# INFORMATION GUIDE TO STRAW BALE BUILDING

FOR SELF-BUILDERS AND THE CONSTRUCTION INDUSTRY



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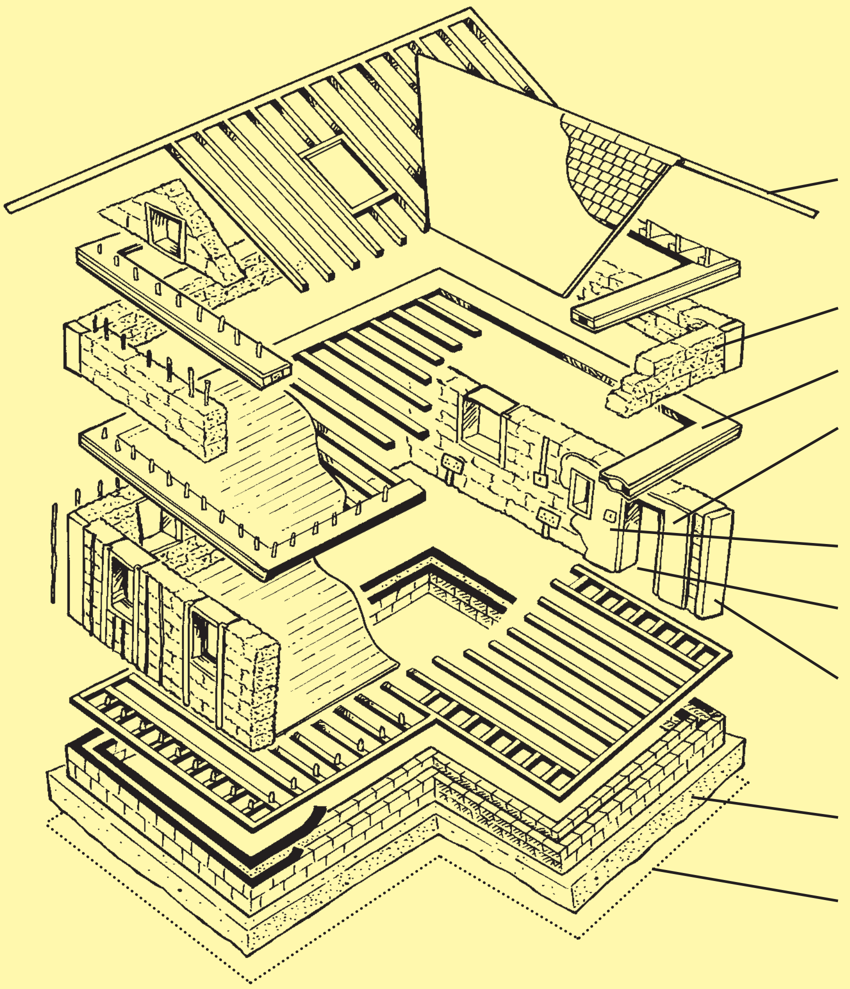


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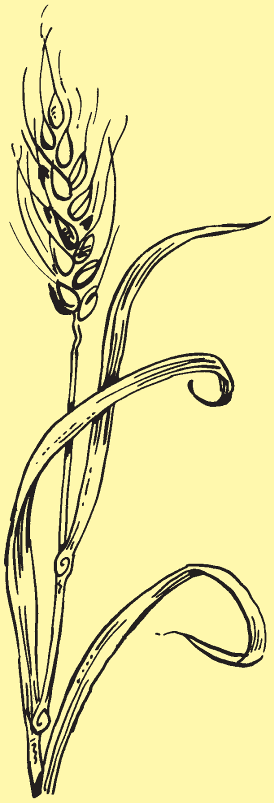
# INTRODUCTION

**Straw bale building** is a smart way to build. It's more than just a wall building technique that has yet to come into its own. It's a radically different approach to the process of building itself. Like all innovative ideas, it has been pioneered by the passionate, and used experimentally by those with the vision to see its potential. Its background is grassroots self-build; it is firmly based in that sustainable, 'green building' culture that has brought to the construction industry many new and useful ideas about energy efficiency and responsibility towards the environment.

It is now at a pivotal point in its development, ready to be taken on by construction firms who see its value in terms of cost-effectiveness, sustainability, ease of installation and energy efficiency. As you will see from this document, the building method itself is based on a block system, making the designs very easy to adapt from one project to another, and giving great flexibility in its use.

The accessible nature of straw means that people unfamiliar with the building process can now participate in it. This opens the door for interest groups to work together on joint projects. Housing Associations and Local Authorities etc., are ideal managers for self-build straw projects that won't take years to complete, and which will engender an excitement and motivation that gets the job done. The atmosphere on a straw-bale building site is qualitatively different to that found on the vast majority of other sites. It is woman-friendly, joyful, optimistic and highly motivated. Knowledge and skills are freely shared, and co-operation and teamwork predominate, all of which has a positive effect on health and safety on site.

Working with straw is unlike working with any other material. It is simple, flexible, imprecise and organic. It will challenge your preconceptions about the nature of building and the correct way of doing things; not everyone will be able to meet this challenge. Its simplicity can be disarming, or alarming. If you need complexity for security, then this may not be for you. Don't be put off by nursery tales about the big bad wolf – we should be wise enough to realise that the wolf probably worked for the cement manufacturers! And don't pay too much attention to colloquial tales about 'hippie' houses – read on, and make your own mind up.



Straw as a building material excels in the areas of cost-effectiveness and energy efficiency. If used to replace the more traditional wall-building system of brick and block, it can present savings of around £10,000 on a normal 3 bedroomed house. Of interest to the home owner is the huge reduction in heating costs once the house is occupied, due to the super insulation of the walls. Here the potential savings are up to 75% compared to a conventional modern house. Building regulations are changing next year (2002), bringing the allowable U-value of domestic external walls down to either 0.35 or 0.25 (the European Union would like to see 0.25) which is challenging the whole industry to meet these requirements. A typical bale of straw has a U-value of 0.13 – significantly better thermal performance than will be required.

The beauty of straw is that it combines very high insulation properties with great load-bearing potential: **a material that is building block and insulation all in one.**

This Guide is aimed at self-builders as well as the construction industry. It is meant to give clear and straightforward information about how to build houses with bales of straw. Since this is a simple and accessible wall building technique available to almost anyone, it is ideal for self-builders as well as mainstream builders at the forefront of sustainable house building. The language and descriptions are necessarily basic to ensure full understanding by everyone, particularly of first principles, and how and why we build with straw.

Throughout this information guide, we will be attempting to encourage you towards the best possible ways of doing things as far as current knowledge allows. It's always good to bear in mind though, that you are involved in a building process that is still developing - one which is simple, straightforward and based on common sense.

One of the biggest attributes of strawbale building is its capacity for creative fun, and its ability to allow you to design and build the sort of shape and space you'd really like. It lends itself very well to curved and circular shapes, and can provide deep window seats, alcoves and niches due to the thickness of the bales. It's also a very forgiving material, can be knocked back into shape fairly easily during wall-raising, doesn't require absolute precision, and can make rounded as well as angular corners. Partly due to its great insulation value and partly because of its organic nature, the inside of a strawbale house feels very different to a brick or stone one, having a cosy, warm quality to it and a pleasing look to the eye.

Different styles and opinions have grown up around the world as bale building has spread. What was suitable in one climate has not proved to be best practice in others, and availability and cost of materials varies from country to country. However, there has been wonderfully imaginative adaptation to conditions. The main concerns in Ireland and the UK have been to do with:

- splash back - rain bouncing up from the ground onto the base of the walls
- rain causing high humidity in the surrounding air for long periods of time,
- wind driven rain.

Most of the differences in technique in this climate are to do with foundation design and the type of render used as a weatherproof coating. We have been able to draw on the rich knowledge of the past, using ideas which have been tried and tested over centuries. In many respects, the requirements of strawbale buildings are essentially the same as traditional cob (earth) buildings. They have high plinth walls, self-draining foundations, and large overhangs to the roof, "a good hat and a good pair of boots" as cob builders used to say. They are also constructed of breathable materials and must not be waterproofed (although they must be weatherproofed). There are currently over 100,000 cob houses of 200-500 years old still inhabited in the UK.

**Building with bales can be inspiring and transformative, and working together with a group of people to build your own home can be one of the most empowering experiences of your life.**

Straw is a flexible material and requires us to work with it somewhat differently than if it was rigid. Accurate measurement and precision is impossible and unnecessary with straw, but working without these aids can be worrying to the novice, and threatening if you're already used to 20th century building techniques. It is very important to make this clear at the outset. You have to develop a feel for the straw. You have to give it time, absorb its flexibility. Yet it *is* possible to be macho about it - to hurl bales around single-handedly and force them tightly into spaces, but this *always* has adverse consequences. Rushing the process, and working alone or competitively can mean that an adjoining section of wall is distorted and pushed out of shape – a section that someone else has spent time and care in getting right. It's as much a personal learning process as it is learning a new building technique. More than any other material (except perhaps cob and clay) it is susceptible to your own spirit and that of the team. Strawbale building is not something to do alone. It requires co-operation, skill-sharing and common sense. Many of the inspirational and artistic features occur in this atmosphere. It is empowering, expanding the world of opportunities for you and making possible what you thought to be impossible!

The atmosphere and environment in which we live is becoming increasingly a matter of concern to home owners and designers alike. There is a growing body of knowledge on the harmful effects of living long-term with modern materials that give off minute but significant amounts of toxins, the so-called 'sick-building syndrome'. Living in a straw house protects you from all that. It is a natural, breathable material that has no harmful effects. Combined with a sensible choice of natural plasters and paints, it can positively enhance your quality of life.

When building a house using bales of straw, it's important to remember that it is the wall building material which is different. This has implications for the type of foundation required and can affect certain design decisions to do with windows, doors, roof bearing and render/plaster finishes. Otherwise, all aspects of the rest of the building remain the same. The installation of plumbing, electrics, interior carpentry, joinery and partition walls may be no different to the methods and materials you are used to. (Of course they could also be re-thought in terms of using sustainable, locally sourced and recycled materials, but this is beyond the scope of this document). This Guide therefore covers details of different types of foundation, how to build walls with straw and stabilise them, how to protect walls from the weather and make them durable and how strawbale buildings can easily meet building regulations requirements. There is also a section on frequently asked questions, and a reference section for further reading, research and contacts.

SUSTAINABLE
BEAUTIFUL
LOW COST & ACCESSIBLE HOUSING

## HISTORY

Strawbale buildings were first constructed in the USA in the late 1800s, when baling machines were invented. The white settlers on the plains of Nebraska were growing grain crops in an area without stone or timber with which to build, and whilst waiting for timber to arrive by wagon train the following spring, they built temporary houses out of what was, to them, a waste material - the baled up straw-stalks of the grain crop. They built directly with the bales as if they were giant building blocks, where the bales themselves formed the loadbearing structure. This is known as the Nebraskan or loadbearing style. The settlers discovered that these bale houses kept them warm throughout the very cold winter yet cool during the hot summer, with the additional sound-proofing benefits of protection from the howling winds. Their positive experience of building and living in strawbale homes led to the building of permanent houses, some of which are still occupied dwellings today! This early building method flourished until about 1940, when a combination of war and the rise in the popularity and use of cement led to its virtual extinction. Then, in the late 1970s, Judy Knox and Matts Myrhman among other pioneers of the strawbale revival, rediscovered some of those early houses and set about refining the building method and passing on this knowledge to an eager audience of environmental enthusiasts. Through the green and permaculture movements the ideas spread very rapidly, with most of the new buildings being this self-build, Nebraska/loadbearing style. (see page 8). Before long, new techniques were developed to improve the building method and 'The Last Straw' journal was founded in Arizona to disseminate ideas, promote good practice, and provide a forum within which owners and builders could network.

The first straw building in the UK was built in 1994, and today approximately 1000 new structures are being built annually all over the world. There are about 70 in the UK and 10 in Ireland at the present time, some with full planning permission and building regulation approval. Amazon Nails has been involved in approximately 40 of these.

Although the UK began building with strawbales earlier than any other European country except France, we have since fallen far behind in terms of official recognition and encouragement of this innovative and pioneering technique. Amazon Nails is at the cutting edge of design for strawbale building in this climate, and our ideas have been widely adopted around the world, especially in the design of foundations and the use of lime plaster finishes. But there is an acute need for comprehensive research and testing of designs under different conditions, particularly under the sort of prolonged wet winters that we experience on our western coasts and uplands. Whilst empirical evidence is reassuring, there is still the need to know how these buildings will survive in the long term in our climate.

# WHY USE STRAW

### Sustainability

Straw is an annually renewable natural product, grown by photosynthesis, fuelled from the sun. Approximately 4 million tonnes are produced surplus to requirements each year in the UK. Using straw can mean less pressure to use other more environmentally damaging materials and in the unlikely event that the building is no longer required, it could be composted afterwards.

### Energy efficiency and greenhouse gas emission

Over 50% of all greenhouse gases are produced by the construction industry and the transportation associated with it. If the 4 million tonnes of surplus straw in the UK was baled and used for local building, we could build at least 450,000 houses of 150m2 per year. That's almost half a million super-insulated homes, made with a material that takes carbon dioxide and makes it into oxygen during its life cycle. Coupled with vastly reduced heating requirements, thereby further reducing carbon dioxide emission (greenhouse gas) from the burning of fossil fuels, **strawbale building can actually cause a net *decrease* in greenhouse gas emissions. To improve the energy efficiency of houses is increasingly becoming the design challenge of the 21st. century.**

### Highly insulating

Straw provides super-insulation at an affordable cost. The K value of straw in a strawbale is **0.09W/mK;** this combined with walls typically over 450mm thick gives a U value of **0.13W/m2K**, two or three times lower than contemporary materials, and much lower than current building regulations that require walls to have a U-value of 0.45 or less.

## Sound Insulation

Strawbale walls are also super-insulative acoustically.
There are two recording studios in the USA built of strawbales for their sound proofing quality and insulation. Strawbale wall systems have also been used near airport runways and motorways in the USA and Europe as sound barriers.

## Low Fire Risk

Plastered strawbale walls are less of a fire risk than traditional timber-framed walls. "ASTM tests for fire-resistance have been completed…..The results of these tests have proven that a straw bale infill wall assembly is a far greater fire resistive assembly than a wood frame wall assembly using the same finishes". (Report to the Construction Industries Division by Manuel A. Fernandez, State Architect and Head of Permitting and Plan Approval, CID, State of New Mexico)

## Low Cost

Straw is currently produced surplus to requirements. It is regarded as a waste product, and a bale costs on average £1.50 delivered or 40p from the field. The walls of a 3 bedroomed, two-storey house can be built with 400 bales, which costs £600 compared with a material cost of £10,000 for a brick and block wall. Also, because the building method is so straightforward, people without previous building experience can participate in the design and construction, thereby saving on labour costs.
The most significant saving on strawbale houses is in the long-term fuel reductions due to the high level of insulation. Heating costs can be reduced by up to 75% annually compared with modern style housing, and the savings therefore accrue throughout the life of the building.

## Structurally sound

Straw bales have passed load-bearing tests both in the laboratory and empirically, and are used to build at least 2-storey houses.

## A Healthy Living Environment

Straw, particularly organic straw, is a healthy alternative to modern materials. It is natural, and harmless. It does not cause hayfever since it's not hay, and in fact is the material of choice for many allergy sufferers because it is so innocuous. Living within straw walls can enhance the quality of air we breathe, because it does not give off harmful fumes such as formaldehydes, as many modern materials do, and because it is a breathable material, thereby helping to keep the inside air fresh. Coupled with the use of non-toxic organic finishes such as clay and natural pigments and paints, and with opening windows, it can provide one of the safest and most comfortable atmospheres in which to live. Another health benefit is the ambience inside a strawbale house which is calm, cosy and peaceful. This is partly to do with the high level of sound insulation, partly to do with the air quality, and partly to do with the organic feel to the house - a beautiful, nurturing and safe environment to inhabit. Try it!

## Empowering and Fun!

The most unquantifiable aspect of a strawbale house has to be the way that the building process itself empowers ordinary people. It *is* accessible to many people who are otherwise excluded from the design and build process, and enables them to transform their living environment, and very often their lives, in a very enjoyable way.

## DIFFERENT METHODS OF BUILDING

LOADBEARING
LIGHT WEIGHT FRAME AND LOADBEARING
INFILL AND TIMBER FRAME
HYBRID DESIGN

## NEBRASKA ALSO CALLED LOADBEARING

This is the original method of building, pioneered by the Nebraskan settlers in the USA. In this method, the bales themselves take the weight of the roof - there is no other structural framework. They are placed together like giant building blocks, pinned to the foundations and to each other with coppiced hazel, and have a wooden roof plate on top. The roof plate is fastened to the foundations and the bales with coppiced hazel and strapping, and the roof is constructed in the usual manner on top of the roof plate. Windows and doors are placed inside structural box frames, which are pinned into the bales as the walls go up. This is the simplest method and the most fun way of building - it requires little previous knowledge of wall construction and is very accessible. Owner-builders tend to prefer this method because of its simplicity, ease of design, minimal use of timber, and the opportunity it affords for a modern day wall raising. The potential for empowerment through working together on a shared project is one of the main differences between this type of building and any other.

### Advantages:

- A simple, straightforward and accessible building method
- Easy for non-professionals to design, following readily comprehensible basic principles.
- Designs from one room to two-storey homes can be created using a simple, step by step approach.
- Curves and circles are easy to achieve, for little extra cost.
- Ideal for self-builders because of its simplicity, accessibility, ease of design, and low cost.
- The straw is very forgiving. Total accuracy in plumb is not a design goal but wilder variations can be brought back into shape easily.
- Great versatility of design shape.
- **It's fast!**

### Disadvantages:

- The straw must be kept dry throughout the whole building process until it is plastered.
- This can be very difficult on a large building, or one that is being constructed slowly.
- Openings for windows and doors must not exceed 50% of the wall surface area in any wall.
- Maximum unsupported (unbraced) wall length is 6m (20').

The Nebraska style is the most common method of building to be found in Ireland and the UK. However, for larger buildings, it is being superceded by:

## LIGHT-WEIGHT FRAME AND LOADBEARING

**One of the most important design features of a loadbearing straw bale house is to distribute the loads as evenly as possible around the whole building. Never use point loads.**

This design has been pioneered by Barbara Jones of Amazon Nails as a way to retain the benefits of the loadbearing style, yet enabling the roof to be constructed before the straw walls are built, thus giving protection against the weather throughout the wall-raising process. It uses a timber framework that is so light-weight that it cannot stand up alone. It requires temporary bracing and/or the use of acrow props to give it stability until the straw is in place. The straw is an essential part of the structural integrity of the building, *more so than the timber,* and it works together with the timber to carry the load of floors and roof. Timber posts are located at corners and either side of window and door openings *only*, and are designed such that the timber wallplate at first floor and/or roof level can be slotted down into them once the straw is in place allowing for compression on the bales. Compression of the strawbale infill walls is *essential* for stability. To increase stability, the bales are pinned externally, and the pins are secured onto the base and wall plate of the framework once all the settlement of the walls is complete. It is constructed in such a way that the wallplate and roof are kept 100mm above the finished straw wall height whilst the wall is being built, allowing for compressive settlement of the straw wall once the bracing and props are removed.

### Advantages:

- The roof can be constructed before the straw is placed providing secure weather protection.
- Framework and posts can be constructed off site.
- Provides greater stability for window and door frames than in the loadbearing style.
- Vastly reduces the amount of timber required compared to the more traditional post and beam method.

### Disadvantages:

- It is more complicated than the Nebraskan style to construct.
- Greater technical ability is required to make the structure stable whilst the straw is being placed.

## INFILL ALSO CALLED POST AND BEAM OR TIMBER FRAME

In this method, the weight of the roof is carried by a wood, steel, or concrete framework, and the bales are simply infill insulation blocks between the posts. This has often been the preferred option for architects, as the structural concepts are not innovative and rely on an already established method of building, therefore the risk associated with an experimental technique is minimised. There is no need to satisfy oneself of the capacity of the bales to take the weight of the roof, since the framework does this. This method requires a high level of carpentry skill and uses substantially more timber than a loadbearing design, which has significant cost and environmental implications.

### Advantages:

- The roof can be constructed before the straw is placed, giving secure weather protection.
- Framework and posts can be constructed off site.
- Provides greater stability for window frames than in the loadbearing style.
- In conjunction with a steel frame, can create large warehouse space (and gives an even temperature throughout the year).

### Disadvantages:

- It is more complicated than the Nebraskan style to construct.
- It requires a high level of carpentry skill (or metalwork experience in the case of a steel frame) to construct the frames.
- It uses a large amount of timber.

## HYBRID METHODS

**There are many types of straw buildings that use a combination of ideas from the above techniques, or use new ideas.**
**It is still an experimental method, and being so simple, allows for invention during practice.**

### MORTARED BALE MATRIX

Here the bales are used much more like conventional brick walls, with cement mortar holding them all together. The bales are stacked in vertical columns so the cement, in effect, forms posts between each stack. The whole building is cement rendered inside and out. It is rarely used now because of the knowledge of simpler methods.

**Advantages:**

- It is very effective and has passed all building regulation tests in Canada.

**Disadvantages:**

- It is very labour-intensive .
- It uses a lot of cement.
- It is susceptible to damp caused by the use of cement render on straw.
- It falls into the category of `no fun' building methods.

## OTHER ASPECTS OF STRAWBALE BUILDING

The methods described above are for a type of wall building system that is different to the methods we have become familiar with in the 20th century. All other aspects of the building remain the same, including plumbing, electrics, roofing etc. The main differences, as mentioned above, would be found in the design of foundations, type of wall building material, and the type of render or plaster.

Straw, being a breathable material, functions best when used with other such materials. Therefore, it is common to design foundations without using cement, or where cement is used, to protect the straw from it by using a different material in between, usually timber, and to incorporate drainage into the foundation itself. In the same manner cement renders and gypsum plasters would not be used, but instead, traditional lime, and/or natural clay renders and plasters would be applied.

Most strawbale houses, of whatever type of construction, are rendered inside and out so that when finished, they can look very similar to a traditional style cottage - very beautiful and with deep walls. It is hard to tell that they are made of straw!

Several coats of lime-wash are essential as a surface finish and weatherproofer, and this must be re-applied, as with all other painted houses, every few years.

**Raise the first course of bales up from the ground by at least 225mm (9"), put a 450mm (18") overhang on the roof to protect the walls from rain, and you won't go far wrong.**

## DURABILITY

**The key to durability with a strawbale house, as with any other, lies in good design and detailing, quality work, & maintenance when necessary throughout its life.**

Because of its simplicity, it is possible to build a wide range of different quality structures; from a strawbale shed to last 10 years, to a strawbale house to last upwards of 100. Strawbale building is still a relatively new concept, and as such some areas of design are still experimental. In the UK, the oldest buildings have stood for only 7 years, and some of the early ones were never intended to be more than experiments. Under construction now however, there are homes for families, classrooms for schools, offices for community groups as well as numerous owner-built houses, offices, studios and garages.

**No strawbale building in the UK has ever been refused planning permission or building regulation approval on the grounds of it being made of straw.**

## THE NATURE OF STRAW

If we leave a bale of straw out in the field to be rained on, it quickly becomes too heavy to lift because of water saturation, and is of no use other than as mulch for trees. However, if we stack lots of bales carefully out in a field, raise them off the ground and put a good roof over the top, they will withstand the weather and simply get wet and dry out. Talk to any older farmer and they will tell you this is how straw (and hay) was traditionally stored: in the field for ease of access. They would raise the bales off the ground first, usually by using a sacrificial layer of bales laid on edge (ie one that would go to waste later), and the rest stacked flat, with a roof of thatch over the top. The sides of the bales would be exposed to the rain and wind, but getting wet was not a problem. Straw does not 'wick' (suck) water into itself like concrete does. It simply gets wet as far as the force of the wind can drive the rain into it. When the rain stops, the natural movement of air or wind around the bales dries them out. This cycle of wetting and drying does not damage the bale.

**It is important not to let the *centre* of the bales get wet through the top or bottom, as they are unlikely to dry out sufficiently for building, but wetting the *sides* of a bale is not usually a problem.**

## HOW TO CHOOSE GOOD BUILDING BALES

Bales should be dry, well compacted with tight strings, be of a uniform size and contain virtually no seed heads.
Bales must not be damp, and must be protected from damp during the building process. Safe moisture levels for the prevention of fungal and bacterial growth are as follows:

EITHER: **moisture content should not exceed 15% (wet weight basis)**

OR: **relative humidity should not exceed 70% (w.w.b.)**

Bales should be as dense and compact as possible. The baling machine should be set to maximum compression; in general this means bales contain about one third more straw than usual. Weight should be between 16 - 30 kg.
Bales should be roughly twice as long as they are wide, and the larger the better. Most baling machines produce bales that are 18” (450mm) wide x 14” (350mm) high and variable lengths from 36” to 45” (900mm to 1125mm), although a few machines are 20” wide and 15” high. Mini hestons of 8ft x 3ft x 2ft can also be used, especially for warehouses.

Strings must be very tight, so that it is difficult to get fingers underneath. They should be about 100mm (4”) from the edges of the bale and not sliding off the corners. String should be polypropylene baling twine, sisal or hemp. It should not be wire. The type of straw is immaterial as long as the above guidelines are followed. It can be wheat, barley, rye, oats, etc. Straws should be long, 150mm (6”) minimum, preferably 300mm (12”) to 450mm (18”).
DO NOT CONFUSE STRAW WITH HAY OR GRASSES.

**Straw is the baled up dead plant stems of a grain crop. It has had virtually all it’s seed heads removed, and contains no leaves or flowers. It is a fairly inert material, with a similar chemical make-up to wood. It is quite difficult to make it decompose, and usually requires the addition of nitrates to do so. Hay, on the other hand, is grass baled up green, with lots of feedstuff (leaves and flowers etc.) deliberately left in there. It readily decomposes, as the organic matter in it begins to rot.**

The age of the straw does not matter as long as the above conditions have been followed, and it has been stored correctly. All the above conditions should ideally apply equally to bales, whether they are being used for loadbearing or infill. However, density is not so important when bales are only being used for insulation.

**It is important to know the size of bales you will be using before finalising dimensions of foundation, wallplate etc.**

Bales can vary a lot in length, from supplier to supplier and within each load. Lengths can vary, as it depends on the skill of the tractor driver and the evenness of the field as to whether the straw is picked up uniformly as it is baled or not.
In practice, relying on the farmer to tell you the length of bales is not a good option. Besides which, you will need to satisfy yourself that the straw is baled dry, and kept dry whilst in transit and storage. Far better to look at the bales once they’re harvested and determine the average length of bale at the same time.
Finding that your delivered bales are not the same length as you expected is not an insurmountable problem. It may mean a little more work in shaping the bales to fit, but this is straightforward and not time-consuming.
As strawbale building becomes more widespread, suitable construction bales will become more readily available. Already, there are wholesalers in the UK who are supplying good construction bales.

It is possible to harvest and store straw in bales of uniform length and moisture content, ready for the building market each season. As demand increases, so will the reliability and availability of supply.

## COST OF BALES

The cheapest way to buy bales is straight off the field after they've been made, and to buy locally so as not to pay large transport costs. This has the added benefit of minimising the environmental impact of transportation. If you collect them yourself they can cost as little as 40p per bale.

When you consider the average 3-bedroomed house will use about 400 bales, this represents a material cost of only £160!

Even when buying in bulk from a wholesaler, delivered to the site, bales will cost on average £1.50 each, which would bring the price of 400 bales up to £600.

Compare this to the material cost of building the same walls in brick and block:
400 bales of size 1.1m x 0.35m = 154m2

A modern brick faced block wall is built of:
blocks of size 0.45 x 0.225m including mortar = 0.10125m2 per block
bricks of size 225 x 112.5 x 75mm including mortar = .0019m2 per brick

The inside blockwork skin of the wall takes

$$\frac{154\text{m2}}{0.10125\text{m2}} = 1521 \text{ blocks}$$

The outside brick skin of the wall takes

$$\frac{154\text{m2}}{0.0019\text{m2}} = 81{,}053 \text{ bricks}$$

If blocks cost 35p each and bricks cost £120 per thousand this represents:

$$(1521 \times 0.35) + \left(\frac{81{,}053}{1000} \times 120\right) = £10{,}258.71$$

**So the first financial saving of building with straw instead of brick and block is approximately:**
**£10,258.71 - £600 = £9658.71**

On top of these costs, you also have labour costs to calculate, with brick and block walls taking a team of 4 skilled people an average of 6 weeks to complete, and strawbale walls taking a team of 10 unskilled volunteers plus a trainer about 2 weeks to complete.

This level of savings from using straw as a loadbearing material instead of brick and block increases with the size of the building.
Although the walls of a building only represent about 16% of the total costs of building, £9600 is a significant saving for any self-builder and becomes more so for construction firms building more than one house. Together with this, the labour times involved in strawbale building are vastly reduced once the labour force is familiar with the material, and the role of trainer becomes redundant.
In addition, the design of the foundation can use less material because straw weighs on average 65% less than brick, and has a wider bearing surface, so spreading the loads further.

**Can you afford not to build with straw?**

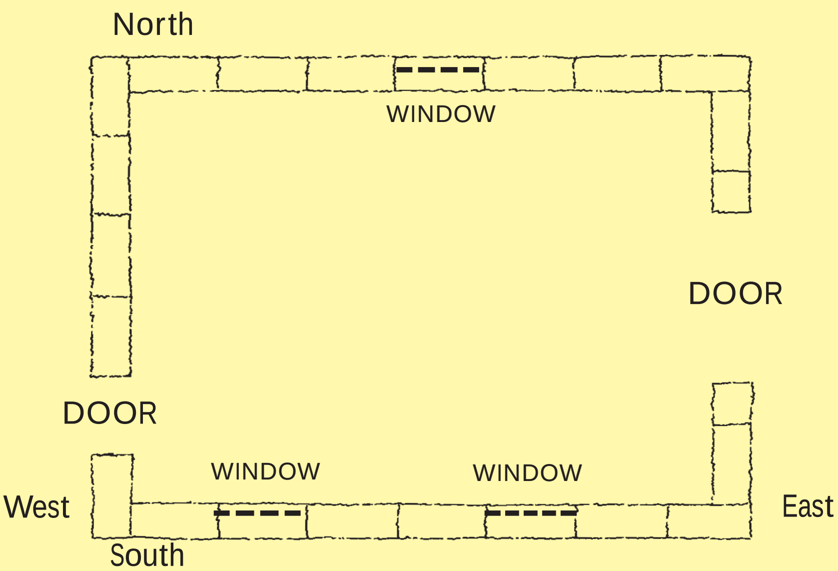
Think about what you want your strawbale house to look like, how you want it to feel inside. Try to forget anything you've been told about building and imagine your ideal space, however wild that might seem! Then work within the practical limitations of the bales to come as close as possible to your dream.
The design of strawbale houses is usually simple and elegant. It is based on a block design and therefore different elements of the structure can be built up easily from the initial shape and dimensions of the foundations. Each section of the house has an obvious relationship to the other sections, and many different houses can be designed quickly and easily from the same basic plan.
For most domestic dwellings, it should be possible for owner-builders to design their own houses. The way a strawbale house goes together is simple. It follows common sense principles and it is effective. By using this guide, you should have no difficulty in working out the construction drawings and methods for any type of domestic dwelling.
Once you've decided on what the building is for, what you want it to look like, and what you want it to feel like, then begin by drawing the outline of your house.

**You will need to start by planning where the bales lie on the first course of the wall.**

Read the section on the nature of straw.
Draw the shape of the building you require, as though you were looking at it from above, this is called the PLAN view. Draw in the shape of the bales, their width and length.

**Click here to see drawing**
No 1

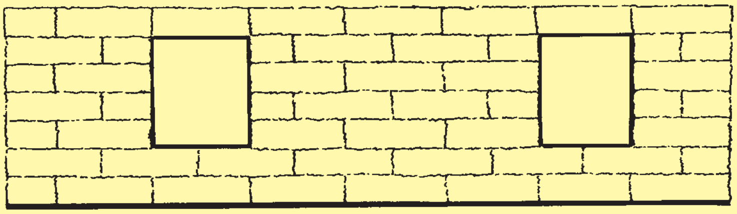
BALE PLAN



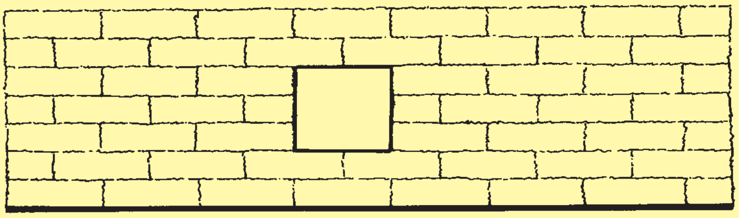

**Click here to see drawing**
No 2

Now imagine you are looking at the finished building, standing on the ground looking north, south, east and west. Draw the face of the building you see from each direction, showing again where each bale is, how they turn corners or curve etc, these drawings are called ELEVATIONS.

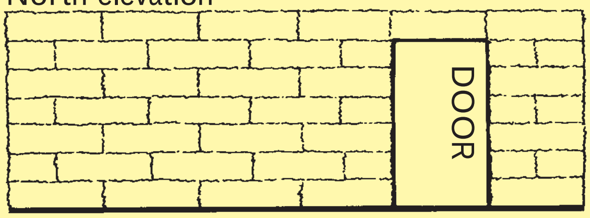
## BALE ELEVATIONS



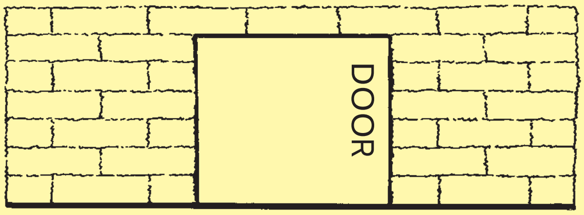
South elevation



North elevation




West elevation




East elevation

**Click here to see drawing**
No 3

From accurate bale plans you can work out how many bales you need, how many hazel pins, staples etc. and other quantities of materials. Details of foundations, windows, first floor and roof can be worked out. You also now have the basis for drawing your own plans for planning permission.

**Click here to see drawing**
No 4

There are some rules of thumb when it comes to building:
Before you draw your final plan, and before you finalise the dimensions and lay out the foundations, you need to know the dimensions of the bales you will be using, they can vary a lot!
The bale plan should be made up of a whole number of bales.
Try not to have any places in the wall (e.g. beside a window) that are less than half a bale length.
Window and door openings must be at least one bale length from corners.
If at all possible, choose window and door sizes that are multiples of bale dimensions.
In a loadbearing design the walls will settle a bit once the weight of the roof is on, so allow for this by leaving gaps above windows and doors that can be filled in later. With good building bales, settlement in a seven bale high wall should be about 12-50mm (1/2-2"). The amount of settlement depends on the density of the bales and the amount of loading applied to

**Loadbearing houses are subject to settlement as the straw compresses under the weight of the floors and roof. Allowance for this must be designed in by leaving settlement gaps above doors and windows.**

# FOUNDATIONS AN INTRODUCTION

All buildings need to have some sort of a foundation on which to build. This will always be a natural foundation, ie the earth beneath you, which can be bedrock, firm clay, compacted gravel etc., and may also include an artificial foundation such as the widened base of a wall. As the foundation has to carry the weight of the walls above it, and other loadings such as floors, furniture, roofs and even snow in winter, it is important to know what type of earth (or subsoil) is found on your building site. Different types of earth will carry different weights. Bedrock, for instance, will carry much greater weight than soft clay. On the other hand, if you increase the surface area that bears the weight onto soft clay - much like wearing snow-shoes - even this can take the weight of a house. For a small building constructed of light-weight materials, there is obviously no need to build massive artificial foundations on any type of soil. Equally, for a heavy building built on bedrock, there is no need to add huge foundations. Almost all our buildings over 200 years old have natural foundations with little or no artificial ones. They may have used larger stones at the base of the wall, making it slightly wider than the wall itself. In all cases, they removed the topsoil (growing part of the earth) and dug down to something solid. Because they chose their building sites well, this was often only a few inches below the ground surface. There are hundreds of thousands of houses still lived in today, that can be excavated by only 6 inches or so to find they are sitting on the earth itself, and yet are completely sound and safe. Unfortunately, there are many misconceptions about foundations today that are partly caused by the rise in popularity of cement and concrete. In some building colleges, students are taught that buildings *must* have foundations made of concrete, despite the evidence to the contrary that surrounds us. Throughout learning about strawbale building, you will be encouraged to look at what's around you, to keep things as simple and straightforward as they can be. There is no need to overcomplicate anything, only to **understand what it is that we want to achieve and make choices based on the different ways that it is possible to do so.**

So for foundations, we want to achieve a solid, stable base that distributes the weight of whatever is built upon it over the ground beneath. We also want to be sure that there is no unequal settlement throughout the building.

If we look at the different weights of materials, we can see that using straw for the walls can have a significant impact on the choice, and cost, of the foundation.
For comparison:

**1m2 of brick = 212kg**
**1m2 of block = 197kg**
**1m2 of straw = 75kg**

Therefore straw weighs 65% less than brick and 62% less than concrete block.

**A single storey structure, built with load-bearing straw walls, should not need more than a base plate the width of the walls to give it a secure foundation. That is, no need for deep trenches filled with concrete, perhaps no need for concrete at all.**

## FOUNDATION TYPES SPECIFIC TO STRAWBALE BUILDINGS IN THIS CLIMATE

Having understood the aim of natural and artificial foundations to provide a solid and stable base from which to build your house, we also need to pay attention to the specific requirements of the wall building material we are using, namely straw.

The base of a straw bale needs to be kept dry in the walls of a building. This means:
It must be raised off the ground sufficiently to avoid damage by splashback from rain bouncing off the ground.
There must be a means of removing any moisture that does occur in the base of the first course of bales.

Both of these can best be achieved by using **self-draining-foundations**.
But there are other reasons for using them too.

**Why use self-draining foundations?**

- They have withstood the test of time, and are a tried and tested method. Traditionally some of the oldest buildings in the UK and Ireland, made from cob (earth), including some that go back over 400 years, are built like this. There are significant similarities in the properties of strawbale and cob buildings and we can use the knowledge of generations to inform our practice today.

- It is sensible in the often wet and windy climate of the UK and Ireland, to use this type of foundation as an important protection against the severity of the weather. If moisture enters the bale walls, it will slowly migrate downwards into the bottom bale, where it will stay, if the foundation doesn't drain.

- When the foundation is built up above ground level, it not only provides drainage for the wall, but also provides protection against rising damp.

- Many people are trying to reduce the amount of cement they use in building (for environmental reasons) and a self draining rubble trench instead of concrete is an option.

- Depending on the design, self-draining foundations can be built cheaply and without the need for professional builders.

## OTHER DIFFERENCES IN FOUNDATIONS DUE TO THE USE OF STRAW:

**Tie-downs**

Foundation design must incorporate some method that allows the wallplate and roof to be fastened down securely to it. This prevents the roof from being lifted off by strong winds. It can be done in several ways:
Metal or plastic strapping can be laid underneath the foundations in a U-shaped plastic pipe (for protection). This can then be carried over the wallplate once the straw is in position, and fastened in tension using fencing connectors or similar.

Anchor bolts can be fixed into the foundations internally and externally to take metal or plastic strapping.
Strapping can be fixed to the timber base-plate that is laid on top of the foundations.

**Fixings for doorframes etc**

Anything, such as doorframes, that fix directly to the foundation, must have provision made for it. Structural box frames on concrete or stone are usually bolted into the foundation. They can also be fixed to the timber base-plate.

## Local stone with timber floor grid.

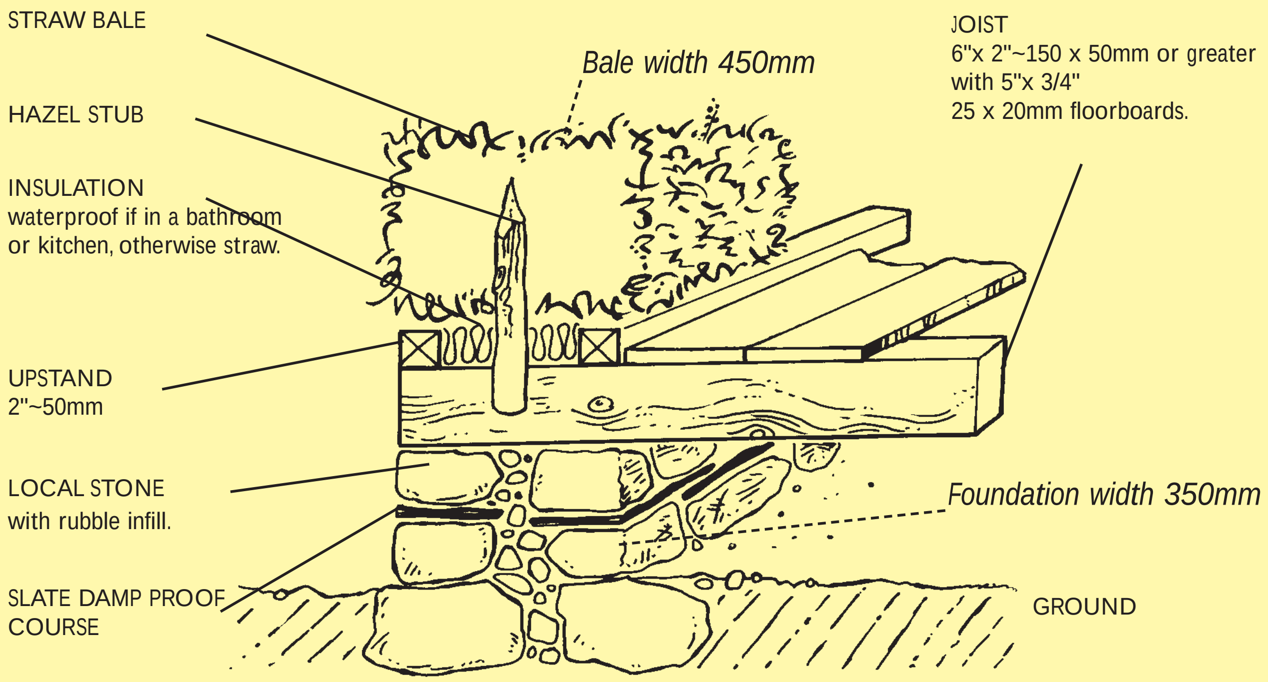
This is the most ideal type to choose, because:

- It is made entirely of natural materials
- The stone can be second hand as well as new
- It is very beautiful to look at
- It is easy to build even with no previous knowledge
- It can all be re-used if ever dismantled

The plinth wall is built at least 9 inches high to protect the base of the straw from splashback, (the rain bouncing up from a hard surface onto the wall).
It is not necessary to build the plinth on top of a draining trench if the ground you are on is sufficiently stable to support the weight of the building, eg. stone, gravel, or compacted clay. You may want to use a shallow rubble trench if the ground does not drain well.
Using local stone is the ideal material for self-draining plinth walls, but they can also be constructed out of other materials.

**Disadvantages:**

- If you are not doing it yourself, labour costs for stone building are greater than for concrete block or other types of foundation.
- If the stone is not second hand, or found, it is expensive compared to concrete block or other types of foundation.
- It is a slower method (because more labour intensive) than others.



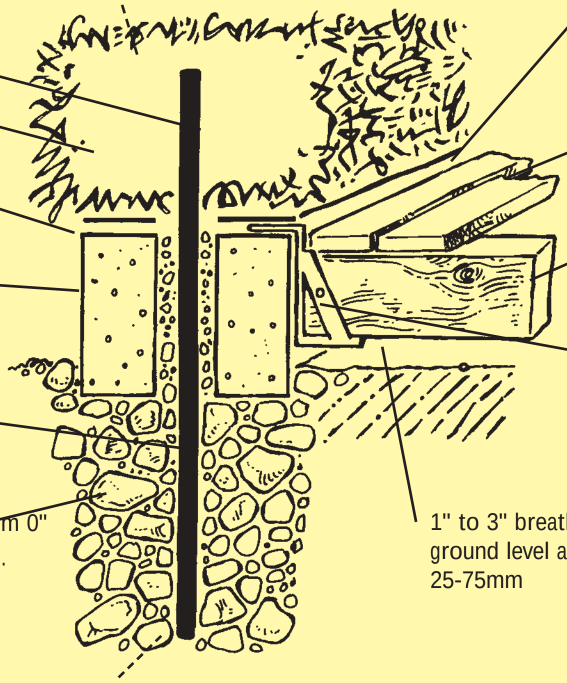
## Simple blockwork foundation

This is often a good choice for a cheap and cheerful building because:

- It's quick and easy to build even with no previous experience
- It is relatively inexpensive.

**Disadvantages:**

- It's ugly!
- It won't biodegrade into anything useful at the end of its life.
- There is constant potential for damp problems between the concrete block and whatever is above it, as concrete is a 'wet' material and draws moisture into itself.



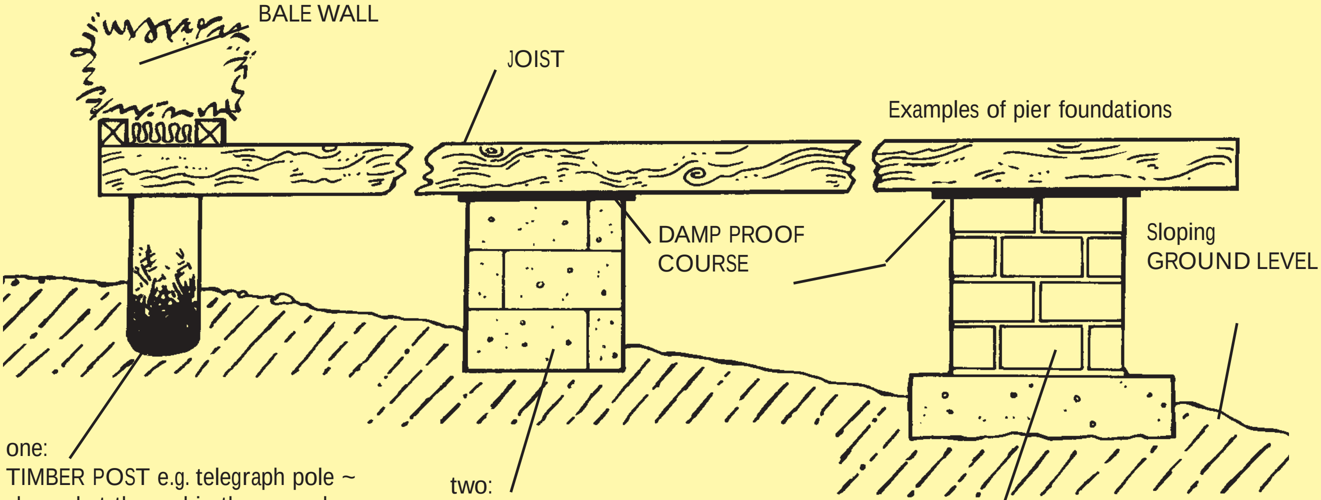

## Pier Foundations

An excellent example of low-impact foundations and especially useful when building on a sloping site because:

- It can easily cope with different heights of ground by simply increasing the height of the post or pier.
- It is low cost. Using a series of posts or piers is far less expensive than building strip foundations of any description.
- It has a low-impact on the environment. A series of holes is less intrusive than a trench beneath the whole house. It can create a useful basement space beneath the house.
- It is relatively easy to construct, no special knowledge is required.
- Depending on materials used, it could be recyclable at the end of its life.

**Disadvantages:**

- It may limit the design choice in some cases.




## Poured concrete with slab

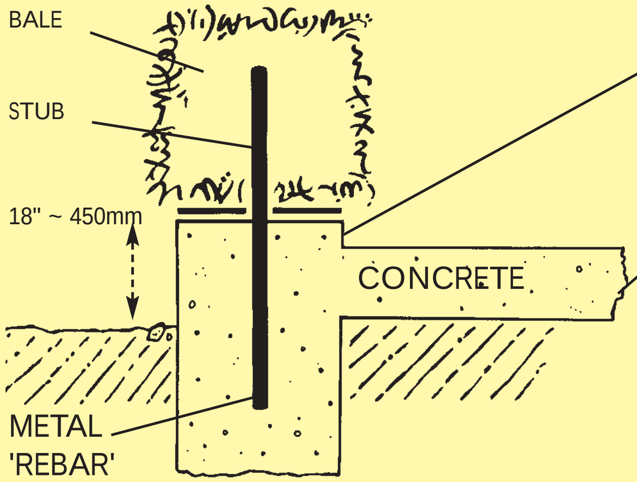
A method that became popular in the 20th century and is used because:

- It is a standardised method that most builders are familiar with.
- If done according to the guidelines in the Approved Documents, there will be no problem in it passing Building Regulations.
- It is quick and straightforward if machinery is used. Once the preparation is done it can usually be laid in a day, particularly useful on a large building site.
- It means you quickly have a floor surface to work from.

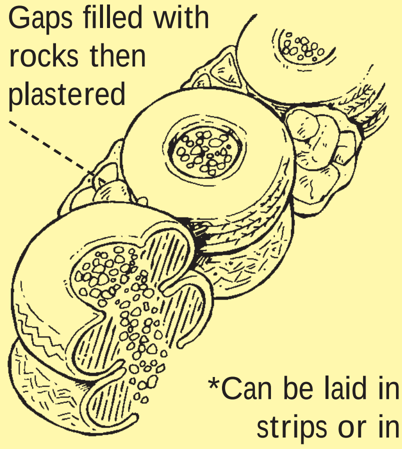
**Disadvantages:**

**It may be over-designed for the purpose for which it is required**

- It creates an enduring damp problem at the interface between the straw and the concrete. Even the use of a dpc at this point doesn't entirely eradicate this. It protects the straw from the constantly wet concrete, but then the dpc itself creates a water-proof surface on which any moisture in the walls will collect! A self-draining foundation is a much better design. Raising the bales up from the dpc on a timber plate will also help but not solve the problem.
- It is costly on the environment because cement takes a lot of energy to produce and to transport, and then at the end of it's usefulness leaves material that does not biodegrade.
- It costs more than you think. There is a popular misconception that laying concrete is cheap – but there is a lot of preparatory work involved to do it correctly. This is increased with a straw building because of the need to raise the foundations above ground level, and to secure metal stubs into them in spacings that correspond to the bales.
- It's hard, heavy work if you're doing it yourself!
- It's ugly!




## Rammed earth car tyre foundation

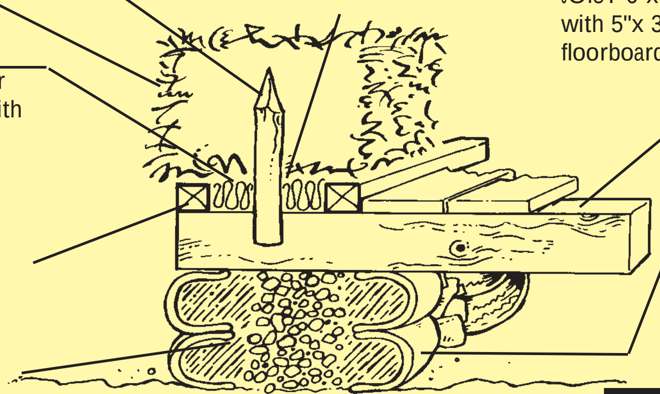



**This is an excellent choice if you have access to a team of volunteers because:**

- It's very easy to construct. No previous experience is needed.
- It costs almost nothing. Car tyres can be collected for free at most garages.
- It uses materials that are otherwise difficult to dispose of environmentally.
- There is no need to use a dpc as the tyres themselves provide this as they are waterproof.
- **It's fun! and very sociable.**

**Disadvantages**:

- It's labour intensive. This can mean it is costly if you have to pay for labour.
- Ideally tyres should be the same size. It can be hard to sort them out when the garage owner just wants to get rid of everything to you!
- They won't biodegrade into anything useful at the end of their life.
- They are ugly. You will have to plaster them outside so they look nice.



The examples above have all been used successfully with strawbale buildings in the UK and Ireland. It is also possible to use these ideas in combination. What is important is following the basic principles:

- **Raising** the bales off the ground.
- **Securing** the bales to the foundations.
- **Raising** the bales at least 25mm higher than the floor level in any room with plumbing, eg kitchen and bath-room.
- **Protecting** the bales from moisture from above and from below.

The foundation does not have to be as wide as the bales of straw. Straw bales are 450mm (18") wide, but because the edges slope off, the outside 50mm (2") either side do not carry load. This means that the foundation does not need to be more than 350mm wide. Also, once in place, the straw is trimmed off to give a firmer, more even surface for plastering, which reduces the width of the bales. Design will depend primarily upon specific plastering details. It would not be good practice however, to build foundations that are wider than the straw, as this would encourage water to sit on top of them, and therefore increase the moisture content of the bottom bale.

# WALL RAISING

## For loadbearing:

For larger loadbearing buildings, it can be helpful to use temporary corner braces, to provide a guide to keep corners vertical.

Structural doorframes are fixed securely to the foundations or baseplate before the straw is laid. Window boxes are built into the walls as they go up and pinned through the base and sides with hazel.

## For framed construction:

Depending on the type of frame construction, frames can be built off-site and then assembled once the foundation is finished. All framing including temporary bracing and propping is done before the straw is placed. The roof is also constructed, with felt and battens to provide waterproof shelter, leaving the final roof covering until the straw is in position, unless the roof covering is very lightweight, such as shingle, which does not need felt.

**BALE FRENZY ~ a sort of over-excitement caused by inspirational moments with straw ~ becomes apparent in any group as soon as the speed with which walls go up is grasped!**

Lay the base plate onto the foundation if one is being used, and also the floor joists. Fix hazel stubs into the base-plate unless they are already part of the foundation.

**Prepare the bales for use (if necessary) by tearing out the centres on each end until a flat surface is created. This ensures that when the bales go together in the wall, there will not be any gaps or large air pockets to reduce insulation.**

The first course of bales must be placed slowly and carefully as these provide the template from which the walls will emerge. It is important to make sure that the overhang of the bale from the foundation is correct both sides of the plinth wall, and that the bale plan is followed accurately.

Bales go together like giant bricks, a second course bale straddling equally the joint between two lower bales. Work from fixed points into the centre of each wall; place the corner bales first, and those beside any framing posts. Bales may need to be handpicked to ensure a snug, not over-tight fit.

**Remember to stay calm, work together, and be aware of what other teams are doing on their sections of wall.**

**Click here to see drawing** No 5

**Click here to see drawing** No 6

**Click here to see drawing** No 7

**Click here to see drawing** No 8

**Click here to see drawing** No 9

It will always be necessary to 'customise' bales: to make half bales and bales to fit a specific gap. This can be done easily by using baling needles and restringing both halves of a bale prior to cutting the original strings. Attempts to do this with a baling machine beforehand have not been successful. It is difficult in practice to make uniform sized bales, and the shorter they are, the harder it is. With practice, it can take two people 5 minutes to customise a bale – a very fast process!
Always customise bales to be slightly smaller than you expect. This allows for the tendency, whilst suffering from bale frenzy, to want to force your new bale into the gap, because you've just spent time making it. And because of the flexibility of straw, this is possible. However, this will almost always result in a distortion of the wall somewhere else, usually at the nearest corner, or in the buckling of a framing post for a window. Do not give in to the temptation to go for speed rather than a snug fit. Watch out for your work partners and encourage them to adopt a calm and measured approach too!

## CUSTOMISING

A baling needle is a simple tool rather like a giant darning needle, but with 2 holes in the end, to take the 2 strings of the bale. A handle is bent on the other end for ease of use.

CURVING BALES
Making bales curve to the shape of a semi-circular design is a highly technical and difficult part of the job. Care must be taken not to laugh too much. The procedure is to turn a bale on its side, lift one end up onto a log and jump on it! The middle straws in the bale can be moved fairly easily in relation to the strings. Make sure not to curve the bale so much that the string slips off. That's all!

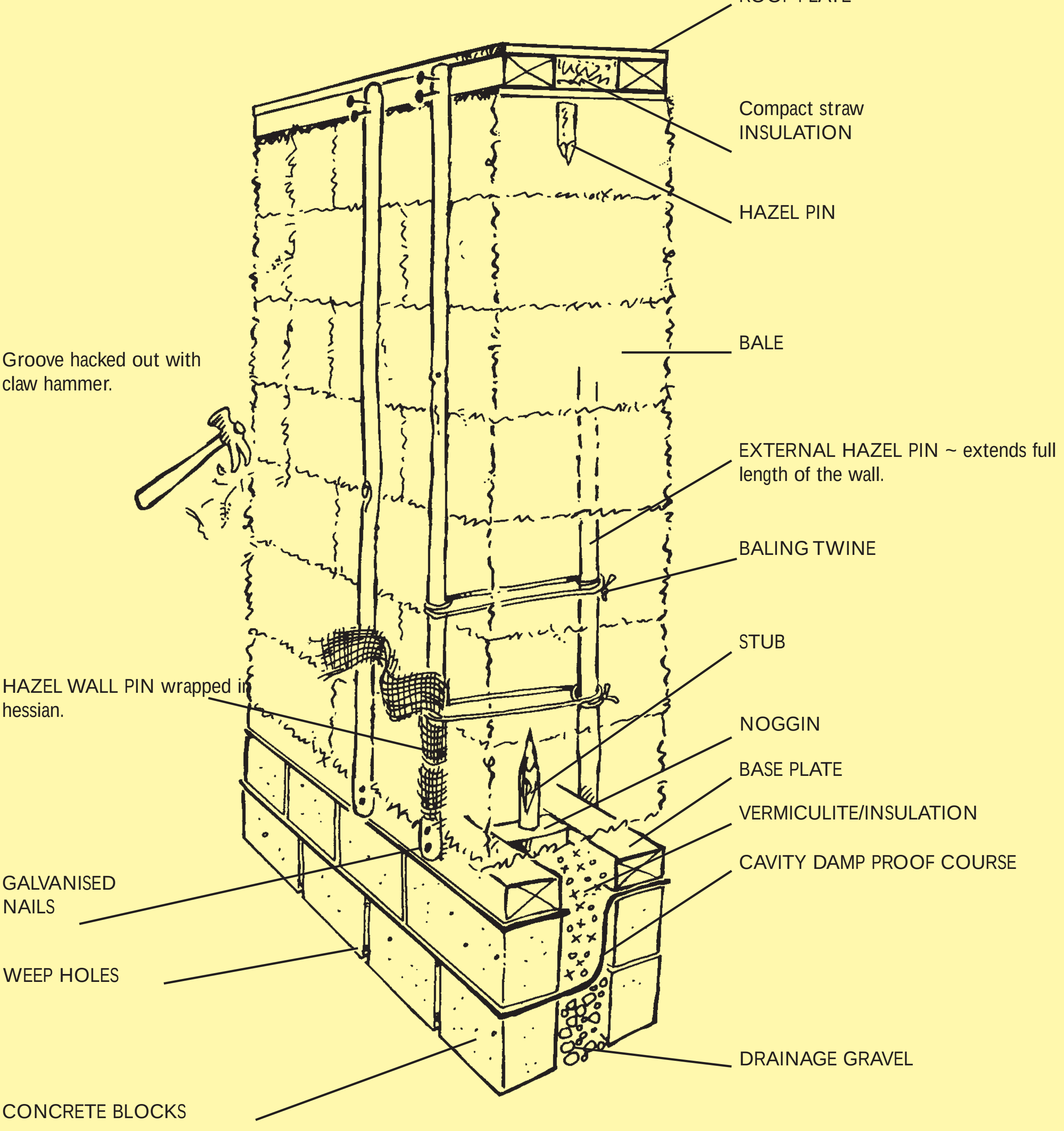
## PINNING

### For loadbearing:

At every radical change of direction, such as at corners, the bales need to be pinned together with hazel hoops or staples. These can be made from 900mm (3') lengths of hazel, 25-32mm (1-11/4") in diameter.
Once the walls are 4 bales high, they need to be pinned with lengths of hazel. The pins give the wall integrity, so that each bale acts together with the others instead of independently. They are as long as the height of 4 bales, less 50mm (2") which is 1.38m (4'6"), and they should be 38-50mm (11/2-2") in diameter, straight, sharpened at the narrow end and without excessive knobbles. There are 2 pins per bale, driven down through the centre of the bale to overlap with the hazel stubs that stand up from the foundations. The same length pins are used in the 5th, 6th and 7th courses too, building up a series of overlapping pins throughout the wall system. The walls of a single or ground floor are usually either six or seven bales high, depending on the design of the foundations and the type of floor installed. First floors are generally from three to five bales high, but can be higher.

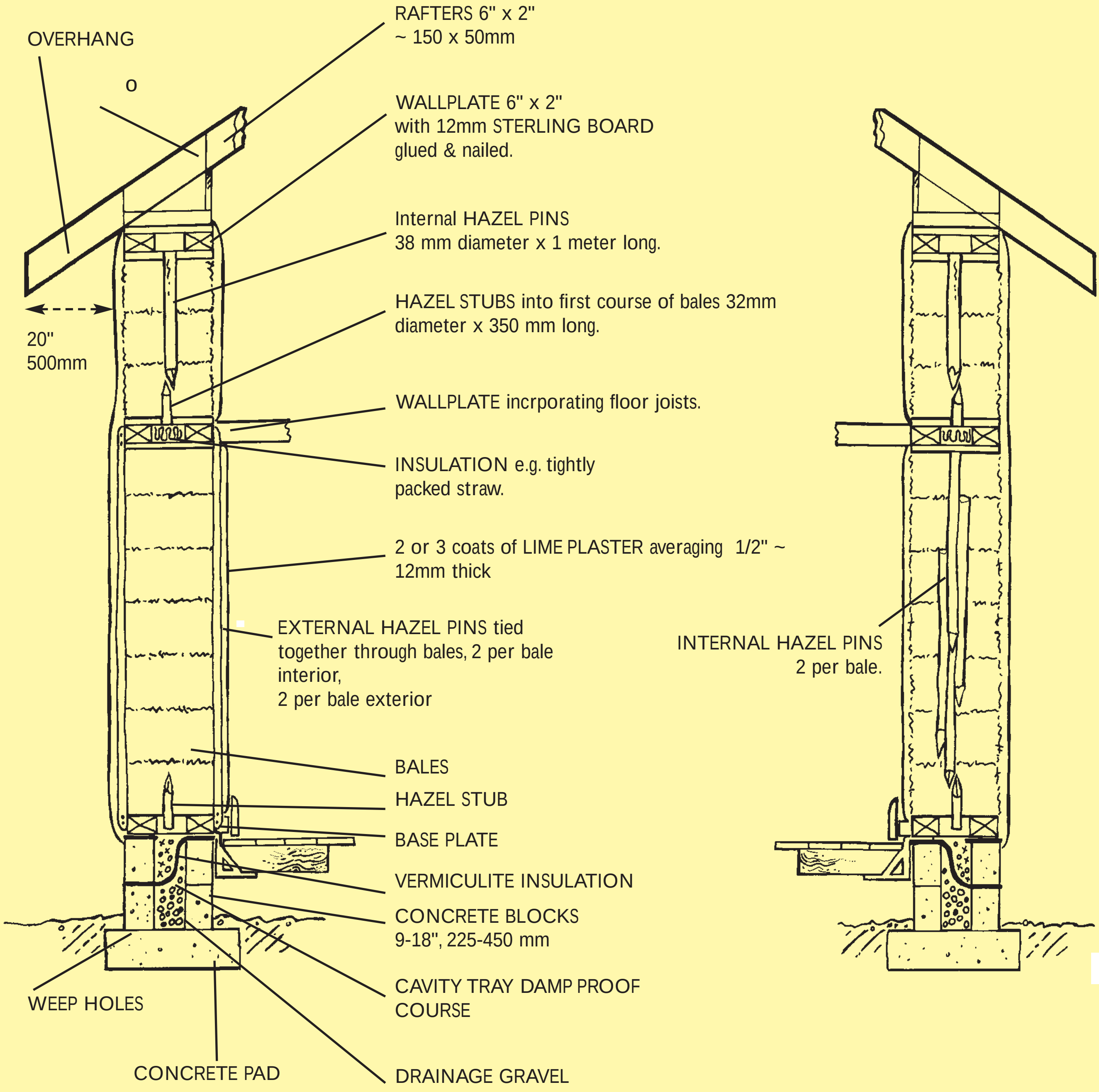
**For framed type:** Here the pins run from base-plate to wallplate in one continuous piece. It may be possible to trim the straw ready for plastering before the pins are put in position. They are placed externally to the straw, again two per bale internally and externally. Grooves are cut into the straw with a tool such as the claw on a hammer so that the pins are flush with the straw. Pairs of pins on either side of the wall are tied together through the straw at each course of bales with baling twine, and are fixed to the base and wallplates with screws or nails. Once in position, the pins are covered with hessian to provide a key for the plaster. The pins can either be hazel or sawn softwood.

LIGHTWEIGHT FRAME WALL



## Section through a LIGHTWEIGHT FRAME WALL

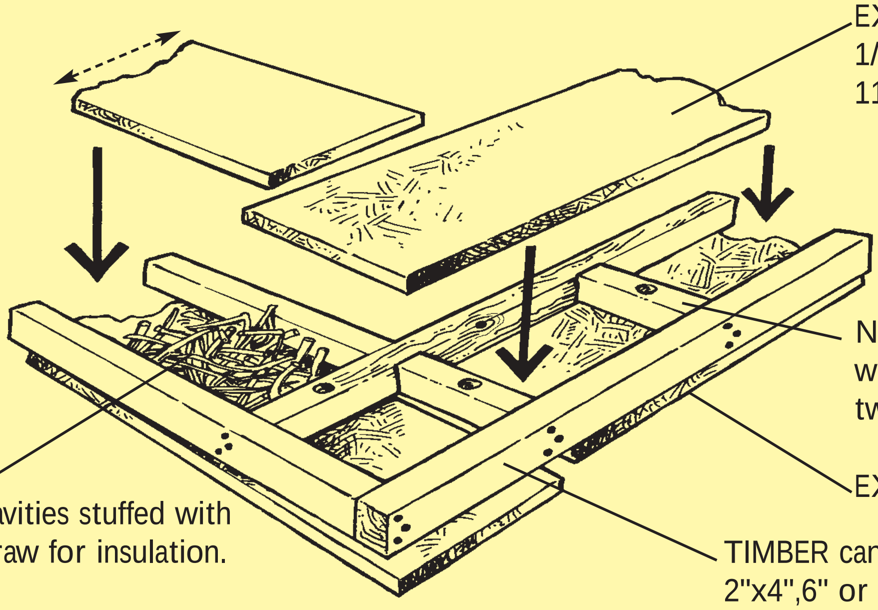
## Section through a LOAD BEARING WALL




**N.B.** **Avoid using metal in the walls if at all possible, since it is a cold material and may encourage warm, moisture-laden air from the inside of the house to condense on it.**

# WALLPLATE OR ROOFPLATE

This is a continuous, rigid, perimeter plate that sits on top of the strawbale walls. It is usually made beforehand in sections, for ease of installation, which are fixed securely together once in position. The size of timbers used will depend on the loading it will carry from the roof, the span of the building etc.
Other types of design than the ones illustrated can be used, for instance, a plate that is located at first floor level can also incorporate the floor joists, so as to save on timber.




# SETTLEMENT AND COMPRESSION

Ideally we would choose the most dense bales to build with, in order to reduce the amount of settlement that occurs due to the loading of other bales, floors and/or roof. The best building bales will compress by between 12 and 50mm (1/2 - 2") in a 7 bale high wall. Windows and doors in load bearing systems have a 75mm (3") settlement gap left above them. During settlement, this gap is maintained by folding wedges of timber that gradually reduce the gap as the building compresses.
These wedges would be used in all places where settlement needed to occur. It is also possible to precompress the walls - especially so in the compressed frame method - by using ratchet straps at 1m (3'3") intervals along the wall, fastened to or through the foundation, to give even pressure on the walls, using the wallplate to spread the load across the width and length of the wall.

## REASONS FOR USING WALLPLATES:

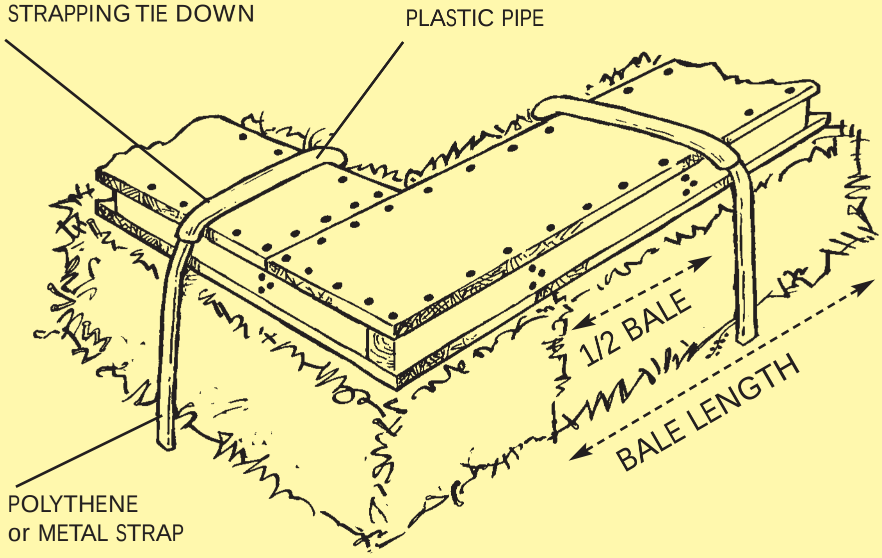
- To distribute the load of the roof or floor above evenly across the width of the wall, and around the perimeter of the building.
- To provide a rigid perimeter plate that affords compression of the straw walls at an even rate around the whole building.
- To provide a fixing point for strapping or anchors to the foundation, to hold the roof structure down against wind uplift.

Once the wallplate is in position, any distortion in shape the walls have suffered due to their flexibility, or bale frenzy, can be adjusted. The weight of the plate immediately gives the walls greater stability. Beginning at the place of best fit, the walls should be persuaded back into correct alignment, and the plate pinned down with hazel 25-38mm (1.5-2") in diameter, 600mm (2') long, again two pins per bale.

**At this stage, there is a dramatic change in the stability of the walls, and instead of being flexible stacks giving the impression of a ship at sea, the walls become remarkably solid and reassuring to work on.**

## TIE-DOWNS

These can be fixed at this point, or wait until the roof has been constructed. It is often easier to trim the walls before the tie-downs have been attached.




## ROOF

The design of roof for a strawbale house is not unusual nor particularly different to that for any other building. The main consideration for loadbearing and compressed frame design is that the loading is spread as evenly as possible around the perimeter walls, and this must be remembered whilst the roof is being covered in. Truss rafters should be spread across the walls, not stored at one end of the building before fixing. As the roof is loaded up with slate, tile etc., these should also be distributed evenly and not loaded in one spot, nor should half the roof be slated before the other half.

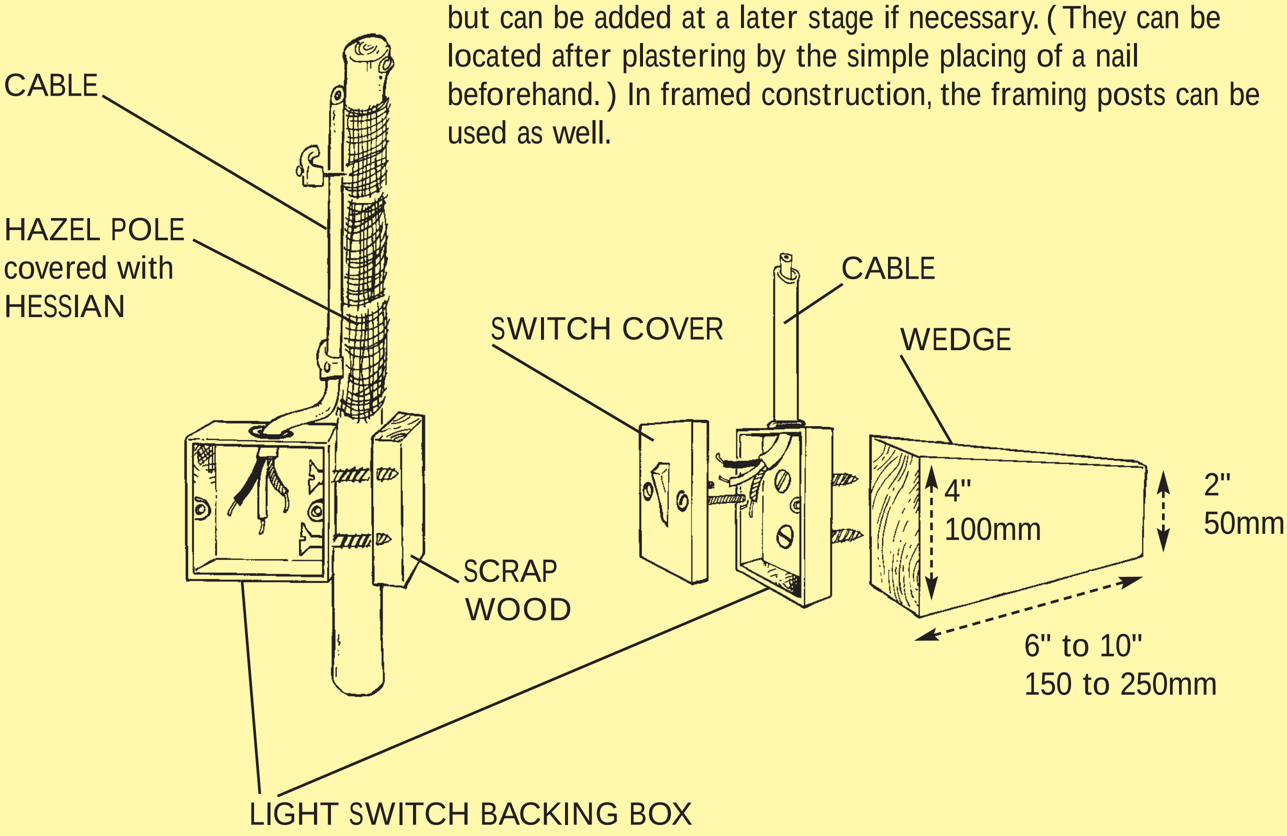
Straw houses need a good hat to protect them from the weather. A large overhang is a feature of straw bale buildings, especially in this climate. Just as trditional thatched houses have a roof overhang of about 500mm (20"), so too do straw ones. This gives really good protection to the top of the walls against the rain.

## ELECTRICITY & PLUMBING

Again, no real differences in installation. Electricity cables should be encased in plastic conduit sheathing to give extra protection for the (as yet unresearched) possible risk due to heat generated by electric cables sited in a super-insulated wall such as straw.
As far as possible, water carrying pipes should be designed to be fixed in internal, non-straw walls, to minimise the risk of water seepage to the straw in the event of a leak. Metal pipes that pass through straw walls should contain no joints, and be encased in larger plastic pipes for the full width of the wall.

## INTERNAL FITTINGS

Cupboards, shelves, light switches and sockets, bathroom facilities etc can all be fixed by using timber wedges knocked into the body of a bale, that provide fixings for screws or nails. These fixing points need to be placed before internal plastering, but can be added at a later stage if necessary. ( They can be located after plastering by the simple placing of a nail beforehand. ) In framed construction, the framing posts can be used as well.



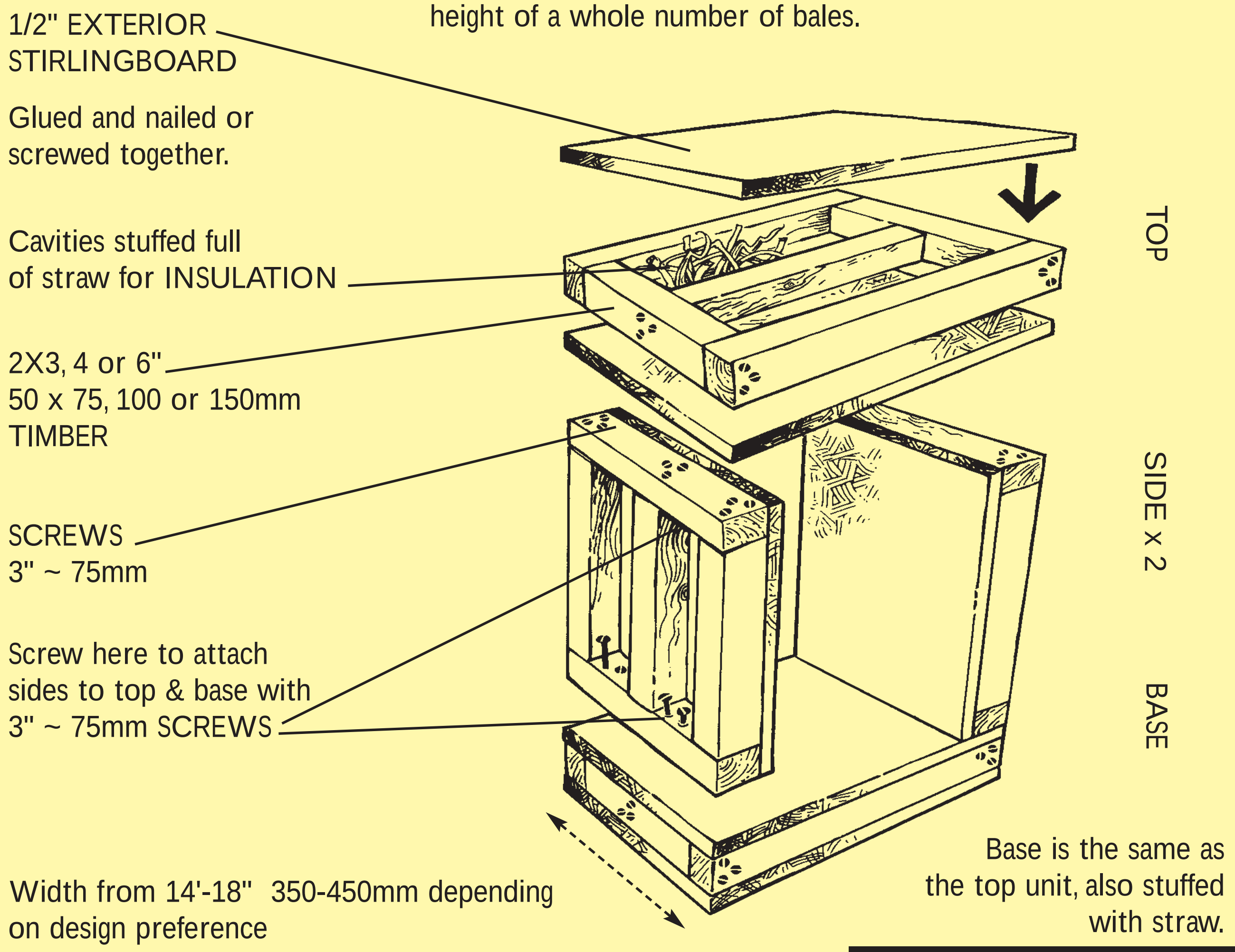
## FOR LOADBEARING

All window and door openings in loadbearing houses must have some way of supporting the weight of the bales, floors and roof over the top of them. Due to the flexibility of straw, the use of concrete or steel lintels is inappropriate and in fact would create problems – the loads need to be spread over as wide a surface area as possible.

The simplest way of dealing with openings is to make a structural box frame into which the actual window or door is fixed.

The design of these frames must take into account the fact that the straw walls will settle under the weight of the floors and roof above. It is impossible to know how much settlement will occur as it depends on the density of the bales and the amount of loading applied to them. In practice, 75mm (3”) is usually sufficient, and the frames are built to be 75mm less than the height of a whole number of bales.

**Structural box frame for windows ~** box frame for doors is the same minus the base box.



Except in unusual circumstances, structural frames should be multiples of bale dimensions. So external dimensions of the frame could be anything from half a bale to 3 bales in width and any number of bale heights minus 75mm (3”) to allow for compression or settlement. Door frames would not have the base box as shown above for a window. Instead, the sides of the frame would stand directly on the foundation and be fixed in position with bolts or screws.

**Click here to see drawing** No 10

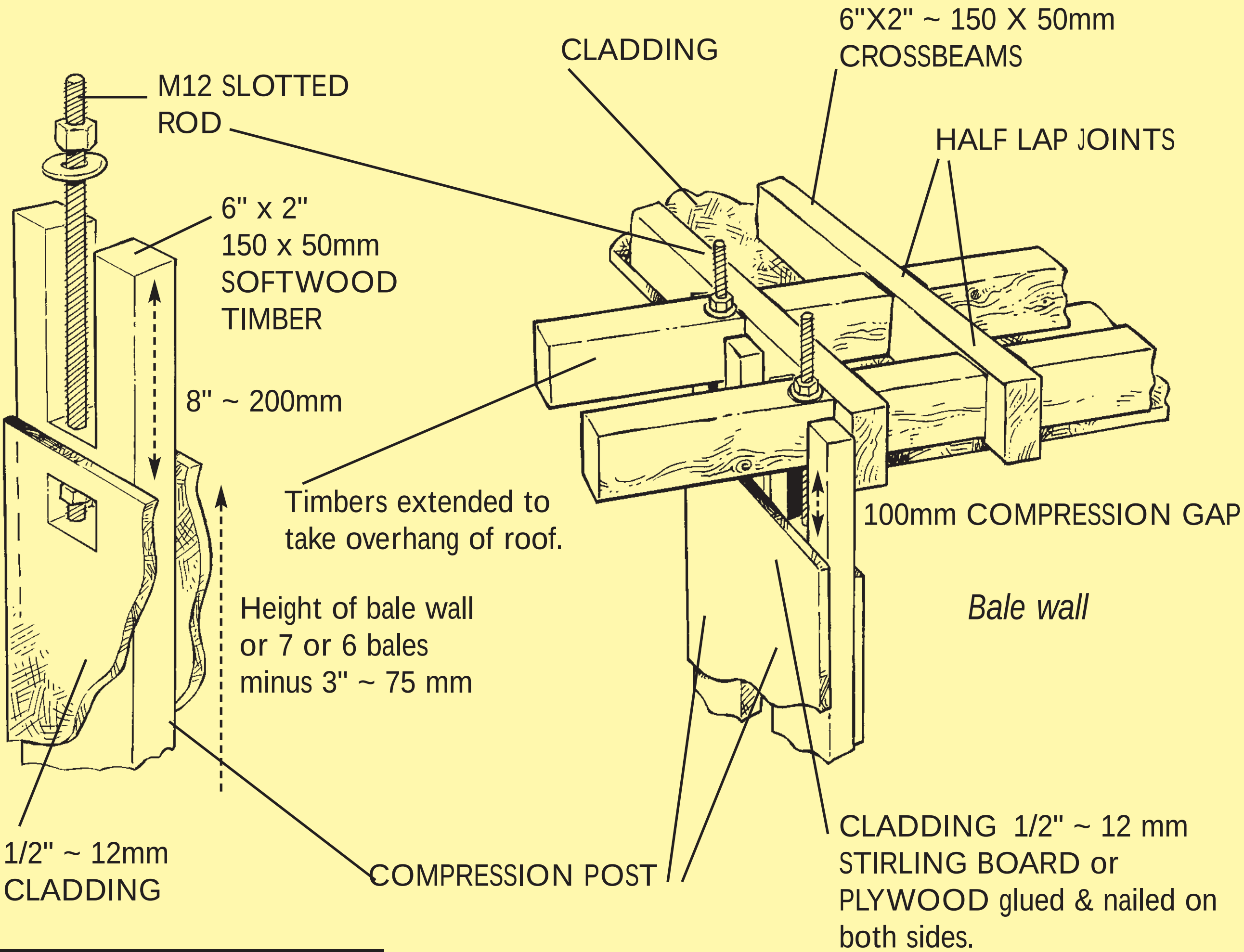
The actual sizes of timber used, particularly for the top of the box, will depend on what weight it has to carry. This will be affected by the design of the wallplate above it, which may be able to partially act as a lintel for the window/door.

## FRAMEWORK METHODS

**Click here to see drawing** No 11

**Click here to see drawing** No 12

In framework methods, windows and doors have upright posts either side of them that run from the base plate to the wallplate above. These posts can be of various designs. A post and beam style would use solid timber and a lightweight frame would use posts slotted at the top to take the wallplate.
(see the diagram on the contents page)



In either case, the framing sill would be fixed only after the straw below it had been placed and compressed manually.

In both designs, it is not necessary to fit the width of the window or door to the bales, but the design should ensure that the gap between fixed posts relates to full or half bale lengths.

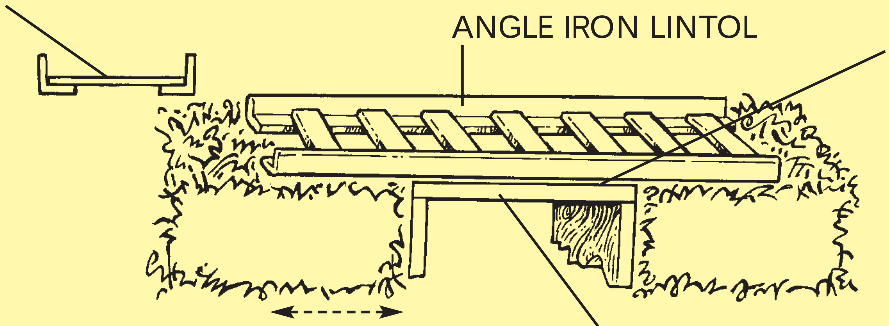
If there is a bale between the top of the window and the wallplate, framing must be designed to carry the full width of the bale, and in the lightweight frame method, allowance should be made for settlement of the wallplate into the slotted posts.

## Other options

### USE AN ANGLE-IRON LINTEL

This is a ladder welded together from angle iron, using cross pieces to form a cradle into which the bale can sit. It must extend a minimum of half a bale width either side of the opening to spread the load.

CAUTION
In general, metal would not be used in the walls as it may encourage condensation of moisture vapour, as it moves from the interior of the house to the outside. If it is used, it should be covered in an insulating material to protect the straw.




**ATTACH** the window and door box frames directly to the wallplate above it. This can be a good option if the design calls for tall windows, but a settlement gap must be left **below** window frames in this case. It has the advantage of reducing the amount of timber required for the frame. However, it is probably only a first choice option on the ground floor of a 2-storey house, as otherwise the overhang of the roof would obscure much of the light.

**Imagine putting a bale of straw into a plastic bag and sealing it up. It will start to get hot and sweaty as anaerobic bacteria flourish.**

Straw is a breathable material. It allows the imperceptible passage of moisture vapour and air through it. If it is sealed by a waterproofing material, it will eventually start to rot.

Straw needs good ventilation around it to stay healthy. In practical terms, this means that anything used to weatherproof or decorate the straw must not block this breathable nature. The ideal finishes for straw are traditional lime based plasters or natural clay plasters, since these are also breathable materials, painted with lime-wash or breathable paints.

## Background to the use of lime.

Lime has been used as a binding material (mortar) between stone and brick and as a surface protector of buildings (called render when used outside, and plaster when used inside) for thousands of years. All European countries used lime for building, hundreds of years before cement was invented. In the UK lime burning was a cottage industry, with local lime pits wherever they were required, and most communities had a working knowledge of its uses and how to produce it. There is no doubt that lime plasters and renders are durable and efficient, well able to do the job of protecting our buildings from the weather.

So, we don't need to argue the case for the ability of lime to withstand the tests of time, weather, and function. However, lime requires thought and understanding of the processes involved in the slow carbonation back to its original limestone, in order to use it successfully. Whilst it is true that a carefully applied lime render or plaster can last for hundreds of years, there have been instances of spectacular failure, and the reasons for these need to be understood if we are not to repeat those mistakes. In essence, the preparation and practice of limework is simple, but variables in the materials themselves, the sand, the lime, and particularly in the weather during application and drying time, are crucial to the overall durability of the material. Traditionally, knowledge about lime was passed down from one generation to the next, and people were used to using it continuously, and so built up a wealth of experience based on a sound knowledge of the material. Today, there are very few skilled craftsmen (We haven't found any women yet) who worked in those times, and we are having to learn as best we can from what we have left, and remembered histories.

To some extent, what that can lead us into is an over technical approach to what was essentially a practical and rather ad hoc building practice. We are trying to specify exact lime/sand mixes when most likely what happened on site was fairly rough and ready, except for the most prestigious jobs. And mostly, it worked! As tens of thousands of houses in the UK, hundreds of years old, can testify. So what follows is an attempt to explain what happens in the lime burning, slaking, mixing process, and what is important to know, so that you can take care of your own limework satisfactorily.

## LIMESTONE AND LIMEBURNING

The raw material for all lime mortars and renders is naturally occurring limestone, shells or coral, which is called calcium carbonate (chemically $CaCO_3$). The process of making lime putty from the stone is relatively simple. Traditionally, the limestone is placed in a specially built kiln (sometimes a pit or a heap) and layered with fuel such as coal or brush and burnt for about 12 hours. It needs to reach a temperature of 900-1200 degrees C; 900 for carbon dioxide ($CO_2$) to be driven off, and 1200 for the heat to penetrate through to the centre of the stone.

As it heats up, steam is driven off first (water, $H_2O$), which is always present in the limestone, and the chemical change of:

$$\text{heat} + CaCO_3 = CaO + CO_2$$

**heat + calcium carbonate = calcium oxide + carbon dioxide**

takes place. At the end of the burning process, whitish lumps of calcium oxide are left with bits of burnt and unburnt fuel. Over burnt limestone appears as black, glassy pieces, and these should be removed and discarded. The chemical reaction that takes place is usually more complicated than this, due to other carbonates and silicates being present in the limestone, but it's important to understand the basic changes that are taking place at this stage. Calcium oxide is very reactive and can be dangerous; it is called "lump-lime" or "quick-lime" and may be left as lumps or ground down into powder. It MUST be kept dry as it reacts very quickly with water, even the water in the air or the moisture in your skin, to form calcium hydroxide, which is the first step to reversing the process back to calcium carbonate again. Just as making quicklime needed heat, the reverse process PRODUCES heat.

**So quicklime added to water gives us... lime putty!**

$$CaO + H_2O = Ca(OH)_2 + \text{heat}$$

**calcium oxide + water = calcium hydroxide**

**Caution: Never add water to quicklime, always do it the other way round and add quicklime to water or else it could explode!**

## HOW TO MAKE LIME RENDER AND PLASTER

There are two main ways to do this

**one:**
**Recipe:**

### Lime putty mix

1 part lime putty
3 parts sand

The sand MUST be well graded and sharp, that is, contain particle sizes ranging from very small (dust) to quite large (5mm or 3/8”), and these should be angular not rounded. When compressed together, the aim is to use as much lime putty as necessary to fill the spaces between the grains (the VOID spaces) but no more. The mix is almost always 3 parts sand to 1 part lime putty (3:1) because the void spaces take up about 33% or 1/3 of the volume of most sands. The only real difference between a plaster (for inside work) and a render (for outside work) is the fineness or coarseness of the sand used. Render may contain aggregate up to 10mm in size in some areas that experience lots of wind driven rain, and usually people prefer a smoother finish on their inside walls, and so would choose a sand with smaller grain sizes. The longer a lime putty has matured, the more solid it becomes, and the better render it makes. It may seem hard to work at first, but by pounding and beating it with wooden mallets or posts it soon becomes more plastic and can be worked into the sand. It can be VERY labour intensive, and this beating part should not be missed out. Because it’s so hard to work, it can be easier to mix the sand with fresh lime putty, and then leave THIS mix to mature for 3 months, traditionally under a thick layer of sand, and then straw!

Well graded sand "SHARP SAND" particle size dust to 5mm.

Poorly graded and round sand with organic debris.

**two:**
**Recipe:**

### Hot lime mix

1 part quicklime powder
3 parts sand

This is probably the most common method used in the past for mortars in the UK. In this method, the quicklime is added to DAMP sand in a bath and mixed with a shovel. Very soon, the mix starts steaming and becomes warm, as the reactive calcium oxide hydrates with the water in the sand. At this point, the mix can be riddled (passed through a sieve, usually 1/4” for renders), as it’s easier to do it when the quicklime has dried out the sand. This process is dangerous because the powdered quicklime blows in the air and can get into eyes and lungs, reacting with the moisture there, plus the mix gets hot very quickly and may be difficult to control. It must be raked and mixed continuously, and may not need any extra water adding, depending on the dampness of the sand. Again, it should be left to mature for at least 3 months.

## HOW TO USE LIME RENDER AND PLASTER

The internal and external faces of the straw walls should be given a very short haircut – trimmed down to a neat finish. All the long, hairy, unkempt bits of straw should be removed. The reasons for this are:

- To minimise flame spread over the surface of the bales, in the event of a fire before plastering.
- To reduce the amount of plaster required by reducing the surface area.
- To even out any large undulations in the surface of the wall.

Plasters and renders can be bought ready-mixed from one of a growing number of suppliers; they can be mixed on site from lime putty and local sand, or sometimes from quicklime and sand, depending on local availability. The lime mix should be applied directly to the trimmed straw.

**There is no need to wrap the straw in stucco or chicken wire first, as many cement rendered buildings in the USA have been. It is totally unnecessary and a waste of time! Both lime and clay stick extremely well to the straw, particularly if applied by hand.**

When the time comes to use a lime mortar or render it should be beaten and worked to a stiff consistency, so sticky that it can be held upside down on a trowel. There should be no need to add water to it, this would increase the risk of shrinkage cracks. It will generally become more plastic with lots of beating! Traditionally, it was a completely separate trade, to be a lime render beater. These days, render can be knocked up in a paddle mill (used by potters) to save all that work by hand. Generally, a cement mixer WON'T do the job as the mix stays in a lump and knocks the machine over, then the tendency is to add water to soften it, and the resultant mix will crack due to too much shrinkage!
The first (or scratch) coat onto straw is usually lime-rich to make it stickier, often a 2:1 mix. The next 2 coats of plaster contain cow or goat hairs, or chopped fibres such as straw or coir, well distributed throughout the mix, to give it much greater strength; in the same way that straw is used in mud plasters, to give it tensile strength.

Click here to see drawing
No 13

**It's probable that lime renders on strawbale walls carbonate more quickly than on stonework, because the straw itself is breathable, and so air has access to the back of the render as well as the surface.**

**It needs to be protected from frost for about 3 months so don't do it too late in the year**

For strawbale walls, it's usually best to apply the first coat of lime by hand (with gloves!) because it's more fun, and the straw tends to flick the stuff back at you otherwise, and it needs to be well rubbed in, to get a good key (join) between the straw and the lime. It's important to encourage the render to cure (go off) from the inside out, not to let the outside skin carbonate too fast, and the way this is done is to keep the whole thing MOIST (not wet).The surface should not be allowed to dry out; it will naturally take 2-7 days before the render feels hard.The first coat should be as thin as possible, leaving stubbly bits of straw sticking out, and will probably be ready for the second coat on the next day, unless there are pockets of thicker mix in places.A rule of thumb, literally, is to put the second coat on when the first is hard enough that you cannot push your thumb into it. Wet the walls down with a mister, not a hosepipe, before putting the second coat on, and work it well in, either with hands again or a wooden float. Keep the render damp by misting it, unless you have ideal drizzling weather! Keep going over the wall with a wooden float, rubbing in the mix and misting it.

Over the next few days, protect the render from direct sunlight, driving rain, forceful wind and frost. Often hanging sacking from scaffolding, and keeping the sacking moist to create a humid atmosphere close to the lime does this.The render WILL crack, and needs to be reworked several times over the next few days to squeeze and compress the sand particles together, before the surface hardens.The cracks are caused by shrinkage as the excess water in the mix evaporates. The aim is to compress all the render so that there are no air spaces left.The misting is not to add water to the render, but to make sure that carbon dioxide can be carried into the thickness of the layer.

It is not a good idea to use a steel float on a lime render, as this polishes up the surface and closes up the texture, thus preventing humid air from penetrating into the body of the render.

## LIMEWASH AND DECORATING

Applying limewash to the building once it's been plastered should be seen as part of the plastering process. If there are any tiny cracks left in the finished plaster, the limewash will seal these up. Over time, lime plasters have a self-healing effect. Any cracks that do appear tend to close up as the lime carbonates, because the calcium carbonate molecule is bigger than the calcium hydroxide one.

Externally, walls that take a lot of weather, usually the south west side, should have about 5 coats of limewash to protect them. The rest of the building may only need 3, although the more coats you apply initially, the better the weatherproofing will be. How frequently it needs re-coating will depend on the weather. The sheltered side may only need limewashing again every 5 years, whereas other parts may need to be done more often.

## NATURAL CLAY PLASTERS AND RENDERS

Although these types of plaster are very common in the rest of Europe, Scandinavia, the USA, the Middle East and Africa, they are not so well known in the UK. Knowledge of their use has largely been lost, although we do still have many fine examples of older buildings with a clay mortar binding the bricks or stones together. And of course, our rich heritage of cob buildings, built entirely of clay and sand, stand testament to the durability of clay finishes.
Depending on the geology of your local area, you may find a clay sub-soil that is ideal for plastering, or pockets of clay that can be added to sand to make a good render. Clay types differ, but in general, a plaster or render needs about 20% clay to 80% sand.

Clay is applied to straw in the same way that lime is. The first coat onto the straw is rubbed in by hand, and would be a thin, clay rich mix. All other coats would have lots of finely chopped straw mixed into the plaster to give it tensile strength and stop it cracking. The final coat would use finer sand to give a smoother finish.
Often, clay coats would be applied before the lime plaster, to even out undulations and to save on the amount of lime plaster used. It is often used as a finish coat inside a house, but would not generally be used on the outside as a finish except in very sheltered positions. Outside, it would probably require several coats of limewash to protect it from the weather.

There is a clay plaster that is commercially available, imported from Germany. It comes in powder form in sacks, and you just have to add water. It works brilliantly well, and there's no waste as anything that is dropped or dries out can just be remixed with water. Different grades are available for the backing coat and finish coats. At the moment, it is expensive to buy, approximately 4 times as costly as the equivalent amount of sand and cement. **It is a market waiting for our own brick companies, to manufacture home-produced clay plasters at reasonable prices!**

Mixing clay and sand from raw materials can be very laborious and time consuming. It works best if the clay is either completely dry so that it can be powdered, or completely wet so it is a thick slurry. In either form, it can then be mixed with sand using a shovel, as though it was cement.
Other ways of mixing are:

- To trample the whole mix by foot. This is a lot of fun if done in a group, but takes a long time and can be tiring.
- To use a paddle mill. Potters may have one of these. It's a round pan with heavy wheels inside that turn and squash the clay mix at the same time as the pan is turning and the clay is scraped up off the base. It's the best way of mixing but it can be hard to find one or expensive to use.
- To use a tractor. This method works very well too, especially for large quantities, but it can take a long time to get all the small lumps out of the mix.

In general, it would not be sensible to mix your own clay plasters except for small buildings, where you have a lot of help, or when you don't have to pay labour costs.

One of the great advantages of taking time to use clay plasters is that it gives a great opportunity for creative expression. The clay can be sculpted and moulded into all sorts of frescoes and reliefs. In fact, it is almost impossible to stop people from being creative with it, it is so tactile and such a lot of fun to apply.

## CEMENT PLASTERS AND RENDERS.

There are hundreds of strawbale buildings in the USA and Canada that have been cement rendered. Most of these are doing fine and are not showing any sign of deterioration. Some of them, however, have become very damp as a direct consequence of using a cement render.

Cement and lime are materials that behave very differently to each other, and are used for different reasons. Whereas lime is a breathable material that holds water within itself whilst it is raining, and releases it once the rain stops, cement is waterproof and works by preventing water from penetrating through it to the surface beneath. Also, lime is quite flexible, whereas cement is rigid. This means that as long as there are no cracks in the cement, it will stop water from reaching the straw. However, due to it's rigidity, it is almost impossible for it not to have cracks in it after a short period of time, especially when it is applied to a flexible backing material like straw. This means that when it rains, the rain passes through tiny cracks and filters down the inside face of the cement, and collects at the bottom of the wall, where it cannot get out. A build up of trapped moisture at the base of the wall causes the rot to set in.

In practice, there may be many instances where you can get away with using cement, or where the life of the building is such that a bit of rot developing at the base of the wall does not matter.

**There is no doubt however, that in terms of best practice, lime renders are superior to cement.**

# PLANNING PERMISSION ISSUES

Planning policy is a political subject that is determined broadly at national level, and in specifics at local level. Whilst there are general similarities throughout the UK, there will be differences in policy locally that reflect local circumstances. However, **the fact that a house is built with straw walls is of very little concern to the planners,** although it will be to the Building Regulation department. The planning department, guided by local elected councillors, will have worked out a comprehensive plan for the Local Authority area that specifies where new housing can be built, which areas are to be kept as green-belt, which is agricultural land etc. Within each area, different types of building will be allowed or not allowed, according to guidelines that have been set by political considerations. It may well be important to know what the planning policy is for your area, and to understand why the Local Authority has made these decisions. For instance, if you wish to build a 3-bedroomed house in a local farmer's field, you are unlikely to get permission to do so, because the field is probably designated as agricultural land and therefore no domestic buildings will be allowed. However, if you wish to build on a site next to other houses, you probably would get permission.

**It is advisable to have a good relationship with your planning officer.**

Most planning decisions are subjective and political, and your planning officer can be of invaluable help in informing you of basic policy, and of particular circumstances in which there may be room for negotiation. It is a sensible approach to recognise your planning officer as someone who has useful knowledge that can be shared with you to enhance your project. An application for planning permission has more chance of success if the planning officer supports it. It is always best to find a way to work together, if at all possible.

## AREAS OF CONCERN FOR PLANNERS

### WHAT DOES IT LOOK LIKE?

All Local Authorities will be concerned primarily with this question. In general, your building must fit in with local surroundings, it usually has to look similar to others in the locality and not be an eyesore. Of course, what we each define as eyesore can vary dramatically! Some think concrete bungalows are beautifully modern, and others hate them. In areas of the Pennines, for instance, all houses must be built of local stone. However, some developers have argued successfully to build out of concrete that looks like stone. And there's at least one strawbale building that has planning permission as long as the outside render is stone coloured. This illustrates really well the possibilities for negotiation that exist within any planning policy.

## WHAT WILL IT BE USED FOR?

The purpose for building is important. Are you going to live in it, open it as a shop, store machinery in it, hold band practices? Homes usually require access for vehicles and means of dealing with sewage and waste water.

What you do in it has implications for wider services and the impact you'll make on the social and physical environment. Just because you want to live on a Greenfield site and make little impact on the environment doesn't mean the planners will let you . They may be concerned, not about you, but about the owners who come after you when you sell. And just because you think you can deal with your own sewage and waste water doesn't mean that the planners will agree. Besides, some areas will be designated for housing and others for remaining unspoilt. It will be difficult in any area (though not impossible) to cross these boundaries.

## WHAT DO THE NEIGHBOURS THINK?

This isn't necessarily as big an issue as it may seem. Planners do have to take into account different viewpoints and in some areas anything new or different will cause a stir but there have to be legitimate reasons in order to object to it. Planners may choose not to contend with a powerful local lobby that has no real grounds for objection, or they may think it's politic not to ignore them. However negative reactions from the neighbours may simply be seen as emotional responses to change, and positive reactions may help you argue your case for innovative design.

## ENVIRONMENTAL ISSUES & AGENDA 21.

Every Local Authority has the duty to implement European directives (Agenda 21) relating to issues of sustainability and protection of the environment. The emphasis these directives are given can vary tremendously from one Local Authority to the next, but in general there is now greater awareness of the need to build using materials and practices that are less harmful to the planet. If your house fulfils some of these directives, the planners may react more favourably to it, even if it differs in some significant way from other planning guidelines. For instance, a plastered strawbale house may be allowed in an area where most houses are brick because although it looks different, it provides three times more insulation – thus reducing dependence on fuel, fossil fuels etc – than equivalent houses in the locality.

There is no need to be unduly worried about whether your strawbale house will meet all the Building Regulation Requirements. It definitely can, and almost certainly will! It's important to understand that we "regulate buildings" in order to make sure that they do not pose a threat to anyone or anything in terms of health and safety.
The building regulations are contained in a number of Approved Documents, readily available from any HMSO bookstore.
The Documents are labelled from A to N, and each cover different aspects of building. They clearly state:

> **"The detailed provisions contained in the Approved Documents are intended to provide *guidance* for some of the more common building situations."**

(my italics) and:

> **"There is no obligation to adopt any particular solution contained in an Approved Document if you prefer to meet the relevant requirement in some other way."**

'Approved Document A' for instance, refers to the structure of a building and will advise you on the minimum thickness your walls should be, and the thickness of concrete you should have in your foundations. This example immediately highlights a major issue around strawbale building and the building regulations; the regulations are written to cover the most common types of 20th century building materials, that is, concrete, brick and timber. If you are choosing to use other types of materials, or to use the same ones in different ways, then you will have to discuss this with your Building Inspector, because there will be no written guidelines. They do not mention straw walls 450mm thick, built on timber posts foundations, for instance. But this does not mean you cannot do it. On the whole, Inspectors are sensible, well-informed people who are up to date with current developments in building practice. They have lots of useful knowledge that can be of help to you in designing your building, and can access their colleagues around the UK or other advisors if they need to inform themselves further about the subject.

There are many people in the construction industry who are not aware that there are other ways of building, or who are nervous of stepping away from what they know, and what is written in the Approved Documents.

This does not mean it cannot be done, and your Inspector is often the best person to help you with this, (together with your strawbale advisor of course!). When contemplating building anything new or unusual it is necessary to go back to first principles and look at what the aim of the Regulations is. When a wall has a greater thickness, as a strawbale one does, but weighs a lot less than more common materials such as brick, then it is reasonable to assume that the foundations would not necessarily need to be as substantial as for a brick wall in order to provide the same level of stability.

The Regulations cover all aspects of building, but for our purposes in the use of straw, the only areas that are substantially different to other types of common 20th century styles are the walls and therefore the foundations. So the areas of concern for Building Inspectors are:

- INSULATION
- FIRE
- STRUCTURE
- DURABILITY (including degradation due to moisture)

## THERMAL INSULATION

Nowadays, all new buildings must be energy efficient. This covers many aspects of the building, including design to reduce heat loss. The usual way we do this is by using insulation of one sort or another. In brick or block walls, this often takes the form of an expanded polystyrene or foam stuck to the back of the blocks inside the cavity of the wall. With strawbale walls, the insulation (straw) is also the building block.

The amount of insulation of a material is measured by its U-value.

**The U-value, or thermal transmittance, of a material is the amount of heat transmitted per unit area of the material per unit temperature difference between inside and outside environments.**

It is measured in units of Watts per square metre per degree of temperature difference (usually measured in Kelvin) W/m2K. Put simply, it's a measure of how much heat a material allows to pass through it.

**The lower the U-value, the greater the insulation of the material.**

Building Regulations currently require that walls of domestic dwellings must have a U-value of 0.45 or less. The requirement for insulation in walls will be increased next year to a U-value of either 0.35 or 0.25

**Strawbales, because their width is 450mm (18") have a U-value of 0.11**

The high insulation value of straw is achieved because of the width of the bales.

Compare the U-value of straw with the U-values of other common wall building materials:

**450mm straw wall - 0.11**

105mm brickwork, 75mm mineral fibre,
100mm light concrete block, 13mm lightweight plaster: ———— **0.33**

100mm heavyweight concrete block, 75mm mineral fibre,
100mm heavyweight concrete block, 13mm lightweight plaster: ———— **0.40**

100mm lightweight concrete block, 75mm mineral fibre,
100mm lightweight concrete block,13mm lightweight plaster: ———— **0.29**
(CIPSE: Thermal Properties of Building Structures)

There is no doubt that strawbale walls exceed by far the requirements of Building Regulations for thermal insulation.

## SOUND INSULATION

New regulations are due next year (2002) covering sound insulation of buildings in order to make homes quieter.
There are, as yet, no official research findings for quantifying the level of sound insulation provided by strawbales. However, we have overwhelming experiential evidence that straw walls offer far more sound insulation than 20th century wall building techniques. People who live in, use or visit strawbale buildings remark on the quality of atmosphere found inside one. They are cosy, calm and quiet. They offer a feeling of peace. There are at least two sound studios in the USA built of straw because of its acoustic properties, and several more meditation centres. Amazon Nails was involved in building a strawbale meditation centre in Ireland in 1998. Strawbale walls are increasingly being used by airports and motorway systems as soundbarriers to reduce traffic noise.

## FIRE

There is no question that strawbale walls fulfil all the requirements for fire safety as contained in the Approved Documents.

**Strawbale walls are less of a fire risk than timber frame walls.**

Research in the USA and Canada has proved this, as these quotes from research documents illustrate:

*"The straw bales/mortar structure wall has proven to be exceptionally resistant to fire. The straw bales hold enough air to provide good insulation value but because they are compacted firmly they don't hold enough air to permit combustion."*
Report to the Canada Mortgage and Housing Corporation.
Bob Platts 1997

*"ASTM tests for fire-resistance have been completed… The results of these tests have proven that a straw bale infill wall assembly is a far greater fire resistive assembly than a wood frame wall assembly using the same finishes."*

Report to the Construction Industries Division by Manuel A. Fernandez, State Architect and head of Permitting and Plan Approval, CID, State of New Mexico, USA.

It is a popular misconception that strawbale buildings are a fire risk. This misconception seems to come partly from the confusion of straw with hay, and the collective memory of (relatively rare) spontaneous combustion in hay barns (from large haystacks baled too wet and green). Straw is a very different material to hay, and much less likely to combust when stored in poor conditions – indeed there are no known cases of spontaneous combustion with straw.

There is a greater risk of fire with straw during the storage and construction process. It is loose straw which is the risk, since it readily combusts. If you were to cut the strings on a bale and make a loose pile of the straw, it would burn very easily, as it contains lots of air. Therefore it is essential to clear loose straw from the site daily, store strawbales safely, have a no-smoking policy on site, and protect the site from vandalism.

Once the straw is built up into a single bale wall it tends to behave as though it were solid timber, particularly when it is loadbearing, but also when used as infill. In a fire, it chars on the outside and then the charring itself protects the straw from further burning.

When the wall is plastered both sides, the risk of fire is reduced even further, as the plaster itself provides fire protection.

A list of research documents can be found in the reference section.

For the purposes of building regulations, a wall built of *any* material that is covered with half an inch of plaster has a half hour fire protection rating, which is the requirement for domestic buildings. All the fire-testing research done on straw-bale walls, all concludes that this type of wall-building system is ***not*** a fire risk.

## STRUCTURE

The requirements laid down in 'Approved Document A: Structure', are for brick, concrete or timber walls. You will find no guidance here for building strawbale walls. This does not mean it cannot be done! Research has shown that structural loadbearing strawbale walls can withstand loads of more than 10,000 lbs/sq.ft equivalent to 48,826 kg/m2.

*Research by Ghailene Bou-Ali:*
*Results of a Structural Straw Bale Testing Program 1993*

There is no doubt that loadbearing straw walls can withstand greater loads than will be imposed on them by floors, roofs and possible snow loading. It is the design of associated timber work, the even spread of loads around the walls, and the quality of building which is crucial here, ***not*** whether the straw can do it.

With infill walls, in post and beam type structures, the straw does not take weight anyway and there are conventional calculations available for structural strength of other types of framing.

## DURABILITY

This is the area of most concern when designing straw bale houses in order to comply with Building regulations.
Will the strawbale walls retain their structural integrity over time, or will they suffer material degradation caused by moisture, either from condensation, rain or ground water?
Whilst this is a consideration for all house builders, in fact all building regulations require is that the walls pose no threat to health and safety.There has been no research so far on the durability of strawbale houses in the UK climate. What little research has been done in the USA and Canada shows that there should be no *need* to be concerned that strawbale walls will not withstand the test of time and the rigours of our climate. The key to durability lies in good design and good quality work. Past experience is an allowable and viable method of establishing the fitness of a material as it says in the 'Approved Document To Support Regulation 7' (Materials and Workmanship):

**'The material can be shown by experience, such as in a building in use, to be capable of performing the function for which it is intended'.**

There is also a specific reference to the use of short-lived materials:

**'A short-lived material which is readily accessible for inspection, maintenance and replacement may meet the requirements of the Regulations provided that the consequences of failure are not likely to be serious to the health or safety of persons in and around the building.'**

In any case, a building that is designed well and built well should not experience any long term effects of degradation due to moisture. There are plenty of examples in the USA of houses enduring for over 50 years with no signs of deterioration. However, it is true to say that our experience of building in the UK is only 5 years old, and we do not have either empirical or practical research to be able to state with certainty that strawbale buildings will survive for long time periods in our climate. We do, though, know that even if there is degradation of the straw, it a) is easily repaired and b) degrades slowly and therefore poses no risk to safety.

You need to be careful about what you read in books and on the internet about strawbale building and how it must be done. Most of the information available up to now is based on American Building Codes and methods of building, which are not necessarily appropriate for us in the UK. There is a fundamental difference between the USA Codes of practice and the UK Building Regulations, and that is:

**In the USA, Codes are proscriptive, that is, they tell you that you MUST do it this way.**
**In the UK, Building Regulations are guidelines, they advise you on best practice, but you can do it another way if you can show it's effective.**

## What about mice and rats?

There is no greater risk of encouraging mice and rats into your strawbale house than there is for any other type of building. Straw is the empty stem of a baled hay crop and unlike hay, it doesn't contain food to attract furry creatures. Any home where food is left out in the open is a potential lure for vermin. Once your strawbale house is plastered, the walls seem no different to a mouse than other plastered walls. Mice and rats like to live in spaces between things, as they are very sociable animals. In barns, they live in the gaps between bales and in houses they live in cavities and under floors. If you build straw walls and then clad them in timber, with an air gap between, this might attract mice: but it's the gap they like, not particularly the straw. If you build straw walls and plaster them with clay/lime, then there are no gaps to invite them in, and no cavities in which they can live.

## How long will it last ?

No one can completely answer this question because the first strawbale house was built only about 130 years ago. In the USA there are about a dozen houses nearing 100 years old that are still inhabited and showing no problems. They have an increasing stock of houses built since 1980 that are also surviving with no problems. Here in the UK, we started building 7 years ago. As with any other technique of house building, if your straw bale house is built with a good design, with quality work and is properly maintained throughout its life, there is no reason why it should not last **at least** 100 years.

## Isn't it a fire risk ?

No. It may seem strange, but when you stack bales up in a wall and plaster them either side, the density of the bales is such that there isn't enough air inside the bales for them to burn. It's like trying to burn a telephone directory – loose pages burn easily, but the whole book won't catch fire. Straw bale walls have passed all the fire tests they have been subjected to in the USA and Canada. Despite the bales themselves not being a risk, if you plaster any wall with a half inch of plaster, it gives sufficient fire protection to satisfy building regulations.

## Is it really cheap to build ?

It depends entirely on your approach to building. If you can put lots of time into collecting recycled materials, or doing the drawings yourself and keep the design simple, or organise training workshops to build the walls and plaster them, then yes, it can be cheap to build. For most people, it is more sensible to think of doing the simple bits yourself (design, foundation, straw and plaster), and employing others to do the rest (carpentry, roofing, plumbing and electrics). A small 2 roomed building might cost about £10,000, a large 3 bedroomed house could be £40,000. Savings are greater on bigger buildings.

**But the real point is that strawbale buildings are much cheaper to run once they've been built, because savings in energy/fuel costs due to the high insulation, can be as much as 75% less than in a conventional house.**

## Can I do it myself ?

Yes, parts of it are quite easy to build. Other parts like roofing and carpentry are more difficult. It depends on how much time, determination and dedication you have. But the straw building technique is simple, straightforward and accessible to almost anyone.

## What about temporary buildings ?

Design of strawbale buildings is very versatile, and can be adapted for a more or less durable function. If a building is only required for a few years, then there may be no need to build elaborate foundations, or plaster it inside or even outside.

## What else can be built with straw ?

Straw has been put to many uses. Apart from houses, studios, offices and community spaces, straw is also used for warehouses, barns and stables, sound studios, mediation centres, acoustic barriers for airports and motorways, food storage and farm buildings.

## What if some of my bales do get wet?

It depends on where, and how badly.
Generally, if a bale gets wet through the top or bottom into the centre, then it will not dry out before it starts rotting. So any bales that are rained on, or stand in water whilst in storage, should be discarded. This also applies to any bales already in the walls that are not covered against the rain. But if you have covered the tops of the bales, and the sides get wet from the rain, this usually presents no problem, as they will quickly dry out once the rain stops. The only time this may not be the case is if the walls are exposed to severe wind and rain at the same time for prolonged periods, as the wind may drive the rain into the bale, where it cannot dry until the rain stops.

## Is it possible to repair straw walls ?

It is not only possible, it's very easy! The hardest part is making a hole through the straw. This can be done with the claw on a hammer or crowbar, and by just pulling at the straw. It can be quite difficult to make the first hole due to the density of the bale. However, once this is done, wedges of the bales can be pulled out quite easily. Hazel pins can be cut through if necessary, and fresh straw wedges can be packed tightly back to fill the gap.

## What if I want an extra window?

Again, it's fairly easy to cut through the walls to create a window-sized hole. Usually, there is no need to support the rest of the wall as the wallplate carries most of the load, and the strawbales act together as an integral material. Either follow the method above, or you can use a hayknife, even a chainsaw, although power tools like this tend to clog up very quickly. Once you've cut the hole, a structural boxframe can be fixed into the gap, with the window inside this.

## Can I use straw to add an extension to my house?

Yes, both loadbearing and framed systems work well here. You may need to think carefully about settlement, and not make the final attachments from the straw to the house wall until after the walls are compressed.

# BOOKS



**THE BEAUTY OF STRAW BALE HOMES**
2000 by Athena and Bill Steen
A wonderfully inspiring book showing just what it says; a range of pictures with brief descriptions of strawbale homes in the USA and Canada.

**BUILD IT WITH BALES** (Version Two)
1997 by Matts Myrhman and S.O. Macdonald.
This is the best and most 'hands on' manual for self-building with straw.

**BUILDING WITH LIME**
1977 by Stafford Holmes and Michael Wingate
An extensive handbook for construction uses of lime for floors, washes, wattle & daub, plasters, mouldings, mortars & more.

**BUILDINGS OF EARTH AND STRAW - Structural Design for Rammed Earth and Straw-Bale Architecture** 1997 by Bruce King.
A technical book but written in an entirely accessible and entertaining way, for uninitiated builders and 'professionals' alike, exploring the methods of building safe and durable straw and earth houses.

**THE COB BUILDERS HANDBOOK**
1996 by Becky Bee
Covers design, site selection, materials, foundations, floors, windows, doors, finishes & creative cob building techniques.

**THE COBBERS'S COMPANION**
2001 by Michael Smith How to build your own low cost cob home.

**EARTH PLASTERS FOR STRAW BALE HOMES**
2000 by Keely Meagan
Covers earthen recipes, testing, problems, how to mix and apply each coat and tools.

**SERIOUS STRAW BALE – A Home Construction Guide for All Climates**
2000 by Paul Lacinski & Michel Bergeron
A Canadian book on design and build covering the serious issues of moisture, humidity and temperature.

**SHELTER** 1973 by Lloyd Kahn
A classic, fascinating book on the variety of structures possible

**STRAW BALE BUILDING – How to Plan, Design and Build with Straw**
2000 By Chris Magwood and Peter Mack
A useful guide for the owner-builder

**STRAW BALE CONSTRUCTION DETAILS BOOK**
Edited by Ken Haggard and Scott Clark
Published by CASBA – good resource for designers, and owner-builders.

**STRAWBALE HOMEBUILDING** 2000 – Earth Garden Books
Collection of Australian building experiences – but where they are still using cement plasters.

**THE STRAW BALE HOUSE** 1994 by Athena Swentzell Steen, Bill Steen & David Bainbridge.
This is an extremely popular and informative book based on the American experience, with beautiful, full colour photographs.

# BOOKLETS

**APPROPRIATE PLASTERS FOR COB AND STONE WALLS**
By the Devon Earth Building Association.
This pamphlet covers use of lime plasters and washes for protection and repair of cob and stone walls.

**COMPACT HOME PLANS FOR STRAWBALE AND SUPERINSULATED CONSTRUCTION**
Community Ecodesign Network - Plans available to buy.

**THE GREEN BUILDING DIGEST**
Department of Architecture, Queens University, Belfast
a guide to building products and their impact on the environment.

**A GUIDE TO STRAW BALE BUILDING**
By Barbara Jones
Basic techniques of loadbearing construction, with information pack,

**HOUSE OF STRAW – Straw Bale Construction Comes of Age**
1995 By US Department of Energy

**HOW TO BUILD WITH STRAW BALES**
by Kevin Beale
A good brief guide to straw bale building.

**AN INTRODUCTION TO THE USE OF LIME AND MUD IN RENDERS AND PLASTERS FOR STRAWBALE BUILDINGS**
by Barbara Jones of Amazon Nails

**RAMMED EARTH CAR TYRE FOUNDATIONS**
By Barbara Jones of Amazon Nails

**SELF-DRAINING FOUNDATIONS**
By Barbara Jones of Amazon Nails

**A VISUAL PRIMER TO STRAW-BALE CONSTRUCTION IN MONGOLIA**
By Steve MacDonald

# VIDEO

**BUILDING WITH STRAW VIDEO SERIES**
By Black Range Films
Vol 1 - A Straw Bale Workshop ~ View post and beam SB building at a weekend workshop
Vol 2 - A Staw Bale Home Tour ~ tour 10 homes ranging from low cost to luxury
Vol 3 - Straw Bale Code Testing ~ US building codes testing – impressive stuff

**HOW TO BUILD YOUR ELEGANT HOME WITH STRAW BALES**
Video and manual set for load bearing construction. By Sustainable Systems Support

**STRAW BALE CONSTRUCTION: BEAUTIFUL SUSTAINABLE BUILDINGS**
Straw House Herbals

**STRAW BALE CONSTRUCTION – THE ELEGANT SOLUTION**
By Sustainable Systems Support.
Inspirational first video produced about strawbale construction in 1992.

**THE STRAW BALE SOLUTION**
By NetWorks Productions.
Overview of benefits of building with straw, featuring the work of Bill and Athena Steen in Mexico

## UK

Amazon Nails www.strawbalefutures.org.uk barbara@strawbalefutures.org.uk

Association for Environment Conscious Builders (AECB) www.aecb.net infor@aecb.net

The Building Limes Forum (BLF) Michael.wingate@zetnet.co.uk

Centre for Alternative Technology (CAT) www.cat.org.uk

The Scottish Lime Centre scotlime@aol.com

Society for the Protection of Ancient Buildings (SPAB)
37 Spital Square London E1 6DY Tel: 0044 171 3771644

Strawbale Building Association for Wales, Ireland, Scotland & England (WISE)
www.strawbalebuildingassociation.org.uk info@strawbalebuildingassociation.org.uk

Women & Manual Trades lwamt@dircon.co.uk

## USA & CANADA

California Straw Building Association (CASBA)
www.strawbuilding.org casba@strawbuilding.org

The Canelo Project
www.caneloproject.com absteen@dakotacom.net

CRATerre
www.craterre.archi.fr craterre@club-internet.fr

DAWN/Out on Bale by Mail
www.greenbuilder.com/dawn dawnaz@earthlink.net

Development Center for Appropriate Technology (DCAT)
www.azstarnet.com/~dcat info@dcat.net

The Last Straw www.strawhomes.com

Surfin' StrawBale
www.moxvox.com/surfsolo.html & www.mha-net.org/html/sblinks.htm

## EUROPE

European Straw Building Network (ESBN) strawbale-l@eyfa.org

Belgium: www.inti.be/ecotopie/ballots.html
Chechia: www.fsv.cvut.cz/lists/ekodum/2001/msg00090.html
Denmark: www.folkecenter.dk/strawbale/inspirations-manual/inspirations-manual-1.html
France: www.la-maison-en-paille.com & www.constructionfibres.citeweb.net/index.html
Germany: www.strawblehouse.de/
Hungary: www.draconis.elte.hu/szalma/zemplen/zemplen.html or text version
www.draconis.elte.hu/szalma
Netherlands: www.ndsm.nl/locatie/docs/houtenkop.html www.rened.cistron.nl
Norway: www.strandsjo.no/htms/over-tysk.html

## AUSTRALIA www.strawbale.archinet.com.au

BALE WALL COMPRESSION TESTING PROGRAMME
Lab-tested 2-string and 3-string walls at Colorado University in 1998.
Info: www.users.uswest.net/~jruppert2/odisea.htm

COMPARATIVE COST ANALYSIS BETWEEN BUILDING METHODS
Investigates the economics of different construction techniques
Contact: Willow Whitton, 20819 NE Interlachen Ln, Troutdale, OR 97060 USA

DEVELOPING AND PROOF-TESTING THE 'PRESTRESSED NEBRASKA' METHOD FOR IMPROVED PRODUCTIONOF BALED FIBRE HOUSING – 1996
Linda Chapman & Robert Plats.
Test report documents development and testing of a prestressed SB wall system.
Summary available from CMHC (Canadian Mortgage & Housing Company)
www.cmhc-schl.gc.ca

EVALUATION OF A STRAW BALE COMPOSITE WALL
Schmeckpeper & Allen 1999
Tests performed on an unusual light-gauge steel/straw bale wall system
Allen Engineering, 917 10th Street, Clarkson, WA 99403, USA

INVESTIGATION OF ENVIRONMENTAL IMPACTS; STRAW BALE CONSTRUCTION
By Ann V Edminster, 1995
In-depth investigation of the environmental impacts of SB construction
avedminster@earthlink.net

MOISTURE IN STRAW BALE HOUSING – Nova Scotia
By S.H.E Consultants, Canada, 1998. sheconsl@istar.ca

NEW MEXICO ASTM E-119 SMALL SCALE FIRE TEST & STRUCTURAL TESTING
Straw Bale Construction Association (SBCA) 1993.
Includes SHB AGRA Lab report, Thermal Testing report from Sandia National Lab and report from New Mexico Construction Industries Division
Copies available through 'The Last Straw' Journal – thelaststraw@strawhomes.com
www.strawhomes.com

PILOT STUDY OF MOISTURE CONTROL IN STUCCOED STRAW BALE WALLS 1997
Illustrated report of the findings of a physical study into the walls of several older Quebec-area SB structures to determine how moisture is affecting them.
www.cmhc-schl.gc.ca

STRAW BALE CONSTRUCTION RESEARCH PROJECT
BY Portland Community College Engineering Technology Dept
An ongoing study of moisture levels in the walls of a small unoccupied building in the Pacific Northwest, now in its fifth year. Joanna Karl – jkarl@pcc.edu
Or Lis Perlman – lisp@iname.com

STRAW BALES & STRAW BALE WALL SYSTEMS BY Ghailene Bou Ali, 1993

Study of structural performance of bales and bale walls, which influenced Tuscon building codes. Short illustrated report on this research available as 'Summary of a Structural Straw-Bale Testing Programme' – available from TLS – thelaststraw@strawhomes.com

STRAW BALE MOISTURE MONITORING REPORT FOR THE CMHC, 1998

Thorough reporting of four case studies in Alberta, Canada.

Summary available via email – robejoll@gyrd.ab.ca

STRUCTURAL BEHAVIOUR OF STRAW BALE WALL CONSTRUCTION, 1998

John Carrick & John Glassford

Compressive, Transverse and Racking load tests of 2-string rice straw bales as called up by the Building Code of Australia.

huffnpuff@shoal.net.au

www.strawbale.archinet.com.au

TESTING STRAW-BALE CONSTRUCTION IN THE SOGGY NORTH-WEST

BY Aprovecho Research Centre

apro@efn.org

www.efn.org/~apro/strawbale.html.

THERMAL & MECHANICAL PROPERTIES OF STRAW BALES AS THEY RELATE TO A STRAW HOUSE 1995, by K Thompson, K Watts, K Wilkie, J Corson.

Reports on structural testing of bales and thermal & moisture monitoring of a SB house in Nova Scotia.

kimt@chebucto.ns.ca

www.chebuto.ns.ca/~aa983strawhouse.html

THE THERMAL RESISTIVITY OF STRAW BALES FOR CONSTRUCTION

By J C McCabe, 1993

Established R-values for wheat & rice straw bales.

http://solstice.crest.rog/efficiency/straw_insulation/straw-insul.html

# CONSTRUCTION DRAWINGS



1. First course Bale detail
2. Bale Plan
3. North Elevation
4. South Elevation
5. Frame Layout
6. Frame A & B
7. Frame CDE & F
8. Frame J & K
9. Frame L & M
10. Detail-threaded rod
11. Post layout and wallplate
12. Window and door reveals
13. Corner post detail
14. Ground and first floor layout
15. Section through

The majority of these drawings relate to a self-build straw bale house near Ledbury, Herefordshire.

The others come from previous projects by Amazon Nails

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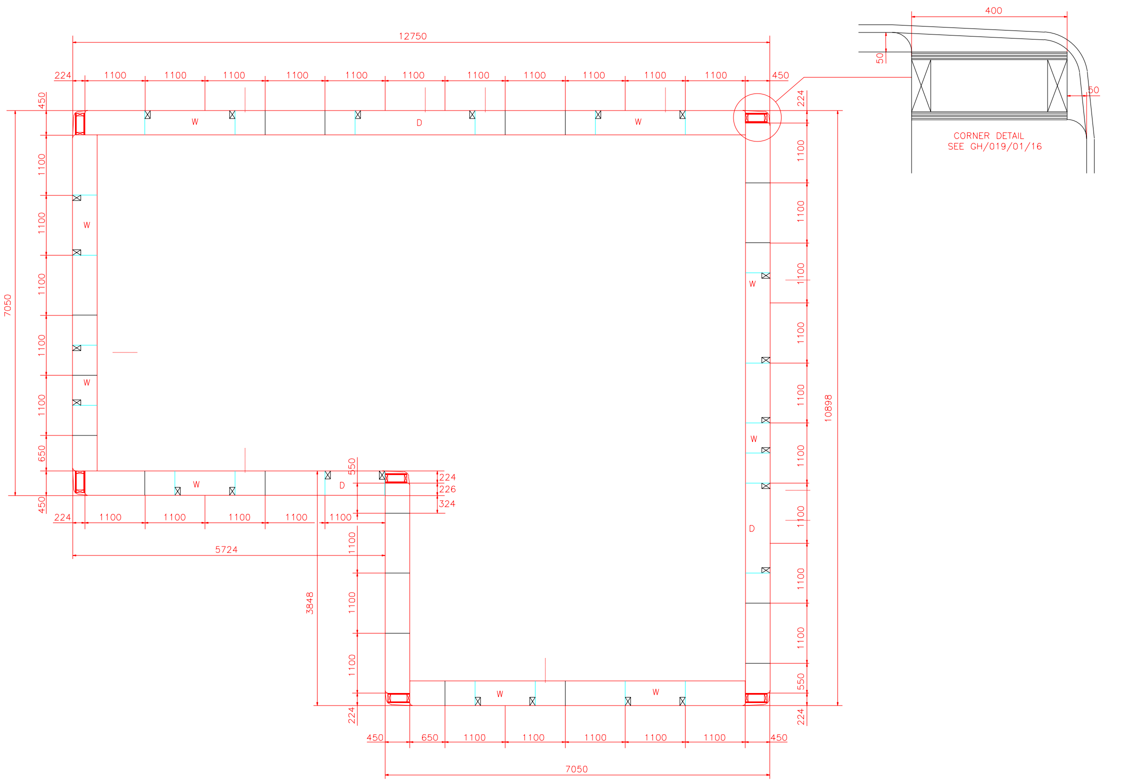


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Kester & Zinnia Wilkinson

# FIRST COURSE BALE DETAIL

| | | |
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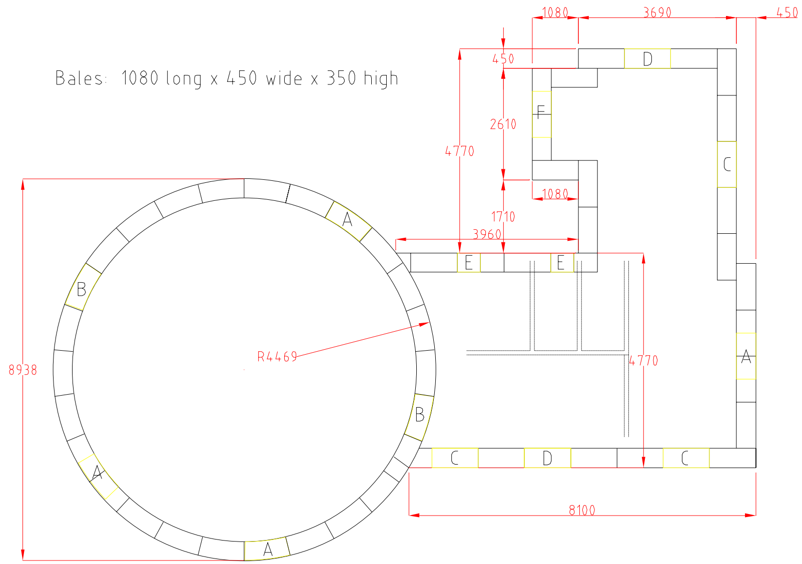
Bales: 1080 long x 450 wide x 350 high

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| Designed by Barbara Jones | Checked by B.J | Approved by - date 17-10-01 | Filename STRAW | Date 17-10-01 | Scale 1:50 |

Bale Layout

The Womens Centre

sh/twc/01/3 | Edition A | Sheet 3 of 6

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NORTH ELEVATION
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NORTH ELEVATION

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SOUTH ELEVATION
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| Kester & Zinnia Wilkinson | SOUTH ELEVATION | | |
| | sh/kw/01/2 | Edition<br>A | Sheet<br>2 |

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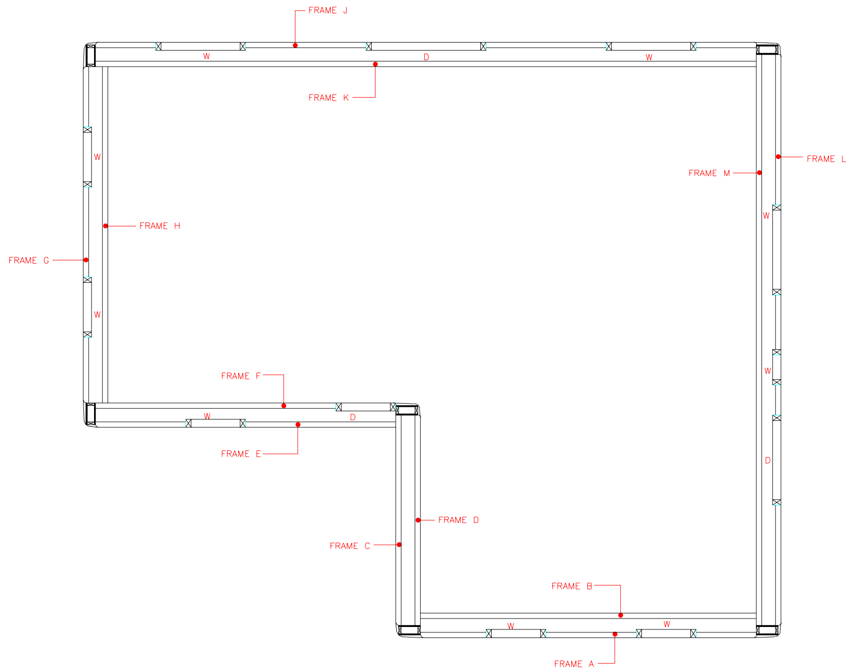
SEE DRG. No's 19,20,21 AND 22
CHECK DIMENSIONS ON SITE.

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| Designed by kw/gh/bj | Checked by bj | Approved by - date 6-10-01 | Filename STRAW HOUSE | Date 17-10-01 | Scale 1:50 |

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# FRAME LAYOUT

| sh/kw/01/8 | Edition A | Sheet 2 |
|---|---|---|

| RevNo | Revision note | Date | Signature | Checked |
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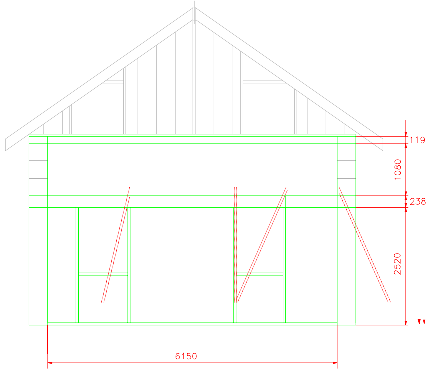
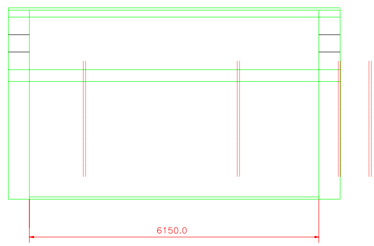
PERMANENT TIMBERS
TEMPORARY TIMBERS

CHECK DIMENSIONS ON SITE

SEE DRG.No's 13A,15 & 23.




FRAME A (FRAME G TO PAIR)
SCALE 1:50




FRAME B (FRAME H TO PAIR)
SCALE 1:50

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| Kester & Zinnia Wilkinson | | FRAMES A & B | | | |
| | | sh/kw/01/9 | | Edition A | Sheet 1 |

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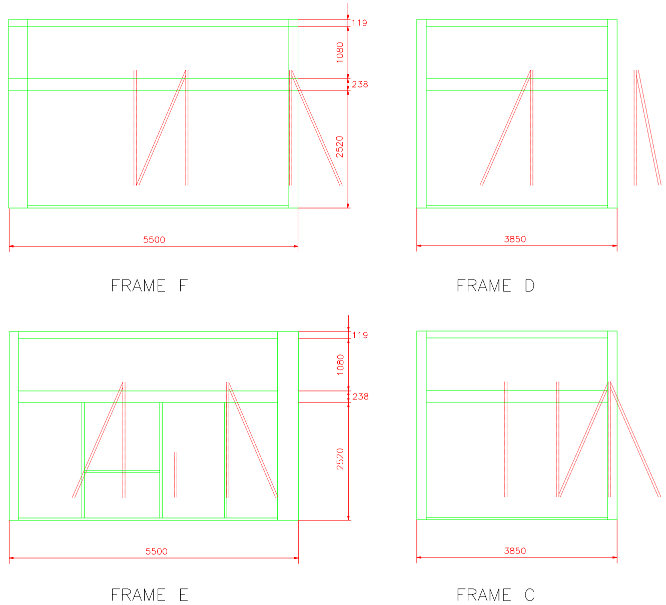


SCALE 1:50

PERMANENT TIMBERS

TEMPORARY TIMBERS

CHECK DIMENSIONS ON SITE

SEE DRG.No's 13A,15 & 23.

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| Kester & Zinnia Wilkinson | | | Frames C,D,E & F | | | |
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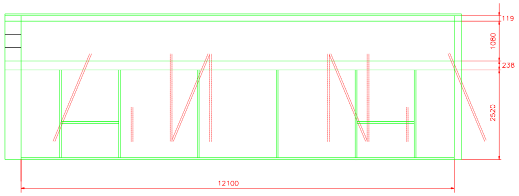
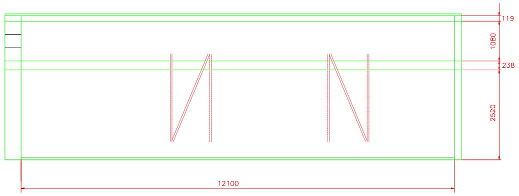



FRAME J
SCALE 1:50




FRAME K
SCALE 1:50

PERMANENT TIMBERS
TEMPORARY TIMBERS

CHECK DIMENSIONS ON SITE

SEE DRG.No's 13A,15 & 23.

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| Designed by kw/gh/bj | | Checked by bj | Approved by - date 6-10-01 | Filename STRAW HOUSE | Date 17-10-01 | Scale 1:50 |
| Kester & Zinnia Wilkinson | | FRAMES J & K | | | | |
| | | sh/kw/01/12 | | | Edition A | Sheet 1 |

| Rev.No | Revision note | Date | Signature | Checked |
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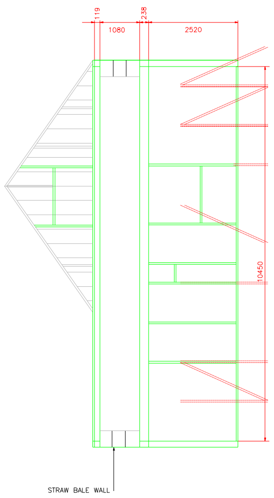
PERMANENT TIMBERS

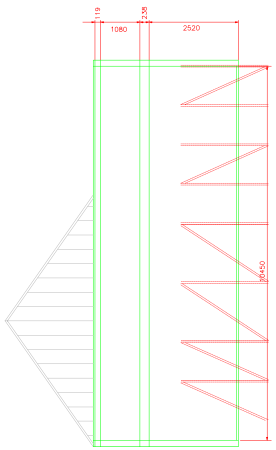
TEMPORARY TIMBERS

CHECK DIMENSIONS ON SITE

SEE DRG.No's 13A,15 & 23.




FRAME L
SCALE 1:50




FRAME M
SCALE 1:50

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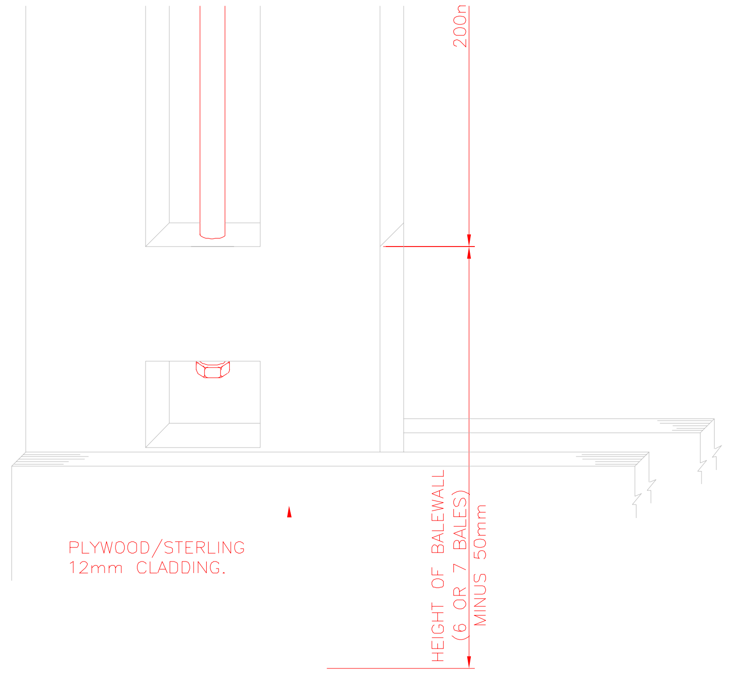
| Kester & Zinnia Wilkinson | | FRAMES L & M | | | |
| | | sh/kw/01/11 | | Edition A | Sheet 1 |

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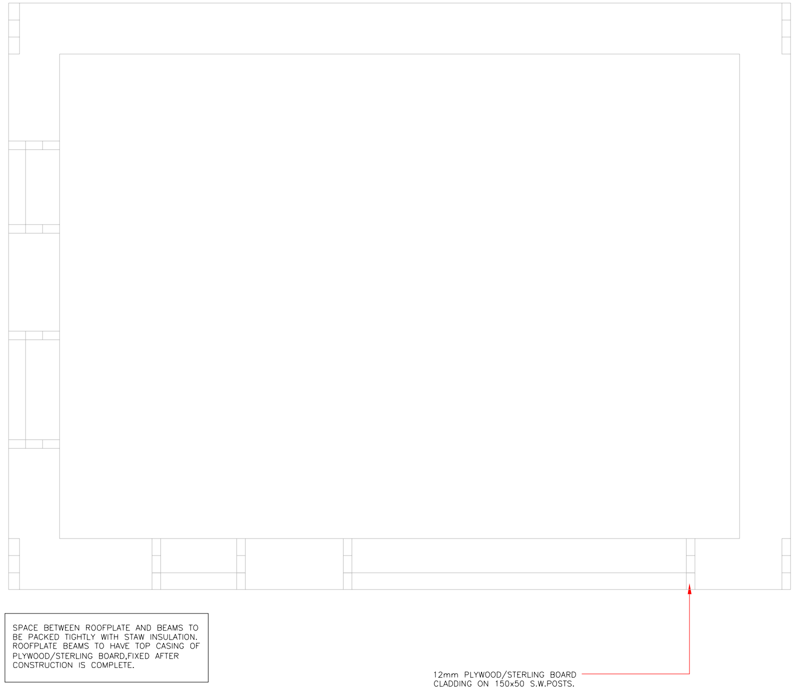
| Itemref | Quantity | Title/Name, designation, material, dimension etc | | Article No./Reference | |
| Designed by<br>Barbara Jones | Checked by<br>Barbara Jones | Approved by - date<br>6-10-01 | File name<br>JULIE PATON | Date<br>17-10-01 | Scale<br>1:1 |
| DETAIL FOR THREADED ROD AT TOP OF POSTS TO CREATE COMPRESSION | | COMPRESSION POST DETAIL | | | |
| | | sh/jp/01/1 | | Edition<br>A | Sheet<br>1 |

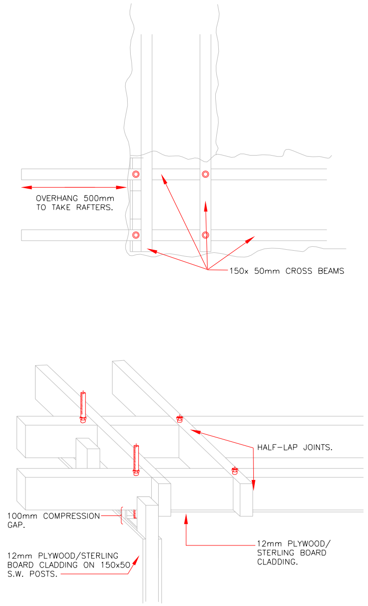
Julie Paton

| RevNo | Revision note | Date | Signature | Checked |
|---|---|---|---|---|




SPACE BETWEEN ROOFPLATE AND BEAMS TO BE PACKED TIGHTLY WITH STAW INSULATION. ROOFPLATE BEAMS TO HAVE TOP CASING OF PLYWOOD/STERLING BOARD,FIXED AFTER CONSTRUCTION IS COMPLETE.

PLAN SHOWING TIMBER POSTS
SCALE 1:50




PLAN AND ISOMETRIC VIEW
OF ROOF PLATES
SCALE 1:10

| Itemref | Quantity | Title/Name, designation, material, dimension etc | | Article No./Reference | |
|---|---|---|---|---|---|
| Designed by Barbara Jones | Checked by Barbara Jones | Approved by - date 6-10-01 | Filename Julie Paton | Date 17-10-01 | Scale AS SHOWN |
| Julie Paton | | FRAME LAYOUT | | | |
| | | sh/jp/01/2 | | Edition 1 | Sheet 1 |

| RevNo | Revision note | Date | Signature | Checked |
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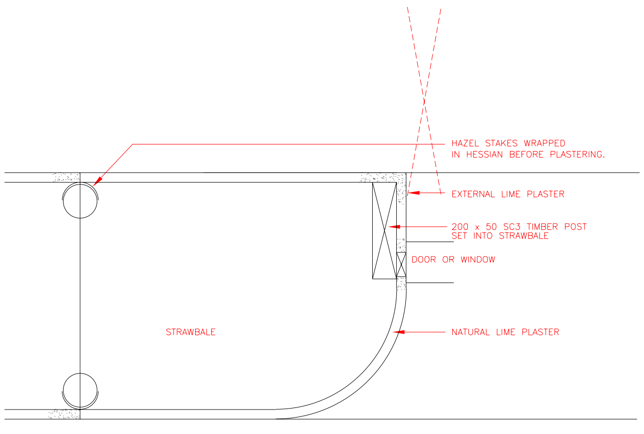
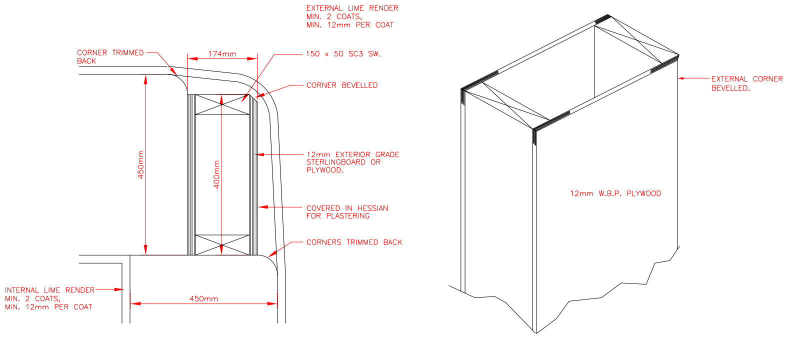



PLAN

## WINDOW AND DOOR REVEALS

| Itemref | Quantity | Title/Name, designation, material, dimension etc | Article No./Reference | | |
| --- | --- | --- | --- | --- | --- |
| Designed by kw/gh/bj | Checked by bj | Approved by - date 6-10-01 | Filename STRAW HOUSE | Date 17-10-01 | Scale 1:5 |
| Kester & Zinnia Wilkinson | | WINDOW & DOOR REVEALS | | | |
| | | sh/kw/01/6 | | Edition A | Sheet 2 |




## CORNER BOX DETAIL

| Rev.No | Revision note | Date | Signature | Checked |
|---|---|---|---|---|

| Itemref | Quantity | Title/Name, designation, material, dimension etc | Article No./Reference |
|---|---|---|---|

| Designed by | Checked by | Approved by - date | Filename | Date | Scale |
|---|---|---|---|---|---|
| kw/gh/bj | bj | 6-10-01 | STRAW HOUSE | 17-10-01 | 1:5 |

Kester & Zinnia Wilkinson

CORNER BOX DETAIL

| sh/kw/01/7 | Edition | Sheet |
|---|---|---|
| | A | 2 |

Lintels over door openings to be 2/200 x 50mm s.w.

Kitchen sink, baths and showers to drain through 40mm PVC pipes and be fitted with 75mm deep seal traps.
Wash hand basins to drain through 32mm PVC pipes and be fitted with 75mm seal traps.

Extraction for bathroom/ensuite/kitchen/utility
Via Willan Passivent Systems.

Space and water heating to be via Trianco Redfyre
Oil fired boiler using balanced flue.

Aga flue to be fabricated Selkirk insulated flue.
Outside of flue to be at least 48mm from any combustible material.
Base to Aga to be 127mm concrete slab on brick base to size shown on plan.

900mm firm level path provided to entrance door from garage/car parking space with wooden ramp fitted to entrance door.

Escape windows provided to all bedrooms and guest room, dimensions to be at least 0.33 metre square, minimum dimensions in any direction to be 450mm, and window placed at least 800mm off the floor and no higher than 1000mm.

Automatic smoke detection and alarms:
Self contained smoke alarms or automatic fire detection and alarm systems to comply with the relevant recommendations of BS5839: Part 1 to be installed in accordance with the requirements laid down in Approved Document B1
Wiring to conform to the current version of IEE Wiring Regulations.

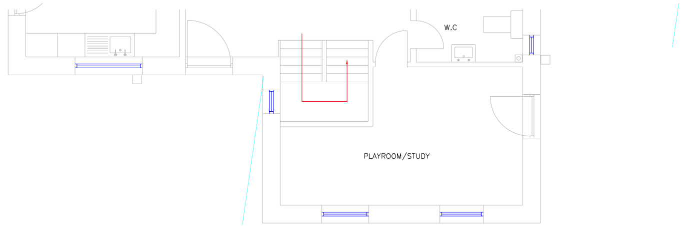
All works to be carried out in accordance with the building Regulations 1991, all relevant British Standards, Codes of Practice and manufacturers recommendations.

Selkirk fire to lounge with prefabricated, insulated chimney and square chimney housing terminal. Fitted in accordance with the current version of the Building Regulations Approved Document J and manufacturers instructions.

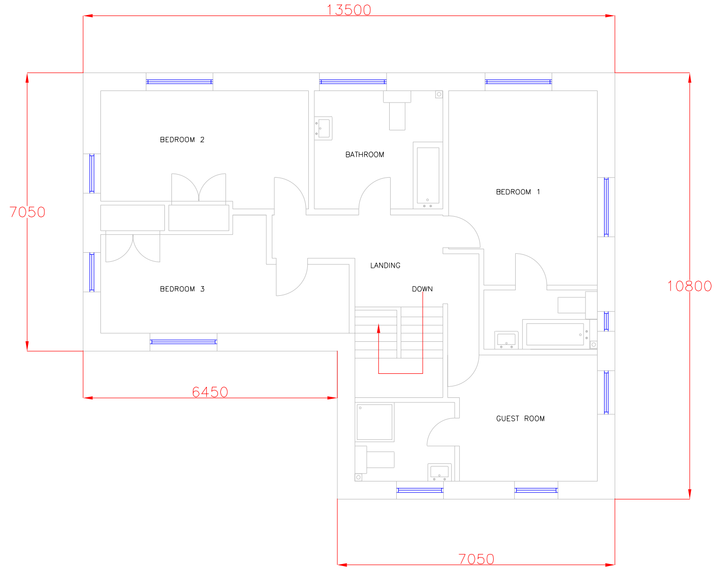
All dimensions on this drawing to be checked on site.

Staircase:
Going to be 235mm constant
Rise to be 195mm constant
Rise and going to be checked on site
Handrails at 900mm
Landings at 1000mm
2000mm unrestricted headroom
No openings in guardings to exceed 99mm
Treads to overlap by minimum of 15 mm

All electrical installations to be carried out in accordance with the current version of IEE Wiring Regulations.




GROUND FLOOR LAYOUT




FIRST FLOOR LAYOUT

All dimensions on this drawing to be checked on site.

| Itemref | Quantity | Title/Name, designation, material, dimension etc | | | Article No./Reference | |
|---|---|---|---|---|---|---|
| Designed by kw/gh/hj | | Checked by hj | Approved by - date 6-10-01 | Filename STRAW HOUSE | Date 17-10-01 | Scal 1:100 |

| RevNo | Revision note | Date | Signature | Checked |
|---|---|---|---|---|

ALL FLASHINGS,SOAKERS, VALLEYS ETC., TO BE FORMED IN CODE 4 LEAD.

ALL CEILINGS TO BE 12.5mm PLASTERBOARD AND SKIM TO GIVE HALF HOUR FIRE RESISTANCE.

PROVIDE 200mm THICK INSULATION BETWEEN CEILING JOISTS TO FIRST FLOOR.

SECTION THRO'
SCALE 1:50

| Itemref | Quantity | Title/Name, designation, material, dimension etc | | Article No./Reference | |
|---|---|---|---|---|---|
| Designed by kw/gh/bj | Checked by bj | Approved by - date 6-10-01 | Filename STRAW HOUSE | Date 17-10-01 | Scale 1:50 |
| Kester & Zinnia Wilkinson | | SECTION THROUGH | | | |
| | | sh/kw/01/3 | | Edition A | Sheet 2 |