ISSUE530

BULLETIN

STRAW BALE CONSTRUCTION

December 2010

- When used appropriately in construction, straw bales provide high levels of insulation and can help to keep a home quiet as well as warm in winter and cool in summer.
- Straw bales have low embodied energy and are a renewable/sustainable building product.
- This Bulletin, which replaces Bulletin 398 of the same name, provides a brief introduction to straw bale construction for New Zealand conditions.

1.0 INTRODUCTION

1.0.1 This Bulletin provides a broad overview of what straw bale construction involves, some advantages and disadvantages of straw bales as a building material and where to find more detailed information and help. It is not a specific design guide for straw bale construction. BRANZ believes that a conservative approach needs to be taken when designing a straw bale building.

1.0.2 Well designed and constructed straw bale buildings with appropriate exterior finishes can be energy efficient, non-toxic and low maintenance. Utilising bales can create an affordable and durable wall system. With an R-value of at least 6.0 for plastered straw bale walls, buildings can be designed and built to provide high levels of wall insulation requiring low levels of energy for heating and cooling over the life of the structure.

1.0.3 Straw has been used in construction for about as long as humans have been creating shelter. Examples of straw being used in the walls of multi-storey historic buildings can still be seen in Europe today. Straw bale construction was started in North America around 1900 after mechanical balers were built, and several of those original bale structures still stand today.

1.0.4 While straw bale structures can be found in almost every climatic region and in at least 43 countries around the world, it is essential to design a straw bale structure that is appropriate for the site and climate. Straw bale design and building should be carried out by an experienced practitioner as flashing and design details are critical for the integrity of the building to meet New Zealand Building Code standards. Expert help should be sought to:

- assess the site to ensure an appropriate straw bale design can be developed
- prepare specifically designed details and documentation for building consent application covering weathertightness, durability, plaster systems and structural design
- provide continuing on-site design assistance throughout construction.

1.0.5 There are straw bale building codes in several countries, but here, it is necessary to have straw bales submitted for consent as an alternative method of construction to show compliance with the New Zealand Building Code – once consented, it becomes an Alternative Solution.

2.0 STRAW BALES

2.0.1 Straw is the dry, dead, hollow stalks of a cereal plant and is an agricultural byproduct. (Hay is dry grass.) Straw is a waste product (often burned in stubble fires during harvest season) that has the potential to provide a very low-embodied energy building material.

2.0.2 Straw bales for construction should have the longest straw possible, and the straw must be dry and compressed into the tightest bale possible at the time of baling. Dense, dry bales will reduce the risk of settlement once installed.

2.0.3 The most vulnerable time for bales is before construction while being transported and stored. It is recommended that bales be shed stored and that storage time is minimised to ensure bales are clean and dry for building.

2.0.4 The moisture content of bales within the wall must remain well under 20% during the life of the building to ensure that the straw and supporting timber structures remain in sound condition. Straw should have a moisture content below 10% when baled. (Most meters designed to measure straw moisture content are not considered accurate below 6–8% moisture content.) This should be checked prior to placement of the bales, using a hay/straw moisture meter with a probe long enough to reach the middle of the bale.

3.0 CONSTRUCTION TECHNIQUES

3.0.1 Straw bales may be used:

- in loadbearing construction
- as infill, with an alternative structural system
- in a hybrid system (a combination of loadbearing and infill).

3.0.2 All three construction techniques involve the stacking of straw bales in a stretcher/running bond pattern like bricks. The bales can be laid flat or on their edges to form a wall, which is then plastered on both faces. The wall system acts like a sandwich panel with rigid skins (plaster) on both sides supported by a spacing web (the straw bales) between.

3.0.3 Infill is the most commonly used system, as the roof is constructed before the straw bale installation to provide weather protection during the bale stacking.

3.0.4 A loadbearing wall system relies on the straw bales and plaster for bracing, which may limit the structural and architectural scope of a project but can provide an extremely simple and economical wall system. Testing shows that loadbearing construction is capable of carrying direct gravitational loads, face-loading resistance and in-plane lateral loads suitable for high wind and earthquake zones.

3.0.5 Both infill and hybrid systems can allow for the use of more conventional sheet and angle bracing systems, which can make structural engineering more straightforward in some situations.

4.0 CONSTRUCTION PRINCIPLES

4.0.1 A dry building is the key to continued durability of a straw bale building, so having foundations, ground clearances, wall construction, plaster cladding and weatherproofing system and eaves that are appropriate for the site is imperative. The aim with the construction is to have a wall system that, on completion, is able to breathe – be vapour permeable while resisting external moisture and water from internal wet areas. In an extremely wet and/or windy location, additional protection such as a rainscreen to minimise the rain wetting of external walls should be considered.

4.1 FOUNDATION

4.1.1 Bales should be well above exterior ground/flood levels as well as being kept above internal floor levels (45 mm minimum) generally using timber sill plates to minimise the risk of excessive wetting.

4.1.2 Bales should be separated from concrete by a damp-proof membrane plus timber sill or bottom plates to avoid moisture being transmitted from the concrete into the straw.

4.1.3 Infill insulation that is non-wicking and won't compress should be provided between the (generally timber) bottom or sill plates.

4.2 WALL STRUCTURE

4.2.1 Loadbearing or hybrid walls must be constructed during fine weather or under a temporary shelter. For this reason, an infill system is often preferred in higher rainfall areas. Once constructed, all three structural systems can have equal durability. The structural design of the wall is likely to need the input of a structural engineer, and a producer statement should be submitted with the consent application.

4.2.2 Infill bale wall systems will settle if care is not taken during the wall stacking so it is important to stack the bales tightly against each other horizontally and to ensure they are well tamped down vertically as each bale is laid. The top course of bales should be forced under the perimeter beam to create a tight/stable wall, which should not settle further. The filling of any voids with straw and/or a straw-clay mix is a very important part of plaster preparation in order to ensure a good solid wall. Once the well stacked bales are detailed for plaster and the plaster system is completed, there should be no further settlement.

4.2.3 Loadbearing and hybrid walls are generally precompressed prior to the roof construction so that further settlement is unlikely or traditionally allowed to settle completely with the roof load in place before plastering. Precompression is achieved by some form of strapping or external compression system, which will act to vertically force the perimeter beam down towards the foundation.

4.2.4 Straw bales acting as infill panels are required to resist face loading from wind and earthquakes. The generous width of straw bales means the height to width ratio of straw bale walls is generally low, providing some natural stability. Tightly installing the bales within the structural frame and between two skins of a well detailed plaster system will usually provide sufficient strength. Straw bales used in loadbearing and hybrid wall systems are stabilised by the precompression process, which also ensures the roof is well anchored to the foundation.

4.2.5 Multi-storey structures can be built using an infill wall system, but close attention must be given to weathertightness techniques and details, as the walls will be exposed to more wind-driven rain, which, like all buildings, significantly increases the risk of failure.

4.3 WINDOWS AND DOORS

4.3.1 Keeping junctions around windows and doors waterproof is critical. History shows the most vulnerable aspects of straw bale structures (as with most forms of construction) are around built-in joinery and roof detailing. Window flashings should include head, jamb and sill flashings that are specifically designed for the project to allow any water that might enter and any water from a window failure to be drained.

4.4 ROOF DESIGN

4.4.1 Roof leaks can allow bulk moisture to enter and possibly damage a structure, so a well constructed and well detailed roofing system, with appropriate overhangs for the site, is essential. A simple roof design is always safest.

4.4.2 Eave widths of not less than 600 mm are considered to be the minimum for sheltered sites in a low wind zone. Widths should be increased for sites that are classified as medium wind and above as the amount of rain-wetted wall increases with wind speed. The width of roof overhangs will depend on a wall's potential for both wetting and drying. Points to be considered include:

- wind strengths and the wind direction that brings the most rain
- exposed wall height – this should be kept to the minimum possible
- the plaster system specified and the weatherproof coating (if any) applied to it
- local rainfall intensities
- orientation of the exposed/protected faces
- site contours
- average relative humidity
- average temperatures
- solar exposure.

4.5 WALL FINISHES

4.5.1 Straw bales require finishing with a vapour permeable (breathable) plaster to both internal and external wall surfaces. Plaster mix options are clay, lime or cement/lime (with a high lime content). Lime or cement/lime plaster should be reinforced with a metal mesh or lath and applied in three coats to the straw. It is critical that the plaster mix is not too wet when applied so that there is no risk of excessive moisture getting into the straw during plastering and curing and also once the building is complete.

4.5.2 External plaster finishes must act as both an air barrier and a barrier to exterior moisture entry into the straw bales. Applied coatings, where used, must resist liquid water but be breathable or vapour permeable to allow any moisture present within the straw to escape.

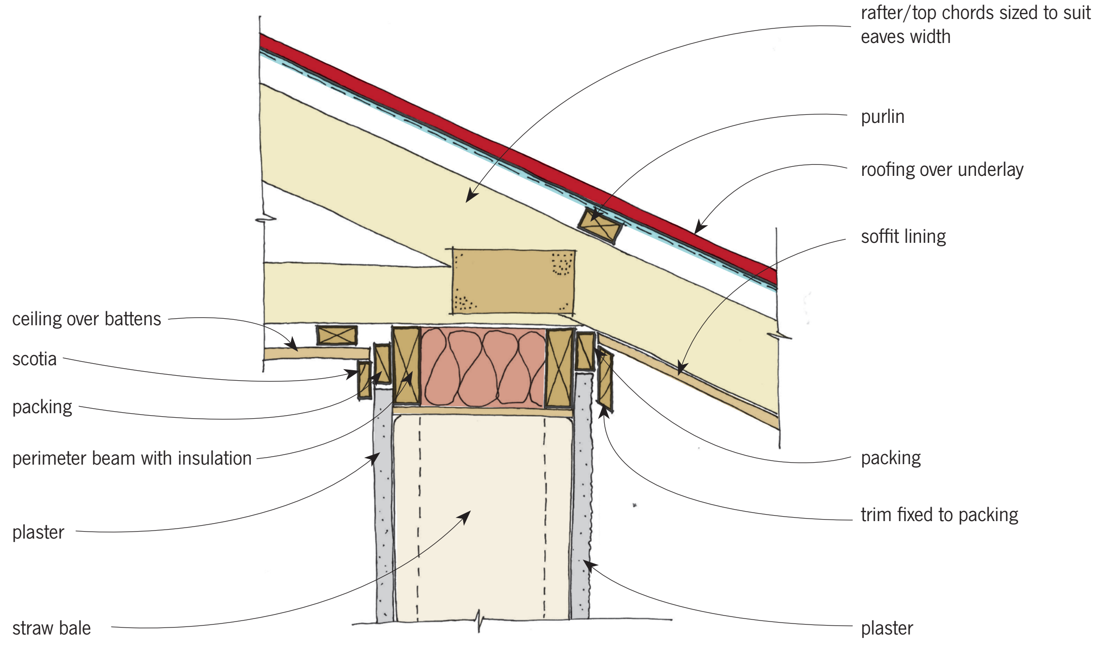

Figure 1. Example of a top of wall detail.

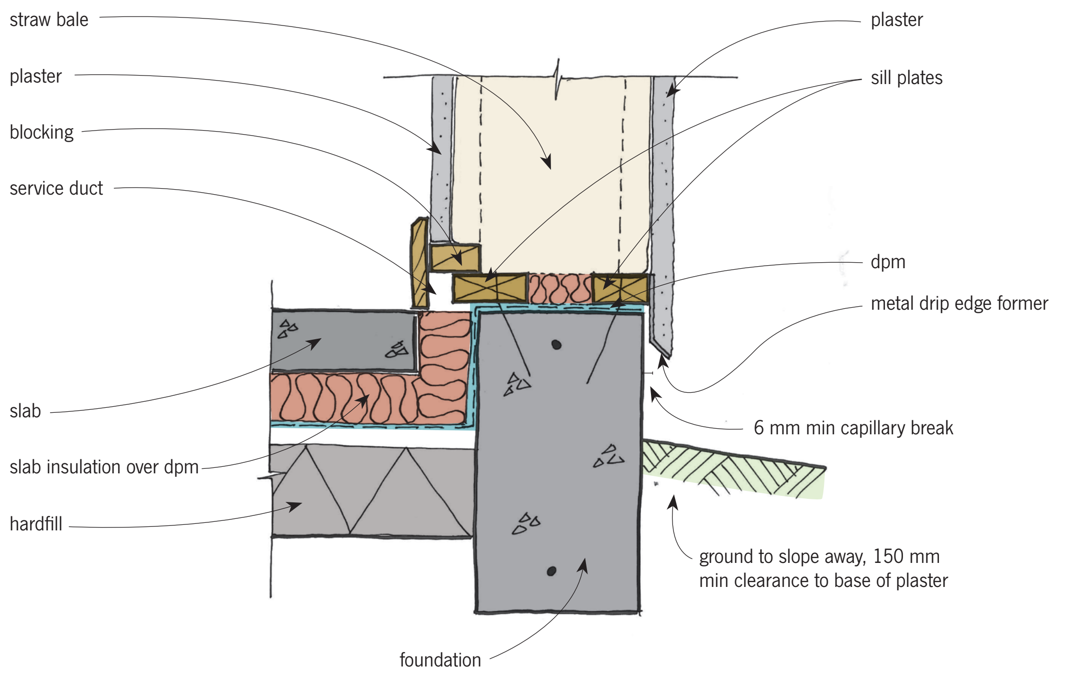

Figure 2. Example of a bottom of wall detail.

4.5.3 Interior plasters within the wet areas of the building (bathrooms, laundries and within the floor preparation area of a kitchen i.e. adjacent to sink benches) must resist liquid water such as splashing while being vapour permeable. Using a plaster finish within a shower or around a shower over a bath (even if coated with an impermeable coating) is not recommended.

4.5.4 The risk of water entry through the plaster finishes will be reduced where:
- the building has wide eaves or verandas to protect the wall from wetting
- design features such as pergolas, posts, beams or framing or services such as exterior wall-mounted lights penetrating the plaster finish are avoided as they create a potential leakage path
- a vapour permeable weatherproof coating system is applied to the external plaster surfaces at the recommended dry film build and ensuring it is free of pinholes that can occur with a textured finish.

5.0 COMMON CONCERNS

5.0.1 With plastered straw bale construction, the combustible material is encased in a non-combustible plaster. If subject to fire, straw bales tend to smoulder over a long period of time.

5.0.2 Fires could easily be started during construction when loose straw is lying about the site and the bales are not yet plastered. For this reason, sites should be kept as clean as possible of loose straw, and caution must be used when naked flames, spark-generating tools or petrol-driven motors are utilised. Smoking on site during construction should be prohibited.

5.0.3 Straw bales contain little food value for rodents. Also, because bales are so compact, there is little room for pests or rodents to live, and it is virtually impossible for them to enter once the plaster system has been applied.

5.0.4 Once the continuous air barrier (plaster) is installed, allergens and odours from the straw itself should be almost non-existent in a straw bale home.

6.0 FURTHER INFORMATION

6.0.1 There are many sources for advice and education regarding the design and construction of straw bale buildings, for example:
- Australasian Straw Bale Building Association (www.ausbale.org)
- The Last Straw (www.thelaststraw.org)
- Development Center for Appropriate Technology (www.dcat.net/resources/index.php)
- New Zealand courses for straw bale design and construction, for example, Aoraki Polytechnic, Timaru, and Central Otago Polytechnic, Cromwell
- King, Bruce. *Design of Straw Bale Buildings: The State of the Art*. Green Building Press, 2007
- Lacinski, Paul and Bergeron, Michel. *Serious Straw Bale: A Home Construction Guide for All Climates*. Chelsea Green Publishing Company, 2000
- Magwood, Chris and Mack, Peter. *More Straw Bale Building: How to Plan, Design and Build with Straw*. New Society Publishers, 2005.

Note: American and Canadian building standards differ from what is acceptable within New Zealand.

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