



by Pierre Roux and Alex Alexander: Anyway Solutions

“In terms of green building, we need to reframe the question to: how much does it cost your city not to have a green building policy.”

Barbra Batshalom, Executive Director of The Green Roundtable, speaking at the U.S. Green Building Council in Chicago (November 8, 2007)



Sustainable building materials can be defined as materials with overall superior performance in terms of specified criteria. The following criteria are commonly used:

- Locally produced and sourced materials
- Transport costs and environmental impact
- Thermal efficiency
- Occupant needs and health considerations
- Financial viability
- Recyclability of building materials and the demolished building

- Waste and pollution generated in the manufacturing process
- Energy required in the manufacturing process
- Use of renewable resources
- Toxic emissions generated by the product
- Maintenance costs

This chapter introduces the concept of sustainable building materials and technologies, and suggests the following as good examples:

- recycled materials and bricks made from building rubble
- earthbag construction
- adobe bricks
- stabilized earth blocks
- compressed sand bricks
- Hydraform bricks

In our current global setting, building construction and operation results in 50% of all CO₂ emissions worldwide. Five to ten tons of cement are used to build the average middle class house, and for every ton of cement manufactured, a ton of CO₂ is released, (Department of Local Government and Housing. 2007), Thermally efficient, low CO₂ emission, structurally sound and inexpensive materials and technologies exist, some of which have been used for centuries. Materials that have great potential for building include adobe, sandbag construction, cob, thatch, brick, stone, hemp and the use of recycled materials. Other low-cement options, including SABS approved compressed earth blocks (CEBs) are currently being investigated and proposed for sustainable neighbourhood designs.



The innovative Western Cape Sustainable Human Settlement Strategy (WCSHSS), objective 8, includes eco-design principles in an official policy document (for the first time). It requires that all new buildings, infrastructure and open spaces be planned according to ecological design principles, and that existing buildings, especially in the public sector, be retrofitted. Eco-design principles emphasized include orientation, insulation, roof overhangs, sustainable building materials minimizing embodied energy, thermal mass in wall material and energy saving devices like PV and solar water heaters.

Background: Embodied Energy

The key indicator of the environmental impact of building materials is provided by the concept of 'embodied energy'. This is the amount of energy consumed to mine, manufacture and transport a particular product. The embodied energy of glass, steel, concrete blocks, bricks etc., or an entire house are measurable. The Victoria University of Wellington, New Zealand provides the following list of embodied energy figures¹.

EMBODIED ENERGY COEFFICIENTS – MJ/kg	
Material	MJ/kg
Adobe block	0.47
Concrete block/bricks	0.94
Ceramic brick	2.5
Glazed brick	7.2
Cement	7.8
Glass	15.9
Steel (structural)	35.0
GJ = giga joule, a unit of energy, 1GJ = 278 kWh	

Bricks are fired with either coal or oil in clamp kilns at high temperatures over long periods of up to 3 days account for the bulk of a buildings' embodied energy, and yet remain the material of choice for developers and homeowners. Low-cost housing is mostly built using concrete blocks with relatively low-embodied energy and emissions, compared with brick and concrete middle and high income residential and commercial buildings.



It is important to use local and unprocessed building materials that minimize transport and manufacturing energy and air pollution. This also creates local employment. The more localized the project, the more money stays within the community. The next section explores building options that use local and recyclable materials which are thermally efficient and cost effective.

¹ Victoria University of Wellington, New Zealand. 2007

Recycled Building Materials

Recycling is an essential ingredient of green building that reduces non-renewable inputs, especially mining activities, energy use and transportation costs. This includes the use of waste products and used building materials. It is especially important to reuse environmentally unfriendly materials that leach toxic materials into the soil and ground water, or release methane into the atmosphere when dumped in landfills.



CASE STUDY

A low-cost home built from rubble, Mbekweni, Paarl

A 'rubble house' known as the 'Stonehouse' was built in December 2005 by Cape Town architects Vernon Collis and Associates, to demonstrate the construction of a low-cost aesthetically pleasing and energy-efficient eco-home using recycled building materials. It was a People's Housing Process (PHP) project of the Western Cape Housing Department.

The inner walls were built with dumped bricks recovered from a local landfill and the outer north and south elongated walls were built with natural stone found on site. The side walls were recycled concrete plaster bricks from Cape Brick.

Building rubble was used in the foundation trenches to enhance thermal mass. An insulated ceiling was installed using recycled carpet under-felt, and the ceiling consists of industrial wood pallets. The window frames were constructed from local wood off-cuts, with recycled glazing.



The 'Stonehouse' in Mbekweni under construction, with Cape Brick masonry in the foreground

Photo: Pierre Roux

Recycled concrete bricks

It makes environmental sense to recover rubble from demolished buildings and reuse it in recycled concrete bricks. Not only are substantial energy savings achieved in the brick-making process, but building rubble, otherwise dumped in landfills, can be recycled.

Cape Brick in Salt River manufactures recycled reinforced concrete bricks and a range of SABS-approved concrete products from building material recovered at demolition sites in and around the city centre. After separating materials such as wood, paper, plastic and metals, the demolition waste consisting mainly of reinforced concrete aggregate (RCA) is crushed and reused in their masonry products. The brick making process using building rubble is described by Cobus Kotze in “One man’s waste – is another man’s treasure,” (Kotze, C. 2008).



Cape Brick’s crushing facility in Salt River, Cape Town is 5 km from the CBD, where most demolition takes place.

Photo: Pierre Roux

Quarried material is becoming increasingly scarce and expensive, as it has to be mined and transported from quarries to cities and building sites, which taxes the road system and increases greenhouse gas emissions. Cape Brick sources most of its demolition waste within 5 km of its plant, resulting in significant transport energy saving. Their ‘green brick’ has the lowest embodied energy of any concrete product in the Western Cape (Cape Business News on line. 2008).

To further reduce embodied energy, Cape Brick use 50% recycled cement slag in their mix, making the embodied energy value of their ‘green brick’ less than half that of a standard concrete block, and a sixth that of a clay fired brick. Cape Brick recycles some 70 000 tons of reinforced concrete and manufactures about 30 million concrete bricks and blocks per year. Its high compressive strength bricks are approved by the SABS and the Concrete Manufactures Association (Kotze, C. 2008).

Earthbag construction

Earthbag construction has recently become a popular natural building technique. Sandbags have long been used by the military to create bunkers and other structures. They are literally dirt cheap, as they use local sand and low-cost polypropylene or geo-fabric bags. The technique is ideal in sandy areas such as the Cape Flats. No bricks or concrete blocks have to be moved, which means there is no energy embodied in transport.



An eco-beam sandbag house under construction

Photo: Eco Beam Technologies website

Eco Beam Technologies in Epping developed a sandbag home building kit and a process consisting of three steps. A structure is erected using eco-beams/lattice beams made of two wooden struts connected with zig-zagged aluminium strips to provide rigidity and strength. The frame is then filled in with sand bags to form the walls. The bags rest on each other and are not cemented together like concrete blocks. Plumbing and wiring are routed through the timber uprights. The sandbag walls are then covered with chicken mesh wire, dampened and plastered. Sandbag walls cannot crack, are fireproof, good insulators and resist water penetration.



Sandbag structures are strong and can even build mansions

Photo: Eco Beam Technologies website

Construction is much cheaper than with brick or concrete blocks, and sandbag houses are 'eco-friendly'. Sandbag building is adaptable to a wide range of site conditions and available fill materials. It demands fewer skills, sandbag construction is easy to learn and sandbag buildings can be built much faster than conventional brick and mortar buildings. The eco beam system is suited for housing delivery on scale and provides job opportunities in local communities. This building method has great potential in the low-cost housing sector in SA.

Sandbag houses, Mitchell's Plain

Sandbag houses have been erected in Freedom Park, Mitchell's Plain using eco-beam technology, and 10 more units are planned. They were designed by MMA Architects, Cape Town, as a Design Indaba project which won an international innovative design award from the University of Kentucky, College of Design. The eye-catching 52m² double-storey houses have a living area and kitchen on the ground floor, two bedrooms upstairs, and a balcony that can be turned into another room. They cost less than the government full housing subsidy of R43 000.00 for construction of the top structure.



Photos: Pierre Roux

Adobe brick building

Adobe bricks are made of earth, water and dried in the sun. They can be made in various ways, depending on the local climate, site, available materials, tools and labour.

Mc Hendry, a Mexican architect in Kennedy (2002) provides the following guidance:

“The simplest way is with a single mould. Mud is mixed and placed in the moulds by hand on a smooth surface. The mould is removed and the bricks allowed to dry sufficiently to stand on edge, after which they are trimmed and allowed to dry completely before stacking or use.

The whole process takes about one week in most favourable dry climates. The brick making process can be expanded with the use of shovels, wheelbarrows, multiple forms, front-end loaders and concrete or plaster mixers. The use of a hydraulic pressing machine that can create a large number of bricks (compressed earth blocks) – up to 4,000 a day – is another option.

Once they are dry, adobe bricks are stacked to make walls. The bricks are cemented together with a mud mortar made up of water and screened soil taken from the same sources as the soil used to make the bricks. Adobe walls should be built on a foundation of concrete or stone to protect them from moisture damage. Frames for windows and doors are set in place as the wall goes up.”



Lynedoch Ecovillage, near Stellenbosch

A number of adobe brick homes have been erected for staff members of the Sustainability Institute and the Lynedoch community. Adobe bricks were made on site using a single hand hold form and then cured for a few weeks on the premises. Adobe soils contain a mixture of clay, silt, sand and aggregate. Clay provides the glue which holds the bricks together. It is important that they should be dry, hard and crack-free.

Adobe bricks have the capacity to absorb, store and release solar heat, i.e. thermal mass, though their thermal capacity is much lower than that of clay-fired bricks or concrete. The walls were built on a concrete foundation and set on a two-brick pre-wall to protect the adobe bricks from moisture damage (damp). The external walls were also protected by a lime and clay mix plaster. Insulated wooden ceiling were installed, and corrugated roof cladding. Vines and trees can be grown to protect them from driving rains. Vine overhangs also provide shading from the sun on north-facing windows during the summer months.

Insulation can include building cavity walls filled in with materials such as mineral wools, strawboard, wood, glass fibre, and cellulose fibre or recycled carpet under felt as used in the Stonehouse project.

However, insulation is only really necessary in the colder climate regions of Northern Europe and America. (Roaf, S et al. 2003). In South Africa's low cost housing sector the only issue is to provide ceilings with proper insulation in order to reduce the thermal comfort of tin-roofed matchbox RDP houses (The envelope effect).



Adobe brick homes, Lynedoch Ecovillage

Photo: Pierre Roux



Adobe can be used to build a luxury double-story house as can be seen at the Lynedoch Ecovillage

Photo: Pierre Roux

Adobe is a truly natural building material, and because the bricks are often made by hand on site, energy use is minimal.

The Tiholego Development Project near Rustenburg in the North West Province is a sustainable ecovillage described in *Building without Borders* by Joseph Kennedy (2004). The building system used is locally manufactured mud-brick walls built on concrete block and stone foundations. The walls were rubbed down with water to reduce cracks and then coated with linseed oil and turpentine for weather resistance. Insulated timber ceilings were installed, with corrugated iron roofs. Passive solar techniques were used like solar orientation, thermal mass and overhangs.

Stabilized earth blocks

Earthen buildings have been built for thousands of years, and there is a strong tradition of earthen structures on the African Continent. Traditional mud huts were the most common form of building before the advent of modern architecture and planning. Earth buildings still shelter more than a third of the world's population.

Recently there has been a worldwide resurgence of interest in earth building, especially in developing countries where local earth is the most accessible source of building material. However, most soils do not contain the mix of clay, silt and sand required for good brick making.

Modern stabilization technology (such as AnyWay Soil Block - a non-toxic chemical stabilizer) has broadened the range of natural soils suitable for making compressed stabilized earth blocks (CSEBs), and increased their strength and durability.

Compressed stabilized earth blocks have the following advantages:

- An earth block walling system is much cheaper than bricks. The use of local soil and on-site manufacturing saves on transport costs and fuel consumption, especially in remote areas with poor road infrastructure.
- Pressed earth blocks have a low embodied energy value of around 0.42 MJ/kg and a negligible carbon foot print.
- Earth structures have good thermal properties which save on heating and cooling costs. A study by the Institute of Technology, University of Fort Hare found that traditional mud huts offer better thermal comfort than low-cost RDP houses, and ash brick houses had a better thermal performance than RDP houses (Makaka, G & Meyer, E. 2006).
- AnyWay stabilized block making is a non-toxic and environmentally safe process.
- Earth blocks are fire, noise and bug resistant.
- It is a labour-intensive brick-making process that can be easily taught, and the stabilizer can be used in remote areas to create earth building material.



Pilot Project in Simunye Township, Westonaria (Gauteng)

A stabilized earth-block house was constructed in December 2006 by AnyWay Solutions together with the Singobile Community Youth Development Trust in the Simunye township of Westonaria (Gauteng). Unemployed people were trained to manufacture compressed stabilized earth blocks (CSEBs) on site with local soil, using a manually-operated press. A low-cost home was built and plastered with earth mortar. The structure was tested by the SABS and found to comply with the requirements of the National Building Regulations.

For CEB's to bind, 6% stabilizer is required. The stabiliser is sold in 25kg bags @ R58 per bag. Students at the Sustainability Institute manufactured 51 blocks using 418 kg of soil and one 25 kg bag of stabilizer, i.e. at a cost of R1.13 per block - far less than the cement equivalent, not to mention the CO₂ reduction gained by using local soil.

The Simunye Project won the Canadian International Cooperation Prix d' Excellence Africa 2007 Award for demonstrating a more socially transformative and environmentally sensitive approach to community development that furthered entrepreneurial opportunities for women in Africa. It was also one of 15 finalists for the International Institute for Sustainable Development and UNDP 2008 SEED Award (www.seedinit.org).



Training given to community members



Sieving the local soil



Mixing soil and stabilizer and adding water



Pressing the earth blocks



Stacking blocks for humid curing



Training on building with CSEBs and local earth mortar



Plastering with local earth plaster
(natural colour of local soil)



SABS rainwater penetration testing



SABS soft body impact testing

Photos: Alex Alexander, Anyway Solutions

Compressed sand bricks

Where suitable soil is not available, river sand can be mixed with cement to manufacture compressed bricks on site. The picture below shows a four room 50 m² house built from compressed bricks in Limpopo Province by the Tzaneen Municipality, as part of a People's Housing Process project. The brick-making process has already been described.

Local brickyard for rural housing in Limpopo



River sand, stone and cement are mixed and concrete bricks manufactured on site. Two wheelbarrows of sand and stone are mixed with 25 kg of cement and a bucket of water in a Pan Mixer. This is then poured into a hydraulic press that produces compressed sand bricks. The facility is 5 km from a rural village where 115 low-cost houses were constructed. The brickyard employs 32 local people. The sand is sourced and carried by donkey carts and tractor-drawn trailers from a river bed 2 km away. The bricks are solar dried in the hot bushveld sun.



50 m² compressed sand-and-cement brick house.

Photo: Pierre Roux

Hydraform bricks

Hydraform bricks are manufactured by hydraulically compressing a soil-cement mixture in a block-making machine. Hydraform in Gauteng sells a range of machines, from a hand-held to sophisticated hydraulic machines for block yards. Hydraform bricks can be manufactured on site and dry-stacked, reducing the embodied transport and curing energy significantly to around 0.635 MJ/kg. The product contains a small percentage of cement which largely accounts for its embodied energy component. Hydraform also has a block yard producing over 2 million bricks per year that comply with SA national building regulation requirements for strength, durability and stability.



Hydraform brick house, Lynedoch Ecovillage, Stellenbosch

This house at Lynedoch Ecovillage used dry-stacked Hydraform bricks made from a local clay soil and cement mixture, using a single-form hand-held press

Fly Ash Bricks

Fly ash bricks are sometimes used in the construction of toilets and other structures in the low-cost sector. This cement-based brick making process has a typical embodied energy value of 0.632MJ/kg. Fly ash is a waste product from coal power stations, and is an environmental pollutant. Generally these bricks are of poor quality and uniformity, and cannot be plastered as they contain magnesium, which reacts with water, making the bricks 'pop out'.

Ash bricks are very abrasive and brittle and a nail cannot be driven into them. Other unsolved problems with fly ash bricks are that they tend to have a high water absorption rate and porosity, but low fire resistance. There are only a few projects worldwide using fly ash in building bricks, and more research is required on the health impact of these bricks, as they can contain hazardous substances.

Other applications

While rammed earth, straw bale, hemp construction and cobbing are widely recognised natural building methods, especially in the Northern Hemisphere, they are not commonly used in the South African low-cost housing sector. These applications can be labour-intensive and some may require highly skilled and qualified artisan expertise ideally more suited to the dedicated "green" owner-builder.



This little gum, wattle and hemp house was built at Ouden Molen, in Pinelands, Cape Town. It has a gum pole frame with an interlocking wattle basket weave (both invasive aliens), filled in and plastered with locally sourced clay and painted with lime.

Photo: Pierre Roux

Not only new building projects, but also existing neighbourhoods inevitably require new infrastructure, or the upgrading of existing infrastructure. Similar to the emergence of sustainable alternatives to conventional building methods, road building has also engaged with the constraints imposed by scarcity of resources. Landfills are struggling to meet the demands for the disposal of building rubble, and our top soils are also being depleted. The next section will speak to sustainable materials use in road construction at a neighbourhood level.

SOIL STABILISATION FOR ROADS, PARKING AREAS AND INFRASTRUCTURE

Soil stabilisation applications can be used to improve the mechanical and physical properties of sub-standard soils so that they can be incorporated into or form the basis for road, rail and building infrastructure. The improvement of in situ soils to required engineering specifications has a far smaller environmental impact than the alternative of rejecting local soils as unsuitable, and importing other selected materials. The benefit of In-situ soil stabilisation technologies includes the possible decrease in transport and building material costs, the conservation of natural resources and the reduction of harmful emissions. The following are examples of successful applications of soil stabilization in construction projects.

The levels of unemployment and poverty in SA, the existing skills-base of many unemployed people and the need for social infrastructure make a persuasive case for far greater use of labour-intensive construction and effective skills transfer. This is recognized by Government and forms part of stated policy.

Soil stabilization empowers local people to fix local problems with local soil, a few simple tools, and their own labour. Suitably trained small teams/SMMEs can undertake many aspects of infrastructure development that directly improves their lives.



Roads and Parking, Residential Complex, Pretoria North

Internal roads and parking areas were required in a residential development in Wolmer Ext. 1 totaling 35,000m². The in situ material, a problematic clayey, silty, sandy soil with a high swell potential (commonly known as 'black cotton soil'), presented a difficult engineering challenge. The original design proposed cutting and spoiling the upper 350mm of in situ soil, followed by construction of 500mm of pavement layers, with 350mm of selected imported aggregates.

A cheaper, faster, more efficient and environmentally-friendly solution was proposed, using AnyWay Natural Soil Stabilizer (ANSS) in the following manner:

- the top 120mm in situ soil was stripped and spoiled
- 120mm of selected G6 material was imported and placed on in situ soil
- ANSS was applied at a rate of 3% on top of the G6 material
- the in situ soil, G6 material and ANSS were mixed using a recycler and water cart, to create a 250mm stabilized layer compacted to 95% MOD AASHTO, over a 2 week period.

This design had the additional benefit of providing sound roads for use by construction vehicles in all weather conditions during the house-building phase which eliminated rain-induced delays on the project. Once construction is completed, the roads and parking areas will be surfaced with 60mm concrete pavers.

Savings using stabilization

- overall cost saving of 40% on the roads and parking areas
- a time saving of 3 ½ months on the construction of the road/parking area
- further time saving on project by all-weather road use
- pavement thickness is reduced from 50 to 25cm.

Environmental savings

- 8,050 m³ less soil spoiled to landfill site
- 8,050 m³ less selected aggregate imported from quarries
- avoidance of 1,208 X 20-ton truck journeys through existing residential area saving road wear and traffic congestion
- a saving of 14 tons CO₂ emissions (global environmental impact).





Township Roads, Dihlabeng District Municipality

Dihlabeng District Municipality has a programme upgrading township roads in its 5 local municipalities. Previously, the in situ clayey soil had to be cut to a depth of 200mm and spoiled, and a 200mm layer of selected aggregate was then imported from a distant and expensive source. As the Municipality wanted to use its own limited road-building equipment and manpower, and reduce costs, it decided to stabilize the in situ soil instead, with great success.

The Municipal Roads Dept. is now able to construct a 1 km stabilized un-surfaced road in 2 days, which previously took 15 days with the “spoil and import” method and limited equipment. The un-surfaced road instantly provides a safe, less dusty, non-slippery wearing surface in all weather. At a later stage the roads are provided with a side-drain and surfaced with 60mm concrete pavers produced by a local community-operated brickyard.

Savings using stabilization per 1 km road

- completed in 2 days, instead of previous 15 days
- a cost saving of 50%+ on road layers (surfacing identical in both designs)
- Stabilized road immediately usable, surfacing done when convenient.

Environmental savings per 1 km road

- 1,000m³ clayey soil not spoilt to landfill site
- 1,000m³ selected aggregate not imported from quarries
- avoidance of 200 X 20-ton truck journeys, saving diesel, reducing road wear and traffic congestion
- a saving of 2 tons CO₂ emissions (global environmental impact).



Original township road



The road after stabilization and compaction, providing a safe, all-weather driving



Constructing the side-drain next to the stabilized road



The finished road, surfaced with 60mm pavers made by a community-operated brickyard.



Gundo Lashu Project, Limpopo, 2005

This was a joint project by the International Labour Organisation and Road Agency of Limpopo, with Council for Scientific Industrial Research participation, to develop effective and appropriate labour-based road construction methods. Various soil stabilizers and application methods were used to upgrade the existing un-surfaced gravel Makopane Road.

The AnyWay trial section used in situ soil next to the roadway, which provided soil for road layers as well as creating a drain to remove rainwater from the road. Only manual labour, hand tools, steel shutters and a walk-behind compacting roller were used. Following stabilization, the road was left un-surfaced for 1 year and then surfaced with an Otta seal.



Mixing the stabilizer with the in situ soil



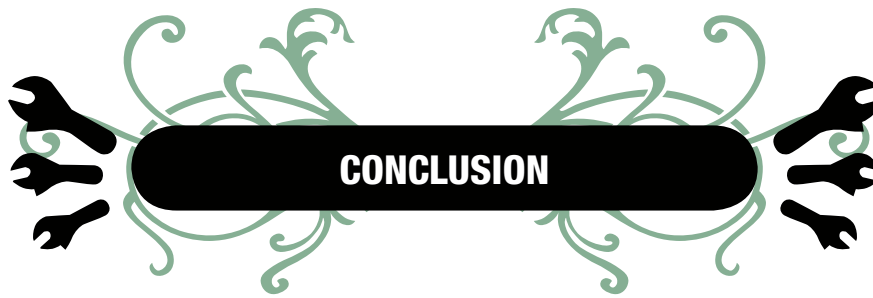
Shaping the stabilized layer



Compacting with walk-behind roller



The Otta seal-surfaced road, still in good condition three years later



CONCLUSION

Sustainable building materials by definition are materials that are locally produced and sourced (which reduces transportation costs and CO₂ emissions), they can include recycled materials, they have a lower environmental impact, they are thermally efficient, they require less energy than more modern, conventional materials, they make use of renewable resources, they are lower in toxic emissions and they are financially viable.

Methods of sustainable building and technologies can include building with rubble, sandbag construction, adobe brick construction, the use of stabilized earth blocks and compressed earth blocks and the use of Hydraform bricks.

Sustainable building materials should be utilised appropriately and contextually in each neighbourhood development. The use of sustainable building materials not only reduces transport costs, carbon emissions, and in most cases materials costs, it also provides employment and skills development opportunities for community members.