BUILDING WITH EARTH IN SCOTLAND:

INNOVATIVE DESIGN AND SUSTAINABILITY

SCOTTISH EXECUTIVE

Central Research Unit

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The historical context chapter of this document relies heavily on the work of Bruce Walker and Chris McGregor but the interpretation put on this data does not necessarily reflect their views.

Cover Photograph: Courtesy of Centre for Alternative Technology.
The cover photograph shows a rammed earth wall in the Autonomous Environmental Information Centre at CAT described in Chapter Six.

CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

1. This report was commissioned to assess the potential for new construction using earth in Scotland and the environmental benefits that could result. The study assesses the heritage of earth construction in Scotland in the context of a modern European revival. It examines the use of earth in relation to the modern Scottish construction industry and highlights opportunities for development.

2. The study was undertaken between November 2000 and June 2001 and was divided between desk based research and field visits to buildings and key people in Scotland, England Northern Ireland, Wales, Holland and Germany.

3. For the purposes of this report, earth is taken to mean naturally occurring sub-soils. These can be mixed with natural fibres, for example straw, to produce a wide variety of construction materials.

HISTORICAL CONTEXT

4. Globally it is estimated that a third of the worlds population live in houses of earth construction. These are both modern and traditional and occur in most cultures and climates. In the U.K. there are estimated to be 500,000 inhabited earth buildings. Earth was the principal material used in Scottish construction until the 18th century and Scotland retains a rich heritage of earth construction with much regional variety. Many surviving buildings are not recognised as being of earth construction and much work has been done on this in recent years by Historic Scotland and others.

5. The research on historical techniques forms a good basis for the development of modern construction applications.

WHY USE EARTH?

6. The principal reason for using earth-based materials is their excellent sustainability characteristics. These include low carbon emissions, efficient use of finite resources, minimising pollution, minimising waste, use of benign materials, local sourcing and biodegradability.

7. The construction industry is recognised as currently being a major source of carbon emissions, pollution and waste production. Within the context of national priorities for reduction of the environmental impact of construction, earth has the potential to make a significant contribution.

THE PROPERTIES OF EARTH AS A BUILDING MATERIAL

8. Earth can be used in a wide variety of ways within construction to form walls (both load bearing and non-load bearing), floors, roofs and other elements. It can provide good thermal and acoustic insulation and has a particularly good ability to regulate internal air humidity and quality. If properly used, it is a durable and beautiful material.

THE TECHNIQUES OF EARTH CONSTRUCTION

9. The most common techniques of earth construction are:

- Mudwall. This is a simple historical technique of monolithic walling, using an earth straw mix.
- Rammed Earth. In this technique earth is compressed between temporary shuttering to create dense monolithic walls.
- Earth Brick. This is an ancient material comprising un-fired bricks of varied composition.
- Compressed Earth Block. This is a modern material similar to earth brick, but having better load bearing capacity.
- Earth Infill in Timber Frame Construction. This involves light earth/fibre mixes either formed on site or in block form. It can give good thermal insulation and is particularly appropriate to Scottish construction practices.
- Earth Products. A range of prefabricated products is available, including blocks, boards and panels. These are currently imported from Germany.
- Earth Plasters. These are effective as either traditional wet plaster or as plasterboard.

CASE STUDIES

10. Thirteen case studies illustrate the surviving heritage of earth construction in Scotland, the lessons to be learned from the few recent modern projects in the U.K. and the more advanced contemporary use of these technologies across Europe. They demonstrate:

- The lasting qualities of earth, as well as good traditional building design and construction practice, which are being reinterpreted in contemporary construction.
- Earth has the potential to be used to produce high quality building products, which satisfy the requirements of existing construction industries in developed European countries such as Scotland.
- There is a small group of designers and builders capable of using earth construction techniques in Scotland.
- There is sufficient and easy access to earth as a resource for building in many regions of Scotland.

EARTH MATERIALS AND BUILDING PROCUREMENT

11. The current market for earth construction is limited to one off projects for clients with a high environmental awareness. It is thought there may be appropriate applications in the new National Parks. The appropriate use in repair and alteration to surviving earth buildings is another potential market. The widespread adoption of earth products outside these sectors will require active promotion.

12. There are currently a few designers with expertise in this field. Easier access to information and technical support in the U.K., as well as an accepted standard, would facilitate design opportunities.

13. Earth construction is capable of demonstrating compliance with the current building regulations, however this often involves considerable additional work for the designer and building control officials.

14. At present earth materials are either imported or produced on a project-by-project basis. There is interest among manufacturers of existing building products to diversify into earth products.

15. At present there are a few specialist contractors competent in earth construction. Establishing a centre for training, testing and dissemination of information could expand this base.

16. There is a perception of ‘novel’ materials presenting difficulties in obtaining finance and insurance. There is little firm evidence of this.

17. There is currently no accepted standard for earth construction within the U.K. This lack of control documents is a significant restraint on the development of earth construction. There are several means to establish such a standard and these would be best promoted from established official organisations.

KNOWLEDGE AND INFORMATION

18. A small amount of testing and research in earth construction has been carried out in the U.K., mainly focussing on traditional practices. This field of research is growing in Europe and is necessary to demonstrate the credibility of new earth building. There are potential testing facilities in Scotland for earth building materials but a lack of expertise to carry out this work.

19. In the U.K. training and education initiatives in earth construction exist on a small scale attached to specific projects or as part of wider university or college courses. German experience illustrates the potential for official recognition with industry-based qualifications in earth building. Wider acceptance of earth building technologies has also been promoted through regional interest groups and specialist publications as well as coverage in the general media.

FUTURE OPPORTUNITIES

20. There are opportunities for further research to:

- Examine the scope of potential environmental benefits
- Test materials properties
- Assess the potential for promotion through use within public procurement

21. There are opportunities to facilitate the use of earth materials in the process of modern construction by:

- Developing an officially recognised standard for earth construction materials and techniques.
- Establishing a centre of excellence to promote training, education and testing
- Dissemination of information and guidance to Building Control officials

22. There are commercial opportunities for:

- The existing manufacturing infrastructure to diversify into the production of earth-based materials.
- Innovative partnerships between industry, educational institutions and the public sector both within Scotland and with mainland Europe.

CHAPTER ONE INTRODUCTION

THE PURPOSE OF THE STUDY

1.1 ‘Sustainability establishes a new, complex and challenging agenda for architecture. It demands that we no longer externalise the costs of environmental degradation, that we shift away from regarding the environment as something distinct from and outside of what we design and build. It will require us to design and manage our built environments in ways which mimic and accord with the patterns and processes of the natural world.’ [1]

1.2 This report was commissioned by the Scottish Executive Central Research Unit in November 2000. Its purpose is to examine the scope for the use of earth in new construction, the potential environmental benefits and issues affecting its use.

1.3 It is written at a time of national recognition of the role that construction could play in the implementation of policy to reduce global warming and improve the sustainable use of resources. In this context, the Scottish construction industry has considerable scope to take up new opportunities being developed in other E.U. countries to adapt its use of materials, construction and procurement methods.

1.4 Internationally, building designers and materials producers are exploring the potential of a range of low impact technologies for use in modern construction. Over the past decade, Scottish designers and producers have begun to participate in this process.

1.5 Earth construction is one of the most interesting of these technologies. It encompasses a wide range of materials and techniques, but unlike many other innovative ideas, has a strong historical tradition. Earth construction has inherently good environmental characteristics, is easily adaptable to the modern construction processes and has the capacity for making buildings of high quality and durability. It is thought that earth may be particularly appropriate for use in new buildings in national parks and as a finish for buildings in special landscapes.

THE SCOPE OF THE STUDY

1.6 ‘Earth’ in its fullest sense is currently widely used in construction, as primary materials such as aggregates, sands and minerals, and as fired clays. However current construction practice generally involves a high level of processing for these materials.

1.7 This report will focus on the use of low-processed forms of earth materials. It will investigate traditional and innovative techniques that have been used successfully in the UK or in comparable contexts further afield. It will focus on techniques that have relevance to the Scottish context for climatic, technical or cultural reasons.

[1] The Development of a Policy on Architecture for Scotland, Scottish Executive, 1999

SPECIFIC EXCLUSIONS

1.8 The report will not examine ‘earth sheltered’ construction, which uses earth as a covering to other forms of construction. Nor will it examine in detail the use of ‘stabilised’ earth, which commonly involves the use of cement, bitumen or lime in combination with earth. These additives fundamentally alter the characteristics of the materials, particularly in regard to environmental impacts, and they have been excluded for this reason.

1.9 Various forms of turf construction, which were historically important in parts of Scotland, are also outwith the scope of this study.

TERMINOLOGY AND DEFINITIONS

1.10 Internationally, earth construction techniques vary enormously according to climate, soil conditions, building typology, and traditional and modern construction practices. This rich diversity is an important resource in the wider context of design and has an equally rich and diverse descriptive language. For the purposes of this report definitions are used that are most clear and relevant to the Scottish context.

Additives	Substances which are added to a base material to improve certain properties. These include benign additives, such as plant oils, dung, urine, etc which have a minor effect, and more powerful stabilisers such as cement.
Earth building	Constructional techniques utilising soil (usually sub-soil) in combination with other natural materials.
Earth Materials	Construction materials mainly composed of unfired earth. The material will degrade back to natural soil when immersed in water.
Embodied energy	The energy that is embodied in a material is equivalent to the total amount of energy used in bringing the material to its present state and location. It may also be thought of as the energy, which could have been saved, had the product never been manufactured.
Life cycle analysis	A method of listing the total environmental impacts associated with a product’s manufacture, use and disposal.
Mud	Earth that is used for construction in a wet soft state.
Mudmason	The traditional term for an earth builder.
Sustainability	The concept of managing the use of natural resources such that the amount of the resource is not irretrievably depleted. Economic development taking place in this way is termed ‘sustainable development’, and has been defined as ‘development that meets the

needs of the present without compromising the ability of future generations to meet their own needs'. [2]

Stabilisation	Techniques involving the addition of processed binders to earth, such as cement, bitumen and lime. These can increase a materials durability and strength, but greatly increase embodied energy, waste and life cycle cost.
Standards	For the purpose of this report 'standards' are taken to mean documents giving authoritative guidance on the nature and suitable use of materials, such as those produced by bodies such as the British Standards Institute, as well as recognised codes of practice, specifications, etc. The 'Technical Standards', which are a specific part of the Building Control system, are always referred to as 'Technical Standards'.
Sub-soil	Soil that occurs below the organic horizon (top-soil) and above the bedrock
Waste	Waste is defined in the Control of Pollution Act (1974) as including:

a) Any substance which constitutes a scrap metal or an effluent or other unwanted surplus substance arising from the application of any process

b) Any substance or article, which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled.

[2] U.N. The Brundtland Report

CHAPTER TWO THE HISTORICAL CONTEXT

INTRODUCTION

2.1 An understanding and appreciation of traditional earth building can inform innovative and appropriate uses of earth in new construction. This chapter will outline the historical basis for Scottish earth building and discuss the diversity of traditional techniques. It will also assess the work that has been done to conserve and understand these traditions.

THE TRADITION OF EARTH AS A BUILDING MATERIAL IN SCOTLAND

2.2 '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 it is capable of fulfilling the most demanding of roles'.[3]

2.3 In the British Isles at present there are estimated to be half a million inhabited earth buildings in a varied range of construction materials and architectural types, each with their individual performance characteristics, regional significance and distinct uses.[4] A significant number of these earth structures can be found in southwest England, the East Midlands, Cumbria, East Anglia and Lincolnshire. There is also a rich heritage of earth building in Ireland and Wales.

2.4 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 varied geology led to the development of a wide range of building types using clay sub-soils and turf.[5]

2.5 In addition to vernacular buildings, a broader use of earth structures was also to be found in major architectural and civil engineering projects. An understanding of the basic principles of earth construction has grown out of investigations concerning the conservation and archaeology of these structures.[6]

2.6 The Historic Scotland Technical Advice Note 6, Earth Structures and Construction in Scotland, outlines the development of traditional earth building and the properties of earth relevant to construction. From prehistoric times there was continued use of earth as a building material, lubricant to move heavy weights, waterproofing agent, decorative finish and colouring agent.

2.7 The use of materials changed significantly during the period of agricultural improvement and industrialisation with a wholesale replacement of the building stock in a short space of time. While traditional materials continued to be used there was a significant increase in the use of stone as a facing material.[7]

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[3] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.
[4] L.Watson in ICOMOS UK, 2000.
[5] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.
[6] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.
[7] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.

2.8 The 19th century also saw the development of a modern construction industry, which made increasing use of Portland cement. In the face of these innovations, earth technology was perceived as out of date and was abandoned due to the labour intensive nature of the work. Until then the use of earth had been so commonplace that it did not require explanation and skills were generally passed on by word of mouth. As a result, archive material tends to emphasise unusual or experimental work rather than everyday practice and the knowledge base was lost.[8]

TRADITIONAL TECHNIQUES

2.9 There were numerous local variations of earth construction in Scotland, which developed in response to the complex geology of the landscape. Where clay soils were abundant, the earth was trodden and mixed with straw, often with the help of a horse or cattle, and the resulting mud was moulded into the shape of thick walls on stone foundations. Examples of this ‘mudwall’ technique can still be found in the Carse of Gowrie near Perth.[9]

2.10 In the north east of Scotland the mud and straw was layered between round boulders known as ‘clay and bool’. These walls were often formed in shuttering[10]. Mud mixes were also common as infill material within timber frames and examples of this technique survive as internal walls in many higher-status stone buildings, such as tower houses.

2.12 Later, types of earth construction developed that used earth in combination with formwork to achieve straight vertical walls of standard thickness. Rammed earth in shuttering, known as pise de terre, was widely employed in France and may have been introduced to Scotland along established trade routes. Earth bricks formed in wooden moulds were also commonly used in parts of England but were not widely adopted in Scotland. They have been used, however, in the consolidation of mass earth walls.

2.13 In the Highlands and Islands turf, sod or peat construction were more commonly used for the main structure, often in combination with stone, while locally occurring clays were used in hearths, for waterproofing wall heads and as plaster. [11]

2.14 Throughout Scotland, many stone buildings still contain earth mortars either as bedding material or as infill within the wall core. Clay plasters were also common in pre 19th century buildings and continued to be used in the construction of lower status buildings until recent times.

2.15 The wide range of earth techniques used in Scotland made the mudmasons particularly adaptable and many of their skills were taken overseas during periods of emigration. It is ironic that Scottish earth builders are now looking to countries such as America and Australia for guidance on earth building. In these countries the knowledge base has developed in more recent times, drawing on both indigenous traditions and those of the Scottish and European settlers.

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[8] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.
[9] B.Walker and C.McGregor, *Historic Scotland TAN 6*, 1996.
[10] B. Walker, 1977.
[11] B.Walker and C.McGregor, *Historic Scotland TAN 5*, 1996.

THE CONSERVATION OF SCOTTISH EARTH STRUCTURES

2.16 Much of the physical evidence for Scottish earth construction is hidden behind later lime or cement coatings in the form of pointing, plasters and renders. A large amount of survey work has been carried out by individuals, conservation bodies and interest groups[12], but there is as yet no comprehensive inventory of surviving earth structures. Those that do survive are often under threat from inappropriate repair methods and neglect.

2.17 In an attempt to relearn these traditional skills, Historic Scotland has commissioned experimental work in connection with historical studies.[13] There has also been well documented. analysis and repair of surviving earth structures.

THE RELEVANCE OF TRADITIONAL TECHNIQUES TO NEW CONSTRUCTION

2.18 'Vernacular traditions experimented with, consolidated and refined over centuries, are among the most valuable and reliable sources of information on the techniques appropriate to the soils of an area, and a guide to the structural and climatic benefits of the systems employed.'[14]

2.19 There are many lessons to be learnt from traditional earth building practice which could inform a modern vernacular for earth building:

- The longevity of earth buildings is due not only to the materials and techniques employed, but also to the quality of workmanship and appropriateness of the design to a particular setting and region.
- The durability of earth buildings is also determined by appropriate maintenance and repairs that are compatible with the original construction.
- In the past earth building was generally a seasonal occupation reliant on good weather conditions. Prefabrication of dry earth components, such as blocks, and protected working environments could widen the scope for year-round use of these materials.
- Traditional earth building techniques, which are simple and labour intensive, could be adapted to modern self-build forms of construction. With developments in mechanisation these techniques could also have relevance for modern industrial applications.
- Surviving earth structures in Scotland illustrate the appropriate use of local materials, which has resulted in diverse and distinct cultural patterns. The maintenance of this cultural diversity and local knowledge is central to the debate on sustainability.

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[12] In particular B.Walker and C.McGregor, and B.Walker's work for the National Trust for Scotland and ICOMOS UK Earth Structures Group.
[13] See Appendix B, B.Walker and R.Little's work for Historic Scotland, Earth Structures and Renders Experiments, 1996.
[14] J.Norton. 1997.

- Buildings composed of natural materials such as earth, straw, timber and stone ‘tread lightly’ on the landscape and have sustainable qualities that could be beneficial to new construction. In particular the ‘deconstructability’ of earth allows for continual use and re-use of materials that are safe and non-polluting. Minimisation of waste is particularly relevant to the current demands of the modern construction industry.[15]

[15] See para.3.14

CHAPTER THREE WHY USE EARTH?

INTRODUCTION

3.1 This chapter will assess the environmental benefits of using earth in construction, both locally and nationally. It will also highlight how this could contribute towards reaching established environmental targets.

EARTH AS A SUSTAINABLE MATERIAL

3.2 Materials selection is one of the critical factors in sustainable building design. Earth as a construction material has inherently good environmental characteristics and could make a significant contribution to the improved sustainability of construction.

Design for Low Carbon Emissions

3.3 Commonly used construction materials, such as ceramic bricks or those based on cement and gypsum, necessitate mining in a restricted number of geographical locations, significant levels of transportation and high temperature firing.

3.4 To prepare, transport and construct earth materials commonly requires about 1% of the energy required by the commonly used cement based alternatives.[16] Air-dried bricks require about a third of the energy of fired bricks to produce (440 KWh/m3 compared to 1300 KWh/m3).[17] One Scottish brick producer estimates that 40% of his production does not need to be fired for the uses to which they are put[18].

3.5 In many forms of earth construction there is the potential for on, or near, site sourcing of materials. This reduces to a minimum the energy used in materials transportation.

Efficient Use of Finite Resources

3.6 In the production of earth materials there are no waste by-products and defective products can be returned to the start of the production cycle and re-used. Where other materials are mixed with the earth these are generally the waste products of other industrial or agricultural processes, for example straw or wood chips.

Minimising Pollution

3.7 Earth materials create minimal pollution. Throughout the entire cycle of production, construction and use, earth materials require a very low level of processing and create very little polluting waste. At the end of a buildings life, the materials can easily be re-cycled or returned to the ground.

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[16] M. Westermarck, 1998, also G. Minke, 2000
[17] M. Westermarck, 1998
[18] Pers. Comm., Erroll Brick Co., 2001

3.8 In contrast, many commonly used building materials can cause significant pollution. Such materials require a high level of processing often involving environmental pollution, create waste during construction, cause atmospheric pollution during building use and are an enduring waste material at the end of a buildings life.

Using Benign Materials

3.9 Earth materials do not present a significant health hazard during production or construction. Used in buildings they can facilitate a good internal air quality by regulation of relative humidity[19].

3.10 In contrast, many commonly used materials present low level health hazards to workers during production and construction and to subsequent building occupants, for example through toxic emissions and dusts.

THE NATIONAL CONTEXT

3.11 Buildings and the construction industry are a major source of greenhouse gas emission, resource depletion and environmental pollution and this is reflected in government strategies.

3.12 Britain is committed to reduce the emission of a range of greenhouse gasses, and in particular to reduce the 1990 level of C02 emissions by 20%, by 2010. Between 40% and 50% of UK C02 emissions are attributable to the use and construction of buildings[20].

3.13 In a reasonably energy efficient building, about 50% of the energy required for a thirty-year design life is attributable to embodied energy and about 50% to energy in use[21]. The introduction of the Climate Change Levy should encourage a reduction in the energy use in production of materials and processes of construction.

3.14 Another national priority is the reduction of resource depletion and waste production. The construction industry uses six tonnes of material per person in the UK each year[22]. Half of UK solid waste is produced by the construction industry. The introduction of landfill taxes has discouraged the production of waste, while the Egan Report[23] recognised the inefficiency and need for better management in the construction sector.

3.15 About 40% of national building procurement is publicly funded, and among public procurers, Scottish Homes have developed a leading policy on sustainability[24] that should have significant influence on this sector. Through determining the design requirements for directly procured buildings, as well as influencing policy for agencies and other public bodies, the Executive has considerable ability to effect change in the construction industry.

[19] See para. 4.11.
[20] Stevenson & Williams, 2000
[21] Pers. Comm., R. Bennetts, DETR, 2001
[22] DETR, 2000, Building a Better Quality of Life: A Strategy for More Sustainable Construction
[23] DETR, 1998, Rethinking Construction, Report of the Construction Taskforce
[24] Sustainable Development Policy, Scottish Homes, 2000

SUMMARY

3.16 The principal reason for promoting the use of earth-based materials is their excellent sustainability characteristics. These include low carbon emissions, efficient use of finite resources, minimising pollution, minimising waste, use of benign materials and local sourcing.

3.17 The construction industry is recognised as currently being a major source of carbon emissions, pollution and waste production. Within the context of national priorities for reduction of the environmental impact of construction, earth materials have the potential to make a significant contribution.

CHAPTER FOUR THE PROPERTIES OF EARTH AS A BUILDING MATERIAL

INTRODUCTION

4.1 Different types of earth possess different characteristics that may or may not be suitable for construction. This chapter will discuss the main properties of earth that are relevant to its success as a building material.

STRENGTH

4.2 Earth used in building has good strength in compression, but less strength in tension, especially in its damp state. When earth is used as a load bearing material, forces must pass down within the thickness of the structure to the ground. For this reason monolithic load-bearing walls tend to be thick (450-900mm). However, it is possible to construct slender walls, arches and vaults in earth if care is taken to support these structures while they are drying out.

4.3 The compressive strength of earth can be increased by compaction, which raises the density of the material.

DURABILITY

4.4 The lasting qualities of soil as a construction material are apparent in the traditional buildings that have survived over two centuries of use.

Effect of Weathering

4.5 Earth buildings in cold damp climates need to be protected from prolonged contact with water. This can be done by placing the earth walls on a water-resistant plinth out of reach of groundwater and splashing; by protecting the walls from rain with an overhanging roof; and by protecting exposed surfaces with breathable surface coatings or cladding. Impermeable membranes such as cement floors and renders should be avoided as they can trap water within the walls and encourage rising damp.

Effect of Abrasion

4.6 Earth surfaces are sensitive to abrasion. Durability can be improved by compaction, application of surface coatings or by changing the earth mix. Additives and stabilisers are also used to improve wearing qualities.

Maintenance

4.7 The longevity of earth buildings is due, in part, to the regular maintenance regimes that were integral to traditional practice A change of attitude is necessary if modern earth buildings are to survive equally well as current construction practice promotes 'maintenance free' products such as cement renders and masonry paints. These are incompatible with earth backgrounds.

Pests

4.8 Anxieties that mice and insects might live in earth buildings are largely unfounded in buildings with solid, well-maintained walls. Pests are only likely to have an effect where maintenance of the walls has been neglected and they are suffering from severe erosion. Rodent damage is also associated with un-threshed grain or other foodstuff in the earth mix, which can be easily avoided.

Shrinkage

4.9 Earth building materials swell in prolonged contact with water and shrink on drying. The shrinkage and swelling of the earth is also determined by clay type and amount and grading of the soil. Various methods of shrinkage control can be employed depending on the building requirements of the earth.[25] The absorption of humidity from the air does not lead to these physical changes.

THERMAL PROPERTIES

4.10 Dense forms of earth construction such as mudwall and rammed earth have high thermal mass and are able to store heat and release it slowly to balance indoor climate. In contrast, light, non load-bearing forms of earth construction such as earth/fibre panels or blocks are resistant to heat flow and provide good insulation. It is possible, therefore, to alter the thickness and weight of the building material to achieve different thermal effects to satisfy the needs of a particular context.

EARTH AS A HUMIDITY REGULATOR

4.11 Earth is able to absorb and desorb humidity and thereby balance indoor climate. Bathrooms built with earth are particularly effective in this regard as the humidity is absorbed by the walls and slowly released back into the atmosphere, thus reducing condensation and inhibiting fungal growth.

[25] G.Minke, 2000.

EARTH AS A PRESERVATIVE

4.12 Timber and natural fibres are conserved in a dry state within earth walls due to earth's low equilibrium moisture content and high capillarity. This is apparent in old buildings that contain well-preserved straw and timber within earth walls.

FIRE RESISTANCE

4.13 Earth building materials have good fire resistance properties unless they contain significant amounts of fibre. According to the German Building Standards, earth, even with a high straw content, is 'not combustible' if the density is higher than 1700kg/m3. For light earth/fibre mixes fire resistance can be enhanced with the use of earth or lime renders and plasters.

SUMMARY

4.14 Earth is a variable and versatile material and can be used in construction to form walls (both load bearing and non-load bearing), floors, roofs and other elements. It can provide good thermal and acoustic insulation and has the ability to regulate internal air humidity and quality. If properly used it is a durable and beautiful material.

CHAPTER FIVE THE TECHNIQUES OF EARTH CONSTRUCTION

INTRODUCTION

5.1 Most earth building techniques in use today have developed from traditional practices. This chapter will discuss the revival and reinterpretation of these techniques in relation to modern construction and highlight those technologies that are most relevant to the Scottish context.

SOURCING EARTH FOR BUILDING

5.2 In many cases it is possible to source earth for construction on site by using the subsoil excavated from foundations and basements. It is important to examine the earth in situ to determine the nature and quantity of material available, as soil types change over short distances and depths.

5.3 Where earth is not available in sufficient quantities it may be sourced from local quarries, clay-pits, mineral operations or other construction sites and is often a waste product in the form of overburden or marginal material. Local sourcing of material is preferable in order to reduce transport and energy costs and minimise pollution.

5.4 The most significant regions for new earth building in Scotland are in areas where clay soils, sands and gravels are abundant. These are generally lowland regions in the vicinity of floodplains, including southwest Scotland, the central lowlands and the east coast. Along with the use of pre-fabricated materials, the potential for other types of earth construction, such as turf walls, might be considered in highland areas.

A SUITABLE MIX

Use of Local Subsoils

5.5 Earth building practice is extremely varied in terms of the soils available, the way they can be used, the functions to which they are applied, and how they perform in different contexts. With a few exceptions, earth suitable for construction is found in the sub-soil layers. Topsoil is unsuitable because it contains organic matter, which will decompose.

Soil Characterisation

5.6 Soils can be categorised, depending on their composition, by grading the proportions of clay, silt, sand and gravel. The generally accepted decimal grading is:

clay less than 0.002mm
silt 0.002mm to 0.06mm

sand   0.06mm to 2.00mm
gravel 2.00mm to 60.00mm
(British Standard Grading)

5.7 The grading of a soil is carried out by sieving out the larger grains; silt, sand and gravel; and by sedimentation of the fine clayey materials. Silt, sand and gravel are particles of rock (aggregates) and form the stable body of the earth during construction. Clay acts as the binder for these inert materials and is characterised by its stickiness when damp and by its hardness when dry. Clays are also susceptible to swell and shrinkage.

5.8 The type of soil available will usually determine the most appropriate building technique to be used. However, it is possible to modify earth mixes to suit particular circumstances. Balancing the amount of clays and aggregates is essential for most types of earth building. For example, rammed earth techniques are most suited to soils that have lower proportions of clay (less than 10%) and higher proportions of sand and gravel, while mudwall can be carried out with heavier soils, which contain higher proportions of clay (15%-40%).[26] Moisture content of the soil also influences the nature and workability of the material for any given technique.

TECHNIQUES

Mudwall

5.9 This technique, known as cob in England and clom in Wales, is most suited to heavy clay soils and is the most common form of earth construction to be found in Scotland. The sub-soil is mixed with straw and water until it reaches a sticky but firm consistency. The mix is then laid in horizontal layers on a stone or brick plinth, trodden down and shaped to form freestanding mass walls. In Scotland this type of construction is best carried out in dry, warm weather so that each lift or layer of mud can firm up before the next is laid. The walls are trimmed back a few days after completion using an adze or sharp spade.

5.10 Openings are formed as the walls are raised and load-bearing elements such as lintels are inserted directly onto the mudwall. Even when damp, the material has the ability to carry significant loads but account must be taken of minor shrinkage and settlement as the material dries out.

5.11 Mudwalls are usually protected by deep overhanging eaves and breathable renders and washes. [27]

5.12 Mudwall is a simple, labour intensive form of construction well suited to self-build and community involvement. Small specialist contractors are also developing efficient ways of using the technique with mechanised mixing and use of plant for moving the material on site. The speed of construction is partly determined by weather conditions and rate of drying.

[26] See Appendix A, Specification for Building Soils.
[27] See para.5.31.

Rammed Earth

5.13 Rammed earth, or pise de terre, consists of moist, loose sub-soil compacted between shuttering in layers. Coarser soils are sometimes sieved prior to compaction to remove larger aggregate. The shuttering is struck immediately and then moved along or upwards to form the next section of wall. Recent technological advances in rolling and climbing formwork, together with the use of mechanical compaction, have aided this process.[28] The exact composition of the soil and the right amount of water content are critical for the success of this method.

5.14 Rammed earth replicates the geological processes that form sedimentary rock. Walls built in this way can be as hard and durable as sandstone, can carry significant loads and are often left unrendered. In comparison to mudwalls, rammed earth walls have greater structural capacity and are subject to less shrinkage. Rammed earth is also suitable for floor construction.

5.15 Experience of working with rammed earth in Scotland has shown that this type of construction is severely constrained by damp weather conditions and is best carried out under cover.[29] This means erecting a temporary roof prior to wall building, or including the earth component as a non load-bearing element within a structural frame.[30] These limitations have implications for design, cost and speed of construction.

5.16 With significant investment in equipment, rammed earth can produce repeatable elements at reasonable cost and speed, thus it is more appropriate to modern industrial applications than 'hand-built' techniques. The need for special equipment is less appropriate for self-build construction.

Earth Brick

5.17 This method of construction covers a range of techniques from hand-made mud bricks, known as adobe, to the factory production of unfired clay bricks and the size of individual units varies according to context. Clayey subsoils are mixed with water and/or fibre to a mud-like consistency before being moulded or shaped. The bricks are air dried before use and are bedded in earth mortars. Their surfaces may be protected with earth or lime coatings.

5.18 The drying of unfired bricks can be slow without the aid of a heat source. Bricks should be protected from frost damage in their damp state.

5.19 The density of earth bricks can be varied according to their function: Denser bricks can carry loads and introduce thermal mass to a building, whilst also eliminating a large proportion of the shrinkage and settlement which occurs in mass earth techniques. Light earth/fibre bricks have thermal resistance and are usually placed within a supporting timber frame.

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[28] D.Easton, 1996.
[29] See Appendix B, B.Walker and R.Little's work for Historic Scotland, Earth Structures and Renders Experiments, 1996.
[30] See para 6.27

5.20 Hand-made earth bricks have the advantage of being simple to make and therefore appropriate for manufacture by unskilled labour. They can be produced in batches as and when time and space permits. The amount of equipment necessary ranges simple wooden moulds for low-tech applications to highly mechanised brick production for commercial use.

Compressed Earth Block

5.21 This type of earth block is produced in a manually operated press, which exerts a large amount of pressure on the earth in the mould. Blocks are thus produced in standard sizes. The soil requirements are similar to those for rammed earth.

5.22 The production of compressed earth blocks is not particularly fast (the output per person day is between 150 and 200 blocks[31]) but drying times are speeded up in comparison to wet moulded bricks. The blocks can be stacked immediately which eliminates the need for large drying and storage spaces.

5.23 While some investment in equipment is necessary the amount of mechanisation can be tailored to the resources of the particular project. Use of the finished product is ideally suited to skills that are already present in the construction industry and this should facilitate the transfer of the technique to wider applications.

Earth Infill in Timber Frame Construction

5.24 In this technique the timber frame provides the structural support for the roof and the earth is used as a non-structural infill for walls, floors and ceilings.

5.25 Traditional heavy daubs are prepared in the same way as mudwall mixes and applied by hand to a range of natural armatures such as woven willow, straw rope or sawn lath.

5.26 Light earth techniques utilise waste products such as wood chips, straw or hemp chaff as well as porous mineral aggregates in combination with a clay-rich slurry. The materials are mixed by hand or machine and can be built in situ within shuttering or formed in moulds for use as dry panels or blocks. The density and porosity of the dry mix will determine the thermal properties of the material.[32]

5.27 These lighter materials are usually clad with timber or protected by wide overhanging eaves due to poor weathering qualities.

5.28 Scotland has an established timber frame industry that could easily adapt to more innovative forms of infill. Self build construction would be more appropriate for labour intensive techniques built in situ, while more commercial applications could utilise standardised units such as light earth blocks and panels.

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[31] G.Minke, 2000.
[32] See para.4.10

Earth Products

5.29 Unfired earth products, imported from mainland Europe, are now available in Scotland.[33] They include:

- Light Earth/Straw Blocks, for use in non load-bearing partition walls. They are easy to assemble and shape and strong enough to take screws and other fixings.
- Earth/Fibre Boards: Composite board made from clay, reed and hessian, to be used instead of conventional finishing board and ideally suited to take clay plasters.
- Earth Plasters: Naturally coloured, fine textured surfaces that can be used over conventional materials as well as on earth backgrounds.

Other Techniques

5.30 A range of innovative earth building techniques is being developed to meet the needs of low impact construction. These include earth bags, extruded earth for internal walls, earth floors and earth domes.

Finishes for Earth Buildings

5.31 Sympathetic and sustainable treatments for earth walls include earth or lime renders and washes, or timber cladding. These materials are simple to repair or reapply.

Additives

5.32 Research investigating the influence of various additives on the performance of earth building materials has indicated the complexity of the issue as some additives improve certain properties and worsen others.[34] Traditional additives have included a range of natural ingredients such as cow dung, horse urine, bull's blood, milk products, seaweed and soap (B.Walker, pers.comm.) These additives improve either the wearing qualities or the workability of earth building materials.

Simplified Graph showing Earth Materials Properties

	Load bearing Strength	Thermal Insulation	Acoustic Insulation	Wet Construction	Dry Construction
Mudwall	·		•	·	
Rammed Earth	•		•	•	
Earth Bricks	•	·	·	·	
Compressed Earth Blocks	·		•	·	
Light Earth Infill		•		·	
Boards		•			·
Plasters				·	

SUMMARY

[33] At Charlestown Workshops, the Scottish Lime Centre, Fife.
[34] G.Minke, 2000.

5.33 Earth techniques, rooted in traditional practice, can be developed to suit the needs of a particular site or project. They have the potential to fulfil many different roles within a building, from dense monolithic walls to light pre-fabricated earth/fibre blocks and beautifully coloured earth plasters. They are also suited to a wide range of skills and applications including simple labour intensive forms of construction such as mudwall, highly mechanised rammed earth forms and the large scale production of machine made products.

CHAPTER SIX CASE STUDIES

INTRODUCTION

6.1 The following case studies have been selected to illustrate the surviving heritage of earth construction in Scotland, the lessons to be learned from the few recent modern projects in the UK and the more advanced contemporary use of these technologies across Europe.

COTTOWN OLD SCHOOLHOUSE

Client: National Trust for Scotland
Contractor: Becky Little, grant aided by Historic Scotland
Project Supervisor: Bruce Walker
Date of construction: 1766
Location: Cottown, Carse of Gowrie, Perthshire

6.2 This case study concerns the conservation of Cottown Old Schoolhouse, a thatched mudwall cottage in the Carse of Gowrie, Perthshire. Due to its large deposits of clay, this area has one of the largest concentrations of mudwall structures in Scotland. The building dates from 1766 and was occupied until 1985. After being bought by the National Trust for Scotland in 1993, a comprehensive programme of research and repairs was undertaken, supported by Historic Scotland grants

6.4 The repair programme involved the reinstatement of the thatched roof with a heather-turf and clay ridge and the consolidation of the mudwalls. The main external problems concerned neglect of the building and inappropriate repairs carried out in the recent past.

6.5 The revival of traditional earth building techniques in Scotland was pioneered during this project under the supervision of Dr Bruce Walker at Historic Scotland (now at the University of Dundee). A specialist contractor in earth and lime construction carried out the work, which included detailed recording of all site investigations and practices. The sequence of works involved removal of cementitious finishes, repair of the earth and the reinstatement of lime coatings once the walls were made good.

6.6 Following analysis of the original mudwall mix, air-dried earth blocks were produced on site to be used as indents for structural repairs. In order to match ‘like with like’, sub-soil from a working clay quarry adjacent to the site was used and mixed with appropriate amounts of aggregate and straw.

6.7 The building has limited road access but remains open to interested parties for study purposes and specialist visits. A series of display boards have been erected on site detailing the conservation work and the form of construction. The conservation scheme at Cottown will offer to practitioners, conservators and historians a greater breadth of knowledge and advice than has been hitherto available.

Conclusion

6.8 The longevity of earth buildings in Scotland and appropriate use of local materials is clearly demonstrated in this case study. The experimentation, research and analysis carried out during the project have contributed to a deeper understanding of traditional practices and generated a body of practical experience that is now being applied successfully to new mudwall structures.[35]

[35] See Case Studies, Loch Lomond Visitor Facility

THE HEBRIDEAN BLACKHOUSE

Client and contractor: Historic Scotland
Project Supervisor: Bruce Walker
Date of construction: 1885
Location: 42 Arnol, Barvas, Lewis

6.9 The Blackhouse, at 42 Arnol, Barvas, Lewis, owned and maintained by Historic Scotland, is an extremely important building both in European and Scottish terms. Buildings of this type were once plentiful in the Highlands and Islands but this is now one of the last complete examples of these long, low chimneyless byre-dwellings[36].

6.10 The building, constructed in 1885 and occupied until 1965. It is part of a distinctive North Atlantic and Arctic regional building tradition characterised by narrow-bodied interconnecting parallel ranges with individual roofs resting on mutual walls. Within this tradition each local community had its own approach to building construction, form and maintenance and each house illustrates a response to local site conditions.[37]

6.11 The Blackhouse has been subject to analysis and repairs since the early 60s. The most recent programme of works carried out in 1990 has been written up by Bruce Walker and published as a Technical Advice Note by Historic Scotland[38].

6.12 The construction uses local earthen materials in a variety of ways: The walls are drystone-faced mudwall, waterproofed at the exposed wallhead with blue clay protected by a layer of living turf. Blue clay is also used in floors, mortar and plasters and to construct the hearth. The roof is thatched in oat straw over a layer of heather turf.[39]

6.13 Other ingenious uses of local materials include a friction course of pebbles hammered into the clay soil at the base of the walls, a roof structure of driftwood or recycled material from shipwrecks, and the recycling of soot laden thatch as a dressing for the potato crop. The design of the blackhouse illustrates the development of a well-insulated, aerodynamic form, where the internal air flow and open hearth result in the smoke acting as a preservative for the thatch and for food such as meat and fish hung in the roof space.[40]

Conclusion

6.14 This building is the result of hundreds of years of experience, community co-operation and sound building practice. It could be considered as an ideal model for the 'green' home of the future as it incorporates many of the principles of sustainability in a well-tuned and appropriate response to the local conditions, materials and skills available.[41]

[36] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 6, 1996
[37] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 5, 1996
[38] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 5, 1996
[39] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 5, 1996
[40] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 6, 1996
[41] B.Walker and C.McGregor, Historic Scotland Technical Advice Note 5, 1996

LOCH LOMOND VISITOR FACILITY

Client: Loch Lomond National Park Authority
Contractor: Becky Little (earth construction only)
Architect: Richard Shorter with Simpson and Brown
Date of Construction: 2000-2001
Location: Rowardennan, Argyll

6.15 In this project the use of earth followed the client's brief for sustainable design and use of local materials, which is particularly relevant to the aims of the new National Parks in Scotland[42]. As the site is open to the public there was also a desire for robust walls that would stand up well to damage and be simple to repair. To this end the building was constructed with external mudwalls. These will be finished internally with an earth plaster and externally with lime and earth renders. Pre-fabricated earth blocks bedded in earth mortar were used in the gables.

6.16 A local source for the earth was established at a former clay pit, but this could not be used as the area was designated as a Site of Special Scientific Interest, the post industrial site having become a haven for wildlife. Clay soil was brought from fifty miles away and mixed with locally obtained aggregates and straw. The blocks were made off site and this proved to be a quick and efficient form of construction.

6.17 The building was designed by Architects who specialise in conservation as well as 'green' construction and the techniques used were chosen as innovative and appropriate to contemporary construction. However, the importance of Scottish earth building traditions was recognised in the approval of the building warrant, which was granted on the basis of the use of Historic Scotland's TAN 6 as a reference document. The Architects had no concerns about professional liabilities and no concerns have been raised regarding funding or insurances.

6.18 A specialist contractor was used for the earth construction, and the design benefited from her involvement from an early stage. The project also illustrated the need for long term planning in the procurement and construction using natural, locally sourced materials in comparison to 'off the shelf' products.

Conclusion

6.19 This case study demonstrates that there is a sufficient base of professional design knowledge and constructional skill to successfully build with earth in Scotland. The use of earth materials in this context has also drawn considerable public interest and reaction has been very favourable.

[42] Simpson and Brown Architects, 2001, forthcoming Scottish Executive research report

LIGHT EARTH CONSTRUCTION PROJECT, LITTLECROFT, MELROSE

Client: Private
Architect: Chris Morgan, GAIA Architects
Builders: Chris Morgan, Charles Dobb, Becky Little
Date of Construction: 2001
Location: Eildon, Borders.

6.20 This light earth/fibre dwelling is due on site in summer 2001. The building forms part of a wider government funded research project that aims to study the potential and benefits of Light Earth Construction (LEC). This will involve testing regimes to establish technical viability for this technique as well as monitoring the performance of the building in use. The economic and environmental viability of the technique will be examined with reference to other sustainable forms of construction

6.21 The project also aims to facilitate compliance with building regulations and financers and insurance requirements, through the development of a set of guidelines which all relevant agencies have approved. These guidelines will be disseminated to practitioners, Building Control officers and financial agencies through published sources and a web site.

6.22 The building will be the first stand-alone LEC in the UK and will comprise a light earth/straw infill formed in shuttering within a structural timber frame. The roof membrane will be protected by a layer of living turf and the walls are to be finished with earth and lime plasters. In an effort to optimise the energy efficiency of the design the earth/fibre mix will be adjusted to suit the thermal requirements of specific areas within the building.

6.23 As a demonstration project, it will be subject to a range of tests including thermal testing, fire resistance, resistance to decay of the earth mix, vapour permeability and humidity control.

6.24 The project team will consist of GAIA Architects as the lead partner, the DETR, a private client, a small steering group of individuals with experience of earth construction, and an Advisory Group. A wide range of national and international expertise has been gathered to form the Advisory Group which will offer feedback on the draft guidelines and ensure the credibility of testing regimes and published work.

Conclusion

6.25 The results from this research project will demonstrate the appropriateness of LEC in the Scottish context. The project will also provide a useful precedent for other research initiatives to investigate the applicability of a wider range of earth building techniques.

SPORTS AND ARTS CENTRE, LANCASHIRE

Client: Maharishi School
Builder/Designer/Engineer: John Renwick, Partnership for Natural Building Design
Date of construction: 2000
Location: Skelmersdale, Lancashire

6.26 This multi-purpose hall is primarily intended for use by children. An ancient design system has been adopted which aims to harmonise the individual with the environment. As a result the choice of building techniques reflects the desire for a natural and healthy space to be used for both physical and artistic activities.

6.27 The construction incorporates rammed earth panels between structural steel frame elements. These elements were finished in 2000, though the building as a whole is not yet completed. The walls will be finished internally with an earth plaster and externally with a lime render.

6.28 Unskilled and volunteer labour were used to manufacture the earth panels, which significantly slowed construction. The designer did not have previous experience of earth construction, but involved experienced advisors and used the ITP publication on rammed earth[43] as a design guide. Despite this inexperience and lack of contractor skill, a good level of construction quality was achieved.

6.29 One notable aspect of this project was that the Building Warrant was obtained through the self-certification process that can be used in parts of England. Rather than apply through the local authority, who were unlikely to have had experience of earth construction, the designer approached consultants in the southwest of England, where new earth construction is much more common. These consultants had sufficient knowledge and experience of working with earth to certify that it conformed to the requirements of the standards.

6.30 Some of the wall elements were stabilised with cement. This has had no noticeable effect on weathering patterns.

6.31 There were no liability concerns raised by the designers and no difficulties regarding finance or insurance for the use of earth materials.

Conclusion

6.32 The success of rammed earth construction in this context is due to a willing body of volunteer labour and a well-informed design team who sought specialist guidance at critical points in the construction process.

[43] J. Keable, 1996

ENVIRONMENTAL INFORMATION CENTRE, WALES

Client/Designer: Centre for Alternative Technology
Contractor: Simmonds Mills Architect Builders (earth elements)
Date of construction: 2000
Location: Machynlleth, Mid Wales

6.33 The design of the new Autonomous Environmental Information Centre at CAT incorporates a number of innovative features including load-bearing rammed earth walls and columns, compressed earth blocks and earth plasters. It is a highly public building associated with the promotion of sustainable design.

6.34 The rammed earth elements were well designed to avoid constructional through holes while melamine-faced plywood shuttering created crisp arrisses and a polished finish. The application of natural oil has brought a rich depth to the colouring of the earth and removed any potential for dusting.

6.35 The same locally sourced earth was used to make 1700 compressed earth blocks, produced on site with an ‘Elephant’ blockmaker. These were used in external cavity walls and internal partitions, and were finished with ‘Claytec’ earth plasters.

6.36 A notable feature of this building is that cement was totally excluded from its construction, including the foundation and retaining wall elements.

6.37 Specialist contractors constructed the rammed earth, with materials being tested at Bath University. Local contractors were used for the block walls and plastering and adapted to the unfamiliar material without difficulty.

6.38 Architects and engineers with relevant experience were involved and there was close collaboration between the designers, materials testers and specialist contractors during the design and construction process. There were no difficulties experienced in obtaining Building Control approval from the local authority, who have previous experience of innovative construction. There were no concerns raised regarding liabilities by those involved in the design and construction, and no difficulties with obtaining insurances.

Conclusion

6.39 This building illustrates that, although the UK has a low level of design and contractor experience with earth materials, it is still possible to achieve a European standard of quality. However, a thorough understanding of the material by the designers and good quality control procedures on site are necessary.

EDEN PROJECT VISITOR CENTRE, CORNWALL

Client: The Eden Project
Controactor: Rowland Keable (rammed earth walls)
Architect: Nicholas Grimshaw & Partners
Date of construction: 1999-2000
Location: St Austell, Cornwall

6.40 The rammed earth in this project is a large external wall within a major public environmental project.

6.41 Earth was selected as a construction material because it fitted well with the environmental ethos of the project. The designers did not have previous experience in its use, but liased with the Centre for Earthen Architecture at Plymouth University and used a contractor with considerable experience in rammed earth. The Architects have experience with leading edge design and in developing new materials and systems. The use of earth passed an internal system of risk analysis and there were no difficulties with planners or Building Control. The principal funders, The Millenium Commission, required confirmation that it was a suitable material.

6.42 The material itself was sourced on site from the remaining waste of the former china clay quarry. Sample panels were built and tested on site prior to the main construction.

Conclusion

6.43 The wall is a major element in a very public building and has been very warmly received by visitors. This high profile should encourage wider acceptance of this form of construction. However, the design was ambitious in terms of the section, detailing and external exposure of the wall. As a result, there has been some localised, superficial failure of the earth surface due to lack of adequate protection from the weather.

KEPPEL GATE , DEVON

Developer: Kevin McCabe
Date of construction: 2001-2002
Location: Ottery St Mary‘s, Devon

6.44 Currently under construction, this is new two storey, luxury house built of load-bearing cob (the English name for mudwall). The building is large, at 300 sq. m. internal floor area, and will be built to a very high standard It has an estimated selling price of £500,000.

6.45 Both the earth and straw for the construction are being sourced in the vicinity of the building and the local farmer is providing labour and plant.

6.46 An interesting aspect of the design of the new house is that it exploits the inherent plastic design qualities of the material to create a non-traditional building form. This demonstrates that the tradition of earth construction in the south west of England is a living one and has been developed beyond the limits of historical precedent. In particular the cob is being used to construct spiral staircases which are sculpted out of the wet material and achieve strength on drying.

6.47 The building is a commercial speculative development by Kevin McCabe, a small-scale builder and developer, who specialises in cob construction. Mr. McCabe has considerable experience in the conservation and alteration of traditional cob buildings in Devon. Over the past ten years he has increasingly concentrated on new build cob construction, though to date this has primarily been as additions to existing buildings.

6.48 There is also considerable experience of cob in the local area, with an active network of practitioners and academics organised through the Devon Earth Building Association. This had facilitated recording and analysis of traditional earth structures as well as organising the training of practitioners, designers and local authority officials. As a result there is sufficient expertise across the building procurement spectrum to ensure that new earth buildings can be constructed, without difficulty, to the highest modern standards.

6.49 This work has also resulted in the recognition of the value of regional building styles to the character of the area, in planning, social, environmental and economic terms.

Conclusion

6.50 As well as developing new ways of using traditional materials, this project is promoting training and education in earth construction through planned site visits for interested parties, on the job training for local trades people and promotion in the local media. It is also significant that, where there is sufficient knowledge, earth construction is being used as a positive marketing point in the speculative housing market.

DOMAINE DE LA TERRE HOUSING PROJECT, FRANCE

Client: Partnership between French Government and Industry
Architect: Various
Contractor: Various
Date of Construction: 1980s
Location: Isle d'Abeau, near Lyons

6.51 This experimental housing project, situated in a new town near Lyons, was built during the early 1980s to demonstrate the possibilities for modern applications of vernacular earth building techniques. In this part of France 90% of traditional rural buildings are constructed of rammed earth.

6.52 The idea for a demonstration village was conceived by the Centre for Industrial Creation (CCI) and was linked to an influential and international exhibition of earth building, which ran between 1981 and 1985.

6.53 Numerous national and regional partners were involved in the project including government departments responsible for housing and the environment. Technical issues and experimentation were largely organised by the Centre for Earth Research and Application (CRAterre), the National Department for Public Works of the State (ENTPE), and the Scientific and Technical Centre of Building (CSTB). Teaching and instruction in earth construction was carried out at Grenoble School of Architecture. The companies involved in the construction were selected through a jury system and given additional training as necessary.

6.54 The project includes over 70 housing units, of which 45% are constructed from rammed earth, 45% of stabilised compressed earth block and 10% using earth/straw mix within a timber frame.

6.55 As well as monitoring building process and performance in terms of thermal, structural and wearing properties the project also explores solutions to social housing problems, building control issues and ways to expand earth techniques into the wider market.

Conclusion

6.56 The success of this project is evident in the positive feedback generated by the residents of the earth homes. Over the first few years of occupation they have experienced high levels of comfort and report on the attractiveness of their homes.[44] Because the houses are modern in appearance, the local perception of earth has altered and it has become accepted as both a historic building material and a contemporary form of construction.

[44] Residents pers comms

CHAPEL OF RECONCILLIATION, BERLIN

Client: The Evangelical Church: Chapel of Reconciliation Parish
Contractor: Martin Rauch
Architect: Reitermann Sassenroth
Date of Construction: 1999-2000
Location: Berlin

6.57 This project involved the use of a variety of earth construction techniques by one of Europe’s leading practitioners in rammed earth, Martin Rauch of Austria. Rauch’s work is of a very high quality and previous projects have included industrial, commercial and institutional buildings, as well as furniture. The building was completed in 2000.

6.58 The building exploits the plastic qualities of earth materials to create tall, load bearing walls that enclose the chapel in an elliptical form. The walls have no applied finish and their rich natural colour is revealed in a tight surface finish. A separate external timber rain screen protects the walls.

6.59 In addition to the rammed earth walls, an earth floor was produced by a similar ramming process. Again, a high quality of finish was achieved, and it’s durability enhanced by the application of a natural oil coating. It is noticeable that the seating in the chapel, which creates focused point loads, has not resulted in defects. The altar in the chapel was also made from rammed earth.

6.60 The use of earth construction has contributed significantly to the quality of space, while the use of earth from the site in Berlin also had a symbolic value. Public reaction has been very favourable.

Conclusion

6.61 This project illustrates the versatility and quality of product that can be achieved by an experienced contractor on a well-organised project. It should, however, be noted that this is not a low cost form of earth construction.

THE OASE PROJECT, THE NETHERLANDS

Client: Oase-foundation
Builders: volunteers assisted by the architect
Architect: Sjap Holst
Date of construction: 1996-2000
Location: Beuningen, the Netherlands

6.62 Situated within a wildlife garden this small building, completed in spring 2001, was conceived as a meditative space and educational resource. It is also being used to store garden equipment.

6.63 Based on an organic, leaf-shaped form, the design demonstrates several traditional and innovative forms of construction such as a living ‘turf’ roof, unseasoned timber frame and breathable lime finishes. The other main emphasis of the project has been volunteer involvement, especially during construction of the earth/fibre walls.

6.64 The main walls were constructed using light straw-earth formed within shuttering. These act a non-structural insulating layer within a structural timber frame. Internally, dense earth blocks were used to form a partition wall. While these techniques are not covered in the national building regulations, the client was able to obtain a building licence that permitted experimental construction in the context of an educational establishment.

6.65 The earth building techniques were successfully carried out by volunteers but the building took four years to complete due to restricted funds and time.

Conclusion

6.66 The light earth/fibre technique used as an infill in this building has produced a beautiful and original design and the construction was successfully carried out at low cost by mainly unskilled labour. However, it has proved to be a slow form of construction that is best carried out in warm dry weather.

CLAY STRAW COTTAGE, SWEDEN

Client: Liisa Lipsanen
Builder: Students from Nordic & Baltic countries
Architect: Professor Sverre Fehn
Date of construction: 1992
Location: Mauritzberg, Sweden

6.67 This building was constructed as part of a wider research project run by the Helsinki University of Technology (HUT) Research Unit for Nature-Based Construction.

6.68 The project involved the pre-fabrication of light earth/straw blocks in moulds using earth sourced on site. The blocks were then air dried and subsequently built, with an earth mortar, into non-load bearing wall panels between timber frame structural elements. The walls were finished with lime plaster internally and earth plaster externally. A number of freestanding rammed earth walls were also constructed and some experimentation of exterior coatings carried out.

6.69 The clay straw blocks were monitored for moisture content and thermal performance. Although the blocks were large (190 x 270 x 540mm) they were ready to be used after twenty days of air drying and fully dry after forty-five days. A very light block was achieved at 300 kg/m3, giving good thermal insulation.

6.70 Although the work was carried out by students using very low levels of mechanisation, a high quality of construction was achieved. The project was completed in eight weeks and the finished building displays an engaging balance between modern design aesthetics and handmade natural construction.

Conclusion

6.71 The form of earth construction used in this project has particular potential for adaption to the current Scottish construction industry, where timber frame construction plays a major role, particularly in the domestic sector.

SUMMARY OF CONCLUSIONS DRAWN FROM CASE STUDIES

6.72 There are many lessons to be learnt from these case studies which are relevant to the potential for new earth construction in Scotland.

6.73 Traditional Scottish earth techniques evolved to take advantage of local skills and materials and respond to local conditions. This surviving earth building heritage provides the starting point from which it is possible to develop a viable living tradition with social, environmental and economic benefits. Examples such as Cottown and the Lewis Blackhouse illustrate the lasting qualities of earth, as well as good building design and construction practice which is being reinterpreted in contemporary construction.

6.74 The case studies demonstrate that there is sufficient and easy access to earth as a resource for building in a significant number of regions and localities in Scotland.

6.75 Several projects show that earth has the potential to be used to produce high quality building products. These can satisfy the requirements of existing construction industries in developed European countries such as Scotland.

6.76 The high profile of many new earth buildings is encouraging a wider acceptance of earth as a viable building material. However, care must be taken in order that these pioneer projects are examples of best practice. This requires careful planning, design and construction and also the sharing of knowledge. Demonstration projects, which involve monitoring and research during and following construction, could encourage the dissemination of practical knowledge and experience.

6.77 The body of expertise for earth construction is currently very small in Scotland but it has the potential to grow as more projects get underway. The new earth buildings that have been completed demonstrate that there is sufficient experience and interest across manufacturing industry, design professionals, academic researchers and building procurers to successfully construct buildings using earth materials. However, training and education will be critical for wider use of earth in building. The experience of specialist contractors has a significant role to play in this transfer of knowledge.

6.78 There is also a significant resource of experience in mainland Europe and this should be utilised by those wishing to develop earth building in Scotland.

CHAPTER SEVEN EARTH MATERIALS AND BUILDING PROCUREMENT

INTRODUCTION

7.1 This chapter looks at how earth currently relates to the whole building process and discusses issues relating to the future development of this sector.

THE MARKET

7.2 The current market for earth materials in Scotland is small, being limited to use in projects where clients are well informed and have a particular interest in the environment and sustainability. Another base market that could be developed is for the use of earth materials in the appropriate repair and alteration of existing earth buildings.

7.3 It was notable that those involved in UK earth construction who assisted in the preparation of this report, wanted to use the material again, in a wider variety of forms, and believed that the market would inevitably grow. This would follow the experience of all other European countries, which were at our current stage of development up to fifteen years ago.

7.4 The benign health qualities of earth materials, as well as increasing implementation of sustainability policies, should encourage their promotion within public sector procurement. This sector, which accounts for 40% of construction, could also provide a vehicle for demonstration projects.

7.5 In the private sector, the small but important market of high quality buildings for environmentally aware clients will continue to grow, and should provide the basis for promotion of the material by example and publicity. This could also provide a setting for education, training and materials development.

7.6 It is expected that the mass market will be reluctant to introduce earth technologies while there remains a climate of perceived risk associated with the general lack of experience and, critically, standards. This sector is, however, influenced by public opinion and would be encouraged by prestigious demonstration projects creating a climate of fashionable aspiration. In England such desirability has led to the use of thatch in commercial housing estates. Thatch has, in the past, been mis-perceived as a poor quality material, a fire risk and a problem for insurance.

7.7 The effect of energy tax policies on material prices, and public procurement policy could also influence the prospects for earth materials in this sector.

DESIGNERS

7.8 At present there are a very limited number of design professionals with expertise in earth forms of construction.

7.9 The buildings that have been constructed to date in the UK have been designed by those who either specialise in sustainable construction techniques or who have educated themselves specifically for a project. The establishment of a proper route for access to training and information would lead to an increased design capacity for earth building.

7.10 There is adequate data available for design using earth materials, though this is primarily from published foreign sources. Published research on indigenous traditional techniques[45] are also useful. Easier access to information and technical support in the U.K. would facilitate design opportunities.

7.11 As is illustrated in the case studies, when a design team have adequate expertise, concerns over professional liability for 'novel' material use do not arise. However, where there is a lack of expertise, these concerns can lead to earth not being used or to inappropriate design.

7.12 The lack of accepted standards for use in relation to earth products in building design, contractual material specification and quality control on site, are significant restraints on increased use.

7.13 Earth materials can present specific design opportunities. Monolithic forms have inherently plastic qualities that allow a similar freedom of design to concrete, but with more attractive tactile and visual qualities. Some materials, particularly mudwall, present sculptural opportunities that have been exploited in domestic and school projects.

7.14 Earth construction has a potential for reinvigorating regional and local construction styles.

BUILDING CONTROL

7.15 Earth construction materials, when appropriately used and properly detailed, conform to the requirements of the Technical Standards for compliance with the Building Standards (Scotland) Regulations 1990, as variously amended. However, the lack of experience, guidance and officially recognised standards mean that designers and the building control system can struggle to process applications involving earth materials. The need for an easier route for approval of 'novel' materials has been recognised for some time.[46]

7.16 A detailed analysis of the position of earth materials in relation to the current Technical Standards is given in Appendix A.

7.17 While it is possible to use earth materials within the existing system of regulation, there are procedural impediments that would deter designers from using them on a significant scale. This is essentially because of the time and paperwork required in support of such applications.

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[45] In particular B.Walker and C.McGregor, *Historic Scotland Technical Advice Note 6*, 1996.

[46] See F. Stevenson & J. Macrae, 1998, Environmental Impact of Specifications in the Technical Standards and S.H. Baxter & H. Liddell, 1996, Sustainable Development and Building Regulations.

7.18 ‘Excessive or inappropriate requirements and controls will lead only to defensive, sterile designs and design strategies that are chosen to protect against liability. The interests of neither client nor society will be served by such an outcome.[47]

7.19 This impediment could be reduced by the following actions:

- The establishment of a recognised U.K. standard/code of practice for earth construction.
- The issue of guidance from the Scottish Executive on the recognition of standards, codes of practice and specifications from other countries.
- The introduction of self-certification for all aspects of compliance with the Technical Standards.
- Dissemination of information to Building Control Officials in the technical aspects of earth materials and construction techniques.[48]

7.20 ‘In recent years, the agenda of the building control system has broadened to include a concern for energy conservation…. We need to consider whether the qualitative aspects of building standards need strengthening and whether standards should directly address issues such as durability, whole life cycle performance and sustainable construction’.[49]

7.21 The Building Control system has the potential to indirectly encourage the use of low carbon emission materials, such as those made of earth. This would occur if the regulations were amended to give targets for embodied energy, the energy used to construct buildings, as well as energy consumed in their use. The system of regulating the energy in use is well developed, though, as has been seen[50], embodied energy can be equally as significant. The methodologies for assessing embodied energy are currently available.[51]

MATERIALS PRODUCERS AND DISTRIBUTERS

7.22 At present there are no established producers of earth construction materials in Scotland. Materials have been produced on site for several projects involving monolithic forms of construction. Pre-fabricated materials have been made off-site by specialist contractors or as one-off productions by manufacturers of similar conventional materials. A range of earth products, including blocks, boards and plasters are also being imported from Germany and Austria and are marketed by specialist suppliers in the UK.

7.23 One-off production and use of imported materials is inherently inefficient and therefore disproportionately expensive. It also leads to significant environmental impact through transportation. The development of indigenous mass production would result in cheaper and more environmentally benign materials.

7.24 With the introduction of the Climate Change Levy and growing demand for earth building materials, interest from manufacturers of related conventional products is increasing.

[47] *The Development of a Policy on Architecture for Scotland,* Scottish Executive, 2001
[48] The Devon Earth Building Association have organised training of local authority officials with great success. See also para. 8.13.
[49] The Development of a Policy on Architecture for Scotland, Scottish Executive, 2001
[50] See para. 3.13.
[51] For example, ENVEST by the Building Research Establishment

The methods of earth materials production are closely related to the production of conventional materials. Earth bricks can be produced by the same mixing and extrusion process used to make ceramic bricks. Gypsum and lime plaster and mortar producers could produce earth based plasters and mortars.

7.25 This ability to utilise current manufacturing infrastructure to produce earth based materials would allow these materials to be developed and marketed in parallel to conventional products by existing manufacturers who have a desire to diversify into more sustainable products. This would allow them to be produced and distributed as demand grows, without the need for major capital investment.

7.26 This model for growth of the sector would follow the experience of mainland Europe, where an industry that began with enthusiastic individuals has been developed by mainstream manufacturers. In Germany, for example, this sector now has an annual turnover of £60m. and has experienced sustained growth of 20% per annum at a time when the rest of the German construction industry has seen no growth[52].

7.27 If indigenous production develops, product availability will encourage use, reduce costs and bring environmental benefits. This production could also displace imported materials and develop a potential for export of UK materials to larger foreign markets. The development of this sector will require education, training, technical research and development and some capital investment.

7.28 The lack of accepted standards for earth products is an impediment to their development, production and marketing.

THE CONSTRUCTION INDUSTRY

7.29 At present, competence in earth construction skills in Scotland is limited to a small number of specialist contractors. If earth is to develop as a material, the ability to use these materials will have to become much more widely available.

Commercial Contractors

7.30 As has been shown[53], the techniques of earth construction are simple and can relate to existing construction skills. Rammed earth construction processes parallel in-situ concrete work. Un-fired brick and pressed earth block mimics brick and concrete block work. Earth plasters require traditional plastering skills. Light clay/fibre infill could easily be introduced into the large timber frame construction sector. The skills gap is small and in England experience has shown that conventional contractors readily adapt to use of earth materials.

7.31 Through lack of experience, non-specialist contractors are likely to be initially sceptical regarding material performance and concerned regarding liabilities. As is shown in the case studies, these concerns should disappear as a contractor gains experience. The more

[52] H. Schroeder, Lehm 2000 Conference Proceedings.
[53] See Chapter 5.

benign working qualities of earth materials as compared to the occupational health impacts of many commonly used materials should be a factor in easing acceptance.

7.32 Ultimately, the commercial construction sector will follow market demand. However, if earth construction techniques remain an area of specialist skill, they will lack the competitive cost pressure of other materials. As has been shown with the growth of the lime construction sector in Scotland over the last fifteen years, it is possible to develop a competitive and competent construction skills base in materials beginning from a small core of specialist contractors. With lime this was done by the establishment of a network for skills training and education, together with the active promotion by government agencies.

7.33 The lack of accepted standards will be an impediment to growth of this sector, by hindering effective quality control.

The Self-build Sector

7.34 Earth is a simple, safe and inexpensive material which lends itself to self-build procurement projects. Mudwall and rammed earth require significant levels of manual labour, even when mechanised. Earth bricks and compressed earth blocks can be made using simple machinery, but also involve significant manual labour. When manual labour is provided at no cost, as in self build projects, the materials costs become very low.

7.35 When people build their own homes, rather than buying buildings produced commercially, they tend to achieve higher environmental standards, both in terms of end product and construction process. It is noticeable across mainland Europe that many community-building projects involve earth materials.

7.36 As earth materials are simple to produce and use, they allow a wide range of people to become involved in the construction process. This provides opportunities for training and community involvement of socially excluded people.

7.37 'People building for themselves will tend to take more care and spend more time getting details just right than those building for profit'.[54] Self-builders have intimate knowledge of their houses and tend to maintain them conscientiously, as means of protecting the initial investment of time and effort, thus the houses tend to have a longer life.

7.38 Self-builders require guidance and training. Within Scotland there is currently a very limited provision for this in relation to earth materials.

FINANCERS AND INSURERS

7.39 In recent years, as sustainable construction projects have increased, there has been anecdotal evidence of difficulties in obtaining finance or insurance for projects involving the use of 'novel' materials or systems. These materials, through lack of experience and accepted standards, are perceived as being higher risk. None of the projects in the UK to date have demonstrated this to be a problem in practice. This may be in part due to the nature of the

[54] P.Borer and C.Harris 1998.

projects, which tend to be fully funded and of a non-domestic nature. Certifying bodies, such as the National House Building Council, which can have a significant influence on domestic projects, will refuse funding on projects using ‘novel’ materials[55]

7.40 Again, it is demonstrable that where there is sufficient knowledge, use of earth materials does not preclude financing or insurance being obtained. The estimated half million habited earth buildings in the U.K. have not demonstrated a significant problem with insurance or mortgages. There is also a sub-market of specialist organisations, such as the Ecological Building Society, who support new projects. In areas of a continuing tradition, experience removes these concerns. A parallel situation has existed for many years for owners of thatched buildings, where there is also a disproportionate perception of risk.

7.41 Within financing and insuring institutions the lack of accepted standards is an impediment to the acceptance of the use of earth materials.

STANDARDS

The Need for Standards.

7.42 As has been noted throughout this chapter, standards are a critical tool within the construction process, ensuring product quality control, appropriate design, accurate contract documentation, assessable construction standards, building regulation enforcement, client protection and financial assurance.

7.43 There are no officially recognised U.K. or E.U. standards for earth materials. As is illustrated in the case studies, in the absence of such standards a number of other reference documents are being used in the U.K. at varying stages in the procurement cycle. These include descriptions of historic techniques produced by the conservation sector, foreign standards and codes of practice, and documents written in the U.K. primarily intended for use outwith the U.K.

7.44 This is not a satisfactory basis for the development of the earth construction industry in the U.K. The lack of adequate control documents will inhibit market development and permit a climate where poor quality construction is possible. This could tarnish the image of earth materials and reinforce the common preconception of these materials as being of low quality. This is refuted by high profile projects which set a good example.

7.45 The case studies illustrate that recent U.K. earth buildings are not without minor defects and the analysis of the procurement process shows that competence at all stages is currently limited to a small number of people. As the sector grows and this expertise disseminates, there remains a risk associated with the lack of standards.

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[55] The NHBC would require demonstration of compliance with a relevant standard to issue their 60 year guarantee. Pers. comm..Neil Smith, NHBC Technical Dept.

Means to Establish a Standard

7.46 There are two models for the introduction of earth standards that can be seen abroad. Firstly a national standards institution can develop an official standard, as has happened, for example, in New Zealand. Alternatively, a group of interested individuals with technical expertise can produce an agreed document, which receives official recognition, as has happened in Germany.

7.47 In the U.K. the recognised standards institution is the British Standards Institution (B.S.I.). This is a commercial organisation, whose work is largely focused on the needs of established commercial industry interests. There is currently no significant earth materials industry in the U.K. to fund such work and the B.S.I. has no plans to begin work on a standard covering earth materials.

7.48 There is, however, a network of people with considerable expertise in earth construction in the U.K., including people who have drafted standards and codes in earth construction for foreign countries.[56] There is also significant international co-ordination between experts and earth construction organisations.

7.49 Given the significant body of useful foreign standards and codes available, it would be possible for a group of U.K. experts to be instructed with the task of writing a draft standard. Such a standard would build on the work of our European and other foreign colleagues and would strengthen the international links of the U.K. earth building community.

7.50 A third option would be for an international standard to be officially recognised in the U.K. The American Testing and Standards Association is currently drafting such a standard, though without official UK involvement.

7.51 A schedule of relevant foreign standards in given in Appendix C.

SUMMARY

7.52 There is a realistic economic case to be made for the development of earth construction in Scotland. Initially this will focus on small buildings but larger ventures may also develop as capability and confidence in the material grows. The market has the potential to grow from the niches of ‘green’ building and conservation into the mainstream.

7.53 The use of local materials and skills for building has a positive impact on local and regional economies. This is most apparent in rural areas where earth building traditions have survived till recent times. A new earth construction industry in Scotland could have relevance for both rurally based economies that are in need of diversification and for national priorities that promote sustainable rural development.

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[56] Peter Walker at Bath University has written a new Australian Handbook and Julian Keable has written a code primarily intended for use in Zimbabwe.

7.54 There is a need to facilitate approval for earth materials within the Building Control system. This can be done by better dissemination of information, to and training of, local officials as well as the establishment of accepted standards.

7.55 There is currently no accepted standard for earth construction within the U.K. This lack of control documents is a significant restraint on the development of earth construction. There are several means to establish such a standard, which would be best promoted from established official organisations.

CHAPTER EIGHT KNOWLEDGE AND INFORMATION

INTRODUCTION

8.1 This chapter will examine the knowledge base that exists for new earth construction in Scotland in regard to testing, research and education. It will also outline national and international efforts to develop testing procedures and quality controls in order to legitimise the use of earth as a modern construction material

TESTING AND RESEARCH

8.2 'One of the main problems for the development of new earth building has been the lack of standard criteria that could inform an accurate evaluation of the finished material. This absence has a negative influence on the owners, decision makers and financial backers because, when considering investment in earth structures, they have no guarantee of the technical quality of the buildings, particularly with respect to their durability beyond the period of the loan.' [57]

8.3 Very few countries have developed standard analyses and tests specifically suited to soil. Tests for soil have often been adapted from other disciplines, such as concrete construction and road building, and these tests are not necessarily suited to earth. The field of earth research is also fragmented. Different countries have adopted different methodologies thus making comparison between research programmes difficult. However, in recent years, research and experiments have made it possible to make a good categorisation of soil as a building material.

8.4 Given the complexity of the subject it is outwith the scope of this study to examine the results of specific research programmes in any detail. However a brief outline of testing procedures that exist for earth building and selected testing regimes have been included in Appendix B.

Testing of Earth Building Materials in the UK

8.5 There are several testing facilities for earth building materials in the UK, notably The Centre for Earthen Architecture at the University of Plymouth and the Department of Architecture and Civil Engineering at the University of Bath. These establishments carry out basic laboratory testing of earth samples, research programmes in contemporary and traditional earth construction, as well as consultancy and advice for specific projects.

8.6 While there are also potential facilities for testing and research of earth building materials within Scottish Universities and similar establishments[58] there is, at present, a lack of expertise and/or experience to carry out this kind of work. There have been several small projects to date, mostly concerned with traditional techniques, and these are detailed in Appendix B.

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[57] H. Houben & H. Guillaud 1994

[58] For example; the Building Research Establishment (Scotlab) and the Scottish Lime Centre.

8.7 There is a need to develop research and testing expertise in Scotland to support a local and regional earth building industry. The development of this expertise could be encouraged by greater demand for these services (arising as more projects get underway) and partnerships with established research programmes elsewhere.

TRAINING, EDUCATION AND DISSEMINATION

Introduction

8.8 While there is a general lack of professional and public awareness in regarding our earth building heritage, there is a growing recognition of the richness and diversity of traditional techniques and their potential application in new sustainable construction.

8.9 As well as flagship projects that demonstrate the viability of new earth construction there is also a need to develop the relevant practical skills and knowledge. Earth building skills are generally simple to learn and execute and mechanisms could be put in place to encourage the sharing of experience and expertise.

Training

8.10 The skills base for earth building in Scotland is, at present, limited to a few enthusiastic individuals who have learnt from their own experience or received training in other countries. There is no formalised mechanism for the teaching of earth building techniques although there have been several one-off training events linked to specific projects or interest groups[59].

8.11 Charlestown Workshops at the Scottish Lime Centre will be running courses in natural building technologies, including earth construction, during summer 2001. These will focus on both traditional practice and new sustainable methods.

8.12 While there is very little training geared towards new earth construction there are several conservation based courses and events within the UK which cover the repair and maintenance of traditional earth buildings. These include courses run by the Society for the Protection of Ancient Buildings, regional earth groups such as DEBA[60] and the Centre for Earthen Architecture in Plymouth. The courses are usually aimed at professionals, practitioners and house owners.

8.13 Professional training is carried out through the Continuing Professional Development network under the auspices of the relevant bodies representing architects, surveyors, Building Control officers and engineers. These events also have the scope to cover earth building issues, as a recent talk in Aberdeen illustrated.[61]

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[59] For example – The Scottish Ecological Design Association
[60] Devon Earth Building Associaiton
[61] CPD seminar on New Sustainable Earth Building Aberdeen, Feb 2001.

German Experiences in Training

8.14 Over the past 30 years different kinds of training have been developed in Germany which target the following groups: self-builders, unemployed people, architects and engineers, entrepreneurs (fabrication and execution), craftspeople/builders and legal authorities. There is a wide range of courses, workshops and seminars from single product presentation days to seminars lasting several days or weeks. In general these events are run on a regional basis and receive partial recognition from the relevant authorities.

8.15 This large and organised body of earth building expertise is gradually working towards a professional designation within the building industry. This will improve the quality and quantity of work being produced and also encourage a much wider acceptance of earth as a 'normal' building material[62]. A recent development has concerned the establishment of a qualification for skilled earth builders organised by the Thuringen Trade Association in collaboration with the German National Association for Earth Construction. The course content is both theoretical and practical and was tested during 1999. In the longer term there are also plans for a nationally accepted qualification in earth construction in collaboration with similar schemes taking place in Europe.

8.16 There is the potential for small-scale training in earth construction in Scotland at present. The German model of industry lead training will become more relevant as the field develops. This kind of official recognition will be necessary if earth is to become a viable alternative to less sustainable forms of construction. Collaboration with European training initiatives may offer opportunities to learn from more developed areas of expertise.

Education

8.17 Within the Scottish University system there is a small amount of formal teaching on earth building issues in the various schools of architecture, engineering, surveying and construction. These issues tend to be taught as elements within wider courses of study such as Ecological Design or Architectural Conservation. Studio work focusing on earth construction also takes place in some schools of Architecture.[63]

8.18 The School of Architecture at the University of Plymouth has developed a more earth specific teaching module which covers both theoretical and practical issues. It is aimed at a wide and multi-disciplinary audience of students, professionals and practitioners. A similar, but smaller module also exists at the Centre for Architectural Conservation, within the University of York as part of the MSC in Architectural Conservation. This course is given almost entirely by visiting lecturers who are specialists in the field.

8.19 While earth construction is not currently covered within the Scottish college system syllabus, the Scottish Lime Centre in partnership with Telford college will jointly run an HNC diploma in masonry and lime construction starting in 2001 which has been accepted by the CITB[64]. This seal of approval by the industry illustrates a significant achievement in the validation of traditional techniques for both conservation and new work.

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[62] Hosrt Schroeder, pers comm.
[63] Fionn Stevenson, pers comm.
[64] Pat Gibbons, pers comm

8.20 In Europe there is a much more developed field of education and research concerning earth as a building material and element of construction. This is mostly to be found in University departments which have specialised in this field. These include the International Centre of Earth Construction at the School of Architecture in Grenoble, the Building Research Institute at the University of Kassel, the Bauhaus University in Weimar and the Technical Research Centre at Helsinki University.

8.21 There is scope for more structured teaching of the subject in Scotland within the disciplines of sustainable design and construction. The development of officially recognised syllabuses in lime technology illustrates the potential for the acceptance and revival of a previously marginal subject into mainstream education.

8.22 The multi-disciplinary nature of the field and it's wide geographic spread also presents possibilities for academic exchange programmes between the various teaching centres. Universities could also be encouraged to organise scientific conferences[65] to encourage sharing of information and improve the comparability of research programmes in different locations.

Dissemination

8.23 The most significant publications to date promoting awareness and understanding of Scottish earth building traditions are the Technical Advice Notes written by B.Walker and C. McGregor published by Historic Scotland.

8.24 Within the UK there are regional earth groups which promote traditional earth construction techniques through workshops, videos and leaflets such as the Devon Earth Building Association publication 'Cob and the Building Controls'.[66] There have also been several national and international conferences on earth construction which have resulted in public events, media coverage and publications.[67]

Organisations which promote earth building

- Scottish Earth Building Forum: This is a recently formed interest group which promotes both the conservation and new sustainable use of earth in building.

- International Council of Monuments and Sites, Earth Structures Group UK: This is a gathering of earth building expertise that organises publications, conferences and events.

- There are also regional earth groups which include the Devon earth Building Association, the East Anglia Earth Building Group, and the East Midlands Earth Structures Society.

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[65] Such as Out of Earth I-III held at the Centre for Earthen Architecture during the 1990s
[66] DEBA, 1997.
[67] TERRA 2000, conference proceedings

Future Opportunities

8.25 In order to encourage new sustainable earth construction in Scotland there is a need to develop both a local and national knowledge and skills base. This could be achieved by several means:

- A national centre for best practice in earth construction that would coordinate training and awareness raising initiatives over a wide geographical area. This centre could also provide a focus for international partnerships and collaboration.
- Local and regional initiatives which meet the training and educational requirements of local businesses and communities.
- The development of educational resources in earth building at Higher and Further education levels.
- Regional CPD programmes.
- Demonstration projects.
- Government funded research.
- Partnerships between universities, clients and industry.
- Apprenticeships and training schemes recognised by the Construction Industry Training Board or similar.

SUMMARY

8.26 A small amount of testing and research in earth construction has been carried out in the UK, mainly focussing on traditional practices. This field of research is growing in Europe and is necessary to demonstrate the credibility of new earth building. There are potential testing facilities in Scotland for earth building materials but a lack of expertise to carry out this work.

8.27 Training and education initiatives in earth construction in the UK exist on a small scale attached to specific projects or as part of wider university or college courses. German experience illustrates the potential for official recognition with industry-based qualifications in earth building. Wider acceptance of earth building technologies has also been promoted through regional interest groups and specialist publications as well as coverage in the general media.

CHAPTER NINE CONCLUSIONS AND FUTURE OPPORTUNITIES

CONCLUSIONS

9.1 The durability and versatility of this type of earth construction is demonstrated by traditional Scottish earth buildings.

9.2 Earth materials have significant environmental advantages when compared to many other building materials. In particular they have significant potential to reduce greenhouse gas emissions and waste generation within the sector.

9.3 There are a diverse range of earth materials and construction methods which can fill a variety of roles within a building. Applications as light infill for timber frame construction and as earth bricks in internal partitions have perhaps the most immediate potential in the Scottish context.

9.4 There are no technical reasons why earth materials should not be used in contemporary Scottish construction.

9.5 There is sufficient professional expertise within the Scottish construction industry to successfully use earth materials, though the knowledge and skills base is very small. There is, however, a considerable body of expertise within Europe, and international links have been established by Scottish practitioners.

9.6 There are no earth materials currently being mass produced in Scotland. Some are being imported from Europe and the existing Scottish manufacturing infrastructure could be readily adapted to produce these materials.

9.7 The lack of accepted standards is a significant restraint on increased use of earth materials.

9.8 There are suitable testing facilities for earth building materials in Scotland but a lack of sufficient expertise to carry out the appropriate testing regimes.

9.9 There is a significant role for training and education in the wider acceptance of earth construction techniques in Scotland. At present this involves a small range of initiatives focussed within university education and specialist training events.

9.10 There may be appropriate applications for earth construction in National Parks and special landscapes.

FUTURE OPPORTUNITIES

9.11 Opportunities for achieving an officially recognised standard for earth construction materials and techniques could be developed.

9.12 The potential for the establishment of a training, education and testing centre, similar to the successful Scottish Lime Centre could be developed.

9.13 There are potential opportunities for the existing manufacturing infrastructure to diversify into the production of earth-based materials.

9.14 There are opportunities for innovative partnerships between industry, educational institutions and the public sector both within Scotland and with mainland Europe.

9.15 The potential opportunities for the use of earth materials in public procurement projects could be assessed, including the potential for demonstration projects to show best practice.

9.16 There is potential for further detailed research into the scope for reduction of greenhouse gas emissions, and other environmental benefits, through use of earth construction materials.

9.17 Opportunities should be developed for further materials research, both in the laboratory and in the field, in the following areas:

- Thermal/humidity controls: thermal conductivity, thermal capacity, and hygroscopic properties.
- Durability: weathering properties, water permeability, moisture movement characteristics, abrasion resistance, defects and repairs, surface treatments.
- Structural properties: compressive strength, shear strength, lateral load resistance of walls, soil mortars, pozzolanic stabilisers.
- Construction process: speeds of construction, quality control testing.

9.18 Consideration should be given to the issuing of guidance on the use of earth materials and aimed at Building Control officers.

9.19 Consideration should be given to the benefits of self-certification within the Building Control system for innovative materials use.

9.20 Consideration should be given to clarifying the relevance of DETR environmental policy and guidance to the Scottish context.

9.21 Non-governmental bodies, such as the National House Builders Council, could be encouraged to relax restrictions on the use of innovative materials.

APPENDIX A EARTH MATERIALS AND THE TECHNICHAL STANDARDS

A.1 This section sets out how earth construction materials, when appropriately used and properly detailed, can be demonstrated to conform to the requirements of the current Technical Standards for compliance with the Building Standards (Scotland) Regulations 1990 as variously amended.

Part B: Fitness of Materials

A.2 This regulation requires that materials are suitable for the purpose for which they are used. The Technical Standard requires that materials must be supported by evidence of suitability or have recognised qualities and properties of suitability. Earth materials do not have UK or EU standards or certification[68] and their qualities are not generally recognised due to their low level of use.

A.3 There are two ways in which earth materials can demonstrate compliance with the 'deemed to satisfy' provisions.

A.4 Clause 1e accepts compliance with 'traditional procedures of manufacture … where they are the subject of a written technical description sufficiently detailed to permit assessment.'[69] Building Control officials have accepted Historic Scotland's Technical Advice Note No. 6 as such an adequate technical description[70]. This document describes the full range of traditional practices of earth construction, including mudwall, rammed earth, unfired bricks and plasters, in sufficient detail to permit their approval on this basis. However, it is not ideal to rely on a document that was not written with new construction specifically in mind.

A.5 Clause 1b accepts compliance with 'a relevant standard or code of practice of a national standards institution or equivalent body of any state within the E.E.C.' and clause 1d accepts compliance with 'a relevant specification acknowledged for use as a standard by a public authority of any State within the E.E.C.'

A.6 Across the E.E.C. there is a range of relevant standards, codes of practice and specifications that could be accepted under these clauses. In England, German DIN standards have been accepted as adequate evidence for earth products imported from that country[71]. There is no known precedent for use of these clauses in Scotland in relation to earth products, but compliance with a U.S. standard has been accepted as adequate evidence of suitability in other contexts.[72]

A.7 Local building control officials, who have responsibility for interpreting the regulations, are likely to be reluctant to establish precedent by accepting individual foreign

[68] See para. 8.26
[69] Technical Standards, section B2.1e
[70] See para 6.17, Loch Lomond Visitor Centre Case Study. With thanks to Richard Shorter, Project Architect
[71] Pers. Comm., Simmons Mills, Architect Builders
[72] NSF 41, Scottish Borders Council, 2000. T. Morton, Archt.

documents as suitable. However, in the absence of UK standards, it is inevitable that applications will be made on this basis, following the English example.

A.8 While it is possible for an applicant to provide sufficient data to an individual Building Control officer, so that he/she is effectively trained to a level of sufficient expertise that he/she can judge a material as suitable for purpose, the efficiency of this process would be improved by better dissemination of information to Building Control departments generally, prior to specific project applications.

A.9 In the absence of a British Standard, there are two means by which this procedural impediment could be eased. Firstly, a technical review of suitable foreign documents could be undertaken and guidance introduced aimed at local building control departments.

A.10 Secondly, self-certification could be introduced into the Scottish system of Building Control, allowing private consultants with expertise in these materials to certify their suitability, as is currently possible in England[73] and possible in Scotland in respect of Part C only. This arrangement is currently being considered as part of a wide review of the Scottish Building Control system.[74]

Part C: Structure

A.11 This section of the regulations ensures the stability of buildings and is normally satisfied by certification by a suitably qualified Structural Engineer. There is sufficient data and testing facilities to allow an Engineer to certify these materials on a case-by-case basis, though there is a need to develop recognised generic testing for earth materials.

Part G: Preparation of Sites and Resistance to Moisture

A.12 This section ensures that buildings are not damaged by condensation or penetration of rainwater.

A.13 Forms of construction involving earth materials are commonly known as 'breathing' construction. As is detailed elsewhere,[75] this has health and constructional benefits. There is sufficient data available to demonstrate that damage from condensation will not occur.

A.14 There is sufficient evidence from existing buildings and published data to demonstrate that, if a building using earth materials is correctly designed, there will be no damage due to penetration of rainwater.

A.15 In both these aspects, individual Building Control officers inexperienced in earth materials may require an onerous level of information to approve an application. Officially recognised standards and self-certification would both ease this procedural impediment.

[73] See para. 6.29, Skelmersdale Case Study.
[74] See Improving Building Standards: A Consultation Paper Inviting Ideas on the Reform of the Building Control System in Scotland, Scottish Executive, 2000.
[75] See para. 3.9, 3.10 and 4.11.

Part J: Conservation of Fuel and Power

A.16 This section concerns the thermal performance of buildings and requires calculations of the heat loss and energy requirements of buildings.

A.17 As has been shown[76], earth can be used in construction in a wide variety of forms that have varying values of thermal performance. There is sufficient data provided in published sources to allow designers to accurately assess and demonstrate an individual material's performance[77].

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[76] See Chapter 5.

[77] The Chartered Institute of Building Services Engineers '*CIBSE Guide Vol. 3, A3, Thermal Properties of Building Structures*' gives some values for earth materials, while there is also an adequate range of foreign published data.

APPENDIX B SUMMARY OF RELEVANT TESTING

B.1 This section outlines testing procedures that exist for earth building and gives selected examples of testing regimes in Scotland and Europe. The tests can be divided into two categories: a) Identification tests to establish the suitability of a soil for building and b) Performance tests applied to building elements or systems.

Tests to analyse the composition and suitability of earth for building.

Simple Field Tests

B.2 A series of simple tests can be done on site to establish the approximate composition and characteristics of an earth for building. They include visual observation, touch, smell and sedimentation[78].

Laboratory Identification and Development Tests

B.3 These tests are used to ensure that a good building material is obtained and to determine the parameters that must be respected when the product is mixed and produced. They include:

- Sedimentation
- Plastic and Liquid Limit
- Linear Shrinkage
- Compressive Strength
- Bulk density
- Voids Ratio
- Mineralogical Identification
- Tensile strength
- Swell
- Water absorption
- Frost susceptibility
- Erosion
- Abrasion[79]

Example 1: A specification for building soils

B.4 The Centre for Earthen Architecture at Plymouth University has developed a series of tests to establish a performance specification for building soils. At present these guidelines only apply to rammed and mudwall mixes but they could be developed for other techniques. Soils that fall outside these guidelines can be modified by adding the appropriate amounts of gravel, sand or clay to obtain a better mix.

[78] J. Norton 1997, H. Houben and H.Guillaud 1994, G. Minke 2000
[79] H. Houben & H. Guillaud 1994

Performance specification

	MUDWALL	RAMMED EARTH
Performance indicators:		
Grading – within recommended zone (plotted as a curve on a graph)		
Clay content	10-25%	7-15%
Moisture content	18-25%	10-16%
Strength	400-1000kN/m3	800-2000kN/m3
Linear shrinkage	less than 6%	less than 3%

[80]

Example 2: Tests to Establish the Physical Properties of Earth as a Building Material, the Building Research Institute, University of Kassel, Germany.

B.5 Over the past 25 years intensive research has been carried out at the Building Research Institute to determine the structural and physical properties of different earth mixtures. Investigations have also been undertaken to find out the optimal types and quantities of aggregates and additives in order to improve weather resistance, to minimise shrinkage and to increase durability. The results of these testing regimes have been published in various sources, notably G. Minke, 2000.

Performance Tests Applied to Building Elements or Systems

B.6 The purpose of these tests is to investigate the performance of earth building materials under simulated conditions of use or in structural systems. These tests also evaluate the aging performance of the building, the likely comfort and safety. There is some overlap with the laboratory identification tests listed above. Additional tests in this category include:

- Loading
- Wind and water erosion
- Freeze-thaw
- Adhesion and durability of renderings
- Fire resistance
- Thermal properties

Example 1: Weathering Tests at the Building Research Establishment, East Kilbride, 1996[81]

B.7 Earth components should not be permanently immersed in water but they should have some resistance to running water, rain and frost. Dry earth block samples were tested at the BRE Scottish Laboratory to obtain information on their performance in relation to water penetration and frost resistance. The test methods were primarily designed for masonry and concrete products and their suitability for earth blocks had not been assessed previously.

[80] D. Clarke, in TERRA 2000 Conference Proceedings, 2000.
[81] Historic Scotland, Unpublished Report (n.d.)

Summary of Results

- The amount of water penetration collected at the rear face of the earth block panels was much less than through brickwork constructed of clay facing bricks (fired) with high absorption rates.
- In the water spray test the erosion of mud joints was greater than erosion of the earth blocks
- There was little difference in the erosion of the surface between earth blocks which contained different amounts of water during production.
- Resistance to freeze/thaw was poor for earth panels but this test was considered too severe for unfired earth. In a well-designed earth structure walls do not suffer from prolonged cycles of saturation and frost.

Example 2: The Earth Structures and Renders Experiment, 1996 to present

B.8 A series of test walls were commissioned by Historic Scotland under the supervision of B.Walker to re-establish sound working practices for a variety of traditional earth building techniques. The walls were built at four sites in different areas of Scotland: Fort George, Inverness-shire; Battleby and Stanley Mills, Perthshire; and Culzean Country Park, Ayrshire. The purpose of the experiments was 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.

B.9 The project is ongoing and subject to an annual monitoring programme. Some of the main findings to date[82] are as follows:

Skills and Technique

- Small sections of wall are more difficult to build and more susceptible to erosion than complete buildings.
- A wide range of clay sub-soils can be tailored to meet the needs of particular techniques but, in general, wet mud mixes were more appropriate to the soils sampled.
- The timing of different tasks is important. For example, soft workable mixes improve if ‘soured’ for a couple of days prior to use.[83]
- Traditional earth building is suited to a communal effort being simple, but heavy work. Mixing is best carried out by mechanical means.
- The strength of foundations and plinth wall is critical for rammed earth techniques.
- Walls constructed with shuttering cannot be built in wet weather conditions

Performance

- Elevations facing south and west experience greater rates of rain driven erosion but are less susceptible to frost damage than those to the north and east.
- Clay rich mortars are more susceptible to frost damage while sandy mortars experience more erosion.
- Weathered earth surfaces tighten over time as the finest particles are washed away thus filling shrinkage cracks and revealing exposed fibres and aggregate.

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[82] R. Little, Interim Report: The Earth Structures and Renders Experiment, 1996 to present. Unpublished Historic Scotland report.

[83] Souring – A traditional technique referred to in historical accounts

- A breakdown of the key is apparent between earth and other building materials such as stone, timber and lime mortar.
- The addition of dung and woodshavings to some earth renders increases their durability.

Example 3: Vapour and Thermal Tests at the Building Research Institute, University of Kassel[84]

B.10 Tests have illustrated the vapour diffusion performance of a variety of earth building materials. Measurements taken in a newly built earth house in Germany over a 5-year period showed that the relative humidity was almost constant varying between 45% and 55%.

B.11 With regards to thermal tests the common perception that earth is a good insulator against heat loss has not been proved. The volume of air entrained in the pores of the material and its humidity are relevant for the thermal insulation effect. The lighter the material, the more its thermal insulation and the more humid the material, the lower is it's insulating effect. The thermal insulation of earth mixes has been shown to increase with the addition of porous substances including plant fibre and mineral aggregates.

Example 4: Testing of Modern Earth Building Products, Helsinki University of Technology, Univerisity of Kassel, Technical Research Centre of Finland[85]

B.12 A group of earth building products are being researched and developed in an EU financed project. The aim of the project is to improve the technical properties and prove the health and environmental advantages of these products in order to bring them into modern building markets.

B.13 Initial results have been obtained for tests which increase the humidity balancing effect, strength and water resistance of earth products.

[84] G. Minke 2000
[85] W Westermarck in TERRA 2000 Conference Proceedings

APPENDIX C RELEVANT FOREIGN PUBLICATIONS

C.1 This schedule comprises a description of the principal foreign standards, codes of practice and other official documents relating to earth construction.

Australia

C.2 *Bulletin 5: Earth-Wall Construction* has long been used as an un-official standard. Following the failure of the joint Australia/New Zealand committee to write a joint standard, Peter Walker of Bath University has written an Australian Handbook to be published by Standards Australia.

European

C.3 The Centre for Development Enterprise in Brussels has published a number of European Guides/standards on compressed earth blocks. These include:

Compressed Earth Blocks – production equipment
Compressed Earth blocks – standards
Compressed Earth Blocks – Testing Procedures

France

C.4 During the period of reconstruction after World War II, three documents of an official nature were published:

REEF DTC 2001 Beton de terre et beton de terre stabilise, 1945
REEF DTC 2101 Constructions en beton de terre, 1945
REEF DTC 2102 Beton de terre stabilise aux liants hydrauliques, 1945

C.5 A special set of specifications was prepared for the Village Terre de l'Isle d'Abeau project[86]. This official document served as a reference document for the financial backers, insurers, the site manager, architect, contractors, and the inspecting body: *Recommendations pour la conception des batiments du Village Terre-Plan Construction, 1982.*

C.6 The thermal characteristics of the soil can be found in the publications of the C.S.T.B. (Paris): *No. 215. Cahier 1682. 198*

Germany

C.7 The development of German standards in earth building has a tradition going back to '*Reichslehmbauordnung*' of 1944. After the 2nd World War some German Federal Countries developed their own regional recommendations, but it was the GDR that saw an intensive

[86] See 6.51 , Domaine de la Terre Housing case study.

development of earth building. There the '*Lehmbauordnung der DDR'* was valid until reunification. The GDR included earth construction in a number of DIN standards but these were mostly withdrawn in 1971. The thermal characteristics still from part of standard: *DIN 4108, 1981*. In 1998 the German supreme state building authority established a new technical regulation of earth construction.

C.8 The German earth construction association, Dachverband Lehm e.V. produced this agreed document that covers all forms of earth construction. This has been submitted for approval to the sixteen federal governments who administer building control. and twelve have now approved this document: *Lehmbau Regeln – Begriffee, Baustoffe, Bauteile.*

India

C.9 This has an official standard: *Specification for soil-cement blocks used in general building construction, IS 1725*, Indian Standards Institute, New Dehli, 1960.

New Zealand

C.10 New Zealand is recognised as having a good public regulatory system and their official standards organisation recently issued a comprehensive set of documents covering earth construction:

NZS 4297:1998 Engineering Design of Earth Materials
NZS 4298:1998 Materials and Workmanship for Earth Buildings
NZS 4299:1998 Earth Buildings Not Requiring Specific Design

Switzerland

C.11 There are three Swiss codes of practice for earth construction. These cover earth building techniques and methods, properties of earth, examples of construction, working methods and techniques, and Swiss examples of earth constructions.

SIA-Document D 0111
SIA- Document D 0112
SIA- Document D 077

U.S.A.

C.12 American standards on earth construction have been issued since 1941 and earth construction practice is currently integrated into a number of national construction codes and standards:

Uniform Building Code Standards – Section 24-15, 2403 Unburned Clay Masonry Units and Standards.

Methods for sampling and testing. Unburned Clay Masonry Units. Recommended standards of the International Conference of Building officials, 1973

Uniform Building Section 2403 - Unburned Clay Masonry, 1973.
Several states have contributed improvements to these national standards, including Arizona, New Mexico, California, Nevada, Utah, Colorado, and Texas. In 1983, certain states published regulations for rammed earth construction, compressed earth blocks, and even for sod.

C.13 In 1991 New Mexico published a code covering unfired brick and rammed earth: *CID-GCB-NMBC-91-1*

C.14 The American Testing and Standards Association (ASTM) is currently drafting a standard for earth brick construction.

United Nations

C.15 Two codes of practice have been published by the United Nations:

58/II/H/4, Manual on stabilised soil construction for housing, Fitzmaurice, R., 1958.

64.IV.6, Soil-cement, it's use in building, 1964.

International

C.16 The International Union of Test and Research Laboratories for Materials and Construction (RILEM) and the International Council for Building Research Studies and Documentation (CIB) established a technical commission (RILEM/CIB: TIC 153-W90 'Compressed Earth Block Technology') on earth construction in 1987 to make recommendations and technical specifications for earth construction. Also RILEM Technical committee TC 164-EBM: Mechanics of Earth as a building material, which ran 1994-2000 and has not yet published its findings.

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www.aecb.net	*U.K.organisation*

APPENDIX E EXPERT CONSULTEES

Expert Respondent	Organisation
Dr. Horst Schroeder	Bauhaus University, Weimar (Germany)
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Kirsty Sutherland	Ice Design
Phil Allen	Natural Building Technologies
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David Clark	University of Bath
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