Graeme is an architect who has specialised over the past 30 years in earth and "alternative" materials. He has been involved with approx 150 earthen architectural projects, as well as some strawbale buildings in New Zealand., and has a wide reputation nationally and internationally for earthen architecture. He is the Chairman of the Standards New Zealand Technical Committee for Earth Building which wrote and published three Earth Building Standards, for which work he received a Meritorious Service Award from Standards New Zealand. He was inaugural Chairman of the Earth Building Association of New Zealand (EBANZ inc) and he has now been made a Life Member. He is an international adviser to the USA Earth Building ASTM committee for earth building, and has been invited to give papers on various aspects of earth building at several international conferences. He received the NZ Institute of Architects Research Award in 2000 for his work towards the writing of the New Zealand Earth Building Standards. He has written or co-authored two articles for the Building Research Association of NZ on strawbale building precautions in New Zealand. In addition, he has, (apart from many articles in many publications), written two authoritative series of articles on earth building for "Growing Today" and co-authored a book with Marion Bridge “Passion for Earth”. Check him out further at www.ecodesign.co.nz.

HOW TO BUILD AN EARTH OR STRAWBALE HOUSE THAT REALLY WORKS.

Graeme North

Building with highly variable natural materials could be a daunting prospect - but we do it all the time with wood. Timber is used for structural and decorative uses, building standards are written for it, strengths are often assumed and seldom tested, yet we do this with few qualms.

Subsoils and cereal crop stems are also highly variable natural materials, yet there are copious amounts of words written about earth and strawbale walled buildings all around the world. However, not a great deal is written on how actually design and build with these materials so that they comply with the provisions of building codes.

New Zealand is the only country in the world with a comprehensive suite of earth building standards. This means that any building designed and built in accordance with them automatically complies with the NZ Building Code. In New Zealand, earth has the same status as timber, concrete masonry and steel as a "codified" building material.
The Standards are:
NZS 4297:1998. Engineering Design of Earth Buildings (Specific Design)
NZS 4298:1998. Incl Amendment#1 2000 Materials and Workmanship for Earth Buildings
NZS 4299:1998. Incl Amendment#1 1999 Earth Buildings Not Requiring Specific Design.

They cover only those techniques that have been well investigated and used during the current 25 year long renaissance in earth building in NZ, namely mud brick, rammed earth, pressed earth brick, and to a limited degree, poured earth. Historic and rare methods are not covered although there is some information given on some new methods (in-situ adobe) or old methods (cob) currently under revival.. There is also some information on earth floors, and plasters (including reference to traditional cowdung plaster!)

NZS 4297 “Engineering Design of Earth Buildings (Specific Design)” is for engineers and gives the data and formula required to successfully engineer earth walled buildings. It is a specialist document for use by structural engineers.

NZS 4299 “Earth Buildings Not Requiring Specific Design” is not a “cook book” as such, but is essential for earth building designers in much the same way as NZS 3604 is essential for light frame timber buildings. It allows the design of relatively simple earth buildings that fall within its limits without requiring specialist engineering. There are many building details given, and bracing values for various types of earth walls from unreinforced (yes!) through partially to totally reinforced earth walls, bond beam sizes and fixings, foundations, window jamb details etc.

Both of these standards rely on the Materials and Workmanship Standard for making, testing and placing of earthen materials to give satisfactory results.
Because these materials are variable, tests are required on building products to check their suitability for building.
The NZ Earth Building Standards describe tests which enable earthen materials to be assessed for strength, durability, and shrinkage, and also describe how to translate these test results into sturdy durable buildings. Most of these tests are very easy to do, and they give results that can be translated into NZ Building Code Compliance.
As Chair of the Standards Committee I was determined that many of the tests would be taken from common field tests used around the world and which can often be done at home. For example, one strength test is a simple field test that drops an earth brick onto a hard surface from one meter high onto its corner. If a piece no larger that a fist (standardised as 100mm dia) breaks off, then a minimum standard grade strength is assumed for the material and design and quality control can proceed on that basis.
If more sophisticated engineering is wanted that requires higher strength materials then more sophisticated test are proscribed for higher grade materials.

All earth building techniques in New Zealand have needed to be adapted to the climatic and weather conditions here, in particular the relatively high rainfall that is often wind driven horizontally onto buildings, and the standards reflect this.

This was such a concern to the Standards Committee that two sections that prescribe the minimum amount of roof overhang were included. One relates roof overhang to durability. The more exposed or the less durable the material, the greater the eaves that are required. To protect earth walls from driving rain wide eaves or verandahs are usually needed.

Most external wall systems in NZ are built with a cladding that allows water that penetrates the outer skin to be harmlessly directed out of the building again, or to evaporate before damage is caused. Those building systems that have not allowed this to happen are now in trouble with rotting timber walls. Earth walls are single skin construction, and are therefore vulnerable to water if care is not taken. Unfortunately there is no magic coating that reliably prevents earth walls or plaster on strawbale walls from absorbing water. There is no such thing as plaster that will not leak, and coatings (which must breathe), although helpful, always seem to fail in the end.

Therefore earth and straw bale buildings must be carefully designed to keep excessive moisture off the walls. Primary weather protection is crucial. Its simple really.

A table from NZS 4299 "Provision of Eaves to Protect Earth Walls from External Moisture", is reproduced here.

Exterior moisture protection for earth walls.

Building Wind Zone	**Ratio of exposed wall height : eaves width**
Low	4:1
Medium	8:3
High	3:2 (See note below)
Very High	1:1

Note- This ratio may be reduced to 2:1 for earth walls not stabilised with cement or lime that have open exposure and face northerly between north east and north west.

In High wind zones this table recognises the improved waterproofing properties of clay surfaces that are free to swell to form a waterproof layer when they get wet compared to the more porous matrices formed within the material by cement and lime stabilisers, especially when combined with the effect of the sun on the northern aspect of a building in helping keep those walls dried out.

The ratios are minimums only. Lesser eaves combined with alternative weather protection measures such as fences, pergolas, or other permanent landscaping features may be possible in some cases but this is outside the scope of this standard and into the realm of specific design. Then the weather exposure on any particular wall and the particular earthen material being used must be carefully assessed and the Council satisfied that the walls will perform adequately.

Relying on surface coatings such as plasters, washes, solutions or slurries as the primary method of waterproofing earth walls was not considered good practice by the Standards Committee as these have often been found to be unreliable or inadequate in service, whether traditional or modern formulations are used. Designing to keep the water off is the way to go.
Once major weather impact is removed from earth walls, other details in the Standards deal with what water does get to the walls, thus giving a full means of compliance with external moisture requirements of the NZ Building Code.

The Standards generally do not distinguish between stabilised and unstabilised materials. They give performance levels that are to be met and how these are met is not proscribed.
Stabilisers may be used to enhance properties such as strength or durability.
However, a material must be able to be formed into an earth building product brick by itself. This is to ensure that earthen materials have enough clay in them to contribute to their performance. Otherwise we are not dealing with earth building.
A mixture of sand and gravel is not cohesive. Add enough clay for cohesiveness and you have earthen material. If a brick is weak and the addition of a stabiliser to improve its strength or durability is permitted. Cement used as an stabiliser for earth is not a magic bullet. Some earthen materials are made weaker or exhibit destructive behaviour with its addition. Cement also

decreases waterproofing, and humidity absorbing benefits, as well as contributing to greenhouse gases in its manufacture. Generally I would strongly discourage its use in earth building.

Although the essentials of successful structural design of earth buildings are covered in the standards, other aspects that are essential to successful performance of a building such as passive solar design and good aesthetics are not assured.

Also of course, there is no obligation to follow the standards.
However, if you do not, then you will need to be prepared to justify your proposal to the local council in order to obtain a building consent.

With straw bale there is an even greater difficulty with moisture sensitivity, and no standards for guidance.
Common faults encountered in New Zealand include:
Poor weather protection of the walls from inadequate eaves or verandahs, construction over one storey or gable ends are of particular concern, construction on exposed sites, reliance on stucco plaster as a water resistant skin, poor damp proof courses, cracked and/or deficient plaster, lack of sufficient clearance between the exterior ground and the straw bale walls, plaster coats that bridge damp proof courses, lack of sufficient toe up at the bottom of the walls, thermal bridging, and poor detailing of windows, doors, or other openings.

Weather protection is much more critical with strawbale building that earthen walls - strawbales must not get saturated before, during or after construction - ever. If most building materials get wet from time to time, they will dry out with little damage. Strawbales are different. The tightly bound hollow straw fibres are capable of holding a great amount of water and will tend to dry slowly, thereby remaining wet long enough for fungal decay to start. They tend to compost rather than dry out. An earth wall that gets wet occasionally is nothing compared to a strawbale wall that might rot.

Also straw bale walls must be covered with a surface plaster that will allow any water vapour that may get into the wall to migrate out again readily ie. the wall must “breathe”. It is important to distinguish between the movement of water in gaseous form in and out of the walls as opposed to the ingress of water droplets. Before plastering, all strawbale walls need to be tightly compressed together to stiffen up the walls and give a tighter substrate.
Earth or lime plasters work well on straw, and are less prone to brittle cracking than cement based plasters.

All plaster systems leak , if not now then sooner or later. Combine this with the possibility of toxic fungi (such as stachybotrys) and moulds and there are very serious issues indeed.
I have been in strawbale buildings in New Zealand that have stunk of decay before they were even finished. Leaking rotting buildings are a major issue in this country right now. Building failures often cost hundreds of thousands of dollars to remedy, usually causing immense heartache.

The remedy is to keep the rain off as much as possible. Strawbale buildings require extremely good primary weather protection and excellent detailing to take care of any rain that gets past that primary protection. A rigorous approach is required and only then can beautiful and durable buildings be made.

The only published guidelines so far in New Zealand have been published by the Building Research Assoc of NZ (BRANZ). These guidelines were evolved by myself and a few colleagues. They emphasise the need for careful consideration of exposure to wind-driven rain. For exterior plastered strawbale wall construction a ratio of exposed wall height to overhang as 3:4 for low wind areas and 1:1 (a full verandah) for medium wind areas is recommended, and suggest that it is foolhardy to even attempt to build a strawbale building in an exposed wind zone, unless a ventilated drained cavity wall construction system is adopted. This means a weather skin off the strawbale altogether.

This approach was given a positive response at an eco-structures conference in the USA in 2001 that I attended, a gathering that attracted some of the worlds leading earth and strawbale building practitioners and academics. The weather shield approach is now being promoted in Canada and parts of the USA as the only way to cope with wind driven rain onto strawbale.

In summary - plaster systems leak, straw gets wet, straw rots. Prevent it by design to keep the worst of the weather off the walls firstly with large overhangs, and very careful attention to design of details around openings etc. In higher risk areas, add another cladding with a drained ventilated cavity. Worries over.

Earth floors are also a real possibility again in New Zealand and are included in the Standards. The best floors I have seen are made using unstabilised earth such as mud bricks that has an oiled and waxed finish that is somewhat like leather and is very pleasant to walk on - it is the only flooring I have seen that brings a smile to the lips when walk on.

Earth roofs are not included in the Standards so need specialist design, but with adequate attention to water proofing and insulation (an earth roof without additional insulation does not perform very well) can be a wonderful addition to an earth or any other building.

To get the best performance out of earth and strawbale building, and to take full advantage of the materials potential, it is still worthwhile to consult a registered architect and engineer experienced in the field of earth building.