PRELIMINARY PROPOSALS FOR TECHNICAL COMPLIANCE

OF

HASTINGS MUD HOUSE

WITH BUILDING REGULATIONS AND BEST PRACTICE

CONSERVATION - AN EXEMPLAR OF SUSTAINABILITY

FOR

DUCHAS NA SIONNA

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with advice and architectural layout from Colm Murray Heritage Consultant/ Architect

October 2023

Funded by
An Chomhairle Oidhreachta
The Heritage Council

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1. RATIONALE AND BACKGROUND

Hastings Cottage, Shannon, is a part mud-walled, part lime mortar masonry protected structure in a ruinous state. Repairing, rebuilding, and adaptively reusing the building offers an opportunity to re-discover the technical *know-how* for high-quality and sustainable building technology. It offers a methodology for repair of earth walls in housing and other low- and medium-rise buildings traditionally found in Ireland from the 17th to the 19th century. Many buildings are constructed of mud mortar and similar conservation projects have been carried out by the authors since 1993.

Heritage Council funding was obtained by Dúchas na Sionna to obtain a technical report covering the reconstruction of the cottage in a sustainable and authentic manner with due regard to current building regulations. This proposal maximises the opportunity for traditional vernacular authentic construction with minor interventions and adaptations to ensure sustainability in a modern context while complying with current regulations. The proposals could be considered as 95% traditional and 5% modern adaptation. They key changes from a traditional mud cottage are: -

- Avoidance of fossil fuel in fireplace – Mitigating fire and providing sustainability
- Modern heat pump underfloor heating- Sustainability
- Fire barrier beneath thatch Mitigating fire risk
- Fire detector and alarm system Fire safety
- Internal lime hemp insulation- Sustainability
- Slimline double glazing in windows- Sustainability
- Underfloor ventilation for radon- Health

There are many types of construction in mud available for construction and restoration.

Table 1 **Earth Construction Methods** *Hugo Hoburn and Hubert Gulliard: ITDG publishing 2001*

	Category	Description
1	Dug out	
2	Earth sheltered space	Structure built in another material with earth roof
3	Fill in	Ungraded soil used to fill hollow framework
4	Cut blocks	Blocks cut directly from the ground
5	Compressed earth	Massive walls by compressing soil in moulds or formwork
6	Direct shaping	Manual shaping
7	Stacked earth	Piling balls of clay
8	Moulded earth	Moulded by hand or in moulds
9	Extruded earth	Machine produced elements from paste
10	Poured earth	liquid soil, similar to concrete pour
11	Straw clay	Clay slurry with straw reinforcement
12	Daubed clay	Infill for timber structure with fibers -wattle and daub

Possible construction for Hastings

Whilst it has been suggested that parts of Hastings could be 'dug out' the fact that no large boulders are found in the walls in Sarah Pavia's report suggests that 'compressed earth' may be a more likely conclusion. The two types are difficult to differentiate between visually. The reconstructed walls will be carried out in compressed earth or rammed earth as it is referred to in the remaining report. The report will be of interest to those attempting other types of earth construction or repair. This project therefore provides an opportunity for understanding mud construction for the purpose of repair and maintenance of Irish vernacular buildings. It also provides a cultural understanding of previous construction technology and maybe of some interest to clients looking to self-build new low-cost housing.

This document draws its rationale from **Rammed earth: design and construction guidelines**, by Peter Walker, *University of Bath,* Rowland Keable, *In Situ Rammed Earth Co Ltd,* Joe Martin, *JM Architects and* Vasilios Maniatidis, *University of Bath* Published by BRE Bookshop. The documented technical guidance is also backed up by 30 years of practical experience in conserving and repairing mud rammed earth buildings by the author Chris Southgate, conservation engineer.

The repair of Traditional Farm Buildings, stimulated by *Heritage Council and Department of Agriculture and Food* grant-aid over the last 15 years, has revealed multiple buildings constructed with walls of mud or earth.

Walls are often 600 mm or more thick. Incipient failure is sometimes diagnosed through erosion of renders, and occasionally slumping out of plumb because of softening due to water ingress.

Others are found with severe lean to the walls stabilised by buttresses. Most commonly, failure can be attributed to the later application of cement renders, resulting in moisture locked into the walls with varying deleterious effects on structural integrity. Rising damp, failed rainwater goods and poor roofing and cills also contribute to problems.

The Mayglass farmhouse, Co. Wexford — an exemplar and rare survivor of a type of two-storied mud-walled, thatched house of the Irish vernacular tradition. Its conservation (1998-2002) drew on international good practice in the repair of earthen structures. It is one of the most significant projects carried out by the **Heritage Council,** who are also providing funding supporting for the Hastings Farmhouse restoration project.

This document covers general design considerations, material properties, testing and selection, engineering design, wall construction, construction details, and good practice procedures for the conservation and restoration proposed for Hastings Mud House.

- **Planning issues and Fire Safety certificate and disability access certificate (DAC) issues are to be considered at a later stage.**

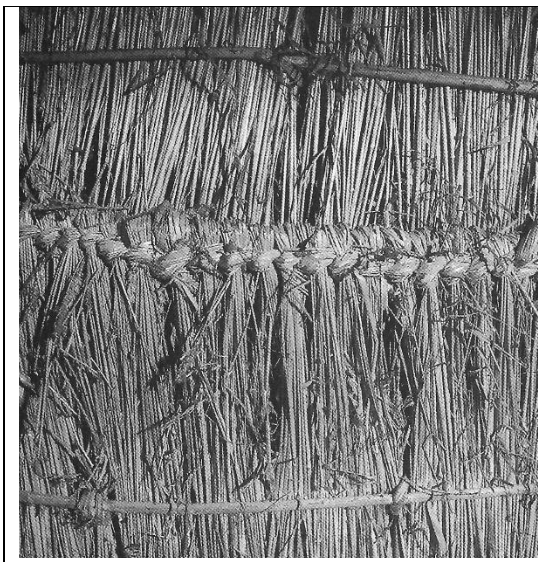
The first consideration is to consider methodology for construction, particularly the mud walls and the roof structure and thatch, and their compliance with Building Regulation and Best Practice Conservation advice.

Hastings Farmhouse and Mr. Hastings c. 1968. ***Shannon Development Photographic Archive***

Kitchen ***Shannon Development Photographic Archive***

Restoration in 2012

Dresser and roof structure
Shannon Development Photographic Archive



Photograph of proposed interior straw lining from a 300-year-old cottage. The internal straw lining is folded and knotted over a length of hazel rod

Notice also lengths of hazel rods (liggers) pinned with scallops top and bottom which is also the method of tying the ridge.

David Shaw-Smith's 'Ireland's Traditional Crafts', 1984, Thames and Hudson, London, p. 134,

Protection status

The building is a protected structure (Clare County Council Ref. No. 664).

Dissemination of information and inspiration for training and sustainable practice

It is hoped that this document and the subsequent building project will provide both training and inspiration for other projects, either new build or repair of traditional buildings. By understanding past methods and practices it is hoped that this project as an exemplar of sustainability can provide inspiration towards the changes needed to build a sustainable future, where the example of materials sourced within yards of the building might challenge some current building practices where often materials have to travel long distances and do not promote a circular economy.

2.0 BUILDING CONTROL REGULATIONS

The Building Regulations ensure the health and safety of people in and around buildings by providing functional requirements for building design and construction in Ireland.

Part	Area	Special considerations in this report
Part A	Structure	Construction in Mud
Part B	Fire Safety	Disaster and risk management for thatch
Part C	Site Preparation & Resistance to Moisture	Land drainage provisions
Part D	Materials & Workmanship	Methods of ensuring compliance during construction
Part E	Sound	
Part F	Ventilation	
Part G	Hygiene	
Part H	Drainage & Wastewater Disposal	
Part J	Heat Producing Appliances	
Part K	Stairways, Ladders, Ramps, Guards	
Part L	Conservation of Fuel & Energy	A sustainable method of heating will be considered although exempt from Part L
Part M	Access and Use	

Considered in this document

Compliance with the Building Regulations is a legal requirement for all new building works. Demonstration of compliance is most commonly through self-certification by the supervising engineer often referring to the technical guidance documents. These do not cover Mud masonry; thatch and the use of green timber and reference is made to international research and guidance.

Part A – Structure Earth

Recent experience in the UK demonstrates that rammed earth can satisfy the requirements of modern building regulations. (In the UK failure to meet requirements of building control officers has rarely been cited as a reason for the failure of proposed rammed earth projects.)[1]

The most significant Building Regulation requirements with respect to the conservation of **Hastings Mud House** are summarised below: -

- Accidental damage to loadbearing walls due to flooding, including burst water pipes, needs to be considered in design.
- The influence of increasing moisture content on material strength, potential loss of section through erosion, the rate of drying and associated rate of strength development, the amount of drying shrinkage and influence of defects (poor compaction) on wall capacity are important considerations for design and construction.
- Material characteristics (compressive strength and drying shrinkage) will be checked during construction. Considerations for material compliance for rammed earth materials are outlined below:

Parameter Specification

Soil composition and selection

Local material has been tested and found to be suitable for grading, plasticity, shrinkage, chemical composition, mineralogy, colour, texture, organic matter content, and soluble salt contents. In general, careful inspection of 'as dug' material will be carried out on site by a competent foreman. Minimum dry density will be 98% of heavy manual compaction test maximum dry density. In other words, all material will be heavily compacted under the supervision of a qualified foreman experienced in rammed earth construction.

Tests may be required by the engineer.

Visual assessment

Cracking In general no cracks wider than 3 mm and longer than 75mm will be permitted.

If concern is raised

Unconfined compressive strength of 1.0 N/mm2 will be required.

Testing will be carried out by an appropriate testing laboratory

Assessment of built walls on site is generally limited to visual compliance by an experienced conservation engineer. Surface hardness testing, using rebound hammers, has been used in the past, but results can prove variable and unreliable.

Drying shrinkage measurements may be undertaken directly and reliably on walls, though the rate of drying needs to be considered; it may take a while for walls to dry out or reach satisfactory stable conditions.

Extent of compliance testing will depend on the complexity of the project. Provided satisfactory results are obtained in terms of drying shrinkage during the construction stage, works can proceed without extensive further laboratory testing, if concerns arise during construction the engineer will request cube testing.

Timber roof structure.

The timber roof structure has been sized in accordance with building regulations, but a traditional use of green timber may be desirable for sustainability reasons. If this is required, a testing regime can be introduced and calculations for the testing of one truss to BS EN 5268 is included in Appendix 2.

The drawings in Appendix 1 show the technical proposals for long term stability and integrity of the structure addressing compliance with ***Parts A, B, C, and D***

Part B – Fire safety

Part B of the Building Regulations requires the building to be designed and constructed to ensure safe and effective means of escape from fire. Rammed earth can be defined as a non-combustible material as it very rarely contains more than 1% (by weight or volume) of organic material. Even a 300 mm solid rammed earth wall will provide fire resistance of at least 90 minutes. Joints in door frames should be sealed with foam strips or similar natural materials with intumescent properties to minimise any interruption to the fire barrier.

In terms of thatch, construction recommendations from a report on insurance and fire safety in thatched properties in Ireland for the DAHGH has formed the basis for a risk assessment and recommendations in the table below: -

Key issues

The study considered and categorised potential mechanisms for 'fire-raising' in, or ignition, of thatch and the following measures are proposed based on a report Insurance *& Fire Safety in Thatched Properties for the DHLGH, Frank Keohane* which showed at least 72 thatched properties have had fires in the last five years caused by chimney fires, often in conjunction with the use of solid fuel stoves. The Fire Protection Association, now strongly advise that '*Wood burning, and multi-fueled stoves are **NOT** recommended for use in thatched buildings as they have been demonstrated to present a greater risk to the thatch than other forms of heating including traditional open fires*.'

	Recommendation	**Rationale**
1	Biofuel open fire **see note below**	Low fire risk and sustainability
2	Heat recovery ventilation in chimney	Maintain air quality and sustainability
3	Air to water heating system	Sustainable heating without fire risk
4	No sources of ignition at roof level LED uplighting	Sustainable no risk of overheating
5	Fire retardant treatment to thatch	Fire prevention
6	60 min fire resistant ceiling	Fire mitigation and firefighting considerations
7	Raise internal walls with thin thatch cover to facilitate fire break during fire	Fire mitigation and firefighting considerations
8	Fire extinguishers and fire blankets	Fire mitigation and firefighting considerations
9	Fire defense plan with local fire brigade	Fire mitigation and firefighting considerations
10	Rules of no fires adjoining building	Spark mitigation
11	Coherent means of escape and L1 fire detection system with rise of heat detectors, emergency lighting and compliance with Fire Safety Cert	Safety of occupants and mitigation of damage to fabric

Note: - The fireplace will be constructed in a traditional manner and adaptation for modern biofuel and heat recovery will be reversible

Future compliance with Fire Safety Certificate

Escape in fire

An initial sketch scheme layout provided by Colm Murray demonstrates that there are adequate means of escape and door widths to imply no obstacles in relation to a future fire safety certificate. These drawings are shown in Appendix 1. This also shows fire detectors in every room (L1 system) and emergency lighting at exits. The Fire officer may have other detailed requirements in due course.
The drawings in Appendix 1 show the technical proposals for long term stability and integrity of the structure addressing compliance with ***Parts A, B, C, and D***

Part C of the Building Regulations requires walls to provide adequate protection to the building and its occupants from the harmful effects caused by ground moisture. The proposal below has been tried and tested by Southgate Associates since 1993 (30 years) and can be tested post construction with a moisture meter.

Penetration of moisture from rain and snow is limited through the absorption and dissipation of the moisture throughout the external vapour permeable hot lime roughcast render and earth construction or hot lime mortar masonry. In drier periods this moisture is released to the atmosphere as part of a breathing wall system. Careful design of the eaves will be required together with protection from horizontal weathering surfaces such as cills.
The resistance of the building to ground moisture will be assessed on completion of the building by monitoring moisture content of the walls.
The drawings in Appendix 1 show the technical proposals for long term stability and integrity of the structure addressing compliance with ***Parts A, B, C, and D***

Part D – Materials and workmanship

Part D of the Building Regulations (2000) requires that building work be carried out with adequate and proper materials and in a workmanlike manner.

The fitness of rammed earth materials will generally be established by sampling and laboratory testing of materials at the start of the contract. In-situ testing of rammed earth is difficult and therefore material compliance testing is normally undertaken on cubes. Adequacy of rammed earth quality of work is measured against the provisions of the specification, previous experience with the material and experienced supervision and inspection by an experienced conservation engineer is required.

Proposed critical quality assurance points in the process.

1. Construction technique or techniques, taken from international good practice, methodically documented, and agreed in principle.
2. Integration and correlation of individual Part-by-Part parameters into outline technical design and specification for complete building
3. Materials selection, management, and storage
4. Construction supervision at identified critical stages – experimentation to fine-tune specification of methods, sample panels, test panels, curing periods for testing, etc.
5. Completion of structure weathering (renders and coatings, enclosure of openings, completion of roof, management of indoor micro-climate
6. Monitoring post-construction for an agreed interim period (3 to 5 years)
7. Evaluation and documentation of the experience of making and repairing this form of structure.

The drawings in Appendix 1 show the technical proposals for long term stability and integrity of the structure addressing compliance with ***Parts A,B,C,and D***

Part L – Conservation of fuel and power

Part L of the Building Regulations (2002) requires that reasonable provision be made to limit heat loss through the building fabric.

In the case of Hastings Mud House – a protected structure it is exempt from **Part L.**

Nevertheless, upgrading the energy performance as follows will be considered particularly to avoid condensation risks: -

- Extra compliance of Roof and floor U values.
- Ensuring wall thickness of at least 600mm
- Lime hemp internal insulation
- High quality air to water heating system and heat recovery ventilation

3.0 PROPOSED USE OF RAMMED EARTH

Material supply

The as dug material will be compared to the remnants of wall construction on site.

The risks of variation of structural performance issues are stated below with proposals for mitigation.

No	Risk/ Issue	Mitigation
1	Aggregate can vary from 6mm to 75mm without affecting strength but can affect compaction	Experienced foreman on site discards larger stones and conservation engineer inspects for honeycombing
2.	Vegetable matter included in mix	Experienced foremen supervising work
3	Two little or too much moisture	Use as dug material and protect from softening during rain in excavation using polythene sheet. Monitor moisture content using gravimetric method
4.	Binder too sandy	Concrete cube tests and visual check by foreman relating to surface abrasion
5.	Poor quality formwork	Inspection and approval of process and temporary works design by foreman and SA
6	Shrinkage effects	SA inspect for cracks less than 3mm as per spec
7.	Inadequate compaction	Shows up in shrinkage and strength tests

Material strength

8.	Inadequate strength	Cube test results
9	Inadequate load carrying capacity	Ful load test of roof structure as appendix 2. Observation by conservation engineer

Deterioration of structure due to moisture during construction

10	Softening of clay past plastic limit and deterioration of structure	See specialist proposals for protection and roof design – Sketch B
11.	Softening around cills prior to weathering	Fit cills and dpc as works proceed.

3.1 ADVANTAGES OF RAMMED EARTH CONSTRUCTION TO RESTORE HASTINGS MUD HOUSE

Sustainability

Earth is a valuable material with sustainable properties. As a natural material, without processed additives, rammed earth can have significantly lower embodied carbon dioxide and energy than conventional manufactured building materials, as well as reduced toxic chemical content and fewer emissions from industrial processes.

Material availability

Testing of the local subsoil has revealed a good local source of high-quality material which is consistent with the mud in the original cottage and has withstood the test of time. Recent deterioration is due to roof failure and lack of maintenance and the original building can be considered a testament to future performance in general terms.

Evidence of the original building shows rammed earth is built-up in a series of approximately horizontal layers of compact soil approximately 150 mm deep. Each layer corresponds to the incremental construction sequence.

Labour force

The rebuilding of Hastings Mud House can be undertaken by an inexperienced labour force, though efficient management is needed. As a labour-intensive technology, this earth building is well suited to community-based low-cost demonstration project which is of value to other mud building owners demonstrating repair technologies and the results of this project will be published and recorded as best practice guidance.

Health benefits

Clays within rammed earth soils are hygroscopic, releasing, or absorbing moisture in response to changing local atmospheric conditions. Studies have proven that earth walls are very effective in regulating the internal relative humidity to between 40 and 60%. This property of rammed earth walls improves indoor air quality with obvious health benefits removing asthma symptoms and improving respiratory health.

Wall construction

The rate of wall construction is typically between 2. 5 and 5 m2/day for a 600mm thick rammed earth wall[2] for a team of three to four workers and is comparable with modern masonry wall construction although additional costs of lime plaster over cement sand render must be considered.

Photograph showing protection during shuttering and pouring of a rammed earth structure.

3.2 LIMITATIONS AND DRAWBACKS OF RAMMED EARTH CONSTRUCTION AND MITIGTION

Durability

Rammed earth is susceptible to decay in the presence of water. This requires special consideration in design and construction and throughout its service life. Construction should be protected from the weather to prevent damage. Generally, the level of maintenance Is critical and affects structural performance.

Careful land drainage and avoidance of flooding is essential. In the case of Hastings Mud House water from the ground in the restored walls must be carefully treated as follows

Wall thickness

To ensure sufficient lateral resistance and allow construction, rammed earth walls are much thicker than modern construction. Wall thickness is governed by low material strength and compaction requirements. Low material strength also places restrictions on the size and spacing of openings. Slenderness (height-to-thickness) ratio is often limited to 12 for loadbearing walls.

Thermal resistance

Rammed earth derives much of its physical resistance from the material's relatively high density, but a consequence of this is its poor thermal resistance. To meet thermal performance levels expected of modern energy efficient buildings and to meet requirements of the Building Regulations, external rammed earth walls must either be very thick (>700 mm) or use additional insulation materials.

The poor insulating qualities of rammed earth might be accepted without modification, and in a more holistic approach other elements (floor and roof) can be 'super-insulated', and together with fuel efficient heating measures ensure an overall satisfactory building performance.

In-situ construction workmanship issues

Rammed earth is primarily built as an in-situ shuttered form of construction, which places demands on both design and construction. Wall design must allow shuttering to be erected and dismantled repeatedly during construction.

Materials should be placed at their optimum moisture content and so soil must be stored and prepared accordingly.

Quality control of the in-situ compaction of materials inside shuttering can be problematic. Shrinkage may require monitoring in the period following construction. Where renders or other protective coatings are to be applied, further wall shrinkage needs also to be considered and adequate time for drying out allowed.

Economic cost especially labour

The finished cost of rammed earth construction varies greatly, depending on the specifications and requirements of the wall finish. Experience has proven that the cost of general quality rammed earth can be comparable to or even cheaper than alternative forms of fully finished masonry wall construction.

Though the raw materials are relatively inexpensive, labour costs associated with the handling of materials and shuttering comprise the main cost of construction. Formwork systems must therefore be used efficiently, and materials prepared well planned and controlled. Handling of formwork typically accounts for 25–50% of construction time, and so simplifications in the formwork scheme can provide significant cost savings. Labour costs can be reduced, and volunteer labour could be beneficial in this case.

4. PRELIMIANRY DISCUSSIONS WITH BUIDLING CONTROL AND CONCLUSION

A meeting was held on site with Angela Naughton and Michael O Brien Clare County Council Building Control and Colm Murray, Chris Southgate on 3rd July 2023 at 11 am.

On the basis of the meeting, there were no apparent obstacles to the proposal.

Items Discussed:	Action
1. If not a dwelling, then the cottage will need a fire cert in the future.	Prediction of impacts is required, for instance door openings, escape provisions etc. SA to consider thatch issue and develop detailed section for outline approval. A fire safety cert will be the subject of a later. phase of work.
2. If not a dwelling a future change of use will be subject to building regulations.	SA to consider various issues of building regulation compliance in a report for submission and future comment by Clare Co Co
3. An outline of foreseen use will help the pathway to building control compliance.	Colm Murray to consider the possibility of a simplified. scheme with teaching facilities and prepare outline sketch scheme
4. Broadly agreeable with the approach/process of building a compliant earthen structure.	SA to submit to Clare Co Council once finalised

5. Detailed discussion of building method, including repair of its structure.	This will be interactive with site methodologies in the future and may be subject to minor alteration, but the expected methodology will be covered in SA report
6. Front door measurement as 1.07m wide, unlikely to present a fire egress problem.	Appears satisfactory without adjustment
7. No surrounding structures a good factor for external spread of flame of roof is thatched.	No anticipated obstacles are envisaged in relation to achieving a Fire Safety cert in the future on the grounds of a thatched roof. Insurance requirements to be investigated. No active electrical services are proposed in the roof space
8. Toilet facilities will be necessary.	Colm Murray to develop outline sketch scheme
9. Building will need to be accessible [notes, two small steps down from front door inwards in concrete]	Consideration will be given to this issue in terms of outline section and sketch scheme to be included in SA report

Conclusion

This document in its current form will be submitted for final comment to Clare County Council, the client, and the Heritage Council but final approval of proposals will have to await the Planning, Fire Safety Certificate and Disability Access Certificate for the final agreed end use at application stage.

We consider that this report addresses the novel and technical building construction issues that need to be addressed in ensuring the repair and reconstruction of Hastings Cottage, Shannon, can be achieved in conformity with the Building Control Regulations. It addresses the four main aspects of the regulations (Part A, Structure, Part B, Fire Safety, Part C Site Preparation and Resistance to Moisture, and Part L Conservation of Fuel and Energy) that impact on the plans to restore this building.

In doing so we have striven to balance the vernacular character of the building remains with the standards for the occupancy and enjoyment of buildings demanded in the 21st century. Every effort has been made to respect the spirit of simplicity and resourcefulness that these surviving buildings embody in so doing. They have much to tech us about sustainable construction. But this must be balanced with wider societal concerns with good and robust building, minimisation of the use of energy, and the health and comfort of building occupants.

Defining these methods, and proving them in formal application, followed through with careful supervision of the construction process, will, we believe chart a path for harmonising vernacular construction and repair procedures, which are very important to heritage, with these aspects of the building regulations.

We commend Dúchas na Sionna with having the foresight and methodical approach to address these issues at this strategic and timely phase of their restoration project, and in doing so, they provide heritage leadership.

Chris Southgate/ Colm Murray Oct 2023

5. REFERENCES

TECHNICAL GUIDANCE

- Walker, Peter, Keable, Rowland, & Martin, Joe, 2005, *Rammed earth: design and construction guidelines,* BRE, Watford.

- Houben, Hugo, & Guillard, Hubert, 1994, *Earth Construction: A Comprehensive Guide*, Earth Construction Series, ITDG Publishing, London

INTERNATIONAL EXPERIENCE OF EARTHEN STRUCTURES PROVIDES ADDITIONAL ADVICE OVER AND ABOVE THE BRE REFERENCE CITED IN SECTION 1

Nina, Juliana F., Eires, Rute, & Oliveira, Daniel V, 2023, 'Earthen Construction: Acceptance among Professionals and Experimental Durability Performance' (https://www.mdpi.com/2673-7108/3/2/10)

> 'Earthen construction is one of the world's oldest and most popular construction methods, and it is still the target of prejudice due to the loss of ancestral knowledge. Due to the need for more effective and healthy building solutions, this study conducted a survey to determine the interest and knowledge of construction professionals regarding sustainable and natural materials and building techniques to understand how open these professionals are to changes in their working methods and if they identify urgency in that change. With the intent of proving the durability of earthen construction materials, laboratory research was developed which involved the preparation and performance evaluation of samples of earthen elements from the most-used techniques: rammed earth and compressed earth blocks. This evaluation was performed using the accelerated erosion test, simulating periods of rainfall, and drying, and the post-test loss of resistance was also evaluated. According to the results obtained from the research survey, there is a predominant lack of knowledge about earthen construction and other traditional and sustainable materials. On the other hand, the experiments demonstrated that earthen construction can be durable when using either a small percentage of stabilizing material or a covering plaster.'

Ben-Alon, L., Loftness V., Harries, K A and Cochran Hame, E., 2019, 'Integrating Earthen Building Materials and Methods into Mainstream Construction Using Environmental Performance Assessment and Building Policy', *IOP Conf. Ser.: Earth Environ. Sci.* **323** 012139

‘Earthen building materials offer an environmentally sustainable alternative to conventional materials because they are locally available, minimally processed, and waste-free. However, they have not been comprehensively implemented because their technical data is highly variable, and they are not fully represented in building codes. To address these hurdles, this paper presents an environmental assessment and a policy repair review, including an environmental embodied impact analysis, and a discussion of the regulatory development required for earthen construction. The results of the environmental assessment show that earthen wall assemblies significantly reduce environmental impacts by 62-99% when compared with conventional assemblies such as timber frame and concrete blocks. Additionally, the policy discussion provides recommendations to overcome materials variability and regulatory organizational collaboration. Overall, this paper highlights the importance of environmental and policy measures that could be used by policy makers and earthen building advocates in their endeavours to catalyse the representation of earthen building materials and methods in mainstream construction.’

- Burt, Richard, 2003, ‘The experimental earthen cottages at Amesbury, England: A long term condition assessment’, in *Conference: Proceedings of the First International Congress on Construction History*, 20th-24th January 2003, Madrid, Spain.

These houses were built in 1919 as building experiments and were re-viewed by Williams-Ellis in the 1940s, and then in the 1990s by Burt. The report is a validation of the technique of building and a demonstration of its 80-year longevity and could be cited as a precedent for building ‘experimentally’ in earth (… even if this is only the re-use of a very old technique).

- Reeners, Roberta (ed.), 2003, *A Wexford Farmstead: The Conservation of an 18th Century Farmstead in Co. Wexford*, The Heritage Council, Kilkenny
- Fitchen, John, 1989, *Building Construction Before Mechanization*, The MIT Press, Camb. Mass.

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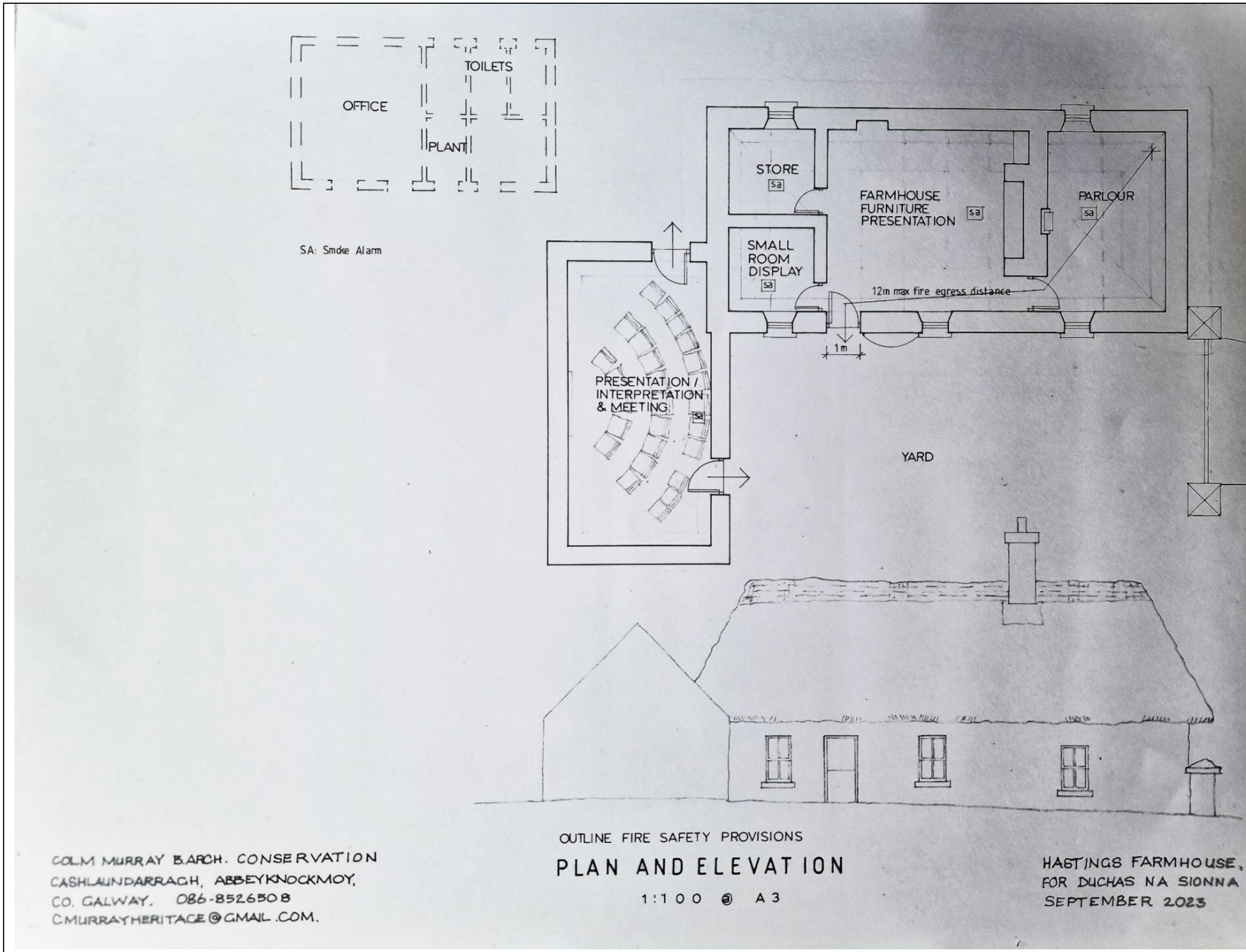
Hastings Cottage, Shannon, Co. Clare, Ireland -A study of earth samples from the walls and the surroundings. S Pavia Oct 2021

Appendix 1 – Drawings

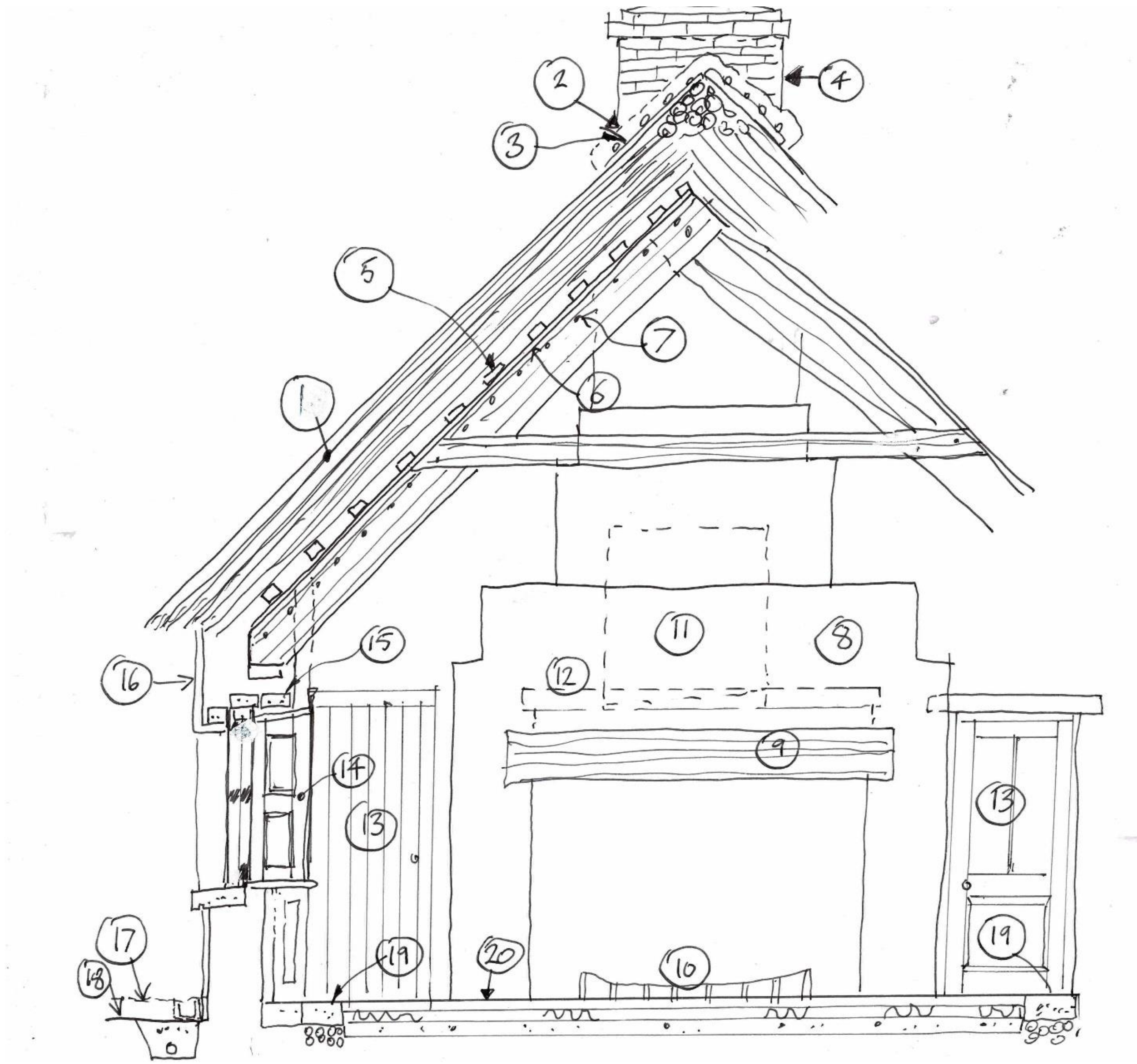


Note: -

Current proposals are to provide an additional building which is shown dotted. This proposal leaves the cottage and adjoining building in its original state.

If early activation of the cottage is desired consideration could be given to providing an accessible wc and plant room in the store/Display room. Whilst saving money this has the effect of further intervention to the cottage which is undesirable.

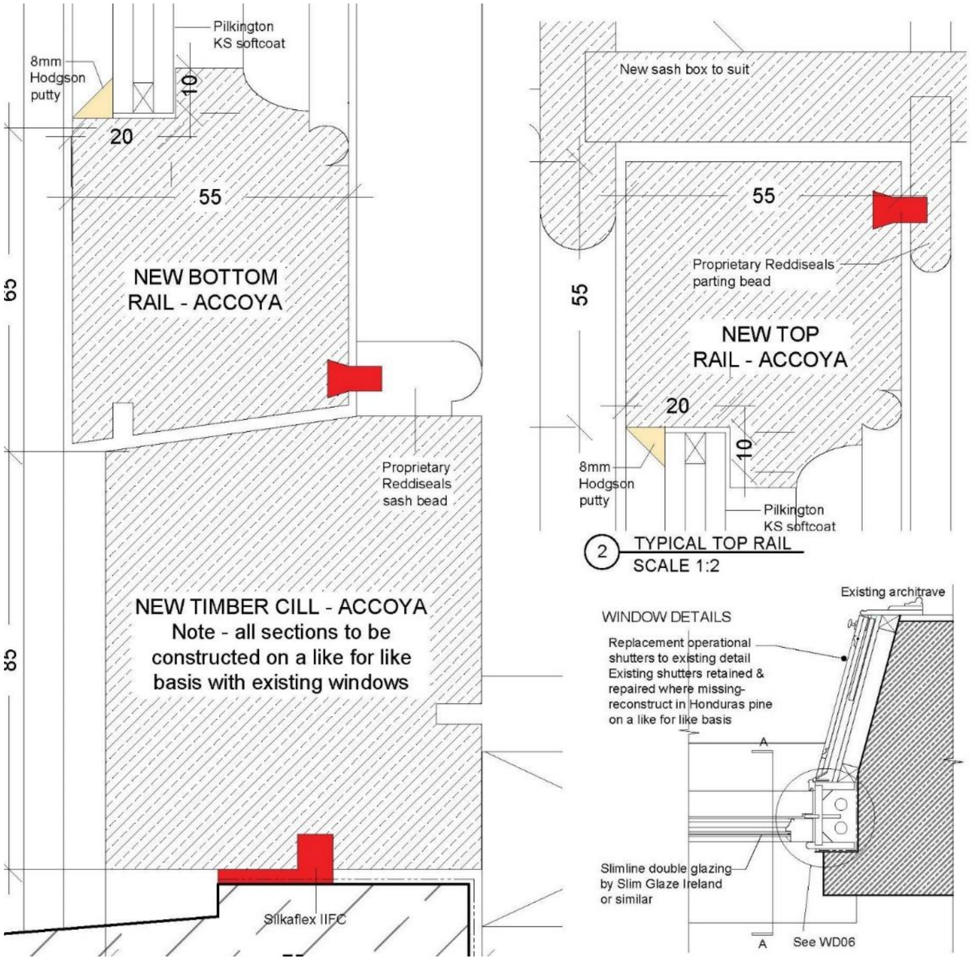
FIRE SAFETY PROPOSLAS FOR HASTINGS FARMHOUSE



Typical Section

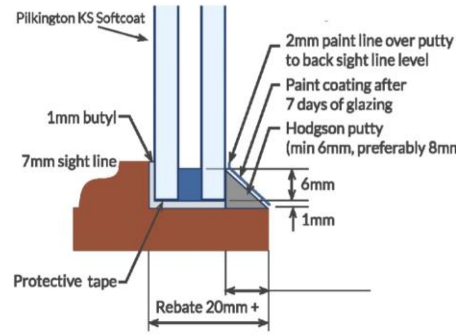
Key

1 Typical Clare reed thatch by specialist
2 Cement flashing to chimney treated with water repellent.
3 Reed ridge with 4 liggers and scallops to thatcher's details dressing horizontal butt ridge.
4 Brick chimney with code 5 lead dpc below string course.
5. 50x50 treated battens at 350c/c
6 20mm Fireline board giving 60 min protection.
7 Decorative straw lining
8 Fireplace in lime mortar stone and brick
9 Green timber bressummer beam
10 Modern Biofuel fireplace
11 Possible cavity for demand control ventilation
12. Actual authentic flue sealed off with reversible shelf to control air movement
13. historic joinery restored
14. Traditional sash and surround with double glazing
15. Concrete lintols to avoid deterioration
16 Hot lime render
17 Ground levels at door built up to level with aco drain for level access.
18 Other areas 200mm lower with land drain
19 Lime concrete border with clay ball or glass ball insulation piped to exterior in 4 No 100mm ducts to release radon.
20 Slate floor on 75 screeds with underfloor heating pipes on 75 insulation on 100 concrete sub floor on radon barrier on hardcore blinded with fines

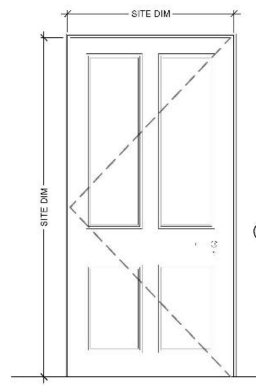


Typical sash window details. Material for sash windows to be from a sustainable source. Accoya is a natural wood product sourced from sustainably managed FSC® certified forests. With no plastic, resin or other harmful additives it is 100% non-toxic, making it the ideal environmental choice. Accoya is more environmentally friendly than many hardwoods.

Typical Slimline glazing detail

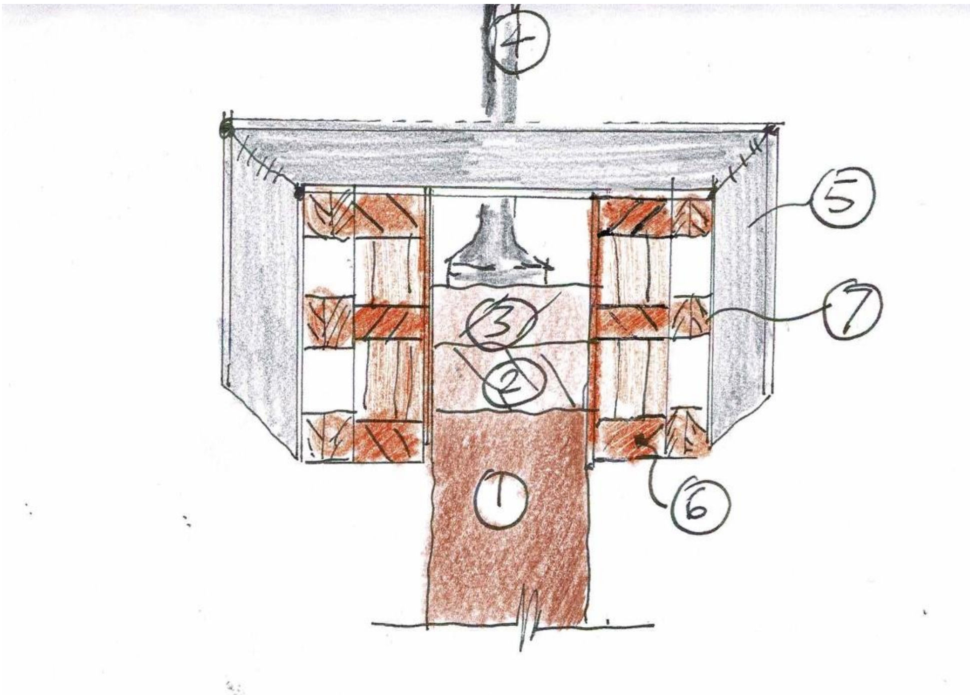


Typical door



Typical Joinery and glazing details

Formwork for constructing mud walls



Key

1. Consolidated mud below
2. Lower pour
3. Upper pour (formwork stays in position for 2 pours)
4. Heavy steel ended rammer
5. Special steel U frames ex 152 Uc at 2.4m centrese
6. Ply faced shuttering panels 4.8m long
7. Folding wedges to tighten against wall as work proceeds

APPENDIX 2 SITE TESTING OPTIONS FOR GREEN TIMBER TRUSSES AND CALCULATIONS

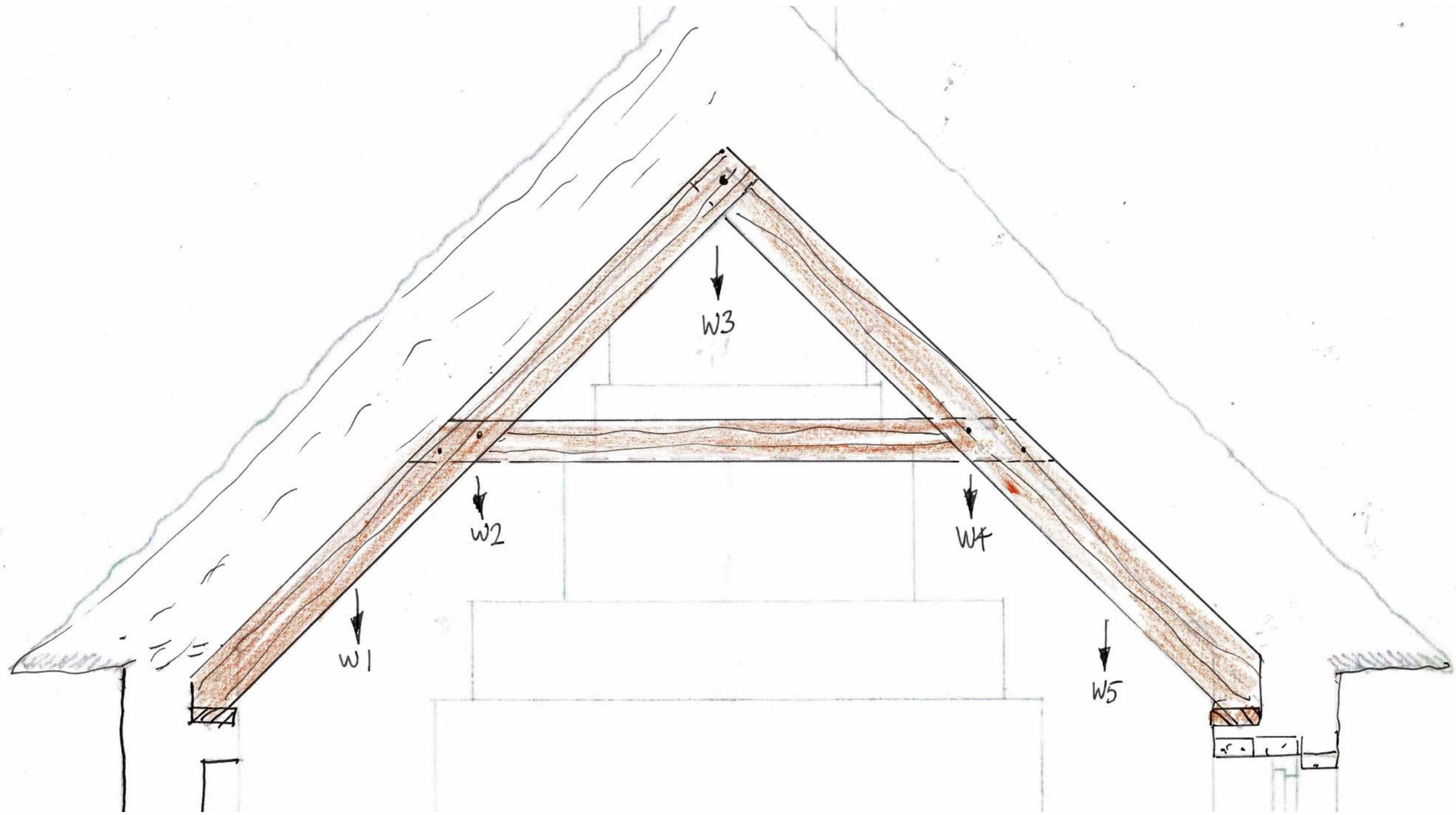
Truss top chords	2 No 300x 150mm	C24 or green timber
Collar tie	225x 75mm	C24 or green timber

	Dead load		Live load		Load test factors K_{85}, K_{73},		BS 5268-2:2002 Test load	
Load case 1	0..75	kN/m²	0.25	kN/m²	1.79	1.25	3.35625	kN/m2
Load case 2	0.75	kN/m2	0.75	kN/m2	1.52	1.25	2.85	kN/m2

		Span (m)	Spacing (m)	Characteristic Dead plus live (* wind)		Total test load ultimate		Moment in top chord ulimste kNm	f_{bc} ultimate N/mm²
Load case 1		6.3	1.2	3.35625	kN/m2	25.37325	kN	26.6419125	11.8
Load case 2		6.3	1.2	2.85	kN/m2	21.546	kN	22.6233	10
Load case 3		6.3	1.2	0.75		5.67	kN		

Loading points	5		load	5.07465	kN
Block Nos	25.06	No blocks	Say 26 blocks on 5 trestles for max load		
	6.59473684	No blocks	Sau 7 blocks per tressle for Deal load		

Load case 1 **D+L**
Load case 2 **D+L +W**
Load case 3 **D**



Note

Top chords approx. 300x 150 x 2No C 24 grade, Collar tie 225x75 C 24 grade. Trussed rafters at 1.2m c/c. M 16 bolts. Or equivalent strength green timber
Each loading point 5 kN (i.e., 26 blocks hanging at each point)

Appendix 3 Specification for rammed earth works.

1 Scope of rammed earth works to be undertaken.

All rammed earth works shall be constructed with appropriate care, site control and supervision so that the minimum design requirements of this specification are met. Construction is to include all rammed earth walls from and including the damp-proof course to the top of the rammed earth wall, including installation of holding-down anchors or ties and wall plates.

2 Submissions to be made.

The rammed earth mix trial. Details of methodology to be submitted at least 1 month prior to rammed earth works starting on site.

5 In-situ rammed earth mix and supply.

Trials of the rammed earth mix design(s) must be undertaken by the contractor, to allow a minimum of 1 month for approval. Materials on site should be handled and stored in a way that ensures that their performance is not impaired. Any materials that have deteriorated sufficiently to impair their performance should be rejected.

5.1 Compressive strength

The mix shall achieve a minimum characteristic unconfined cube dry compressive strength of 1 N/mm2.

Cubes shall be prepared and tested in accordance with engineers' instructions.

5.2 Mix constituents

The rammed earth will contain no additives or admixtures.

The maximum aggregate size shall not exceed 25 mm. The material shall have a combined organic matter, soluble salt and other deleterious matter content not exceeding 2-3%

The material shall be properly mixed to provide an even and consistent material. Mix proportions of all materials should comply with those specified. Methods used to measure materials should ensure that specified proportions are controlled. Mixing should ensure that all ingredients are evenly distributed throughout the mixture.

5.3 Moisture content

The moisture content for the rammed earth at time of compaction shall be within ±1–2% of the agreed optimum moisture content for compaction and handling. A heavy manual compaction test shall be undertaken to determine the optimum moisture content at least 1 month before the start of work. The moisture content shall normally be regularly checked (in micro-wave oven) to ensure a consistent and uniform material throughout construction.

5.4 Drying shrinkage

The drying shrinkage of the rammed earth shall be evaluated by inspection of cracks less than 3mm.

5.5 Material supply

As dug material.

6 Testing and certification of materials if required by the engineer.

6.1 Recording

Representative location of specimens prepared and submitted for testing shall be recorded.

6.2 Test laboratory

Any material testing required by the engineer shall be undertaken by an approved laboratory. Cubes shall be prepared and tested in accordance with engineers' instructions. Cubes that break during preparation or fail to meet specified requirements shall be retained for inspection.

7 Placement and compaction

7.1 Preparation

At time of placement, all surfaces, including shuttering forms which rammed earth is to be compacted against, shall be clean and free of debris and excess water.

7.2 Transportation

During transport of rammed earth from mixing area to site for compaction, avoid contamination, segregation, loss of ingredients and excessive evaporation. Cover rammed earth during heavy rain.

7.3 Placement

Place loose prepared material in the formwork in courses of even and controlled depth. The maximum depth of loose material should not exceed 150 mm. Cold joints between lifts should be protected from excessive drying and scarified before proceeding with further work.

Record the time, date and location of all rammed earth works. During compaction ensure that the temperature of rammed earth does not exceed 30 °C or fall below 5 °C. Do not place against frozen or frost-covered surfaces. The rate of construction should be regulated to minimise the risk of deformation or instability.

7.4 Compaction

Rammed earth material is to be fully and properly compacted, taking especial care around inserts, formwork corners and at joints. The rammed earth should achieve a minimum dry density of not less than 98% of the heavy manual compaction test maximum dry density.

8 Drying and protection.

8.1 Drying

Protect walls in cold weather from frost damage throughout the drying period. Detailed records of the location and timing of compaction of individual batches, removal of shuttering and removal of coverings is to be maintained on site for inspection.

8.2 Protection

Protect walls from direct rainfall, splash-back and runoff by means of roof protection and surface coatings as necessary. Protect walls from abrasion, other physical damage arising from construction works, thermal shock, impact, overloading, movement, and vibration. Take care to avoid uneven drying of walls where one face is in direct sunlight and the other shaded,
which may lead to leaning or bowing of walls.
Waterproof sheeting used to protect walls from rain damage should be held clear of the surface to allow air circulation and to allow drying out of the rammed earth walls.

9 Formwork

9.1 Construction

Construct formwork accurately and robustly with adequate supports to produce finished rammed earth to the specified dimensions. Formed surfaces must be free from twist and bow. with all intersections, lines and angles being square, plumb, and true.
Construct formwork, including joints in form linings and between forms and completed work, sealing joints where necessary. Secure formwork tight against adjacent rammed earth to prevent formations of steps.

Confirm positions and details to ensure that alterations to and decisions about the size and location of inserts, holes and chases are not made without the knowledge and approval of the
engineer. Fix inserts or box out as required in correct positions before placing rammed earth. Form all holes and chases.
No metal part or device for securing forms, such as ties, is to remain within the completed rammed earth.
No release agents are to be used on the formwork faces.

9.2 Striking of formwork.

Strike formwork without disturbing, damaging or overloading the structure, and without disturbing props. Notwithstanding other clauses in this specification and any checking or approvals by the engineer, the responsibility for safe removal of any part of the formwork and any supports without damaging the structure, rests with the rammed earth contractor.

9.3 Formed finishes.

All finished and visible surfaces on rammed earth walls should be free from cracks exceeding 3 mm in width, mechanical damage, sections of loose friable material (soft spots), staining,
and open bolt holes.
Wall finishes shall meet minimum agreed variations with respect to color, texture, boniness, flatness, formwork patterning, allowable cracking, extent of patching and repairs,
and the number and style of cold joints. Any defect should not impair either the form or the function of the wall. All repairs should be undertaken using color-matched similar materials.
The visible surface standard of the completed wall, including all repairs, should be measured against that of an agreed test wall or other agreed reference finish.
Gradual irregularities, expressed as maximum permissible deviation from a 1 m straight edge, are to be not greater than 5 mm. Formwork tie holes to be in an approved regular pattern, filled with matching earth.