Unfired earth brick building

The idea of using unfired earth bricks for building homes in the UK is not just pie in the sky. It is a method that anyone could consider now! **Tom Morton** explains...

The main benefits of earth construction (a healthy indoor environment and low environmental impact) have been increasingly well documented over the last fifteen years, particularly in Germany where manufacturing of proprietary products, contractor training programmes and governmental approval of industry standards have fostered an increasing catalogue of high quality examples of modern earth construction.

In the UK, for a variety of historical, cultural and economic reasons, the development of modern earth construction is about ten years behind Germany. However, the technical development illustrated in foreign projects and an increasing market for sustainable construction have created conditions in the UK where earth construction could break out of it's nurturing niche into mainstream construction over the next 5-10 years.

In 2003, with funding from the DTIs Partners In Innovation project and Communities Scotland, Arc Architects began a detailed, 2-year study to assess the potential for the benefits of earth to be realised in low cost UK construction projects.

The design, construction and habitation of a new house in

Perthshire was studied in detail by a team including Dundee and Robert Gordon Universities, Natural Building Technologies Ltd. and the Errol Brick Company Ltd., with a wide advisory group representing the various parts of the UK construction industry, as well as earth experts from Germany, the USA and Canada.

Low-cost earth house?

The house was designed to be as 'eco-friendly' as possible over a broad range of criteria and within the financial and physical constraints of a low cost housing grant scheme. The aim was not to create the best earth house that could be built, but to use earth materials to achieve a range of specific technical benefits at an affordable cost within a holistic, simple and efficient design. The key to achieving this was to gain multiple benefits from one easy-to-use material.

Earth brick masonry was specified for the inner leaf of the external walls and for internal partitions. The materials used were Errol 'eco-bricks', air-dried extruded bricks made from a mixture of clay, sand and sawdust. These mass-produced materials had been thoroughly tested as part of a BBA certification process and were considerably cheaper than comparable products imported from the continent. The brickworks also supplied powdered clay and a lignosulphate (tree resin waste by-product of paper pulping) additive for the mortar.

Earth bricks are easy

The availability of these materials at 'low cost', compared to other earth materials, sheds light on the development of the market for earth materials. At present there is little demand for proprietary earth materials and those imported from Germany are expensive. The manufacture of the Errol unfired bricks required no new equipment, labour skills, or methods of marketing and distribution for the manufacturers. The brick company could therefore diversify into producing more sustainable products for a relatively modest investment. While the brick industry is vulnerable to increasing energy costs and taxation, manufacture of the unfired bricks needs only 14% of the energy of their fired equivalents.

However, the Errol Brick Company did invest in new equipment for the manufacture of clay mortars and carried out a lot of testing in the development and certification process for the bricks, though this was grant aided by the local enterprise company.

Other forms of earth construction that require unfamiliar specialist processes, such as rammed earth, and those that used hand-made or untested earth materials, such as in vernacular cob construction, are limited to a niche market. However, the mainstreaming of new sustainable materials requires them to be simple to use and similar to ubiquitous conventional materials, as the successful marketing of sheep's wool insulation has shown. An increasing market for earth masonry should allow costs to reduce with a rising scale of production. This has been demonstrated in Germany over the last 5 years, where the earth construction sector has sustained significant growth over a period when mainstream construction has stagnated.

Earth in a layered construction

The same practical considerations fed into the design and construction of the building. The earth materials were intended to be suitable for use by standard tradespeople without specialist training, equipment or supervision, ie in normal low-cost construction circumstances. The house was therefore built without the specialist input that is normal for earth projects.

The building reversed normal timber frame construction. An external timber frame, clad in local untreated larch, achieved a quick and structurally efficient weatherproof envelope. Inside this the earth construction could

proceed unimpeded by the variable Scottish climate. By separating the inner finish from the structural frame, the frame could be sized for optimal structural efficiency while allowing cellulose insulation to be as thick as desired for thermal insulation. Fully filling the cavity, the installation of insulation to the walls and roof was carried out in one day.

The location of the earth materials within the building design was intended to have multiple benefits:

- to remove any risk of condensation from the wall construction
- to give the building strategically located thermal mass
- to regulate internal air relative humidity
- to provide a degree of acoustic insulation
- to achieve a perception of solidity to the internal construction

The earth brickwork proved straightforward to construct, with the bricklayers keen to use the materials again. Problems did occur with the clay plaster finish, relating to the difference of working qualities between clay and gypsum plasters. In a project with small rooms, the plasterers found it frustratingly difficult to effectively programme the drying time of the plaster. Their tendency to overwork the topcoat, from years of polishing gypsum with steel floats, resulted in some separation of the clay binders and fine sand, causing some cracking and surface dust. These relatively minor defects are simple to remedy, but did demonstrate the need for training to achieve consistent quality.

Plasterers needed to get used to the slower drying rates of earth render and other working qualities compared to gypsum

Timer frame building in reverse - frame and timber cladding on outside and heavy masonry as interior skin.

All photos courtesy of Arc Architects.

Monitoring proved earth's performance

The building's thermal and moisture performance was monitored in multiple locations every 15 minutes for a year. The detailed picture this provided confirmed that the earth masonry achieved its intended performance, with the regulation of internal air relative humidity the most important attribute highlighted in the study.

The relationships between indoor relative humidity (r.h.) and occupant health is increasingly well understood. Scotland has the world's highest rates of asthma among young people and the link between r.h. and asthma is well established, most clearly laid out in a recent book by Stirling Howieson, 'Asthma & Housing'. CIBSE has recognised this link in their guidance on good practice and there are moves to incorporate indoor air r.h. targets within building standards.

The ability of unfired clays to absorb and desorb atmospheric moisture is the key attribute that also makes them effective in a

wide range of building applications, such as the control of mould spores and the creation of stable environmental conditions for museum artefacts and acoustic musical instruments.

In this house the key target of regulating internal air r.h. to 40 – 60% was generally achieved, but the strength of clay's performance exceeded expectations. Tests in the bathroom showed that there was no statistical difference in the rates of decay of atmospheric moisture after showers, whether the extract fan was running or not. The ability of the clay surfaces to passively absorb excess air moisture was thereby demonstrated to outperform and render unnecessary the standard electro-mechanical device.

Another strong result was the low level of waste produced. After it was established that the cost of returning the waste to the brickworks for re-cycling was more expensive than their value, the waste off-cuts from bricks was naturally biodegraded into the site soil. The bricks create no waste during their manufacture and even the clay extraction is ecologically beneficial, with worked out clay pits being flooded to become biodiverse SSSI's.

A detailed audit found that the earth masonry had an embodied energy of 123.5 KWh/tonne and 22kg CO_2/tonne at the factory gate. Accurate comparable figures are difficult to obtain, but this amounts to about 14% of the embodied energy and carbon of common fired bricks. The estimated saving in this building is 24.9 MWh and 7036 kg CO_2 over common bricks, and 14.5 MWh and 4104 kg CO_2 over lightweight concrete blocks. This calculation does not take into account the plaster.

A construction cost of £650m² was estimated to be the conventional main contractor procurement equivelant, calculating out the special factors relating to the procurement of this house. This is a 2003 figure and £750m² is probably more realistic today.

The house owner/occupiers are very pleased with the house, despite the minor defects and the restrictions that earth materials place in internal decoration. The house performs quite differently from their previous cold and drafty stone cottage and they have adapted their occupancy patterns as they get used to its thermal response.

Comparing the results from this house to that on other types of housing, it is apparent that there is a value in the thermal mass and slow response of the heating system. Evidence from tightly designed lightweight construction projects, which rely on controlled ventilation and heat recovery, show that in reality people's uncontrollable occupancy patterns, in particular their desire for natural ventilation and ability to manage heating systems, often undermine the theoretical efficiency of such designs.

In contrast, while the occupants of this house created ventilation rates far in excess of what was necessary, the thermal and moisture regulation achieved through the mass of the earth masonry did much to regulate the impact of this on comfort and cost.

The future for UK earth building

The full final report on the project, together with a four page summary and an interim design guidance leaflet are available from Arc's website www.arc-architects.co.uk. Arc are currently writing a book, Earth Masonry Design & Construction Guidelines, which is scheduled to be published by BRE Publications early next year.

The future for earth construction in the UK is uncertain. Unfired clay's fundamental properties as a flexible, healthy, low-energy binder give it great potential in an evolving sustainable construction industry. This example of earth masonry construction could help establish a basic mass-market for earth materials in the mainstream sector, which could foster more exciting research and development into prefabricated composite materials and sprayed applications. The commercial reality is that while some major brick producers are making noises of interest in producing earth bricks, the kind of investment that is needed for really progressive development is still a long way off.

The increasing growth and diversity of interest in earth construction from professional designers, materials suppliers, academics and the conservation community merits the establishment of a UK Earth Building Society to promote the development and conservation of earth building in Britain. Acting as a forum for debate, such an organisation could foster significant progress by establishing working relationships with its European counterparts and UK governmental and industry organisations.

Tom Morton - Arc Architects

Arc Architects interest in earth construction has developed through the conservation of UK vernacular earth buildings, the study of earth building techniques abroad, the development of new proprietary unfired clay products and the design of new buildings.

Errol Brick Co: **www.errolbrick.co.uk**
NBT: **www.natural-building.co.uk**
Arc Architects: **www.arc-architects.co.uk**