STABILISED RAMMED EARTH (SRE) WALL CONSTRUCTION – NOW AVAILABLE IN THE UK

By Dr Matthew Hall, The University of Nottingham, and Bill Swaney, Earth Structures (Europe) Ltd

What can stabilised rammed earth offer?

Stabilised rammed earth (SRE) is a low-carbon masonry wall material that successfully combines ancient earth-building techniques with modern commercial technologies and building practices. The finished product is a durable material that is cost-effective and infinitely recyclable, but with natural high-quality aesthetics that are reminiscent of cut sandstone. It is a commonly reported fact that around half of all global CO_2 emissions can be attributed to the construction, and more importantly the operation, of buildings. The reason why SRE is an effective low-carbon technology is that it tackles both of these areas.

In the construction phase, SRE contributes very little embodied energy for two main reasons:

1. approximately 95% of the component materials are unfired
2. the use of locally-available raw materials minimises the level of transportation required.

More recently, crushed recycled demolition rubble from used bricks and concrete is increasingly used by SRE contractors instead of sub-soils. This offers the advantage of significantly reducing landfill by converting the on-site waste materials into a high quality product to make new buildings. This also offers considerable cost advantages to the contractor by eliminating charges for masonry waste, haulage and disposal.

The most significant advantage of SRE is during occupation where the walls act as a source of building-integrated renewable energy. This is due to the large thermal storage capacity contained within the walls enabling them to be used as a storage battery for passive heating and cooling of the building. This enables designers to use SRE walls for the combined functions of a load-bearing structure and also as an energy-saving device. Many such designs have been shown to offer both significant reductions in average annual energy consumption and improved levels of thermal comfort during occupancy.

SRE is a programmable system of wall building that is manufactured to close tolerances making it highly compatible with existing trade practices. It can be made using local sub-soils, quarry waste materials, or even recycled bricks/concrete crushed to an ideal particle size specification. SRE offers a rapid rate of production at typically 10 to 15m^2 of 300mm-thick solid wall per day. It has a uniquely attractive, layered appearance and is available in a wide range of natural earthy tones that normally reflect the materials available in a given area.

Earth Structures Ltd

Earth Structures (Australia) Pty Ltd is an established and well-respected rammed earth contractor based at Mansfield, Victoria in Australia. It is a member of the Affiliated Stabilised Earth Group (asEg) of companies, the largest corporate group of rammed earth contractors in the world. Earth Structures Ltd was founded in 1992 by Managing Director Rick Lindsay. He has completed in excess of 250 stabilised earth structures including large public buildings such as the Juvenile Justice Detention Centre at Dubbo, NSW (see: Figure 1) and, more recently, the Science & Resources Centre at Lauriston Girls School, Melbourne, Australia (see: Figure 2). He has also produced numerous residential properties (see: Figure 3) and holiday homes (see: Figure 4).

In response to the huge potential for stabilised rammed earth in the United Kingdom, Earth Structures opened a European branch based in Northamptonshire. The managing director of Earth Structures (Europe) Ltd is Australian ex-patriot Bill Swaney who has significant experience with a number of rammed earth projects both in Australia and the UK. Recent examples include the Medal-winning Australian Inspiration Garden (Fleming's Nurseries Garden) for the Chelsea flower show in 2004 and a large stables outbuilding in Northamptonshire (see: Figure 5).

Earth Structures Ltd are effectively a global company who are now able to direct and apply their experienced site supervisors and trained workforce wherever it is needed between both the Australian and the UK branches. They have

Figure 1 – Orana Juvenile Justice Detention Centre at Dubbo, NSW, Australia (© Earth Structures Pty Ltd.)

Figure 2 – The Science & Resources Centre at Lauriston Girls School, Melbourne, Australia (© Trevor Mein)

Figure 3 – The Big Springs homestead (© Earth Structures Pty Ltd.)

Figure 4 – Passive solar-design holiday home (© Earth Structures Pty Ltd.)

Figure 5 – The stables outbuilding at The Manor, Northamptonshire, England (© Earth Structures Ltd.)

recently been asked to supervise new SRE building projects in Thailand and Korea. This unique ability allows them to confidently apply the proven technique of SRE in the UK market, thus providing the same high levels of quality and workmanship that has made it so successful in Australia.

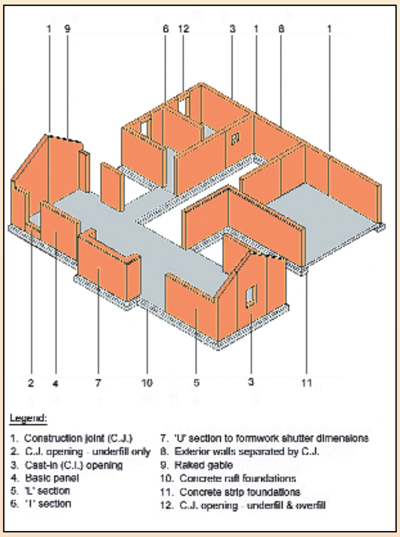

Figure 6 – An isometric view showing the configuration of typical SRE wall elements in a building produced using the Stabilform™ system (© Affiliated Stabilised Earth Group)

The Patented "Stabilform™" System

Stabilform™ is a patented formwork system specifically designed to meet the special requirements of SRE. It has been developed and perfected for over 25 years and has been successfully used to produce several thousand SRE structures throughout Australia. The Stabilform™ system allows architects to design buildings and structures using a highly programmable range of standard-sized SRE wall elements (see: Figure 6). Each wall element is made up of 'lifts'; these are generally 600mm high and can be a range of different standard lengths such as 1,200mm, 1,500mm, 2,400mm etc (see: Figure 7). A typical 2.4m high wall, for example, will have the appearance of four lifts in height giving the walls a unique aesthetic form. The Stabilform™ standard-sized units are also available to produce special shapes such as 45° & 90° corners, 'T' sections, 'Z' sections etc. In addition, SRE can be used to form gable ends, columns, arched openings, radius curved sections and any other custom-sized wall section, although a greater cost is normally incurred for this service.

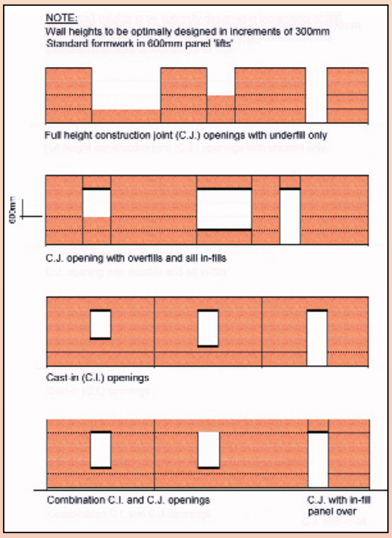

Figure 7 – An elevation showing the configuration of typical SRE wall elements produced using the Stabilform™ system (© Affiliated Stabilised Earth Group)

Window and door openings can either be full height, or they can be cast into the wall section using block outs (see: Figure 8). Designing SRE buildings with the Stabilform™ system offers the advantage of increased quality control, speed and reduced construction costs. The dimensions for standard lifts and elements are available in printed format or even in electronic format as software add-ons for use with AUTOCAD. Once the architect's drawings for a building/structure have been completed, Earth Structures Ltd can supply an all-inclusive quotation expressed as a cost/m² of wall face including set-up costs, labour and materials.

Figure 8 – The use of Stabilform™ to produce solid cavity-insulated SRE wall elements for a residential property in Benalla, Australia (© Earth Structures Pty Ltd.)

Research and development

Dr Matthew Hall is a Lecturer in Sustainable Technology at the School of Built Environment, The University of Nottingham. The School has a worldwide reputation for research in sustainable technologies and has been ranked number one in the UK for the last three consecutive years (2002-2004) in the building category of the UK University League Tables published by the Times Higher Education Supplement. Matthew has been researching rammed earth construction since 2001 and has chiefly investigated the mechanisms of moisture ingress and migration in rammed earth wall materials in order to assess their suitability for the UK climate. Dr Hall is now collaborating extensively with Bill Swaney of Earth Structures (Europe) Ltd in order to further research and develop SRE. He also instigated the successful construction of the first SRE public building to be fully accepted under all relevant sections of the 2002 Building Regulations for England and Wales (Hall, Damms & Djerbib, 2004). The building is intended for use as a bowls pavilion/community centre and was designed and constructed in collaboration with Chesterfield Borough Council in 2003.

Structural properties

The minimum characteristic unconfined compressive strength (f'_{cu}) for SRE is 3.5 N/mm². This is easily achievable and has already been deemed to satisfy Part A: Structural Stability of the Building Regulations 2000 (Hall, Damms & Djerbib, 2004). Compressive strength can be tested prior to and during the construction phase in order to ensure quality control. The test specimens are produced as 100mm cube samples as per BS 1881 for concrete (Hall & Djerbib, 2004a). The f'_{cu} can be increased up to ≥10N/mm² to suit particular applications and this is normally achieved through alterations to the mix design.
Standard reinforced concrete, steel channel or timber lintels can be used with SRE walls (see: Figure 9) and require a minimum bearing depth of 300mm (Hall, Damms, and Djerbib, 2004). Steel reinforcement can also be cast inside SRE walls either horizontally or vertically. This allows the construction of tall, slender wall sections that are resistant to buckling, as demonstrated by the 8m high 300mm thick steel-reinforced SRE walls used for

Figure 9 – The use of wide-span lintels with SRE walls at The Charles Sturt University campus building, NSW, Australia (© Earth Structures Pty Ltd.)

Figure 10 – The Champion Forms Printing Factory, Victoria, Australia (© Earth Structures Pty Ltd.)

the Champion Forms Print Factory (see: Figure 10).

Durability and moisture ingress

Testing has proven that SRE materials rarely have any problems meeting the requirements of even the most severe durability tests (Walker & Standards Australia, 2002). Tests have been performed on a series of full-size SRE walls in a climatic simulation chamber. The 5-day test routines simulated high levels of wind-driven rainfall based on the standard test procedure provided by BS 4315-2: 1970 *Methods of test for resistance to air and water penetration – permeable wall construction [water penetration]* (BSI, 1970). High-pressure spray nozzles were used to simulate a sustained rain shower where the equivalent of 84mm (3.3") of rainwater run-off is applied to the face of each test wall every hour for 6 hours in a given 24-hour period (see: Figure 11). Both the degree of moisture ingress and material loss (due to erosion) in each SRE test wall was observed to be insignificant (Hall, 2004). By comparison, previous tests on a series of stone walls had shown both full penetration and significant internal leakage via the mortar joints within three hours.

Figure 11 – An SRE test wall being exposed to pressure-driven water penetration testing in the climatic simulation chamber at Sheffield Hallam University (© Hall M)

Moisture ingress in SRE due to capillary suction has been observed to vary greatly depending upon soil type, and that the performance of the material can be greatly increased through optimisation of the soil grading (Hall, 2004). Capillary moisture ingress in well-graded rammed earth has been observed to be typically lower than that of vibration-compacted C30 concrete (Hall & Djerbib, 2004b). Earth Structures also use a proprietary water-repellent admixture for SRE walls that, in addition to correct soil grading, can give significant further reductions in the level of moisture ingress.

Thermal properties

As with most masonry wall materials, SRE walls have an inherently low thermal resistivity. However, SRE walls have a very high capacity to store heat energy – commonly referred to as 'thermal mass'. In simple terms, this means that they do not readily prevent the flow of heat energy but, owing to their high density, they can absorb and store it. High thermal mass can be used to great effect by architects along with passive solar design in buildings. By reducing the need for heating/cooling in a building this can have the effect of significantly lowering fuel costs. This also gives the added comfort benefits of radiant heat as opposed to using the air within a building as the transfer medium, as with most conventional central heating systems.

According to Standards New Zealand (1998), in the absence of laboratory test data the thermal resistivity (R) of an SRE wall can be calculated using:

$$R = 2.04d + 0.12$$

Where: d is the cross-sectional thickness of the wall element in metres.

According to Part L1 of the Building Regulations 2000 for England and Wales the cross-sectional design of an external wall element in dwellings can demonstrate compliance by having a minimum U-value of 0.350 W/m^2 k (ODPM, 2002). A comparison between the calculated U-values for conventional masonry wall designs and typical SRE wall designs has been provided in Table 1. One possible Part L-compliant SRE wall design is to install internal dry lining or timber stud walling including insulation bats. This technique has the advantage of retaining the full aesthetics of the rammed earth on the exterior, and also provides a key for movable interior partition walls. Unfortunately, with this method the benefits from the wall's thermal mass are effectively isolated from the interior of the building by the insulation. An alternative is to apply profiled insulation cladding, for example, on the external wall face. This allows the wall's thermal mass to stay connected with the interior of the building, and also provides a more conventional aesthetic for commercial properties, for example, allowing SRE to be used in areas where an exterior appearance that matches adjacent properties is desired.

A new solution has been developed by Earth Structures to construct SRE solid cavity walls incorporating rigid insulation bats (see: Figure 12). This approach has been so well-received by their clients that it is now being used on most new SRE projects. Earth Structures have successfully built several new buildings using this method, both in Australia and the UK, and the demand is increasing. SRE cavity walls are still built using the Stabilform system, but they incorporate a solid cavity fill of rigid insulation material such as extruded polystyrene or polyisocyanurate. The inner/outer leaves are both typically 175mm thick and are tied using stainless steel cavity wall ties. This design solution retains the thermal mass properties of the rammed earth inside a building, and yet prevents excessive heat loss through the wall fabric in winter. It also ensures that both the interior and exterior appearance of the rammed earth is not hidden in any way.

Figure 12 – The construction of an SRE wall incorporating solid cavity insulation and stainless steel wall ties (© Earth Structures Pty Ltd.)

Acoustic properties

SRE is an extremely dense masonry wall material where the dry density (p_d) is typically 2,100 kg/m^3. The weighted sound reduction index (R_w) of a solid masonry wall is strongly dependent upon the dry density of the wall material. According to the 'mass rule' for a solid masonry wall, as defined by BS 8233 (1999), we can calculate R_w using:

$$R_w = 21.65\log_{10} m' - 2.3$$

Where m' = the surface mass of the wall (kg/m^2)

According to the Building Regulations (2000) Approved Document E: *Resistance to the Passage of Sound*, as amended July 1st 2003, in order to demonstrate compliance the laboratory values for new internal walls within dwelling-houses, flats and rooms for residential purposes must have a minimum R_w of 40 dB. A typical 300mm thick SRE wall, with an assumed dry density of 2,100 kg/m3, would have a weighted sound reduction index (R_w) of 58.3 dB and so easily satisfies the requirements of Part E.

Summary

The exciting potential of stabilised rammed earth (SRE) construction is now commercially available as a low carbon building material anywhere in the UK. The collaborative partnership, between Bill Swaney of Earth Structures (Europe) Ltd and Dr Matthew Hall of the University of Nottingham, brings together a wealth of construction knowledge and experience, combined with the latest developments in research and development. SRE can be used for any low- or medium-rise masonry wall structure, and has already successfully been used to demonstrate compliance with relevant sections of the Building Regulations (2000) for England and Wales.

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Table 1: A comparison between the calculated U-values for both 'conventional' masonry and SRE wall designs

Cross-sectional wall design	Thickness (mm)	U-value (W/m² k)
Solid brick wall Internal plaster finish	215 15	2.300*
Solid SRE wall	300	1.370
Outer leaf brickwork Insulation-filled cavity (e.g. EPS; where $k = \leq 0.04$) Lightweight concrete block Plasterboard	102.5 60 100 13	0.450*
Solid SRE wall Air cavity (+ vapour barrier) Internal timber stud walling inc. mineral wool bats Plasterboard	300 38 100 12	0.290
SRE (cavity wall) inner leaf SRE (cavity wall) outer leaf Celotex Tuff-R™ Zero GA3050Z cavity insulation	175 175 50	0.335
SRE (cavity wall) inner leaf SRE (cavity wall) outer leaf Celotex Tuff-R™ Zero GA3075Z cavity insulation	175 175 75	0.245

* Data provided by McMullan R, 1992