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## **Sustainable Construction Technologies: Earth Buildings in New Zealand**

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### **ABSTRACT**

Earth-building construction in New Zealand is used since the nineteenth century. Despite the initial upsurge of earth-buildings, earth was not the preferred building material, giving way to popular construction methods for residential construction.

The aim of this paper is to examine how earth brick construction technologies differ from conventional residential timber framed construction, focusing on the interrelated challenges of insufficient architectural and engineering design knowledge in the area, scarcity of experienced labour and adequate knowledge of the relevant legislation dealing with earth-buildings. Case studies of earth-buildings, in the Auckland region (New Zealand), are presented to support the points raised in this paper. They are complemented by site visits and interviews with design professionals and manufacturers.

The paper concludes that whilst conventional building technologies have proved adequate for residential construction in New Zealand, the greater variety of sustainable construction systems on offer has not been adequately utilized as a viable alternative.

### **INTRODUCTION**

Earth-building construction in New Zealand is not a new construction system as it dates back to the nineteenth century. The main forms of earth construction at present are adobe, rammed earth and pressed brick. Most of New Zealand housing is timber framed governed by the New Zealand Standard 3604:1999. Clay, straw-bale and all other earth buildings are classified as alternative construction buildings and must follow the same regulations as the timber framed buildings. Standards New Zealand has produced a comprehensive set of standards for earth buildings which means that any building designed and built in accordance with these standards automatically meets the requirements of the New Zealand Building Code. The New Zealand climate of driving rain, strong winds and the possibility of earthquakes make it a hard place to work with earth. All earth building techniques in New Zealand have needed to be adapted to the severe seismic and weather conditions here, in particular the relatively high rainfall that is often wind driven horizontally onto buildings.

Three case studies of earth buildings in the Auckland region, utilizing different earth building techniques, are presented to support the points raised in this paper. They are complemented

by site visits and interviews with design professionals and manufacturers. The aim of this paper is to examine how earth brick construction technologies differ from conventional residential timber framed construction, common in New Zealand. A comparative analysis of earth building and conventional timber framed residential construction identifies some significant challenges which, if not addressed in due course are likely to hinder further use of earth-building as a sustainable alternative construction technology in New Zealand. Some of the identified challenges include insufficient architectural and engineering design knowledge in the area, scarcity of experienced labour and adequate knowledge of the relevant legislation dealing with earth buildings.

## **HISTORICAL BACKGROUND**

Building with earth has a long history of about 10,000 years with archeological and historical research providing an overwhelming body of evidence from the Middle East. The first recorded earth building technique is adobe, unfired mud bricks containing straw [Keefe 2005]. Adobe mud brick houses dating from 8,000 to 6,000 BC have been discovered in Russian Turkestan [Minke 2006]. Later another earth building technique was introduced - rammed earth utilizing timber formwork and producing mass earth walls. Rammed earth foundations dating from 5000 BC have been discovered in Assyria [Minke 2006]. Today, approximately one third of the world's population or some 1.5 billion people live in houses constructed of raw earth.

Earth-building construction in New Zealand dates back to the nineteenth century when the New Zealand Maoris first used earth predominantly for weather-proofing by piling it against timber walls or plastering wet mud on a lattice of sticks to provide shelter against the prevailing wind. Monolithic earth building in New Zealand is of much more recent origin – a mere 150 years [Allen 1997]. Its historical underpinning was the accelerating colonization of the country which was in full swing by 1839. The colonial settlers brought a wealth of knowledge with them causing an upsurge in erecting residential, commercial and public buildings. The early European settlers applied traditional English techniques of earth construction – using predominantly wattle-and-daub, cob and mud brick in the South Island in the areas of Marlborough, Nelson and Otago and rammed earth in the North Island. Pompallier House (1841) at Russell, Bay of Islands, is a well-known example of rammed earth construction, which has stood the test of earthquake, storms, and time [WCC 2008]. The interest in earth construction fluctuated greatly over the years undergoing a steady decline and an almost complete disappearance by the late 1940s. A major factor that contributed immensely to this decline was the rapid expansion of the government-backed timber industry centred on state-owned forests and mills [Allen 1997]. Timber construction techniques provided definite advantages over the slower, more labour-intensive earth building methods. Allen [1997] speculates why earth building is not used more widely in New Zealand and argues that the answer to this question can be found in the “colonial history of firm control over raw materials by a benign but conservative government” citing two political reasons. The first one is the increased and secured employment that the forest and milling industries can provide. The second reason is associated with the greater power that Governments can exercise in a timber dominated market through the introduction of taxes and other means of market controls. On the contrary, the earth building industry offers little in the way of taxes, does not help unemployment as the owner can perform the tasks of the builder and moreover earth is a building material that is freely available.

There were more than 600 historic earth buildings in New Zealand before the revival of interest in earth building that started in the 1980s. As a result a number of modern earth

buildings have been erected in the last few decades. There is no hard evidence of the exact number of these new generation earth buildings although some sources suggest that this number is several hundred in total [WCC 2008] while others provide a more concrete figure of 1 per cent of all new houses in New Zealand [Bridge and North 2000] or on average 20 buildings per year, mostly single storey [2009, personal comm. 17 March]. The reasons for this renaissance can be grouped in three categories [Allen 1997]. Firstly, the increased public awareness and involvement in ecological and environmental matters have forced producers to reassess alternative more environmentally-friendly products and services, such as earth. Secondly, the unlimited supply of earth provides independence from government policies and controls. Thirdly, earth construction has inherent aesthetic, acoustic and thermal properties offering at the same time design freedom and opportunities.

## **NEW ZEALAND EARTH BUILDING STANDARDS AND REGULATIONS**

Most of New Zealand housing is timber framed governed by the New Zealand Standard 3604:1999 Incl Amendment#1&2 2008 Timber Framed Buildings Not Requiring Specific Design. Clay, straw-bale and all other earth buildings are classified as alternative construction buildings and must follow the same regulations as the timber framed buildings. Standards New Zealand has produced a comprehensive set of standards for earth buildings which means that any building designed and built in accordance with these standards automatically meets the requirements of the New Zealand Building Code. The Standards cover only those techniques that have been well investigated and used during the current 30 year long renaissance in earth building in New Zealand, namely mud brick, rammed earth, pressed earth brick, and to a limited degree, poured earth. The Standards are:

### NZS 4297:1998 Engineering Design of Earth Buildings (Specific Design)

This standard covers the durability and structure of unfired earth wall construction in the cases of poured rammed earth, adobe and pressed bricks, all made of clay without chemical stabilization. The standard is intended for use by structural engineers.

### NZS 4298:1998 Incl Amendment#1 2000 Materials and Workmanship for Earth Buildings

This standard provides a means of compliance with the materials and workmanship requirements of earth walled structures. Test methods for earth building materials and criteria for acceptable results are included. Requirements are given for all forms of earth construction but more specifically for adobe, rammed earth and pressed brick.

### NZS 4299:1998. Incl Amendment#1 1999 Earth Buildings Not Requiring Specific Design

This standard provides methods and details for the design and construction of earth walled buildings not requiring specific engineering design. The standard covers buildings with single storey earth walls and a timber framed roof, or single lower storey earth walls with timber second storey walls and a light timber framed roof. The scope is limited to footings, floor slabs, earth walls, bond beams and structural diaphragms. The design of the timber roof structure is covered by the NZS3604 Timber Framed Buildings. The standard provides various details of un-reinforced and reinforced earth walls, bond beam sizes and fixings, foundations, window jamb, head and sill details. The NZS 4299 Earth Buildings Not Requiring Specific Design is the earth wall construction equivalent of the NZS 3604 with similar methodology. It is intended to provide a means of compliance with the New Zealand Building Code.

### NZBC E2/AS2 2008 External Moisture: Acceptable Solution E2/AS2

Earth buildings complying with NZS 4299 as modified by this Acceptable Solution meet the performance criteria of the New Zealand Building Code E2. This document provides useful footing details, soffit to wall junction details in the case of a flat and an angled soffit, timber framed gable to earth wall details and head, jamb and sill details in the case of timber and aluminium joinery.

The Earth Building Association of New Zealand (EBANZ) was formed in early 1988 but it was not until the mid-1990s that it became an incorporated society, operating under a mission statement: "...Promoting the Art and Science of Earth Building" [EBANZ 2009]. The primary reason for forming the Association was to promote earth construction, distribute earth building information, undertake and support research and liaise with the territorial authorities (TAs) in the country in order to promote the acceptance of earth building [Allen 1997]. The EBANZ has listed eleven detailed objectives on their web site among which promoting the use of earth as a building material in New Zealand and the use of the Earth Building Standards [EBANZ 2009].

### **General design requirements**

The New Zealand climate of driving rain, strong winds and the possibility of earthquakes make it a hard place to work with earth. All earth building techniques in New Zealand have needed to be adapted to the severe seismic and weather conditions here, in particular the relatively high rainfall that is often wind driven horizontally onto buildings [2009, personal comm. 17 March]. As a consequence the Earth Building Standards that were developed and introduced had to take into consideration these severe weather and seismic conditions. Two sections of the NZS 4299:1998 prescribe the minimum amount of roof overhang, which is 600 mm, to ensure reasonable protection of earth walls.

Most external wall systems in New Zealand 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. Earth walls are single skin construction, and are therefore vulnerable to water if care is not taken. Unfortunately coatings, which must breathe, although helpful, always seem to fail in the end. 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. Therefore earth (and straw bale) buildings must be carefully designed to keep excessive moisture off the walls [2009, personal comm. 17 March].

Earth roofs are not covered by the Earth Building Standards, and because of the engineering required to hold up heavy roofs of this nature, it takes professional advice to design them. Earth floors are usually made from mud bricks, pressed bricks or poured earth. The best floors are made of unstabilised earth with an oiled and waxed finish. As with all in-situ techniques, shrinkage is a vital issue. One method of dealing with the cracks is to simply fill them as they occur, and another one is laying the material in a way that will control shrinkage. The NZS 4298:1998 has a section on earth floors for guidance.

The typical residential earth building in New Zealand is a single level house with earth walls and a timber framed roof or single lower storey earth walls with timber second storey walls and a light timber framed roof. The average floor area is between 60 and 400 square meters with a 100 to 200 square meter range being the most common [2009, personal comm. 5 March]. The typical floor is an earth one with an oiled and waxed finish or a concrete slab-

on-ground. The exterior and interior earth walls are usually treated with an earth plaster, which contains lime and colour. The roof structure can be either a trussed one or can utilize a system of posts and beams, which is the preferred one. The window and door joinery is either a timber one, which is the preferred option or an aluminium one. E2/AS2 2008 provides head, jamb and sill details for both timber and aluminium joinery in earth walls.

## **THE SPECIFICS OF EARTH BUILDING IN NEW ZEALAND**

### **Earth building methods in common use in New Zealand**

The Building Research Association of New Zealand [BRANZ 2007] specifies the following earth building methods:

- Structural walls of rammed earth or pisé, where the earth is progressively compacted into removable formwork
- Earth bricks (adobe) as a veneer tied back to a structural frame of timber or steel
- Rammed earth or earth brick as an infill to a structural timber post and beam structure
- Structural walls of earth bricks (adobe) – though this is uncommon.

The main forms of earth construction at present in New Zealand are adobe, rammed earth and pressed brick. Adobe and cob are the most common types of older earth buildings still existing today. Cob construction involves placing a puddled earth mix consisting of earth, straw and water, directly into place in walls without the use of formwork or mortar [Isaacs 2006]. Cob, an old technique, is being revived and used again as advances in engineering analysis enable rational engineering solutions to be applied to these structures [WCC 2008].

Adobe construction uses sun-baked, but unburned, earth blocks. Chopped straw or grass is added to clay, or low-clay earth with sand is used. New mixes for mud bricks using wood fibres and paper (cellulose) pulp are making very robust bricks that are less dense, giving bricks much better insulation properties than dense bricks [WCC 2008]. The addition of water ensures achieving the right consistency of the mix, which is then placed into open-bottom moulds. Different shapes of bricks can be cast to create wedges for corners or arches, 45-degree corners, or rebates for jambs. Holes can be cut in newly cast bricks for reinforcing or services [WCC 2008]. Once the mix is dry enough not to slump, it is removed from the mould and set to dry in the sun. The completed wall can be plastered, often with a mud or lime wash [Isaacs 2006]. Both unstabilised adobe and adobe stabilised with cement are used in New Zealand.

In-situ adobe is a method currently being explored in New Zealand. This technique is particularly suitable for freeform walls. The wet mix, containing cement, hydrated lime or asphalt as additives, needs to have the consistency of stiff cake mix that is cast into place in a wall using a small sheet metal mould (typically about 300x300x150 mm high). The mould is removed immediately and the brick is ‘worked’ against previous work to create good bonding and to give the desired surface finish [WCC 2008].

Rammed earth comprises monolithic wall panels constructed with damp well graded sandy soils compacted in 100 to 150 mm thick layers between temporary movable formwork. In New Zealand the soils are usually stabilised with 5 to 10 percent cement. Rammed earth walls are limited to the shapes that can be built with removable shuttering, so the building should be designed to make practical and effective use of the available shuttering. The walls are often left as they are, ‘off the form’, and can reveal a natural-looking strata pattern from the ramming process [WCC 2008].

Pressed earth brick is one of the more modern additions to the earth building scene, dating from the 19th century [WCC 2008]. Pressed bricks use similar soils to rammed earth and are formed in a mechanical press which is either hand or machine operated. Pressed bricks are dense and regular in shape, with approximate dimensions around 300x300x130 mm, laid with sand-cement mortars. . Most presses will enable some variety of shapes to be made so holes for reinforcing and rebates for window jambs can be pre-formed, but bricks of a different size are usually difficult to produce [WCC 2008]. The authors of this paper visited Muriwai Earth Bricks, which is one of the few commercial manufacturers of earth bricks in the Auckland region, on the 5 March 2009 and interviewed the manager of the factory. The earth bricks that they manufacture have dimensions 290x290x130 mm and the use of cement in the mix for additional strength is a common practice. The exterior and interior faces of the completed walls are treated usually with lime wash and paint or sealant can be used on the interior face [2009, personal comm. 5 March].

### **The concept of Permaculture**

The word permaculture (permanent agriculture) was coined by Bill Mollison and David Holmgren in the mid-1970s. These are some of the definitions currently in operation: "Permaculture is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems" [PiNZ 2009]. Two other definitions are: "Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local needs" and "I see permaculture as the use of systems thinking and design principles that provide the organising framework for implementing the above vision" [PiNZ 2009]. The latest and most updated definition of permaculture was provided by Graeme North during our interview with him on the 17 March 2009: "Permaculture design integrates buildings into consciously designed landscapes that mimic the patterns found in nature while yielding an abundance of food, fibre and energy for provision of local needs" [2009, personal comm. 17 March].

The twelve principles of permaculture are the work of David Holmgren, co-founder of the Permaculture concept [PiNZ 2009]:

1. Observe and Interact - Good design depends on a free and harmonious relationship to nature and people, in which careful observation and thoughtful interaction provide the design inspiration, repertoire and patterns.
2. Catch and Store Energy - This principle deals with the capture and long-term storage of energy, that is, savings and investment to build natural and human capital.
3. Obtain a Yield - This principle reminds us that we should design any system to provide for self-reliance at all levels (including ourselves) by using captured and stored energy effectively to maintain the system and capture more energy.
4. Apply Self-Regulation and Accept Feedback - This principle deals with self-regulatory aspects of permaculture design that limit or discourage inappropriate growth or behaviour.
5. Use and Value Renewable Resources and Services - Permaculture design should aim to make best use of renewable natural resources to manage and maintain yields, even if some use of non-renewable resources is needed in establishing the system. Renewable services (or passive functions) are those we gain from plants, animals and living soil and water without them being consumed.

6. Produce no Waste - This principle brings together traditional values of frugality and care for material goods, the mainstream concern about pollution, and the more radical perspective that sees wastes as resources and opportunities.
7. Design from Patterns to Details - The commonality of patterns observable in nature and society allows us to not only make sense of what we see but to use a pattern from one context and scale to design in another.
8. Integrate rather than Segregate - This principle focuses more closely on the different types of relationships that draw elements together in more closely integrated systems, and on improved methods of designing communities of plants, animals and people to gain benefits from these relationships.
9. Use Small and Slow Solutions - Systems should be designed to perform functions at the smallest scale that is practical and energy-efficient for that function. Human scale and capacity should be the yardstick for a humane, democratic and sustainable society.
10. Use and Value Diversity - The great diversity of forms, functions and interactions in nature and humanity are the source for evolved systemic complexity. Diversity in different cultivated systems reflects the unique nature of site, situation and cultural context.
11. Use Edges and Value the Marginal - This principle reminds us to maintain awareness, and make use, of edges and margins at all scales, in all systems.
12. Creatively Use and Respond to Change - This principle has two threads: designing to make use of change in a deliberate and co-operative way, and creatively responding or adapting to large-scale system change which is beyond our control or influence.

## CASE STUDIES

Three case studies utilizing different earth building technologies have been selected in this research to illustrate earth building in a New Zealand context with locations in Helensville, Warkworth and Albany, Auckland. The architect of all three case studies is Graeme North, one of the leading specialists in earth architecture in New Zealand. The fourth case study is a typical timber framed house in Titirangi, Auckland, which is used as a reference in this paper to produce a comparative analysis of construction techniques.

### In-situ adobe house in Helensville



**Fig 1. Interior and exterior photos of the house in Helensville**

Helensville is a relaxed small town nestled beside the Kaipara River on the south edge of the Kaipara Harbour and a scenic 40 minute drive north from downtown Auckland. The owner-built and architecturally designed single-storey house of 180 square meter area required nine

years of work and was completed in 2005. The authors of this paper visited the house and interviewed the owners on the 14 May 2009. The design embodies the principles of warmth and light characteristic of Graeme North's earth architecture. The north facing windows ensure all day sun for passive solar heating and the few south facing windows provide mostly light without relying on any thermal contribution. The round feature window in the main foyer, designed and manufactured by the owner, and decorated with recycled coloured bottles, offers magnificent views of the South Kaipara Coast. The wide verandahs and pergolas on the north and south façades protect the unplastered adobe brick walls from high rainfall that is often wind driven horizontally onto buildings and can cause erosion.

The owners of the house had a great input in the interior design and decoration manufacturing almost all the furniture, windows and doors, kitchen cupboards and even the bathroom washing basins [2009, personal comm. 14 May]. The main house structure was built of recycled timber and the adobe walls were formed by hand from local soil. The main roof is made from reinforced concrete and has an octagonal shape in plan view. The material of the floors varies with some spaces having recycled timber floors and others earth slate. The timber that was used throughout the interior was untreated, just oiled to eliminate the potential of releasing toxic fumes. In general, there are no painted surfaces or chemically treated materials. The glass northern façade enables passive solar heating, which is supplemented by a wood fire used for cooking, hot water and additional heating. The house is virtually maintenance free, apart from the incoming services. The property features many permaculture aspects, such as a waterless composting toilet and a windmill that pumps water to the garden. The rainwater tank installed on the site uses rain water from the grassed roof above the bedrooms near the main entry. The thermal mass of the 400 mm thick adobe walls provides the necessary thermal insulation eliminating the need to use a special insulating material. The initial cost of this in-situ adobe house was slightly higher than its timber framed equivalent but the running costs proved minimal.

### **Mud brick, cob and straw bale house – all built inside a conservatory in Warkworth**



**Fig 2. Interior and exterior photos of the house in Warkworth**

Warkworth is just an hour's drive north of Auckland, and a world away in terms of character and pace. Vineyards, local markets, iconic beaches and islands, marine reserves and wildlife sanctuaries are all within a short distance of the village centre. Warkworth's rich heritage is reflected in its buildings and sites of historic interest. The single-storey adobe house built entirely inside a conservatory is located on the village fringe in a picturesque remote area. The authors of this paper visited the house and interviewed the owner, who is also the architect of the design, on the 17 March 2009. The single-storey, owner-built, 110 square meter house was completed in 2003. The unusual design of the house combines a few green building methods, such as in-situ adobe in the north wall, mud brick, lime mortar, rammed earth and bottles for the south wall with the bathroom, cob and straw bales in the internal and



south walls. The walls are built on a concrete strip footing. Ordinarily, many practitioners work with just one system of green building, such as rammed earth, mud brick or hay bales. In this particular case, the idea was to advocate and combine all these methods for the reason which will be suitable for the construction. The design is based on the principles of warmth and light characteristics. The high colorful north facing wooden framed windows and the glass top of the conservatory, which is overgrown with vines, ensure all day sun for passive solar heating in the living room. The few south facing windows provide mostly light without relying on any thermal contribution. The top of the conservatory is erected on ten poles which carries a steel construction. The hessian louvered ceiling is made of long single brownish fabric parts, which when closed keep the living area warm and cosy, and can be opened to let in the air and light from the conservatory above. Other parts of the roof are constructed with old sanded tree branches. The main idea was to use non-toxic, recycled timber and a range of other alternative approaches and materials. The floor is made of rammed earth. The house features a number of permaculture aspects, such as the pond right next to the main entry, the rainwater tank and the windmill with a pump in the garden [2009, personal comm. 17 March].

### **Pressed earth bricks in timber framed construction in Paremoro, Auckland**



**Fig 3. Interior and exterior photos of the house in Paremoro**

Located in the northern residential suburbs of Auckland and nestled in the nearby bush clad hills of the Paremoro Scenic Reserve, this two-storey adobe house is a NZ\$1.6 million dollar project. The site area is approximately two hectares and it is a 25-minute drive from downtown Auckland. A new modern shopping centre, erected in nearby Albany, is only 10 minutes away from the site. The building is currently under construction and the authors of this paper started visiting the site regularly from the 21 May 2009. The main structure is timber with steel beams that are specific engineered design. The thermal mass of the 400 mm thick adobe walls provides the necessary thermal insulation. The clay and clay bricks, used for the construction, were prefabricated and trucked to the site from a distance of 80 kilometers. The exterior and interior walls have concrete strip footings. The internal walls are plastered with a clay and sand mix and the external walls are plastered with a white lime clay mix. The colour scheme of the house aims to achieve contrast between the white lime plaster on the exterior of the house and the black window frames and wide verandahs around the building. The external cladding on the upper level is made of black wooden weatherboards mounted on a cavity system with a building wrap fixed to clay bricks. The lower level floor is made of rammed earth and the upper level floor of native timber. The north facing high windows ensure all day sun for passive solar heating and the few south-facing windows provide necessary light. The living, dining, master bedroom and office are also facing north and guarantee all day natural light. All windows and doors are aluminum with a thermal break and are double-glazed. The connections between the walls and structural frames are filled with self-expanding foam. The heating is centralized with a big

oven that will heat both the lower and upper floors. The hot water cylinder is powered by solar energy. The rainwater is collected and the site has a septic system installed [2009, personal comm. 21 May].

#### **Typical timber framed house in Titirangi, Auckland**



**Fig 4. Interior and exterior photos of the house in Titirangi**

Titirangi is a small relaxed suburb of West Auckland within a driving distance of 20 minutes to downtown Auckland. Titirangi is known for its ECO or alternative movement and life style in the native bush. The site is located on a small peninsula and at the end of a very long and steep driveway and overlooks the Manukau Harbor. The large 7180 square meter section of land is surrounded by native bush. The architect Graeme Johansen designed a 497-square meter, two-storey modern timber framed house, which was completed in 9 months. The total cost of the project is NZ\$1.2 million. The authors of this paper visited the house and interviewed the owners on the 8 July 2009. The house uses a standard 100 mm concrete slab-on-ground. The standard framing of 90 x 45 mm is insulated with Pink Batts (R value 2.2) in the wall and ceiling space. The exterior cladding of the upper level is coloured weatherboards and parts of the lower level of the building are clad with brick veneer. The windows and doors are built with single glazing and no thermal break in the aluminum framing is used. The connections between the walls and frames are filled with self-expanding foam. The roof trusses and the rafter system were covered with asphalt shingles. The south-east façade with the high windows and decks offers magnificent views of the Manukau Harbor. In comparison the sun facing façade on the north-west side has fewer windows. The site has a septic system and water tanks, designed to meet the requirements of Waitakere ECO-Water. Runoff from the site is to mimic natural runoff patterns and not to discharge directly into the open drain watercourse [2009, personal comm. 8 July].

#### **CONCLUSION**

Earth building in New Zealand has been undergoing a revival in interest over the past 30 years. Building with earth materials can be considered as a form of sustainable management of natural resources. Earth buildings avoid deforestation and pollution, and can achieve low energy costs throughout their lifetime – in the initial manufacture and construction, in their use as homes, and eventually in their recycling back to the earth [WCC 2008]. Some of the advantages of earth buildings are: low cost of materials, low energy and transportation costs, provision of a thermal mass for natural heating by the sun, a non-combustible and virtually soundproof material that is a renewable non-toxic resource, which can be readily recycled. Despite these advantages earth building is not common in New Zealand as timber framed construction is the preferred choice in the residential market.

The authors of this paper selected three earth buildings in the Auckland region that use different earth building techniques in an attempt to present a snapshot of New Zealand's earth building construction sector, which is extremely small. Identifying specialists in the field for interviewing was extremely hard and was a challenge. A typical timber framed house was used as a reference to generate a comparative analysis. The paper concludes that whilst conventional building technologies have proved adequate for residential construction in New Zealand, the greater variety of sustainable construction systems on offer has not been adequately utilized as a viable alternative.

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