and provide opportunities for other wildlife, including late pollinators that may not have access to suitable habitat elsewhere. Initiatives to link pollinator habitats include B-lines and the National pollinator Strategy.

Because of the scale and nature of the sites, there may be limited capacity to enhance ecosystem services beyond a local scale, although they may form part of larger strategic enhancement work. Supporting services might be achieved by creating a soil layer and vegetation that plays a role in nutrient cycling and primary production. The grass habitat can provide some regulating service including carbon sequestration and runoff reduction / water storage. Cultural services will be enhanced in the long-term by the improved lifespan of the historic assets, but reburial makes them inaccessible in the immediate term.

Social value

Reburial is proving a cost-effective method for vulnerable historic ruins, conserving them for future generations as a more sustainable solution to on-going decay of valuable assets that are under increasing threat from environmental change. Reburial may be controversial – removing access to monuments by the general public. Education opportunities exist to convey the conservation value of this approach, but information is not available on public opinion about reburial, although anecdotal evidence suggests it has generally been viewed very positively. Digital technologies (such as high resolution scanning prior to reburial) offer significant opportunities to overcome some of the challenges; interactive 3D models could be produced to aid education and interpretation and to conserve public 'access' to the buried asset.

Who can apply this intervention / technique?

Anyone looking to conserve degrading masonry structures, and where alternative conservation strategies are not possible or appropriate. The burial techniques are reasonably straightforward and the materials widely available. It is important that specialist guidance is taken if deciding to rebury protected historic assets. Digital preservation of assets prior to reburial is highly recommended, and for this additional funding and expertise will be required.

Scaling up the benefits

There are a great number of historic monuments, ruins and masonry walls that might benefit from reburial, especially were alternative conservation approaches are deemed unsuitable and / or where funding is very limited. For public assets, ensuring people are engaged and educated about the purposes and benefits of reburial will be important if this is to be adopted more widely as a strategy.

Data Quality

The table shows the relative strengths of the Economic, Technical and Environmental data available. They are classified as:

Scheme Specific
part of a PhD or similar detailed research

Expert Judgment
interpretation of the scheme by one or more experts

Wider Supporting Evidence
extrapolated from published work or reports by practitioners.

DATA TYPE	DATA QUALITY / QUANTITY						
	Scheme specific information			Expert judgement		Wider supporting evidence	
	No Data	Limited reported sources	Strong reported sources	Some expert opinion	Multiple experts	Some sources	Multiple sources
COST			●				
ENGINEERING			●	●			
ECOSYSTEM		●		●			

Further information / Contacts

Buglife (2017). B-lines - Wildflower initiative for pollinators: https://www.buglife.org.uk/b-lines-hub [Accessed August 2017].

Historic Environment Scotland, Jedburgh Abbey: https://www.historicenvironment.scot/visit-a-place/places/jedburgh-abbey/ [Accessed August 2017].

Morton, T. et. al. (2011). Soft capping in Scotland: the content and potential of using plants to protect masonry, Historic Scotland Research Report. URL: https://www.engineshed.org/publications/publication/?publicationId=5a2c8f33-dc6a-4604-9df6-a5af00960d7b

National Pollinator Strategy (2015). https://www.gov.uk/government/publications/national-pollinator-strategy-2014-to-2024-implementation-plan [Accessed August 2017].

Contact:
Peter Ranson, Historic Environment Scotland
peter.ranson@hes.scot

Historic Art of the Possible

Art of the Possible

HISTORIC

AP-H1

Soft capping of Historic Walls in Fife, Scotland

What is the measure?

Vegetation and growing medium applied to the top of historic wall to provide sustainable and low intervention improved resilience. Local clay and sand mortar mix is applied to historic ruin wall tops and capped with local turf and sedum. Trialled by National Trust for Scotland with funding from Historic Environment Scotland at Balmerino Abbey, Fife.

Primary Driver

To adopt a low impact and sustainable method of protecting the underlying masonry and wall core, reducing the risk of damage from water penetration at high level. Roofless and ruinous monuments can be at risk of erosion and damage from increased rainfall. Sustained saturation through the wallhead can result in loss of structural integrity and disfiguration due to lime-binder leaching through the wall core. Soft capping is a low maintenance, non-destructive, reversible, sustainable and visually pleasing alternative to the business as usual rough racking (stone and mortar) technique.

Benefit

Straightforward and relatively inexpensive measure which mimics natural soft-capping, providing low maintenance and visually pleasing protection to roofless monuments requiring minimal intervention. Soft capping ameliorates the effects of exposure and erosion, improving resilience, and protecting the monument from the effects of climate change.

Cost

Materials for soft capping are low-cost (see CS-H1) and may be sourced on site or locally. Sand and turf are readily available as are plug plants which are used to stabilise the turf. However time for preparing clay, applying on site, finishing and protecting can increase labour costs compared to conventional rough-racking. Success can be weather dependant and more watering is required during dry or warm periods. Both green and business as usual methods require routine maintenance and inspection.
Long terms cost benefits are anticipated to be significant as the soft capping matures and stabilises requiring less maintenance, and the protection afforded to the wallhead reduces the risk of damage to the monument.

Engineering

The resilience of the wall can be increased with the introduction of the soft cap. Vegetation can reduce thermal flux, shade against sun-damage and reduce frost damage and wind erosion. Where soft capping is maintained and performs well, water ingress is reduced and resulting damage avoided. Soft capping may not be suitable for very dry or drought-prone sites.

Asset Resilience

Well maintained soft capping can reduce climatic impacts. Using living plants and clay/soil provides a water resistant layer that acts as a buffer which protects the masonry from penetrating damp and cyclical wetting and drying, freeze/thaw cycles.

Ecosystem Services

Soft capping can improve biodiversity on historic sites and reduce water run-off from wallheads, improving site water management.

Social

Historically, ruins with natural soft capping have been appreciated for their beauty, demonstrating a visually pleasing harmony between the built and natural world. Both naturally occurring and applied soft-capping can soften the appearance of a ruined structure and improve the visual appearance of the site.

Policy

Use of soft capping on monuments can help meet Scottish Government targets and public body obligations related to enhancing biodiversity and use of sustainable materials.
It also supports the Scottish Adaptation Framework set up improve Scotland's resilience to the climate change.

Further information

Lee, Z, Viles, HA, Wood, CH. (2009). Soft capping historic walls: A better way of conserving ruins? English Heritage Research Project Report. URL: https://historicengland.org.uk/images-books/publications/soft-capping-historic-walls/

Morton, T. et. al. (2011). Soft capping in Scotland: the content and potential of using plants to protect masonry, Historic Scotland Research Report. URL: https://www.engineshed.org/publications/publication/?publicationId=5a2c8f33-dc6a-4604-9df6-a5af00960d7b

Jessica Hunnisett-Snow, MRICS IHBC, Historic Environment Scotland: jessica.snow@hes.scot

This forms part of Naylor, LA., Kippen, H, Coombes, MA., et al. (2017). Greening the Grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report. URL: http://eprints.gla.ac.uk/150672/

Art of the Possible

Soft capping of Historic Walls in Bothwell, Scotland

What is the measure?

A clay capping topped with turf was added to the top of historic wall to provide sustainable and low cost intervention, serving as form of adaptive (proactive) conservation. Clay and sand mix is applied to historic ruin wall tops and capped with turf incorporating sedum plants to edges. It was installed on a length of the curtain walls at Bothwell Castle, Scotland in 2013.

Primary Driver

Climate change is forecast to increase rainfall in central Scotland, which may increase the rate of deterioration of historic monument assets of high cultural value. Sustained saturation through the wallhead can result in accelerated masonry decay and loss of structural integrity. Traditional rough racking capping methods are expensive to implement and maintain and they deteriorate quickly (c. 25 year design life). Soft capping is a low maintenance, reversible, sustainable and visually pleasing alternative method of protecting the underlying masonry, reducing the risk of water penetration damage.

Benefit

Straightforward and relatively inexpensive measure which mimics natural vegetation colonisation, providing low maintenance and visually pleasing protection to roofless monuments requiring minimal intervention. Established soft capping is self-sustaining like an untended meadow and ameliorates the effects of exposure and erosion, improving resilience, and protecting the monument from the effects of climate change. It also reduces the need to regularly inspect for loose rough racking stones and the potential hazard they pose.

Cost

Materials for soft capping are low-cost and easily sourced - sometimes locally. Sand, turf, plug plants and pegs are used to establish soft capping on wallheads. However preparing wall heads masonry to receive, working clay, applying on site, laying turf finishing and protecting are all labour intensive, and access scaffold costs need to be factored in.

Long term cost benefits are anticipated to be significant as the soft capping matures and stabilises requiring less intensive maintenance than rough racking methods (which need periodic maintenance and full replacement every ~25 years), and the protection afforded to the wall masonry reduces deterioration risk and associated maintenance needs.

Engineering

The resilience of the wall can be increased with the introduction of the soft cap. Vegetation can reduce thermal fluxes, frost damage and wind erosion. Where soft capping performs well, wall head water ingress is minimised and run off down wall faces is reduced protecting historic masonry. Maintenance of the soft cappings are less expensive than for rough racking and involve periodic inspections to remove woody species which can usually be done without incurring the scaffold costs rough racking overhaul entails. Maintenance needs in the 5 years since installation at Bothwell have been less than anticipated.

Asset Resilience

Well maintained soft capping can reduce climatic impacts on ruined structures. Observational evidence from this site suggests that the walls are drier using soft capping compared to conventional rough racking methods.

Ecosystem Services

Soft capping can improve biodiversity on historic sites and slow water run-off from wallheads, has potential to marginally improve site water management. They also help sustain cultural ecosystem services (see social).

Social

Historically, ruins with natural soft capping have been appreciated for their beauty. Soft capping helps conserve and sustain historic structures by stemming decay so their cultural (national identity, community and tourism) value can continue to be enjoyed and appreciated by future generations – national identity value, community value and tourism value. See comment above hazard inference.

Policy

Use of soft capping on monuments can help meet Scottish Government targets and public body obligations related to heritage conservation, enhancing biodiversity, sustainability and improving Scotland's resilience to the climate change.

Further information

Hyslop, E. (2014). Climate Change Adaptation in Historic Scotland: First Steps. URL: https://www.adaptationscotland.org.uk/application/files/1614/7094/7071/2014_ALE_workshop_HistoricScotland_presentation.pdf

Morton, T. et. al. (2011) Soft capping in Scotland: the content and potential of using plants to protect masonry, Historic Scotland Research Report. URL: https://www.engineshed.org/publications/publication/?publicationId=5a2c8f33-dc6a-4604-9df6-a5af00960d7b

Scottish Government. (2014). Our Place In Time - The Historic Environment Strategy for Scotland. URL: http://www.gov.scot/Resource/0044/00445046.pdf

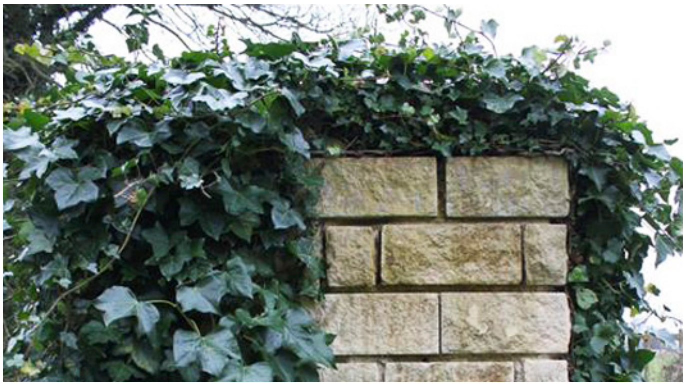
Historic Environment Scotland, HMEnquiries@hes.scot

Art of the Possible

Ivy on Historic Walls

HISTORIC

AP-H3



What is the measure?

This is a new way of thinking about ivy growing on historic walls and buildings. Rather than automatically removing it under the assumption it is always damaging, there is now strong evidence to suggest that–where managed sensibly–ivy can provide benefits for asset resilience alongside other environmental gains.

Primary Driver

Ivy often colonises old walls and ruins naturally over time, and there is a general assumption that it is always damaging and should be removed. This can be costly to do and, in some cases, can make the situation worse. Research has been carried out to assess when ivy is likely to be bad (and should be removed) and when it can be good and should be left/managed to avoid costly removal and help protect walls from other agents of deterioration (e.g., frost).

Benefit

Largely dependent on nature of the structure (especially its current state of repair), type of growth, existing risks and management practice. Likely to be highly case-specific.

Cost

A research project by the University of Oxford, funded by Historic England, built stone and lime mortar test walls (c. £5k) using traditional construction methods. On four different aspects (N, S, E, W) ivy was grown up one side of the wall and the plant's interaction with the materials was monitored over several years. In most instances, ivy colonises naturally and therefore no costs are involved. Alternatively, it could be planted intentionally, with minimal cost. Any ivy will require maintenance – it should be trimmed regularly to keep growth under control.

Engineering

For masonry structures that are in a good general state of repair, and where appropriate steps are taken to manage the plant, ivy will have minimal/negligible risk to the structure. Ivy has no capacity to 'bore in' to a wall unless there are already existing defects. Where ivy is already well established, care must be taken if deciding to remove it – where it is growing into the fabric of assets in very poor condition, the plant may be contributing to the stability of the structure. A covering of ivy can make structures more difficult to inspect and so targeted removal (in small patches) may be needed to do this.

Asset Resilience

A cover of ivy may help extend the life span of the asset by reducing rates of weathering (caused by heating-cooling, wetting-drying, salt crystallisation and frost) relative to bare walls. It can also act as an effective anti-graffiti measure. Monitoring on the test walls showed that physical deterioration was no faster under a cover of ivy over a period of 3 to 4 years.

Where it is not deemed necessary to remove ivy, it should nevertheless be managed. Annual/biennial trimming to keep climbing/clinging stems away from gutters, window frames, roof slates, and coping and caps is important.

Ecosystem Services

Ivy is very important for biodiversity, especially in urban areas where (evergreen) cover for nesting birds can be limited. Ivy is particularly attractive to insects (including bees) and is a valuable source of nectar and berries late in the season. Ivy should never be cut or removed without first checking for nesting birds.

Social

Where obscuration of architectural detailing is not a concern, a cover of ivy can enhance the aesthetic of a wall/building. A cover of ivy is often appreciated for adding a natural/romantic aesthetic to ruined sites, walls and historic buildings.

Policy

Local Planning Authorities make most decisions on managing heritage assets, though often under expert guidance. Historic England guidance on managing ivy on historic walls calls for careful evaluation of whether it should be removed or left. It should not be automatically assumed it is doing damage, and in many cases can be used as an interim or more permanent measures to help conserve vulnerable walls/buildings, as well as support local biodiversity.

Further information

Detailed information of the monitoring and experiments undertaken to evaluate the roles of ivy on walls is available from the Historic England research report:

Coombes, M.A., Viles, H.A., Cathersides, A. (forthcoming) Ivy on Walls. Historic England Research Reports Series.

Martin Coombes, University of Oxford: martin.coombes@ouce.ox.ac.uk, @MACoombes

This forms part of Naylor, LA., Kippen, H, Coombes, MA., et al. (2017). Greening the Grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report. URL: http://eprints.gla.ac.uk/150672/

Art of the Possible

Ivy for Air Pollution

What is the measure?

This was an experimental investigation into the effect of ivy foliage on air pollutants in a range of different settings in and around the City of Oxford, as part of a larger project on English ivy funded by Historic England. Ivy leaves were collected from existing plants on walls exposed to different levels of traffic pollution. Leaves were examined using an electron microscope and the number, size and density of particulate pollutants were measured.

Primary Driver

Traffic pollution in urban areas is a major issue for the conservation of historic buildings and structures, as well as for human health. Airborne particulates (e.g. those from combustion and traffic fumes) react chemically with stone in combination with rainwater. This can lead to surface blackening through the formation of unsightly gypsum crusts.

Benefit

Ivy was found to be an effective filter of airborne particulates from a range of sources including coal and diesel combustion. The number of particles on leaves was closely linked to traffic volume – more pollutants were trapped on ivy leaves where traffic flow was highest. In these cases particulate density was up to 30 thousand particles per mm^2 compared to leaves from a rural (low traffic) site with as few as 60 particulates per mm^2.

In high traffic areas, ivy foliage significantly reduced the amount of pollution reaching the face of the walls it was growing on – leaves closer to the wall face had significantly fewer particulates than those nearer the pollution source. In this way, ivy was found to be an effective filter of urban airborne pollutants.

Cost

This experiment was part of a research project by the University of Oxford, funded by Historic England. Costs involved researcher time for sampling and analysis.
Where it colonises naturally (which is common on historic structures) there may be no costs involved in growing ivy. Alternatively, it can be planted intentionally. In all cases, regular maintenance is essential given the potential for the plant to cause damage in some situations - see other ivy examples in the Historic Bundle.

Engineering

For masonry structures that are in a good general state of repair, and where appropriate inspection and maintenance measures are taken, a cover of ivy has low potential to cause structural damage.

Asset Resilience

With respect to air pollution, a cover of ivy can reduce rates of surficial weathering and discolouration. The significance of this will vary depending on the particular concerns for the structure in question e.g., whether preventing black crusting is a priority or whether obscuring a surface with ivy is deemed inappropriate etc. Some stone types like limestone are particularly vulnerable to black crust formation, meaning that using ivy as a protection measure may be more or less appropriate depending on the existing risks, as well as the current condition of the asset.

Where it is not deemed necessary to remove ivy, it should nevertheless be managed. Annual/biennial trimming to keep climbing/clinging stems away from gutters, window frames, roof slates, and coping and caps is important.

Ecosystem Services

Ivy has very important benefits for biodiversity in urban areas. It serves as an important source of nectar for insects and berries for birds late in the season. Ivy should never be cut or removed without first checking for nesting birds.

Social

The particulate filtering effect of ivy has two main social benefits: (1) it reduces potential damage to structures of heritage value caused by discolouration and surface crusting; (2) although not the focus of this experiment, ivy was found to be an effective filer of airborne pollutants indicating that it can contribute to improving local air quality in urban areas, especially alongside other measures such as traffic management and other forms of greening.

Policy

Local Planning Authorities make most decisions on managing heritage assets, though often under expert guidance. Historic England guidance on managing ivy on historic walls calls for careful evaluation of whether it should be removed or left. It should not be automatically assumed it is doing damage, and in many cases can be used as an interim or more permanent measures to help conserve vulnerable walls/buildings, as well as support local biodiversity.

Further information

Sternberg, T., Viles, H, Cathersides, A., Edwards, M. (2010). Dust particulate absorption by ivy (Hedera helix L) on historic walls in urban environments. Science of the Total Environment 409, 162-168.

Contact:
Prof Heather Viles, University of Oxford
heather.viles@ouce.ox.ac.uk

This forms part of Naylor, LA., Kippen, H, Coombes, MA., et al. (2017). Greening the Grey: a framework for integrated green grey infrastructure (IGGI). University of Glasgow report. URL: http://eprints.gla.ac.uk/150672/