Earth Building in Scotland
Past, Present, Future

A Paper for the first International Conference on Ecological Building Structure

San Rafael, California

July 2001

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They have collaborated on projects for several years, initially concentrating on lime technologies and more recently focusing on earth. This year they completed a report for the Scottish government on the potential for new earth construction in Scotland.

Introduction.

Scotland is a small country of 30,414sq. miles. (78,772 sq. km) situated on the north west Atlantic fringe of Europe. Its population of 5.1 million people is concentrated in the central lowlands. Other parts of the country are some of the most sparsely populated in Europe. Scotland has a varied geography: bleakly beautiful mountains, a wild north Atlantic coastline and rich arable land. Edinburgh, the capital, is on the same latitude as Moscow and Hudson Bay, but the northern climate is tempered by the warm Atlantic Gulf Stream.

Scotland has been inhabited for ten thousand years and has a history of construction going back at least six thousand. The surviving buildings are predominantly less than two hundred years old and made of stone, timber and cement construction. In common with many developed countries, Scotland currently has an addiction to unsustainable suburban development and some severe problems with a legacy of poor quality post war social housing.

Historically, Scotland had strong commercial and cultural ties with France and the northern European countries. These links were a major influence on construction, but ended in the 18th century on political union with England. There followed the growth of industrialised cities, depopulation of the countryside, mass emigration and the riches of the empire. The recent re-establishment of a Scottish Government has fostered a climate for social, environmental and cultural progress.

As part of the work of the new government a series of studies have been made on the uses of natural materials in construction within an environmental and cultural context.

The Sustainability Agenda.

'*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]

Within the United Kingdom there is increasing recognition of the role that construction could play in the implementation of policy to reduce global warming and improve sustainability. In this context, the Scottish construction industry is significantly behind those of many other E.U. countries, notably Germany, in adapting its use of materials, construction and procurement methods.

The environmental impact of construction is a complex issue, but two factors can be used to illustrate the current Scottish and U.K. situation: carbon dioxide emissions and waste production.

Carbon Dioxide.

At Kyoto the U.K. agreed to reduce the 1990 level of C02 emissions by 20%, by 2010. This will be achieved by the change of electricity generation from coal to gas, but the government has not identified sources for the reductions that will subsequently be required.

In the U.K., between 40% and 50% of C02 emissions are attributable to buildings[2]. Cement production alone accounts for 10% of global CO2 emissions and this is increasing faster than any other industrial source, with production rising by 5% per annum.

In a reasonably energy efficient new U.K. building, up to 50% of the energy required for a thirty year design life is attributable to embodied energy and about 50% to energy in use. The introduction this year of the Climate Change Levy (a tax on energy use) should encourage a reduction in the carbon emissions from production of materials and in the processes of construction.

Rates of Climate Change Levy on Business and the Public Sector:

Electricity	0.43 p/kwh
Coal	0.15 p/kwh
Natural Gas	0.15 p/kwh
Liquid Petroleum Gas	0.07 p/kwh

In fact the current rates are negligible compared to the market commodity fluctuations, but an important principal has been established.

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

Waste.

Another national priority is the reduction of resource depletion and waste production. In the U.K., the construction industry uses six tonnes of material per person each year. Half of U.K. solid waste is produced by the construction industry. The introduction of landfill taxes has discouraged the production of waste, while government reports have highlighted the inefficiency of the construction sector and the need for better management.

Sustainable Materials.

Over the past decade, Scottish architects, builders, materials producers and academics have begun to explore the potential of a range of low impact technologies to reduce the environmental cost of contemporary construction. Earth is one of the most interesting of these technologies with good environmental characteristics in all respects:

- Design for Low Carbon Emissions. For example, air-dried bricks require about a third of the energy of fired bricks to produce (440 KWh/m3 compared to 1300 KWh/m3).[3] One Scottish brick producer estimates that 40% of his production does not need to be fired for the uses to which it is put[4].
- Efficient Use of Finite Resources.
- Minimising Pollution & Waste.
- Use of Benign Materials.
- Local Sourcing
- Biodiversity / biodegradability

The use of stabilisers compromises most of these characteristics and therefore is not promoted in Scotland.

Other sustainable materials in the Scottish context include timber and straw bale, but earth is unique in its range of potential applications and ability to be adapted to the modern construction industry. These two critical factors mean earth has the potential to grow out of the niche market of ‘alternative’ building and to effect a significant degree of change in the construction industry.

[3] M. Westermarck, 1998

Achieving this move from the niche to the mainstream is perhaps the most important issue to be addressed. It involves the creation of a climate of public desirability and technical acceptance. But it also presents the opportunity of spreading a wider appreciation of the philosophical, environmental and economic principles behind natural building techniques.

A great advantage in the promotion of earth is that it has strong traditional base. The establishment of bioregional construction materials is important in the development of sustainable construction and has the important benefit of creating cultural richness through diversity of regional building styles.

It shouldn't be a surprise to find sustainable materials and techniques in any pre-industrial tradition of building. People chose materials because they were readily available and were easily worked. This local selection of materials created buildings inherently linked to the landscape that produced them.

These houses at Skara Brae in Orkney are the oldest surviving settlement in Europe. They were built two and a half thousand years before the Great Wall of China and fifteen hundred years before the Pyramids of Giza.

The walls were built from the easily split local stone and waterproofed with blue clay. The roofs probably had a driftwood and whalebone structure covered with seaweed thatch. An understanding and appreciation of traditional earth building can inform innovative and appropriate uses of earth in new construction.

The Scottish Tradition

''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.'' [5]

In the British Isles there are estimated to be half a million inhabited earth buildings in a varied range of construction materials and architectural types.[6] These are concentrated in southwest England, the East Midlands, Cumbria, East Anglia and Lincolnshire. There is also a rich heritage of earth building in Ireland and Wales.

[5] J. Norton 1997

In Scotland, stone is generally perceived to be the principal building material, but during the greater part of Scottish history, earth construction was predominant. An understanding of the basic principles of earth construction has grown out of investigations concerning the conservation and archaeology of these structures.

The varied geology led to the development of a wide range of building types using clay sub-soils and turf. 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. In addition to vernacular buildings, a broader use of earth structures was also to be found in major architectural and civil engineering projects.

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.

The 19th century also saw the development of a modern construction industry that made increasing use of Portland cement. In the face of these innovations, earth technology was perceived as out of date and abandoned due to the labour intensive nature of the work. Unfortunately, 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 has been lost.

Traditional Techniques

There were numerous local variations of earth construction in Scotland that 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” (cob) technique can still be found in the Carse of Gowrie near Perth.

Earth infill in timber frame

Sod wall

‘Clay and bool’ walling

Mudwall under a lime render

In the north east of Scotland the mud and straw was layered between round boulders known as “clay and bool” and these walls were often formed in shuttering[7]. 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.

Later, types of earth construction developed 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.

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[8].

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 lower status buildings until recent times.

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.

[7] B. Walker 1977

The Conservation of Scottish Earth Structures

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[9], 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.

In an attempt to relearn traditional skills the national conservation body, Historic Scotland, has undertaken experimental work in connection with historical studies. There has also been analysis and repair of surviving earth structures, which is well documented.

The Relevance of Traditional Techniques to New Construction

''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.''[10]

There are many lessons to be learnt from traditional earth building practice that 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 maintenance regimes and repairs that are easily carried out and compatible with the original construction.

- Surviving earth structures in Scotland illustrate appropriate use of local materials, resulting in diverse and distinct cultural patterns. The maintenance of this cultural diversity and local knowledge is central to the debate on sustainability.

- 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.

- 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.

[9] In particular Dr. Bruce Walker at Dundee University, Chris McGregor at Historic Scotland, the National Trust for Scotland, the Highland Folk Park, Newtonmore and ICOMOS UK Earth Structures Technical Committee

- 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 that 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.

Examples of Traditional Buildings:

1. The Hebridean Blackhouse, Lewis

Client and contractor: Historic Scotland
Location: 42 Arnol, Barvas, Lewis, Outer Hebrides

The Blackhouse 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[11].

The building, constructed in 1885 and occupied until 1965, is part of a distinctive North Atlantic and Arctic region 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 responds to local site conditions.

The construction uses local earth 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.

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 Blackhouse is a well-insulated, aerodynamic form, where 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.[12] This design is the result of hundreds of years of experience, community cooperation 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 base available.

[11] Historic Scotland Technical Advice Note 6

2. Cottown Old Schoolhouse, Perthshire.

Client: National Trust for Scotland
Contractor: Becky Little Construction

This thatched mudwall[13] cottage dates from 1765 and was inhabited until 1985. It is located in the Carse of Gowrie, which has one of the largest concentrations of mudwall structures in Scotland. The area has vast deposits of clay which have been used in both fired and unfired clay products over the past three hundred years.

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

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).

Following analysis of the original mudwall mix, air-dried earth blocks were produced on site and used as indents for structural repairs. In order to match “like with like” sub-soil was acquired locally from a working clay quarry adjacent to the site and mixed with appropriate amounts of aggregate and straw. Flax straw was the preferred type because of its strength and binding qualities. The blocks were produced under cover during the winter and used the following spring.

The experimentation, research and analysis carried out during this project have contributed to a deeper understanding of traditional practices and have also generated a body of practical experience that is now being applied to new mudwall structures in Scotland.

Examples of New Buildings:

1. Loch Lomond Visitor Facility, Rowardenan, Argyll

Architect: Richard Shorter with Simpson & Brown
Builder: Becky Little Construction

This project involved the building of a visitor facility in the National Park at Loch Lomond, where the use of earth materials followed the client's brief for sustainable design and use of local materials.

The building has external mudwalls, finished internally with earth plaster and externally with lime and earth renders. Pre-fabricated earth blocks bedded in earth mortar were used in the gables.

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 Special Site of Scientific Interest, the post industrial site having become a haven for wildlife. Clay was brought from fifty miles away and mixed with locally obtained aggregates and straw. The blocks were made off site and proved to be a quick and efficient form of construction.

The use of earth materials has drawn considerable interest as the site is a public one, and reaction has been very favourable.

2. Light Earth Construction Project, Melrose, Borders

Architect: Chris Morgan, Gaia Architects

This light earth/fibre dwelling is due on site in the summer of 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. Its economic and environmental viability will be examined with reference to other sustainable forms of construction

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

The building will be the first stand alone LEC in the U.K. and comprises earth, straw and woodchip infill formed in shuttering within a structural timber frame. The roof membrane is protected by a layer of living turf and the walls will 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 structure.

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.

3. MacDuff's Cottage, Lindores, Fife

Architect: Tom Morton

This project involves the restoration of an 18th c. thatched cottage by a local Building Preservation Trust. There is no evidence of earth construction within the surviving fabric, but earth is proposed for the new works on the basis of sustainability.

A local brickworks is developing prototype earth/woodchip blocks in collaboration with the builder and architect. These will be used for internal partitions, clayboards will be used to line the external walls and all walls will be finished with an earth plaster. In line with traditional practice, puddled clay will be used under turf as the ridge capping to the reed thatch.

It is hoped that this project may lead to the local commercial production of earth bricks and plaster. There is also the potential to develop production of composite reed / clay products, as the thatching reed are also locally produced.

Future Development.

As will be apparent, in Scotland we are behind many other countries in the modern application of earth construction. However, with a strong historical tradition as a base for growth, an accepted agenda for a shift to sustainable forms of construction and the support of our more advanced European colleagues, there is a good climate for the renaissance of earth building in Scotland. But it is important to recognise that among the opportunities, there are also potential pitfalls.

The Market.

The market for is currently limited to projects where clients are well informed and have a particular interest in the environment and sustainability.

This demand for one-off high quality buildings will continue to grow, and could provide the basis for promotion of the material by example and publicity. It may also provide a setting for education, training and materials development, but cannot, in itself, make a significant impact environmentally.

The benign health qualities of earth materials, as well as increasing implementation of sustainability policies, should encourage their promotion within public sector procurement, which accounts for 40% of construction in Scotland. This sector could also provide a vehicle for demonstration projects. However, government projects are inherently beaurocratic. Policy documents are often encouraging, but practical implementation lags far behind.

The commercial mass market will be reluctant to introduce earth technologies while there is perceived risk associated with the lack of experience and standards.

In England there is a parallel with thatch, which has been perceived as a poor quality material, a fire risk and a problem for insurance. In fact it has good environmental characteristics and a strong, neglected tradition. A climate of desirability, fostered by romantic imagery, has led to the recent use of thatch in commercial housing estates.

The Designers.

The few U.K. design professionals competent in earth construction are generally self-educated. If there is to be an increased design capacity for earth building, access to training and information must be established.

Recently, the attractive ‘engineered’ quality of rammed earth has led to its use in a number of prestige buildings. Where there is a thorough respect and understanding of the material and teamwork between designers and builders, a high quality has been achieved. However in at least on case, the material was chosen for stylistic reasons and was not properly understood by the designers. Inappropriate design lead to localised failure.

Building Control.

'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'[14]

'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'.[43]

The Scottish system of Building Control is essentially a performance-based system. In principal, earth techniques can be approved by replicating a historical technique, by complying with the standard of another E.U. country or by providing primary data. All these methods require considerable additional work of the designer. The establishment of an accepted standard would enormously ease this significant procedural barrier to sector growth.

The Building Control system is used as a tool of government policy, e.g. energy efficiency and disabled access. It could be used to indirectly encourage the use of low embodied energy materials by giving targets for embodied energy as well as energy in use. There is currently a major review of the Building Control system under way and we await the results.

Materials Producers and Distributors.

Currently, there are no established producers of earth construction materials in Scotland. Materials are produced on site or pre-fabricated off-site. A range of earth products, including blocks, boards and plasters, is being imported from mainland Europe.

One-off production and use of imported materials is inherently inefficient and environmental damage through transportation. The development of indigenous production is critical to establish a mass market and maximise environmental benefits.

There are no fundamental barriers to this, with the manufacturing technology being readily transferable from conventional materials. Earth bricks can be produced by the same mixing and extrusion process that makes ceramic bricks. Gypsum and lime plaster and mortar producers could produce earth based plasters and mortars.

This ability to utilise existing manufacturing infrastructure means that earth materials could be developed and marketed in parallel to conventional products by existing manufacturers. Encouraged by tax policy, this should allow them to be produced and distributed without the need for major capital investment. It will also avoid the danger of antipathy from some vested interests.

This model for growth 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

[14] *The Development of a Policy on Architecture for Scotland*, Scottish Executive, 2001

sustained growth of 20% per annum at a time when the rest of the German construction industry has seen no growth[15].

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

The Construction Industry.

At present, competence in earth construction skills in Scotland is limited to a very 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 readily available.

Commercial Contractors.

As with product manufacturing, the various techniques of earth construction are simple and relate to existing construction skills. In particular, light clay/fibre infill could easily be introduced into the large timber frame construction sector. The skills gap is small and our experience has been that conventional contractors readily adapt to use of earth materials.

Through lack of experience, non-specialist contractors are initially sceptical regarding material performance and concerned about liabilities. These concerns disappear when a contractor gains experience. The more benign working qualities of earth materials as opposed to the health impacts of conventional materials should (but probably won't) be a factor in easing acceptance.

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 conventional 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 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.

The Self-build Sector.

As is seen in continental Europe, the simple, safe and inexpensive nature of earth materials lends them to use in self-build projects, allowing a wide range of people to be involved in the construction process and giving opportunities for training and community involvement.

But self-builders require good guidance and training, both currently lacking, and this sector will have only a minor influence in the establishment of a mass market.

Testing.

"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" [16]

Very few countries have developed standards for analyses and tests specifically suited to soil. Tests for soil have often originated in other disciplines, such as concrete construction and road building, and these standards are not necessarily suited to earth building.

Standards.

Standards and codes of practice 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.

There are no officially recognised U.K. or E.U. standards for earth materials. In the absence of such standards a number of other reference documents are being used in the U.K., including descriptions of historic techniques produced by the conservation community, foreign standards and codes of practice, and documents written in the U.K. primarily intended for developing world situations.

In the U.K. the recognised standards institution is the British Standards Institution (B.S.I.). This is now 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 an earth standard.

With the significant body of useful foreign standards and codes available, it would be possible for a group of U.K. experts to be formalised 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 links between the U.K. earth building community and foreign groups.

Another 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.

Conclusions.

The future is bright for earth if we can:

- Establish a climate of desirability
- Innovate from the traditional base
- Actively guard against bad practice
- Establish standards
- Foster co-operation between designers, builders, materials producers and researchers
- Co-operate internationally

Postscript.

Earth building in Scotland has been restrained for social reasons rather than technical. The common perception has been of an inferior material lacking durability. They have been seen as the product of poverty and shunned for that reason. The antithesis has seen earth construction as historically important and ecologically desirable.

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