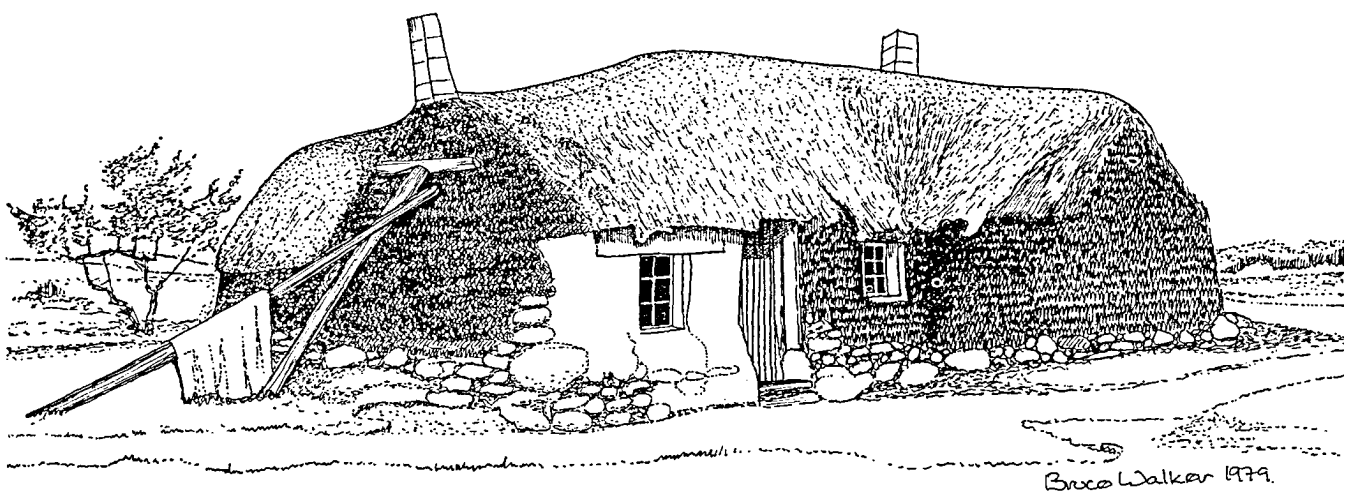
Earth Structures and Construction in Scotland

A guide to the Recognition and Conservation of Earth Technology in Scottish Buildings



Historic Scotland Technical Advice Note 6

HISTORIC SCOTLAND

HISTORIC SCOTLAND TECHNICAL ADVICE NOTES

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No 6 - Earth Structures and Construction in Scotland

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A Guide to the Recognition and Conservation of Earth Technology in Scottish Buildings

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HISTORIC SCOTLAND

FOREWORD

My first serious encounter of the use of clay as a structural material occurred during the late 1960s when, as an architectural student, I undertook a study of farm buildings in upland Angus. Until that point my awareness was limited by a lack of knowledge and understanding. Hitherto, clay had only been recognisable as a structural material through illustrations of vernacular buildings from the middle east and it took me some time to recognise what the mortar materials were in the partially collapsed buildings that I was studying.

With a greater understanding came the recognition that, in addition to vernacular buildings, a broader use of earth structures were also to be found in major architectural and civil engineering projects.

As an international material, earth provides the ultimate "green" construction substance. However, there remains a considerable amount of professional ignorance and misunderstanding of the material. And, with so many other traditional construction techniques, we are currently in the process of having to relearn much of what we were once familiar.

Survey and analysis can help, but the best experience will be gained from undertaking experimental work in connection with historical studies. In an attempt to relearn some of the lost techniques Historic Scotland initiated an experimental earth structure research project in 1996. At three sites around Scotland (Culzean, Battleby and Fort George) test walls and panels have been constructed. These will enable us to monitor, over time, weathering mechanisms, moisture movement and sinkage.

Inevitably, such an approach is a great simplification of what was an infinitely variable use of the material around the country. But it will enable us to start exploring this significant material in a serious manner. Through relearning from analysing emerging faults, and the techniques used in undertaking the building and repair work, it is anticipated that we will eventually be able to offer a greater understanding and awareness of the traditional craft skills required to effectively work with the various mixes.

This Technical Advice Note, the sixth in the series, attempts to provide a preliminary look at what the material is, and how it was used. It also tries to set the scene in such a way that earth, in all its forms might be used to a greater extent in the future. Through building upon the knowledge amassed through Dr Walker's long standing academic studies, and practical Historic Scotland casework experience, the intention is to help professionals, and education and training providers, working in the field of architectural conservation in Scotland gain a better understanding of what is involved.

It is also recognised that the TAN's content will have an international significance. Perhaps, for the first time, this will enable the Scottish perspective to be taken into account along with that from other countries where a greater understanding of the material is much more acute than here.

INGVAL MAXWELL
Director, TCRE

1 July 1996

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CONTENTS

Earth gable, Gamrie, Banffshire

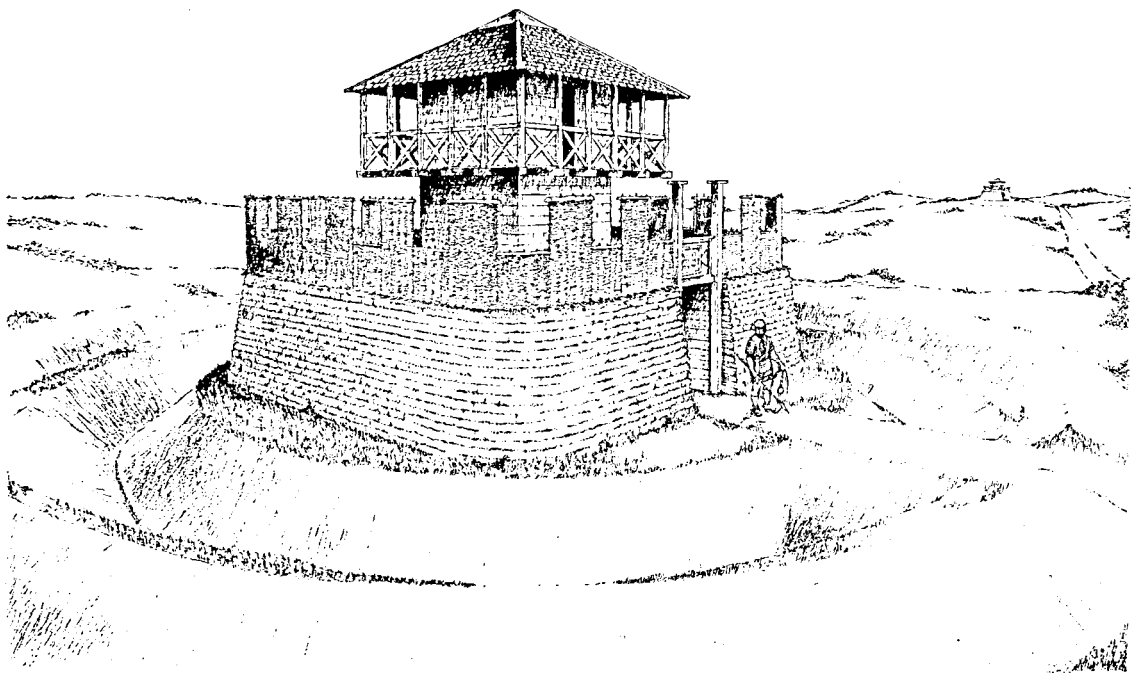
1
INTRODUCTION

Earth is the most basic, and the most ubiquitous, building material known to man. It has the benefit of being easily worked, using the simplest of agricultural tools, yet is capable of fulfilling the most demanding of roles. These facts are not of purely historical interest as earth still continues to be used to provide housing and civil engineering structures throughout the World. The housing varies from the poorest squatters' huts to the houses of some of the World's most powerful leaders. CRATerre-EAG estimate that two-thirds of the World's population still live in earth-walled houses and there is no reason to suppose that this number will decline, rather the reverse is more likely.

In Scotland, stone is generally perceived to be the principal building material, but during the greater part of Scottish history, earth construction was predominant. The use of earth as a building material, lubricant to move heavy weights, waterproofing agent, decorative finish and colouring agent is continuous, from the earliest settlement to the present day. Even the construction of major masonry structures such as the large chambered tomb at Maes Howe, Orkney is the result of using: fine clay as a lubricant-mortar to position the stones; puddled clay as a waterproofing agent round the stone structure; mounded earth to form an earth shelter; and turf to construct the enclosing bund.

The Antonine Wall - Reconstructed phase II fortlet

HS



Phase I plan

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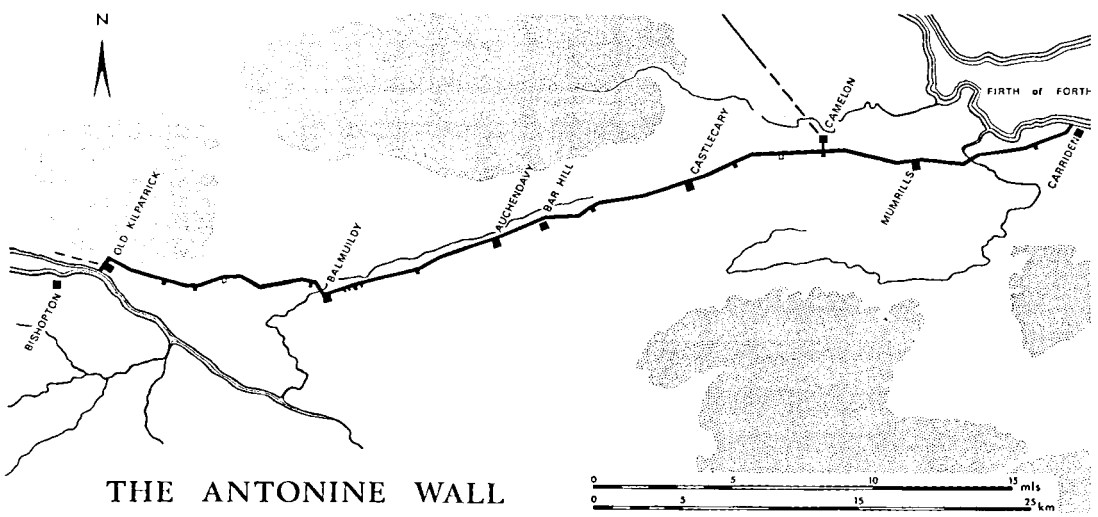

THE ANTONINE WALL

Part of the wall today

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Part of the wall today

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Reconstructed view of construction phase

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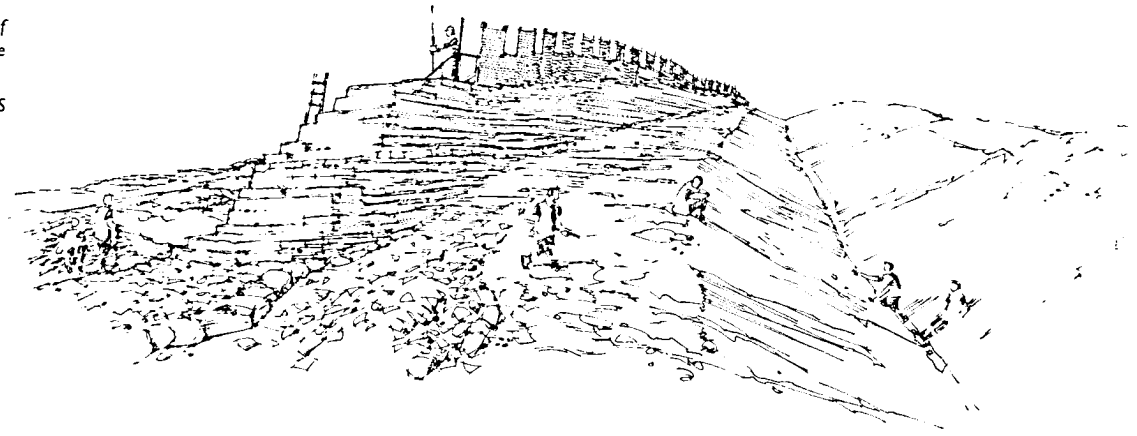

Reconstructed section of construction phase

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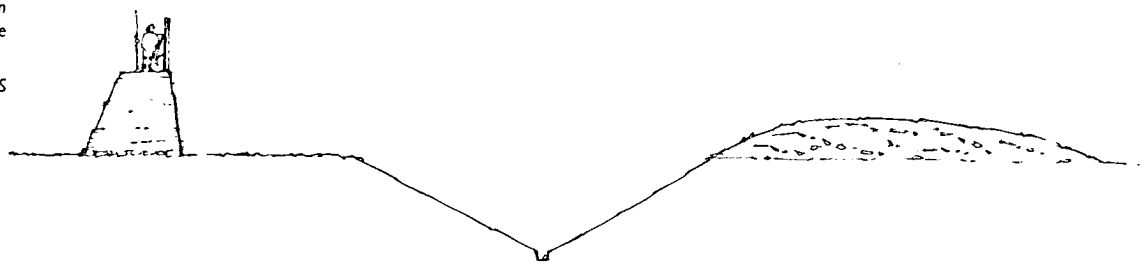


The largest earthen structure in Britain is the Antonine Wall built by the Romans to form a defensive structure between the rivers Forth and Clyde. This defensive theme re-appears in the timber framing and clay infill found in early castles. Indeed, much of the distinctive aesthetic associated with the later masonry towerhouses derives from the constructional details associated with timber-framed structures with clay infill.

The emphasis changes significantly at the period of agricultural improvement and industrialisation in the eighteenth and nineteenth centuries. In Scotland the "great rebuilding" took place in parallel with agricultural improvement and industrialisation resulting in a wholesale replacement of the building stock in a short space of time. The traditional materials continued in use but there was a significant increase in the use of stone as a facing material, and although this was pointed or harled using lime, the mortars and wall cores remained earth based. Much of the present confusion regarding wall core material stems from contemporary Government reports where the phrase "substantially built of stone and lime" is favoured even when the buildings described are now known to be constructed from a range of materials including pisé, claywall, mudwall, half-timbering, timber, brick, drystone, or masonry built using clay mortar. Lime is found in some early structures but normally those linked with English monastic foundations or later Government utilities, rather than vernacular structures.

Although official reporters see "stone and lime" as the ultimate building material, Dorothy Wordsworth, travelling through Dumfries-shire in 1803, notes:

> "Those houses by the roadside which are built of stone are comfortless and dirty: but we peeped into a clay "biggin" that was very "canny" and I dare say will be as warm as a swallows nest in winter."

The changes brought about by the "great rebuilding" were still incomplete when a new "wonder material" - Portland cement appeared on the market. Scotland saw some of the early uses with Smirke adopting mass-concrete strip foundations at Kinfauns Castle, Perthshire in the 1820s and Telford carrying out mass-concrete works at Dundee Harbour in the 1830s. The technique spread quickly and the proliferation of mass-concrete buildings in the Perth-Dundee area provided many of the examples and illustrations in published works on the subject in the 1870s.

The strength and versatility of Portland Cement had a significant impact on the use of earth-building techniques with a subsequent loss of expertise. Unfortunately, all this occurred at a time when the technique was so common that it did not require explanation and the success of the innovative materials appeared to be assured. The archive and published material still available tends to emphasise the unusual or the experimental rather than what was commonplace. Commonplace structures are only

described in detail in sources where the intention is a change of context: for example, a detailed description of the structure of a Highland cottage is provided in a book dealing with sheep management where the author is advocating this structure as a method of building sheep cots. The material that does survive must be tested in the field to assess its relevance and this publication is an initial attempt to make owners, builders, architects, engineers, surveyors and others involved in the conservation of historic structures aware of the materials used and the principles employed in the design and construction of these structures. Through this it is hoped to curtail the inappropriate alterations, additions, extensions and remedial works that threaten to destroy our built heritage.

The use of earth technology is not dead: its use continues, usually in the form of clay as a waterproofing material, in a wide range of engineering projects such as docks, harbours, sea walls, aqueducts, canals, lades, reservoirs, bridges, viaducts, wells and decorative ponds. Clay puddle provides the waterproofing in the Meggat Dam near Edinburgh, completed in the early 1950s. Specialist clays are used as lubricants on the drilling rigs used for oil exploration in the North Sea and earth sheltered structures are developing to new levels of sophistication: the largest example, open to the public, is the nuclear-war command post, now known as the "Secret Bunker" situated close to Crail in Fife.

However, if the built heritage is to survive for the interest, pleasure and education of future generations, it is essential that it is better understood. By linking the information available in Scotland to the practices and expertise surviving in some of the neighbouring countries, (accepting the sea as a highway rather than as a barrier), we can initiate experimental work on earth structures, that may help to prove or disprove theories, stimulate discussion, and develop sympathetic conservation practices.

This publication is aimed at all earth-building owners, historians, geographers, conservation officers and practitioners with an interest in earth structures. It urges: caution when deciding to change the status quo; dialogue and discussion on conservation practice and procedure; reporting of any hitherto unknown archive material: experimentation and recording; and, most importantly, a change in attitude to these historically valuable structures.

The conservation of earth structures is still in its infancy in Scotland. Many of the opinions expressed by historical reporters have not been tested and are included in this publication as evidence to allow the reader to consider all the available information in forming his or her own opinions. Similarly, initial reactions to recent conservation initiatives and experiments are included, but cannot be considered conclusive as they can only be confirmed after a sufficient passage of time. This document should therefore be considered as an initial guide to a complex and often contradictory subject. Historical accuracy should be respected, yet at the same time it is essential to understand the significance and implications of all decisions taken in respect of the structure under consideration. Many of the historic decisions have since proved detrimental to the original fabric, and it may now be essential to reverse these and find a more sympathetic solution.

2
NATURAL SOIL-BINDING AGENTS

All earth building techniques depend on a binding agent to hold the soil particles together and prevent slump to the soil's natural angle of repose. Binding agents can occur naturally and combined with immense pressure can produce sandstone, shale and slate. By choosing the correct blend of binding agent and soil particles, the earth builder can produce a building product that does not require immense pressure to initiate binding but has superior wearing and structural qualities to many of the poorer quality sandstones found in the Central Lowlands of Scotland.

The main binding agents traditionally used in Scotland are natural fibre and clay. Oils, lime, bitumen and cement can also be used, but these materials bring their own problems and are discussed in item 5.02(vi).

2.01 Naturally Occurring Fibre

This category includes all those materials held together naturally by fibres in the material. The fibres can comprise the root systems of plants or compressed vegetable material such as that occurring in peat bogs. Material from peat bogs also contains a natural vegetable oil that assists in the consolidation process and gives the material water repellent qualities lacking in many earths and sandstones.

2.02 Clay

Clay is found in various forms, each with its own characteristics. It is important that these characteristics are recognised when using the material and that the material is tempered in an appropriate manner. "Fat clays" are the preferred material. These have a high colloidal particle level, are greasy to the touch and are very plastic. "Lean clay" on the other hand has a small colloidal content. The range of available clays is as follows.

2.02(i) Ball-clays

These are plastic kaolinitic clays from transported sediment and are generally deposited in lacustrine basins. These clays are composed of secondary kaolinite together with some micaceous material and may contain a proportion of sand or silt which forms 60 per cent or more of the ball clay.

2.02(ii) Bentonite

This is a clay derived from the alteration of volcanic dust and ash deposits and is mainly composed of montmorillonite. Owing to the capacity of this material to absorb water within the crystal lattice, as well as acquiring a film of water around each particle, bentonite clays swell enormously on the addition of water, forming a viscous mass.

Can be used in engineering to help support gravels in the walls of excavations.

2.02(iii) Bituminous Shale

Also known as Oil Shale. It is black or dark brown in colour and contains natural hydrocarbons.

2.02(iv) Brick Earths

These are brown or red silty clays which are thought to have been formed in glacial waters in front of the ice sheets during the Pleistocene period and are still used in the making of bricks.

2.02(v) Fireclays

These are rich in kaolinite and commonly contain small amounts of quartz and hydromica. They occur below coal seams in the coal measures in two types: silica rich and alumina rich. Characteristically, they have a very low content of alkalines, can be exposed to high temperatures without melting or disintegrating and are used in the manufacture of refactories.

2.02(vi) Loess

These are wind blown deposits of fine particles of the clay and silt grades.

2.02(vii) Marl

Marl is a calcareous shale or clay. The calcium carbonate content ranges from about 7 per cent to over 20 per cent.

2.02(viii) Alum-shale

This is a shale containing alumina and pyrites. On exposure to air and water pyrites oxidises, liberating sulphuric acid which attacks alumina to form aluminium sulphate, from which alum can be formed by adding ammonium or sodium or potassium sulphate.

2.02(ix) Varved Clays

These are red clays and muds of deep sea origin.

• • •

Theoretically any of the above clays can be used to create earth structures but the shales would require to be broken down and reconstituted which would be wasteful of energy. Of the other clays, sharp sand and gravel should be added to create a loam that is easy to consolidate and that sets well. In Scotland a loam of this type was referred to as MORTAR. In practice, Alum-shale and fireclays are not recommended for earth structures.

Gordon Houmont House, Broken Bow, Nebraska

Dun Nosebridge Fort, Islay

3

NATURALLY OCCURRING FIBRE STRUCTURES

One of the simplest ways of using earth for building is to cut material that is naturally reinforced with vegetable fibre. Turf with thick fibrous roots keeps its shape during the building process and if cut and built at the right time of year and in a controlled manner, the roots can be encouraged to continue growing forming an increased bond between blocks of material. Similarly, material such as peat contains natural oils that render the cut block waterproof if cut and dried in an appropriate manner, again making an excellent building material.

These materials have the added advantage of being readily available throughout most parts of the country and they can be worked using comparatively inexpensive agricultural or horticultural tools such as spades. When these materials were in regular use for building, a range of specialist spades was developed to allow the material to be extracted from the ground in regularly sized blocks in the best possible condition for use in building.

The designs of the specialist spades reflect the ingenuity and requirements of the builders in different regions of the country, each being influenced by the nature of the turf or peat in that region. The older spades are iron shod timber tools, the blacksmith and wright combining to produce the necessary tool for the job in hand. In turn, modifications in the design of the tool used is reflected in the appearance of the structure being erected, giving the structure its "local" character.

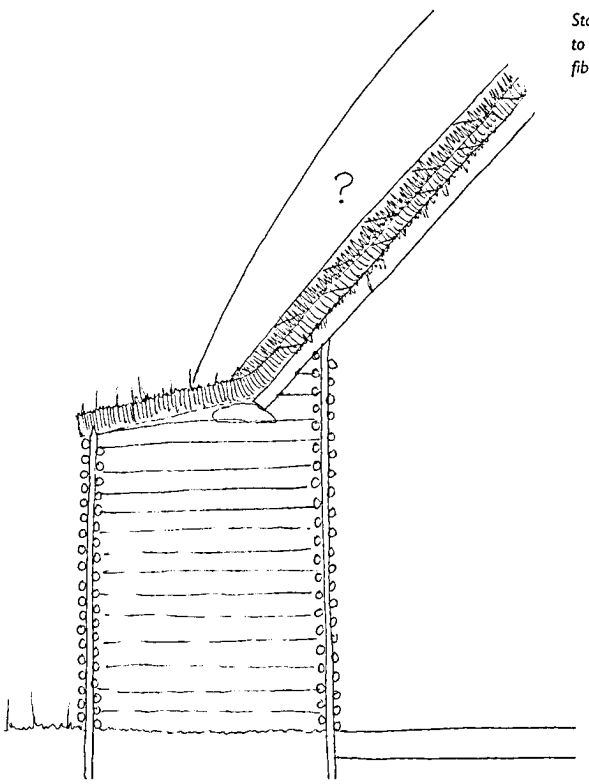
If carefully built and reinforced, natural fibre can be structural to two storeys and can carry a substantial roof. This is not known in Scotland where it is much more common to find the material built against a timber structure rising from the ground or a low foundation wall.

The Gordon Haumont house serves as an example of what can be achieved using natural fibre as a structural material. The house, now sadly demolished, stood twelve miles north-east of Broken Bow, in Nebraska, USA. It was built by a Belgo-French family in 1885 and incorporated many interesting features. The walls were about a metre thick and were laced with timber at the sill and head levels of the windows. This spread the load of the walls and roof evenly through the structure. The lacing at the window heads also carried the floor joists and roof timbers on respective floors. Additional lighter lacing was also used over the first floor joists to create an even surface from which to build the first floor walls. Turf structures tend to be vulnerable to erosion at the corners. The Haumont house had solid circular features at the corners to improve the weathering qualities. The house stood for almost a hundred years before being demolished by an irate owner who failed to get grant for its upkeep.

Although there are no domestic survivals of this type of structure in Scotland, there is no reason to exclude this type of structure from consideration. Indeed, many of the larger material fibre structures such as indigenous hill-forts and Roman remains incorporate timber lacing in the structure.

Stake and rice (wattle) can be used to provide additional support and wearing surfaces to natural fibre walls. A number of descriptions survive, mainly from the Western Highlands and the Hebrides, of constructing turf walls between two stake and rice walls. Unfortunately, these descriptions do not make it clear whether the resultant wall is structural or requires additional support to carry the roof. It is likely that these walls provide the only support for the roof timbers as many of the descriptions are from areas where caber roofs, without roof trusses and purlins, survive to the present day. An attempt has been made to combine the description of the turf-filled stake and rice wall with caber roof construction - see section - but experimentation is required to establish whether this will work in practice.

The other factor in favour of this technique being used structurally is the shortage of standing timber in those areas where the descriptions originate.



Stake and rice used to contain natural fibre wall

A description of 1876 reads:

"The old house of Glendessary ..... was constructed, like a few more, of wickerwork: the outside being protected with turf and the interior lined with wood."

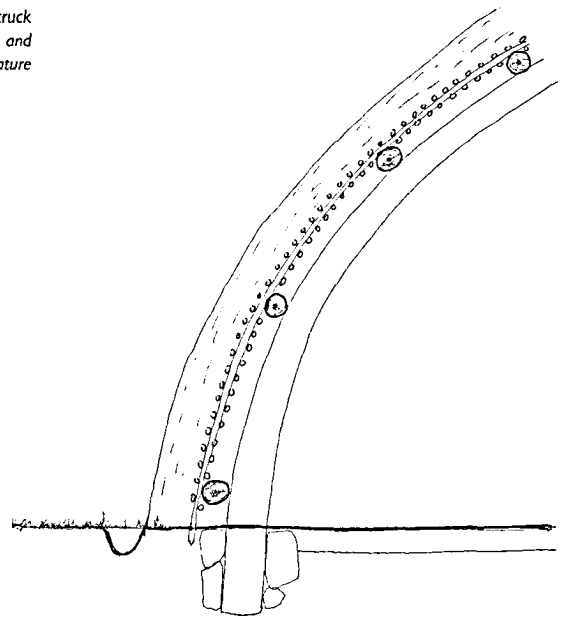
This introduces another element into the construction, that may be part of the original structure or may be a later improvement.

Throughout the rest of Scotland natural fibre is used in conjunction with cruck construction. These are not always full crucks, as are found in the richly wooded areas of parts of England, but are more often composite crucks, bracketed trusses or trusses rising from timber posts - all appearing under the generic number of COUPLES or CUPELS in Scottish building records.

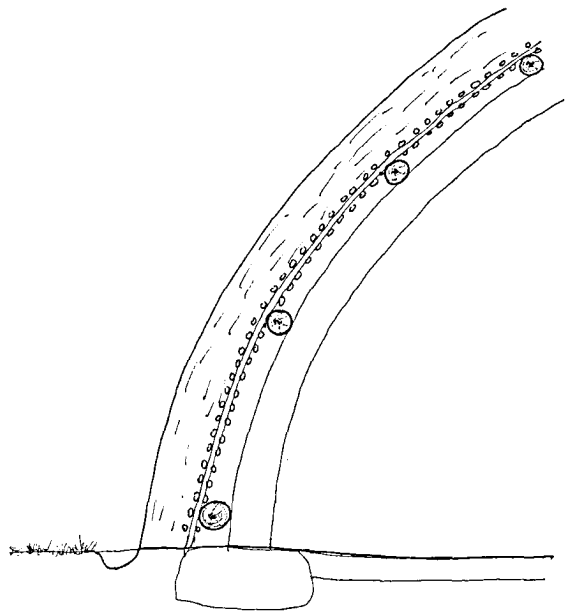
Crucks can be earthfast, being set into a posthole with or without packing stones; can sit on padstones, flush with the ground or raised above ground level; can be positioned within the volume of the dwelling or other structure; or be built into the wall. All are equally valid and all techniques can in theory be found in a single period structure. The determining factor is always availability rather than structural purity. Many structures incorporate second hand timbers, often from shipwrecks, resulting in some bizarre solutions.

A number of wall sections have been prepared to show a range of common constructural methods. This is by no means exhaustive and other recorded examples will be welcome for future editions of this publication.

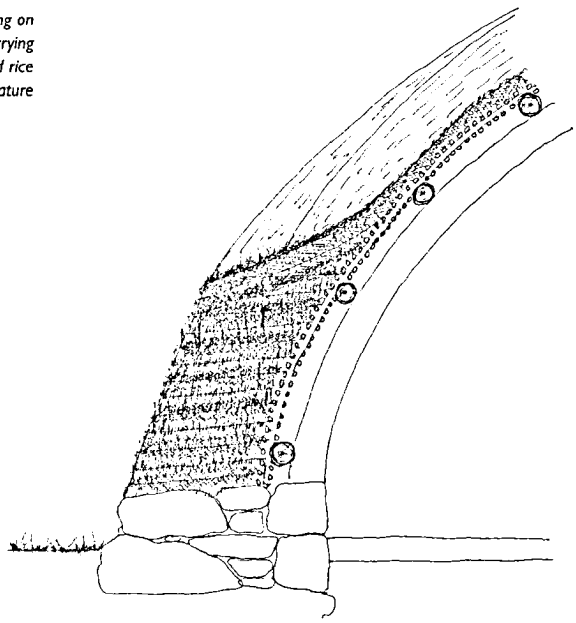
Earthfast cruck carrying stake and rice armature



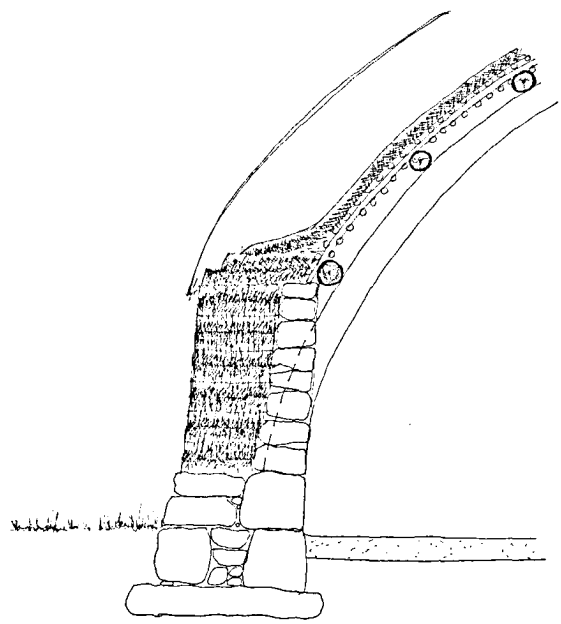
Cruck sitting on padstone carrying stake and rice armature



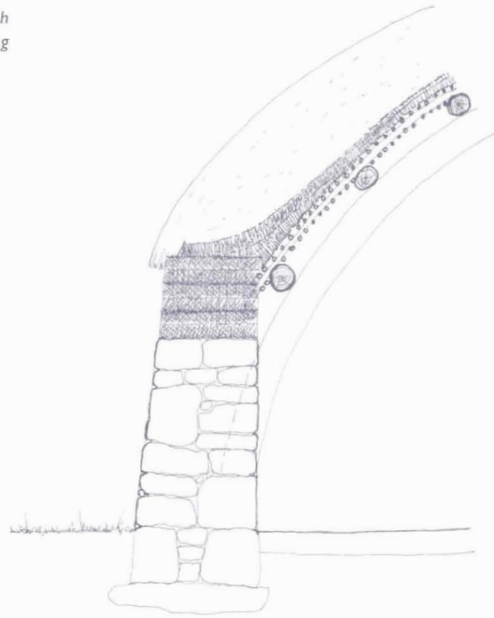
Cruck sitting on dwarf wall carrying stake and rice armature



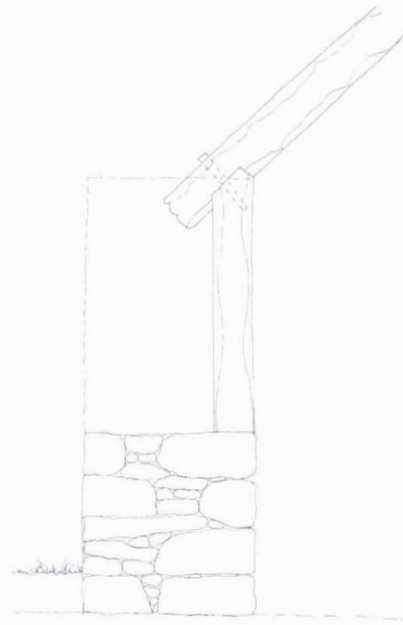
Cruck sitting on dwarf wall continued into drystone inner skin



Masonry wall with turf topping



Variation



Dulnan, Inverness-shire circa 1920s - I F Grant

3.01 Excavated

In Scotland, excavated structures normally occurred in areas where peat was being extracted for commercial purposes or where there was a need for a storage structure within a peat bog. Peat bogs were known as "mosses" and this type of structure was normally known as a "moss-house".

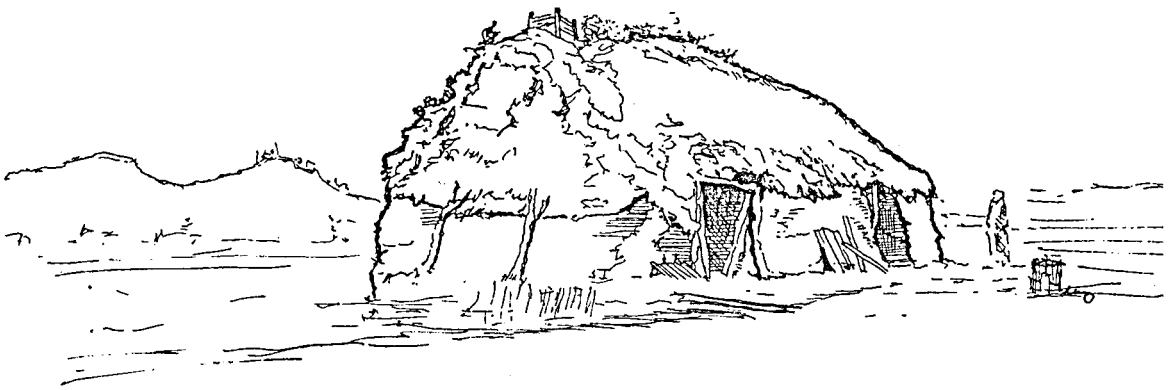
Peat shrinks considerably when the moisture is removed and the common practice allows for this. An area of bog is chosen where the peat depth is twice the height of wall required for the house, that is from three to four metres. The area of the house is then pegged out on the surface of the bog and a ditch, at least two metres wide but often considerably more, is cut through the peat to the clay sub-stratum. The inner face of this ditch corresponds to the outer face of the house wall. A smaller ditch is then cut into the clay sub-stratum. This ditch should be at least 30 cms deep and cut to drain to a convenient outfall. The interior of the house is then excavated leaving the outer walls insitu. Crucks or wall-posts to carry roof trusses are then inserted against the inner face of the walls. These rise from the ground (clay sub strata) level. If the walls prove to be too low or if gables are required, cut peat or turf can be used to heighten them. The door is cut after the wall consolidates. Small windows can also be cut but early versions of these houses appear to have been windowless. The roof was finished in accordance with local tradition.

Superficially, this may appear to be an expensive way of producing the outer walls of a building, but when one considers that the resulting wall is homogeneous, will become water repellant as it dries and that the excavated material is a fuel that may be used by the occupants or sold commercially, the economics become clear.

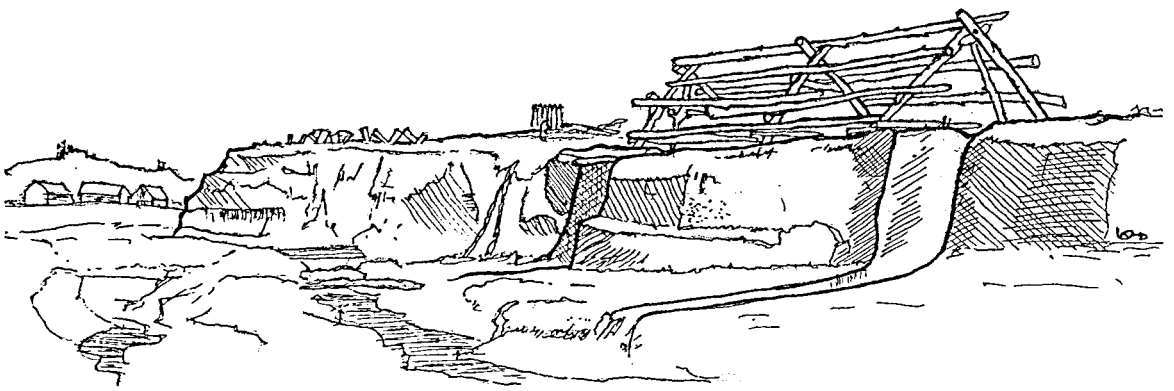
The best known moss-houses in Scotland are those of the Blairdrummond, Kincardine, and Flanders mosses in Stirlingshire recorded by the visiting artist Joseph Farrington in 1792. Other contemporary descriptions exist, the most recent being published in 1882 as a method of constructing small inexpensive ice-houses for the west-coast salmon fishing industry.

Mosshouse, Carse of Stirling, 1792 (after Farrington)

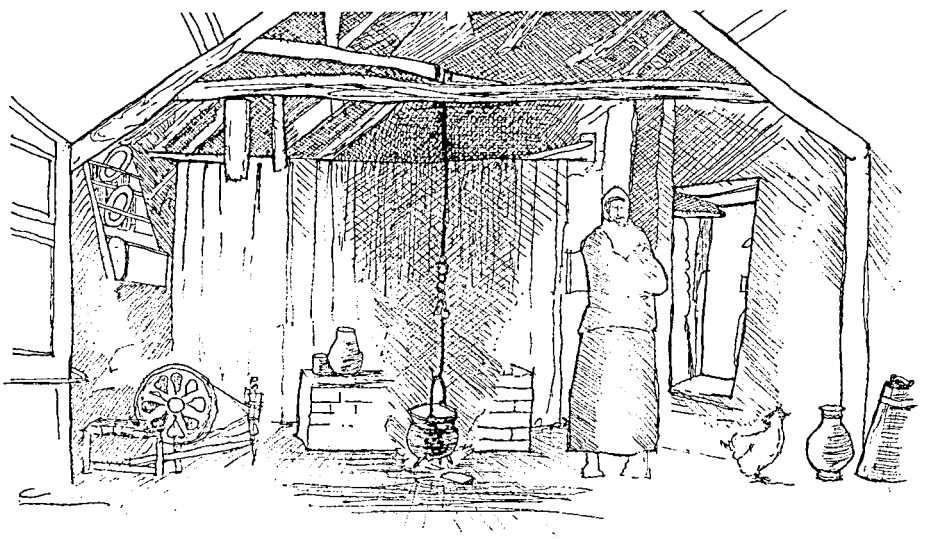
Exterior



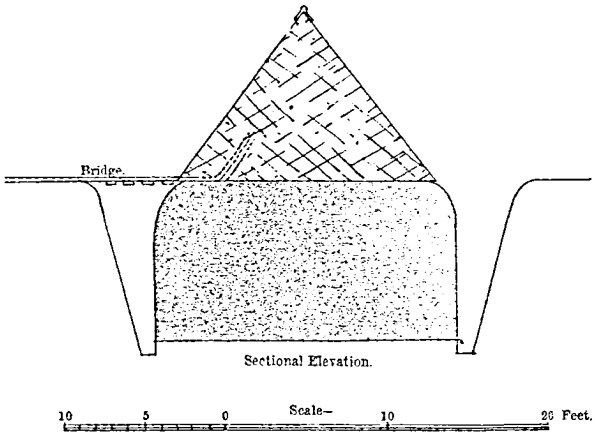
Under construction



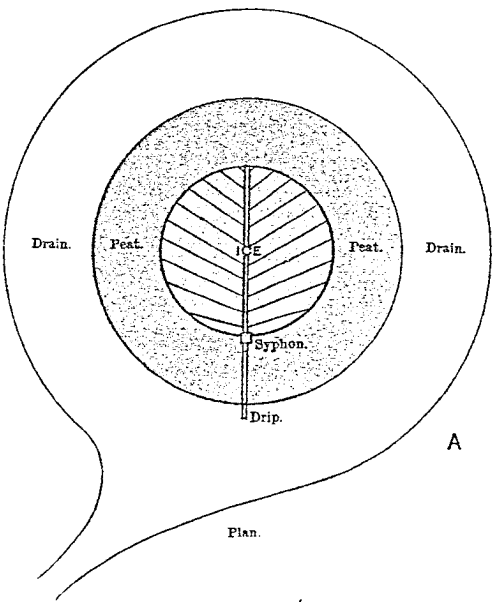
Interior

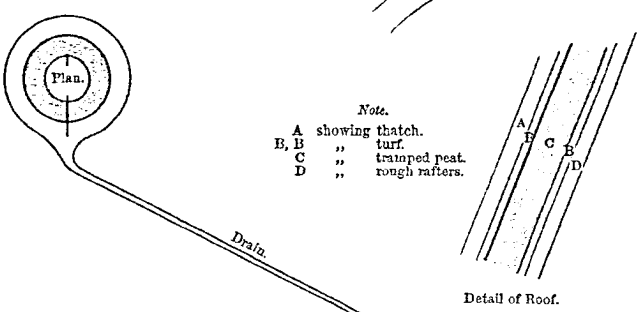


Peat icehouse, 1880s

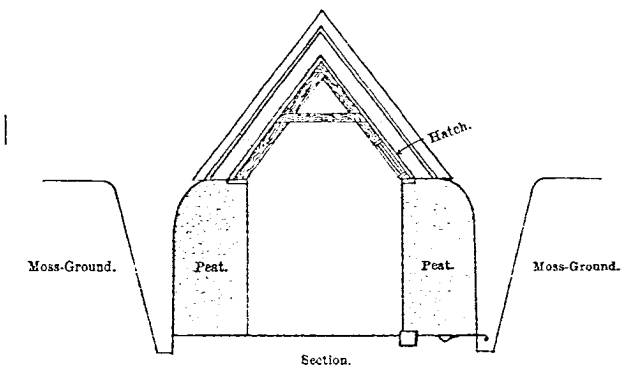


PEAT ICE-HOUSES





PEAT ICE-HOUSES



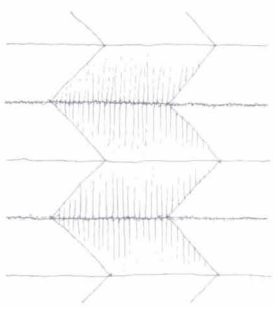
South Uist

3.02 Fale

The term fale, fail or feal when used generally can be applied to any form of turf used for building but when the terms divet, sod and turf are given specific meanings and removed from the equation, the term fale can be taken to mean a large thick fibrous block often cut to a parallelogram section and used for building walls. Examined walls suggest that the block may include the surface vegetation but only where the underlying material is peaty in nature, the change in character being easily seen in the cut section. Fale can also be applied to any form of peat cut for building purposes rather than as fuel.

Unfortunately, as with many materials in common use, writers usually fail to describe the size and nature of the blocks, assuming that their readers already know these facts.

The parallelogram blocks are set in the wall in a herring-bone pattern. The theory being that the inclined joint closes under the pressure of the overburden leaving a tight waterproof structure. When building with a good quality peat the joints often appear to be extremely accurate. Unfortunately, little is known about the actual procedure of building. Ideally, a builder should be aware of: when to cut the peat; how long it should dry before being applied to the wall or whether it should be applied immediately; the method of drying to avoid distortion; the number of courses that can be built in a day if the material was applied directly to the wall; and so on.



Parallelogram blocks set herring bone pattern

The percentage of fale in a wall varies according to the prosperity of a district and the date of construction. Fale can be built: off a low footing; off a half wall; or as a topping to a masonry wall. The topping is usually between one and two feet in depth and is used to provide an easy fixing for pegs to hold down the roping of the thatch.

In Watten parish, Caithness, in 1794, the buildings are described as follows:

"The walls of their dwelling houses consist of two or three feet of stone, coarsly huddled together with

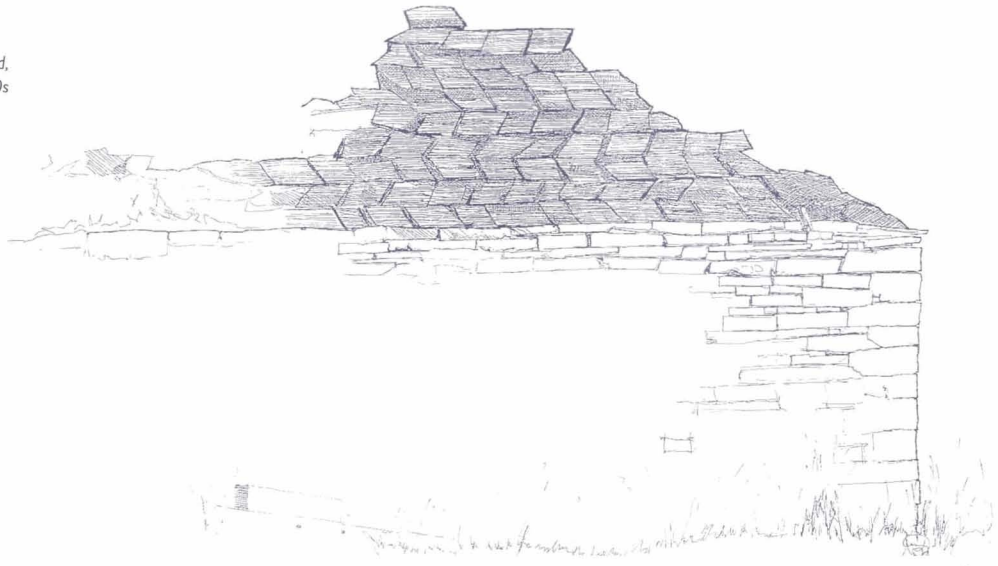
South Uist house. 1886 (from photograph)

three or four feet of feal laid above them; their roofs very thinly wooded and covered with the lightest divots (or turfs) they can procure, tied down with ropes made of heather, to prevent blowing off by the winds."

In the adjoining parish of Wick in 1845:

"The houses ..... are built partly of stone and partly of turf. Some of them are turf altogether."

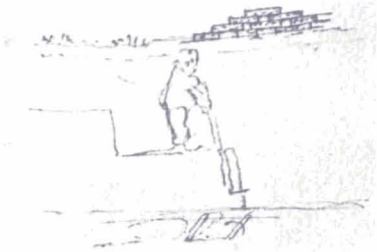
Hopefully, more experiments will be carried out in the near future, trying to replicate surviving walls, and assessing the most practical ways of achieving this.

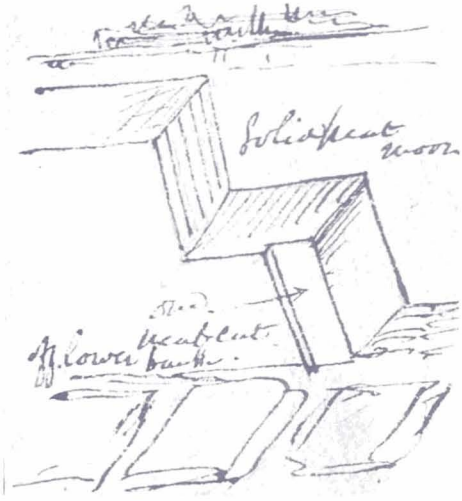


Dunnet Head, Caithness, 1970s

Much can be learned from archaeology. Eighteenth and nineteenth century fale blocks are similar in external appearance to the blocks used to construct the Antonine Wall in 143 AD. Historians writing on turf structures in Iceland have illustrated a range of turf blocks designed for specific purposes. It is almost certain that an archaeological investigation of Scottish fale construction will reveal a similar range of block types and uses. This is suggested in item 6.02 where blocks are trimmed, rutted and pared to ensure a snug fit with no open joints within the structure.

Fale hen-house

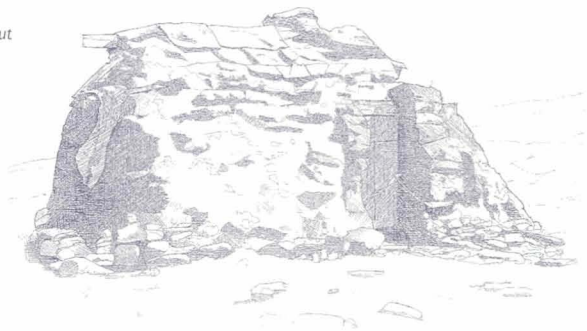




Peat Cutting Techniques

© CLA

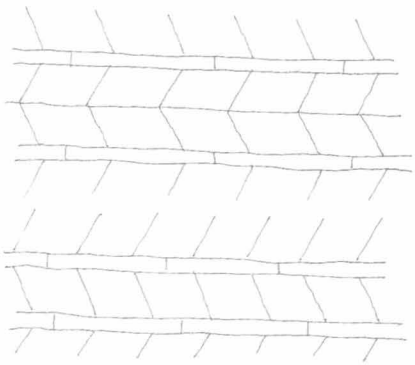
Fale Sheiling Hut



3.03 Fale and Divet

Fale and divet utilises the same herring-bone pattern as described in item 3.02 but with the insertion of a thin grass turf or divet course between each fale course. It is assumed that in some way this provides a more stable wall yet it does not seem to be a popular technique where the fale is cut from mature peat. It may well be a way of incorporating the grass turf removed from the top of a recently formed peat-bog to allow more accurate cutting of the immature peat below. Certainly, many fale blocks show a graduation from a compressed vegetable material to a mature peat in the depth of a single block suggesting that the immature part of the bog is used for building whilst the mature peat is cut for fuel. The immature peat is known as YARPHA in Orkney and Caithness.

Fale and divet



In 1743 the manse at Cruden, Aberdeenshire required extensive repairs.

"Biggin builders needed 13 single trees, 2 deals, 7,000 divots, 700 flaughter fail and including mending the stonewalls of the office houses, and bigging the walls of a byre and bringing mud to it."

A new manse was proposed in 1792.

In 1763, fourteen houses were built for ex-soldiers at Strellitz, Cargill, Perthshire. These houses cost seven pounds each even although the estimate was five pounds.

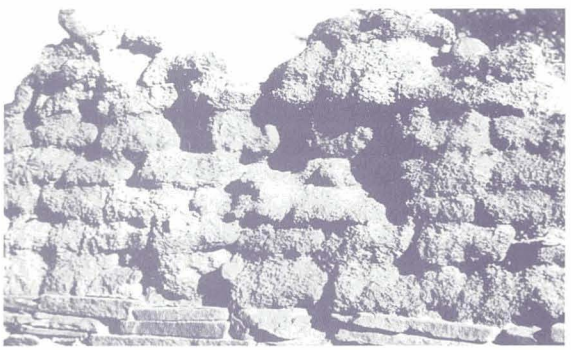
"If the houses were made of straw and mortar, instead of divots, would make them dearer still."

Several attempts were made to have these houses removed but they were still there in 1816.

3.04 Turf

Turf, occasionally referred to as sod, building is carried out with rectangular blocks cut from well established pasture. It is essential that the turf has a well matted root system through the entire depth of the building material. Turves are generally removed using a flaughter-spade designed to suit local circumstances and practice. A flat-bladed flaughter-spade removes evenly thicknessed turves, a dished-bladed flaughter removes tapered turves. Both perform equally well in a wall but generally the tapered turves are better suited to roofing purposes.

Turf should only be cut for building during periods of strong growth. The cut turf should be incorporated in the wall on the same day as it is cut thereby encouraging the root system to continue growing interlocking with the other turves in the wall.



Gablet in quarrymens houses, dated 1841, Greystyone, Carmyllie, Angus

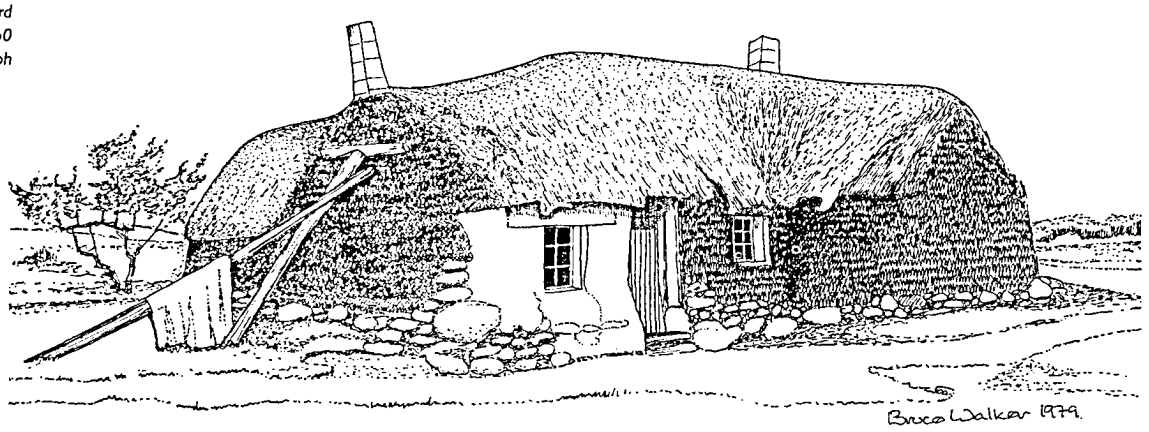
Generally turf is built grass to grass and root to root alternately. The size of turf used depends largely on the depth of the root system and the size that can be removed, handled and built without damage to the block. They are normally bonded in the same way as masonry or brickwork with staggered joints and trimmed to a flush external surface with a paring spade.

Turf walls of this type are often free-standing but they can also be built against an inner face of wattle as described in the eighteenth century accounts of "creel houses". Turf walls built against an inner surface of wattle are often finished with a battered external face. This face was left to grow as a steep grass bank. Similar grass bank walls protected the timber inner structure of houses in Shetland, the Faroe Islands and Iceland, the timber structure being imported from Norway.

A description of building a turf walled house in East-Central Scotland reads:

"Thick turfs taken from the best of the pasture were used for the walls, which were seldom more than six feet high, each course as it was laid, beaten flat down with the spade used in cutting the turfs, known as a "flaughter spade", care being taken to keep the courses as level as possible, to prevent the walls from swaying. The walls were made solid all the way round the house: the door and the window openings being

UP Manse, Howford Bridge, Nairn, circa 1860 from GWW photograph



cut out after the walls have solidified. This saved labour in forming the checks of these openings .....

..... sometimes where stones could be got for window soles or lintels, these would be placed in course of building the walls, otherwise timber would be used. The door was so low that even an ordinary sized person could not enter without stooping .....

..... The gables and ridge were loaded with thick turfs taken whence the best matted roots were to be found.

Much good pasture land was utterly spoiled to provide the turfs required for a house."

Another method recorded in 1791 at Corieburgh, Argyll uses cabers as a form of armature:

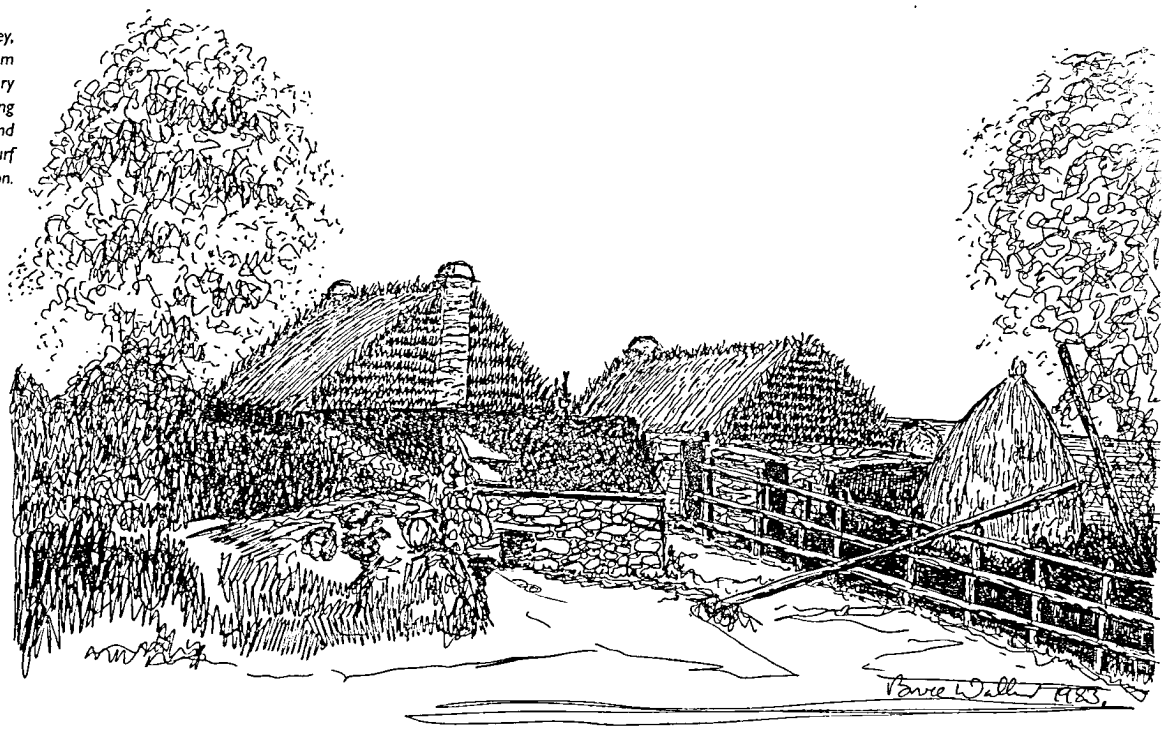
"He describes what he calles the picturesque huts at Corieburgh and says that they are formed in the following manner:

An oval spot is enclosed with poles stuck into the ground, and fresh turf is built around the poles to a height of six feet. A roof with a gentle slope is put on this wall and covered with grassy turf, and as care is taken to lay the sods outwards, the whole building is finished, except the door and window, covered with verdue and seems to be a cave dug into a grassy knoll. When the grass continues to grow, these huts are said to be the most beautiful and picturesque, but, such is the connection between beauty and deformity, to be the ugliest of hovels when it fails."

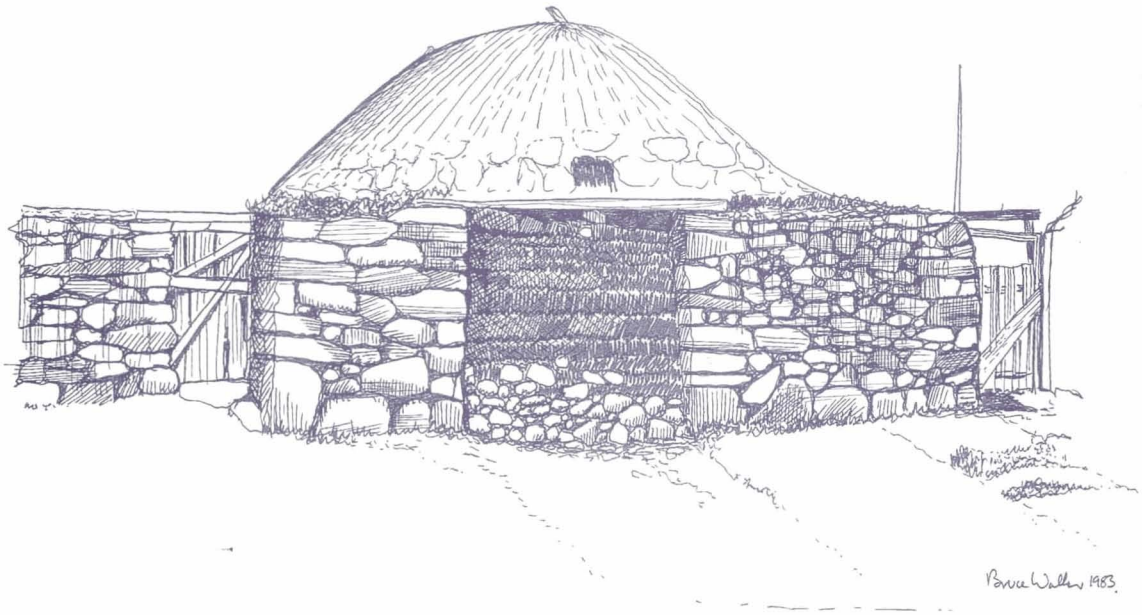
Other earthen materials were also used:

"The floors were of earth, or where it could be got, of clay, well padded down with the naked foot."

Old Drumgley, Glamis, Angus, from late 18th century painting showing allinating stone and turf gablet and turf construction.



North Uist, 1920s



Turf gable panel, Lewis, 1949 (from Åke Campbell photograph

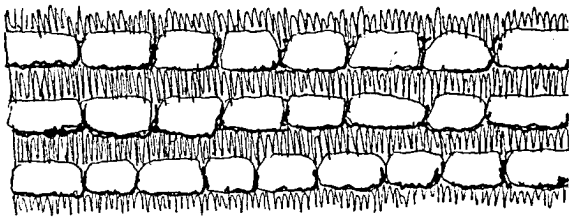
Annie Shaw's Castle, Nairn

GWW:PC

3.05 Alternating Stone and Turf

The use of field boulders or other irregular stones in alternating layers with turf or fale creates a sound wall. The presence of the stones improves the wearing qualities of the wall and the turf or fale, used as a form of mortar, accommodates the irregularities, provided some attempt is made to size the stones in each particular course. The technique has a long and distinguished history and remained the principal earth building technique in Scotland until about the mid-nineteenth century. It is not always easy to recognise, as growth from the exposed turf often covers the stone layers, rendering the stones invisible.

Alternating stone and turf



3.06 Masonry-faced Turf

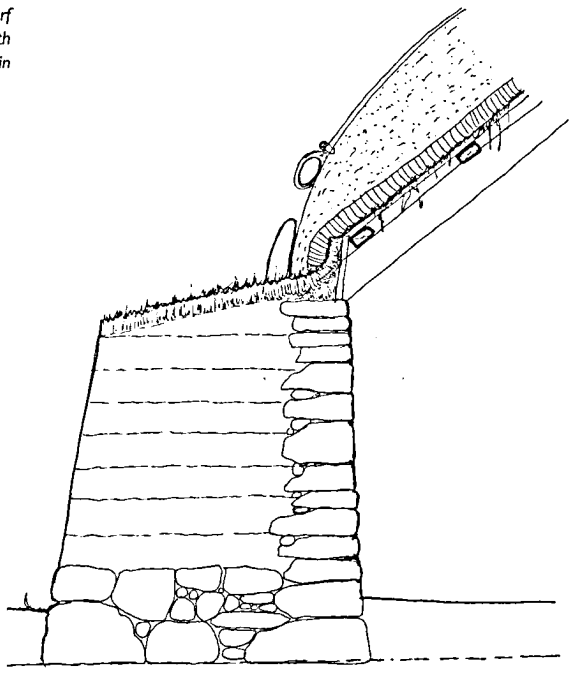
A drystone wall is often used to face the inner surface of a turf or alternating stone and turf wall essentially to provide a permanent wearing surface. Item 3.04 mentions wattle used in this capacity but wattle may rot or be attacked by wood boring insects. Penant describes turf houses with an inner skin of drystone as he passes through Deeside in the later eighteenth century. Other writers repeat the claim in other parts of the country and the present authors visited a byre at Shader, Isle of Lewis which was built in this way as late as 1951 in response to the shortage of conventional building materials after the Second World War.

Although the use of an inner skin of drystone as a wearing coat seems to have been a natural response to the problem of housing animals in a structure that, when dry, could be rubbed away by a beast scratching its flank: the use of a similar skin on the outside of the wall appears to be an estate instruction, possibly aimed at improving the appearance rather than the performance of the wall.

The "Rules and Regulations for the Lewis Estate in 1879" read:

"The dwelling houses to be erected by the tenants ..... shall be of stone and lime, or of stone and clay, pinned and harled with lime, or with stone on the outer face and turf and sod on the inside ....."

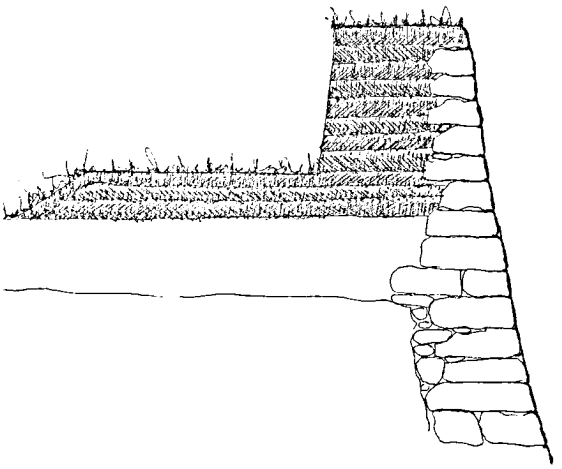
Section through turf or fale wall with masonry inner skin



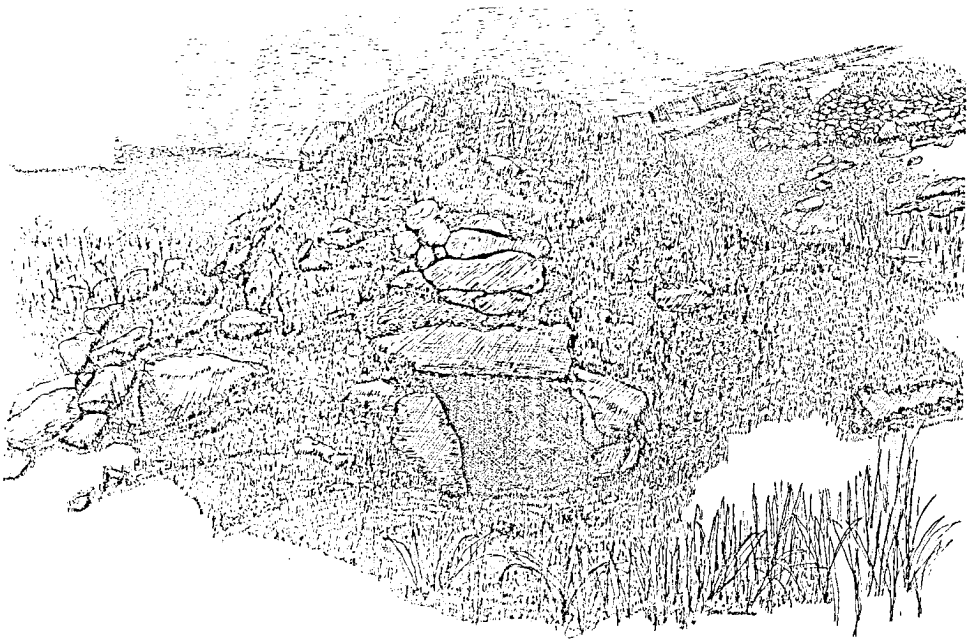
Sheiling huts (Lewisiana, 1875)

This ignores the reason for having a stone skin to the turf wall and the fact that many turf-walled houses on the Long Isle already had drystone faces to the inside walls. The outer drystone skin tends to create its own problems as water getting down the back of the stonework is held against the fale or turf, softening the surface or causing the roots of the turf to rot. This brought about a change in the construction of these walls. For specific details of blackhouse wall construction see TAN 5: The Hebridean Blackhouse.

At Fort Charlotte, Lerwick, Shetland turf was used to back the stone parapet wall, along the seaward facing perimeter wall, and to form the firing step. The exact dimensions of the turf backing are not known but a section based on the best knowledge available at present has been prepared and is shown to the right.

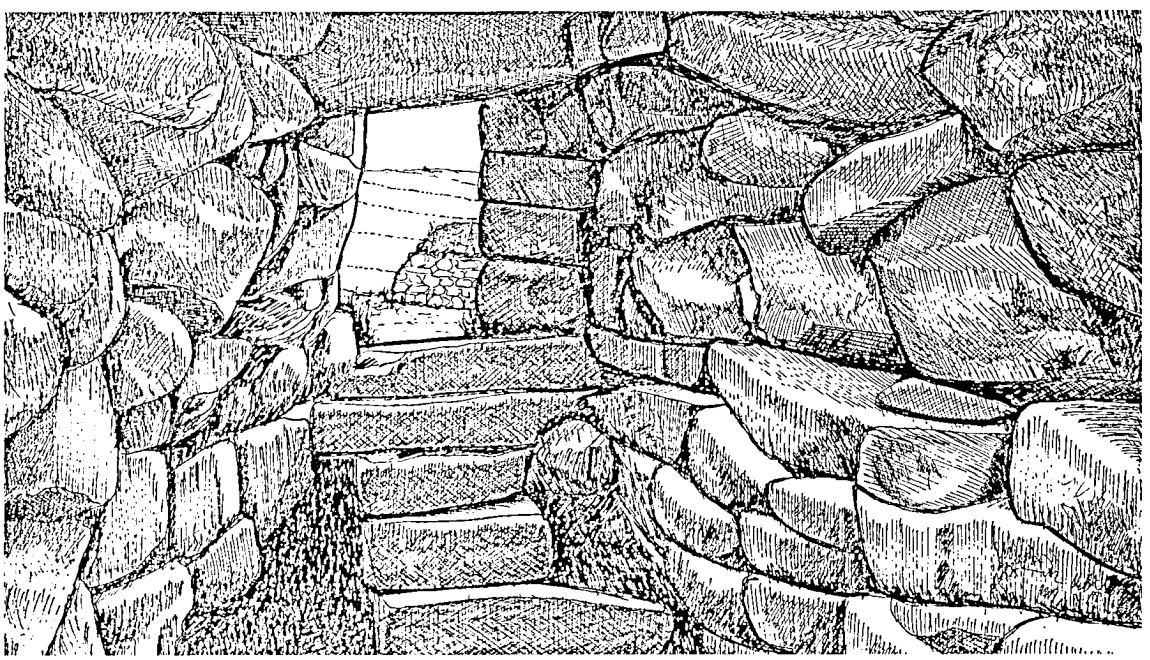


Rampart at Fort Charlotte, Lerwick, Shetland showing turf inner skin and firing step



Sheiling hut, St Kilda

J Tavendale

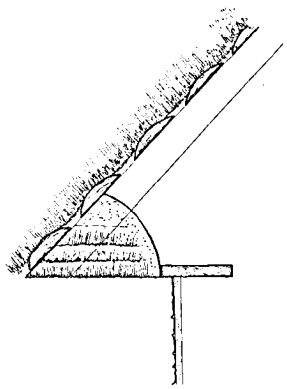


Interior of hut, St Kilda

3.07 Beam-filling

Eighteenth and nineteenth century building contracts commonly refer to the use of three layers of turf on the wallhead as beam-filling at the eaves. This is confirmed by fieldwork as being a fairly universal finish to buildings up to the standard of large farmhouses, particularly those that are, or were, thatched.

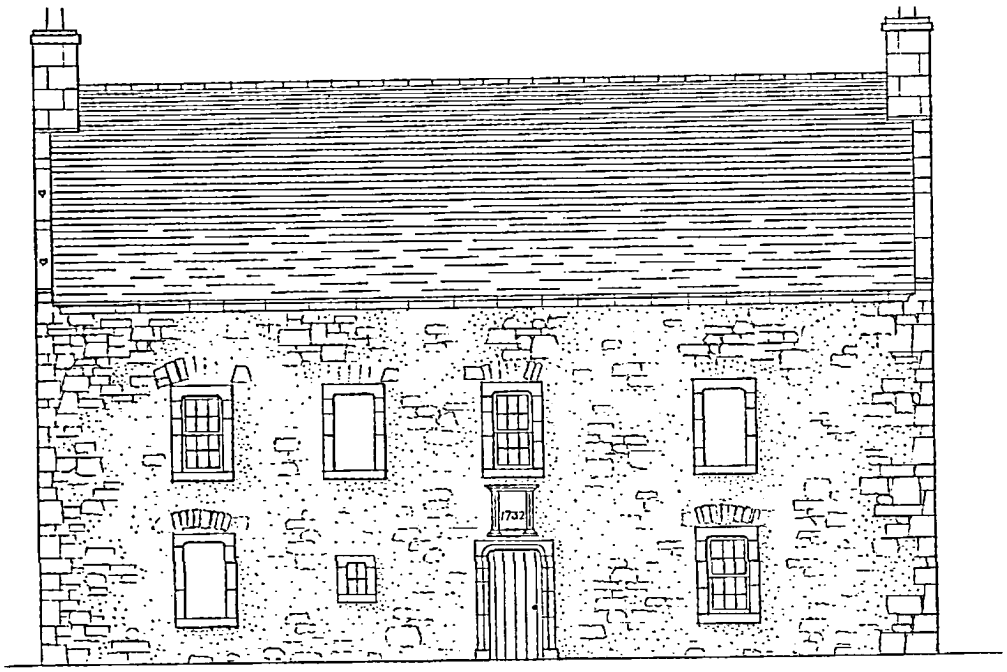
Recently, however, a number of examples of earth-plastered turf beam-filling have been located in the Black Isle-Cromarty area. These are neatly finished as a reverse cove.



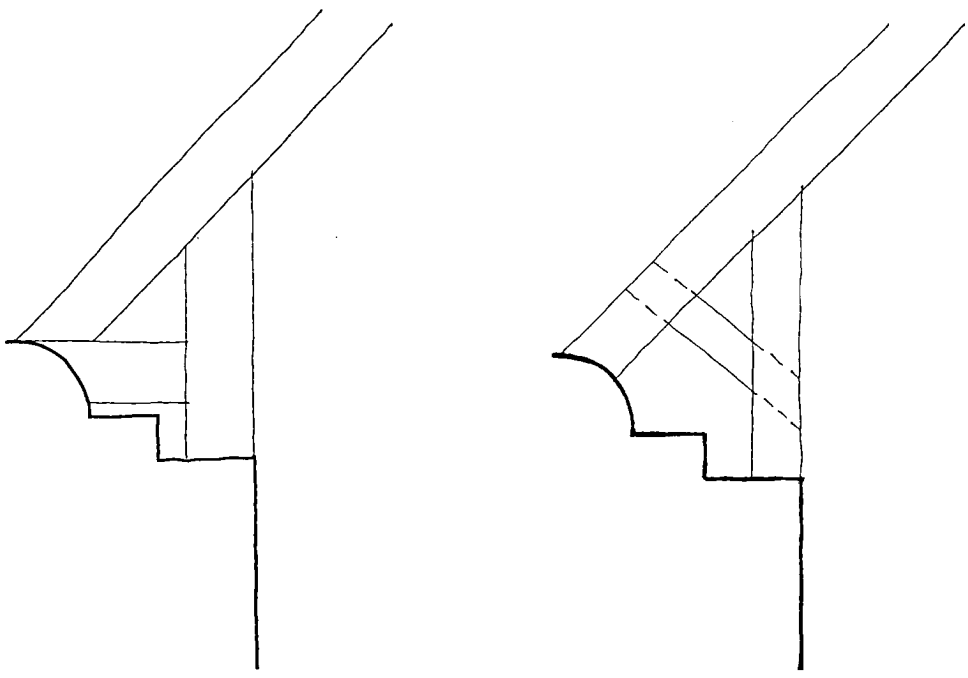
Section at eaves, Maji Cottage, Avoch, Ross-shire showing turf beam filling and clay finish

Hilton, Craigend by Perth

J Reid



Section at eaves Hilton by Perth



3.08 Wall-topping

Three layers of turf is also a common specification for the turf topping to drystone walls.

Many specifiers use the same specification when forming protective turf tops to mortared walls. This is totally inadequate as the turf in itself is not waterproof and does nothing to protect the wall from moisture penetration. In cases like this blue clay (if available) or puddled clay should be used to create a damp-proof course prior to the turf being applied.

A description of the manse at Ellon, Aberdeenshire dated 1683 refers to the use of fale as a wall-topping or thatch. It reads:

"The outer gate had a knock and had an arch or roof over it, covered with flaughters fail."

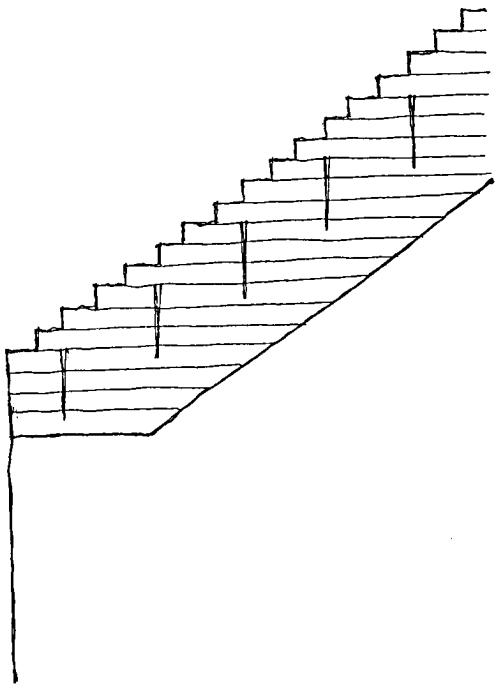
Unfortunately, this is a description of a standing structure rather than a specification and therefore crucial information as to the type of mortar used in the wall and the method of waterproofing are missing. The same reporter describing the manse at Tarves in the same Presbytery notes:

"Walls of stone with clay mortar - dry stone foundation of large boulders ..... Outside walls partly or altogether of fail .....

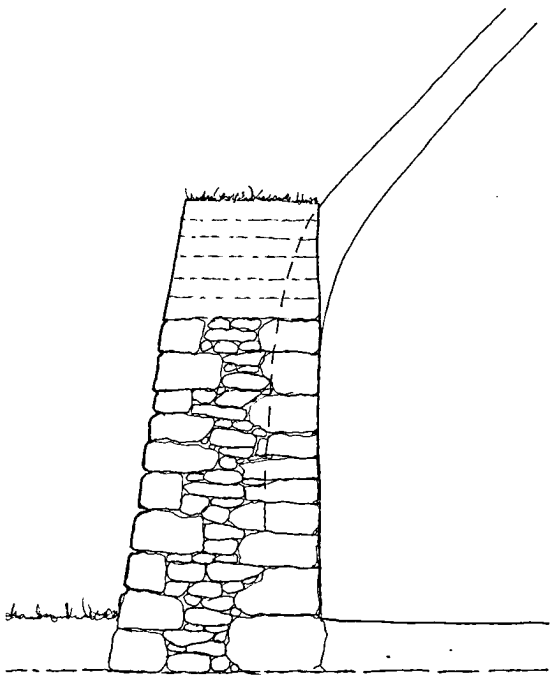
The entrance gate was roofed with an arch of flaughter faill and thatch .....

West wall of pantry of faill or sod."

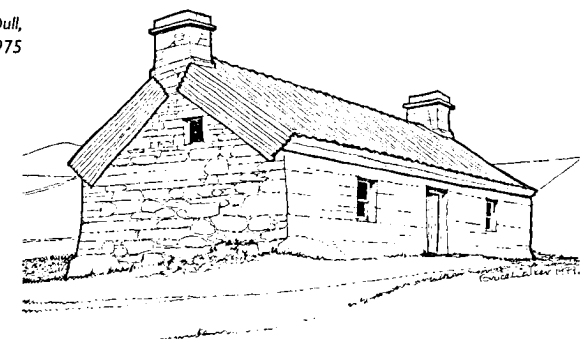
In the remainder of the report the tradesman valuator distinguishes among "mudwork", "drystone", "hewen work" and "fail work", but does not go into detailed construction.



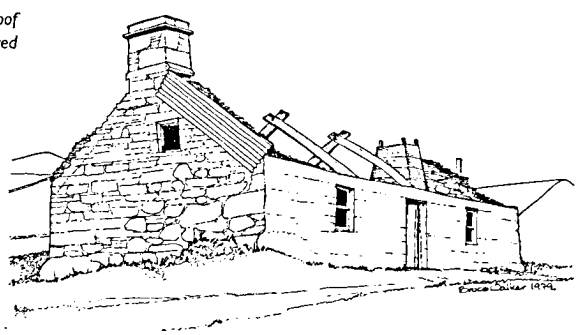
Drumdewan
Turf top to skew



Turf top to masonry wall



Drumdewan, Dull, Perthshire c.1975



Drumdewan with roof removed

3.09 Internal tomb-covering

The Mackenzie Aisle at Beauly Priory contains two tombs covered by a thick turf mat, the whole size of the lair. The significance of this mode of burial is not known but it appears to be a family tradition. Naturally, in an internal environment, the turf dies taking on an appearance not dissimilar to the type of coconut fibre mats that used to be used in gymnasia. The mechanics of cutting, moving and relaying a turf two metres long and one metre wide, without damage to the fabric of the turf, is an interesting challenge.

3.10 Insulation

Dried turf makes an excellent insulation material and as early as the 1830s was being used to insulate corrugated iron structures, both under the roof covering and occasionally between the iron and the internal lining of the walls.

Auchterless, Aberdeenshire. Turf used as insulation under corrugated iron

3.11 As Part of the Thatch

Turf plays a prominent part in the forming of many types of thatched roof. It is a very common sub-stratum over which many thatches are formed. In this situation it is laid over the cabers or thatching battens to form a complete cover. The thatch is then generally either: laid on this surface; stobbed into the surface; or stitched through the surface. Turf can also be used to form a complete thatch in itself but, if the turf used has no natural oils to render the inner layers waterproof on drying, tramped peat can be used between the turf layers. It is also a common ridging material. For specific details as to its uses in thatching consult TAN 4: Thatches and Thatching Techniques.

3.12 Loft floors

The majority of Scottish houses built prior to 1850 were open to the apex of the roof. As chimneys were introduced in the eighteenth and nineteenth centuries, the roof space was increasingly used as a place for storage or sleeping. A number of mid-to late- eighteenth century houses have been located where the loft floors are constructed of closely spaced cabers spanning between the bottom collars of the roof trusses and covered with a single or double layer of turf to form a makeshift floor.

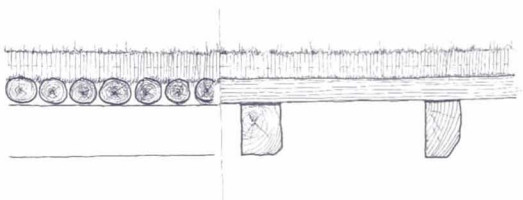
Lofted house, Glenesk, Angus

Greta Michie

Lofted house, Jericho, Glamis, Angus

Lofted house interior - after David Allen's Penny Wedding

Turf over cabers forming loft floor



3.13 Furniture

Turf was used to form benches beside the fire from early times. Dorothy Marshall describes such a bench at MacEwans Castle in Argyll, dated from about the seventeenth century. In Aberdeenshire a bench or couch of this kind was known as a FEALEY-SUNK.

Old earth wall and new drystone wall, Fair Isle

CLA-RMS

3.14 Field Boundaries

Natural fibre field boundaries are normally given the all-encompassing title of FALE DIKES but in reality there is a wide range of boundary types often incorporating other building materials or specially planted shrubs.

3.14(i) Fale Dike

The fale dike in its simplest form comprises a stone foundation, normally incorporating boulders removed as part of a field clearing operation. These would have accumulated in the balks of the former ridge and furrow (runrig) system and would be moved to the boundary on setting out the new "improved" farms in the eighteenth or nineteenth century. Fale, fale and divet or alternating stone and turf walls would then be built from these foundations, usually with vertical or slightly battered sides to the walls. Occasionally the walls have a steeper batter and wider top but these normally incorporate the planting of quickthorn, hawthorn or some other spiny form of hedging.

R W Dickson includes a section on walls and fences in his 1806, two volume work, Practical Agriculture. He is dealing with the range of field boundaries found throughout Britain but does include Scottish material provided by eminent Scottish improvers such as Sir John Sinclair of Ulbster.

Some of Dicksons more relevant "Earth Fences" are reproduced.

Figure 1: "a common stone wall coped with sod or turf."

Figure 2: "a wall formed wholly of turf".

Figure 3: "a turf and stone wall".

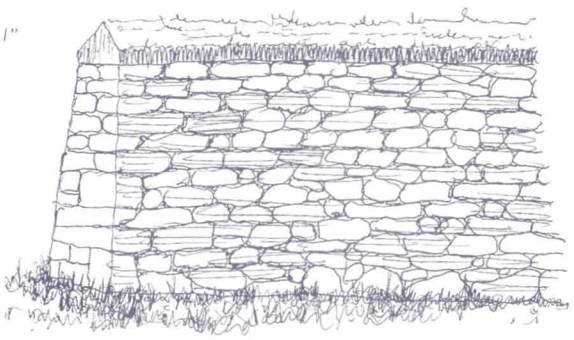
Figure 4: "a mud and straw wall".

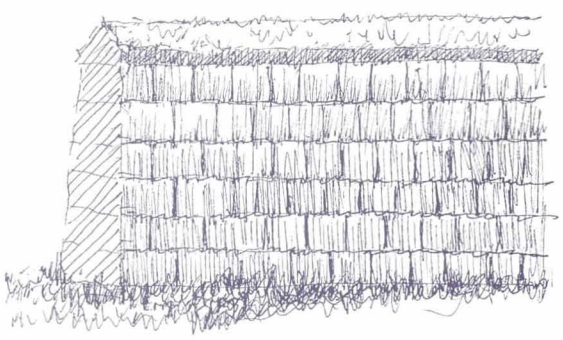
Figure 5: "a frame for constructing mud walls".

Figure 6: "a gallaway dyke or wall (appears to be part drystone and part irregularly placed turves".

Figure 7: "a simple dyke or ditch fence; the quicks are put in behind the earth thrown up, and protected by a dead hedge behind them" (no evidence of this in the section)."

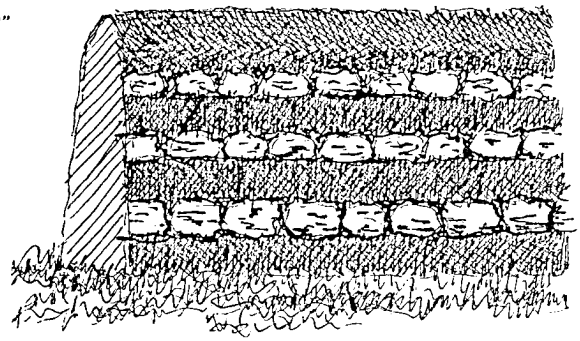
"Figure 1"



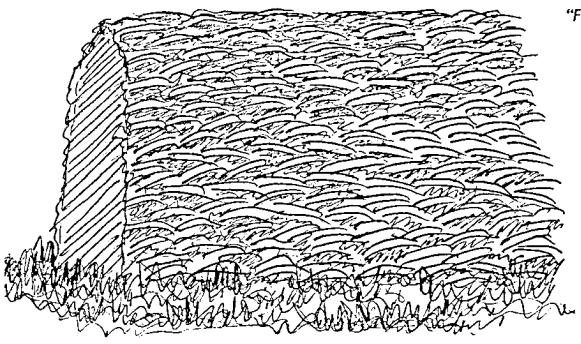


"Figure 2"

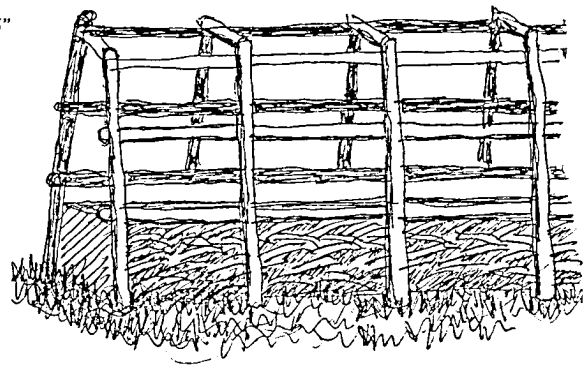
"Figure 3"



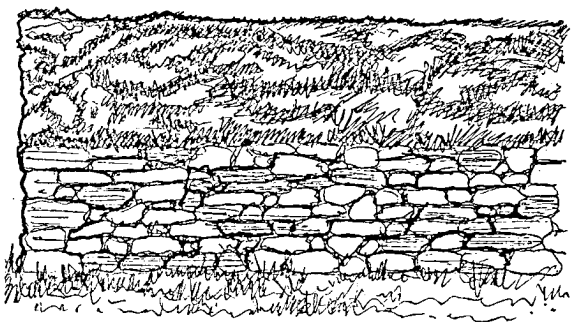
"Figure 4"



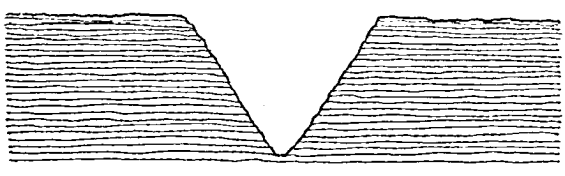
"Figure 5"



"Figure 6"



"Figure 7"



"Figure 8"

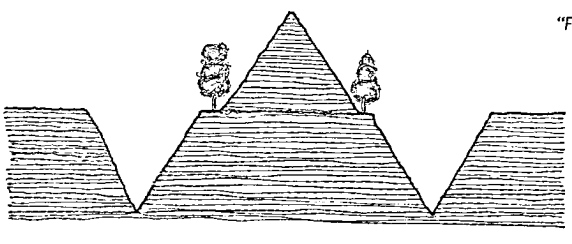


Figure 8: "a double ditch, the earth taken out being formed into a bank in the middle. Quickes may be planted on one or both sides of the banks according to circumstances, and protected by hedges when necessary."

Figure 9: "A sunk fence faced with stone. When faced with turf this sort of fence should have a slanting form."

"Figure 9"

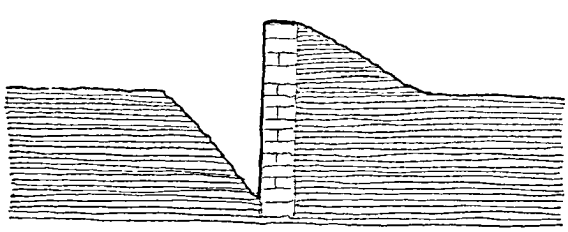


Figure 10: "A series of figures "representing the manner of forming earthen fences so as to prevent their crumbling down and being destroyed. It is recommended by Dr Anderson."

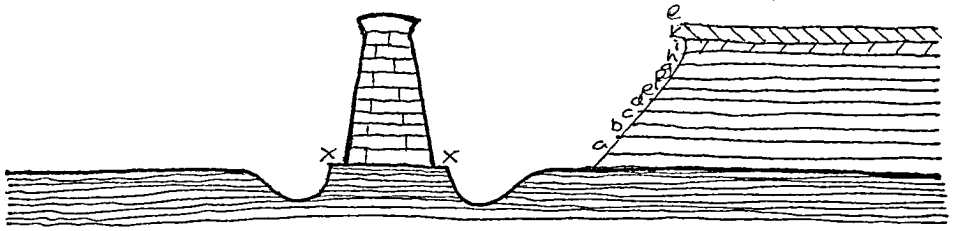
(i): "perpendicular section"

(ii): "side view"

(iii): "a perpendicular view of each row of turfs as it lies in the fence. The mode of construction is thus: a long rut xxxx is made with the spade along each side, with the back to where the fence is to be, so as to form the cut of the turf slanting outward; another rut az is then made parallel to the former, at the distance of the length of the turf a from it, with the face to the fence, so as to slope inward as at R. (iii) in order that the first row of

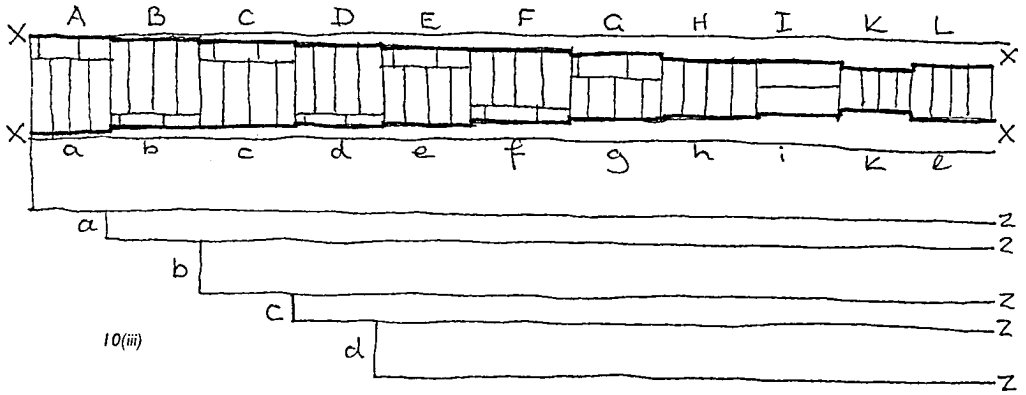
turf may be raised with facility; it is then cut into sods of proper breadth, as at dotted lines a, which being raised by the spade are laid into the fence with the grassy side undermost as at a (i, ii, iii): the other side being finished in the same way, the upper surface of the whole course is pared smooth, and clapped down with the back of the spade for the reception of the next course: another row of turf bz, is then marked off to the distance of the breadth of that at b, from the former, with the face towards the fence; and the through band turf B on the opposite side being first lightly laid, this is put across the ends of them lengthwise, so as to form a side band b; another rut cz is then formed at the distance of the length of turf e from the former; but before it is raised it is necessary to draw a rut in the line bz, with the back towards the fence, which gives it the form BAC(iv) leaving a small triangular piece at S; so that when put in the fence it was in the position shown at BAC, and thus permits the opposite side band O to join intimately with it, which should otherwise have projected outward above as to D, so that the turf O could not have joined it so closely, but have left a triangular opening in the middle, and thus rendered the fence less compact and solid. The work is to proceed in this manner, always rutting the through band rows of turf in both ends, but the side bands only on one side, beginning every course with those that cross the fence.

The top course should be cut a little longer than those below it, and placed with the grassy side uppermost, so as to protect a little, as at Ll(i) or, what is perhaps better, set on edge, as in (fig iv); as by this means the water is not only better thrown off, but the fence rendered more secure from cattle and the effects of wind. At the foot of the fence a ditch, as XX (fig i) should be dug on each side, a foot and a half or two feet deep, a ledgelet being left a few inches in breadth, to guard against the effects of crumbling, keep the foundation dry, and prevent the intrusion of cattle."



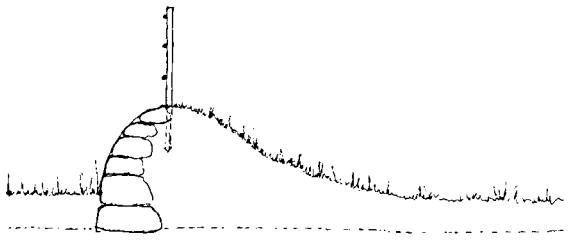
10(i) 10(ii)

"Figure 10"

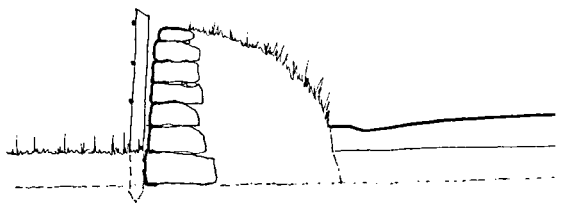


10(iii)

Cairnbulg Mains, Rathen, Aberdeenshire



Quithelhead, St Cyrus, Kincardineshire



3.14(ii) Stone facing to one side

Head-dikes to townships or dikes between fields and a public road are often constructed with a drystone face to the outside and a battered fale face to the field, the core of the dike being any of the materials listed in item 3.14(i).

The drystone face can be vertical, slightly battered or convex and thorn hedges can be planted along the crown.

This type of wall appears to have been known as a "half-dyke". Henry Hamilton includes a description from the Monymusk estate in "Life and Labour on an Aberdeenshire Estate 1735-1750". The agreement reads:

"July 6, 1741

Agreed with John Wright at Bridge of Ton to build a half dyke faced with stones and well backed up with earth to the top, so as the earth shall not fall from the stones and the stones and part of the earth covered on top with a flatt gang of fail laid lengthwise outward, and all the stones took from the inside of the fence and all stone yt 4 men can roll, to be brought to the dyke - of 7 quarters hight of stones, to goe from the north-west corner of Mains firr park in a straight line to the road to Tombeg, and from thence in a straight line to the corner of Glaice Parke, the whole to be completed against the 1st Novr. and to be well executed, under the penalty of £20 Scots; and all the good workmen of the parish to be admitted to a share of it - they being bound as above - for which I am to pay 2s. Scots per ell in length and to pay the same as every 40 ells is finished, or to pay the third of price, as 40 ells is finished at half height, which it must all be done, before any of it is caryed to the full height - and then begin to raise to the full height, where he begun first to the half of the height, so as the earth may have time to settle."

3.14(iii) Stone facing on two sides

Walls of this type are very similar to those described in item 3.14(i) but have drystone faces. The faces are almost always battered, possibly in an effort to avoid the type of damage described in item 3.06. Unfortunately, there has been no opportunity to section such a wall to establish whether the top surface is waterproofed.

3.14(iv) Dike and Ditch

Field boundaries often run on the line of the field drainage ditch, carrying away water from the underground drainage system.

The type of field boundary described below not only incorporates the ditch but provides an upstanding dike and hedge. It was constructed at Gallery in Angus and reported in a publication of 1762.

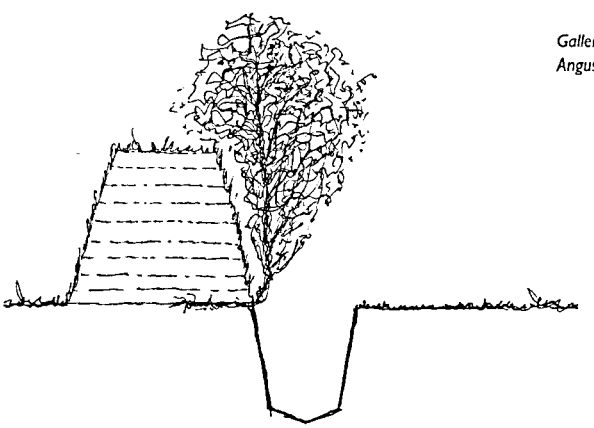
"..... at last I observed that nothing ate up or destroyed the Sweet Briar or Eglantine plants. So I set to work gathering the hips, and laid them in a tub until March; then the seeds rubbed easily out, and I sewed them in ground prepared for Garden pease ..... I got my crop of pease without prejudice to my briars, which came up the next year to be a foot high .....

I rooted out my ditch, and laid my plants upon the grass, under the first feal of the dike, with the tops out to the ditch, and about 18 inches distance. I laid the earth side of the feal on the roots of the briars, so when the dike and ditch are made the briars stand out towards the ditch at the foundation of the dike: They in four or five years, made a fence, that no sheep, black cattle, or horses can pass.

Mr Fullarton of Gallarie."

The depth of the ditch would obviously be governed by the depth of the field drainage - at that time probably surface drainage in the baulks of the runrig although some early rubble drains are known. It also has to take into account the need to reach a suitable outfall or soak-away.

Gallery, Logie Pert, Angus



3.14(v) River Embankments

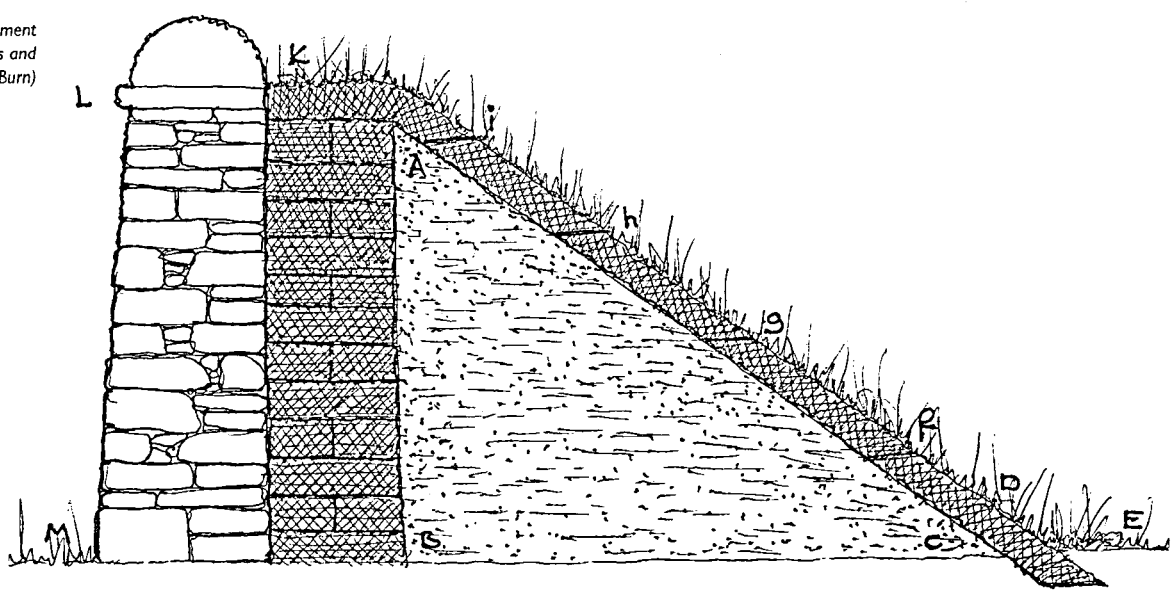
A variation of the single faced dyke can be used to restrain "the swollen water of a small rivulet. Henry Stephens describes a structure of this type.

"It is formed of turf derived from the rivers bank, and faced with a stone dyke to prevent its being injured by stock on the side of the field, where the dyke answers the purpose of an efficient fence. The line of the embankment should be marked off with pins, and the turf raised along the breadth of the ground to be occupied by the embankment. In raising the turf, that intended to cover the face of the embankment next the stream should be at least one foot square, unbroken, and tough; and if the river bank does not afford turf of this description, it must be obtained elsewhere, and brought to the spot. The turf to build the face-wall may be of any description possessing tenacity at all. The turf for the sloping bank should be cut with bevelled edges, so that each turf may overlap two lower turfs, with two of its edges - the one edge, the lowest, overlapping in the direction of the slope of the bank, the other overlapping in the direction of the flow of the water of the river. These circumstances settling the proper and relative position of the turfs, the embankment should begin to be constructed at the lowest point down the stream, and carried upwards; and it should also be begun at the water's edge and carried upward to the top of the slope.

Suppose the turf wall a b to be 4 feet in height, then a breadth of 5 feet from b to c being the base of the slope of the embankment may give sufficient stability to the structure, and slope to the face. The line b c, however, will vary according to the nature of the ground on the river-bank. In a steep part it may be less than 5 feet, in a gentle slope it will retain its proper length, and in a sudden and narrow hollow it may be necessary to fill up the hollow altogether, in order to make the bank uniformly even, in which case the slope may have to be built from the very edge of the water.

The first operation in the actual construction of the embankment is building the turf wall a b, the sods of which are laid with the grassy face downwards, on the same principle as breaking joints in masonry. As the wall proceeds, earth is taken from the field in spadefuls to pack behind it, and to fill up the entire contents of the embankment included within a b c. This earth should be free of stones, and if disposed to rise in lumps, should be chopped small with a spade, and beaten firmly with a wooden beater. After a sufficient quantity of earth has been placed behind the turf wall, the turfs of the slope c a are then begun to be laid on the lowest point c, where the first turf d, with the grass side upmost, is made to grip under and abut against the sward e of the river-bank by a notch cut out of the latter with a spade, the object of the notch being to plant the edge of the turf through the sward, to prevent the water getting hold of it and carrying it away. Another turf f is made to overlap with its lower edge the upper edge of turf d just laid, and the earth is brought behind it with a trowel or with the hand, to the shape of the slope c a. In like manner the turfs g h and i are laid one after the other, till the top of the turf wall b a, and the top of the slope c a, are reached at the same time, when a thick turf k, with the grass upmost, covers the top of the wall, and finishes the slope. When the turfs are cut square, and all of the same size, which they should scrupulously be, they are quickly and evenly laid. The whole of the turfs are then beaten firmly down with the back of the spade. It will be concluded from this description that the building of the turf wall should

River Embankment (after Stephens and Burn)



proceed in advance of the laying of the turf upon the slope. In conjunction with the turf work, the building of the stone dyke l m may proceed, and finish the whole embankment at once. Such a dyke as is here required is called the single-faced dyke, having only one finished face, towards the field, with broad projecting covers and a strong cope ...

Such an embankment should be constructed at as early a period of the season as possible, to give the turf time to grow together before the occurrence of the earliest flood. In a very dry summer the turf may become brown, when water should occasionally be thrown upon it, with a scoop from the rivulet; and in any kind of season it is possible that a turf will die here and there, when it should be removed and a fresh one substituted. Until the turfing becomes converted into a thick and tough sward, it should be frequently inspected, and every gap in it plugged up, whether occasioned by accident, such as the feet of cattle trespassing from the opposite side or the burrowing of animals, such as rabbits or water rats.

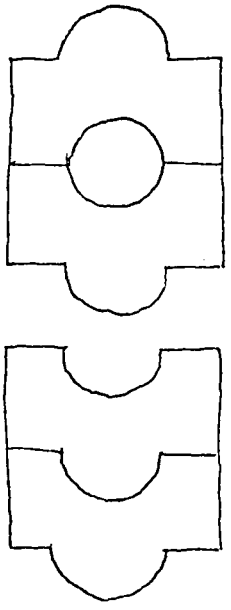
In the succeeding season the grass will grow luxuriantly upon the embankment, when it may be mown early in summer, to give it time to grow into a thick sward before winter. After this period the earth will become quite firm, and the embankment require nothing more than a general supervision every year."

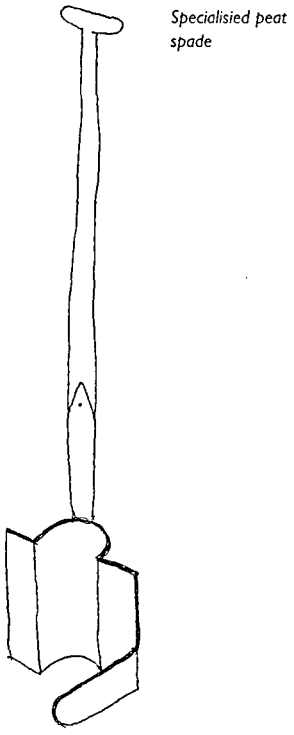
Stephens goes on to describe a double slope embankment incorporating a puddle wall to prevent leakage. This will be dealt with in item 6.02.

3.15 Peat drainage-pipes

Underground field drainage pipes were tried in the Stonehaven area in the mid nineteenth century. It is uncertain how successful the experiment was and how long the drainage tiles lasted but the Stonehaven Journal carried an ongoing dialogue in 1848. The theory had been expounded in Stephens' Book of the Farm but there was a problem with the design of the peat spade. The author of the Stonehaven Journal article had solved this but pointed out that it was essential that the peat was very solid and compact and free of twigs. Messrs Slight of Leith Walk, Edinburgh made spades on the improved principle and the Highland Society offered a premium for further practical information on the subject.

The process involved the use of a special peat spade, illustrated in Morton's Cyclopaedia of Agriculture to cut a square sectional block of peat with a semi circular groove in one side. Two blocks were placed together so that the grooves formed a pipe which was then laid as a drainage tile.





Remains of turf-walled click mill. Uig, Lewis

Åke Campbell

4

EARTH SHELTERED STRUCTURES

Earth sheltered structures can be subdivided into five distinct categories. These are: natural caves: tunnels: underground chambers, wells and cisterns: surface chambers that are completely earth covered: and surface chambers that are only partly earth sheltered.

The constructed structures range in age from prehistoric chambered tombs, through the medieval and renaissance periods to post-war structures such as command bunkers and nuclear weapon silos.

4.01 Natural Caves

Caves have been used for a range of human activities since man first settled in Scotland. Little can be done to conserve natural structures of this kind, but deposits on the floor can contain important archaeological information.

4.02 Tunnels

Tunnels have been constructed for a wide range of purposes. Early survivals are normally through bedrock and therefore present the same problems as natural caves.

Mine and countermine, St Andrews Castle, Fife

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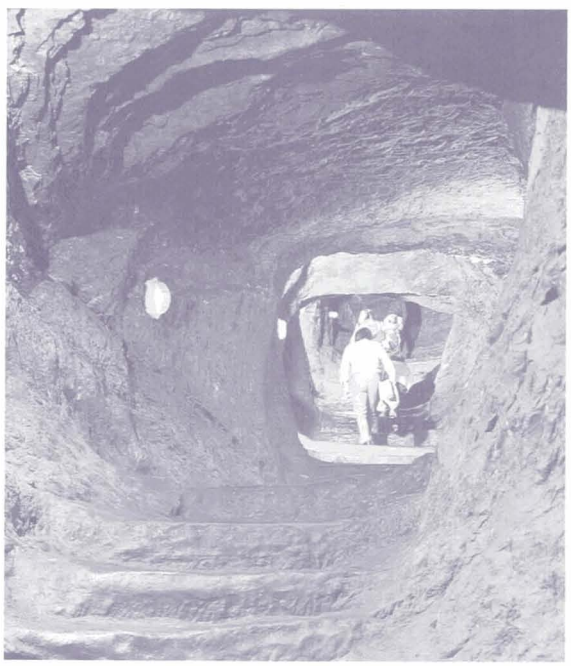

Built tunnels are normally protected from water penetration by a layer of puddled clay. This material was still in use until the mid-twentieth century when it was superseded by concrete and asphalt tanking. It is important that the role of the puddled clay is recognised when alteration or conservation works are undertaken.

4.03 Earth-covered Structures

Structures and buildings of all sizes have been covered with earth since the evolution of the first civilisations. In Scotland, some of the main reasons behind this practice included:

(i) making the underlying structure difficult to find

(ii) giving the structure additional protection

(iii) giving the structure additional prominence

(iv) providing insulation from either heat or cold

Sheiling hut, Lewis

Åke Campbell

(v) protecting a rigid structure from direct impact by absorbing shock.

(vi) providing a surface that will stop rather than ricochet missiles aimed at the structure.

Gun emplacements, Broughty Castle, Dundee

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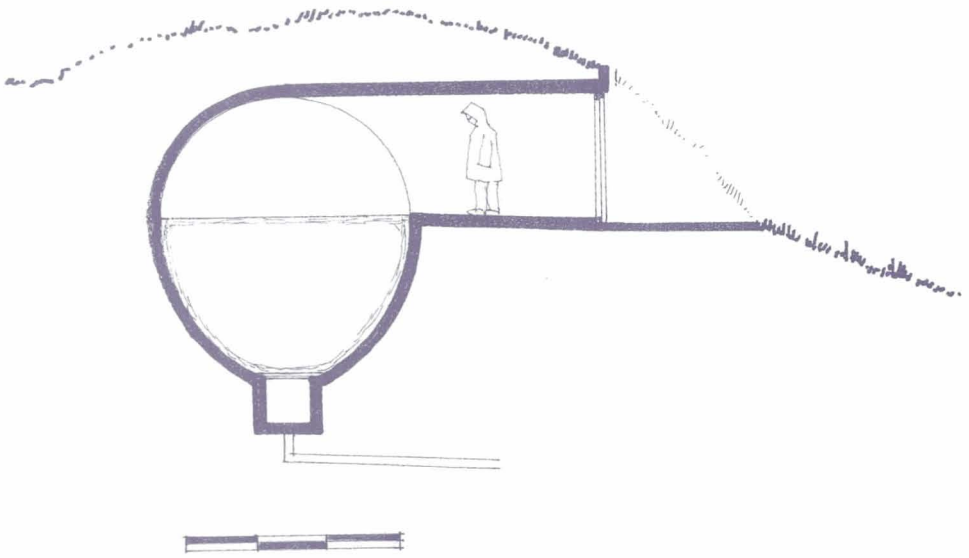
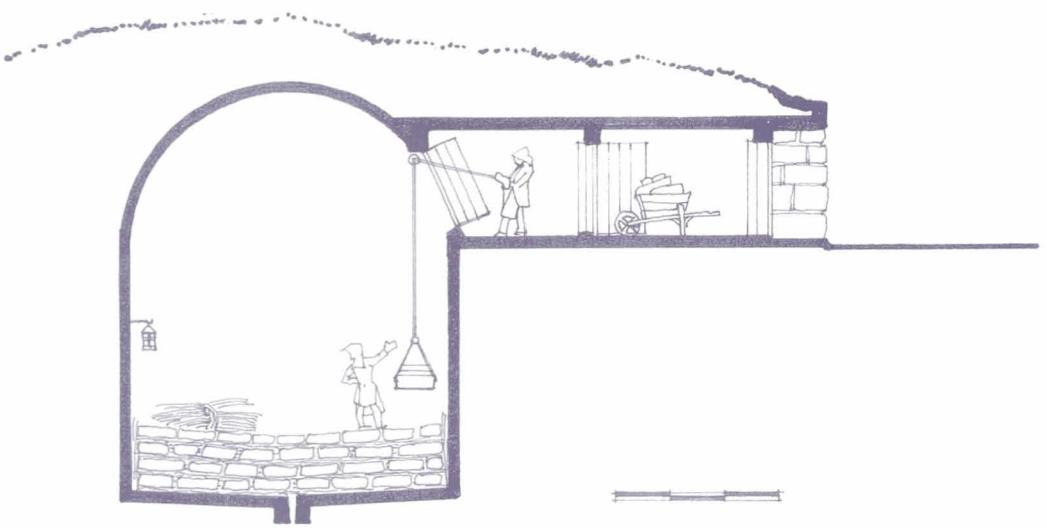
(vii) creating a specific microclimate.

It is not intended to develop these reasons in this publication, or to try to analyse all the methods used in covering each type of structure. The types of structure include: individual graves; chambered tombs; souterraines; underground storage including



Section through "cup & egg" domestic icehouse (17 century)

Icehouse, Dunrobin Castle, Golspie, Sutherland



Section through rectangular icehouse (19 century)

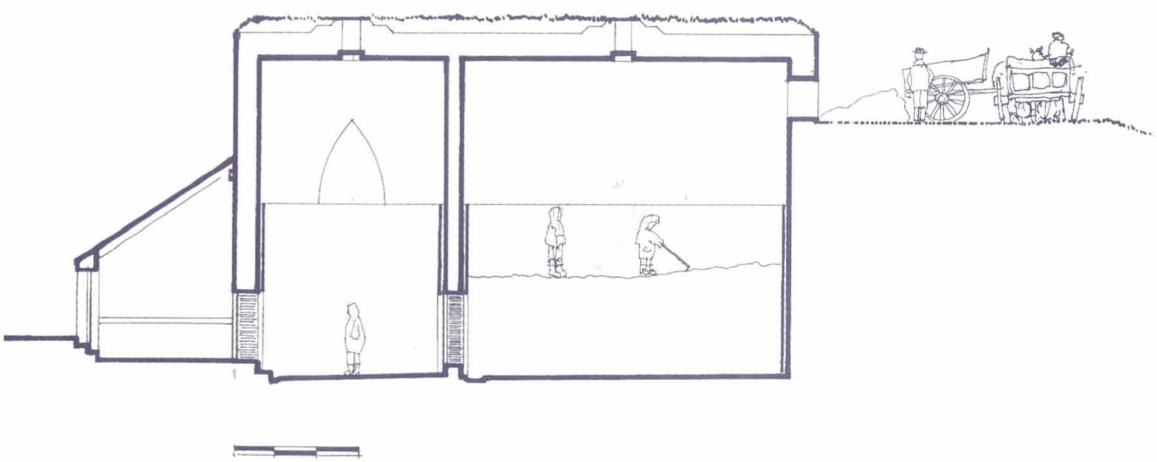
granaries and potato stores; semi-underground dwellings; ice-houses; game larders; dairies; rabbit warrens; defensive earthworks; foreworks for military installations including casemates, place of arms; glacis; gun emplacements; lunettes; pill-boxes; oil storage tanks; munitions stores, and warfare trenches; sand bagging; and command bunkers ranging in size from small units to strategic command installations.

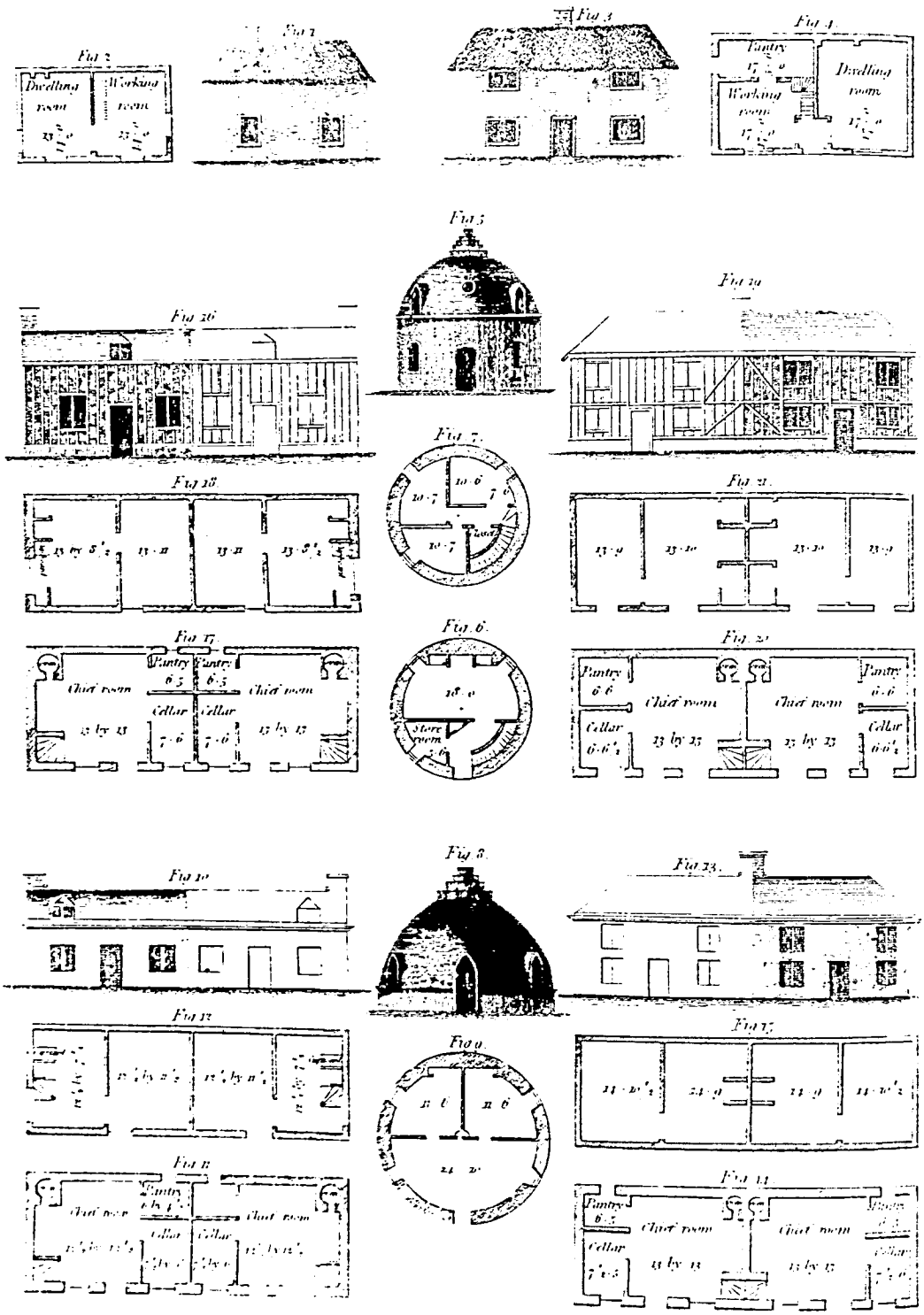
In almost every instance, apart from individual graves, some attempt is made to keep out water. The normal solution, prior to the twentieth century, is to use puddled clay as a waterproofing layer against the outer face of the structure. This is the case at early sites such as Maes Howe Chambered Tomb, Orkney; in large scale eighteenth century structures such as the casemates in the perimeter wall at Fort George, Ardersier, Inverness-shire; and in engineering works such as underground cisterns.

See section 6.00: Puddled Clay.

Icehouse, Cromarty, Ross-shire

Section through double chambered icehouse, Kinnaber, Angus




FARM COTTAGES.
Fig 1
Fig 2
Dwelling room
Working room
Fig 3
Fig 4
Pantry
Dwelling room
Working room
Fig 5
Fig 6
Store room
Fig 7
Fig 8
Fig 9
Fig 10
Fig 11
Pantry
Chief room
Cellar
Fig 12
Fig 13
Fig 14
Fig 15
Fig 16
Fig 17
Fig 18
Fig 19
Fig 20
Fig 21
Fig 22
Fig 23
Fig 24
Fig 25
Fig 26

5
TEMPERED EARTH STRUCTURES

Tempered earth is a blend of soil particles technically referred to as a loam but known to Scots builders as mortar. In some instances natural loams can be used for building but normally these are too free to bind effectively. To produce an ideal building material a binder, such as clay, is mixed with aggregate, such as sharp sand and gravel to form a blend that may be compressed into a cohesive material. Liquid is an essential part of this process but normally in small quantities, as the over-application of liquid can carry away the finer particles of clay and silt.

Other materials may also be added to the mix. These include straw, heather, broom, flax, hair, bristle and dung. The nature of these materials, their treatment and the proportions added to the mix depend entirely on local traditions. Hair and flax fibre provide obvious advantages in plasters and renders but it must be stressed that none of these additives are essential and many are not even desirable unless replicating existing techniques for conservation purposes.

A plate from R W Dickson's 1806 Practical Agriculture illustrates a typical range of inexpensive "pattern book" designs for Farm Cottages.

Figure 1: "a small mud-walled cheap cottage, the chambers being lighted from the ends."

Figure 2: "ground plan (figure 1)."

Figure 3: "cheap sort of cottage on a larger plan, built of cob dab."

Figure 4: "ground plan (figure 3). These are the cheapest sorts of cottages that can be built, and are from plans of Mr Crocker."

Figure 5: "circular cottage, recommended by Sir John Sinclair."

Figure 6: "ground plan (figure 5)."

Figure 7: "second floor (figure 5)."

Figure 8: "another cottage of the same sort, but without any second floor."

Figure 9: "ground plan (figure 8).

These are capable of being built wholly of brick at a small expense."

Figure 10: "plan and elevation of two small-sized bricked cottages."

Figure 11: "ground plan (figure 10)."

Figure 12: "chamber floor (figure 10)."Figure 13: "plan and elevation of two cottages of the same sort, but of a larger size and with hipped ends."

Figure 14: "ground plan (figure 13)."

Figure 15: "floor above (figure 13)."

Figure 16: "plan and elevation of two stud-work cottages, with brick gable ends."

Figure 17: "ground floor (figure 16)."

Figure 18: "floor above (figure 16)."

Figure 19: "plan and elevation of two cottages of the same kind, but of a larger size and with hipped ends."

Figure 20: "ground floor (figure 19)."

Figure 21: "chamber floor (figure 19).

These cottages are recommended by Mr Kent, as being capable of being built at a moderate expense, and as convenient and well adapted to farm purposes."

It may be argued that these designs were not adopted in Scotland but the Rossie Priory Estates in Perthshire and the Portland Estates in Sutherland are two that adopted half-timbered styles at this time.

Dickson discusses the merits of various building materials.

> "In regard to the materials for building cottages with, those will in general be found the least expensive that are nearest to the places where they are to be erected. Stone is a very good and substantial material, and frequently much cheaper than brick; but good cottages may be built with many other substances more cheaply than with either of them; such, for instance, as different compositions of well tempered earths. These, when well prepared, will stand a long time. Most of the strong loamy sorts of soil are found to answer these purposes; but where there is much sand, clay must be mixed with the earth till it has the proper degree of tenacity and consistence. Clay alone is not, however, suitable for this purpose, as it cannot be rammed sufficiently hard, and is of course liable to crack in drying. Earthy compositions for this use should always be capable of being closely united by means of a heavy rammer, made of cast-iron, as without this they have not sufficient stability."

Dickson is obviously referring to rammed-earth mixes such as pisé then goes on to show that he is also aware of the more traditional mudwall mixes.

> "A cheaper method is frequently followed, which is that of forming the walls of mire and

straw well trodden together and laid on in layers to the proper height."

Another method is described which has not been located to date.

"A strong earth, such as is proper for making bricks, is formed into walls of a suitable height and thickness; after which they are left for some time to dry, when different sorts of light combustible matters are placed round them, both on the inside and outside, and set on fire, by which means they are burnt into a kind of solid brick. The doors and windows are made afterwards by cutting them out of the solid walls, and the chimneys are built up of any suitable materials."

This sounds an inappropriate way to build an earth wall. The heat achieved is unlikely to fire the earth into a brick and the heat against recently built walls could well result in structural cracking.

A range of traditional mixes and techniques are described below. The properties of these materials are discussed in section 10.

5.01 Applied to Armature

The earliest use of tempered-earth mortars involves applying the material to an armature. The armature provided the structural strength and the mortar was applied as a filter to create a weatherproof coat. Armatures can take many forms, each with their own idiosyncrasies. Some of the more common forms are described below, giving the derivation of their Scots name to assist in interpreting old documents and descriptions. Although these descriptions are commonplace, it must be stressed that in conservation works, the model for any reinstatement should be taken from the remains of the existing structure, rather than from this document. Similarly, local techniques should always take precedent over techniques listed below. Detailed descriptions of individual techniques should be sent to TCRE, Historic Scotland for inclusion in further publications.

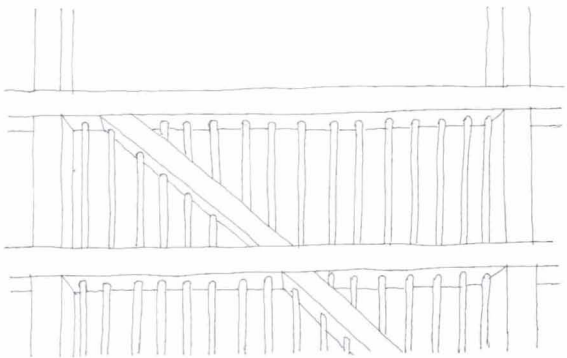
The Old Statistical Account describes eighteenth century Dundee.

"..... even in the middle of the century, when it had a population of 6,000, there was no shop

Timber clad house, Nethergate, Dundee

Lamb

High Street, Dundee, "Our Lady Warkstairs" is shown under the Old Steeple



Half-timbered armature

2. The materials of the houses on the west side of the Boatman's Close: also to be taken down for the said street."

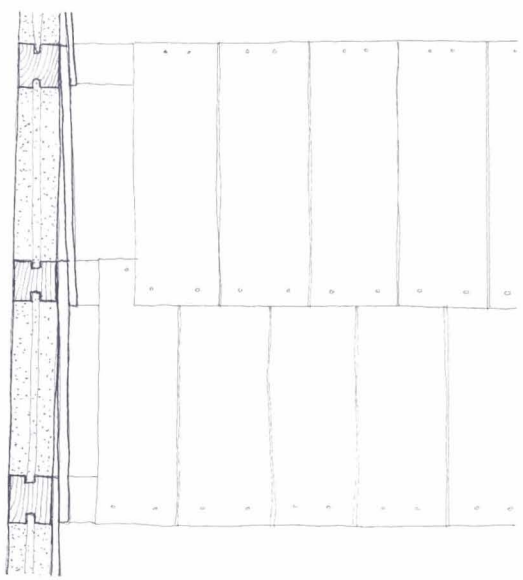
The street being formed was Union Street. By the third quarter of the century there were few wooden lands left. A wooden-land, at the extreme west end of the Overgate: built prior to 1513 was demolished in 1876. Our Lady Workstairs, near the centre of the burgh was the last of these timber-fronted houses remaining in its original form. It was built circa 1450 and on March 22, 1508 was described as "ye land of Will ye Barrie, callit ye Lady Wark". This building was demolished in 1879. Not all of the wooden-lands were demolished, some were encased in stonework

rented over £2 or £3 and it had not above four houses at the Cross completely built of stone, all the rest being partly wood."

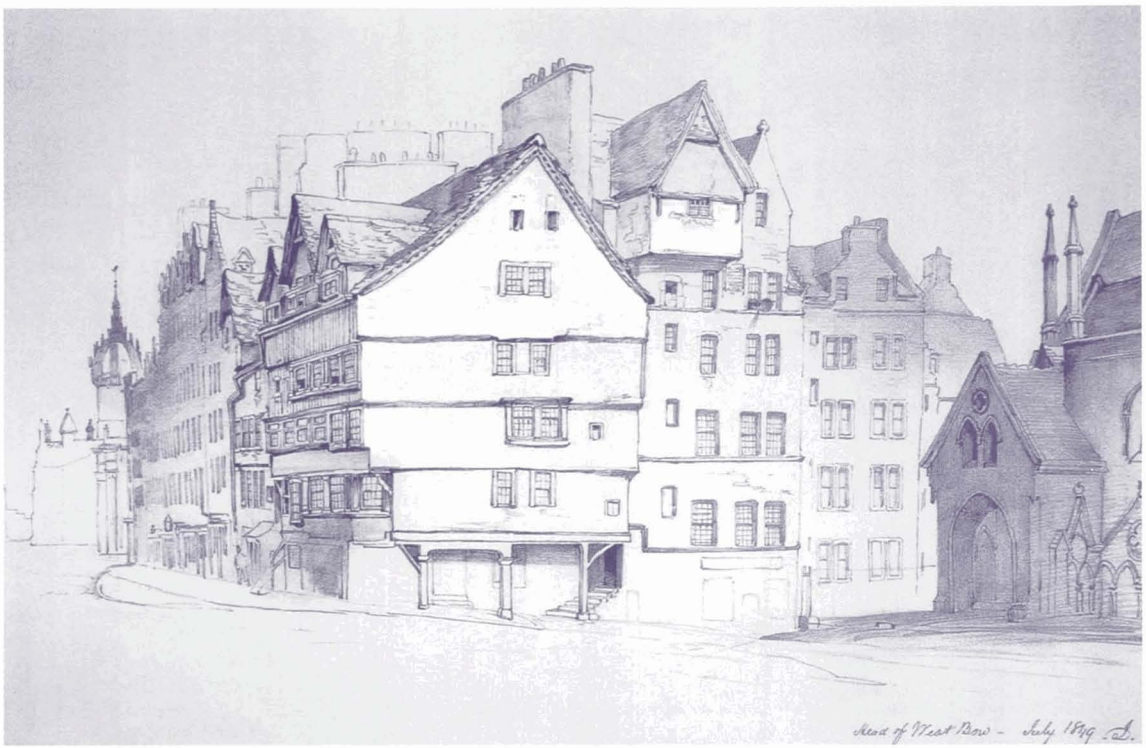
These timber framed buildings had clay infill-panels utilising a range of armatures on which the clay was applied. These buildings were being demolished in a systematic way throughout the nineteenth century and advertisements appear regularly in the local press offering materials or asking contractors to tender for the work. One such advertisement in the Dundee Advertiser of June 14, 1827 reads:

"To MASONS, WRIGHTS, ETC

1. The materials of the wooden house on the south side of the Nethergate, which is to be taken down, with a view to the proposed new street between the Nethergate and the Ferry Harbour.



Half-timbered armature, filled with mortar and clad with timber boards



Head of West Bow from Lawnmarket, Edinburgh, 1849 (James Drummond) - Plastered facade.

©RCAHMS

and fragments of timber frame can still be located in buildings on the north side of the High Street.

Other Scottish burghs followed similar patterns. The last known timber-fronted building in Scotland was Kinnoul Lodging in the Watergate, Perth demolished in 1966.

It must be stressed that this is a particularly important element in the history of Scottish building techniques. At one time most of the buildings in the Scottish burghs were of half-timbered construction although most of these had been demolished by the end of the nineteenth century. Visual evidence survives in prints and drawings and written evidence in descriptions and newspaper advertisements for their demolition.

Sir George Steuart Mackenzie gives a good description of a sheep cot, based on the construction of a Highland cottage. The reason for building these sheep cots was to protect ewes and their lambs from foxes and dogs. They were particularly common in Lochaber and Lochalsh and many survive in the form of hay barns.

> "Cots may be very easily and cheaply constructed after the manner of Highland cottages, where birch trees, or others having a natural bend, or branches of any large trees can be got. The framework is constructed as follows:-
>
> Two trees or large branches, are laid together, so that the distance between the thick ends may be 12 or 14 feet. The small ends are then morticed together and fastened with a wooden peg. About four feet below this a piece of

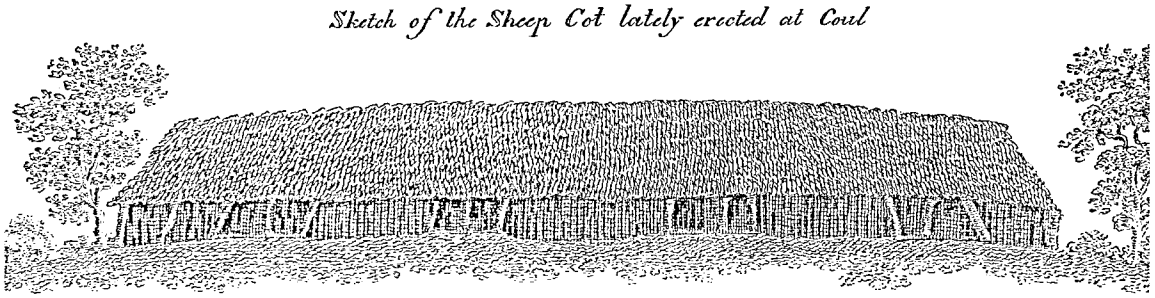
Head of West Bow from High Street, Edinburgh, 1849 (James Drummond) - Timber clad facade.

©RCAHMS

Drawing of Highland cottage converted to sheep-cot.

Elevation

Mackenzie



wood is laid across, mortised and fastened; the ends projecting about a foot on both sides. Small projecting pieces are also fixed at a height where the roof is to begin. These parts are now called couples, and when a sufficient number have been prepared, they are set up at the distance of ten feet from each other. They are now joined together at top by straight trees, being laid along into the forks made by the crossing of the ends of the couples. Similar pieces are laid along the sides resting on the projections, and the whole are fastened by means of pegs, similar to what ship carpenters call treenails. To form the roof, small straight trees, usually birch or Scotch firs, are laid across the rails, the thick ends being nailed to the lower-most rail. A rail is also fastened along the inside of the couples near the bottom. On this, and the lower roof rail are nailed spars, which are placed close together, but not so as to exclude a free circulation of air. In the front, spaces are left open at intervals. The thatch consists of heath, which is the most durable of all others. There is some art required in laying it on, although the operation appears to be very simple. The first layer consists of heath, having the thick roots cut off, and nicely arranged and fastened down by long pieces of wood tied with willow twigs to the framework. The heath is then laid on without regard to the roots, except having them inmost. The thatch is laid on thicker and thicker towards the top, where it is fastened by means of a thin sliced turf laid along. The whole is distinctly seen in the plate which represents the framework and the appearance of a cot which has been constructed as already described.

Moveable cots may be made, with frames filled with straw or heath, by means of wicker work; the sides being made of wickerwork alone."

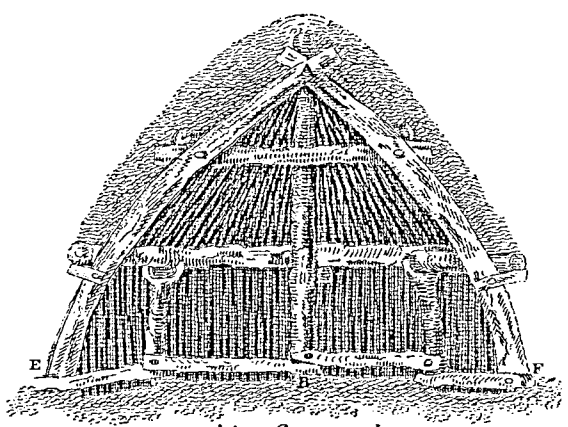
This was published in 1809 and is a more complete description of the type of building known as a creel-house, particularly when the "stake and rice", wattle or wickerwork internal skin was adopted. (See item 5.01(I)). Cottar houses used the internal skin as an armature to accept some form of earth finish. The framework described with vertical spars or cabers is known as "kebber and mott" (see item 5.01(ii) when mortar is applied to the face.

In the countryside armatures are generally considered to have been of these lighter materials, but there are exceptions and these are now beginning to be recognised.

Drawing of Highland cottage converted to sheep-cot.

Section

Mackenzie

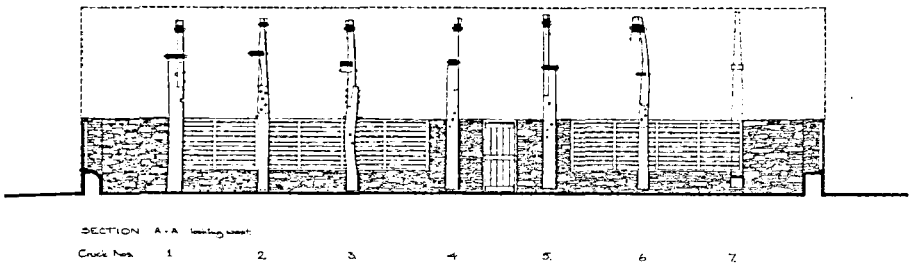


Inside of one end of the Cot

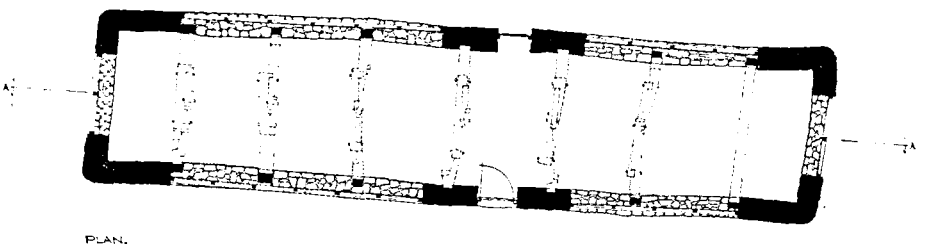
Southey describes the Generals Hut in which Wade is said to have lived:

"that is, where he had his headquarters while his troops were making the road from Fort George to Fort Augustus, is built of mud and straw within squares of wooden framing."

The "negative" of a house of this description still survives on south Loch Ness-side to the north-east of East Croach. The original building had been timber-framed but at some time in the past the infill had been removed and the timber frame encased in a mass concrete external wall. By the time the authors were notified of this interesting discovery a firm of woodworm eradicators had removed the deteriorating timber frames from the concrete walls. The timber must have been close to dust at this time



Sheep cot/barn, Fernaig, Lochalsh, Inverness-shire

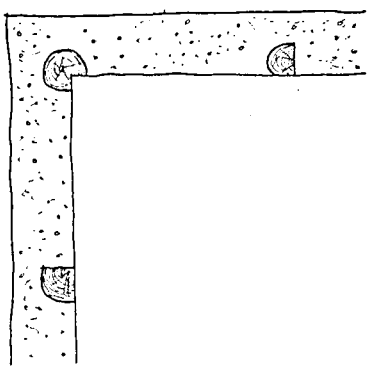


as the timbers were removed without damage to the concrete leaving a well defined imprint of the original timberwork. The imprint shows that the posts were widely spaced and correspond with Southey's description. The concrete walled building is obviously nineteenth century in construction and character but the evidence of the timber framing runs into the present basement showing that the building has been completely remodelled. Its position on the side of the military road makes it a strong contender to be the original General's Hut.

A similar structure has been located in the backlands of South High Street, Grantown- on-Spey, Inverness-shire near the crossing of two military roads. This building has been dismantled by GUARD for the Grantown-on-Spey Museum Trust who plan to re-erect it at their new museum site. Here the infill to the timber frame was lime-concrete.

The choice of armature has a bearing on the cost and performance of the completed wall. This is being confirmed by the initial results derived from the Earth Walls Experiment - see item 10.07.

Plan of corner of wall, East Croach, Daviot, Inverness-shire



5.01(i) Stake and Rice

Also known as "stab and rice", "stake and raip" and "wattle-work".

The name derives from the use of stakes, stabs or poles interwoven with rice, oziers, ropes or brushwood. ("Rice" derives from "hris" - the Old Norse word for brushwood.)

Stake and rice can form the main structural element of a wall or it can be used as an infill armature within the individual panels of a timber-framed wall. This is a time- consuming, and therefore costly form of construction that can be left exposed on one side as a decorative element, or can be completely encased in mortar. The firm interwoven base makes an ideal armature providing a good grip for the mortar. According to eighteenth century reporters, its use was widespread and provided not only the core or facing to walls, but support to thatched roofs, doors, gates, fences, hurdles, and in a finer form, normally referred to as basketwork; creels, and even furniture. Many of these applications are replaced with simpler armatures but stake and rice held its place as a material to provide the armature for large canopy chimneys.

There has been little opportunity to examine complete wattle structures in Scotland as demolition contractors do not normally take an archaeological interest in the material they are demolishing and most professionals are not on-site during demolition. Archaeological sites have provided most of the interesting findings to date, but it is unusual to find a stake and rice wall of any height in an archaeological excavation. Although a substantial stake and rice wall has been excavated recently, the analysis and report is not yet available.

Clachan on shores of Loch Duich, Lochalsh, Inverenss-shire showing partly rendered stake and rice wall, above row-boat

GWW-PC

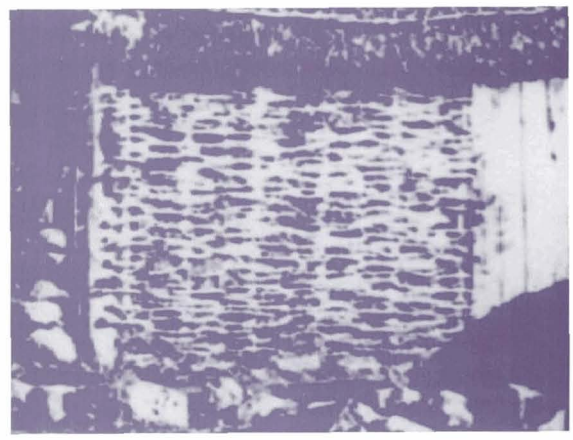
A report on a wattle structure excavated at Deer Park Farms, Co. Antrim, Northern Ireland gives some indication of the type of information that may be available. On this site the uprights are spaced at 20 cm centres and the wattle is cut to 2 metre lengths. The wattler starts at an upright with the end of the wattle to the inside face of the wall. The wattle is then passed out past two uprights and back in past two uprights alternately until the other end finishes on the inside face of the wall. This is repeated round the entire circular structure in a clockwise direction. A second and third course, each constructed as above are added but in each case the wattler starts one upright round in a clockwise direction from the original starting point. The process is then repeated for a further three courses but working in an anti clockwise direction. The wattler continues working three courses moving clockwise then three anticlockwise alternately until the top is reached. The vertical stakes can be extended by lapping the original stakes on one side using the already woven wattle to hold them in position.

Stake and rice is often formed with double, or even triple, oziers. If thin, these may be used whole but larger wands are normally split and used with the split side outwards.

Stake and rice can be used to form large canopy chimneys. These are normally plastered over with a tempered earth or clay-dung mix. The material can also be used to form continuous roadways over soft ground: the stakes running across the width and the rice running lengthwise along the roadway. A tempered earth surface can be applied to the road. Wattle can also be used to stabilise the sides of excavations, drainage ditches, soak-aways and other structures let into soil.

When used as an infill armature to timber framing, the stakes can be set in vertically or horizontally. Vertical stakes are let into a socket in the top member then dropped into a corresponding socket in the bottom member. Horizontal stakes are let into a socket at one side and swung down into an open-topped socket on the other.

When applying the mortar, it should be applied with force, in handfuls, simultaneously from either side of the wall. The mortar is finished flush with the outer faces of the timber frame using a Dutch float and a plasterers' float.



Detail of stake and rice panel above row-boat

Eassie Pictish cross-slab depicting decorative stake and rice panels, in single and double strand work.

5.01(ii) Cabers

A technique known as "kebber and mott" comprises an armature of parallel cabers almost touching at the base with mortar or mott pushed into one or both sides of the cabers and smoothed off with a float.

The cabers are normally set into the ground and continue upwards in the form of a palisade to the underside of the roof. Originally, this technique was used for all the walls of a building but the surviving examples are all internal walls.

This is a common technique in the Easter Ross and Laigh of Moray areas but variations using roughly squared timbers can be found in other parts of the country. One example in Avoch, Ross has roughly squared timbers, more widely spaced than normal and linked by horizontal straw ropes at 30-40 cm centres. Some of these ropes are fed through holes bored through the cabers. Others are tied round the timber. The wall in this case is finished with clay plaster.

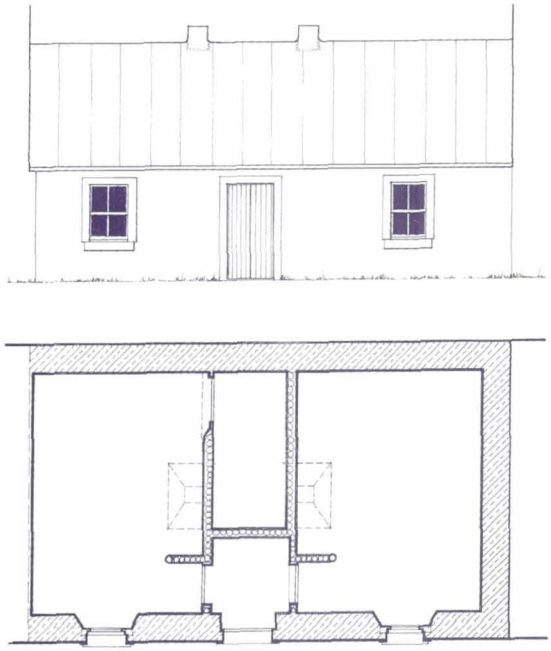
Another variant involves nailing or tying short lengths of thin cabers to horizontal rails set into a frame in the same way as described in item 5.01(i). This armature is treated and finished in the same way as stake and rice.

Perth, High Street. Double and triple strand stake and rice.

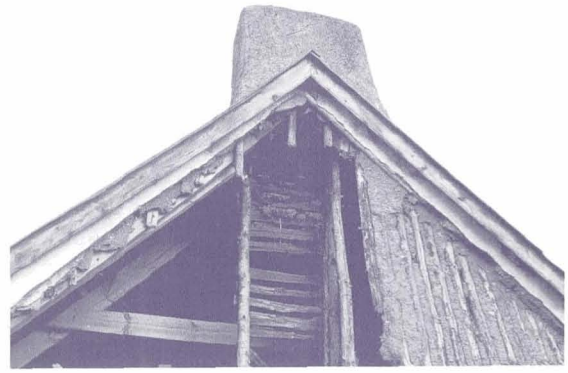
Hill of Fearn,. Ross-shire. Kebber and mott internal gablet - untreated side

High Street, Perth. Stake and rice roadway under Marks and Spencer site.

2 New Street, Shandwick, Ross-shire, showing internal kebber and mott partitions



Hill of Fearn, Ross-shire. Kebber and mott external gablet.



5.01(iii) Standards with Horizontal Rails

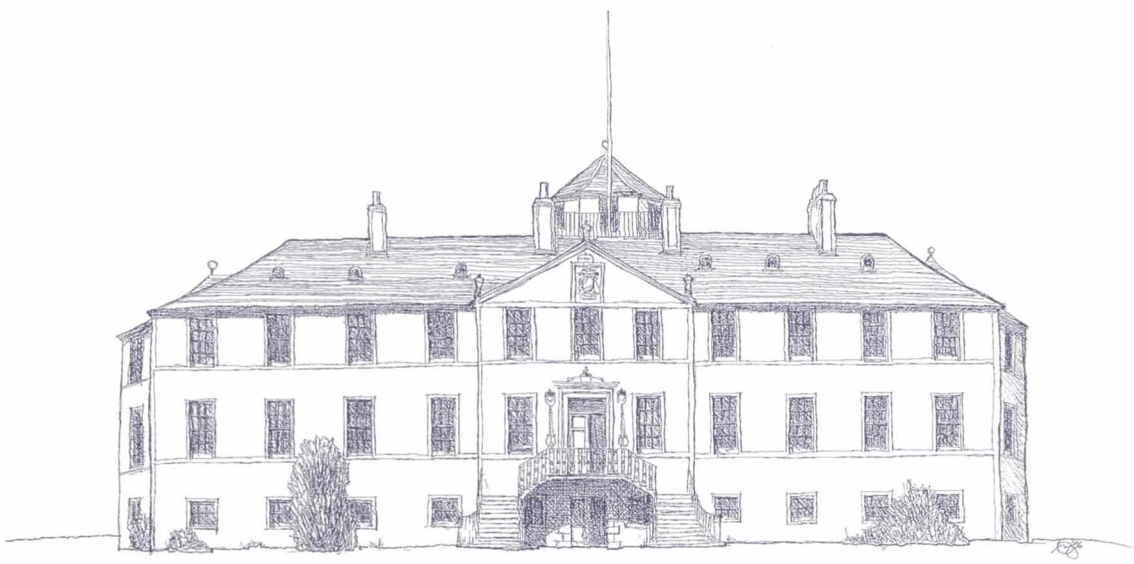
The oldest recorded version of this technique occurs in Foulis Castle, Evanton, and may well have been the external wall of the original towerhouse on this site. The timber standards in this case are 20 by 20cms in section with 2.5cm rails running horizontally through the standards at 30cm centres. The standards are continuous from floor to ceiling in the basement and from attic floor to the underside of the roof. The two intermediate floors are finished with seventeenth or early eighteenth century panelling and therefore cannot be investigated at present. The mortar is very hard and smooth and finished flush with the face of the standards. The surface has been scratched in a diagonal pattern to form a key for plaster.

Later standards are 10 by 5cms or 7.5 by 5cm and the horizontal rails are let into checks in the sides.

In both types, the application of mortar is difficult unless some form of shuttering is put up on one side. The mortar can then be thrown in with some force and beaten into position. The final finish on both sides is created by a float.

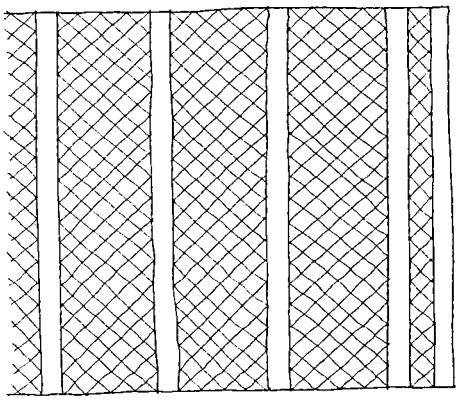
Shrinkage cracks may occur, approximating to the line of the rails, but as these are not discernible on many of the historic examples, it may be possible to prevent the cracks by adjusting the mortar mix. The cracks do not appear to jeopardise the stability of the wall and can possibly be filled without detriment to the wall - see Earth Structures Experiment, item 10.07.

Foulis Castle, Evanton, Ross-shire

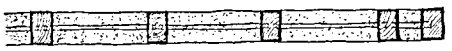


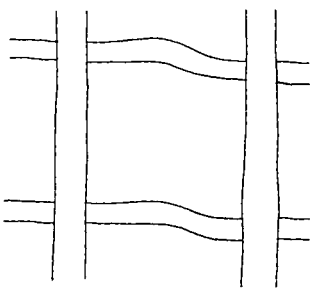
R W Dickson describes a similar wall but at a much later date and as a constructional method for cottages rather than towerhouses.

> "... sometimes a footing of stone or brick-wall is made about two feet in height, on which is placed a cill of strong timber, with upright quarterings at the distance of two feet, between which rounds of coarse wood are placed crosswise at the distance of five or six inches from each other, until the proper height; the spaces between the rounds are then filled with the composition of mire and straw, and the whole plastered with good mortar, which should afterwards be well rough-casted over: it adds also considerably to their neatness and general effect on the eye of the traveller, if they be well whitewashed ..."

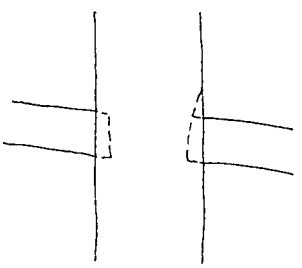


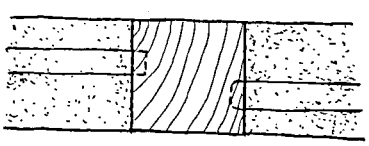
Foulis Castle, Evanton Ross-shire. Half-timbered wall



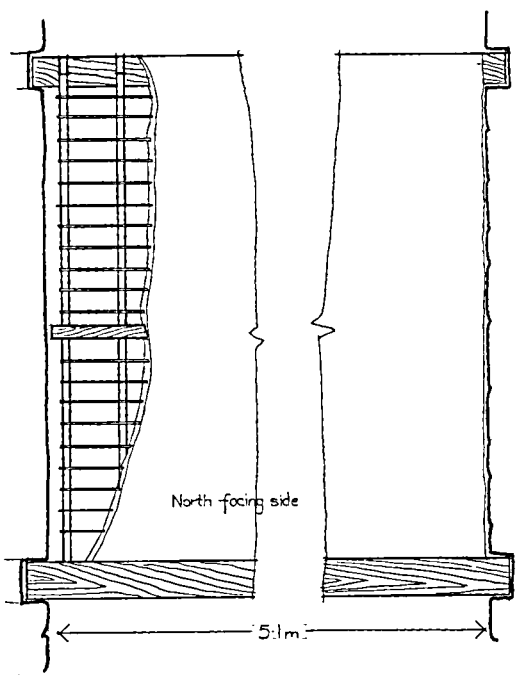


The Cross, Cupar, Fife, Standards with horizontal rails





Braikie Castle, Kinnell, Angus. Partition with straw rope armature

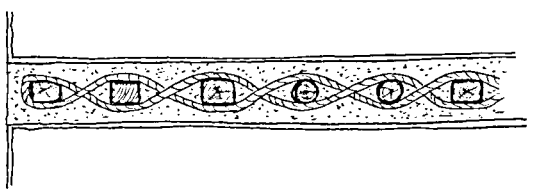


5.01(iv) Standards with Horizontal Ropes

This is an alternative to the above. In many cases the ropes pass through the standards and are knotted in a narrow space between two standards at the ends of the wall. Less commonly, the ropes are tied round the individual standards and the mortar is carried over the timber rather than finishing flush with the faces.

Using a flexible armature such as straw rope prevents shrinkage on the line of the rails as described in item 5.01(iii). Shrinkage with a flexible armature occurs round the perimeter of the panel making the shrinkage crack simple to caulk. The problems of filling the voids are similar to those in item 5.01(iii).

Maji Cottage, Avoch, Banffshire. Straw rope armature on caber partition



5.01(v) Straw-mat

A straw mat can be formed by weaving straw rope back and forward, usually between horizontal rails. It is essentially a variation on stake and rice but the proportion of armature to mortar is dramatically increased. In this technique the mortar is little more than a binding coat to a straw wall-core. The examples located to date are all internal walls in reputedly seventeenth - or early eighteenth century structures.

5.01(vi) Reeds

A layer of reeds sandwiched between two timber frames or between a timber frame and substantial strapping can be used as an armature. The technique is not common in Scotland but has been recorded in the Borders area. The reeds would have to be very hard and cane-like to withstand the impact of mortar being applied with force.

5.01(vii) Nogging

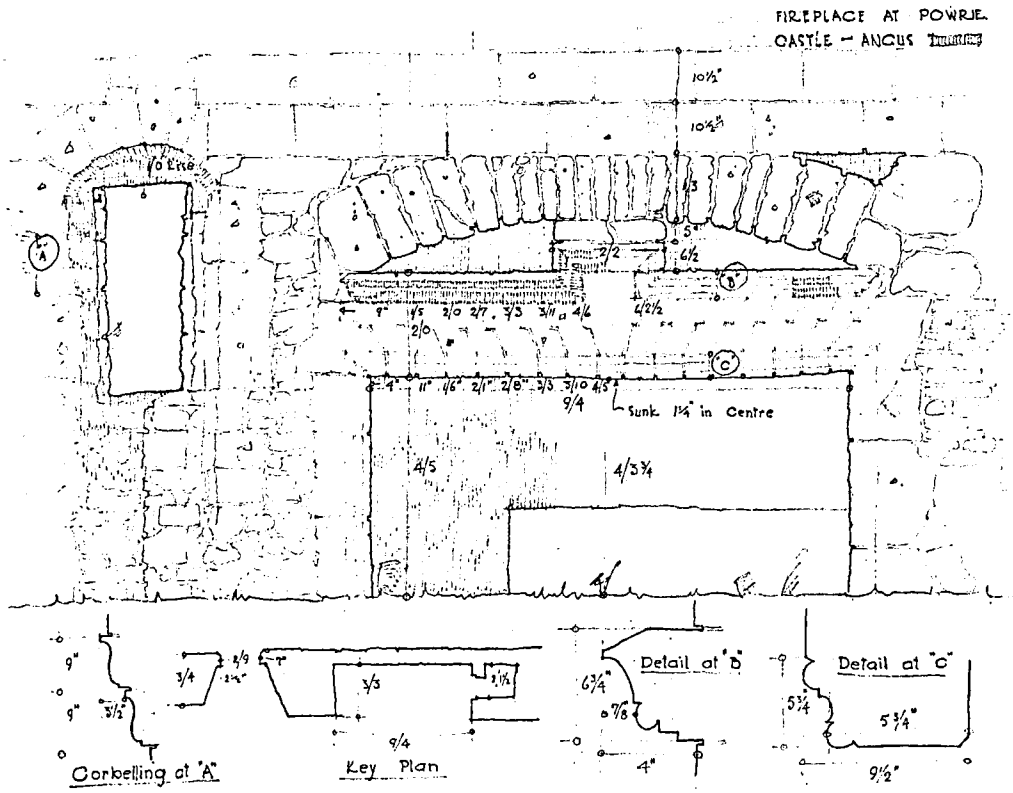
A nogging of small stones and mortar can be built within the panels of a timber frame. This technique is particularly common in the Western Isles where the frame is often extremely light. When forming the nogging it is necessary to use some form of temporary shutter on one side of the wall to help support the material until the mortar has set. Presumably the final finish is a clay plaster or lime wash. Unfortunately, all the examples examined to date have become visible by being exposed to the weather in semi-collapsed structures, but remnants of both these finishes have been recorded.

A description from Galashiels, dating from 1802, reads.

> "..... partitions of perpendicular standards of three-quarter inch deal - 4 inch board, set about three feet apart. A flat board (e.g. old door) is laid on as a shutter and the spaces filled up by a mason with small chips of stone and lime mortar.
>
> Every three feet up, a cross binder of wood is laid. The surface is finally smoothed with plaster lime."

Although this description refers to the use of lime, many of the recorded examples have been built using an earth mortar.

Internal gable with stone and mortar nogging - Argyll/Inverness-shire 1930s.



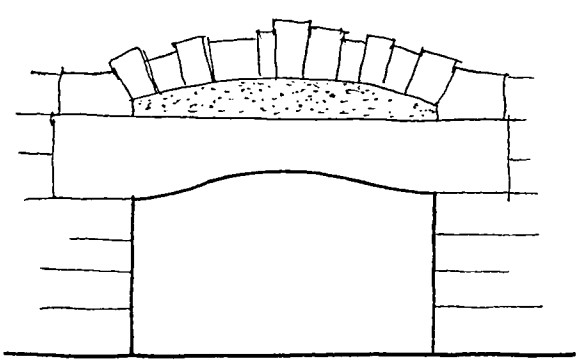
Powrie Castle, Mains, Angus. Space between relieving arch and lintel arch formerly filled with mortar

5.01(viii) Infill-panels in Masonry

Tempered earth infill panels are particularly common in the thin front walls of flues between a relieving arch or lintel and the arch or lintel it is protecting.

The use of tempered earth or mortar rather than masonry in this situation ensures that there is no direct pressure applied on the upper surface of the principal arch or lintel. When mortar is used it shrinks, leaving a tolerance that allows for some deflection of the relieving arch. If masonry is used, there may be some stone-to stone contact that might result in a pressure point on the principal arch or lintel, causing unsightly cracking or even failure. Fireplace lintels are particularly vulnerable to this type of damage owing to the thermal movement of the stone.

Cardoness Castle, Kirkudbrightshire

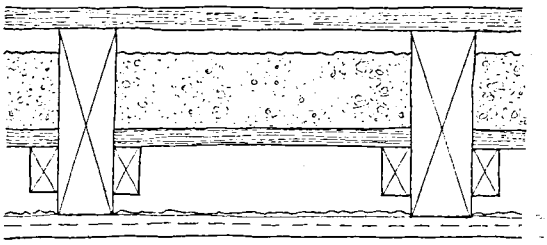


5.01(ix) Deafening

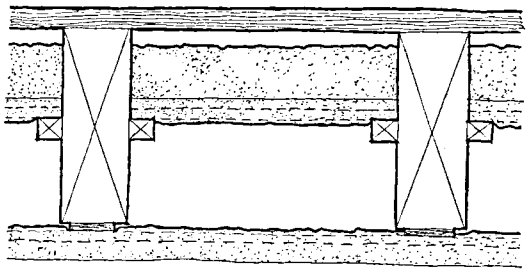
Tempered earth deafening is often provided between the joists of intermediate floors to reduce the amount of airborne sound passing through the floor.

As a general rule, the heavier the deafening material used, the greater is its efficiency and five to six centimetres of a heavy tempered earth mix is normally considered sufficient. Occasionally, the earth is tempered with cinders leaving more air spaces in the mix. This is usually increased in depth to maintain the weight whilst the air spaces increase the acoustic insulation.

The armatures carrying the mortar fill vary, but the commonest type comprises butt jointed sarking boards laid between timber grounds attached to the sides of the joists. At the now demolished Castle Carbet, Broughty Ferry, Angus, the late nineteenth century deafening was supported on plaster laid over loose timber laths supported on grounds attached to the sides of the joists and at Kirkside, St Cyrus, Kincardineshire, the mortar backs shallow brick arches springing from timber fillets attached to the side of the joists. This house dates from 1670 but the wing in which this construction is found is 1807 or earlier. The technique of using shallow brick arches springing from timber fillets attached to the side of joists or trimmers is illustrated by J C Loudon in 1832 in his Cottage, Farm and Villa Architecture. Louden describes the technique as a means of creating a hearth in a timber floored room.



Addison Place, Arbroath, Angus. Clay mortar deafening.



Carbet Castle, Broughty Ferry, Angus. Clay mortar deafening.

5.02 Construction Without Formwork

Mortar and other forms of stabilised earth walls can be constructed without the use of an armature or external formwork. In some cases the material is heaped on the foundation then tramped and beaten into the shape required. Other techniques involve pre-shaping the mortar before building the resultant blocks into the structure. In others the material is used to bind other bonded materials.

5.02(i) Mudwall

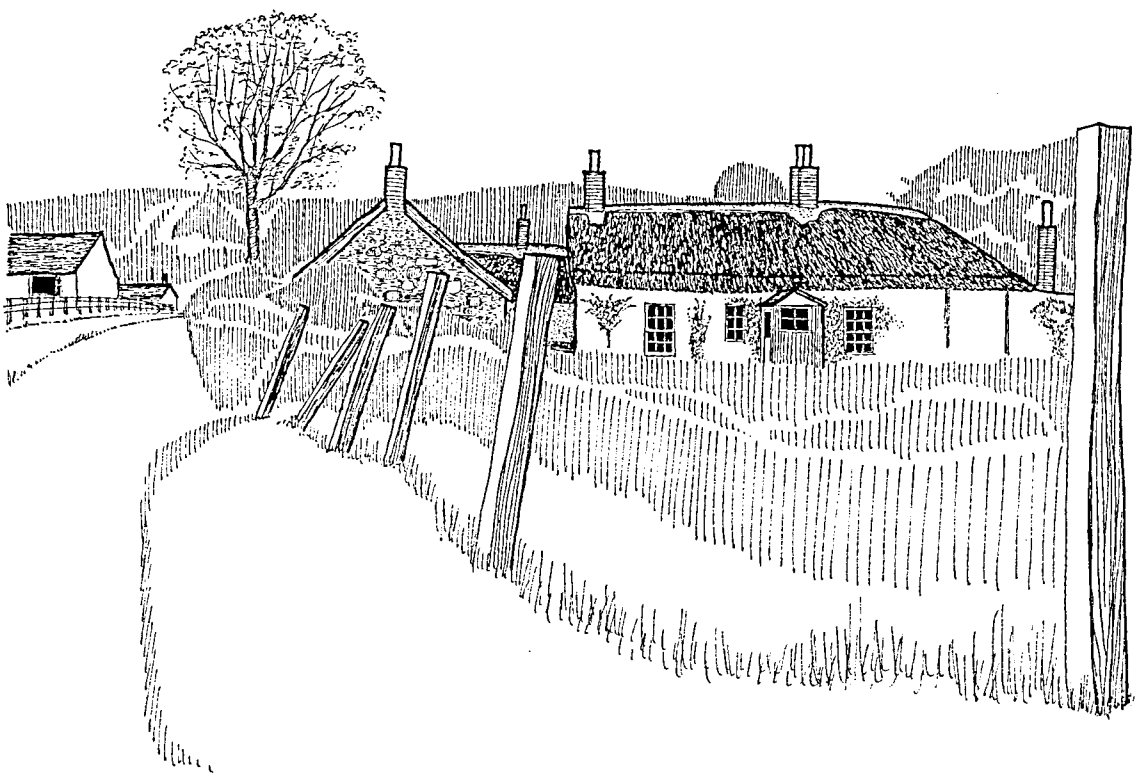
Mudwall in the commonest form of all mortar wall found in Scotland. Its use extends over half of the country from Dornoch in Sutherland through the coastal plain of Easter Ross, along the Laigh of Moray, through Banff, Buchan, Howe of the Mearns, Strathmore, Strathearn, Carse of Gowrie, Fife, Central Scotland to Berwickshire in the east and Dumfries and Galloway in the west. There are regional variations in the mix and the height of each lift but basically the method is similar throughout this vast region. In many respects the Dumfries and Galloway area is more closely linked with the mudwall techniques of Cumbria, Isle of Man and Ireland than with the rest of Scotland but more work is necessary to establish whether this represents a basic change of technique.

A direct comparison is possible through early nineteenth century correspondence between the Earl of Mansfield and his factors on the Dornock and Graitney Estates in Dumfries-shire and the Scone Palace Estates in Perthshire. The Earl had requested information on clay building and the factors replied as follows:

"My lord Scone 22 Sept. 1816.

I have made some enquiries into the method of building clay cottages as practiced in the Carse of Gowry which is, they first turn up a sufficient quantity of clay on the most

Cottown School and Schoolhouse, St Madoes, Perthshire.



Cowgate, Errol, Perthshire. Mudwall houses

convenient spot to the intended house - then straw is strewd on the top of it and three or four horses are yoked together and they trample it until the straw is broke to pieces and properly incorporated with the clay. It is then fitt for use - the walls are then raised with this mixture about 2 feet in height and then left for about 8 days (if dry weather) till it is sett and then 2 feet more is added and so on till the walls are completed -"

J. Cattell."

"My lord Scone 14 April 1817

As it will soon be a good season of the year to put up the Clay Cottages I would be glad to know if your Lordship has determined to have two put up at the Lodges -

James Cattell."

"My lord Scone 16 May 1817

On the other side I have shown a sketch of the lodges ... I think your lordship will not build them with clay on account of the expense. The outer walls on this plan will contain about 57 square yards of building about 2 feet thick. I have got an estimate for building them in Clay the lowest price of which is £8 which is more than I could get them done for in good stonework .....

James Cattell."

"My lord

Clay Cottages,

There is no instance of these being built by estimate or contract in this country -. When a person intends to build he procures a quantity of Common Clay, according to the thickness of the walls, which are various, and works it repeatedly with water into a good mortar, in which state it is generally allowed to lay until it gets more consistency. A quantity of tough oat, or barley straw (wheat straw is not found to answer the purpose) or sometimes fine heath, more or less according to fancy, is then provided, to mix with the clay in building. The foundation being cleared, and sometimes built

High Street, Errol, Perthshire. Mudwall houses

or laid with stones - the frame of the door is fixed in its position, and the above materials in readiness -. The whole neighbours assemble, in very great numbers to assist in putting up the walls, which is often the work of a few hours only - some mixing the straw and mortar for use with such water as may be necessary - some carrying - some laying the mortar, so mixed, in a rough manner on the walls, and others dressing or trimming these etc. - all of which is done with a common byre greap, or three pronged fork, and it is surprising to see with what neatness. In Building - The windows are paid no attention to, only the wooden lintels are laid at their proper places, and when the walls are sufficient dry, the window spaces are cut out below them. If the materials are not of sufficient consistency to admit of the work being done in a day, the people assemble from time to time until the whole be finished; and in general the high end walls are left undone until the walls below be thought sufficiently dry to carry these.

> The carpenter here is of the opinion that a Clay Cottage with Home Wood and Thatched Roof might be built for little more than £30 and with a coarse slated roof for about £40 but I have been waiting other estimates from the neighbourhood of Carlisle where these cottages are more frequent ...., Joseph Smith."
>
> Comlongon Castle, 19th Sept. 1810.

Both factors recognise that the technique depended on community effort but failed to report on the party atmosphere that prevailed. The Old Statistical Account for the parish of Dornock, Dumfriesshire gives a similar account to Joseph Smith but adds:

> "Upon a day appointed the whole neighbourhood, male and female, to the number of 20 or 30 assemble, each with a dung fork, a spade or some such implement. Some fall to working the clay or mud, by mixing it with straw, others carry the materials; and 4 or 6 of the most experienced hands, build and take care of the walls. In this manner the walls of the house are finished in a few hours; after which they retire

Leetown, Errol, Perthshire.

Mudwall houses and byres

> to a good dinner and plenty of drink which is provided for them, where they have music and a dance, with which, and other marks of festivity they conclude the evening. This is called a daubing; and in this manner they make a frolic of what would otherwise be a very dirty and disagreeable job."

Similar descriptions exist for other areas of the country but the main differences between the techniques used in Dornock, Dumfries-shire and other areas of Scotland are: the amount of water used in the initial mix and the height of the lift. In Dumfries-shire the lift is between 15 and 20 cm. In the Carse of Gowrie, Perthshire the lift is 60 cm. These are the two extremes but 45 to 55 cm is normal. Mudwall is usually 55 to 60 cm thick at the base of the wall.

Errol, in the Carse of Gowrie, Perthshire is the centre of a mudwall tradition. In 1792 the village of Errol is described as expanding.

> "As there is no stone in the neighbourhood, the buildings are mostly built of clay, and huddled together without much order or regularity. Excepting gentlemen's seats, all the old buildings in the parish are of that substance, which, when properly cemented, is rekoned the warmest and most durable of any; and there are some fabrics of it still in tolerable repair, the date of which cannot be ascertained.
>
> In forming such edifices, every man is his own mason, raising them by times, and putting on one layer as the other is condensated .....
>
> It is thought that the people have now in some measure, lost the art of preparing the materials, and compacting them together, so as to give the clay houses the solidity they had in past times.
>
> They are however, adopting a plan of building much more agreeable to the eye ..... moulding the mortar into bricks, and with these forming their dwellings."

A century earlier at Foveran Manse, Aberdeenshire contractors appear to have been used to build mudwall. A description of 1714 refers to one part of the house as the "mudd house" or "mudd hall" and as being roofed with 4,000 divets. Part of the account for work carried out reads:

> "Are accompt of muddwork:

Ardgaith, Errol, Perthshire.

Mudwall houses.

> The mudd hall - a rood and a half of muddwork at 6 pound the rood, 4 pound for halling and leading of it, and 4 pound for straw, and 4 pound for working on it _____ 21 lib:
>
> The brewhouse - half a rood of mudd; the stable - a quarter of a rood of muddwork; half a quarter of a rood in the head of barn."

This description refers to repairs to an old building. In 1727 further repairs were required and by 1751 part of the old hall had fallen and a new manse had been proposed.

A description of Garmouth, Moray by Sir Thomas Dick Lauder describing the floods of 1829 states:

> "The populous village of Garmouth stands above a quarter of a mile above the embouchure of the Spey, occupying the base and slope of a gently rising ground. It consists of several winding streets. The houses, many of them three storeys high, are built of clay, kneaded up with straw, in a frame as practiced in the south of France, at Roanne, for example, the whole of which town is of these materials. Here they are plastered or roughcast with lime, so as to present an extremely good exterior."

It is not certain whether Lauder is describing a half-timber technique or a form of shuttering when he refers to a "frame" but the 1811 description below, and a continuation of the Lauder description referring to the adjoining burgh of Kingston, suggests a mudwall technique.

> "Kingston ..... has its name from the historical fact that Charles II landed there from Holland in 1650. Many still alive remember to have seen the house entire (where Charles II dined). It was two storeys high, built like the others, of clay and straw, with an outside stair, and contained three rooms and a kitchen. The upper apartments were panelled all round. Part of the gable is still standing 16½ feet wide and 5 feet high ..... The premises are the property of John Geddes, wright, and are styled in his titles: "The Laird's Loft". The lairds of Innes were superiors of the village."

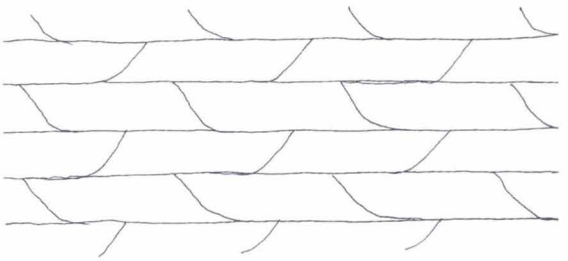
A report to the Board of Agriculture, published in 1811, states:

> "The village contains several neat houses, though the greater part of the buildings are composed entirely of clay made into mortar with straw, in some cases having a foot or two from the

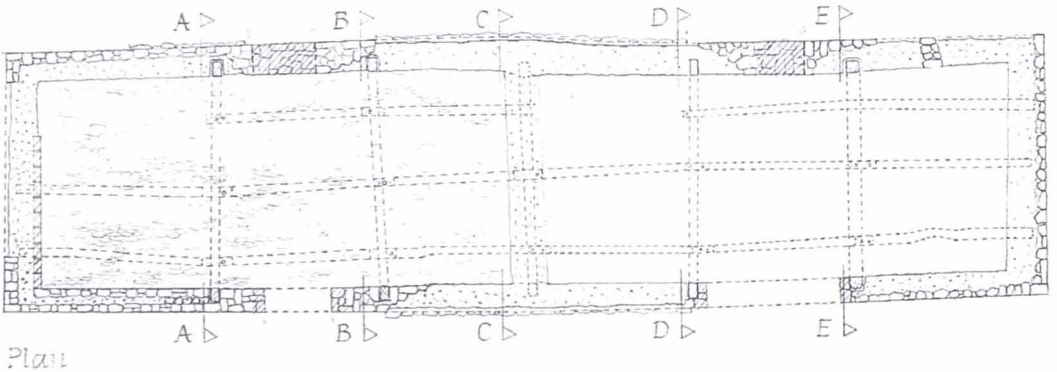
Mudwall house, Canonbie, Dumfriesshire

©RCAHMS

foundations built of stone. In the execution it is necessary to suspend the work a little on the addition of every yard of height, that it may not warp from the perpendicular: with this precaution it is raised to the height of two storeys, bears a slated roof, and is neatly completed within. If sufficiently covered on top, it is equally durable, the more impervious to wind and damp, and when daubed over on the outside with lime mortar it appears equally handsome, as a wall of stone in the common fashion."



Dumfriesshire style mudwall



Mudwall house, Canonbie, Dumfriesshire (Plan)

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Mudwall house, Canonbie, Dumfriesshire

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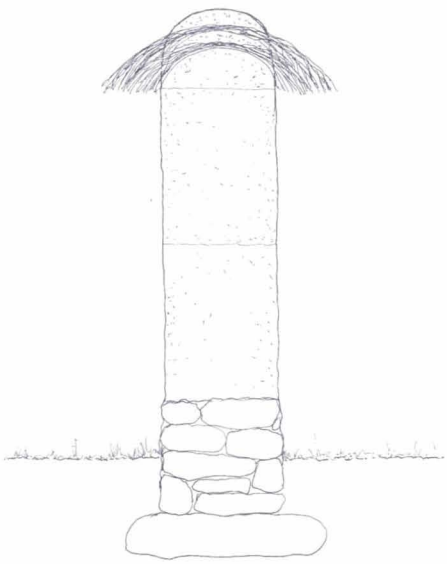
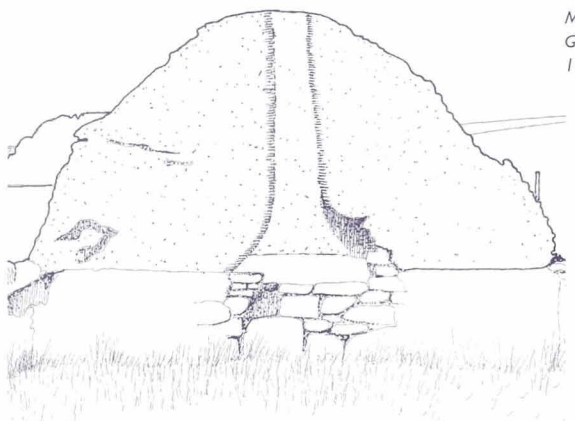
Mudwall boundary wall, Normandy, France



Mudwall gable, Gamrie, Banffshire. 1974



Mudwall house, Canonbie, Dumfriesshire (Sections)

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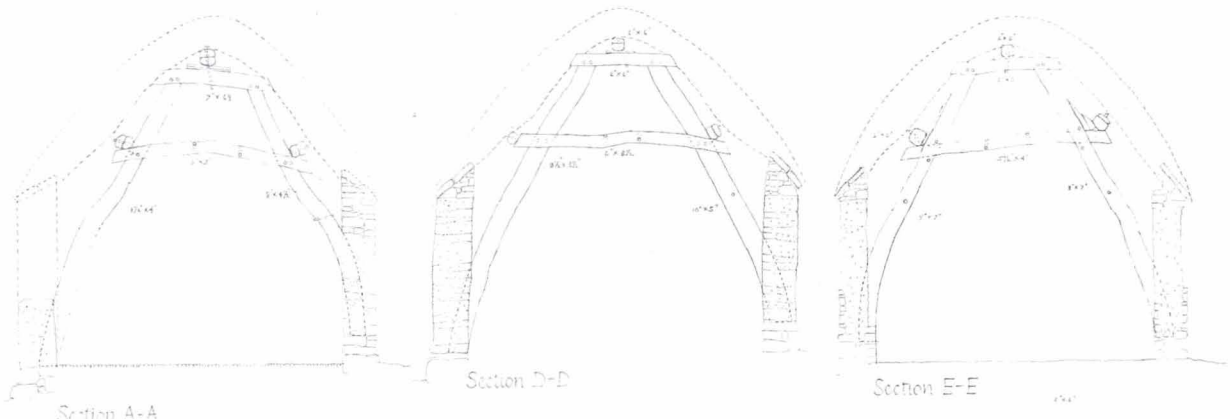
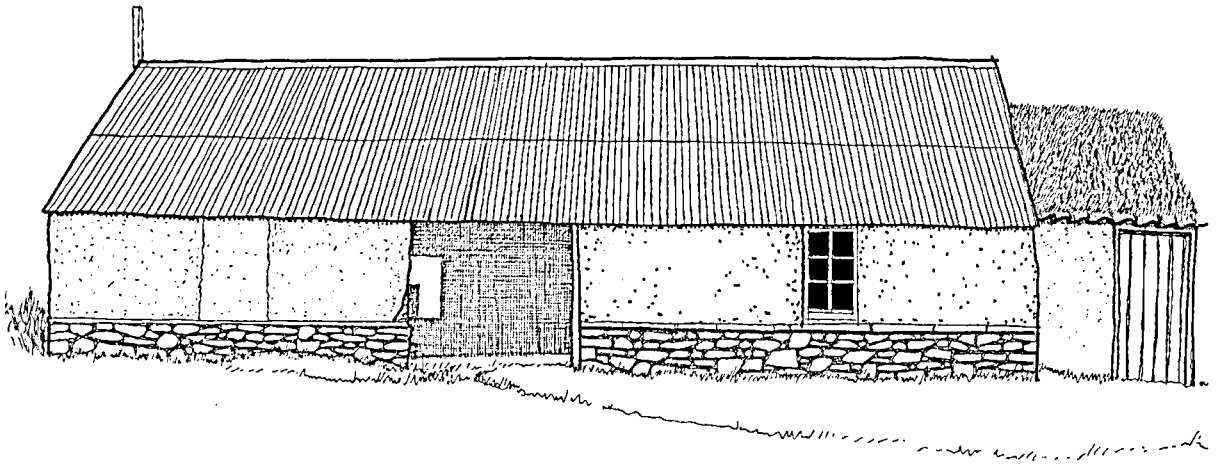
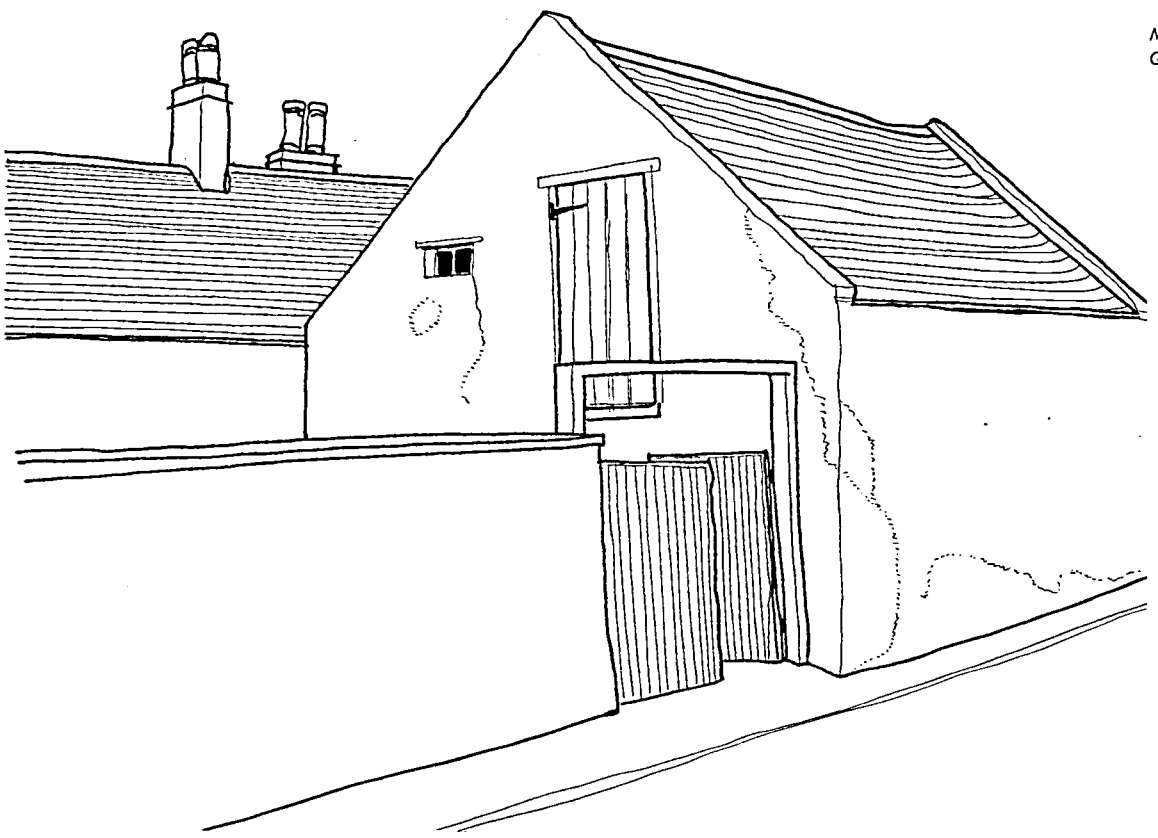




Heather mudwall house, Rathven, Banffshire



Mudwall byre, Garmouth, Moray

Mudwall/claywall houses, Inverness

Mudwall house, Bisset's Close, Inverness

Mudwall (some masonry faced) building, Westown, Errol, Perthshire (now demolished)

5.02(ii) Masonry Faced Mudwall

Masonry faced mudwall, erected without shuttering, is mainly found in the Hebrides. The outer skin is drystone and is erected as the core is filled. The mudwall comprises a mix of blue clay, soil, peat dust and peat ash and the wallhead is sealed with 15 cm of blue clay topped with green turf.

See Historic Scotland TAN 5: The Hebridean Blackhouse: A Guide to Materials, Construction and Maintenance.

5.02(iii) Brick Faced Mudwall

Brick skins are occasionally applied to existing mudwall structures. This practice is recorded as early as the mid-eighteenth century a well known example being Burns Cottage, Alloway, Ayrshire.

Usually the walls are a single brick-width thick, in current terms a half-brick wall. Ties are rather infrequent and are usually purpose-made by a local blacksmith. The resulting irregular cavity between the mudwall and the brick may be left or filled with mortar as the work proceeds.

When investigating walls of this type it must be remembered that brick is often used as a permanent shuttering for both mudwall and pisé. This is discussed in item 5.03(v).

5.02(iv) Clay Block (Adobe)

Clay block construction is not common in Scotland and therefore there is no Scottish terminology for the technique. Generally the Spanish term "Adobe" is the most commonly used but the technique is also known as "clay lump" in parts of England.

The reason for including clay block in this Advice Note is that it makes an excellent conservation technique for all types of mass mortar walls. The mortar is mixed to suit the type of wall to be repaired and formed into blocks. The size of the blocks can be tailored to suit the type of repair to be undertaken but generally blocks of the same dimensions as standard concrete blocks are good for large areas of repair and blocks similar in size to eighteenth century bricks are ideal for small repairs.

Using clay blocks in this way allows the mortar mix to be pre-shrunk prior to being built into the wall. This is particularly important when the repairs are at the base or in the middle of a wall as shrinkage of the new material would leave the wall unstable.

The blocks are easily cut with a small mattock designed for use with one hand whilst the other holds the block.

The mortar used is similar to that used in making the block but omitting any large aggregate or long

lengths of vegetable material. The surface being patched and the blocks are both wetted prior to applying the binding mortar. Mortar joints should be kept in tight as possible again to eliminate or reduce shrinkage.

Clay blocks that are to be used as ties across structural cracks or between materials should have a tough fibrous material in the mix. Flax has been found to give clay blocks the tensile strength required for this purpose but other materials such as hair or man-made fibre can also be used.

Farming encyclopaedias in general circulation in Scotland describe how to make clay lumps - the English version of adobe.

Loudon quotes John Curtis of Rougham as follows:

> "Three loads of soft tender clay, which should be yellow, not blue, the latter being too strong, will make one hundred lumps; which, when dry, will weigh six stones, of fourteen pounds each. The three loads should be put into a heap, all large stones being carefully picked out, and soaked with as much water as the mass will absorb; then tread it with one or two horses, and, as it is trodden, mix as much short old straw as can properly be mixed with it, by adding more water as may be required. The edges of the mass should be turned into the middle of the heap from time to time; and the horses should be kept treading it till all the clay is thoroughly broken, and mixed so as to become like a stiff mortar. All the secret depends on well mixing the clay with plenty of straw. It should not be made too thin. As soon as this quantity is properly prepared, men should be making it into lumps, which is done by putting sufficient clay into a mould of wood, of the following dimensions; eighteen inches long, twelve inches wide and six inches deep, no bottom. The mould, when well filled, by the men putting in the clay with a spade, and pressing it with the foot, the top being smoothed with the back of the spade, should be lifted up, and the lump will be left perfect. Wet the mould with a wisp of oat straw, to prevent the clay hanging to it and place the mould about two inches from the first lump, and fill as before; then wet the mould and proceed as before.
>
> This filling of the mould is best done on level grass ground. As soon as the lumps get a little stiff, that is, just enough to admit of handling them, they should be set on one edge, and as they dry be turned; and in doing this place the wet side to the sun. The rough edges must be trimmed with a spade, or any edged tool, as they become dry enough to be haled (that is built up in rows about three feet high, one brick wide, and the lumps one or two inches apart at the ends, as new-made bricks are before they are burned), so that the wind can pass between each lump. Winter is the best time to get the clay into heaps, that the frost may pulverise and mellow it. In March, as soon as the severe frosts are over, begin to work the clay and make the lumps, and, if the weather is favourable, they will be fit to build with in three weeks or a month."
>
> "To build a cottage, barn or any building, with clay lumps, the foundation must be good; that is, built with brick or stone at least eighteen inches above the surface of the ground. The larger the building the higher the foundation should be; say three feet; and it should be two inches wider than the lumps, so that one inch of plaster may be put on each side of the wall; the width of the walls being according to the size of the building. Of course lumps can be made to any size, according to the building intended. The expense of building the walls (which are eighteen inches thick) is 6d per yard; and 1d per yard, covering each side of the wall with cement, which is only common clay mixed well with very short straw, being very particular in picking out every stone; and treading it more than usual, let it lie in a heap till the autumn and then (in October) apply it to the walls as a coat of plaster is applied to any common wall - J.C. Feb. 3 1842."

Loudon continues:

> "The only objection that we see to these walls is, that they do not appear to admit of finishing with common lime plaster within; but on writing to Mr Curtis on the subject, he informs us that he has no doubt lime plaster will adhere equally well with plaster of clay. It does so in the pisé walls of France."

Stephens and Burn also include a description but under the title "Unburnt Bricks".

> "Unburnt bricks form a much drier wall than ordinary burnt bricks, inasmuch as they are not so absorbent of wet or damp. To make these any ordinary clay will answer. If dry when obtained, it must first be moistened and thoroughly worked by the feet of cattle, or pounded by hand. Cut some straw into pieces about six inches in length. After being duly mixed the clay is ready to be made into bricks. A mould of any size must be made; a convenient size is twelve inches long, six wide, and five deep: this mould should have a bottom, but not airtight, in order to prevent the brick from sticking in the mould. The clay is put in this mould, and the brick formed much in the same way as ordinary bricks.

Should the clay be very tenacious, a little sand sprinkled in the mould will enable the brick to leave it freely.

The bricks are placed on level ground to dry, turning them on their edges on the second day; thereafter left in piles, protected from the rain, for ten or twelve days.

The foundation must be formed of stone or burnt brick; and to prevent damp from rising, a course of slate should be laid above the footings in hydraulic cement.

The walls formed of these bricks will be exactly twelve inches in thickness - that is the length of the mould; the partitions are formed by laying the bricks lengthwise, thus giving a thickness of six inches, the breadth of the mould. To obtain the bond in these walls, the work is carried up in alternate courses of headers and stretchers - one course having the bricks laid across the wall, the next course having them side by side. A good ordinary brick-mortar is to be preferred, although a weak mortar of lime and sand will do for laying the bricks.

The doors and window-frames should be previously made to be ready to insert when required. These frames should be of stout plank, the exact width of the thickness of walls: they will thus help to cover the joints and strengthen the walls. Lintels and sills of stone, when easily had, will much improve the appearance of the structure: pieces of timber three inches thick, width equal to thickness of walls, may be used in place of stone; these should have a clear bearing of at least twelve inches on each side of the opening.

Of whatever kind the roof is, it is essential, in this form of material for external walls, that it should be an overhanging one, in order to guard the walls from vertical rains. The outside of the walls is plastered with good lime-mortar mixed with hair, and then with a second coat pebble-dashed as in roughcast. The inside walls are finished in the usual way. A cottage may be built in this way for an incredibly small sum - warm, dry and of course comfortable. As to its durability, it is only necessary to state, that it is by no means a difficult matter to adduce instances where such structures have existed in thorough efficiency for a great length of time; in some, for upwards of two hundred years.

The method of forming the unburnt bricks will be found described under the heading of BRICKMAKING in the Handbook of the Mechanical Arts by R Scott Burn, Blackwood & Sons."

Although examples of this technique have not yet been identified in Scotland, they may well exist. Certainly Scots emigrating about this time are known to have used earth building techniques taken from Scotland to their adopted country. Techniques such as kebber and mott are to be found in Scots settlements in Canada, mudwall in Scots settlements in South Africa and so on.

An adobe house was erected two and a half miles east of Virginia, Cass County, Illinois by a Scots settler Andrew Cunningham. This is particularly intriguing as it is the only adobe house in Illinois, uses a different size of block to most American adobe, and has a unique mix of clay, tanners bark and hair scraped from hides in the tannery. Cunningham was born in 1806 in Bonnington near Edinburgh. He emigrated in 1834 to Canada, then moved to Illinois in 1837, revisited Canada briefly to marry then moved to Virginia, Cass County where he purchased land and built this unusual house. The house design is not Scottish in origins although it could be compared to some of Loudon's designs, as these were freely re-interpreted by Andrew Jackson Downing for his pattern books. The earlier work at the house, called "Allendale" after Cunningham's wife, was completed in 1852. Those wishing further information should consult Kay MacLean: 1973 and 1974: A Scots Builder and his House in Illinois (Manuscript MA candidate class papers Sangamon State University, Springfield, Illinois, USA) or the American Historic Buildings Survey "Allendale" Survey No ILL-261, Works Progress Administration Official Project No 65-1715. United States Department of the Interior National Park Service, Branch of Plans and Design.

5.02(v) Unfired Clay Bricks

Some types of clay brick can be used in their "green" state, that is, unfired. Ideally, the clay should be tempered to suit the mixing, extrusion and air drying process, to provide an unfired brick with many of the qualities of a clay block.

The main advantage of this type of brick is the capacity of brickworks to work, extrude, air dry and handle large quantities of bricks in a short timescale but to eliminate the costly firing process.

Experiments have still to be carried out regarding changes in the mix, mortar types and strengths, methods of delivery and on-site storage. Some work has been done but as yet detailed information is not available.

This is an earth building technique for new-build works rather than conservation.

5.02(vi) Stabilised Earth Blocks

Stabilised earth blocks are made by adding a binding

agent to an earth loam to change the inherent properties of that material.

Stabilised earth blocks usually involve the use of soils that lack natural binding agents but may also be used to change the nature of the natural binding agent. Stabilising materials occasionally appear in recipes for plasters and renders in Scotland but not in the main structural walling. The stabilising techniques have been developed internationally, essentially for new build works although they have been used for conservation projects, usually with dubious or disastrous results. However, it is worth considering the properties of these materials if only to achieve a clearer understanding of their limitations for conservation projects.

A. Bitumen: This material is used in a diluted form to work on the finest particles in the soil. Its principal purpose is to reduce the absorption and evaporation of soil thereby making it more stable. The amounts used are crucial. Small quantities can help cohesion of loose soils but higher quantities weaken the dry strength of the block. It can be used with clay soils but these require proportionally more bitumen to achieve stability which has an adverse affect on the strength of the block. When used with soil the bitumen must be dissolved with solvents such as petrol, paraffin or naphtha or mixed with water with the assistance of an emulsifier such as soap or a proprietary product. The amounts used must be established by testing on the particular soil to be used.

B. Cement: Ordinary Portland cement mixed with water can be used as a stabiliser to reduce the porosity of the soil, increase compressive strength and reduce expansion and contraction of the blocks as they are wetted and dried. It works in the same way as clay to fill the voids and coat each particle of soil. It therefore works best on coarse sandy particles increasing the compressive strength but this strength decreases proportionally as the clay content increases. As with bitumen, the exact mixes must be established by testing in relation to the particular soil to be used.

C. Lime: This works with the clay minerals in the soil to produce a pozzolanic reaction thereby increasing the soil strength and reducing the blocks susceptibility to water damage. As with bitumen, the mix is crucial as too high a proportion of lime can be counter productive. Exact mixes must be established by testing in relation to the particular soil to be used.

The main advantage of this type of brick is the capacity of brickworks to work, extrude, air dry and handle large quantities of bricks in a short timescale but to eliminate the costly firing process.

Clay mortared stonework, Dounby, Orkney

Clay mortared walls, Muness Castle, Unst, Shetland

5.02(vii) Clay Mortar

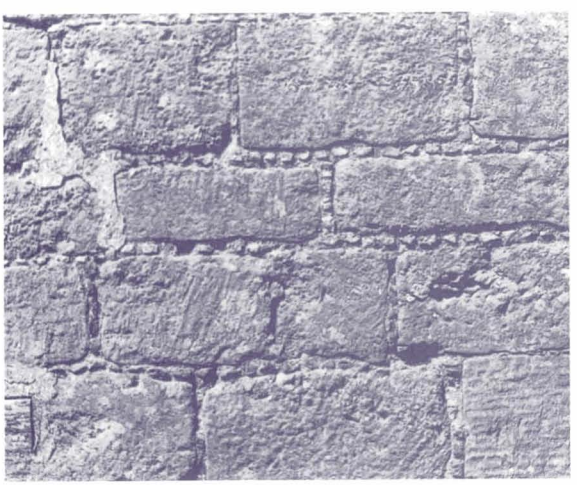
Clay mortar is mixed in the same way as a cement mortar but using clay as the binding medium rather than ordinary Portland cement. It is important that the clay fills all the voids in the aggregate but that there is not a surplus of clay as this could result in the mortar being too slippery for the accurate bedding of the masonry.

Unfortunately, the material appears to have been in such universal use in Scotland that it was considered unnecessary to describe mixes or additives in any part of the country. Simple clay:sand:fine-gravel mixes have been used successfully in conservation projects but more work is necessary to analyse the wide range of mixes still insitu in masonry walls all over the country.

The technique is seen by some reporters as a natural progression from alternating stone and turf (see item 3.05). Headrick reporting on Angus in the early years of the nineteenth century states:

> "The next step in the progress of improvement, was to throw aside turfs as cement, in the building of houses, and to substitute wrought clay, in which the stones are embedded. Accordingly, many of the farmhouses and cottages are still built in this manner."

He continues to claim that the pointing of stone with lime only occurs after the improvement of the road system, that is, after the construction of turnpike roads. This is obviously untrue for polite buildings but may well be the case for vernacular structures.



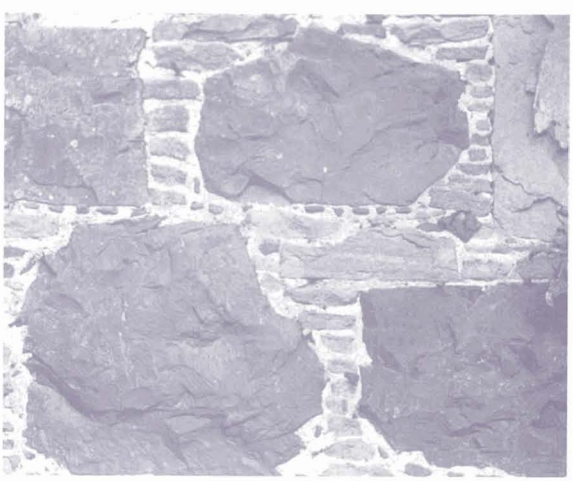
Arbuthnott, Kincardineshire

Newton of Affleck, Monikie, Angus

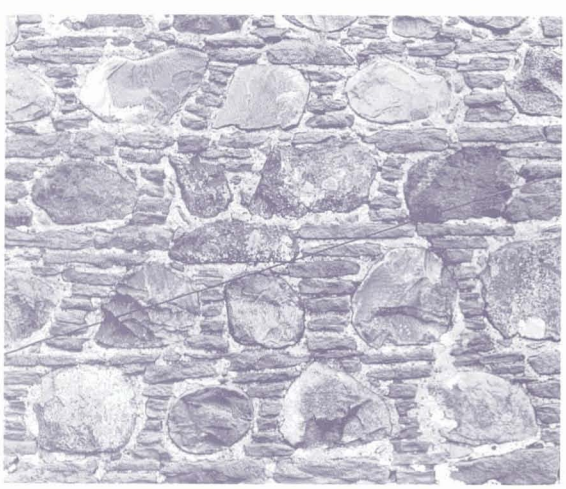
Clay mortared walls, Carnassorie Castle, Kilmartin, Argyll

Craigton, Monikie, Angus

Kinneff, Kincardineshire



Kinneff, Kincardineshire



Kinneff, Kincardineshire

It is known that some mortars may contain natural lime if mixed using calcareous clays. Similarly, others contain kaolin. Vegetable fibre such as straw occasions comments about dung being used as a mortar. There may be a proportion of dung in the mix, resulting from the use of livestock to mix the material, but dung was too valuable a commodity to use as the main mortar material.

5.02(viii) Clay Additives to Lime Mortars

Many calcareous clays possess the property of hardening under water when incorporated in a hydraulic lime mortar. Ten to twelve percent of clay gives a setting time of about twenty days but when the proportion of clay rises to twenty to twenty-five percent, the hardening time reduces to two to three days.

This information has still to be tested and proven and the original source is unclear as to whether the clay is added in a raw state or burnt with the lime but they claim:

> "A minute division of the clay, and a condition in which part of the silica is given up on the application of caustic potash, is considered to give the best results."

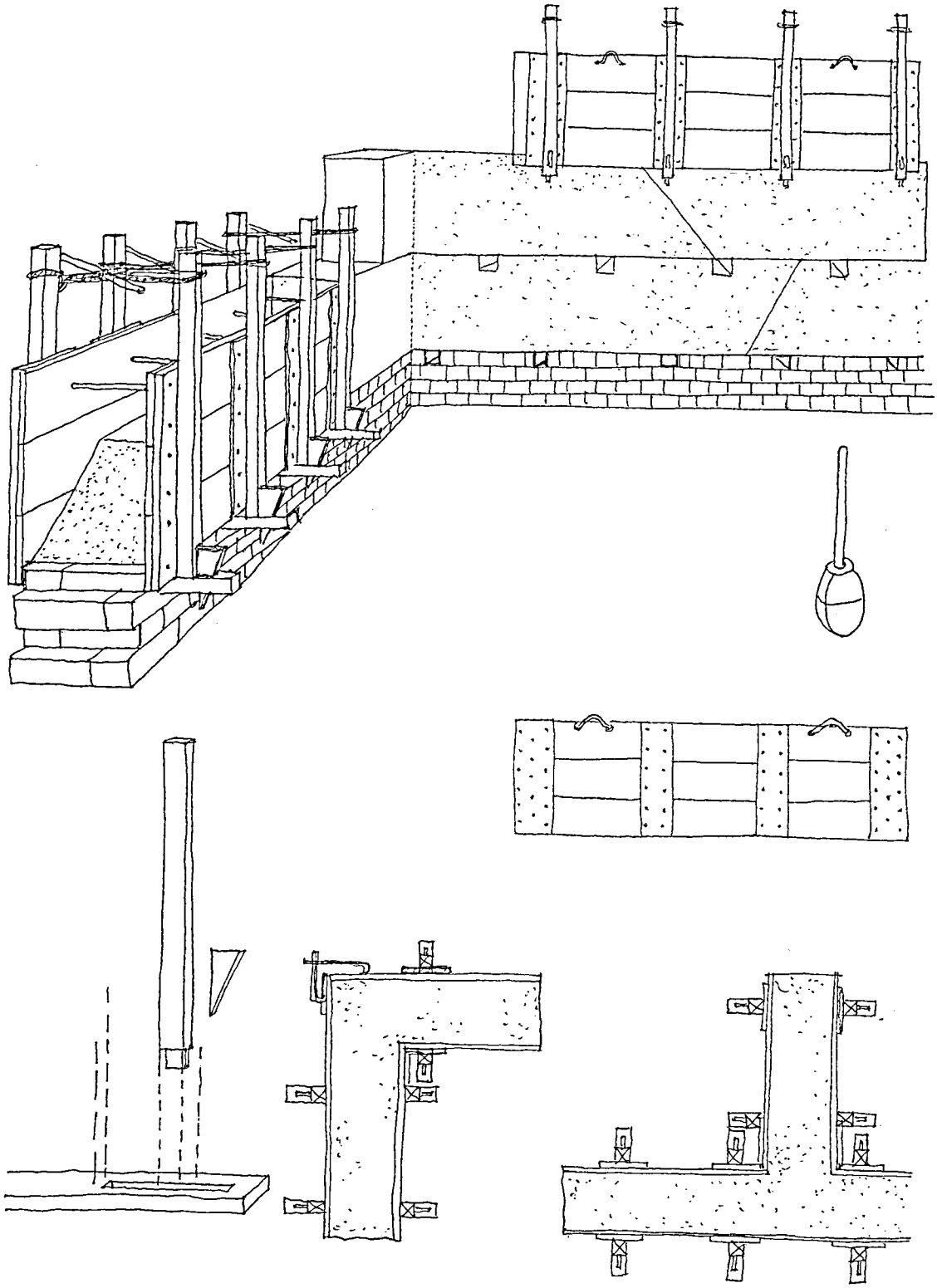
5.03 Construction Using Formwork

The date of introducing formwork, in the construction of earth walls, is not known but the earliest European descriptions date from the eighteenth century. The principal advantage is in being able to work quickly whilst creating walls that are straight, vertical and of standard thickness. It also allows greater pressure to be applied to the mix thereby reducing the need for fibre reinforcement. It can be argued that the introduction of formwork results from the understanding of soil mechanics and represents the change from a craft to a science. In almost every case the use of formwork is linked to the introduction of the rammed earth technique now universally known as PISÉ or more correctly "Pisé de Terre".

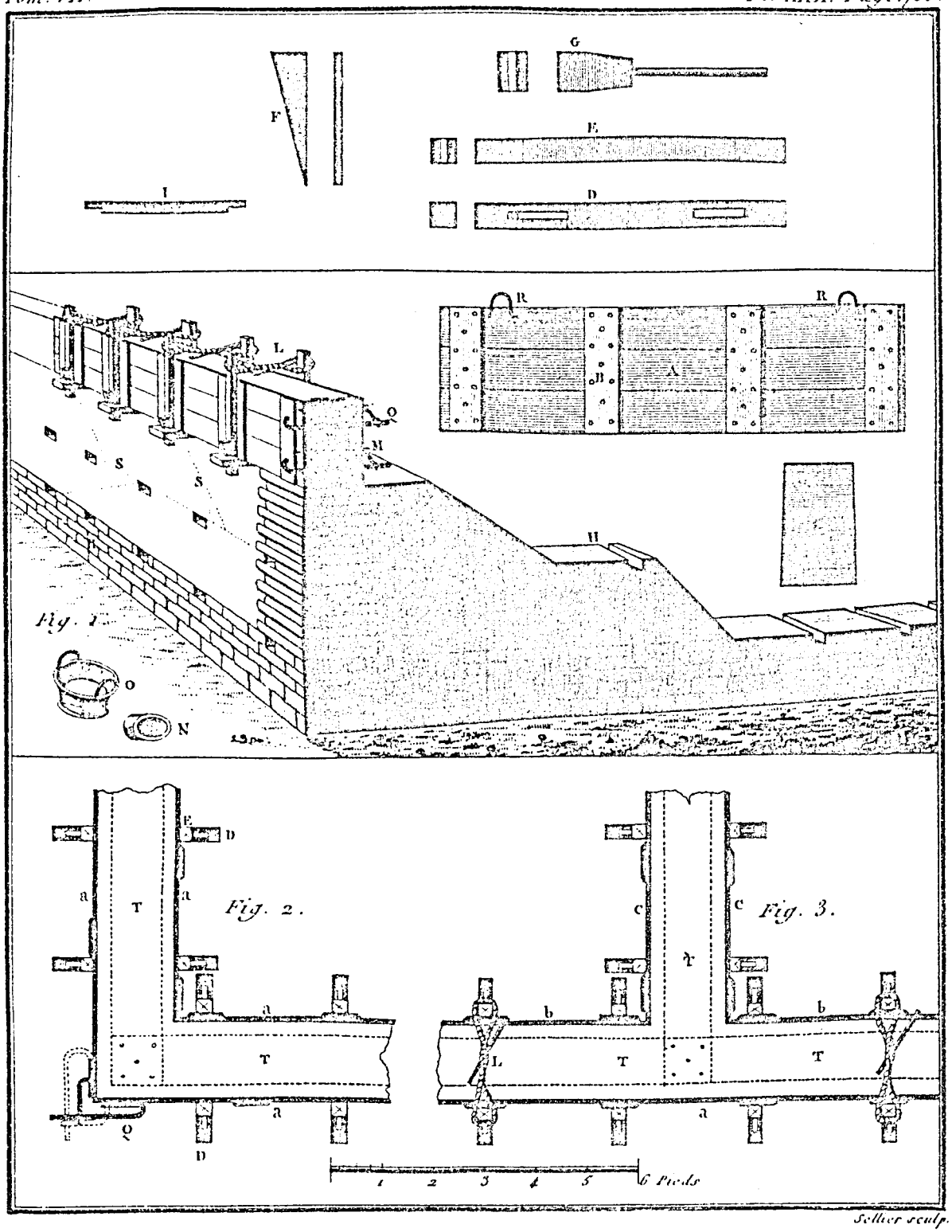
Although formwork appears to have been developed in conjunction with pisé construction, it presented opportunities to both the mudwall builders and to those wishing to develop techniques with a more obvious wearing surface.

Pise-walls, Prestonhill, Gamrie, Banffshire

Shuttering drawing



Shuttering details, Diderot.



5.03(i) Pisé

Pisé is a rammed-earth technique, formed in shuttering and utilising a dryish loam, free from all organic material. The technique appears to have been developed in France, in the second half of the eighteenth century, and its use spread quickly. Pisé may have been introduced to Scotland from a number of sources. The French connection is obvious as claret was still the national drink in the eighteenth century. A great deal of Scottish trade was still through the Netherlands where the technique was also used and individual lairds such as Lord Gardenstone recorded similar techniques on their travels and brought the ideas home to their own estates.

One of the most complete early descriptions of the process of erecting pisé walls appears in *Cours Complet d'Agriculture, Therique, Pratique, Economique et de Medecine Rurale et Veterinaire, suivi d. une Methode pour etudier l'Agriculture par Principes: ou Dictionnaire Universel d'Agriculture* ... in 1786. The translation by Catherine Meyer, originally from Grenoble, France but now living in Wellbank Angus can be summarised as follows.

A wall or pisé is an agglomerate of lumps of natural earth ... mixed, compacted and hardened on site through the skill of the 'piseur' ... There is no earth that is unsuitable for pisé, except pure clay or sand ... Earth which coagulates easily can be recognised when the print of a hand remains on the lump of earth ... One can successfully use strong earth (clay) mixed with gravel ... Avoid roots and dung ... The earth used must have approximately the same humidity as found a foot down ... If the earth is too wet, the volume of water contained makes it unstable preventing compression ... Dry earth is also unsuitable as it is porous and full of air. Take earth from below the cultivated level. It is essential to:

1. Maintain natural humidity by covering the pit.
2. Break the earth as much as possible with a pick, spade and rake to eliminate lumps. If the earth lacks humidity add water with a watering can then mix well. If it sticks to the "pisois" it is too wet. If soaked by heavy rain, suspend work. The pit can be dug in such a way that one part is always dry when the rest is too wet.

Abundant gravel adds to the excellence of the earth but diminishes the strength of poorer quality soils. If good earth is in short supply use for the lower sections of wall.

The number of workers required for a nine by twelve foot mould is six: three "piseurs" or beaters, two earth carriers and one labourer. If the earth is to be carried more than twelve to fifteen 'toises', two carriers will not be enough.

The best time to build starts in March and finishes in August. Rainy days must be excluded as parts of the walls just finished would not dry quickly enough to take second layers: one good day or night is enough to make it good. The great summer heat is also harmful as accelerated drying creates cracks ... Avoid frost ... Time varies according to local conditions.

The report continues with a description of the pine formwork, the 'pison' for consolidating the pisé and the masonry foundations, bound with lime mortar. The process continues:-

"The piseur grabs the basket by the two handles and spreads the earth in the formwork where he stands and gives the basket back to the carrier who repeats the process of filling and carrying. The piseur levels the earth with his feet then tamps with the pison, lifting it up from ten to twelve inches. The first strokes are directed systematically along the shuttering. The second stroke half covering the first and so on. The blade of the pison worked parallel to the shuttering against which it slides so that it reaches the earth at the angle of the formwork. The piseur will hold the handle tilted towards the opposite shutter. Once he has tamped along one side he repeats the process on the other, then tamps across the formwork keeping the blade of the pison parallel to the end shutter. The piseur tamps the same layer a second time in the same order. If the earth contains a lot of gravel, he must tamp a quarter more and beat harder. The second piseur does the same with the second load, the third with the third load each of them tamping the earth as soon as it is poured and not waiting for each other to start and finish a layer ... The piseurs each occupy one third of the mould, timing themselves to move back and forward without disturbing each other. It is important not to add new earth to a layer that has not been tamped sufficiently, that is when the pison hardly leaves a print. This sequence continues until the formwork is full. When the formwork is full it is dismantled immediately and used to form the next section.".

The description then covers the differences in formwork used in building level walls and inclined walls. It then describes the formation of corners and changes of angle.

The walls should be protected from rain during construction ... and covered with wooden slabs or even tiles ...

The render is not applied to the completed wall until the following year, or even the year after.

Walls can be rendered in the usual manner but we

advise that harling is infinitely better ... being thrown on with a little brush without pressing with a trowel. It is more durable, more economical and holds the pisé without the surface being picked.

The harling is made of a lime mortar and extremely clean sand. It is soaked in buckets till like a paste, then taken up and thrown against the wall with a brush, starting at the top in vertical strips five or six feet high and one foot wide. This operation is repeated until the whole wall is covered. This harl is not smooth but looks like rough stone. Half the amount of mortar of an ordinary render will be used. It is not as neat but more durable ... "

Although a limited number of Scottish lairds may have had access to French agricultural encyclopaedias in the eighteenth century almost every substantial farmer would have had a copy of Henry Stephens *Book of the Farm* and almost every estate would have had his *Book of Farm Buildings*. His description of Pisé walls takes the French description several stages further.

"Brick earths are well adapted for pisé; but, owing to the capacity for retaining moisture, they are apt to crack, unless carefully shielded from the wet during the process of drying the walls. All kinds of earth, however, may be used, with the exception of light poor lands and strong clays; these, however, will do if judiciously mixed with other better-fitted soil.

To show how his this mixing may be most successfully carried out, a few sentences may be useful: the principle of mixing is simply to blend a light earth with a strong, a clayey with a sandy or gravelly kind. Where the best kind of soil - that is gravelly - cannot be obtained, small round pebbles etc may be mixed with it. All animal or vegetable substances that are apt soon to decay must be carefully kept out of the soil to be used. The following indications, which may be observed in order to judge of the fitness of the soil for pisé in any district, may be useful. In digging, if the spade brings up large lumps at a time, the soil is well adapted for the work: this holds also where the soil lies on arable land in large clods, and binds after a heavy and a hot sun. Where vermin holes are smooth in the inside and firm, or where the small lumps generally found in plenty in all fields are difficult to be crumbled between the fingers, the soil is good. Soil of good quality is generally found at the bottom of slopes that are in cultivation, and on the banks of rivers.

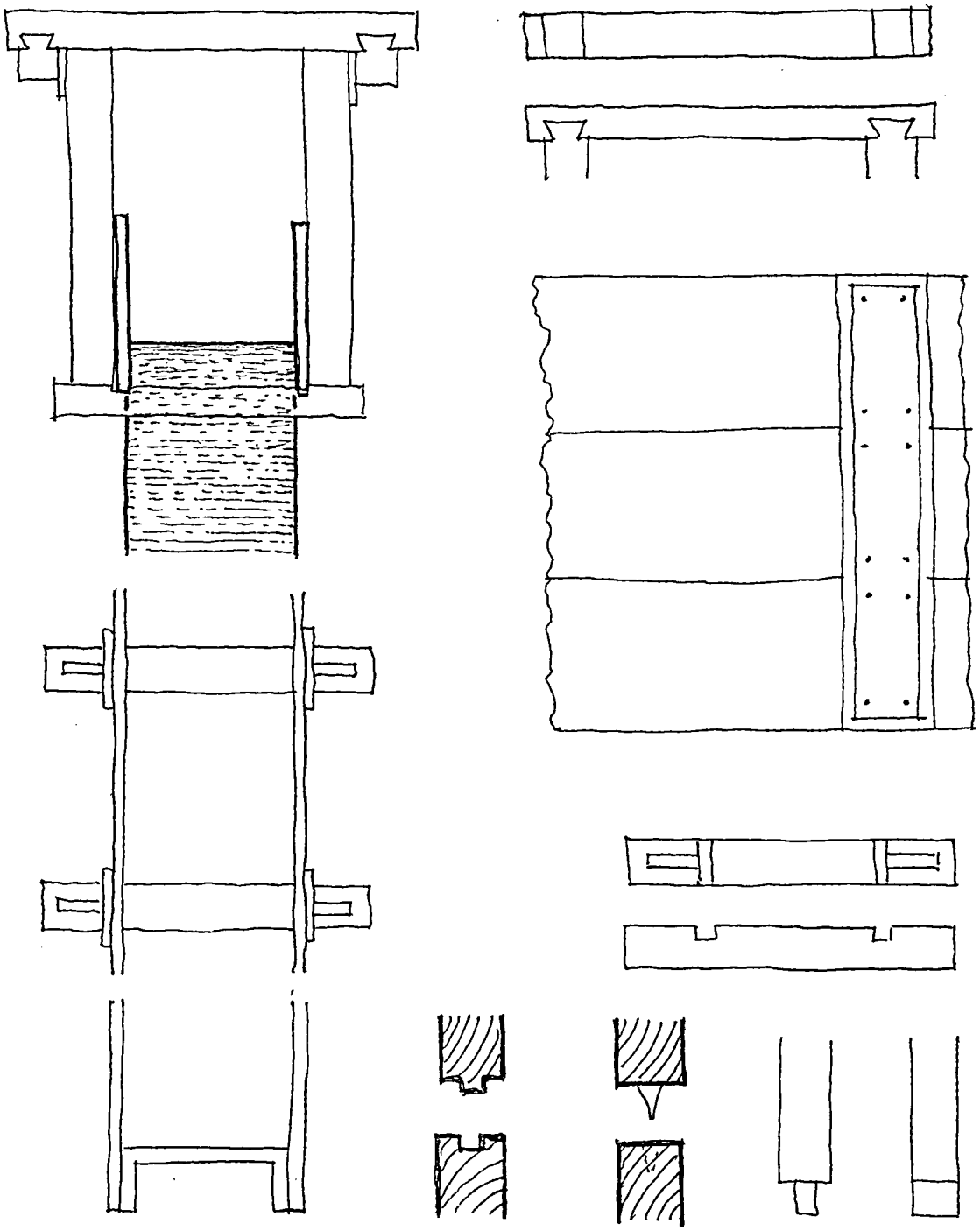
In preparing the earth for building, the first operation is breaking the clods or lumps, and thereafter placing the soil in a conical heap; this form facilitates the removal of large, flat, and circular stones, which, falling to the bottom, are easily removed from the mass by means of a rake. The teeth of the rake should be placed at intervals of one inch or thereabouts, so that only stones exceeding this size may be withdrawn; or what would be better and quicker, a bricklayers sieve or "screen" might be used, having the meshes about an inch square.

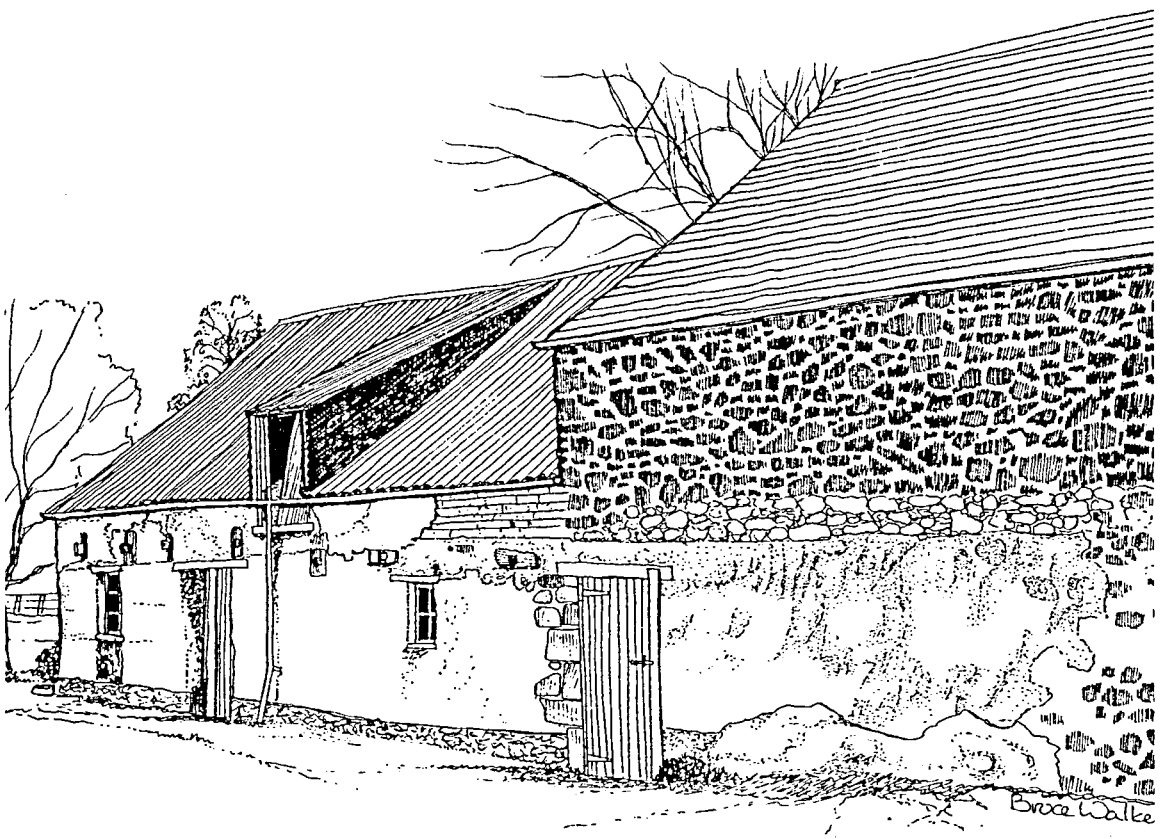
Where two varieties of soil are to be mixed, the operation should be done at this stage. Enough of soil should only be prepared to last a day's working. Care must be taken to prevent rain saturating the earth with water, as in this state it will form mere mud in the mould. It is necessary to note that the soil is in best condition for working when neither too dry nor too wet. It is very evident that less time will be lost in slightly wetting the soil when too dry, than to waiting for it to dry should it get saturated with rain by a careless exposure.

Before commencing to ram the earth in the mould, it will be necessary to try it by means of a plumb-line and square, to ascertain that it is properly levelled. The operations must be commenced at one angle [corner] of the wall, the head of the mould being at the outer extremity of the wall, within 14 inches of it, the joints being at that distance from the outer extremity in consequence of the thickness of return wall.

The labourers appointed to prepare the mould, [earth] hand it up to those engaged in the mould in ramming: these take the earth and lay it out at the bottom of the mould to the depth of 3 or 4 inches: more than this depth should not be put in at one time. The first strokes of the rammer should be made close to the edges of the mould, thereafter going over the whole surface in regular succession, from the head of the mould downwards; then crossing these first blows or indents by another succession. Care should be taken to give to each layer as equal a compactness as possible, which is easily attainable; the parts under the caps must be carefully looked to, as, from their position, the rammer must be used obliquely. The mould being thus filled by successive layers, each equally well rammed, the wedges holding the caps must be withdrawn, the caps taken off, the sides thus released taken out, and the joists finally drawn out of their holes in the wall, which should be filled up by proper means. Infilling up the mould, the inner end should not be filled up to the same height as the other parts, but should be made to slope gradually down. This is shown in the figure.

Shuttering details. Stephens and Burn





Barn, Flatfield, Errol, Perthshire. Built 1784 - extended late 19th century.

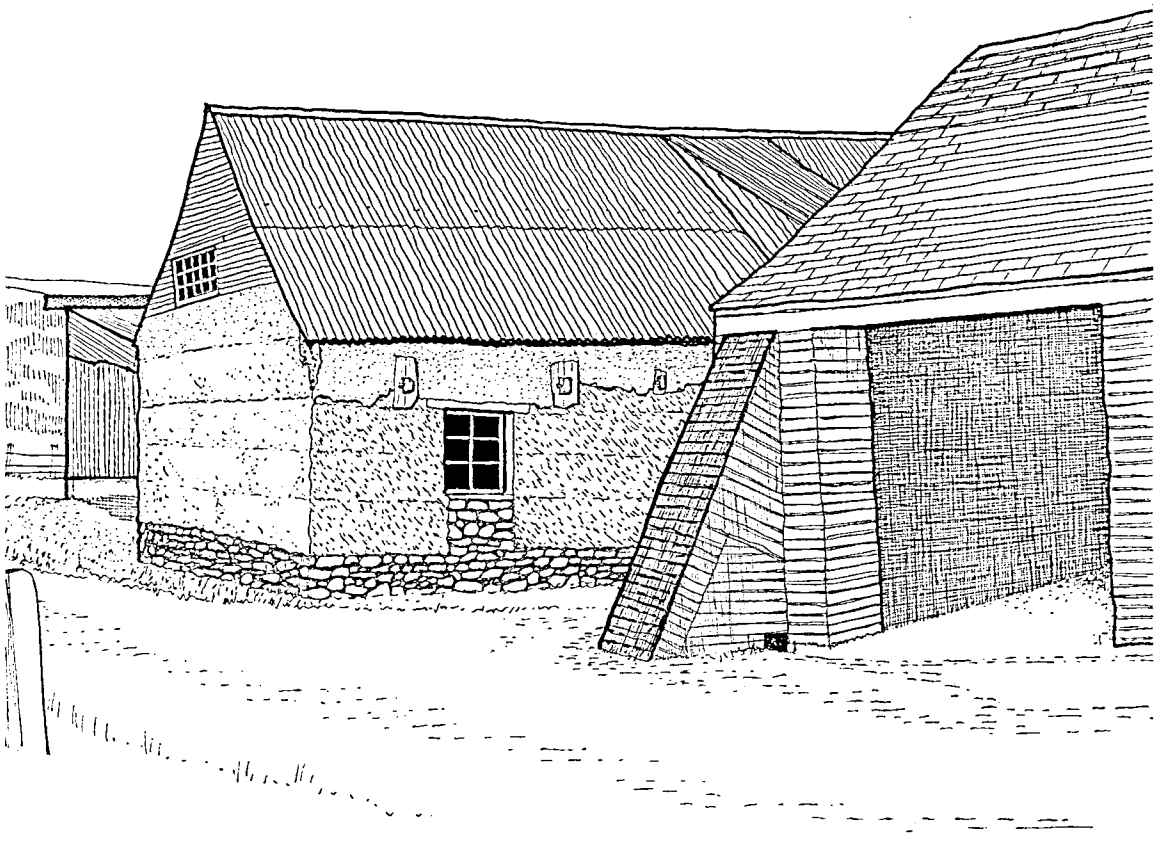
The joists are next to be placed in the adjoining holes, the sides of the moulds being without battens at the ends - these not being required, as no end to the mould is needed. The outer end of the sides should be so adjusted that they are on a line with the top of the slope of the first course of rammed earth. By this means, when the earth is filled in to the second mould, one end of it will lie upon the sloping end of the first course, thus forming a species of bond. The foundation-wall being, by a succession of moulds, covered with a wall of rammed earth, the height being equal to the depth of the mould, holes or slits are cut in the upper surface in which to lay the joists. These being prepared, the mould is to be set up as before at an angle to the wall, the sides having the battens at one end against which to fix the end; but the operation is to be begun at the opposite end of the wall to that originally started with. By this means, as each end of the mould is left sloping off as before, the sloped surfaces in the second course will lie the contrary way to those in the first; the bond between the several courses will thus be increased in efficiency. It should be borne in mind that the holes for the joists cut in the upper surfaces of the successive layers, should be so placed as not to be exactly above one another in all the courses, but each succeeding series between those of the series below. These recommendations will be exemplified in the figure.

The gables of a house can easily be made by making the successive layers each shorter than the one immediately below it; the requisite slope will thus be obtained. When a day's work is finished, the walls should be covered with boarding, so that they may be covered in the event of rain; and the roof should be placed as soon after the walls are complete as possible.

The roof should overhang at least 12 inches, to protect the vertical walls from the effect of rain. Where the building consists of two storeys, the walls of the upper storey may be made thinner than the lower, by setting at the level of first floor a depth of 2 or more inches from the inside, the outside being flush with the outside of lower wall.

Bond timbers may be used with advantage in pisé walls; they should be of the length of the mould, and in breadth equal to one-third the thickness of wall. As they are completely embedded in the earth, they last for a great length of time. If considered necessary or more economical, the inside faces of the bond timbers may be made to lie flush with the inside wall of the house. In this case they will serve as battens in which to drive nails or holdfasts for many convenient purposes. The openings for doors and windows should be left a little less than required; they may be dressed after the building is finished to the proper dimensions. Wood brides should be built in

Barn, Flatfield, Errol, Perthshire. Built 1784 - extended late 19th century.



here and there to which to fasten the dressings and frames. The openings are made by placing heads or a head in the mould at the place where the wall is to terminate and the opening begin."

5.03(ii) Mudwall

Mudwall is occasionally formed in shuttering. If the mix is kept stiff and dry it can be reasonably successful and is sometimes linked with other materials to create a strong wearing surface: see items 5.03(iii-vi).

Wet mixes, particularly those wet enough to pour like concrete, are very slow to dry. This ties up the shuttering for considerable periods, adding to the expense. Recent work carried out by this method in England does not appear to be providing consistent results.

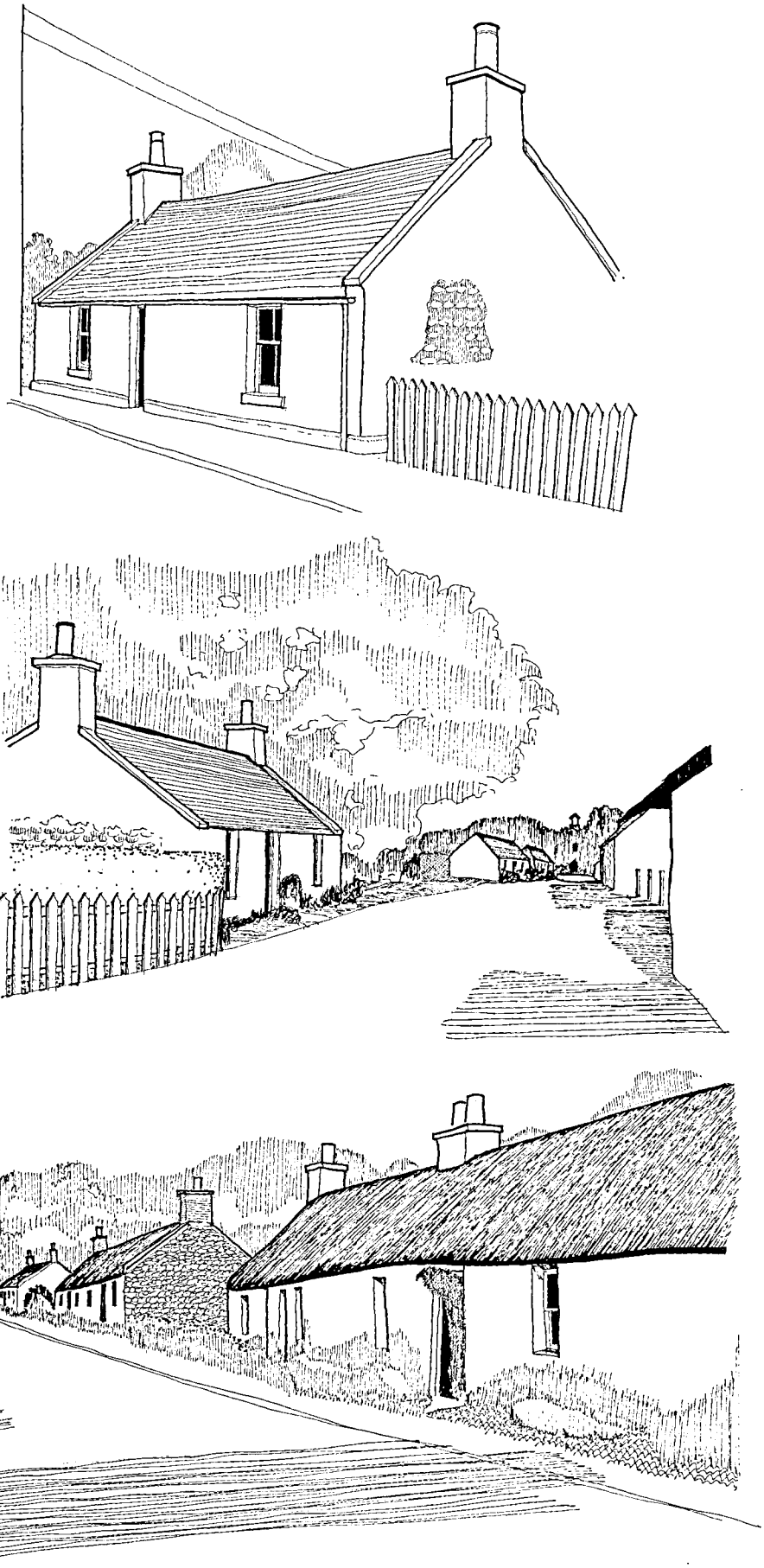
Experiments are being carried out with stiff mixes, and should these prove successful, it is likely that wetter mixes will also be tried. This is a slow process and it may be several years before more detailed information is available for publication.

5.03(iii) Clay and Bool

This is a variation on pisé or mudwall where rounded river or sea-washed boulders-bools - are set into the mix. The bools are placed in even sized rows with their outer faces touching the inside face of the shuttering on both sides of the wall and the tempered earth mix is then tamped round and between them. The quality and sizing of the bools varies from wall to wall but, where evenly sized bools are available, and they are carefully placed in the shuttering, a decorative effect can be achieved. The final effect depends on the external tempered earth mix weathering back to expose the bools. At this point they are finished by pointing the spaces between the bools with lime and lime washing the face of the wall.

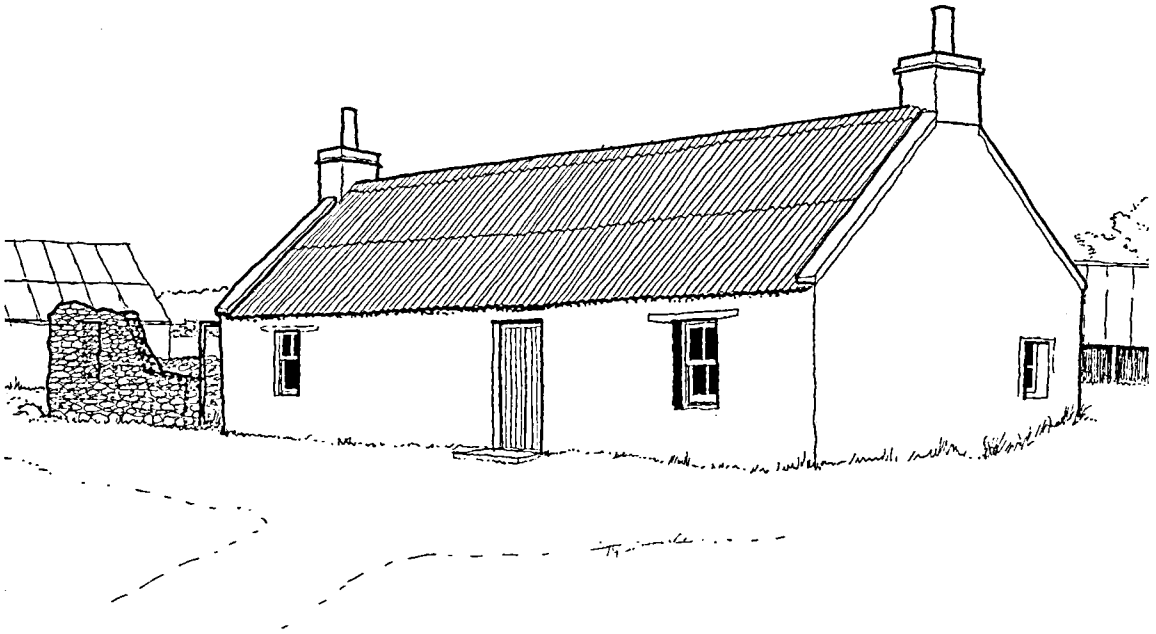
This decorative external finish is known as "Auchinhalrig Work", after the Moray village of that name where the technique is reputed to have been developed, or as "Ham and Egg Work".

In some cases the external wall is rendered before the weather has the opportunity to expose the bools making the technique almost impossible to detect unless the plaster or render is removed or falls off.

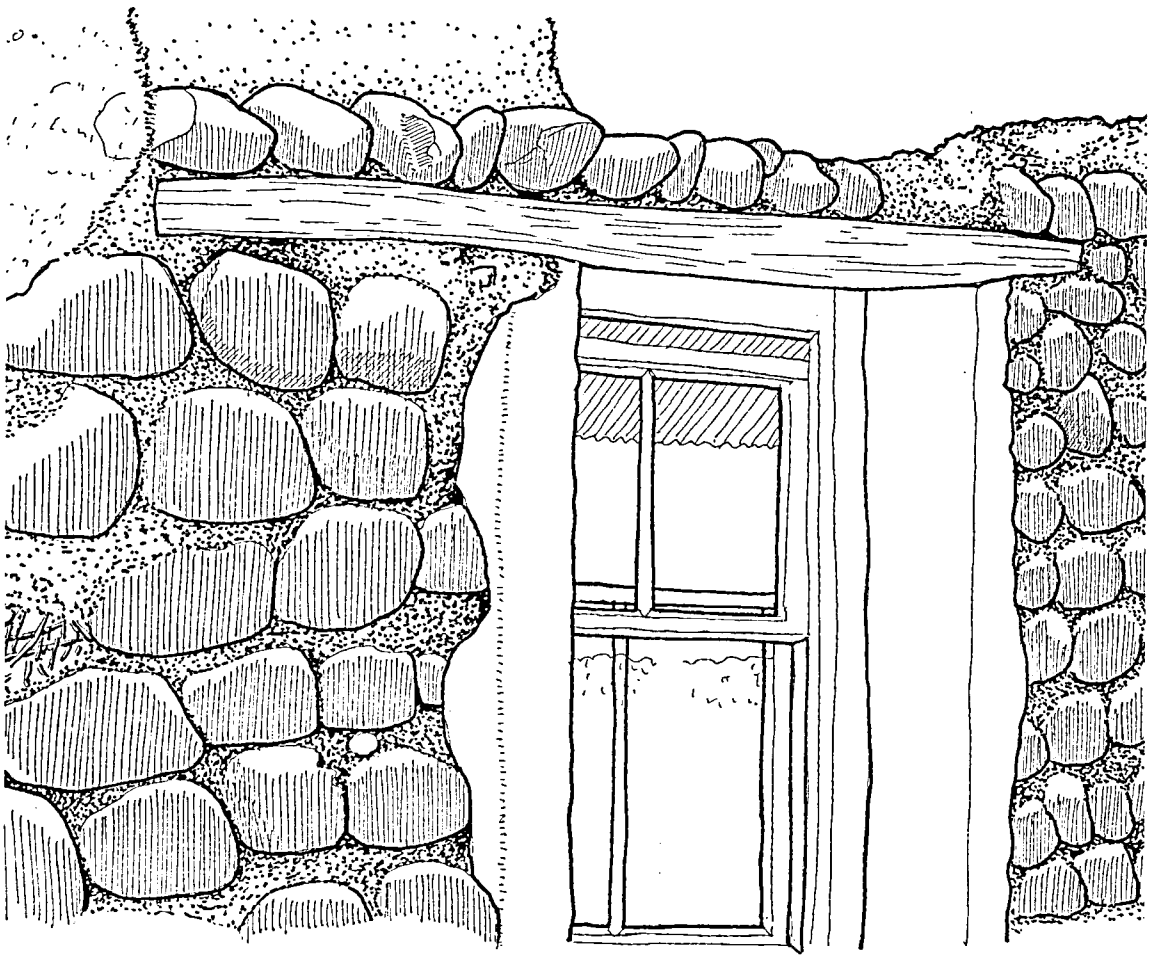


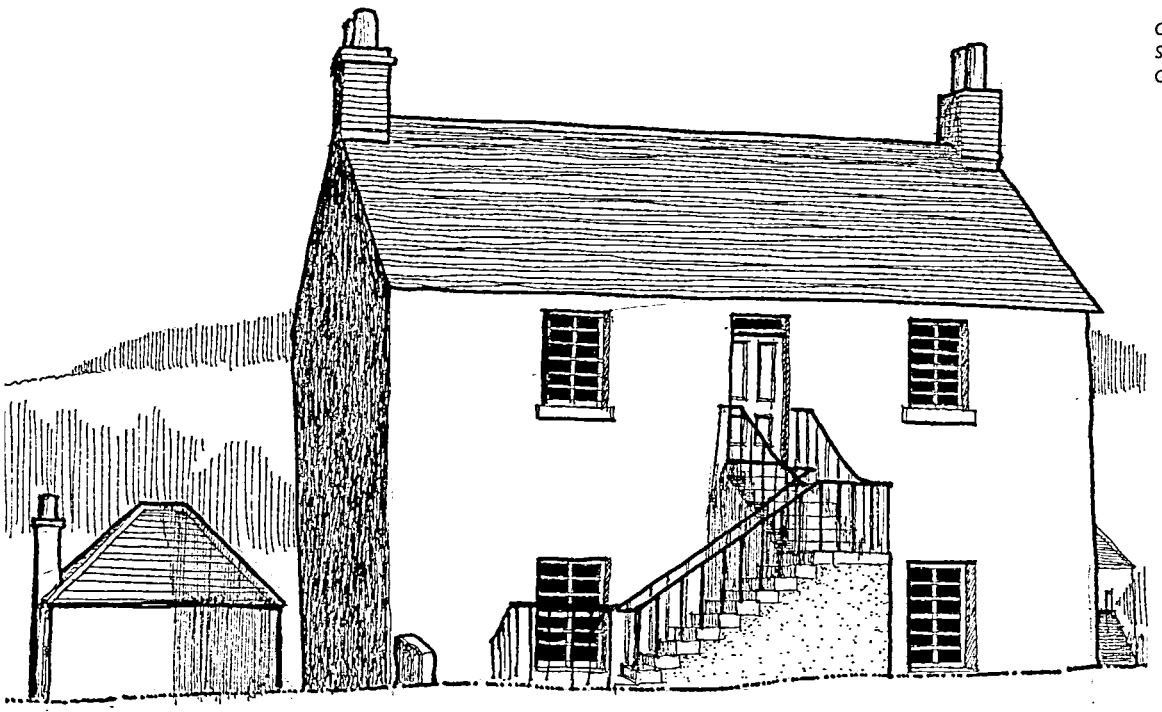
Clay and bool cottages, Urquhart, Moray

Clay and bool work, Bogmuir, Bellie, Moray



Detail of ruin to left of house





Claywall School and Schoolhouse, Glendoick, Perthshire

5.03(iv) Claywall

The term claywall is used to describe a wall of tempered earth that has the superficial external appearance of a masonry wall. This can include specific wall types such as clay and bool, masonry faced mudwall or masonry faced pisé. If these specific types are excluded then the term refers to a type of rough masonry wall formed between shuttering and lacking the normal bonding of individual stones.

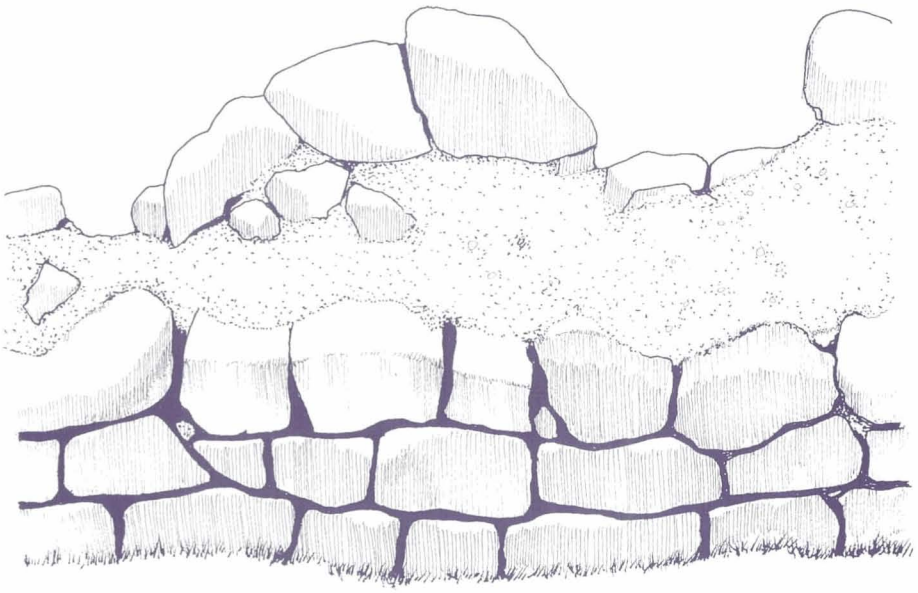
The stones used for claywall are often rounded river - or sea-washed boulders, field clearance boulders, quarry redd, or other types of inferior stone better suited for use as hardcore than as building stone. The stones are often randomly placed in the shuttering, or where some attempt is made to create a reasonable facing, in the wall core. The clay used with this technique is often more plastic than the earths normally used and when the wall is sectioned, the random nature of the build is all too apparent.

This appears to be a late eighteenth century development of the earth building techniques. On April 21, 1772 Patrick Proctor, factor to the Strathmore estates, Glamis, Angus recorded the following entry in his Ledger of Improvements.

> "To cash paid Alexander Fairweather for coming from Brechin to commune about building the clay houses ...".

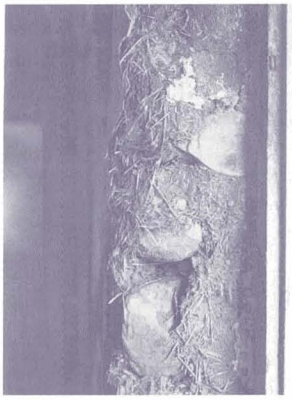
The ledger shows that in the years following this entry, a number of 'clay' houses were constructed on pendicles on the estate. One of the largest concentrations on the estate was to the north of Glamis Castle and included the Plans of Cossans, Dairsie, Drumgley and Drumshade. Careful examination of the buildings still surviving shows that although the better class houses are built of sandstone with clay mortar, the 'clay'

houses are all claywall. Following the reference back to Brechin it is immediately apparent that although there is a concentration of mudwall and pisé construction in the villages of Laurencekirk and Luthermuir, Kincardineshire, the buildings in the surrounding area are all claywall. As a constructional technique, claywall is far more common than the purely earthen structures. It can therefore be claimed that although the purely earthen structures survive in pockets where there is little in the way of good building stone, claywall can be found in almost any area of the coastal plain and central Lowlands of Scotland.



Claywall, Bogmuir, Bellie, Moray

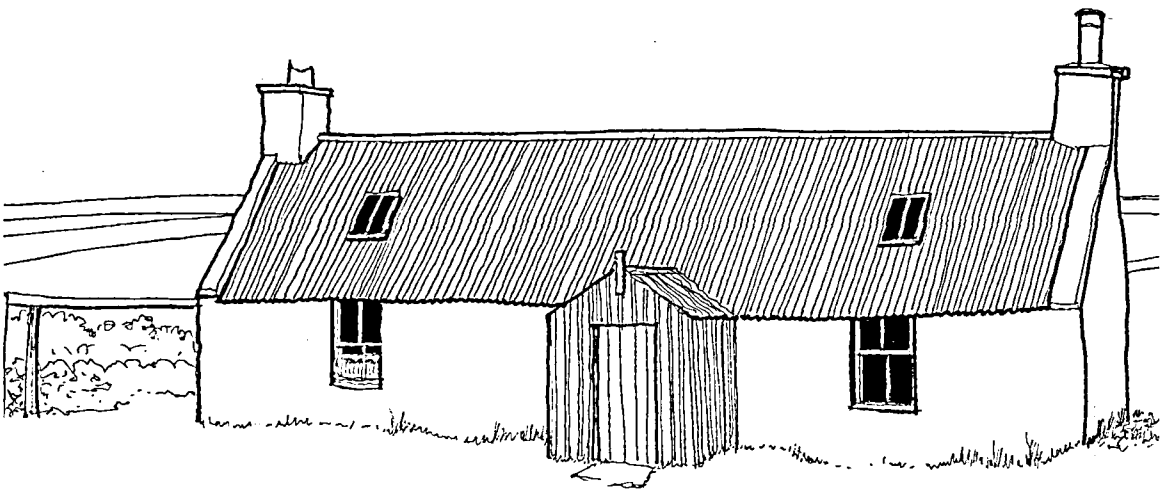
Usually the claywall builder tends to place the best stone faces against the inner faces of the shuttering filling the core with a mix of small stones and a reasonably plastic clay. Tempered mixes are also to be found, some similar to pisé, others to mudwall. The length of time the formwork has to remain in place is not known but will obviously vary according to the mix. It is hoped to carry out experiments in the near future to establish a more predictable set of performance indicators.



Claywall off shuttering, Bogmuir, Bellie, Moray

Kirkton of Scone, Perthshire circa 1693

Claywall graduating to mudwall houses. 1 Spey Street, Garmouth, Moray



Claywall, 4 Overbrae, King Edward, Aberdeenshire

Claywall houses, The Square, Errol, Perthshire

GWW:PC

5.03(v) Masonry Faced Mudwall or Pisé

Mudwall or pisé can be faced with masonry either by building the stonework against the face of the shuttering or adding a masonry skin to the completed wall.

Masonry built within the shuttering is common where there is heavy traffic in contact with the wall. The stone skin is seldom more than ten centimetres thick and simply acts as a wearing coat to counteract animals or people brushing against the surface of the wall. It was obviously time consuming to build in this way and the areas of stone facing are generally kept to a minimum.

Masonry skins added to a completed wall are an alternative to harl and are partly decorative and partly utilitarian. The technique is similar to that described in item 5.02(ii).

5.03(vi) Brick Faced Mudwall or Pisé

Brick can be built to provide a permanent shuttering to a mudwall or pisé structure. When this is done it is essential to allow sufficient time for the brick mortar to set before commencing the pisé work as the ramming action can cause the brickwork to fail.

Brick skins can also be added to a completed wall as an alternative to harl. The technique is similar to that described in item 5.02(ii).

5.03(vii) Stabilised Earth

Stabilised earths as described in item 5.02(vi) can be used as an alternative to pisé. This is not recommended in conservation work unless used on a like for like basis, as the stabilised earth will behave differently and may cause accelerated deterioration of the abutting pisé.

5.04 Floors

There are literally hundreds of references to floors being constructed of earth but very little information on how these floors were formed. Even architects such as Alexander Hutcheson fail to give mixes. He states:

> "The floors were of earth, or where it could be got, of clay, well padded down with the naked foot."

Others describe sheep being used to trample the clay to make a well compacted floor. This technique is reflected in the name "sheeps foot roller" referring to pronged rollers used in road and motorway construction.

5.04(i) Clay

One of the earliest recipes for making a clay floor appears in the Dalguise Muniments under the title "My Megies Book 1692".

Clay floor and hearth, Dun Carloway, Lewis

Åke Campbell

"To Lay Clay Floors.

First lay all the floors with stones the bigness of yr hand. Take three parts of clay and a 4th of lyme, work and beat it extreamly well together, let it sower 2 or three weeks. Take another part of small stones, the bigness of pease or beans, wash all the earth from them, then mix them with the clay and lyme. Lay the so mix'd above the round stones as big as your hand. Beat it well down with a betton, and watter it with lyme. Watter as fast as it dryes and rises. Coat it anew, and, last smooth it over with a plaisters troual.

NB: It will take 6 weeks to dry.

Even as late as 1922, Frank W Macey is still advocating clay floors in cattle stalls.

"Puddled clay may be for a distance of about 3 feet 6 inches at the head of the stalls by about 9 inches to 12 inches deep, and the concrete should be placed underneath the clay."

This is confusing as puddle does not make a good floor and the section shows that there is no concrete under the clay but only at the lower end of the stall abutting the drainage channel.

"The puddled clay forms a soft bed for the cows to rest upon when getting up or lying down. The dunging passage may be formed with asphalt, concrete, stone or brick. The feeding passage may be plain earth, or else paved with any class of paving: it is usually placed at a slightly higher level than the floor of the stalls."

External clay floors are a possibility although not common in Scotland. Clay tennis court construction comprises: one inch clay and sand: a two inch clay bed: three inches of cinders: one inch of gravel: and five inches of crushed rock. Drainage pipes are run through the crushed rock.

5.04(ii) Clay-ash

Many floors incorporate ash as an ingredient. This particular recipe also includes a high proportion of lime in the mix but lime is not a prerequisite and clay can be used as an alternative.

"To make floors for plain country habitations. Mix together two-thirds of lime with one-third of coal ashes well sifted, with a small quantity of loam clay: temper the whole well with water, making it up into a heap: let it lie for a week, and then temper it over again.

After this, heap it up for three or four days, and repeat the tempering very high, till it becomes smooth, yielding, tough and gluey. The ground being then levelled, lay the floor therewith about two-and-a-half or three inches thick, making it smooth with a trowel: the hotter the season is the better; and when it is thoroughly dried it will make the best floor for houses."

Cinder footpaths are often located in country lanes and private grounds. Generally these are now overgrown but in the days of solid fuel boilers and private gas works they formed an inexpensive pathway. The cinders are screened and laid three to four inches thick, with the screenings forming a top coat about one to two inches thick and well rolled in.

5.04(iii) Additives for Wearing and Decorative Purposes

Special effects may be obtained by the addition of certain additives. To make the clay-ash floor look better:

"let them take a line of rag stones, well tempered with the whites of eggs covering the floor about half inch thick with it, before the underflooring is dry. If this is well done and thoroughly dried, it will look, when rubbed with a little oil, as transparent as metal or glass. In elegant houses, floors of this nature are made of stucco, or plaster of Paris, beaten and sifted, and mixed with other ingredients."

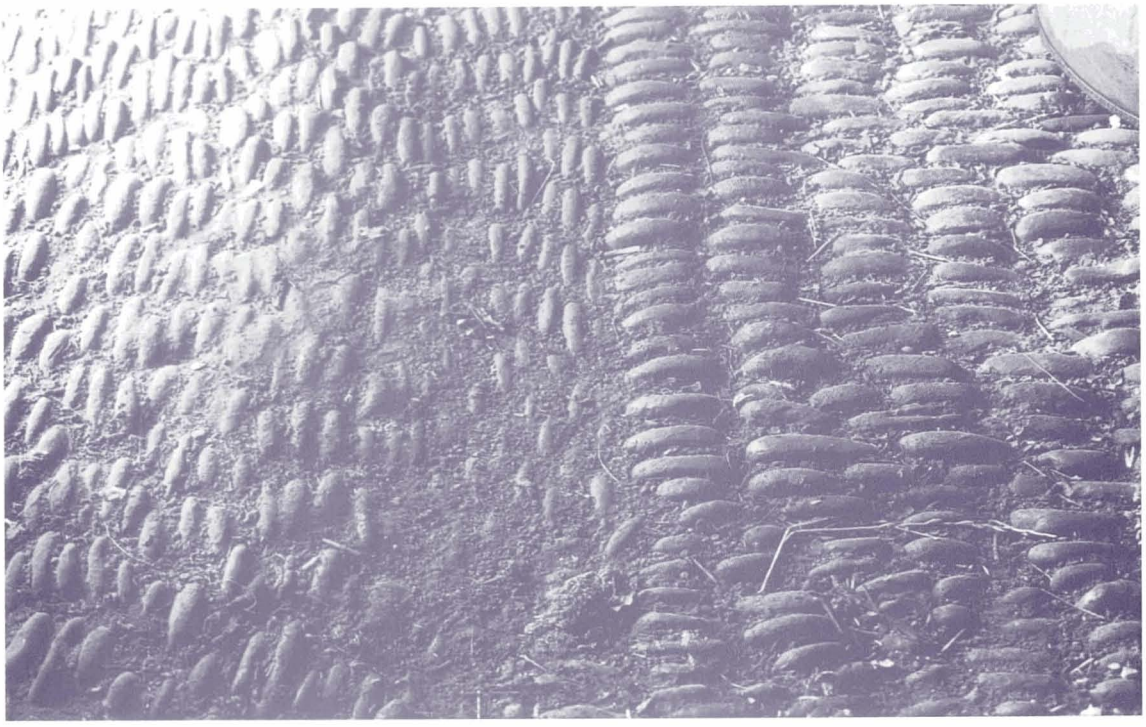
The most commonly referred to additive is blood, which turns the floor either dark brown or black according to the quantity used. This is often used in conjunction with tallow or oil to help bind the earth and reduce dusting of the surface. The surface application of oil to any of the above floors produces a shiny finish which is sometimes compared with linoleum or even marble.

5.04(iv) Cobbles and Paving

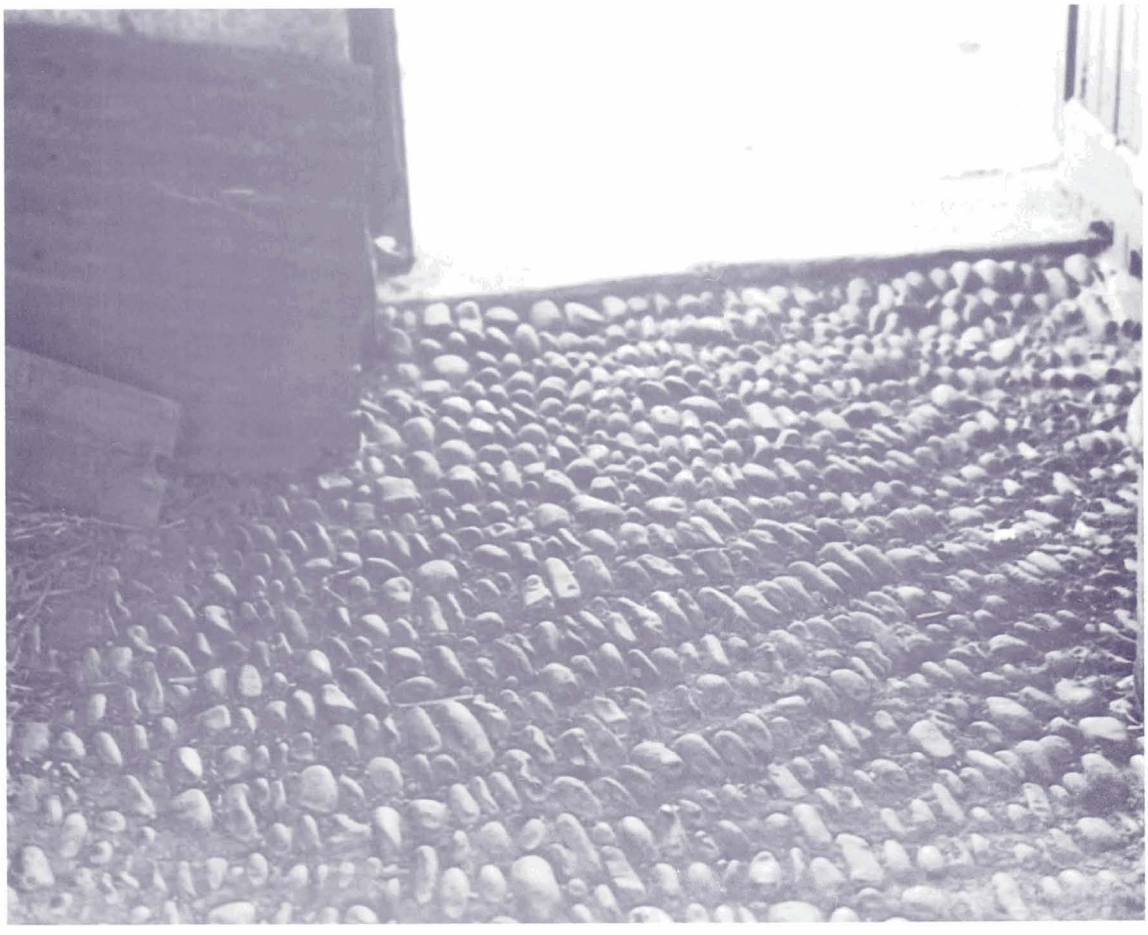
Roadways, pathways and internal earthen floors can be finished with paving or a cobbled surface. The cobbles used vary from irregular broken stone to riverwashed stones and boulders. The character of the finished floor is wholly determined by the type of stone available, and the care taken in the selection and laying. Imaginative patterns can be created with varying colours or textures.

The earthen mix has been described in item 5.04(i) but in the case of roadways, crossing bridges or other structures that require specific waterproofing, may incorporate a layer of puddle.

Paving is normally laid on a sand bed, but cobbles are hand placed into a sandy loam. They are tapped into position to provide an even surface to the roadway or floor, with a consistent resistance to pressure. The individual stones are placed on end or on edge to ensure a tight bond resistant to dislodging by the impact of boots or horse shoes.



Cobbled floors, Rathven, Banffshire



5.04(v) Macadam Roadways

John Macadam devised a new form of road surface as an alternative to paving and sets. He recognised that road coverings have three conditions to fulfil:

"1. They should provide a firm and compact covering to the road base.

2. They should be smooth.

3. They should provide a firm and secure foothold for horses."

The material "macadam" fulfils these requirements. It is based on the use of materials of uniform size, none of which are large enough to act as a lever. Macadam describing his theory states:

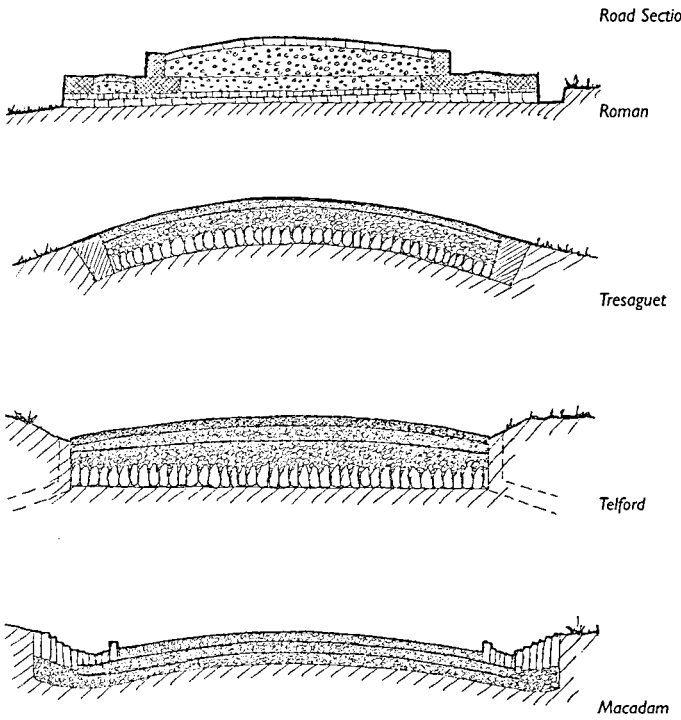
"The size of stone used on a road must be in due proportion to the space occupied by a wheel of ordinary dimensions on a smooth level surface: This point of contact will be found to be, longitudinally, about an inch, and every piece of stone which exceeds an inch in any of its dimensions is mischievous."

The production of "macadam" by hand is a skilled process involving the use of several weights of hammer to reduce stone to appropriate dimensions without totally crushing it. Today stone breakers reduce rock to chips of even size. Macadam is a hand-formed chip surface. In laying, the material should be spread using shovels, in an even layer not exceeding three inches in depth. Compaction is achieved by rolling with a heavy roller. Additional layers should be applied in the same way, each rolled for compaction, until the requisite thickness is achieved. The work should ideally be carried out in moist conditions and, to aid compaction, loam or quarry dust can be added, but not in a true Macadam road. Care must be taken not to use this in proportions which will destroy the natural drainage of the surface.

The repair of "macadam" surfaces involves loosening the compacted material with a pick, raking and spreading additional chips in a stratum not exceeding their own dimensions in depth, then rolling the surface to reconsolidate the material. Depots for broken stone of the correct type are to be found every quarter mile along the length of the road.

Urban roads of this type are normally designed with kerbs, gutters and footpaths. Rural roads normally use sod to create the channel for the surface water but occasionally a pitched channel is formed as shown in the figure.

A "macadam" surface is designed as a sacrificial layer protecting the sub-stratum which is the most important element of the road construction. It is essential that the sub-stratum be properly



constructed, well consolidated and well drained. Drainage is normally provided by a ditch to either side of the road and by finishing the road with a camber that throws the water to either side.

Roads over bogs are often formed on a raft of brushwood or faggots, four to six inches thick and placed at a depth that will not be affected by frost or drought. The roadway is formed over this raft using compacted soil similar in composition to pisé. This in turn carries the "macadam" roadway.

Other common substrata include the use of lime concrete. This can be found in roadways from Roman times to the nineteenth century. In the nineteenth century a change of technique appears. The lime concrete is laid then just at the final stages of drying "macadam" is applied. This creates a strong bond between the concrete and the "macadam" and after rolling or being subjected to traffic for a few days, the remaining coats of "macadam" are applied.

Telford roads take a different approach. The bed of the road is prepared, consolidated and levelled then a layer of hand-set paving is introduced. This may be seven inches thick at the crown of the road and may taper to three inches at the edges. The stones are placed to run lengthwise across the road. All irregularities are dressed off using a mason's hammer and all the interstices are filled with stone chips, firmly wedged or packed by hand using a light hammer. The preferred stone is soft sandstone generally of too poor a quality to use in building. The finish is again "macadam" chips.

Clay thatch over claywall, Aberdeenshire

CLA-RMS

5.05 Thatch

The use of earthen materials in the construction and finish of thatched roofs is widespread in Scotland. The constructional applications include: the use of turf as a sub-stratum; the use of tempered earth or turf as a secret anchorage or fixing for the thatching materials; the use of turf as a thatch; the use of clay or turf for ridging; and the use of clay or turf as a top dressing. All of these techniques and more are discussed in Historic Scotland Technical Advice Note No 4: Thatches and Thatching Techniques: A Guide to Conserving Scottish Thatching Traditions.

6
PUDDLED CLAY

Puddled clay, often referred to as PUDDLE, is perhaps the most useful, ubiquitous, yet least recognised, waterproofing agent in Scotland. Its use as a building material is continuous over at least 5,500 years, particularly in quality structures.

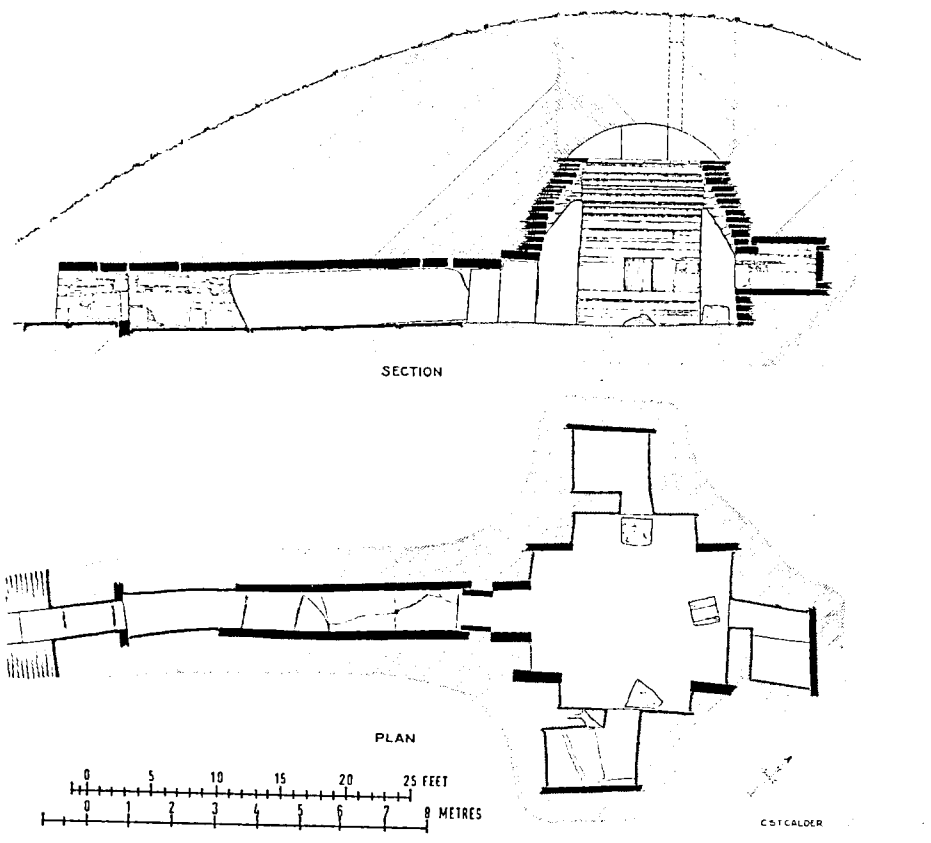
Its use is mainly as a waterproofing material but it could also be used to slide large blocks of stone into position. At Maes Howe chambered tomb, Orkney, the massive stones making up the roofs and floors of the burial compartments are bedded on puddle and puddle is still protecting the outer face of the stone structure from water penetration through the earthen mound. Other tombs in Orkney are protected in the same way, the exception being Wideford Cairn, where archaeologists excavated to the stonework, then replaced the earth covering without the puddle, resulting in a perpetually wet interior.

Maes Howe is also wet internally, but only in warm humid weather, when visitors push waves of warm humid air into the cool interior resulting in condensation on the face of the cold stonework.

Puddle is also used to protect the eighteenth century casemates at Fort George, Ardersier, Inverness-shire. It performs a similar function in medieval to

Maes Howe, Stennes, Orkney 1875

Plan and section of Maes Howe



Fort George, Ardersier, Inverness-shire. South flank from south-east bastion.

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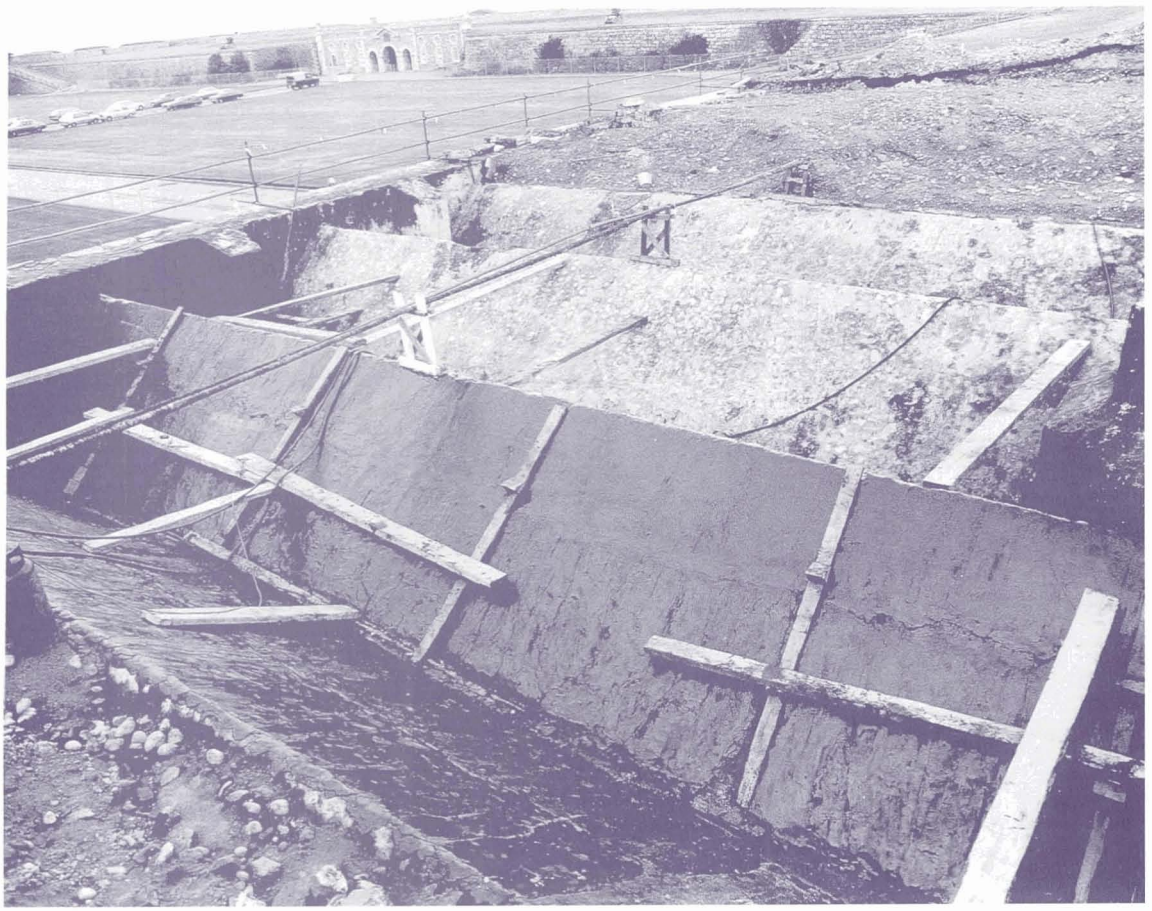

Exposed casemates in south flank wall, showing puddled clay being replaced with asphalt.

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South east bastion from over principal gate.

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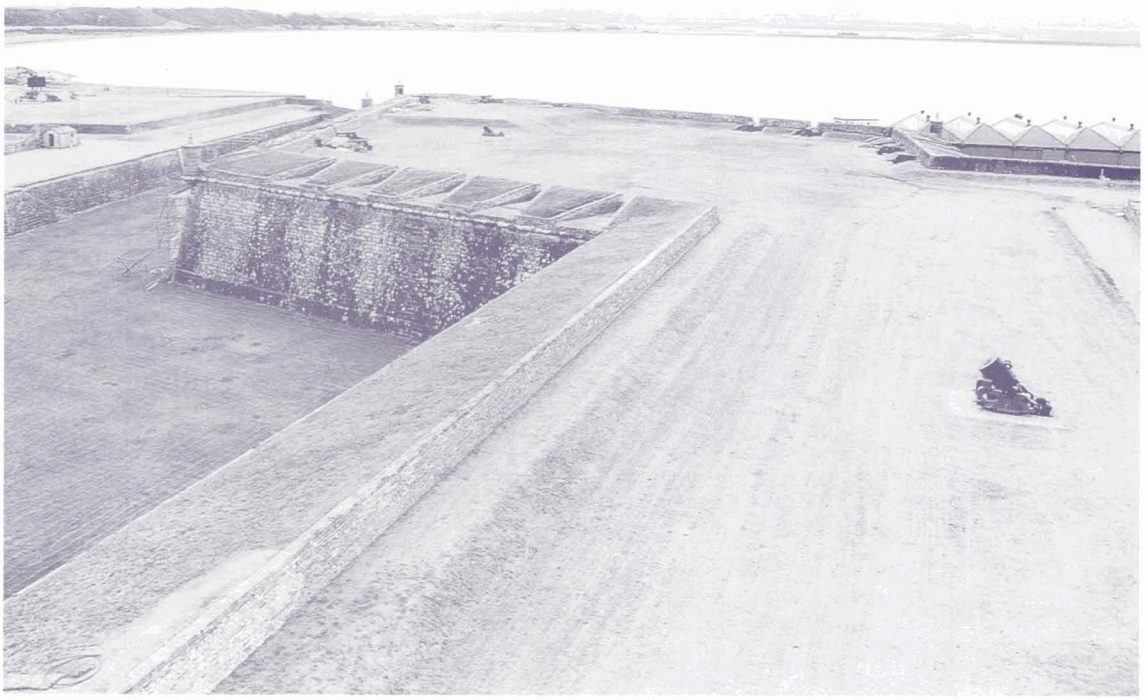
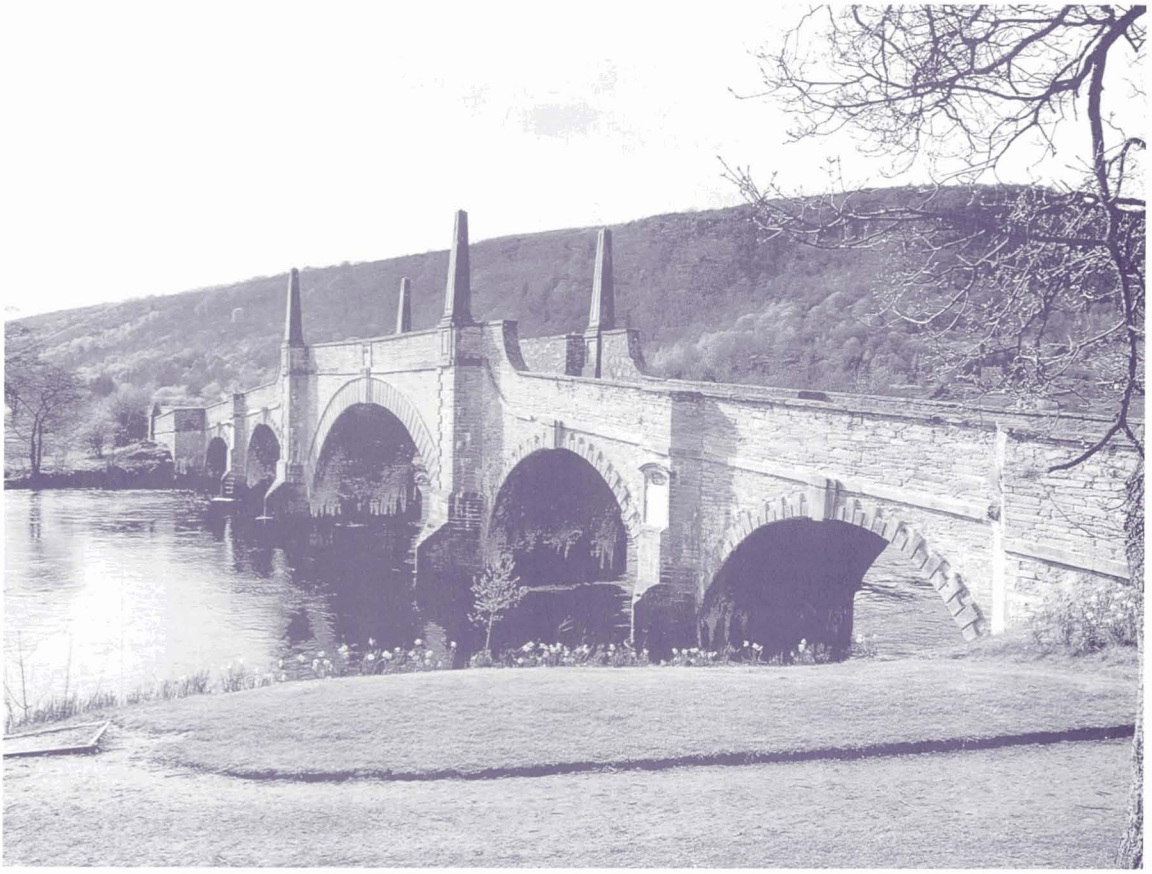


Wade bridge, Aberfeldy, Perthshire. Bridges of this type have puddled clay under the roadway, at the back of the masonry arches and spandrels. Damage to this clay is evident from the limescale visible under the arches.

© RCAHMS



twentieth century masonry arch bridges where it is applied to the back of the arches and spandrel panels in addition to waterproofing the road deck. It is used on the earth side of retaining walls and as a waterproofer in artificial-ponds, cisterns, dams, reservoirs, wells, aqueducts, canals, conduits, flood-barriers, docks, harbours, sea-walls and many other purposes.

The modern application of puddle to engineering projects is accredited to James Brindley who developed a method of mixing pure clay with a proportion of sand which was wetted and kneaded until it becomes a completely leakproof lining, provided it is kept in a wetted condition. It is likely therefore, that some of the puddle walls referred to by Stephens and Brown, and other writers have more tempering or some other additive to prevent structural cracks on drying out. The traditional method of laying is to "heel" the mixture.

It is totally impracticable to attempt to consider the whole range of applications in a publication of this type as there are many sophisticated engineering considerations that may require specific knowledge, calculations and tests. Sufficient therefore to consider these structures that would fall outwith the normal specialist engineering categories. However, it must be stressed that all professionals and operatives involved in the repair or conservation of structures of this type, must be made aware of the importance of puddle, how to recognise it, how to protect it, and how to repair it should damage be inevitable. Failure on any of these counts can be costly either in terms of disfigurement, as moisture passes through the facework causing stains or limescale, or more critically in structural or constructional failure, when dealing with water-retaining or water-repelling structures. Such failures can be disastrous in the case of water-retaining structures.

The material also has a second-hand market. An advertisement in the Dundee Advertiser of Thursday, November 10, 1825, reads:

> "SALE OF CLAY
>
> The clay used in forming the coffer dam at the entrance lock to the harbour, will be sold by private contract.
>
> The Harbour Commissioners will lay the clay down on the quays; and the purchaser will be bound to remove it as fast as it is laid down ....."

6.01 As Water Repellent

Puddle can be applied to the exterior of any earth-sheltered structure to prevent water penetration into the interior. Chambered tombs, souterraines, casemates, underground chambers, tunnels and basements are all obvious candidates. In most of these cases the puddle is applied as an external render, then immediately covered to prevent its drying out and subsequent cracking which renders the puddle useless. It is also used to prevent surface-water penetration into cisterns, conduits and wells especially when these are in close proximity to livestock, middens or other effluent. This is particularly important in wells still used to provide drinking water. The principle is that the drinking water in the well rises from a bore hole in the bottom of the well and that the outer face of the sides of the well is encased in puddle to prevent sub-surface or field-drainage water from entering the well and contaminating the water supply.

Road surfaces and railways, particularly those crossing masonry-arched bridges or viaducts are normally waterproofed with puddle. This waterproofing prevents the structure filling with water. The early bridges of this type are normally: hump-backed, ensuring a steep slope on either approach to encourage the water to run away quickly; inclined across the bridge, giving the same effect; or where the roadway is level, the gutters to either side of the carriageway discharge through drains or gargoyles. Recent changes, to reduce the risk of long vehicles grounding on hump-backed bridges has often resulted in the scraping away of the original puddle waterproofing layer. The asphalt laid in its place is not fully waterproof and this has allowed the earth core in the centre of the bridge to saturate with water. The core is normally a tempered earth and therefore structural in itself but when soaked over a long period of time, reverts to its soil condition with a normal angle of repose. This changes the function of the spandrel panels from being purely a facing to being a form of retaining wall - a function for which they are not suited - with subsequent failure. Early warning of this failure can be obtained from the sudden appearance of limescale leaking from lime mortar joints as surface water penetrating the road deck finds its way between the earthen core and the spandrel panels and stone arch.

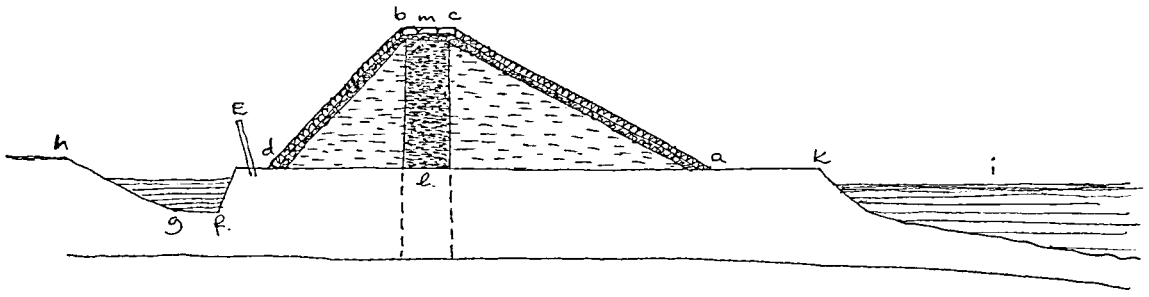
Frank W Macey gives the following specification:

> "The outside of all walls, tanks, cess pools and arches, or other brickwork in contact with the soil, is to be puddled round with well kneaded clay puddle, nine inches thick."

6.02 As Water Containers

Puddle can be applied to a porous surface to make it contain water although it is much more practical to use it in a composite structure designed to protect the puddle from drying out and consequently cracking.

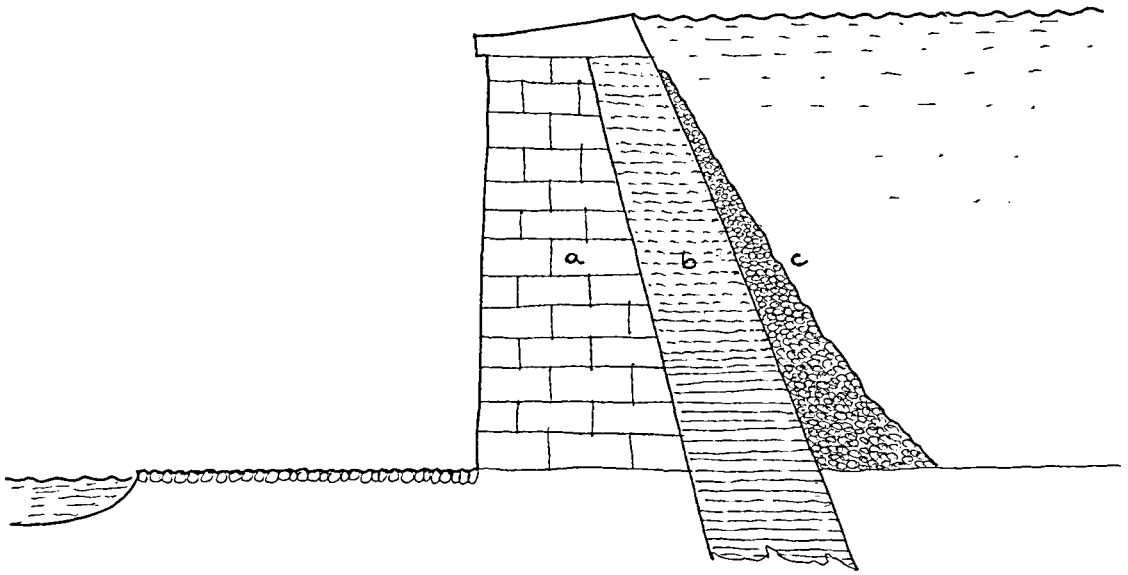
Section through river embankment with central puddle wall.



Stephens and Burn illustrate this in the design for a river embankment as recommended by a Mr Johnstone, for low ground on the side of rivers.

> "The slope of the embankment towards the river from a to c should be longer than that of the land side, as from b to d. The base of the embankment, as a d should be three times its height, as l m; the width b c at the top one-third of the height l m. The distance of the foot a of embankment from the river, as the distance a k, is shown in the figure at 10 feet; and all trees, brushwood, etc should be removed from the space, as these may shake the earth and render it loose, and give admission to the water. The earth to form the embankment should be taken from the land side, none from the river; this obviates the necessity of breaking and loosening the surface next the river. The earth may be taken from adjoining heights, or from the ditch h g f, which is formed at the back of the embankment, to lead the surface water from the field. A paling or fence e should be put up at the outer side of the scarcement d e, to prevent cattle from going up and trampling upon the embankment, until it be consolidated and well swarded. The slope of the embankment in this case is supposed to be covered with grass turf; but, in the absence of this, a stone facing may be adopted.
>
> The body of the embankment may be formed of the earth in the immediate neighbourhood, care being taken to beat it well down; but for better security, and to prevent all leakage - which in time endangers the stability of the embankment - a puddle wall should be placed in the centre as shown l to m.
>
> Some writers state that, in founding the embankment, all that is necessary is to remove the turf from its site; it is obvious, however, that this only holds where the subsoil is impervious and retentive. If it is light and porous, admitting the water easily beneath the embankment, it is absolutely essential to make a complete union between the subsoil and the lower courses of the embankment. This will be best effected by sinking a trench the same width as the puddle wall and continuing this down to an impervious layer. The embankment on either side resting on unturfed soil.
>
> As the stability of the embankment depends upon the thorough incorporation of the mass of earth which forms it, no pains should be spared to secure this. The materials should be placed down in thin layers, and each well rammed down before the next is superimposed ... It is recommended that embankments be formed of alternate layers of earth, clay, or other soil, with small stones or gravel, forming a species of artificial puddling stone. The great point to attend to is securing the materials from the attacks of rats and other vermin ... Care should also be taken to preserve throughout the embankment the proper slope or angle of its sides; to ensure this, a wooden template or mould should be made to guide the workmen in laying down the materials.
>
> In exposed situations the river-side will be most effectually protected when a stone facing is employed. This facing may be made thus: over the whole of the river-slope place a layer of broken stones, not less than eight inches deep; ram these well down. Over this rubble-stones are laid, and continued upwards beyond the line where the waves dash at their heighest: if carried over the top and down the land side, the embankment will be secured from the ravages of vermin. This, however, will be so expensive, that it will be sufficient to stop the stone facing near the top of the river-slope.
>
> To secure a good bond between the stones of the facing, piles or short stakes are driven into the face of the slope at intervals, and a row close together at the bottom line."

Puddle can also be used under a facing of stone or turf to improve the water resistance qualities of the face of the embankment.



Masonry dam protected by puddle.

Masonry dams can also be protected with puddle. The section shows a stone dam, taking the force of water against a convex plan form.

> "The top of the wall must be exactly level throughout its whole extent, so that the water, in times of flood, shall go over the weir in a stratum of equal thickness, and so prevent any undue action on one part more than another, which would be the case if this precaution was not taken. The top should be provided with a coping of flat stones, projecting slightly over the face of the wall.
>
> To prevent the action of the water on the upper face of the wall, a layer of clay should be well rammed down against its whole height and length. This clay should extend lower than the foot of the breastwork. An apron of gravel c thrown down before the clay, presenting as great a slope as possible, will still further prevent the action of the water on the dyke."

Puddle is also used in the base of some dams and in most canals. The exact thickness used varies according to the soil or rock types being traversed. The base layer of puddle in a canal passing through clay lands or reasonably impervious rock can be quite thin. On porous rocks or sands the base might be formed with a masonry skin used in conjunction with up to thirty inches of puddle.

In repairs to one section of the Caledonian Canal the puddle was used in conjunction with woollen cloth laid along the damaged bank.

Smaller watercourses are often protected by driving a series of alder poles "in the round" into the clay at the base of the waterway. These are restrained at the head by a horizontal pole and tied back to the bank. The space behind the poles is filled with clay or marl rather than puddle. This type of arrangement, with either vertical or inclined poles, can be seen in the pows of the Carse of Gowrie, Perthshire.

6.03 As Damp-proof Course

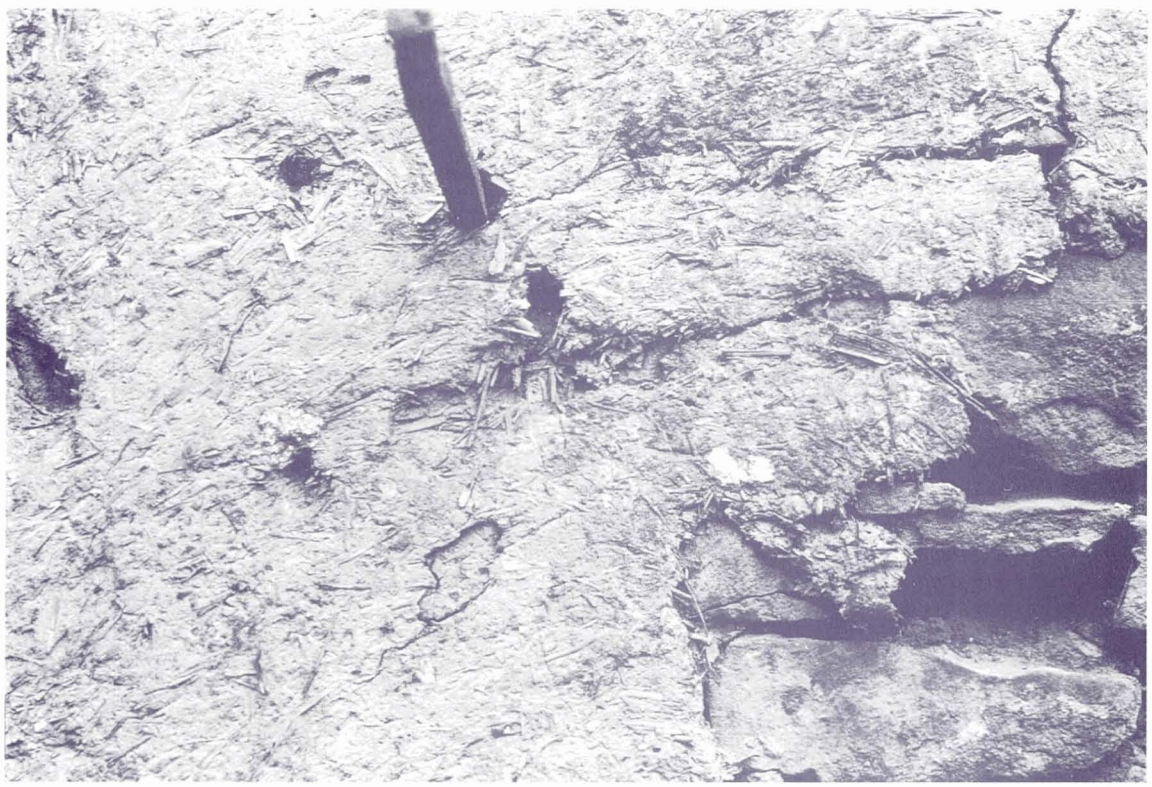
A layer of puddled clay can serve as a damp-proof course provided it is used in a position where it is unlikely to dry out. That is, where one side remains consistently damp. Puddle is normally an extremely fine material lacking any form of tempering (see above for exceptions) and it is these characteristics that make it efficient when wet but subject to severe shrinkage and cracking when dry.

Experiments are required to establish whether a light oil could be used to replace the water in the clay. This appears to be feasible as many African countries pound up vegetable matter to produce an oily additive to external renders. Similarly, linseed oil is known to have been added to Scottish earth renders and there is an obvious oil presence in 'blue clay' found at the bottom of peat bogs and often used for weatherproofing purposes.

7
PLASTERS AND RENDERS

Clay plaster is common in pre-nineteenth century houses of all categories and its use continues into the twentieth century in small farm, croft and cottar houses. One of the earliest written references to the term CLAYING - meaning 'plastering with clay' is recorded in the Accounts of the Masters of Works for Building and Repairing Royal Palaces and Castles 1646-1649 as edited by Imrie and Dunbar. The early eighteenth century House of Gray, Liff and Benvie, Angus, has a ground coat of clay plaster under two

Jericho, Glamis, Angus
Clay Plaster



coats of lime plaster. This does not appear to be a local idiosyncrasy as the practice is well known in Hampshire mansions of this period.

Clay renders have been located in the National Trust for Scotland mudwalled school and schoolhouse at Cottown, St Madoes, Perthshire, but literary references suggest that the practice was widespread. This would confirm a parallel with the northern European nations and Scandinavia. In Norway, earth-based renders were applied to the exterior of log structures whilst in Denmark, the Netherlands, Belgium, France and Germany, earth-based renders are reasonably common on historic structures.

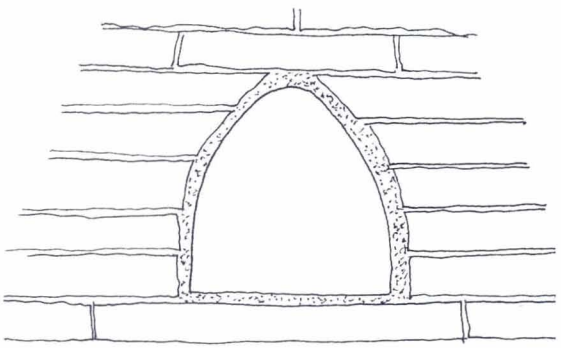
Kennels Cottage, Cromarty, Ross-shire Clay Plaster

A red clay and straw external render still survives at 5 Place de Mesdames, Remiremont, Haute Vosges, France. This was first noticed in 1991 at a time when the limewashed surface had only just broken and the clay was exposed. Now the water has penetrated behind the clay and the render is breaking away from the wall. The render is approximately 12 mm thick and appears to have been applied as a single coat. It is finished in places with what appears to be a skim coat of cow sharn -excrement without the straw that would make it dung. This treatment is also known in Scotland on clay thatched roofs where it is used to provide a tough waterproof skin. The whole wall is finished with yellow ochre limewash.

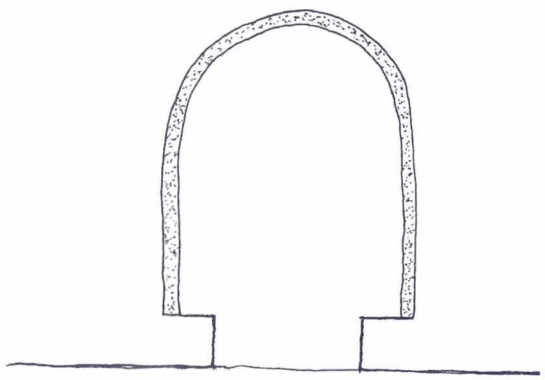
The wall described above appears to have been part of an internal courtyard to the "Maison Canoniage de Madam la Comtesse Anne - Eve de Ferrette Dame-Secrete du Chapitre XVIII eme Siecle". The courtyard appears to have been destroyed when a road was pushed through between this house and the Palais Abbatail, now the Hotel de Ville.

7.01 Tempering

The clays used in plastering are tempered in the same ways as mudwall and pisé mixes but the coarse aggregate is omitted and any straw, hair or other binding material is chopped into short lengths before being added to the mix.



Clay render to interior of oven. Cubbie Roo's Castle, Wyre, Orkney



7.02 Additives for wearing and decorative purposes

Vague references to the addition of linseed oil or tallow to clay plastering or rendering materials have been located but no specific details have emerged.

7.03 Application

Both clay- and lime-based renders are used on clay walls. These are not the thick cementitious renders applied to all Scottish buildings since the late nineteenth century, but thin single- or two-coat work.

Stephens and Burn give some hints on the external rendering of clay buildings.

"The outside walls of pisé houses are finished in two ways, these are roughcast and stucco. Rough-cast consists of a small quantity of mortar diluted with water in a tub; to this a trowelful of pure lime is added, so as to make the whole the thickness of cream. To finish the walls with greater expedition, the joist holes may be left not filled up; into these, joists may be inserted, on which to place scaffolding to bear the operatives. The walls are prepared for plastering by indenting them all over from top to bottom with numerous hammer or pick marks: the closer these are to each other the better. The rough-cast is laid on as follows: the indentations in the wall being first carefully swept, the wall being sprinkled with water, the workman takes his brush filled with rough-cast mortar and dashes it against the wall. The indentations in the wall give the appearance of the ordinary rough-cast with pebbles in it.

The scaffolding being placed at the top of the wall, he lowers his scaffold, takes out the joists, fills up the holes with bricks, mortar, etc and fastening his scaffold lower down, proceeds as before."

Roughcast of this type might be referred to as a lime or clay slurry as, after it has been lime washed several times it takes on a flatness normally associated with a "bag-rubbed" finish. Some of the roughcasts recorded appear to have been formed using a dark-brown thin mud render. The dark brown colour suggests the presence of oil and references to adding linseed oil to render mixes have been located. Samples of this type of render have been removed from Cottown School and Schoolhouse, St Madoes, Perthshire and are being analysed but as yet no report has been received.

Stephens and Burn describe stucco, for outside work on pisé walls, as being made with one bushel of unslaked lime to six bushels of clean sharp sand.

"Stucco-finishing is laid on as follows: The walls being previously indented, swept and sprinkled with water, the workman places some mortar on a flat piece of board 12 inches square, provided with a handle, and with a plastering-trowel lays this on the wall, pressing it closely between the indentations, and working the surface, finally, fair and level, it being sprinkled at the same time by means of a brush with some of the thin mortar, - the poorer the mortar the better the stucco. Lime-wash is used as a final covering to the stuccoed wall. This is made by dissolving some unslaked lime in clear water, and sprinkling it on the wall before the stucco is dry. When applied in this manner the stucco sets very hard, and the white colour of the wash is so incorporated with it that it will never wash off, although no size or oil is used - indeed, the using of these renders the white dead and less brilliant; whereas, if the lime-wash is alone used, the colour will remain naturally as long white as the plaster lasts. All plastering should be done at one time: new plastering never sets well with old. If this is not attended to, the plaster will inevitably scale and blister off, leaving unseemly spots."

When rendering stone or brick faced pisé the technique changes.

"First wash the earth from the gravel or coarse sand, and bring it to a uniform size by sifting it, or passing it through a screen; mix the gravel with newly-slaked lime and water to the consistence of thick cream. Having cleared the part of the wall to be operated on with a rough brush, a coat of lime and hair is laid on smooth, and, as fast as some two or three square yards are finished, the rough-cast is thrown upon it. Some recommend the first coat of lime and hair to be allowed to dry, and a second coat put on, upon which the roughcast is finally thrown. Instead of throwing the rough-cast on, small pebbles may be stuck in the mortar while yet in a soft state. This, however, is a tedious process."

Tedious or not the technique was at one time reasonably common, particularly in the coastal communities where shells were used in conjunction with pebbles to create a decorative finish. The "buckie house" on the corner of the street opposite Anstruther Wester Parish Church, Fife is a typical example.

Loudon adds a little detail to the roughcasting technique described above.

"Plaster over the wall with lime and hair-mortar; when this is dry, add another coat of the same material laid on as smoothly and evenly as possible. As fast as this coat is finished, a second workman follows the other, with a pail of roughcast, which he throws on the new plastering. The materials for roughcasting are composed of fine gravel, reduced to a uniform size by sifting or screening, and with the earth washed cleanly out of it; this gravel is then mixed with pure new slaked lime and water, till the whole is of the consistence of a semi-fluid: it is then forcibly thrown, or rather splashed, upon the wall with a large trowel,

which the plasterer holds in his right hand, while in his left he has a common whitewash brush. With the former he dashes on the roughcast, and with the latter, which he dips into the roughcast, he brushes and colours the mortar and roughcast that he has laid on, so as to make them, when finished and dry, appear of the same colour throughout."

7.04 Finishes

Specific finishes aimed at imitating grander construction are sometimes attempted in small earth-built cottages. Loudon claims that this is usually achieved by painting lines on the finished wall or by the use of coloured paper. Both have been recorded but at Maji Cottage, Avoch, Ross-shire, lines representing wainscoting panels are inscribed into the thin clay plaster forming the finish to kebber and motte partitions.

Loudon comments:

> "Whitewashing and colouring the inside walls and the ceilings of cottages should not be attempted till they have dried at least a year. If the plaster be of the commonest kind, without a finishing coat of stucco, it is only adapted for water colours, or colour rendered tenacious by glue, paste or other mucilaginous matter instead of oil; because of its porosity, which would wholly absorb the oil. The most common colouring for cottage walls is what is technically called lime-whiting, which is nothing more than the finest particles of lime or chalk mixed with water, with the addition of a small quantity of size. The colour of this is varied by the addition of black of charcoal (commonly called blue-black, as distinguished from the soot of lamps, which is called lamp-black), or by yellow ochre, by verdigris, or any cheap pigment."

To paint plasterwork Loudon recommends:

> "White lead and linseed oil, with a little litharge to facilitate the drying, are mixed together to about the consistence of thin cream; a coating of this being applied, the oil from it is soaked into the plaster in the course of a few hours, leaving the white lead apparently dry upon the surface. In the course of a day or two, when this coat has sufficiently hardened, another is given a few degrees thicker, the oil from which is partially absorbed according to the nature of the plaster. In the course of a few days more a third coat is applied. This coat is made pretty thick; and if the absorption of the oil from the second coat has not been great, about one fourth of spirits of turpentine is added; but when the absorption has been great a less proportion of the spirits of turpentine is employed. Into this coat are put the colouring ingredients, to bring it as near the shade intended for the finishing coat. Should the plaster now be thoroughly saturate, the flatting or finishing coat is applied; before this is done, however, a fourth coat, thinned with equal proportions of oil and spirits of turpentine, is generally given, particularly when the work is wished to be of the most durable kind. The flatting or finishing coat, is composed entirely of paint, that is, of white lead and the colouring ingredients mixed together, and ground in oil to an impalpable paste. This mixture is of a very thick consistency, and must be thinned with spirits of turpentine until it will flow easily from the brush. The spirits of turpentine, being very volatile, evaporate entirely, leaving the surface of the paint of a very compact and hard nature. By this process, the plaster is rendered incapable of absorption; and the surface of it is hardened by the oil which it has sucked in from the first and second coats, and is thereby rendered less liable to breakage, with the great advantage of being washable."

A similar specification using boiled-oil as a primer was still being used by fishermen painting the exterior of their houses in the 1950s.

Stephens and Burn give a number of similar recipes for oil paints but suggest a more durable paint for the outside walls of cottages.

> "Take freshly-burned unslaked lime, and reduce it to powder. To one peck or bushel of this add the same quantity of fine white sand, or fine coal-ashes, and twice as much fresh wood-ashes, all of these being sifted through a fine sieve. They should then be thoroughly mixed when dry. Afterwards mix them with as much common linseed-oil as will make the whole thin enough to work freely with a painter's brush. This will make a paint of a light-grey stone-colour, nearly white. To make it fawn or drab, add yellow ochre and Indian red; if drab is desired, add burnt umber, Indian red and a little black; if dark stone-colour add lamp-black; or if brown stone, then add Spanish brown. All these colours should of course be mixed in oil, and then added. This paint is very much cheaper than common oil-paint. It is equally well suited to wood, brick or stone. It is better to apply it in two coats - the first thin, the second thick."

7.05 Pargetting

There is no evidence for decorative pargetting in Scotland and the term tends to be applied to a plastic form of flue lining made with a mixture of clay and dung and applied to the sides of the flue as the flue is built.

Earlier canopy chimneys would be pargetted from within the flue as there was normally sufficient space for a man to work.

8
EARTHEN COLOURING AGENTS

At the end of the eighteenth century Scotland still retained the tradition of painting trade symbols on the outside of the buildings. Dorothy Wordsworth liked this and comments:

> "One thing that was like Germany pleased me: the shopkeepers express their calling by some device or painting: bread bakers have biscuits, loaves, cakes painted on their window shutters; blacksmiths horses shoes, iron tools etc. etc. and so on through all trades."

Edward Topham, another English reporter, writing about Edinburgh in 1774 takes a different attitude:

> "The merchants ..... have the horrid custom of painting on the outside of their houses, the figures of the commodity which is to be sold within: which in this place, makes the oddest appearance you can conceive: for each storey perhaps from top to bottom, is chequered with ten thousand different forms and colours: and the whole resembles the stall of a fair, presenting at one view the goods of several shops. They are likewise remarkably fond of glaring colours; as red, yellow and blue on which the figures are painted in black.
>
> You would laugh to see a black quartern loaf directly over a black full-trimmed periwig of a professor, with a Cheshire cheese, and a rich firkin of butter, displayed in black greasiness under stays, petticoats, and child bedlinen."

All of this is lost, although some fragments of paint may be retrieved particularly where a former external wall is now internal: but in country districts simple colouring agents were the norm. Various natural additives, some of them types of earth, are used to colour limewashes, paints, renders and plasters, used in conjunction with earthen structures.

8.01 Ochre

Ochre is a mineral of clay and hydrated ferric oxide, used as a pigment for all types of colour wash and paint. The colours vary from light yellow to browns and deep red. A strong yellow variety is found in Fife, relating to the coal seams and an ochre mine and grinding mill, still survive in Leven Glen Country Park, Scoonie, Fife. This is now a tourist attraction but at the time of the New Statistical Account for Scotland published in 1845, ochre is noted as an export material.

Yellow ochre appears to have been the most widely used colouring agent for Scottish limewashes and archive sources record its use from the sixteenth century onwards. This does not preclude its earlier use but simply reflects that records are not available.

Although the ochre used, as a general colouring agent, appears to have been sourced locally, there is an international trade in pigments for use by artists and painters. Early records of this trade have not been located but the firm of Moxon and Carfre, Painters and Colourmen, in Edinburgh specialised in grinding pigments. A Memorandum Book of 1831 records "Oxford Oker", "New Vein Oker", "Dutch Oker", Foreign Oker", "French Oker" and "Derby Oker" in the raw materials being handled.

8.02 Copperas

Copperas is the name applied to green iron-sulphate crystals which, when added to limewash, turns the liquid a duck-egg blue. The limewash on drying turns orange, the more crystals of copperas used, the stronger the colour.

8.03 Ash

The use of ash in making paint has been discussed in item 7.04 but its use as a colouring agent is particularly interesting.

The following information was obtained from an 87 year old crofter, Neil McVicar at Grimsay, North Uist on 4 May 1988. The interview was carried out in Gaelic by Donald Archie Macdonald and Roger Leitch of the School of Scottish Studies, University of Edinburgh and was concerned with thatching techniques. Towards the end of the interview Mr McVicar introduced the topic of peat for fuel and the use he made of the ash from a particular source of peat - "Cnoc dubh nan Cleibh" - the black hill of the creels.

N McV "..... and the ashes from Cnoc na Cleibh were red, like lead paint. I used this ash for painting the wheels, the trams and the sides of the cart - red lead."

D A McD "Was it as red as that"

N McV "It was just like red-lead paint - the ashes were. You let the lightest of it away and then add oil to it and it was excellent."

"Another use we had for it was to put it on the cattle for beasts, for killing off lice. You put it on your fingers, parted the animals hair and rubbed it on."

D A McD "Have you actually done this?"

N McV "Yes, many times - there must have been some kind of mineral in it. We painted the carts every summer."

Many other local variations of this type must have existed and opportunities must be taken to sample and analyse all forms of vernacular paint.

8.04 Oil

Some clays, such as those from the bottom of peat bogs, contain natural oils. Fibrous materials such as peat and turf from peat bogs, also contain these oils. On drying, the oil creates a waterproof skin that prevents these materials returning to their semi-plastic state, thereby improving their performance as building materials.

Where these naturally oily clays are not available, the performance of floors, plasters and renders can be improved by the addition of oil. The normal oil used comes from linseed oil that has been boiled or even twice-boiled prior to use.

8.05 Blood

Blood is commonly referred to as an additive to clay floors. This apparently helps the binding process; stops or reduces, dusting; and changes the colour to a dark brown or black according to the quantities used. This has still to be tried and the results of any experiments will be published independently or in the next edition of this publication.

Tulloch's Philosophical Magazine (pre 1806) recommends the addition of the "serum of blood" to lime or whiting, and the required pigments, as a binding agent.

8.06 Tallow

Tallow is often added to whitewash. This is found mainly in cellars, roof timbers, sheds and walls in common work, either internally or externally. The mix normally comprises "white fat lime, Russian tallow and water".

Tallow is also mentioned in connection with some clay mortars and renders but further investigation is required before positive statements can be made.

8.07 Buttermilk

Stephens and Burn describe a type of paint made with lime and buttermilk as follows:

> "A paint which dries quicker than oil paint, and has no smell, may be made of milk and lime as follows: Take of skim-milk nearly two quarts, of fresh-slaked lime about six ounces, of linseed oil about four ounces, and of whiting three pounds: put the lime in a stone vessel, and pour upon it a sufficient quantity of milk to form a mixture resembling thin cream: then add the oil, a little at a time, stirring it with a small spatula; the remaining milk is then added, and lastly the whiting. The milk must on no account be sour. Slake the lime by dipping the pieces in water, out of which it is to be immediately taken, and left to slake in the air. For fine white paint the oil of caraway is best, because colourless, but with ochres, the commonest oils may be used. The oil, when mixed with the oil and lime, entirely disappears, and is totally dissolved by the lime forming a calcareous soap. The whiting or ochre is to be gently crumbled on the surface of the fluid, which it gently imbibes, and at last sinks: at this period it must be well stirred in."

A version of this technique was recorded by Anne Kahane in Argyll.

> "In the early years of this century, my mother's family camped every summer somewhere along the coast between Glennan and Ascog Bays, on the east side of Loch Fyne. Mrs Taylor at Low Stillaig used to use buttermilk (I understand, instead of water) to mix up the limewash.
>
> There was some suitable clay nearby which Mrs Taylor added to the mixture to give a pleasant primrose yellow colour to the walls."

8.08 Other Pigments

A wide range of other pigments is recorded including adding certain lichens to quicklime before it is slaked. The slaking process apparently driving the pigment out of the lichen and into the lime. The pink coloured harl and lime wash of central areas of Scotland are the result of this process.

The most common additives are a range of "blacks" used to change the tone of a limewash or colour-wash. These comprise: "lamp-black" either specially prepared, or used in its raw form, as soot from oil lamps: "ivory-black" correctly made from calcined ivory but occasionally incorrectly used to refer to good quality lamp black: and "blue-black" made from charcoal. Obviously in poorer households any form of soot can be used for the same purpose.

Other earthen materials such as: "sienna" a ferruginous earth used "raw", to produce a brownish-yellow or "burnt" to produce a reddish-brown: or "umber" a natural pigment like ochre but darker and browner, used "raw" for a dark yellow colour, or "burnt" to produce a deeper and redder colour. Because these are imported materials they do not have the same impact on limewashes and house-paints.

Stephens and Burn give a number of other recipes:

> "A cheap lime wash can be made by slaking fresh quicklime with boiling water and adding some

sulphate of zinc - sufficient water being put in to bring the whole to the consistence of cream. The addition of sulphate of zinc tends to harden the wash, and make it more durable. The addition of a little sulphate of iron will give the wash a warm tint, which will be much more agreeable to the eye than the pure white resulting from the above."

Not all the recipes given are for vernacular structures. They include: the whitewash used to coat the White House in Washington, USA; various oil paints for both internal and external work; and varnishes.

9
CONSERVATION ISSUES

The science of the conservation of earthen structures is still in its infancy in Scotland. A number of conservation projects have been undertaken and much has been discovered about the capabilities and performance of the materials in a conservation context. However, a great deal more has to be done before this section can be developed to provide authoritative guidance.

The work that has been undertaken to date is based on what we know of Scottish earth buildings and the conservation of earthen structures in other parts of Europe. The principal sources are the CRATerre-EAG publications from the International Centre for Earth Construction and School of Architecture in Grenoble. Much of this information has been brought together in a single volume by Hugo Houben and Hubert Guilland. Originally published in 1989 as *Traite de construction en terre de CRATerre* it is now available in English as *Earth Construction: A Comprehensive Guide* Intermediate Technology Publications, London 1994 (ISBN 1 85339 193 X). Current English practice is explained by Gordon Pearson in *Conservation of Clay and Chalk Buildings*, Donhead, London, 1992 (ISBN 1 873394 00 4), and by Larry Keefe and others of the Devon Earth Buildings Association.

Ideally all repairs should be on a like-for-like basis, the operative ensuring that the mix used for the repair is as close as possible in :clay type:aggregate size and proportion; and type and proportion of additives, to that used in the original wall. This is not easy as we are dealing with materials that often vary at source and are mixed by operatives using their intuition and experience to determine the final mix. As a result the mix varies even within the same "lift" of a wall. This is often pronounced enough to be recognised with the naked eye, particularly where the quantity of larger aggregate or vegetable fibre is increased, decreased or inadequately mixed.

The replication of the original mix is not the only problem. Most forms of earthen wall are homogeneous and even, assuming that an exact replication of the original mix can be achieved, the initial shrinkage of the new material can destroy the bond between new and old.

Prior to commencing any repair, it is absolutely essential to establish the cause or causes of the damage and to take appropriate action to prevent a recurrence of the problem.

Any form of earth wall, or earth fill, that is used structurally will be weakened by the presence of dampness. Care must be taken to ensure that: the wallheads or upper surfaces of the structure are waterproof; that all external skins, renders, plasters and paints do not form impermeable barriers that trap moisture within the wall (similarly impermeable flooring materials and skirtings can cause rising damp); that materials are not heaped against the lower surfaces of the walls; that there is no vegetation growing from, or clinging to, the face of wall; and that surface water is drained away from the building.

Other problems can result from the thrust of a weak roof structure, movement in the foundations, flood damage, pest damage, abrasion, erosion, and to a lesser extent impact.

In every case the aim should be to eliminate the cause of the problem, then to repair on a like-for-like basis, avoiding all forms of intrusive intervention.

9.01 Vegetation

All forms of vegetation growing from the surface of the wall are potentially hazardous and should be removed. Small soft-rooted plants can only grow if the wall is retaining moisture. The source of this moisture should be eliminated and the plants killed off with an approved weed killer.

Woody plants growing into the wall or foundation, should be cut back and the roots poisoned. Rot in the root system caused by this action may have to be cut out at a later date and repaired using one of the techniques described in items 9.08 and 9.09.

The woody plant most likely to cause problems is ivy. The foliage should be carefully cut back close to the wall and the remaining foliage sprayed with an approved weed killer. After the leaves turn brown the remainder of the ivy including the woody stems can be carefully cut away exposing the surface of the wall. Surface damage can then be repaired as can any damage caused by particularly large sections of root, rotting in the wall. It may take some time to finally eradicate the plant but it is essential that this is complete before renders and finishes are applied.

9.02 Pests

The most common pests are rats, mice and bees.

Rodent damage is normally associated with some form of weakness in the walling and the presence of unthreshed grain or other foodstuff in the mix. Pisé mixes are normally unaffected whereas mudwall mixes containing unthreshed or partly threshed seed-heads of cereals are the most vulnerable.

Before commencing any work on rat-holes and rat-runs it is essential to plot their extent. Ensure that all loose debris is removed and that all fill material is properly consolidated. Runs along the surface of the

wall behind impermeable plasters or renders can be dealt with using earth-block repairs as described in item 9.09. Tunnels that are accessible to the operatives, working on site, can be filled using well compacted plastic repairs as described in item 9.08. Runs that cannot be reached in any other way can be filled using a low pressure or gravity fed grout with as low a shrinkage co-efficient as possible. Since these runs are normally in the core of the wall, the hardness of the grout in relation to the surrounding mix is less crucial.

Should there be any doubt about the stability of the wall it is essential to provide adequate shoring during the consolidation process. Impermeable mixes should never be used in positions where they may trap water and cause an accumulation of dampness. In cases such as these professional advice should be taken, but only after ensuring that the professional understands the principles of earth building.

Masonry bees and other types of non-communal bees make individual bikes by burrowing into the face of earth walls. This seems to be a particular problem when the mix used for the wall has been damaged by frost. The holes can be filled using an earth render. Only one building in Scotland is known to have been severely affected by masonry bees. It stood in School Road, Errol, Perthshire and the south facing gable was covered with bee burrows. The problem appeared to stem from the use of an impermeable render on this gable with subsequent build up of dampness behind the render, weakening the earth mix. On the collapse of the render the weakened surface attracted large numbers of bees. This probably took place over a number of years but in a neglected property no attempt was made to curb the activities of the bees. The burrows in turn allowed ingress of water in winter and subsequent frost damage followed by further attacks by bees the following spring. Eventually the property was demolished. The new mutual gable, also earth construction, is rendered and as yet shows no sign of any problems.

9.03 Abrasion

Abrasion caused by animals brushing against the wall or licking the wall surface is mainly a problem in unrendered walls. When it is intended to leave walls unrendered and abrasion is anticipated, masonry or brick skins are often incorporated in the design.

In existing structures, some mechanical device must be introduced to keep animals, tractors, vehicles and people clear of the structure if circumstances change and abrasion is anticipated.

Damage usually occurs quickly after some change in circumstances. A turf gable at Corse Croft, Huntly, Aberdeenshire that was covered with ivy when the croft was purchased, had the ivy removed. The gable was in good condition and remained that way. The field abutting the gable was used for arable purposes, but in 1995, cattle were put into the field for the first time since the gable was exposed. The owner observed that the cattle were all lined up against the gable and on investigating found they were licking the wall as they would a salt block. This caused considerable damage in a very short time.

If the earth wall is to be exposed, anticipation of abrasive sources must be incorporated into the scheme. Rendering does much to eliminate the problem as far as animals and humans are concerned but mechanical devices are still required where vehicles or agricultural machinery pass close to the structure.

9.04 Impermeable Renders, Plasters and Floors

Water coming in contact with the surface of an earth wall may penetrate slightly but will tend to run off and the surface will dry quickly by natural evaporation. Impermeable renders, plasters and floors tend to trap moisture that has penetrated the walls through cracks in the render or contain rising damp that would normally evaporate away. Both scenarios result in the earth wall becoming excessively damp either immediately behind the render or throughout the wall if this occurs at the footings.

Permeable renders such as earth and lime renders enhance the natural performance of the wall by allowing any penetrating water to evaporate through the render in dry weather.

The position at the footings is often more difficult to resolve as many surveyors and building control officers request a damp proof course at this point and a waterproof floor. Improvement of the land drainage round the building may counteract the effect of a waterproof floor but the insertion of a damp proof course should be resisted as it may cause more problems than it rectifies. Most earthen walls are coarsely textured and contain a myriad of shrinkage cracks round the aggregate surfaces. Tests carried out in Devon show "that the vertical movement of moisture in an un-rendered cob wall will not normally exceed 150 to 250mm". The situation does not change if any render that is applied is water-permeable and by dropping the water-table under the building by means of land-drainage a physical or chemical damp-proof course is unnecessary. Not only is the damp proof course unnecessary, but a water barrier at that point could trap water that has penetrated cracks further up the wall, causing dampness to accumulate at the base of the earth wall.

9.05 Site Drainage

The need for improved site drainage has been made in the preceeding item 9.04 in the land-drainage close to the building but surface water drainage should also be considered to avoid any build-up of surface water close to the structure.

On areas of carse land where drainage agreements are in force, it may be necessary to remind adjoining owners of their drainage obligations to prevent flooding on a particular site.

9.06 Joints Between Earth-walling and Other Materials

Earth structures used for domestic purposes often incorporate brick or masonry flues, patching, arrises, or sections of wall. The bond between these materials is normally mechanical being formed by inserting ties into the first-built material and incorporating these into the second-built material. Although this provides a mechanical bond, the initial shrinkage of earth-walling built against an existing brick or masonry structure, must be seen as a weakness and must be handled with care.

Weather-stops may be built into the joint but more commonly the joint may be caulked with a mixture of earth mortar and a binding medium such as hair or flax.

Where a mechanical bond is not present and the walls of different materials have separated, the resultant crack should be treated as a structural crack - see item 9.07.

9.07 Structural Cracks

The tensile strength of an earthen wall can be relatively low and as many of these walls are fully load-bearing, movements in the roof-timbers or the stone plinth may result in structural cracks developing vertically through the wall. Possibly the most common form of failure occurs between the gable and the lateral walls as the lateral walls take the thrust of the roof and the gable carries its own weight. Similar cracks may occur at the corners of piend-roofed buildings if the pien is exerting undue pressure in one direction, usually towards the lateral wall.

Structural cracks should not be repaired until the cause has been established, remedial action taken, and the wall to either side of the crack has stopped moving.

Stitches may then be used to form a mechanical bond between the two parts of the wall. This can be done using pre-shrunk earth blocks or tiles, possibly containing additional fibrous material such as hair, flax or man-made fibre to improve the tensile strength or by insitu plastic repairs incorporating non-ferrous metal or fabric reinforcement. Some authorities suggest that the cracked section be cut out completely, forming vertical faces to either side of the former fissure, and the insertion of an oak shear-key or weather-block into each face prior to rebuilding the removed section of walling using a mix and technique similar to the original. This has the disadvantage that the new panel is subject to the initial shrinkage experienced with all forms of earth construction and may require caulking of the two vertical joints - one at either side of the new section - after the shrinkage has occurred.

9.08 Plastic Repairs

The appearance of earthen walls makes the use of plastic repair techniques seem logical, but the problem of the initial shrinkage of the new material against the already stable old material, makes successful bonding of new to old, extremely difficult to achieve. The use of drier mixes may assist, as do mechanical ties, but the basic weakness is still present.

Mechanical ties may take various forms, the simplest being to insert timber-dowels into pre-drilled holes in the old material, leaving the ends projecting into the cavity to be filled with the new material. Naturally oily woods are less likely to expand and contract with the moisture in the mix but may give less of a key. Each area formerly had its own approach to this problem but this can only be re-established by finding the remains of such fixings in the ruins of earthen structures.

Even allowing that a satisfactory mechanical bond can be achieved by the use of dowels or non-ferrous ties, it is still advisable to restrict plastic repairs to small indentations of no structural consequence or to repairs to wallheads or to other areas where the new material's own weight helps form the bond, rather than depending on the mechanical ties. This may still result in shrinkage cracks either on the line of the joint or slightly into the repair.

9.09 Earth-block Repairs

Earth block makes an excellent repair material for badly eroded or damaged earth walls. The problem of initial shrinkage is removed by pre-shrinking the blocks. The blocks can be made to a mix that matches the wall to be repaired. The eroded or damaged areas can be cut out to a rectangular section and the blocks can be inserted using tight earth-mortar joints. The skill lies in the careful cutting of the eroded section, the dampening of the surfaces to be bonded, and the tight fit of the indented blocks.

See item 10.05 Cottown, St Madoes, Perthshire.

9.10 Permeable Plasters and Renders

It is important that all renders and plasters be permeable to avoid any entrapment of water behind the render or plaster, where it could affect the structure of the earth wall.

Arguments have been put forward in the past for impermeable renders and plasters. In theory, this appears to be logical but unfortunately, even the slightest hair crack can allow water to penetrate, particularly when assisted by wind pressure, but the water then disperses behind the impermeable surface and cannot escape. The result is an ever increasing amount of water at the base of the wall. This softens the wall mix till it loses structural integrity and either sheds the render or fails structurally.

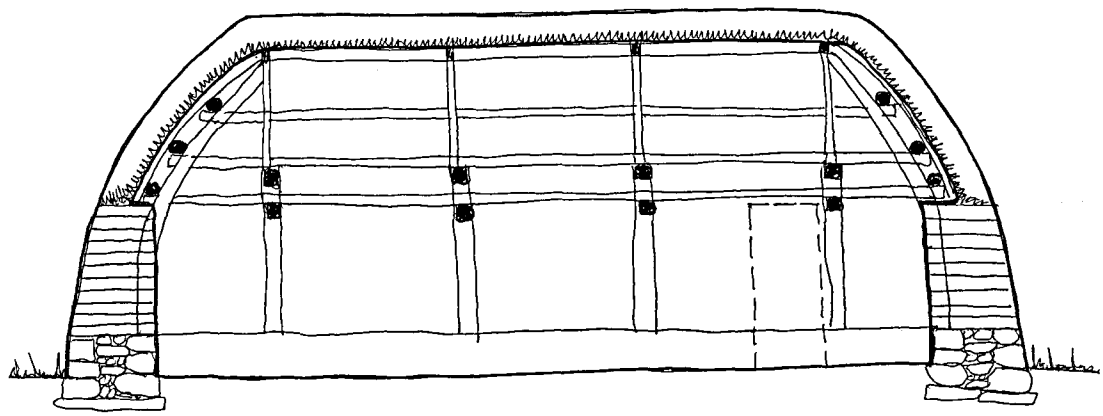
Permeable renders accept the water. The outer pores soon saturate, causing excess water to run over the surface to the ground. When the rain stops, the water held by the render evaporates back into the atmosphere without any risk to the integrity of the wall. Similarly, water vapour within the building penetrates the internal plasterwork but soon evaporates off once the building is ventilated or the source of excess vapour is removed.

It is essential that all colour coatings and decorative finishes have the same permeable qualities. Traditionally, the material providing these qualities was limewash, distemper or some of the sand-lime or sand-ash paints described elsewhere. Modern emulsion paints are often considered to have these properties but unfortunately most are impermeable after the initial set. Specialist masonry paints may have the necessary properties but are very expensive. Generally for conservation work the lime wash or other traditional lime-based mix is preferred.

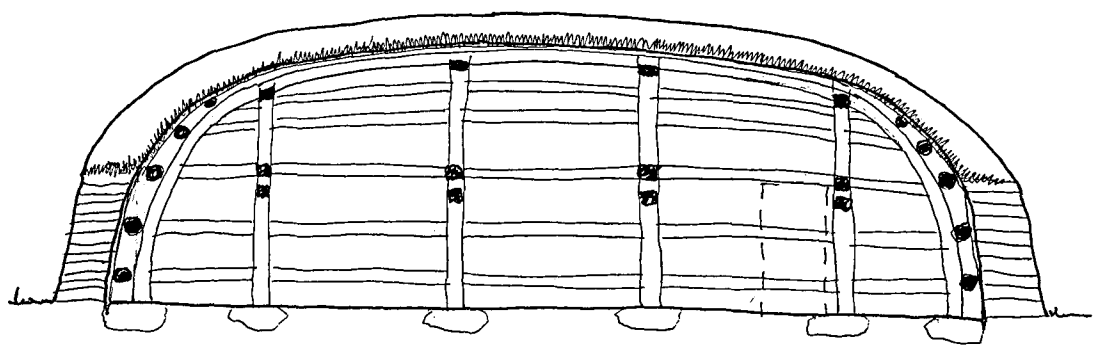
9.11 Floors

The traditional forms of earthen floor are described in section 5.04 but most of these fail to comply with the current Scottish Building Regulations.

If impermeable floor finishes are to be used, this should be done in conjunction with lowering the water table under the floor and round the perimeter of the house to prevent water accumulating and ascending the walls by capillary action.



Turf House Experiment Longetudinal Section as Reconstructed



Alternative section using same crucks

10
CASE STUDIES

A number of experiments and conservation projects have been carried out over recent years and a selection are set out here to give a clearer understanding of the complexities encountered when using these apparently simple materials.

10.01 The Turf House Experiment, Highland Folk Museum

Ross Noble, curator of the Highland Folk Museum has a long-standing interest in turf building. His first experiment, a four feet high dyke round a kail yard in the museum, uses turves built grass to grass and root to root alternatively. The walls are constructed with a batter to the outside and are standing up well to the abuse they receive in the museum.

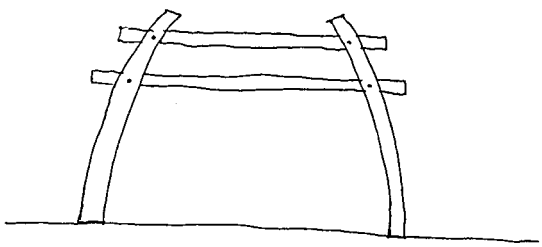
A second wall built using the same method of construction with vertical walls never achieved stability. Unfortunately, an insufficient record was kept to explain why. It may be that the turf sat too long in the sun before being built into the wall, or, that like the turf house experiment, bought turf was used. This type of material may recover when laid as a lawn and watered but unless the turf is wet and actually growing when built into a wall it is almost impossible to achieve stability.

The turf-house experiment was executed as a Community Enterprise Programme for the temporary employment of the long-term adult unemployed, and, in the author's opinion, suffered from the timing of the funding and the requirement to complete the work within set financial years. A complete history of the building of the house is set out by Ross Noble in Folklife 22 under the title "Turf Walled Houses of the Central Highlands". This was a considerable undertaking but suffered from a number of fundamental errors.

The house was based on a pair of crucks, taken from Morile Mor, Tomatin, Inverness-shire surveyed by the Royal Commission on the Ancient and Historic Monuments of Scotland in 1972, but was constructed as a house with four sets of crucks. The crucks had peg holes, for a curved yoke at the head, similar to the crucks recorded by RCAHMS at Corrimony, Urquhart, Inverness-shire, but had been adapted to a ridged form, perhaps to change the style of thatch, but more likely, to accommodate a corrugated iron roof covering. The crucks were made during the spring and summer forcing the turf building into the autumn and winter. The back surface of the Morile Mor crucks has peg holes to take purlins almost to ground level and these are likely to have carried stake and rice screens against which the turf was built. The experimental house had unsupported turf walls, vertical internally and battered externally. This resulted in a difficult junction between roofing-turves and wall-turves. The steepness of the roof made it difficult to keep the roof-turves from tearing, particularly along the line of the junction between cruck and angular extension. Some turf work was carried out at temperatures several degrees below freezing, the temperatures dropping to - 12°C overnight. The roofing divots were purchased as second grade golf-course turf. The roof of divots, laid as an undercloak for thatch was left as a divot thatch, something it was not designed for. The building took ten months to complete, and was finished in May 1982.

The errors in construction proved costly and there were problems not only at the roof but at the wallheads and the unsupported end walls. The building eventually collapsed.

Ross Noble took his evidence exclusively from the Central Highlands of Scotland: had the research been wider, many of the mistakes could have been avoided. Turf building is not exclusively Scottish and the principles are reasonably standard. This accepted, the experiment highlighted the problem areas and has been of considerable assistance in the preparation of specifications for other projects.



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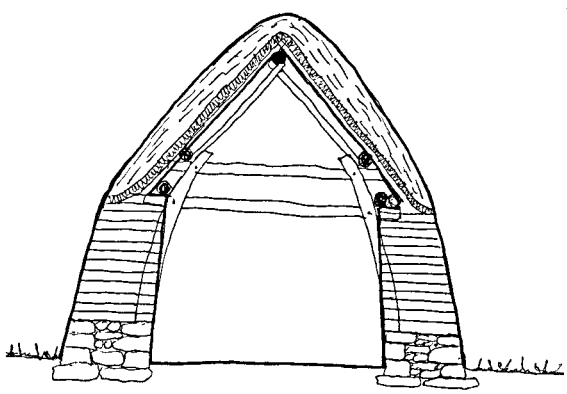

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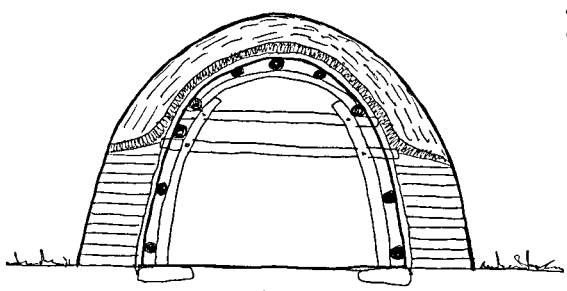


Alternative Section using same cruck

10.02 Callanish Standing Stones, Uig, Lewis

The consolidation of the site round the standing stones at Callanish is not an upstanding structure but a method of preserving the archaeology of a site in danger of being destroyed by increasing visitor numbers.

The problem stems from the site having developed as a natural peat bog. The sub-stratum naturally holds water, and only the excess drains away from the crest of the hill. A number of drains have been cut into the natural bog but these date from the clearing of the peat from the site prior to its being taken into the guardianship of the Secretary of State for Scotland.

Re-cutting the original drains or cutting new drains was not an option owing to the archaeological significance of the site and at the same time a significant increase of visitor numbers began to erode the site on all the approach routes.

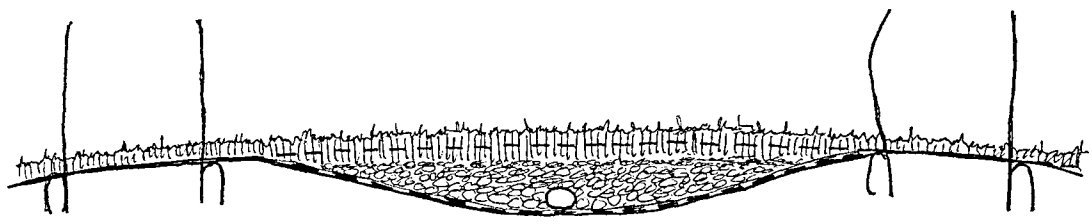
In 1990 the site was waterlogged or flooded all winter, was ankle deep in mud in spring and autumn and was dusting away in the summer. Features were appearing on the eroded surface that had not been seen in previous archaeological investigations. The problem presented was to re-establish the original ground profile and to manage the increasing number of visitors. It was obvious that simply tipping earth onto the site and re-turfing would simply exacerbate the problem of the boggy ground, and it was decided to utilise the worn areas to create a drainage system above the level of the surface, at that time, but below the level of the original ground profile.

The archaeological deposits were protected with a layer of geotextile. The detailed survey commissioned prior to the work commencing was used to determine the main flow of surface water and plastic field drainage tiles were laid along these routes. Historic Scotland were aware that this would provide a route for excess water but would not drain away the water that would reform the peat bog. Quarry scalpings were laid to either side of the drainage pipes to encourage the free movement of excess water over the site. Archaeological records and the level of the packing stones round the main orthostats were used to re-establish the ground profile and the quarry scalpings were profiled to reflect this but thirty centimetres below the original profile. At this stage the surface of the quarry scalpings was blinded with quarry dust and thirty centimetre deep turves were placed over the entire area of the quarry scalpings and blended into the non-eroded areas using diminishing thicknesses of turf. This is an extremely skilled operation depending largely on the skill of the operatives but even more on the "eye" of the Technical Officer in charge of the operation, in this case, George Newlands from Fort George.

Although a great deal of effort was put into obtaining a turf of the same mix, of rye grass and marsh grass, to that existing on the Callanish site: the new turf quickly lost its marsh grass content. This was due to the improved drainage under that part of the site. Expert ecological advice was sought and the ecologists report confirmed what was happening but pointed out that rye grass will stand up to visitor pressure better than marsh grass and that within twenty-five years the whole site will merge naturally. This is already beginning to happen.

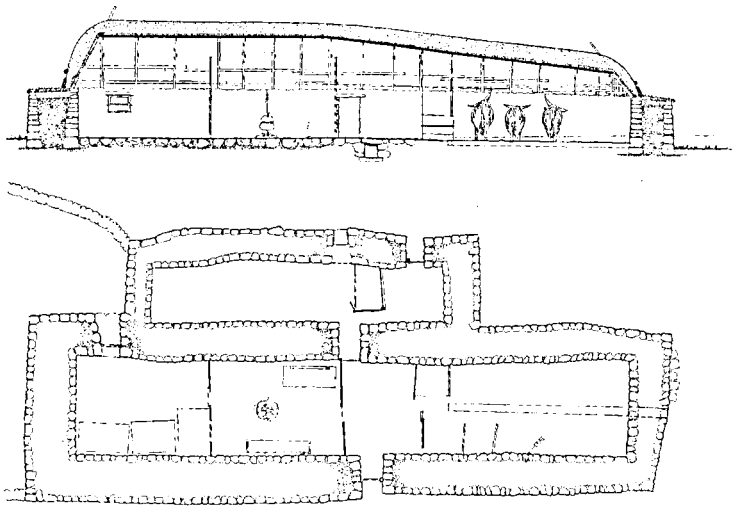
Before commencing the reinstatement of the original ground profile, a survey was carried out amongst visitors to the site. Many had no opinions as to visitor management other than that Historic Scotland should do something to keep the visitors' feet dry. This is not a good enough reason to resort to interventionist tactics, but, other visitors, particularly those trying to photograph the stones, felt that a perimeter route gave all visitors a better appreciation of the stones in their setting and owing to the fall in the ground to either side of the main axis, kept the visitors on the other side below the horizon of a crouching photographer.

It was agreed that a path was required, to minimise further erosion whilst the re-profile programme was being set up and to protect the new turf when it was laid. Again, the path had to respect the archaeology of the site and the solution adopted was to lay a geotextile strip slightly wider than the path: weight the edges with three thicknesses of turf and infill between the turf kerbs with quarry scalpings blinded with quarry dust. The weight of the path did compress the peat under the surface but this will probably return to its original volume when the path is eventually removed or repositioned even further down the slope from the monument. The path has attracted criticism, particularly from those wishing to obtain aerial photographs, but it is protecting the monument to the extent that peewits (lapwings) and other ground nesting birds are nesting on the formerly eroded visitor routes.



Section through eroded section showing drainage and fill

Blackhouse, 42 Arnol, Lewis
Plan and section



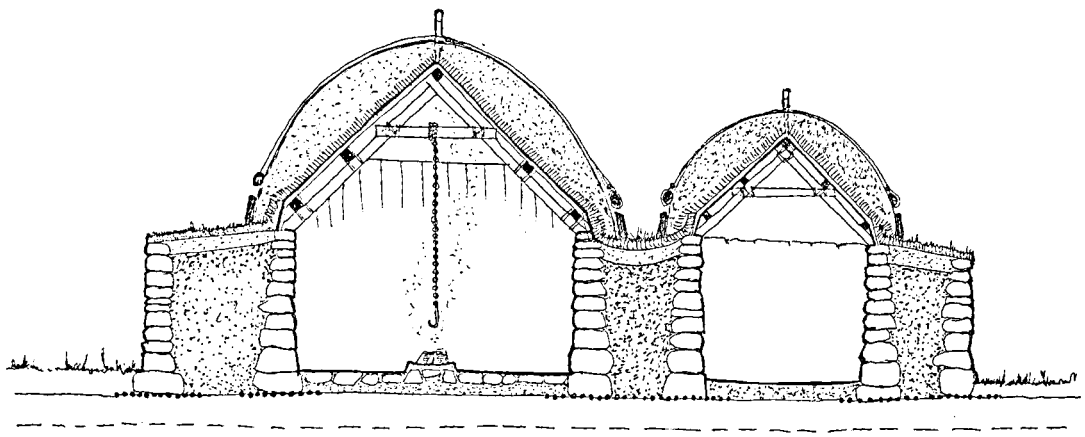
10.03 Blackhouse, 42 Arnol, Lewis

The blackhouse at 42 Arnol utilises various forms of earth construction. The walls are drystone-faced mudwall, waterproofed at the exposed wallhead with blue clay protected by a layer of living turf. The living turf is turned up a low soldier course at the base of the roof and the heather roof turves, forming a substratum to the thatch, are applied heather side down over a slatted surface.

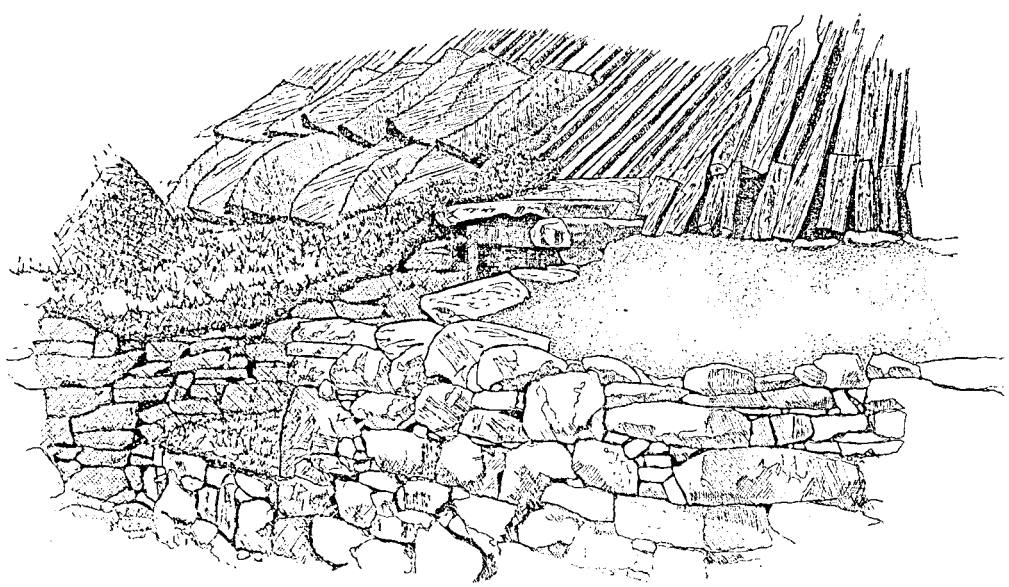
The foundation to the drystone wall-face is stabilised by the use of a friction course formed of pebbles hammered into the surface of the clay sub-soil. The floor in the living areas of the house is roughly paved and pointed with blue clay. The hearth and the floors to the barn and byre are clay.

The building is described in detail in Historic Scotland -Technical Advice Note 5: The Hebridean Blackhouse -A Guide to materials, construction and maintenance.

Section



Detail of restoration showing blue-clay wall topping, turf cover to wall topping and turf under cloack to thatch



10.04 Morlannich, Killin, Perthshire

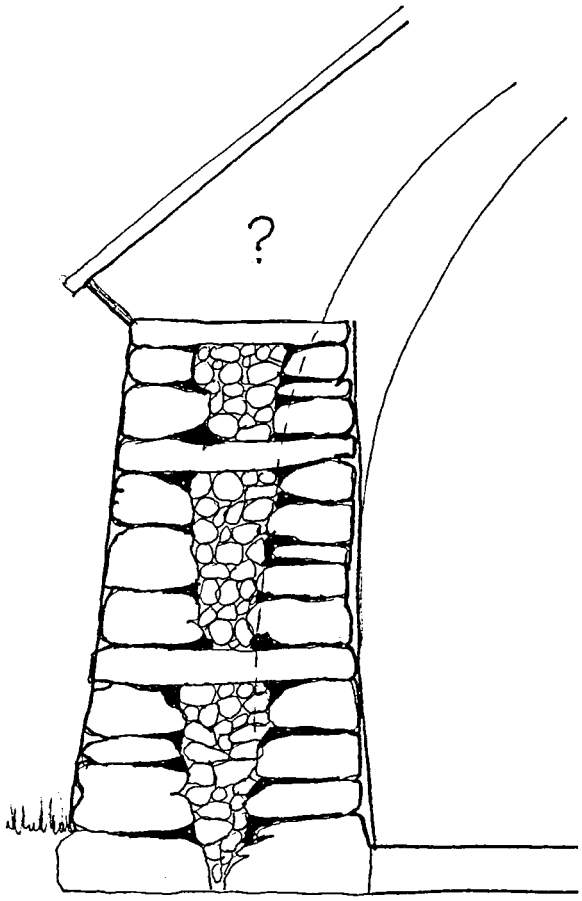
An unusual use of an earthen mortar has recently come to light at the National Trust for Scotland property at Morlannich, Killin, Perthshire.

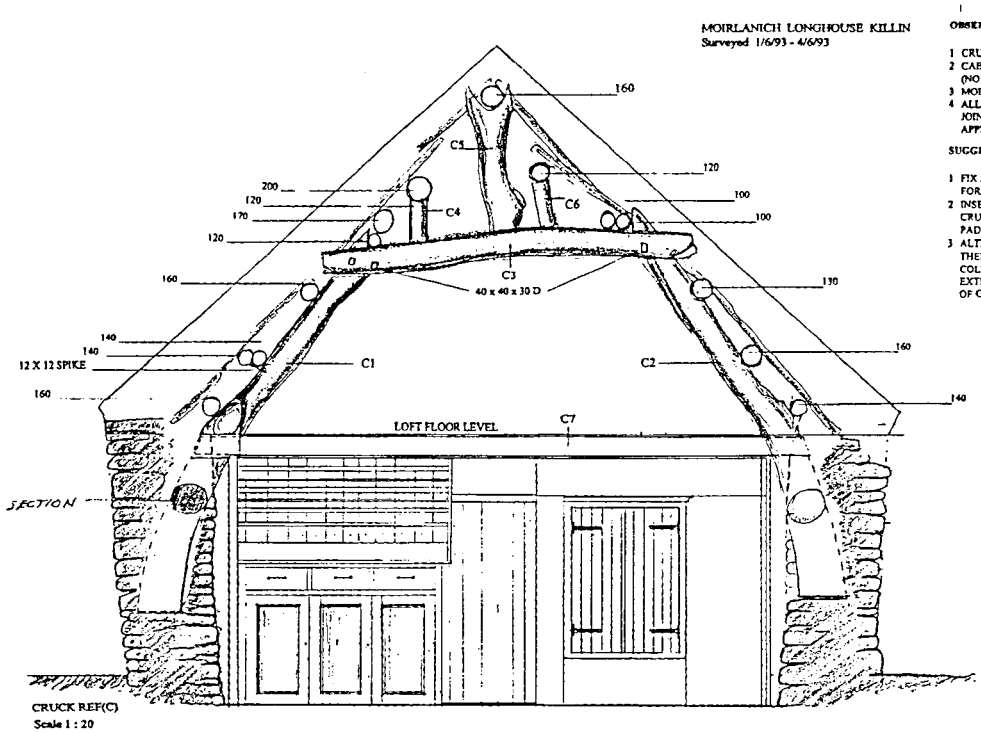
Partial rotting and subsequent movement of the crucks and roof timbers caused an outward thrust on the apparently drystone walls of the property. Some of the bulges were approaching the point where they would collapse. The Trust employed Brian Wilson as contractor, to carefully dismantle and rebuild the dangerous sections. This was done after the preparation of record photographs, used in the reconstruction work.

The wall construction proved to be extremely interesting. The stonework comprises two drystone skins with occasional bonding through-stones and a dry rubble core. Clay mortar is used to pin the inner ends of the drystone skins rather than the more traditional snecking stones. The clay mortar was analysed and new mortar mixed to the same proportions of clay, sharp sand, and gravel. This arrived on site in tubs provided by Douglas Johnston of Masons Mortar, Edinburgh. The mix was easy to use, set hard and has been a complete success.

Externally the wall is finished with lime slurry and limewash: internally, with clay plaster, limewash and wallpaper. The property will be open to the public, by arrangement, from late 1996 - contact NTS Central, Tayside and Fife Regional Office.

Section through wall



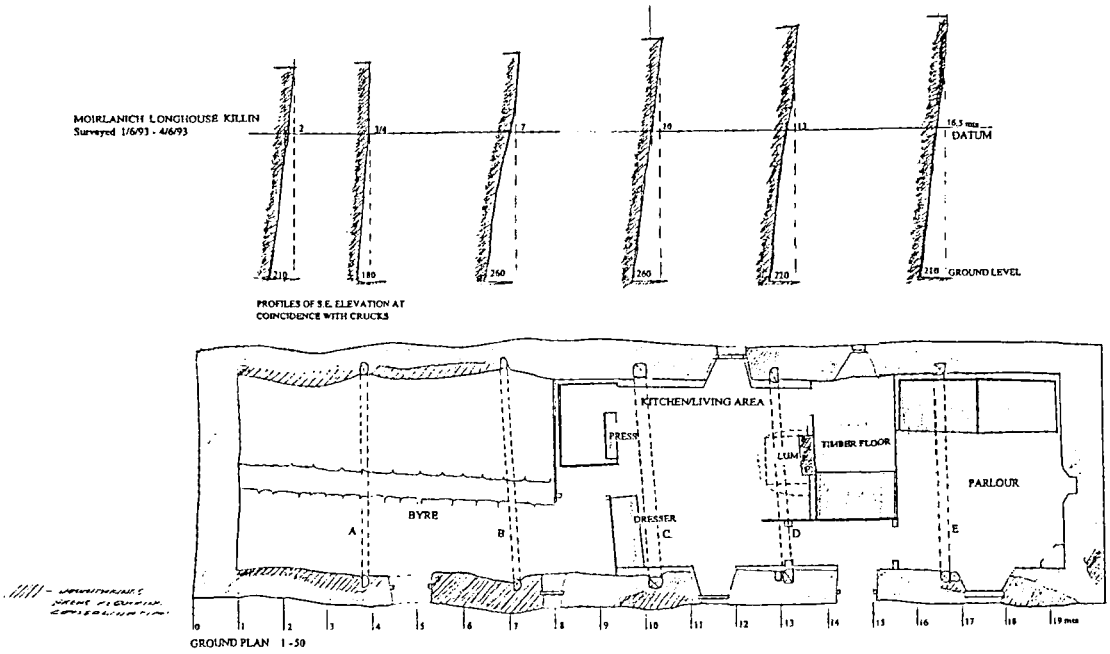


Morlannich, Killin, Perthshire - survey drawing

NTS

Morlannich, Killin, Perthshire - survey drawing

NTS



10.05 Cottown, St Madoes, Perthshire

The former School and Schoolhouse at Cottown is a predominantly mudwall structure, recently purchased by the National Trust for Scotland with grants from the National Heritage Fund and Perth and Kinross Heritage Fund. Conservation works have been undertaken in partnership with Historic Scotland with the assistance of a Historic Buildings Council Grant.

The building, dating from 1745 with rebuilding in 1766 and 1818, presented many challenges as it was the first mudwall structure to be conserved in Scotland. To allow freedom in the investigation and conservation works an agricultural shed was erected over the entire structure.

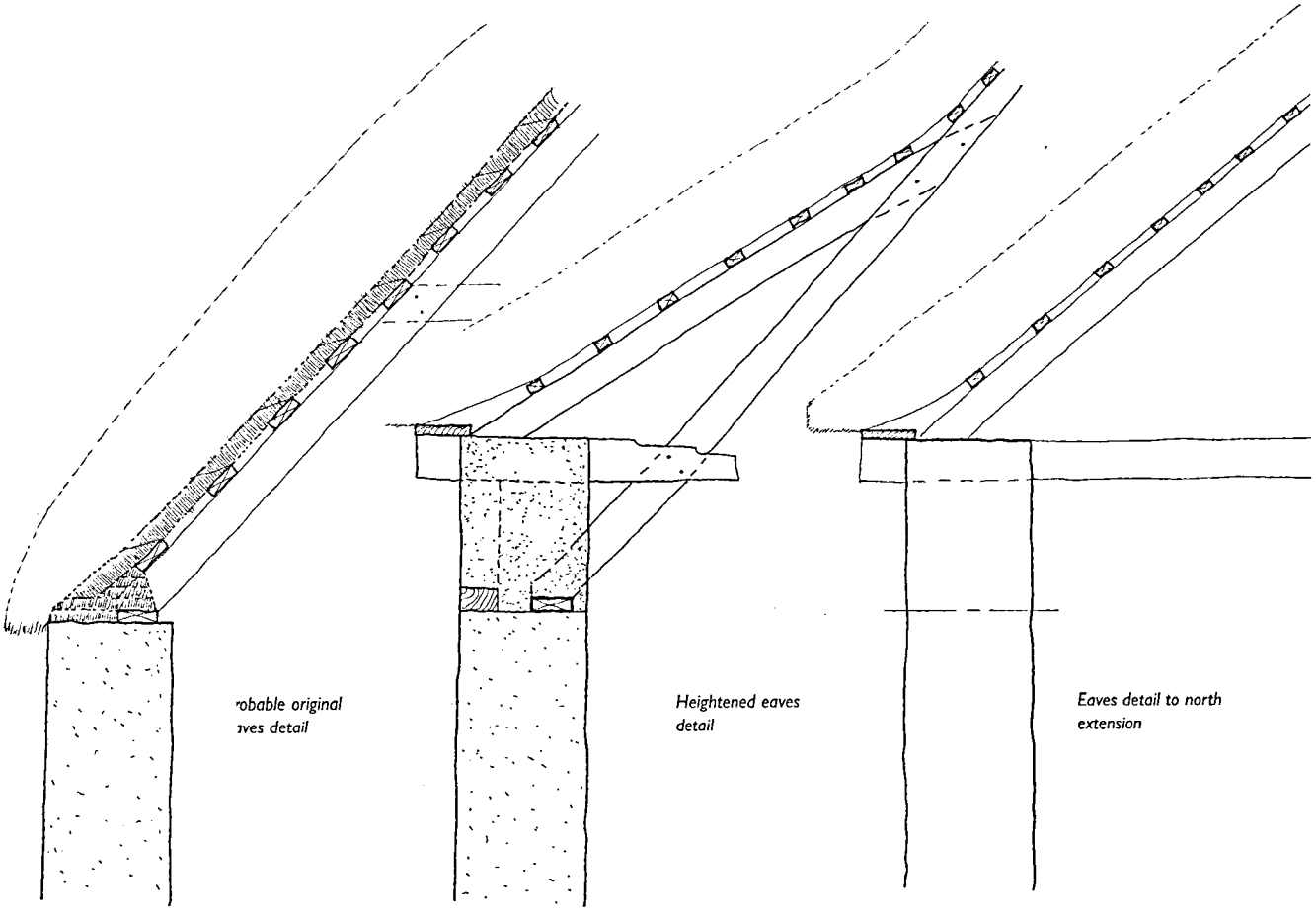
A method of working was devised, that allowed for the careful removal of damaging impermeable plasters and renders whilst retaining the structural integrity of the building. This was essential as the building had been subjected to flooding prior to purchase by NTS and the base of the earthen walls, sandwiched between impermeable renders, was still drying out. The removal of the external cement renders was carried out by the authors, assisted by Gregor Stark of Historic Scotland. Several areas of cement render were left insitu at that time to ensure structural integrity but as much as possible was removed to allow drying and further investigation of the structure. At this stage the internal renders were left insitu.

A former Historic Scotland lime internee, Rebecca Little, who had gained some experience of earth construction in Denmark, Devon and Lincolnshire was appointed as the contractor for the conservation of the earth structure. She agreed to work with various groups of volunteers. These included the National Trust for Scotland Volunteers; conservation and architectural students from Duncan of Jordanstone College, University of Dundee; conservation students from Heriot Watt University, Edinburgh; architectural students from Robert Gordon's University, Aberdeen; interested individuals; and classes of local primary school pupils.

The mudwall required: indenting at the base where there was a combination of erosion and rat runs; replacement of some poor quality sandstone blocking that was slack and obviously letting water into the wall (other small blockings that were sound were left insitu); plastic clay mortar filling to internal rat runs; plastic repairs to shallow hollows in the wall surfaces and to the wall-top of the gable; mechanical ties between the mudwall and a poor quality sandstone-clay mortar panel in the south elevation and analysis of the earth renders and lime renders from various parts of the building.

All indenting was carried out using pre-shrunk mudwall blocks and tiles, prepared over the winter months and air dried within the building. The original mudwall mix incorporated straw but the straw available locally had been grown using intensive nitrate fertilisers resulting in a poor quality straw. Locally grown flax was also available and although the vegetable material of the flax straw also broke down readily, due to a high free-nitrogen content, the fibres improved the tensile strength of the blocks. The blocks were trimmed to size using a

View from east

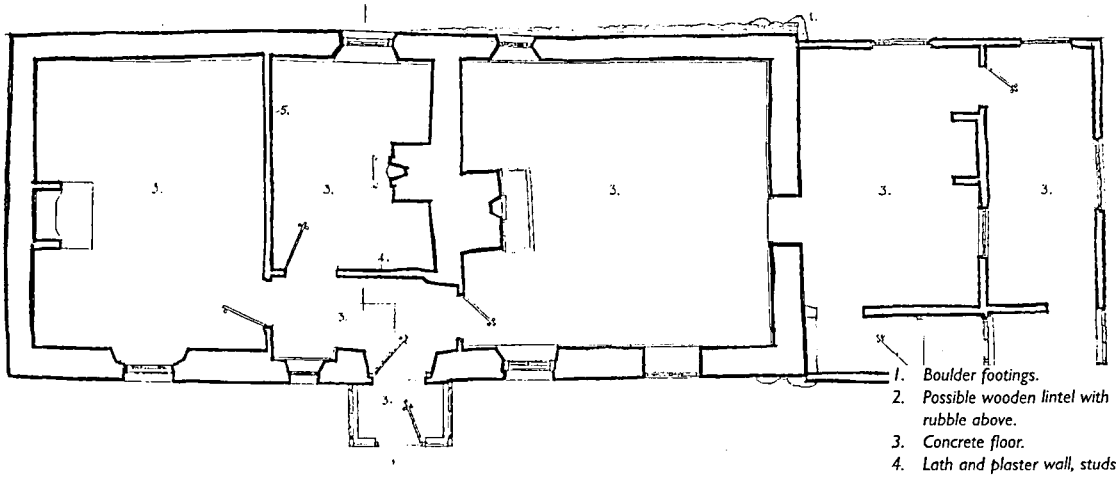


robable original
ves detail

Heightened eaves
detail

Eaves detail to north
extension

Cottown, St Madoes, Perthshire - survey drawing

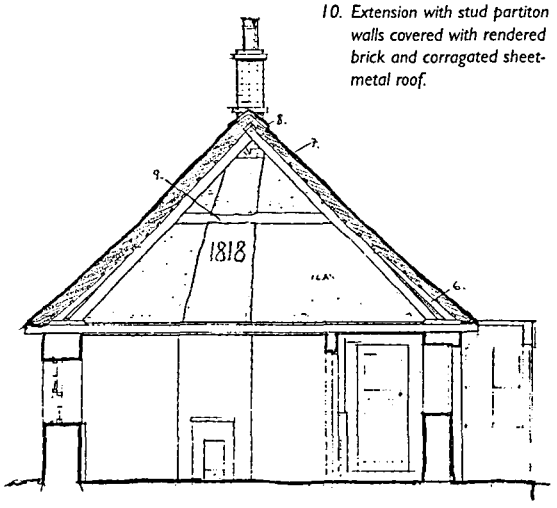


1. *Boulder footings.*
2. *Possible wooden lintel with rubble above.*
3. *Concrete floor.*
4. *Lath and plaster wall, studs wih brick infill.*
5. *Stud wall with clay infill.*
6. *Sprocket (on west half only).*
7. *Reed thatch.*
8. *Concrete coping ridge.*
9. *Collar beam partly through chimney.*
10. *Extension with stud partiton walls covered with rendered brick and corragated sheet-metal roof.*

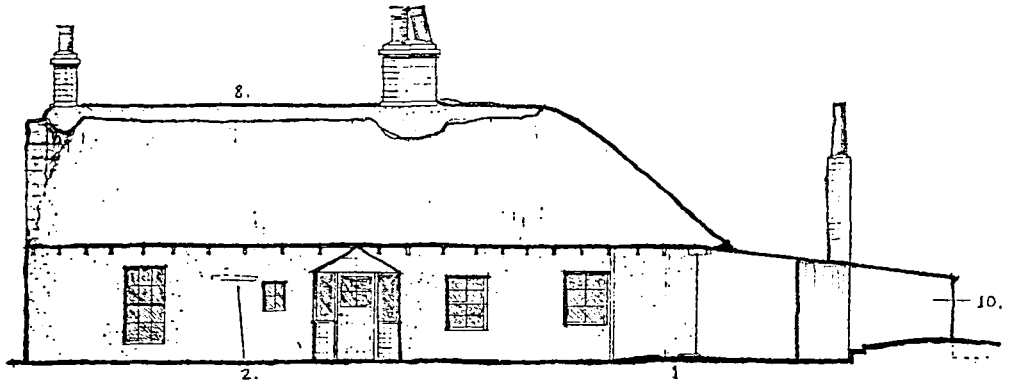
Danish tool, designed for the careful removal of plasterwork, which looked like a hammer sized mattock. The blocks were bonded with an earth mortar of similar mix to the block but omitting the larger aggregate.

After the consolidation of the external surface of the external walls, the same process was repeated in the internal faces. There the impermeable cement render tended to be at the base of the wall, almost as a continuation of the cement screeded concrete floor. Archaeological investigation of parts of the floor failed to reveal the original construction and it has been decided to leave the concrete floor as found. This will necessitate the formation of land drainage round the property directly under the drip from the thatched roof to minimise the likelihood of rising damp in the walls.

One of the internal walls is of kebber and motte construction and the flood damage to the base of that wall was repaired using a mixture of mudwall block and plastic repairs - mudwall block where the evidence had disappeared and plastic repairs where the original construction was obvious. The chimney

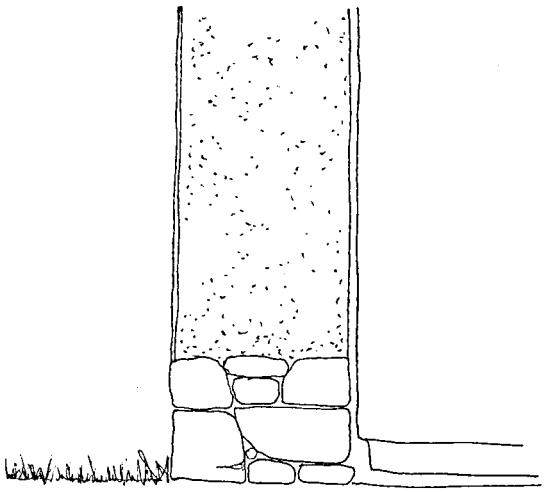


Section A A'

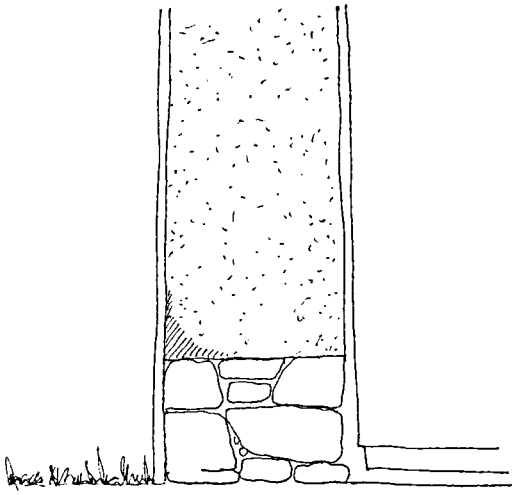


S.E. elevation

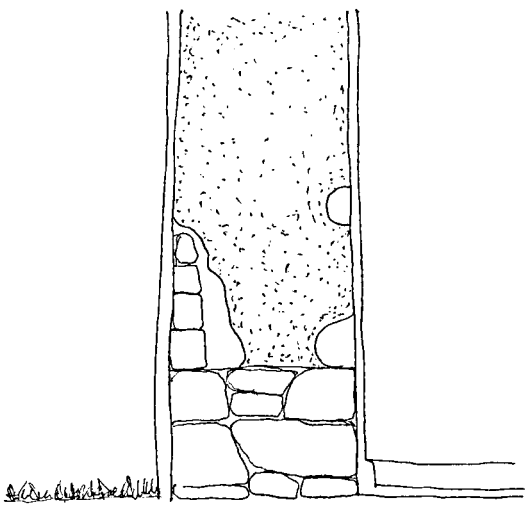
Original wall-base detail



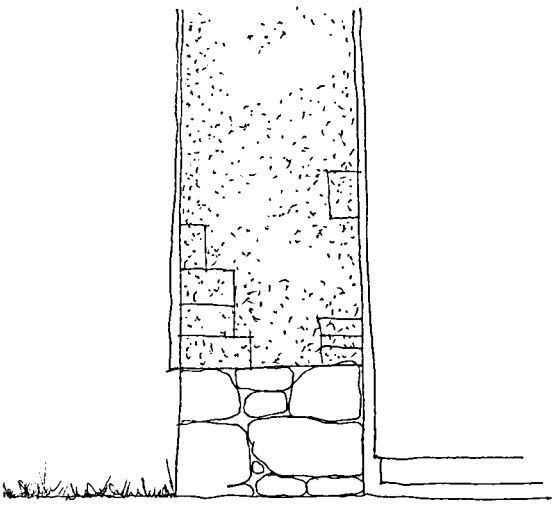
Dampness after impermeable render was applied



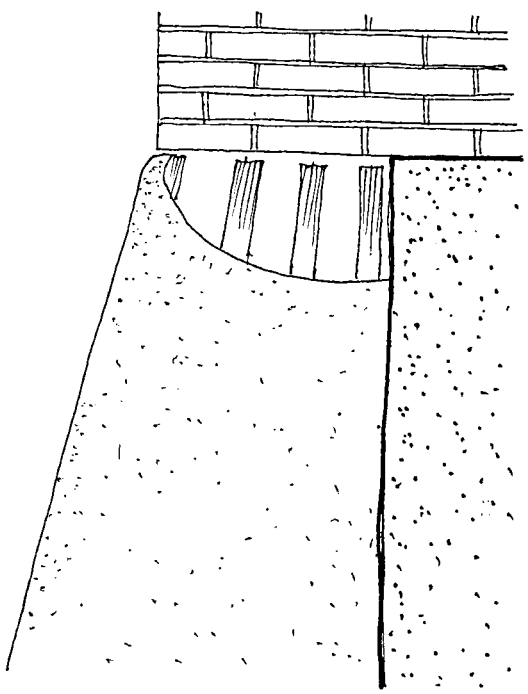
Damage, patching and further damage



Blockwork repairs



Caber and mud chimneyhood against mudwall gable, supporing brick chimney head



flues are of similar construction but using lighter timbers. These support brick chimneyheads.

Lime plasters were retained internally and lime was used to replace the cement renders at the base of the walls.

A clay and turf ridge is being used to complete the thatch. This is a traditional finish in this area and can be seen on early photographs. Obviously this cannot be completed until the agricultural shed is removed from over the building.

Work is nearing completion and interim reports have already been published by Walker and McGregor but the final report is likely to take the form of a Historic Scotland Technical Advice Note.

10.06 Maji Cottage, Avoch, Rossshire

In contrast to the properties owned by Historic Scotland and the National Trust for Scotland, Maji Cottage is in private ownership as a dwellinghouse.

The house is of composite construction reflecting a long history of change and alteration in whatever material was popular at that particular time.

The lateral walls and one gable, to eaves level, are clay and bool construction, cement rendered externally and clay plastered internally. The clay and bool gable has been heightened in fired-clay bricks. The other gable is mass-concrete construction. Internal walls are of kebber and motte with clay plaster finish inscribed to give the impression of wainscotting. The roof structure is cruck framed carrying purlins and caber type rafters. The roof covering comprises a turf undercloak to a partly stobbed, partly clay-anchored, thatch. This is covered with strapping fixed through the thatch into the cabers and sheeted in corrugated iron. There is a small gabled projection to the south lateral wall of similar construction to the rest of the house but having a turf apex to the clay and bool gable. An extension has recently been added against the north lateral wall.

The client was anxious to retain the historical elements of the construction but also wished to have a comfortable house. The client's architect was less interested in the historic features and was also hampered by a lack of contractors prepared to work with clay plasters and clay repairs.

A compromise was reached where features such as the crucks and purlins were retained throughout the house, but expressed fully only in the living room (former kitchen) which is open to the apex of the roof. The damaged clay plaster and kebber and motte partitions have been retained but behind strapping and plasterboard, to allow their full reinstatement, when expertise is available in that area, and if further works are carried out on the house.

The cement render to the clay and bool walls is very hard, but also in good condition, and this has been retained as it was considered that to remove it might destroy an otherwise sound wall. The fact that this wall is clay plastered internally is a major factor in this decision as the wall is fully permeable on that side.

The turf undercloak to the thatch was in poor condition and inclined to revert to dust when disturbed. The thatch and turf was removed and replaced with insulation board, lined inside the livingroom with match boarding. The corrugated iron roof covering has been overhauled and retained.

10.7 Earth Walls Experiment

In an effort to re-establish sound working practices, Historic Scotland has commissioned Rebecca Little to build a series of experimental external walls and internal panels at four sites in different areas of Scotland. The sites are:

(i) Fort George, Ardersier, Inverness-shire.

(ii) Battleby, Redgorton, Perthshire.

(iii) Stanley Mills, Redgorton, Perthshire.

(iv) Culzean Country Park, Maybole, Ayrshire.

Only one site, the Scottish Natural Heritage site at Battleby is open to the public. The others can only be visited by arrangement.

The purpose is to illustrate that the technology is available to build with a range of earths and to produce an end product that will stand up to the Scottish climate. This may seem unnecessary when we have buildings, built of these materials, standing insitu 200 to 250 years after their original construction but with a technology that has died, we may have to go through a long process of re-discovery to regain the knowledge. After it has been established whether or not the test walls are perfectly stable, the walls will be used to test various forms of render to establish the best ways of protecting these structures in the long term.

Information sheets will be produced at regular intervals describing: the layout of walls or panels at each of the sites; the constructional techniques adopted for each wall or panel: the performance to date: any remedial works that have been found necessary: the types of renders applied: their performance: and so on. The information sheets will be available from Historic Scotland or from the Battleby Centre.

The sites were all chosen for specific reasons and to give a range of climatic conditions. Some are in secure compounds, not only to reduce the risk of vandalism, but to allow walls to be tested in ways that may be dangerous to the public.

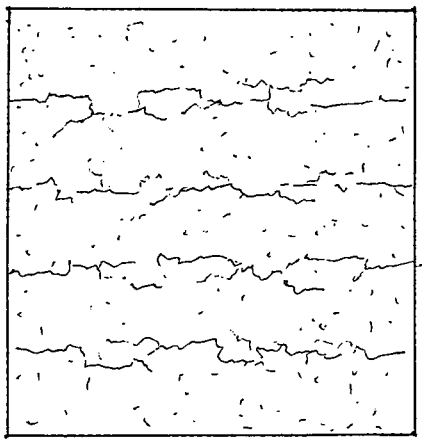
(i) Fort George, Ardersier, Inverness-shire

This is a Historic Scotland property. The site chosen is in a works compound on the edge of the firing range at Fort George. The site is open, windswept and completely devoid of trees.

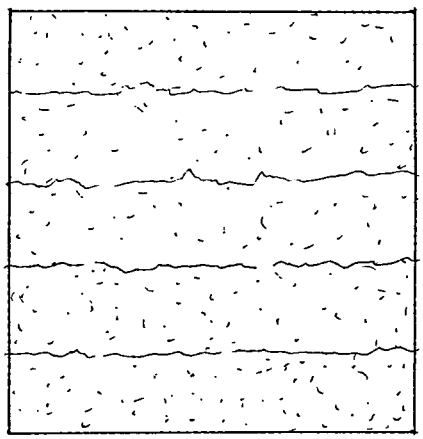
(ii) Battleby, Redgorton, Perthshire

This is a Scottish Natural Heritage property, open to the public and used as a conference and training venue for professionals involved in all aspects of the environment. The site chosen is positioned between the workshop block and the car parks close to a number of different methods of forming car parks, screens, retaining walls, children's

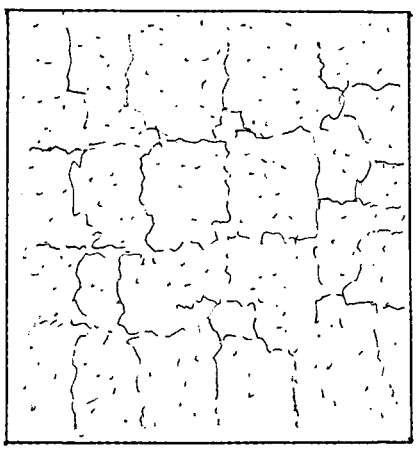
Shrinkage patterns



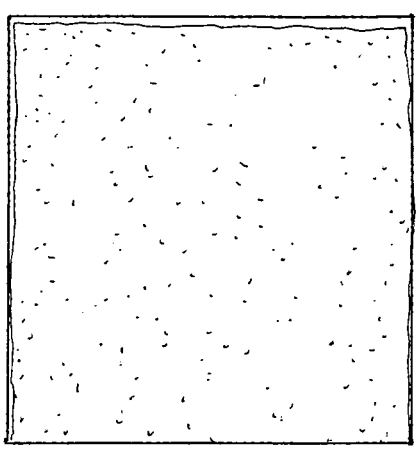
Horizontal rails with vertical straw rope



Horizontal rails



Stake and rice



Horizontal straw rope

play areas, signs, and other elements introduced into the countryside in an effort to provide information, control and protect both the environment and the visiting public.

(iii) Stanley Mills, Redgordon, Perthshire

This is a recently purchased Historic Scotland property, not yet conserved and, at present, closed to the public. The ground floor of the Mid Mill has been used to set up a series of internal wall panels, partly to establish the problems associated with different types of armature and partly to give surfaces that may be tested with both appropriate and inappropriate renders in the future. This site may have to change and each of the panels has been made to be demountable whilst still leaving the earth wall intact.

Future plans for the site may involve other forms of conservation training and testing but there is still a great deal of discussion to take place before even this principle is established.

(iv) Culzean Country Park, Maybole, Ayrshire

This is a property of the National Trust for Scotland. The site chosen is in the works compound, to the rear of the joiners shop. It is completely enclosed by mature forest trees, and these overhang the test walls.

• • •

Contact Technical Conservation, Research and Education Division of Historic Scotland should you wish to arrange regular updating of copies of the research material (for address see item 13.00).

11
TOOLS AND EQUIPMENT

Clay building died out in Scotland, not because it was an inferior product, but because it was perceived by estate factors as being too expensive. The tradition had been developing naturally from the earliest recorded times to the early nineteenth century. It was illustrated in many early architectural pattern books but when estate factors were asked to obtain tenders for buildings on their own estates the "labour intensive" argument was put forward in response to high tenders from their normal contractors. Anyone connected with building knows that any departure from the normally accepted specification tends to result in an increased cost until the industry comes to terms with the full implications of the change. Granted, the traditional methods of earth construction are labour intensive but so was the quarrying of stone or the manufacture of bricks before the application of ingenuity and imagination to the traditional practices.

Knowledge of traditional working procedures and tools are important to the understanding of the principles behind the constructional methods, but tools and working procedures can be improved to make earth building competitive whilst retaining its status as an environmentally friendly product.

EXCAVATION

Traditionally, this was a job involving pick, shovel, mattock and spade. Clay in particular is very difficult to dig and modern excavators should be employed from the outset for all large scale projects.

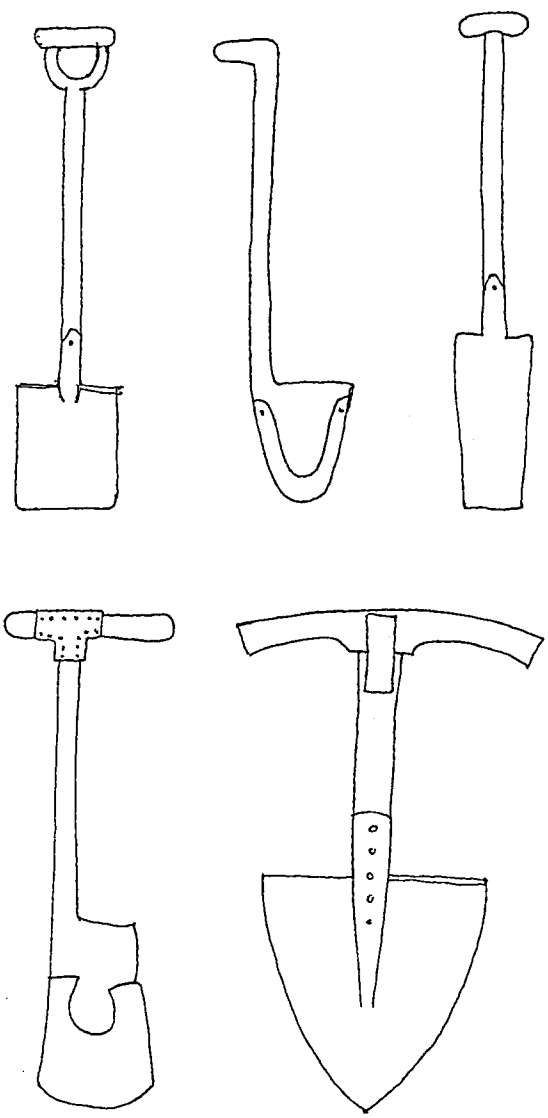
11.01 Spades

A spade is a tool for digging or cutting ground, turf, etc, having a sharp-edged broad-metal blade and a wooden handle. It is used with both hands, pressure being applied with a foot.

Prior to the Industrial Revolution and the mechanisation of agriculture, spades were manufactured by local wrights and blacksmiths to serve the needs of each community. The patterns were diverse and evolved to suit the type of ground encountered, the purpose they were to be used for, and the inclination of the operative. They were often constructed entirely of timber, shod by the blacksmith at the cutting edge. Shafts were often off-centre and spades were produced for right and left-handed operatives. The pattern and size of the blade often reflected the form and dimensions of the product being extracted. Peat spades for example were made with a wing, at right angles to the blade, to allow a standardised block to be cut with a single thrust of the spade. Similarly, ditching spades were often tapered to a narrow cutting edge whilst paring spades were wide with a curved or pointed cutting plane.

Owing to the rate of change in the rich agricultural areas in the nineteenth century, specialist spades seldom survive other than as symbols on late eighteenth century tombstones. In the Highlands, and on other areas of marginal land, the use of specialist spades survived to a much later date, sometimes early this century, and the use of some types, particularly peat spades, continues to the present day, as do ditching spades used by statutory undertakers for trenching.

The common garden spade can be adopted to most purposes and turf can be pared using this tool but not with the same precision as was possible with the flaughter spade.



Spades

11.02 Flaughter Spades

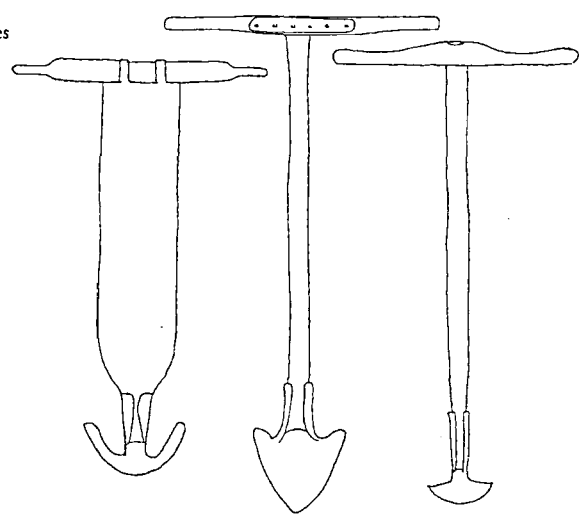
The flaughter spade or breast plough is ideally suited for paring the surface of meadow land to produce good quality turves for either building or roofing purposes. It has a flat or slightly dished blade that lies parallel to the surface of the ground when the T-handle is clasped firmly at either end and the centre rests against the base of the rib-cage.

Traditional patterns can be obtained from local museums but rather than reproducing the spade in timber with a blacksmith-made iron-blade, it is advisable to have the whole made up in welded tubular steel with a steel blade. This reduces the weight whilst giving a stronger product.

An edging tool is used to cut a series of tram-lines the width of the turves required. A second series of tram-lines at right angles can establish the lengths of the turves. The flaughter spade is inserted to pare through the base of the root system and a series of individual turfs are cut ready for transportation to the wall or roof.

Traditionally, turves were always cut by hand as the action must be steady and controlled. The first known attempt at partial mechanisation is on the Nebraskan prairies. Cutting turves using an adapted flaughter spade, was tried using horses. This failed owing to the horses sudden surge of power when an obstacle caused some resistance. The horses also tended to move too quickly, tearing the turf and rendering it useless for building. Oxen were found to provide the steady power required and the turves were turned to one side using a specially designed wire mould-board. Should a large scale turf building be considered for some future project a flaughter plough as described by Roger Welsch in Sod Walls could be adapted to tractor power.

Flaughter Spades

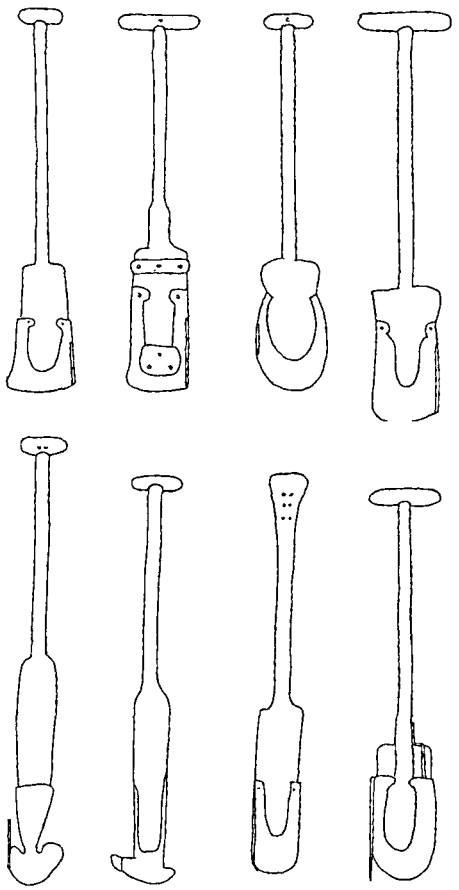


11.03 Peat Spades

Peat spades are normally constructed of timber and shod with an iron cutting edge with a wing or tongue projecting at right angles. The dimensions of the blade and tongue determine the cross-sectional dimensions of the cut peats. Each area has its own preferences, some cutting almost square sectioned peat, others rectangular sectioned, cut lying against the blade, others at right angles to it. Rectangular sectioned peat can be cut using a wide blade with a short wing, or a short blade using a long wing, according to preference.

The tool cuts two sides of the rectangle at once making it ideal for the systematic removal of regular sized blocks. The peats are removed by one movement of the arms and laid out on the surface of the peat bog to dry. This is again a precise process and the blocks are moved, propped and stacked in individual ways according to local practice.

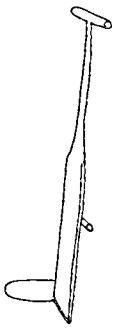
Peat spades



A tool similar to a peat spade but with a foot rest to one side was developed and used for the removal of narrow trenches of clay to make field drains. This is called a BITTING IRON and according to Morton is:

> "a narrow spade, three and a half feet in length and one and a half inches wide at the mouth and sharpened like a chisel; the

Bitting iron



mouth or blade being half an inch in thickness in order to give the necessary strength to so slender an implement. From the mouth on the right-hand side, a wing of steel, six inches long and two and a half broad, projects at right angles, and on the left, at fourteen inches from the mouth, a tread, three inches long is fitted.

The method of using this tool is as follows: When the first and second splits have been removed, the bitting iron is turned half round from the position represented in the cut, and is pushed down into the soft clay to the required depth of the drain: it is then withdrawn: and, being turned round into the position represented in the cut, it is then pushed down to the same depth as before, but six inches further back in the trench. By these two cuts a piece of clay, six inches in length, and of the depth to which the tool has been pushed, is separated on all sides, and is withdrawn, by the tool. These operations are repeated until a neatly-formed trench is completed, from which any crumbs are removed by a narrow scoop."

A tool for cutting peat drainage-tiles - see item 3.15 - is also illustrated by Morton.

11.04 Edging Tool

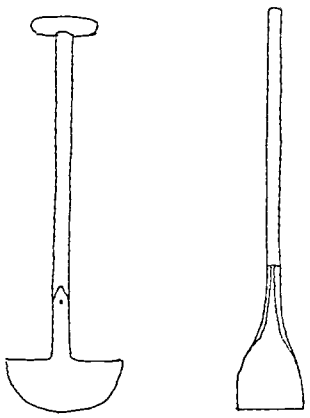
Traditional spades normally have a flat blade and can be used as a cutting tool to cut the surface turf. Since the introduction of modern garden spades with dished blades, an edging tool with a curved cutting edge is preferred for pre-cutting the turf widths and lengths. An ordinary garden spade can also be used but not necessarily with the same precision.

11.05 Shovels

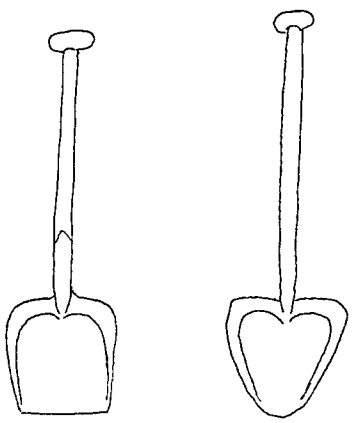
A shovel is similar in form to a spade but with the sides and back of the blade turned up to increase the capacity when lifting loose material.

Generally the blade of a shovel is thinner than that of a spade and its use is restricted to lifting loose material rather than delving and cutting.

Edging tool



Shovels

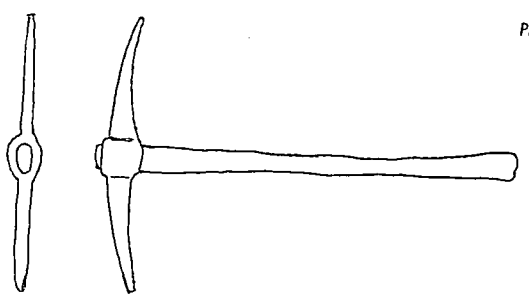


11.06 Picks

A pick is a tool comprising a tapered iron bar with pointed ends and a central wooden handle passing through the middle of the bar. The bar is normally slightly curved with the pointed ends turning back towards the handle.

A pick is useful for loosening hard packed gravel or other materials with an irregular particle size.

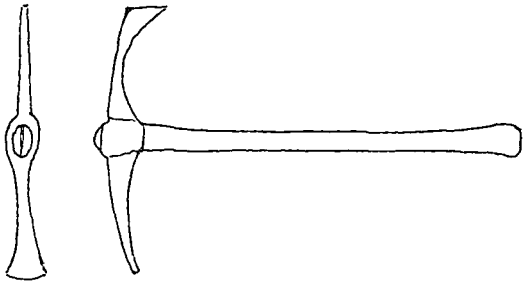
Picks



11.07 Mattocks

A mattock is an agricultural tool of similar form to a pick but with an adze edge at one end of the bar and a chisel edge at the other. It is ideal for cutting roots. Mattocks with their capability to cut rather than penetrate are more useful than picks in clay soils.

Mattocks

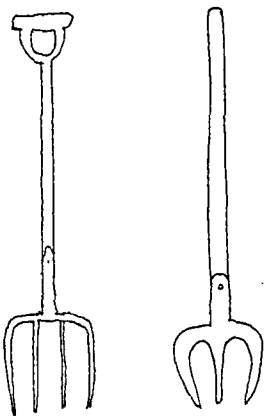


MIXING

11.08 Forks

A fork is a pronged agricultural implement used for digging, lifting, carrying and throwing. It has been developed for working heavy mixes or materials containing a high percentage of fibre. When turning heavy clay soils or heavy tempered mixes, a fork is easier to use than a spade. It can also be used to form a rough dressing to mudwall as it is being built, making the surface easier to pare to the correct plane.

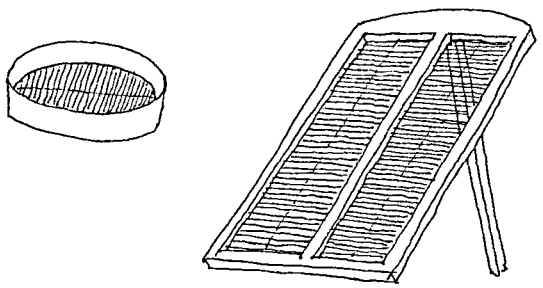
Forks



11.09 Riddles

A riddle is a coarse sieve used to size gravel, cinders, earth, etc. A set of riddles is useful to ensure that there is no oversized aggregate or lumps of other material in the mix.

Riddles



11.10 Trampling

The traditional way of mixing tempered earths is to place the material in a pit or on a flat clean surface and to trample it using either a large squad of labourers or heavy animals such as oxen or horses.

When carrying out this task using labourers, it is essential that they have heavy, well fitting laced boots. The best action is obtained using the heel of the boot rather than the whole sole. "Heeling" is also the traditional way of applying puddle to the base of canals or aqueducts.

The trampling effect for mixing materials can be achieved mechanically by laying out the materials on a solid base then driving a tractor back and forwards over the mix. Whether using a tractor or traditional trampling, the flattened mix must be regularly turned over and piled up before repeating the process till the desired mix is achieved.

11.11 Mechanical Mixers

Various types of mechanical mixers are available that are capable of mixing earth mortars, but, as the mixes should be kept as dry as possible, only heavy duty equipment is successful.

The ordinary cement mixer is useless for this type of work as the stiff mix sticks to the blades inside the drum and simply revolves with the drum without any mixing action taking place.

A motor driven pug-mill with two pulverising wheels can handle about 7m² per day. A horse driven pug-mill suitable for this type of work was surveyed by RCAHMS on Islay, Argyll.

Linear mixers are widely available in Europe. There are a number of variations each adapted to the type of mix required and the weight of the soil. Some operate with a single-shaft, others with double-shafts: some are designed to operate on a continuous flow action, others on discontinuous flow. Capacity ranges from 4 to 5m² per day for the smaller machines to 50m² per day for the largest. A similar kneading action can be obtained from a second-hand commercial dough-mixer as used by some of the larger commercial bakeries. This type of machinery is used for many commercial potteries for mixing their clay.

Vertical mixers can be made using basic materials. These are horse driven and have not been examined by the authors but designs may be available from CRATerre-EAG, Grenoble, France.

Concrete mixers, screw mixers and planet wheel mixers can all be used for mixing muds or plasters but generally these are not suitable for structural earth-building mixes.

11.12 Mixing Pit

Ideally all mixing should take place in the pit where the material is being obtained. The pit should have a stable bottom inclined to allow machinery to enter and leave but also to allow excess moisture to drain from the mix. An excavator working in such a pit is capable of producing about $10m^2$ of mixed material in an hour.

TESTING

Testing can take many forms. Houben and Guilland describe many tests, each developed to establish specific criteria and their chapters on: Soil Identification: Soil Suitability: Tests: and Characteristics give good advice on testing procedures and practical application of the information. However, for conservation purposes, the source of the original materials is often reasonably obvious and the tests required are simply to establish that a similar mix is being used for the conservation work as was used originally.

Sedimentation, shrinkage and simple tactile test can give sufficient information to allow work to proceed and the existing mix to be replicated. Compressive strength tests should be carried out on sample blocks to establish that load bearing material is capable of taking the projected loads.

11.13 Tactile Tests

No specific equipment is required for the simple tactile tests other than vision, sense of smell and touch. Large stones, gravel and coarse sand should be removed from the samples prior to starting the tests.

When dry soil is examined with the naked eye, it is possible to estimate the relative proportions of fine and sandy particles. Fine particles are those below the resolving power of the human eye, that is, less than 0.08mm diameter. This develops with experience but can be backed up by sieve tests of the dried material.

Soil should be smelt immediately after removal from the ground. Musty soils generally contain organic matter. The smell can be exaggerated by heating or wetting the sample.

Soils may be tested in the mouth but only where samples are taken from an obviously safe place and not if they fail the smell test. A small pinch of soil can be tested between the teeth. Sandy soil grinds with a disagreeable sensation. Silty soil can be ground between the teeth without the disagreeable sensation and clayey soil is smooth or floury and is sticky when applied to the tongue.

The touch test involves rubbing the soil between the fingers and palm of the hand. Sandy soil results in a rough sensation and the soil has no cohesion when moist. Silty soil gives a smoother sensation and is reasonably cohesive when moist. Clay soil resists crushing in the hand but when moist becomes plastic and sticky.

If the hands are washed with a slightly moistened soil they will rinse clean if the soil is sandy. Silty soils appear powdery but still rinse clean without difficulty. Clayey soils give a soapy sensation and can only be rinsed clean after considerable effort.

A small moist ball of soil can be cut in two using a knife. The cut surfaces will appear dull if the soil is silty and shiny if the soil is clayey.

These are test types collected from different parts of the world by CRATerre-EAG and are all useful in prospecting for suitable materials. The only test which consistently appears in Scottish literature is a simple cohesion test involving taking a handful of soil and squeezing it in one hand. If the material breaks up on opening the hand it is too gritty. If it sticks to the hand it is too clayey and wet, but, if it stays whole, takes the imprint of the hand but does not stick, it is perfect to build with. Adjustments may be carried out to achieve the correct cohesion.

11.14 Sedimentation Flask

The tactile tests described above give an impression of the nature of the soil. To confirm this more exactly a simple glass jar or flask is all that is required.

The flask should have a capacity of at least one litre. It should have a flat base, a top wide enough to get a hand into the flask but small enough to seal it off with the palm of the hand.

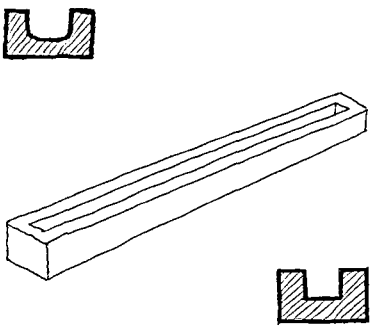
Sedimentation flask

The flask should be quarter filled with soil, and topped up with water. It should stand until the soil is fully saturated. This process can be accelerated by disturbing the soil manually. The flask should then be shaken vigorously and the murky water decanted. Repeat the process after an hour and decant again. After a further forty-five minutes it will have separated into layers of gravel, sand, silt and clay with any organic material floating on the surface of the water. Normally the material is allowed to stand for eight hours before the layers are measured and calculated as a percentage of the total sediment depth. This gives an approximate percentage for each type of aggregate and binding material.

11.15 Shrinkage Test

A linear shrinkage test, known as Alcock's Test, is carried out using a simple wooden box measuring 60 cms by 4 cms by 4 cms deep. The inside surfaces are greased or oiled before filling the box with moist soil at optimum moisture content (OMC). The soil is carefully pressed into the corners of the box using a sculptor's spatula which is also used to smooth off the surface. The filled box is exposed to the sun for three days or is left in the shade for seven days. Shrinkage occurs and the dried hardened soil is pushed to one end of the box and the total shrinkage is measured.

Shrinkage guage



11.16 Laboratory Tests

A complete range of laboratory tests is described by Houben and Guilland and the tests carried out can be tailored to the needs of each project.

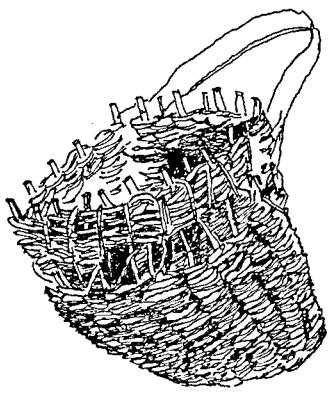
11.17 Compression Tests

Compression tests, to establish the bearing capacity of any mix to be used for load bearing purposes, should be carried out prior to the work proceeding. Any reliable structures laboratory can be used for this purpose.

TRANSPORT

A wide range of devices were used traditionally to transport the raw materials and building mortars to the site or the walls where they were to be used. The list has been reduced to methods that may be used today for short distance transport, that is from mixing point to wall.

Creel



11.18 Creels

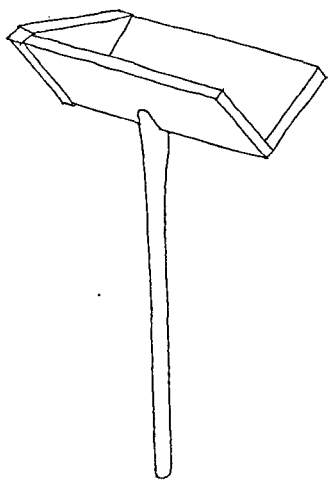
Creels or baskets either carried by the operatives or mounted as panniers on garrons or ponies are a traditional method still in use in some parts of the Hebrides. Although normally associated now with peat cutting operations, fale for building could be transported in the same way.

As an alternative, wet blocks of fale could be slipped off the spade onto a shelved back pack to be transported to the wall or a more suitable drying site.

11.19 Hods

A builder's hod is a light open trough mounted on a staff and used for carrying bricks or mortar. A bricklayer's hod can be used to carry the material to the wall, particularly in the form of adobe blocks or tiles.

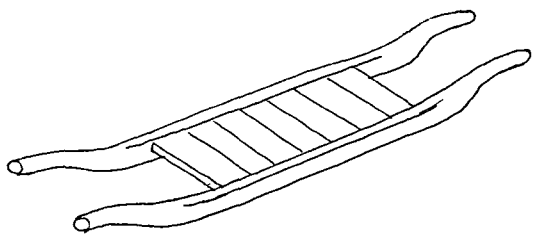
Hod



11.20 Barrows

A mason's barrow in the form of a stretcher with a plank floor or a normal builder's wheel-barrow is useful for moving material but heavy turves being transported over a large site are better on a motorised barrow with caterpillar tracks.

Mason's Barrow



BUILDING

11.21 Moulds

Traditional moulds are not known in Scotland as there is no evidence of clay-block being used even

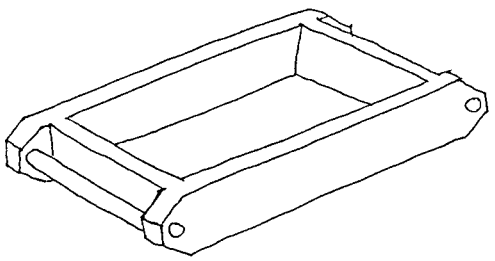
although Scots settlers in the colonies appear to have used the technique.

The moulds used to make the clay-blocks and clay-tiles for conservation work take two main forms: those which are rigid and those which are demountable.

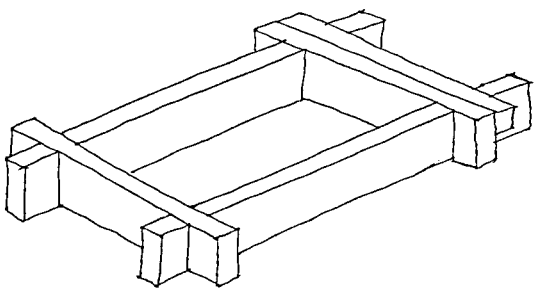
Rigid moulds comprise a hardwood frame with a built in handle at either end. This is necessary to lift the mould clear of the block. Various techniques, such as oiling the mould or dipping it in water and applying sand, prior to filling it with the mix, have been tried to make the mould easier to remove but all have failed to achieve an easy release. A board has been cut to pass easily through the mould and, on filling the mould with the clay-mix, the board is placed on top, an operative stands on it and two others lift the mould clear of the block.

Demountable moulds are easier to operate. The mould is set up with a wedging piece at one end. After filling, this is removed and the mould comes apart releasing the block.

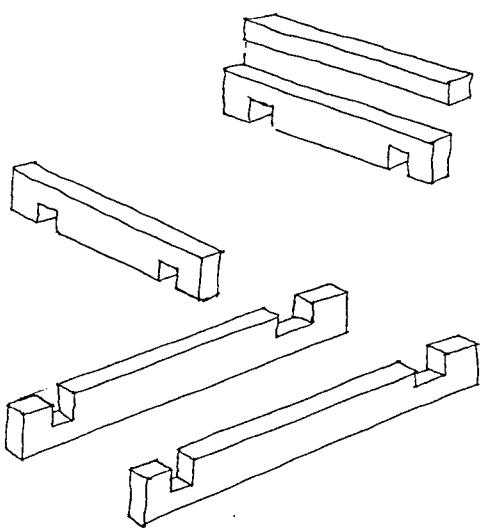
Rigid mould



Demountable mould assembled



Component parts



11.22 Shuttering

A number of drawings and descriptions of shutter types are available. Stephens and Burn describe the shuttering as a "mould".

"This should be made with clean thin planks of pine, or other light wood, well seasoned, to lessen the chances of warping. Their thickness should be about 1 inch, well planed on both sides. The length should be from 12 to 14 feet for ordinary work; but shorter moulds, as 7 feet, will be at times useful. The depth of the mould should be 14 inches - some recommend 2 feet 9 inches; but practical experiment, where the former depth was adopted, showed that it was more convenient than the latter, giving at the same time greater facilities for detecting error in carrying up the walls. The two sides of the mould, of whatever depth, are formed by the requisite number of planks laid edge to edge, and tongued and grooved or held together by pins (dowels) placed at a distance of from 4 to 6 inches. Battens should be nailed on the outside of the side of the frame at intervals of 30 inches, or thereabouts. Iron handles may be placed at each end of the upper edge of frame, to facilitate its removal. It is necessary to have the boards forming the side of frame, and the battens, of one uniform thickness.

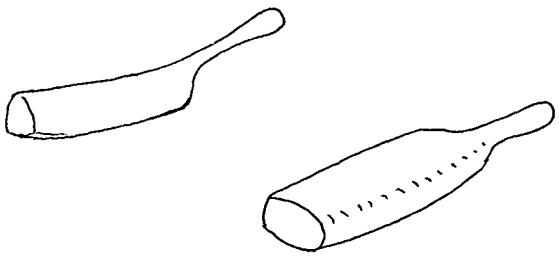
In forming the angles, a separate frame is required; this should be of same depth as the other, but having battens at each end only, and these in the inside. These should be put firmly on with screw-nails, as the ordinary ones are apt to start. The use of these battens is to prevent the head of the mould from springing out when forming the ends of the wall. The pressure being outwards, the head of the mould must evidently be of the same depth as the mould, and its width equal to the intended width of the wall. This is shown in the figure where aa are the sides of the mould, bb the inside battens, c the head. The next point to be attended to is the "joists". These are to be made of hard timber, 4 inches broad and 2½ deep. Suppose the thickness of the wall to be 14 inches, the sides of the mould or frame being each 1 inch thick, mortises must be cut at each end of the joist, as at aa, the distance between the inner ends of which must be 16 inches. This will give a width between the inside faces of the mould of 14 inches, equal to the intended thickness of the wall. The figure shows the plan of the joists and sides of the mould when laid on the wall. The mortises should be 1½ inch wide, and some 4 or 5 inches long; and in order still further to facilitate the placing of the sides of the mould, a groove bb some ½ inch deep, and 1 inch wide (the thickness of the sides), may be made in the upper sides of the joists, close up to one end of the mortise. "Posts" are next to be provided, 4 inches square, and equal in length to about twice the depth of mould. Tenons will be made at one end to fit into the mortise in the joists. The outer sides of the mould will thus press closely against the inside face

of each post. It is essentially requisite that all the posts shall be of uniform scantling, and the tenons all the same size: this will prevent numbering being necessary, and facilitate operations. The foot of the posts aa, showing tenons bb, is shown in the figure. "Caps" are next to be described. These consist of pieces of hardwood aa, 4 inches broad and 2½ or 3 inches thick, having snugs bb same breadth, and 2½ inches thick, dovetailed at each end. The distance in the inside of these snugs should be 25 inches, so that space may be afforded on each side to drive thin wedges between the inside face of snugs and outside face of posts.

The method of using the apparatus may now be briefly described. The foundation of the building to be erected is to be of stone or brick at least 18 inches above the level of ground. The joists are next to be laid on the wall, at distances corresponding to the length of boards forming the sides of mould. The joists should be so laid that the inside and outside line of foundation-wall shall correspond with the inside line of mortises cut in joists. Having adjusted joists, the foundation wall, in stone or brick must be increased in height a course or two, so as to enclose the joists in the body of the wall. The posts with tenored ends are next to be inserted in the mortises of the joists, the sides of the mould placed in the grooves, the outside end filled in with the prepared board, and the caps finally adjusted over the upper ends of posts, and driven hard up by means of the wedges. The mould sides will, by this means, be able to resist the force of compression used in ramming the earth; while the end nearest the extremity of wall will be prevented from flying out by means of the battens placed at the ends of each side forming the mould, as before described. In the figure the arrangement of the various parts may be seen: aa is the brick or stone wall, bb the joists, cc the posts, dd sides of mould, e the cap, ff the wedges to drive up the same. It should here be noted that, as the foundation in stone or brick is worked round, the joists used at one part of the building should be driven out (to facilitate their removal, they are made slightly narrower at one end than the other), and placed as before; thus, when the foundation is finished, it will present the appearance of a wall 20 to 24 inches high, having all round it square or oblong holes, in which the joists can be placed. Before commencing to ram the earth in the mould, it will be necessary to try it by means of the plumb-line and square, to ascertain that it is properly levelled."

11.23 Beaters

Small timber beaters, similar to those used by plumbers to dress lead, are useful in forming the sides of mudwall or for filling clay-block and clay-tile moulds. Beaters with a convex face are best as there is less chance of adhesion pulling the mix from the wall.



Beaters

11.24 Rammers

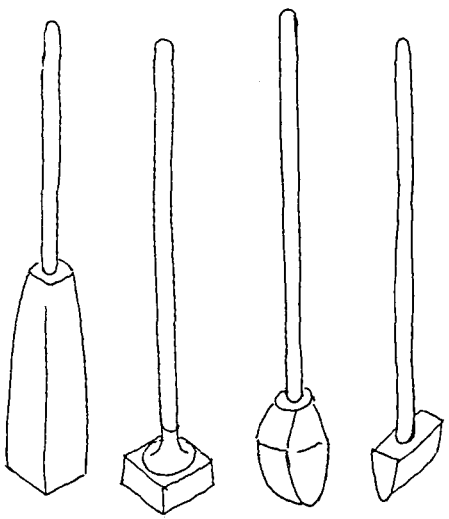
Rammers for pisé work take three main forms.

a. The flat headed rammer sometimes made of timber but often of metal with a timber shaft.

b. The spade shaped wooden rammer.

c. The wedge shaped iron rammer.

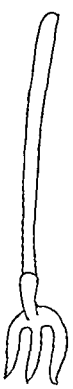
All are designed to be reasonably light to lift whilst exerting considerable force when dropped or thrust into the mix.



Rammers

11.25 Mudwall greap

The mudwall greap, graip or fork is a specialist tool made as a version of the normal garden fork. The prongs are wider and flatter than the garden fork prongs and are normally three in number.



Mudwall greap

11.26 Paring iron

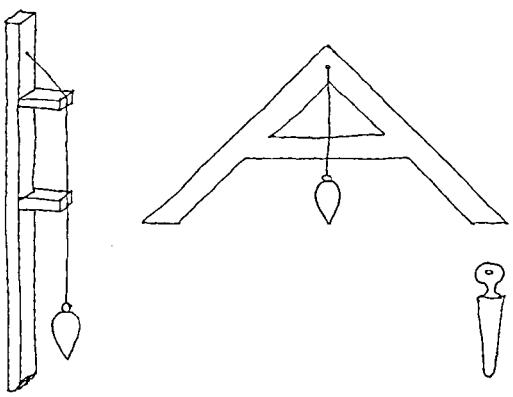
The paring iron for surfacing mudwall is spade shaped but lacks the shoulders used to exert pressure on a normal garden spade. The cutting edge is normally straight but this is not crucial. One feature that is important is that the back of the paring iron is flat allowing the tool to be used vertically from the wallhead.

Paring iron

11.27 Plumb-line

This is often replaced by a spirit level but plumb-lines mounted on simple structures can form an inexpensive alternative. Ancient examples of plumb-lines for assessing vertical and horizontal surfaces are shown in the diagrams.

Plumb-lines

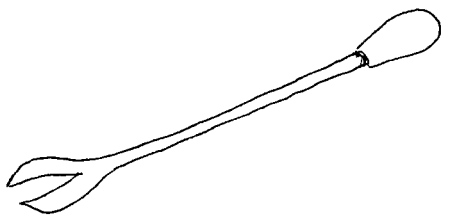


FINISHING

11.28 Prong

A single or double pointed prong is used to prepare any form of shuttered pisé or mudwall for plastering or rendering. The tool is straight but used like a hammer to strike the surface to form a series of indentations. These indentations in turn form the key for the plaster or render.

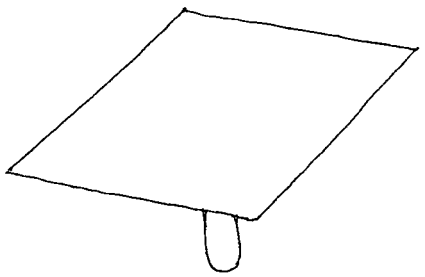
Prong



11.29 Hawk

The hawk is a square board fitted with a vertical handle on the underside. This is used by plasterers or by masons pointing stonework as a means of carrying the plaster or point about to be applied to the wall. It is assumed that the name "hawk" refers to the way that bird is carried on the wrist. The name has been in continuous use since the seventeenth century.

Hawk



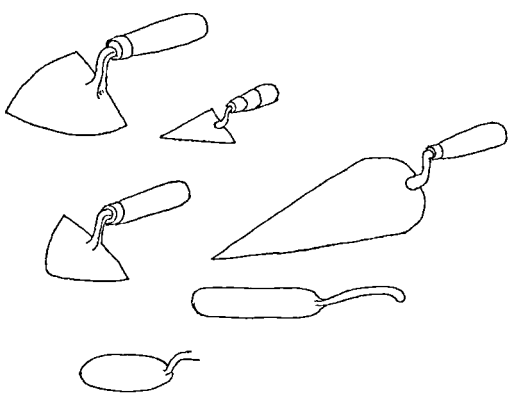
11.30 Spray

A small fine-jet water spray is useful for wetting existing surfaces before the application of new material.

11.31 Trowels

Trowels are flat-bladed short-handled tools used for spreading mortar. They are often pointed at the free end but the size, weight and shape is a matter of personal preference, tempered by the job to be carried out.

Trowels

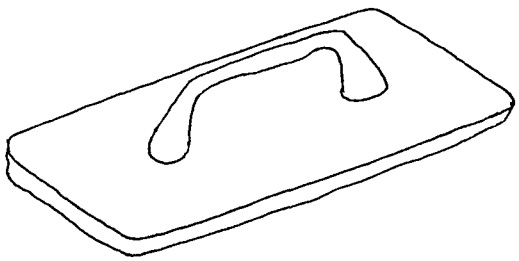


11.32 Floats

A float is a rectangular block of wood, sheet of metal, or block of plastic, fitted with a handle and used to smooth clay or plaster.

In trials: timber floats have been found to drag clay off the wall; metal floats are too smooth and bring all the fines to the surface, which then tends to crack: but good results have been obtained using plastic, the surface being left flat but evenly textured.

Floats

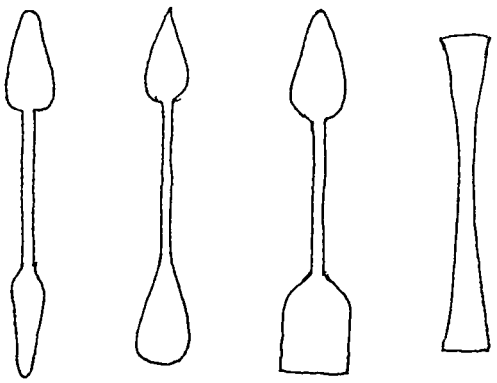


11.33 Spatulas

Metal, bone and box-wood spatulas have been used for pointing and by sculptors, working in clay, since Biblical times and possibly earlier.

The spatula is a hand tool, usually with a slender shaft and widening at the ends to pointed, rounded or squared blades that apply, smooth or model the material.

Spatulas



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GLOSSARY

ADOBE
Unburnt air-dried brick formed of earth mortar.

BALL-CLAY
Pipe-clay.

BATTERED
Inclined towards the wallhead.

BEAM-FILLING
Nogging between rafters or ceiling joists at their support, used to stiffen the timbers and close the eaves.

BIGGIN
Building.

BLAES
Bluish-grey indurated clay or soft slate. Mudstone.

BOOL
A rounded river-washed or sea-washed boulder.

CARSE
Low land beside river.

CASEMATES
A chamber in the thickness of the wall of a fortress.

CAT
A handful of straw, mixed with soft clay, used in building mud walls. The bundles are placed between the laths and the walls, or between the wooden posts used in constructing the walls. The word is most commonly used in the phrase - cat and clay.

CLAIK
To bedaub or dirty with any adhesive substance.

CLAMP
A straw and earth covering to a pile of bricks for burning; or root crops for storage.

CLART Clort, Claurt, Clairt, Clert.
Mud or mire.

CLAT
To bedaub.

CLATCH
Anything thrown for the purpose of daubing.

CLATCH-UP
To fill or stop up with any adhesive substance.

CLAUT AN(D) CLAY, Clat an clay.
Straw covered with mud and clay and plastered on a wooden frame work to form a rough kind of wall.

CLAY-AN'-DUBBER
A builder of houses with mud walls, one who does cat-an-clay work.

CLAY-LUMP
An alternative name for adobe.

CLEIT
A wattle framework forming an armature for turf.

CLEM. Klem, Clam, Clim.
To stop a hole by means of lime, clay, or by using any viscid substance; also to clem-up.

COUPLES - Cupples
The early use of this expression in Scotland refers to any pair of inclined rafters or crucks supporting a roof of a house. More recent usage limits the term to the common rafters.

CREEL
A wicker basket. A deep wicker basket carried on the back by means of a strap passed round the breast or, more rarely, the forehead, or slung one on each side of a donkey or garron.

CREEL-HOUSE
A house of wattle or wickerwork used as an armature to support turf walls and roofing.

CRUCK
Pairs of large curved timbers used as the principal framing of a house. They combine the functions of rafters and wall posts. In many parts of Scotland the crucks are made up of smaller timbers jointed and pegged to provide a continuous support, as described above.

DEAFENING
Pugging used as an acoustic barrier.

DIKE

A ditch: low wall, especially of turf; or embankment.

DIVET. Diffat, Devit, Divot.

A thin flat turf, generally of an oblong form; used for covering cottages, and also for fuel.

EARTH-CUPPLE

A turf gable used as a support for the roof-purlins.

FALE, Fail, Feal.

Any grassy part of the surface of the ground, as united to the rest.
A turf, a flat clod covered with grass cut off from the rest of the sward.

FEALLY-DAEK

A Shetland name for a dike built of fale.

FEALLY-SUNK

A seat in the form of a low turf wall.

FIRING STEP

A step on which a soldier, behind a rampart, steps to fire.

FLAA. Flaas.

A thin turf or more correctly a form of water propagated vegetable mat comprising sphagnum moss interlaced with the root system of plants that have propagated on its surface until it forms a thick homogeneous mat.

FLAG

A piece of green sward, cast with a spade. A large sod, put on the back of the fire, is called a flag.

FLAUGHTER

To pare turf from the ground.

FLAUGHTER-SPADE

A two-handed spade with a broad heart-shaped blade used for cutting surface turf.

GLACIS

Bank sloping down from fort, on which attackers are exposed to defenders' missiles.

GUN-EMBRASURE

An opening for a gun in a wall or parapet.

HALF -DIKE

A dike or wall with a single vertical face.

HALF-TIMBERED

Having a wooden framework with infill of other material such as tempered earth.

HEAD-DIKE

The enclosing wall of a township or field system.

HURDLE

A portable wooden frame strengthened with wattles and used as temporary fencing.

ICEHOUSE

Building often partly or wholly underground used to store ice.

MOSS

A morass or bog. An alternative name for peat.

MOSS-HOUSE

A house excavated from the living peat-bog.

NOGGING

Material used to infill the panels of a timber framework.

OSIERS

Long rod-like twigs (usually willow) used in basketry. Wicker-or wattle-work.

PONE

A thin oval strip of green turf measuring about 15 x 5 x 1 inches. Used in Shetland in the roofing of houses or peat stacks.
Swards of earth, cut very fine, upon the surface of which grows a short grass. Used for the sole purpose of roofing.

RIN-WA', Run-wall.

An internal cross-wall or gable.

SCRAWS

A thin turf or sod, generally used for roofing.

SCRAW-BUILT

Built of sods or turf.

SKEW

Verge.

SOD

A species of earthen fuel, used for the back of a fire on the hearth.
In Ireland, a building material comprising green turf.

SODDIE

A seat of sods or turf in a cot house.
A turf walled shack, in America.

SPAUD

Spade.

TIMBER-LACING

Timber boards built into a wall as a form of reinforcement or to spread the load of floor joists.

WATTLE

Poles intertwined with twigs, reeds or branches used in the construction of walls and fences.

YARPHA

A name for immature peat used in Orkney and Caithness.

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Earth Structures and Construction in Scotland

A guide to the Recognition and Conservation of

Earth Technology in Scottish Buildings

Historic Scotland Technical Advice Note 6

Bruce Walker

Christopher McGregor

This publication is aimed at all earth-building owners, historians, geographers, conservation officers and practitioners with an interest in earth structures.

It urges: caution when deciding to change the status quo; dialogue and discussion on conservation practice and procedure; reporting of any hitherto unknown archive material: experimentation and recording; and, most importantly, a change in attitude to these historically valuable structures.