Background

Jane and I have lived in West Wales since Dec 1989, trying out the ideas of permaculture on a smallholding of 1.5 acres, growing our own veg., keeping chickens and ducks, living simply. We experimented with ways of reducing our bills by giving up a flushing loo in favour of a compost toilet, and by building solar water heating panels and a rainwater shower heated by the sun. We converted the house lighting to 12 volts, installed photovoltaic cells and a small wind generator, and I built and played around with various designs of den and studio buildings made from recycled materials (especially windscreens and double glazing units) and slab wood offcuts from the local sawmill. We got rid of our car and bought an electric milk float. A normal country life, in fact. Each week we would hold a practice with Rasalila, the acoustic circle dance band we are still part of, in the Cone, a wooden tipi studio that doubled as our bedroom. Emma, who plays fiddle, bagpipes, whistles and clarinet, used to fill us in on progress at Brithdir Mawr. A tumbledown farmhouse and outbuildings with acres of fields and forest about 18 miles from us, that she and her husband, Julian, had bought with the intention of forming a sustainable community. We would exchange experiences about our respective gardens, and Emma would often remark how easy it would be if we built a little den down near the woods at Brithdir. I could still do woodturning there, and she would no longer have the long drive to band practices. As we saw the community beginning to take shape over the next two years we realised that these suggestions had a lot of sense in them. It's OK living in an agricultural workers' bungalow in Wales in the summer, but each winter you become aware of just how badly they are designed and how poorly insulated they are. I've lived in four since 1977, and not a year has passed without me thinking about designing a house of my own that wasn't always cold and draughty; a house that faced and welcomed in the sun; a house that made sense and was fun to live in; something that didn't cost the earth to build and didn't need a mortgage, so left me free to live simply. Jane and I had 1.5 acres of tightly packed Douglas Fir alongside our track. One day we started thinning the wood. We were going to build a den at Brithdir.

So many people would love to build their own place, and so few do, especially in Britain. So many need to live and work and be in nature, yet so few are allowed the space to do so. I can understand the planners' fears that if everyone were allowed free range to build what they liked where they liked this small country would be overrun, but yet there is something in me that revolts against a system that assumes that I and nature don't mix. At the heart of our planning laws is the unspoken assumption that people and the countryside are bad for each other. This is clearly nonsense - we have only evolved as we have over hundreds of thousands of years, by being tuned in, precisely and acutely, to the seasons and rhythms of nature. It is as natural for us to build an appropriate shelter as it is for badgers. There is no evidence that it works in the long term to keep humans confined to towns and cities, except for a few mechanised industrial farmers who are supposed to keep us all supplied with cheap food. It's not working for wildlife, for the farmers themselves, nor for us, fighting as we have to for overpriced and badly designed flats and houses in fume filled towns and cities. For us to live sustainably on this endangered jewel of a planet it will take radical re-appraisal of how we relate to and use the land, and I want to be part of the solution, not the problem.

We had to think all these things through before deciding to build a den that would certainly have been denied permission, had we asked for it. At the moment (and things could change very quickly) I consider it folly to assume that the powers that be are capable of taking rational, sustainable, holistic decisions. They are too stretched; their offices are too noisy; their journey to work is too stressful; they are too cut off from nature. I worked in that world for seven years. A council Chief Executive once said to me "I'd love to be green, but I can't afford to. I have to fiddle while Rome burns

I don't want to make anyone wrong. We're all doing our best. I've simply decided that no one has the motivation to sort my world out more than I have. I have taken reponsibility for my life, so I decided to build my dream house here, before I get too old to be able to lift a rafter. Anyway, it's in my genes. My grandfather built his own wooden house. Now I've done it too, it seems the most natural thing in the world.

Design

On with the nitty gritty. I have realised, through making plenty of mistakes, that it pays to think hard before building anything, and to write down my thoughts as I go along. I have found the principles of permaculture (Pc) an essential tool in this design process, and cannot recommend highly enough that you go on at least one Pc design course and read at least a couple of Pc books before you consider building your own home (or even a home for your hens). I started this project by re-reading my favourite book on self-build, Ken Kern's *Owner Built Home* and his sequel *The Owner Built Homestead*. Then wrote a simple brief to myself: "Goal: An autonomous house of wood; very warm, very dry, cheap to run. Made from pine logs from Erw Deg (where we lived). Turf/bracken roof...It is built on a slope near woods."

Over the next year, we agreed the best site for the house with Emma at Brithdir. It had to be preferably on a south facing slope, invisible from the mountain, Carningli, or surrounding hills and near the woods. The place we chose was on a bank covered with bracken in one of the smaller fields, just below a pair of hawthorn trees, near the end of a green lane and about 400 metres from the farmyard and main house of the community.

Brithdir Mawr and Carningli mountain.

The whole farm is 165 acres, rolling fields, big hedgerows with oak and ash standards, and includes about 60 acres of woods. Big and green and fairly wild. So I needed to take some time thinking about an appropriate building/den/hogan/cabin for this kind of landscape. Something that would not impose anything on the land or be inorganic and heavy. Something that could even rot away when we are dead. Something incorporating low embodied energy. Lowest building materials for embodied energy are cob, straw and unsawn wood from on site. Also, cement manufacture now accounts for 10% of global CO_2 emissions.* OK. No cement. This was going to be an attempt to build a home whose materials were very natural and very local. A sustainable home.

Iron age dwellings at Castell Henllys.

We had two young people, Dima and Carol, staying at our place as 'Wwoofers', working for their keep for a couple of months. For one winter (96/7) we spent at least half of the daylight hours available thinning our bit of Douglas Fir wood across the track. Each day we would note the trees that were too crowded, too small or that had been blown at an angle by the wind. With an axe and bowsaw Dima and I cut them down and Jane and Carol did the snedding - cutting off all the little branches with hand axes. In the evenings I read *Shelter*, the American book on ethnic hand built housing the world over, and borrowed a book on log cabins. I revisited Castell Henllys, two miles from here, where there are precise reconstructions of a settlement of round wood, mud and thatch houses from two thousand years ago, rebuilt in their original post holes; all made of natural materials.

The design for this roundhouse started out as an eight sided hogan with split level roof whose centre would be supported by enormous forked beams. The roof would be Navajo style 'whirling logs' - a circular

* *source Tomorrow's World.*

pile of 100 trees. The walls would each be 12 ft (3.5 ish metres) long, joined at the corners by overlapped joints. The log cabin book showed how to cut each log along its length with an indentation in its underside so that each would fit tidily and warmly on the one beneath it. This seems the best alternative to adzing each one roughly square, or having the whole lot milled by a sawmill, a prohibitively expensive operation. I tried it using an electric chainsaw. The little machine just couldn't handle the work and I couldn't handle the noise and strain of shaping every single wall member along the grain like this. OK, back to the drawing board. Where was that tiny reference to cordwood walls - using different thicknesses of logs, all cut to the same length and stacked up as in a firewood stack (or 'cord') to make a wall? I found a couple of small references. It was a technique used by European (usually Swedish) settlers in the mid-west US and Canada in the 19th century, to make 'poor people's' houses. Warm, easy to build for a non professional, and using all sorts of wood. The book also said that softwood, such as pine, loses heat two and a half times more readily through the end grain as laterally. To have the equivalent of a 6" / 150mm thick wall - a fairly standard Swedish style log cabin thickness - I would need 2.5 times that as cordwood, i.e. 15" logs. I actually settled for 16", to be on the warm side, and because it translates easily into metric - 40cm. OK it's a weird reason, but it's the truth.

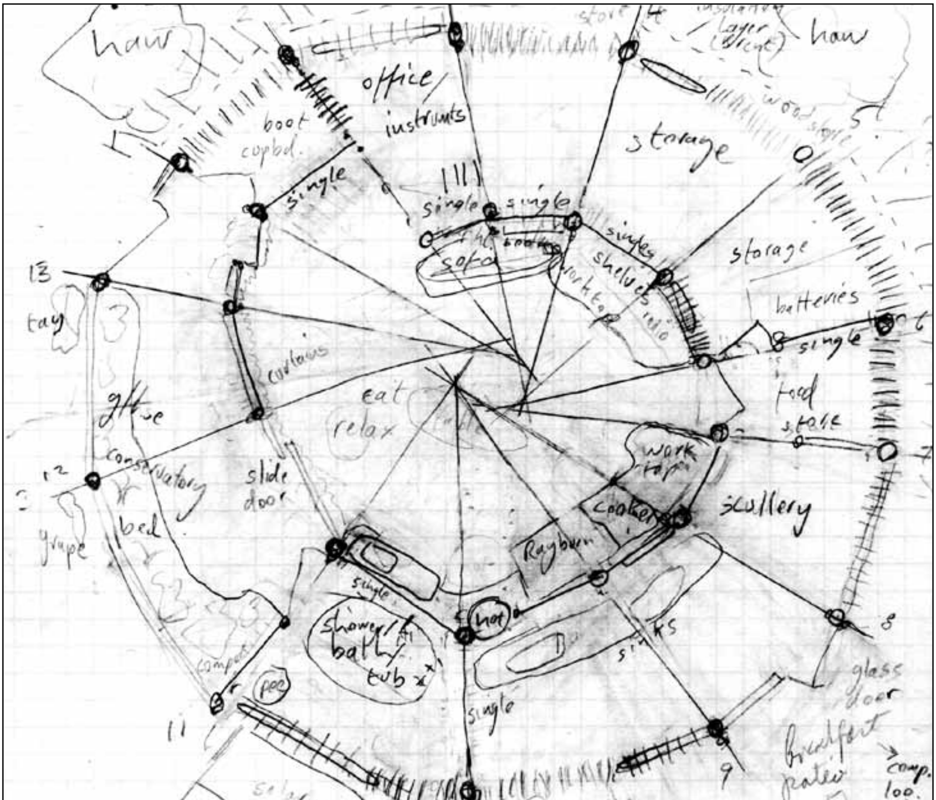
If you ever get into designing things, you will find that you evolve ways of working that make sense to you. You have to, because it actually involves a lot of concentration. I have two basic methods. The first is to carry out a conversation with myself in writing and drawings as the design takes shape. I have 25 - 30 pages of these pencilled conversations showing the gradual evolution of this design over about nine months. It is useful at the end of a design session on, say, the roof, the floor, the windows, the drainage system - whatever - to state the conclusions drawn and the things to do next. This is because all parts of a holistically designed building impinge on each other, and often you are left with questions rather than answers. For example, I left any detailed consideration about what to make the back walls and floor with until the JCB had dug the hole into the bank. This was because if we had hit rock a foot down the whole design would have needed to change. It was worth writing down the questions I was left with after each design session. Doubts too. I have long harboured dreams of heating a house by the slow convection of air from pipes through and around a vast underground water tank that has been accumulating heat from solar panels all summer. Fair enough, lets go for it. As I worked on thinking it through it became obvious that this was actually going to be more complicated than I could handle. Maybe you've got plenty of money to pay consultants for this kind of thing. Fine, but we had no money at all. This whole house was built on trickles of cash in, using natural and recycled stuff, and good luck. So if there was a doubt that (*a*) the water and plumbing system would be just too complicated and (*b*) a huge water tank in the middle of the floor might affect the footing for the main house supports (just a feeling rather than anything definite), I chose simplicity and went back to the drawing board again.

I am sorry if this seems too long winded for you, but I cannot stress strongly enough that if your house is going to work for you perfectly in the situation you have, then you will need to take just as long designing it as building it. So much waste in our society comes from people wanting a quick off-the-peg solution, and that usually means more transport, less sympathy with the environment, and just silly design. Look at all those new housing estates with the houses dutifully facing the road, whether the road is to the north or the south. Simply by locating a house to face the south you are reducing heating bills by at least 13%. And all those south facing roofs with not a solar panel or PV tile to be seen. It drives me mad. Planning? Don't make me laugh.

The other type of design work is something that maybe you already do very well, but I've never seen it talked about much. Virtual Reality is now a concept that many people are familiar with, though, so it is certainly happening in cyberspace. I hope the Kogi native people of Colombia will not be offended if I use their phrase 'working in Aluna' to describe it, for that is what I call it. The mind is a wonderful thing. Recently psychologists advising an American football team carried out a series of experiments on the team members. Success in American football apparently involves a team in having a series of multiple-move strategies that the captain can summon up, like a program, in the course of play by yelling out a number. The team then make the appropriate moves to carry out this strategy. The psychologists worked with the team to go through several virtual games, hunched up together in a room without touching a real ball, concentrating in their minds, imagining each move and the counter moves of the opposition. It was assumed that this kind of virtual practice session would not be as good as the real thing, but might just be of some use. In fact they found it to be of more use than a real practice, and got better at it, too. The team performance dramatic-ally improved. When I read this I remembered the film From the Heart of the World that the BBC made at the invitation of the Kogis, a native nation in Colombia that has retained its culture since before the conquistadores. As I remember it, the Mamas, the leaders, do not take any decisions on the physical plane until the consequences and details have been worked on in Aluna; in darkness, in their minds. Using this idea, I developed for myself a way of imagining in detail everything about a particular aspect of the house that I was working on. If you do this you will find that you can at first only imagine one or two steps or objects, but as time goes on you can develop Aluna into a very creative space in which questions can be posed, practical solutions put forward in succession, and each possibility looked at in 3D and full colour. You can turn something around, imagine it in pouring rain, imagine five nine year old boys climbing all over it and so on. As this house became a reality, I found that at least half of the time I was working in Aluna, usually on a practical detail that I had never actually encountered in real life, or at least never on the same scale. For me the best time to do this is the middle of the night, unfortunately, when all is totally still, so Jane got quite used to me getting up at two or three a.m. to draw some detail of the plumbing system, a window frame or the roof rafters. The Kogi, I think, believe that on the Aluna level all minds are linked. I have since found out that several ideas that came to me in Aluna have been the subject of quite detailed trial and error work by pioneers in alternative building methods such as Rob Roy in the US, who contacted me when my house

Rob Roy's cordwood and masonry house.

became known about and told me that it was a cordwood masonry house. Anyway, there you go. It is a way of designing that soaks in all available data and then allows another part of the mind to mold it. It works for me. It is the main reason why I couldn't apply for planning permission in advance, as a matter of fact. How can you put in detailed drawings if you don't know what you are going to do until the night before you do it? From now on there will be a simple description of construction details. Please don't ask me to explain everything, though, because I've forgotten most of it. We just woke up the next morning and got on with it. I bet that's how our ancestors worked for the last few hundred thousand or so years that we have been building simple shelters.



(diagram 1) This is about as detailed as any design got: post and beam structure, round, with reciprocal frame roof. Outer circle of uprights to go up first, then henge crosspieces, then roof. Cordwood in walls.

Materials

We took a winter to get the wood cut. Dima, Carol, Jane and I would plunge into the damp deep sloping pine woods in the mornings with a sharp bowsaw, two little axes for snigging (I think that's an old word for cutting off minor branches - the other good word like that is snedding, which is dragging the big logs out by horse power), a really sharp felling axe, some rope, and tough gloves and boots. The inventory I was working to was:

roof supports (rafters) 6m+ - 13 off plus spares
pole uprights (9″ diam pref) 3m - 13 off
inner uprights (8″ diam) maybe 5m - 13 off
walls: a rough guess of 210 x 16″ (40-cm) logs per full wall, = approx 24 lengths of about 4 m each! Say 9 walls max, allowing for windows, so: lengths of all thicknesses 4 m - 200 off.

So we had plenty to be getting on with. We got really good at tree felling and thinning by hand, and measuring by foot. I used a tipi pole marked out in lengths of 4m and 6m with yellow insulation tape, but the working situation was temperate forest with brambles, small streams and occasionally almost impenetrable undergrowth at a slope of about 1 in 3. I use metres for stuff like this because 1 metre is one of my paces with big Swedish army boots on (vintage 1941! - aren't street markets amazing sometimes?).

Thinning trees for building material in our pine woods.

Logs being transported by milk float.

I like to have all important building materials ready before starting work, so made a call to Kevin Thomas, a friendly glazier whose workshop was only 10 minutes away by milk float. Glaziers get enormous amounts of double glazing units that are perfectly good, but have been taken out in some renovation job, or have been ordered in the wrong size for a particular frame. If you can be flexible in your size requirements for windows, as of course you can with cob, wood, cordwood and strawbale buildings, you save a fortune on windows. One day Kevin called me back. "Got a load of patio doors and windows. I'm clearing out the workshop. I've got to skip a whole load. Do you want to come up in the next half hour (sic) to have a look?" SCRAMBLE. I bought three double patio doors, about three ordinary wood framed small windows, and about 15 big double glazed units (several too big for one person to lift) for £125. Just fitted them all on the open back of the milk float. (Don't ask me all about that - suffice to say that if you want to wean yourself off a car, get a second hand electric milk float. The old batteries will still last you about three years. You've got a range of about 25 miles for an average 15 electricity units, charged overnight, and a float will carry 1.3 metric tonnes. That's a real load of wood, logs, manure, or windows. Mind you, keeping one going requires a steep learning curve involving DC electrics and battery charging and maintenance. If you're tempted though, check out your nearest dairy that uses floats, and go for it. Make all your neighbours laugh.)

The only other materials I bought in advance were 2 rolls of galvanised steel fixing strap from a builders' merchants, and a good supply of nails of all sizes, including 30-40 6"/150mm nails.

Embodied Energy

This is the energy tied up in a structure by virtue of the transport, extraction, processing and other costs that go into all the building materials. Cement is very high in embodied energy. So is aluminium - all that mining, all that electricity to make it; transport from, usually, Canada. If all countries in the world used as much aluminium by 2050 as Britain uses today, the global capacity to sustain such production would be exceeded by eight and a half times. New glass and bricks (all that baking) are also high in embodied energy. Generally, the true cost of road transport, if built into the embodied energy costs of building materials, can make a huge impact on the environment. If you use wood in London that was felled in Scotland, for example, it will have a higher embodied energy than the same kind of wood imported from Latvia, because the latter comes by boat to London docks, whereas the Scottish wood has come maybe 600 miles by road. This is one of the critical, yet almost invisible, factors that form part of the big issue of living sustainably in everything we do. Seeing just how much wasted energy goes into the building of an ordinary modern house was one of the main reasons that drove me to designing and building an alternative model from scratch. I learned most of it by joining the Alternative Technology Association run from CAT(Centre for Alternative Technology), the Ecological Design Association and reading books like *Our Ecological Footprint* and the FOE publication *Tomorrow's World* (*see Appendix*).

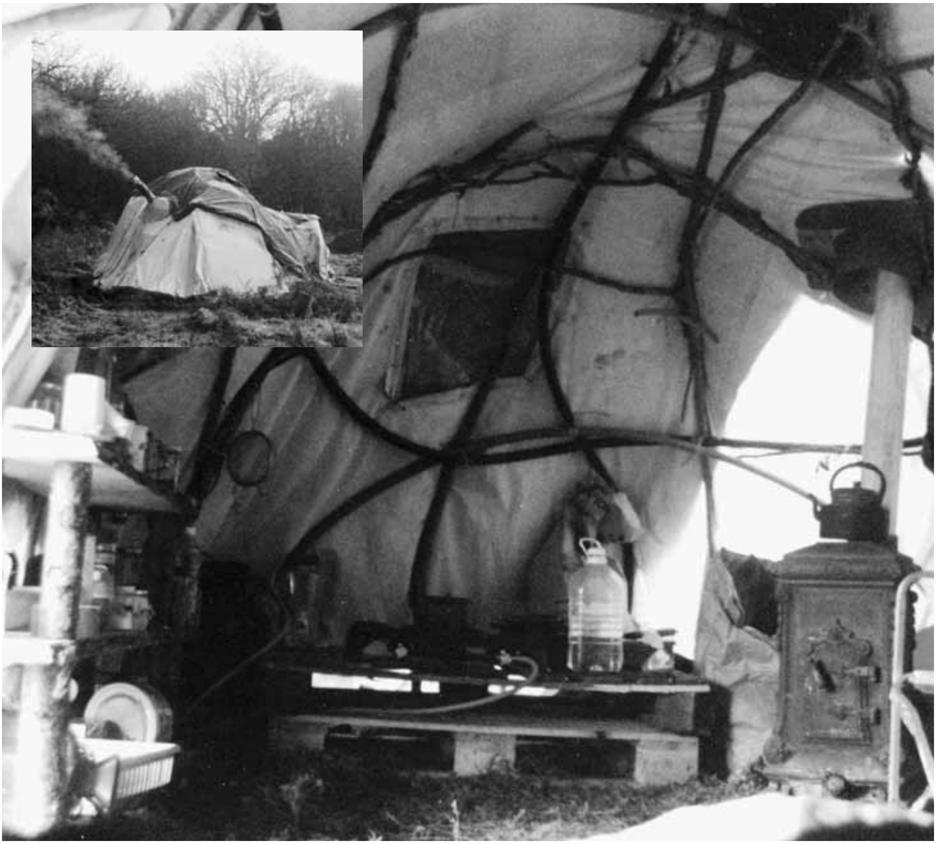
The house with rock bottom embodied energy, and therefore the kindest to the earth to build, would be made of natural materials found and processed by hand on site. Our ancestors built houses from cob (clay with some sand and straw), local stone, wood and thatch. Nowadays I would contend that by adding straw bales and a modern technological miracle - large seamless rubber pond liner sheets - to this list (admittedly rubber is imported, so higher in embodied energy, but grown in sustainable conditions giving livelihood to rainforest dwellers), we can still produce warm, dry and organic houses at a fraction of the cost to ourselves and to the environment.

We brought the wood the 19 miles from our old place to this in

This is the amount of wood needed for the structural framework.

two big lorry loads, the lorry being specially equipped with a long lifting arm and chains. We then carried it the 400 metres down the track by tractor and trailer; maybe twenty loads, spread over the next three months or so. We used no power tools on site, so I cut up the wall log-ends up by the farm house with an electric chainsaw. (I'll follow American custom and call them log-ends from now on). So even a low impact building like this has quite a bit of embodied energy. Electricity was consumed for the cutting. Some was renewable energy, mind you, because our community bought an inverter that enables most electric appliances such as hand tools, electric chainsaw, computers etc. to be run from the battery bank fed from stream turbine, solar PV panels and wind turbine. Diesel was used for maybe 80 miles of lorry transport plus maybe 5 miles of tractor use. I have some regrets that even the small embodied energy costs in this house could not be avoided, but it is pointless being against all technology, isn't it? We didn't have to build an earth sheltered house into a bank, but I'm glad we did (there's a great gale blowing around outside as I write this and we hardly notice it in here) and I'm grateful a JCB was on hand to save us weeks of back-breaking digging into clay.

The JCB revealed the perfect material for filling between the log-ends - cob, as we had hoped. If we had hit rock a foot down I would have



Inside the bender (inset) the outside view.

had to redesign the whole thing, so flexibility was crucial. We made three piles - subsoil to either side of the hole and one big pile of topsoil for spreading back around the house and for the roof.

By September 1997 we had the main logs by a big clayey hole in a bank. Jane and I set up a bender at the top of the bank, made of bent hazel poles covered by canvas, and borrowed a little wood burning stove. This was our home for four months. Don't attempt this with someone you don't know very well. At times, after weeks of rain, mud and sleet, it felt like Scott of the Antarctic's last camp. Slugs eating our books; wheelbarrowing batteries through ankle deep mud; wet clothes, aching bodies. I won't go on any more about it, but please don't think that building your own place is some kind of easy option! Right. We're ready to start.

The Skeleton

A traditional and safe way of building a simple house is to make a 'post and beam' skeleton and fill in the spaces. The skeleton of this roundhouse is a wood henge of uprights with cross pieces forming a complete circle, and a reciprocal frame roof, all of round Douglas fir poles. The reciprocal frame means that the rafters rest on each other in a circle at the centre, where there is a hole. More strength, for a turf roof, is supplied by an inner circle of supports, but the outer circle comes first, and the size of that was actually dictated by the flat space we had available when Berwyn left on his JCB.

First we laid out the rafters on the ground to get an idea of the thing. It's no use building something to some theoretical size if in practice the ends of your rafters are a bit weak and dodgy looking. It's always worth having something small and strong rather than maximum width and sagging in the middle. So Willow (a permaculture friend and tree planter extraordinaire) and I laid out the strongest of the poles around the circle. "How many poles you having?" asks Willow. "Twelve," say I, because I've already made one with twelve poles in the field across the way, that we still use for a marquee frame. "No," says Willow, "It's got to be thirteen. I'm not going to help you build a house with twelve sides. It's got to have thirteen." It's no point asking him why. Willow can talk all day about the moon phases and the Mayan calendar and stone circles and just about everything. In a quick mental resumé of the last nine months of design work I think, "How attached am I to it having twelve sides?" The answer comes back - not at all. The more sides, in fact, within reason, the better, as each cross piece holding the sub-rafters has less weight to hold. "OK, thirteen," I say, and from that moment on all thought of attempting to calculate measurements in advance goes out the window. Try dividing anything by, or multiplying it by, thirteen. From then on it was rule of thumb. Just as well really, because I didn't have a tape measure long enough to reach across the whole house circle, and still don't. The circle is not exact - it fits the space and suits the strength of the rafters, but I still can't tell you precisely how wide it is.

We laid out the thirteen rafters and stuck a stick in the ground where each support would be. Then we started digging holes and painting creosote on the bottom metre of the main supports. I know that poles rot if you put them in the ground, especially in the area just around ground level, where bacteria and fungi have moist air and damp wood to work on. Oak and chestnut resist rot for 40-50 years; sycamore, hazel and ash will last about 18 months, and most woods are somewhere in between. On previous projects I have tried charring the bottoms as our ancestors did, creosoting, standing the pole in a plastic bag with creosote in and putting concrete around the bag, and doing nothing. After about ten years, none have rotted away yet, but I guess the 'doing nothing' will go first. If we were using concrete here, we could stand the poles on concrete plinths, steadied by stainless steel pins, but then the uprights would need much more bracing than they've got, to stop them twisting or moving sideways. Call me old fashioned or unrealistic but I don't think you can beat a nice hole with the pole stuck good and fast in it. This whole building will rot anyway, one day. I don't want the poles to rot faster than anything else, though, so each time I clean out the chimney I put the natural creosote and soot into the clay around the base of a different pole. The holes are a cubit deep. Here's Jane finishing one off. When she can't scrape any more from the bottom of the hole, that's a cubit.

Jane digs a post hole; she can just reach a cubit down.

When all the poles were in, we cut them so that the tops were all exactly level. This is important so that the whole place doesn't look completely skew-wiff. The load from the roof is distributed evenly, and I could use the henge cross pieces as a level when it came to fitting windows, etc. How to do it is to make a bunyip. Not a word you see much, is it? A bunyip is a length of hose of approx 10m length with about a metre of clear plastic at each end. If you fill this with water, making sure that all air bubbles have left, you will find that the level of the water visible in the clear plastic ends is the same, no matter how far apart you hold the ends. Don't attempt this without a friend helping you. You nearly go mad as it is, because it's all too easy to move one end up or down too suddenly, with the result that a jet of water comes from the lower end, and you have to replace the water and start again. Still, when you get the knack of it, which can involve marked sticks attached to each end, pieces of chalk, communications skills and a bit of cursing, you end up with a series of marks on the uprights that you can guarantee, by scrupulous cross checking, are all level with each other. I started with the pole in the south west that I knew I wanted for a door post, and made a mark 2m from the ground level. (The other time you may find a bunyip useful will be if you want to dig a swale or ditch for draining/water retention along a contour. In this case a marked stick against the clear plastic is essential.).

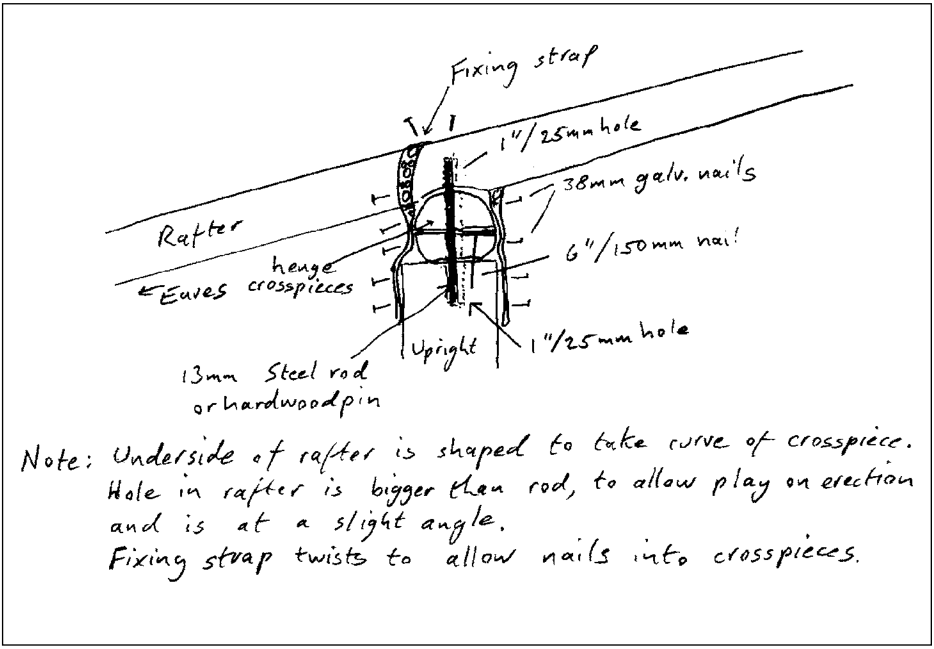
The posts go into position.

At this point we have 13 marked uprights in holes. I actually cut the tops off as they were standing, as I could not manipulate them single handed (each pole was about three metres long and at least 25cm in diameter, so weighed more than me). If there is a team of you, you can take each pole out, cut it to size then replace it, but I find earth falls in the hole and I can't be sure of the level again, so I cut them where they are.

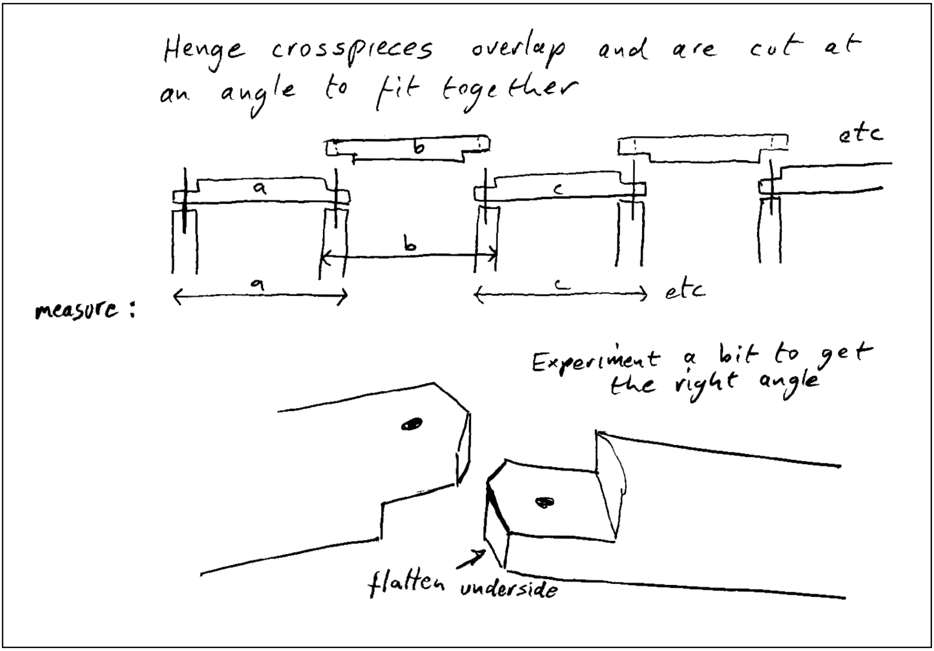
Each pole stands on a rock at the bottom of the hole, is jammed tight with stones, then tamped upright using a plumb line. Don't try and put up your main supports without testing that they are plumb straight. No point tempting gravity, is there? There is a case for drilling the hole in the top of each upright before you do the final tamping, because the pole moves a bit as you lean against it with a step ladder. Drilling these holes, 3 - 4" (75-100 mm) into the end grain 2m up a stepladder, with a brace and bit, was the single most exhausting operation of this entire project, by the way, so when you've done that, relax. The rest is downhill.

To make the henge, I measured the exact distance between the centres of each upright at ground level, and cut the cross piece to this length plus one pole diameter. This is important so that your henge pieces overlap and are pinned together on the top of each upright *(see diagrams 2 and 3*). This is a way of doing it that I have evolved over ten years or so. If you can do it better, by all means do so. It is important to use the henge to hold itself as a strong circle, to allow for most of the roof weight to come down each support evenly. The pin going from the upright through the cross pieces into the rafter ensures structural strength, and acts as a useful fulcrum when adjusting the rafters. At first it is a fiddle cutting each cross piece to get the angles reasonably tight, but actually it doesn't take that long, and looks great. As the electric chainsaw would save a lot of time with these overlap joints, I cut the cross pieces in kit form up by the community workshop, using measurements of each gap marked out on a piece of paper. I have fond memories of this scruffy, damp piece of paper being passed from jacket to trouser pocket and back with the circle of posts marked out and 223, 219, 226 etc. in all the gaps. (I find cms are quite good for measuring this kind of size, then feet for a bit bigger, then metres for long lengths. What do you estimate and measure lengths in? Be honest. It's a mess, isn't it?)

I had the henge finished in two weeks, working every day, usually with Emma as helper, to whom I am eternally grateful. At this point I could see what the size would be - the henge contains the space, and the imagination starts filling in plenty more ideas.



(diagram 2) Henge, crosspiece, rafter fixing detail.



(diagram 3) Arrangement and joint detail for henge crosspieces.

Reciprocal Frame Roof

Ever since building my first reciprocal frame roof, on a simple building at our last place that we called the Dojo, I have been fascinated by the ease and strength of them. The idea was made popular by an architectural firm called Out of Nowhere, but I don't think they invented it. Our friend Jack Everett built his dojo near Stroud with one in the early 1980s. Anyway, it is a great way to use round timbers to hold a roof up without needing a central pillar; you get a hole for a skylight instead. The essence of a reciprocal frame is that the rafters are self-supporting at the centre; each resting on the one under it, in a circle. You do not attempt to hold the rafters at any particular pitch - you let them rest on each other and the pitch is what you get. The weight is transferred evenly down each rafter to the uprights, and vertically down to the ground. Putting up a reciprocal frame is great fun, but has an element of danger too, so it's best to ensure that there are no children running around when you do it, and that if you have helpers, they are not afraid of long poles rolling about above their heads. (Some people are - surprising, isn't it?)

Now we have a henge of posts and crosspieces, with a hardwood peg projecting about 20cm above the joint. The essential extra for erecting a reciprocal frame is the Charlie stick - a strong pole in a Y shape strong enough to hold all the rafters up until the last one fits in above the second to last and under the first one, when the Charlie stick can be removed. I have a rule of thumb with these roofs that seems to work: the length of the *Charlie stick must be: henge height + (no. of rafters x their average thickness at their ends) + 1 foot/30 cms, minimum.* For this house the Charlie needed to be at least 14 ft; that's about 4.5 metres long. Such poles are not easy

Dojo at Erw Deg.

The nearly completed henge, with a crosspiece awaiting fitting.

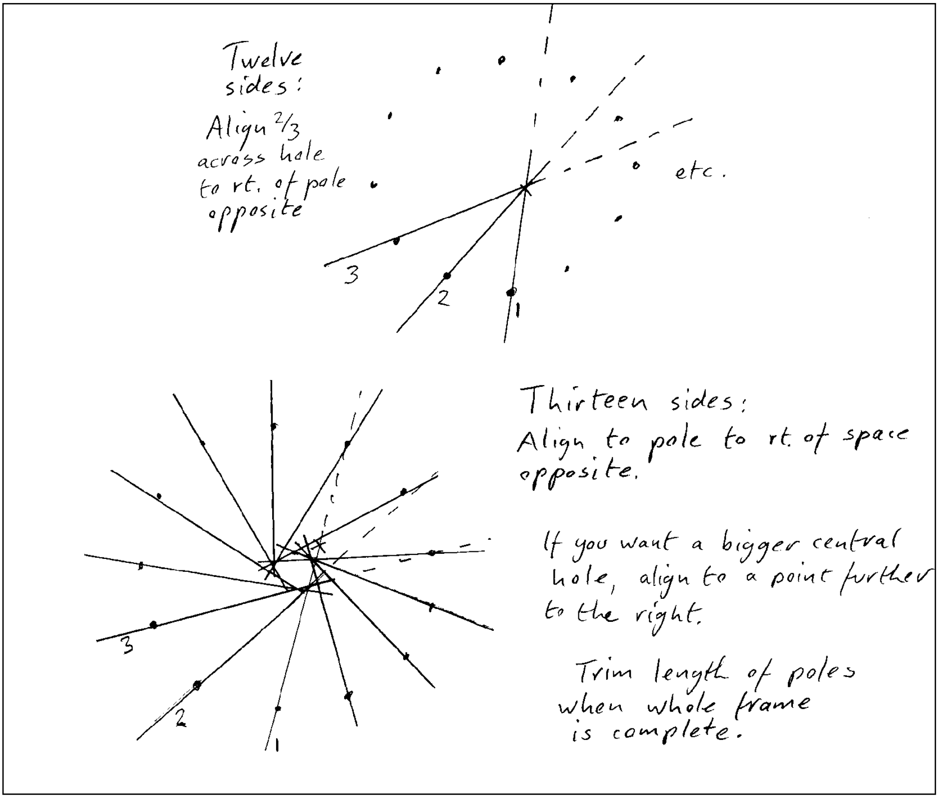
to come by, so when you find one, mark it, tell all your helpers about it, and don't cut it up. From the 250 or so trees we felled I found one, and only one, perfect Charlie stick. So now, a year later, its time had come. First I built a stepladder tripod like an adventure playground climbing frame about 4 metres high in the middle of the circle, using the longest step ladder we had. This actually felt much safer to climb on than the step ladder itself, as the base was well puddled clay, and the step ladder with its neat little metal feet would gradually tilt to one side until it fell over.

Next I set up the Charlie stick in its place. This needs some thought. The best way to get an even circle hole/skylight in the middle of your reciprocal frame is to have a standard alignment of each rafter pole. If you want a clockwise spiral/iris effect when you are standing under your roof, as I did, then you need to move clockwise round the circle in placing your poles, and each pole has to be displaced a standard amount to the right of the centre of the circle. If you are using an even number of henge uprights, this is a matter of standing at one upright, looking at the pole directly opposite you, then aiming at, say, the centre of the space to the right.

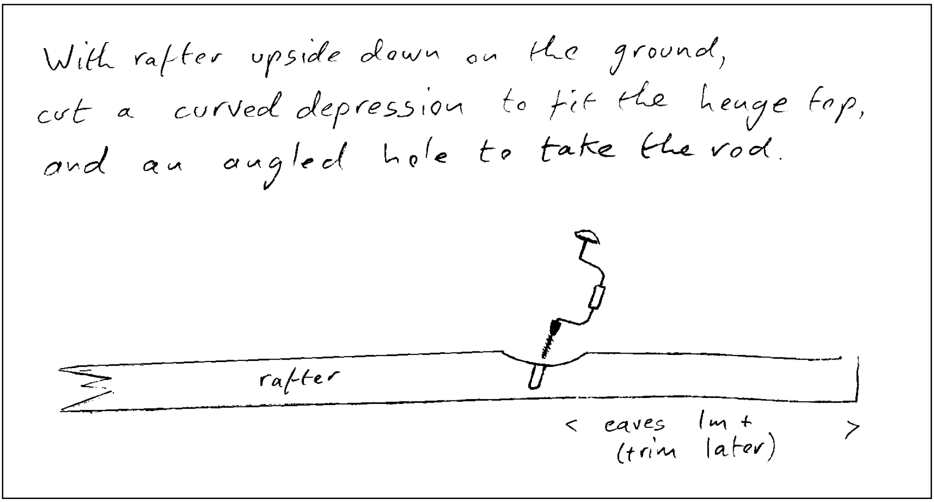
A point near the next upright will give you, ultimately, a large central hole - a point near the centre line will give you a smaller hole. In this case, as we had an uneven number of uprights, I aligned each post near the post on the right of the space opposite (*diagram 4*). This means that the Charlie stick, which has to hold the first pole, must itself be off-centre. I wanted a hole about a metre across, so figured that if I offset the Charlie by half a metre to the right, that would work, and so it did. The Charlie was put up standing vertically on the ground, gripped in the jaws of a workmate to stabilise it lower down, and lashed to the wooden tripod to stabilise it high up. It is good if you can also have an assistant to help you to hold the Charlie stick as the first rafters are being put into place, because if it collapses half way through it's like Pick-up-Sticks with hundred-weight heavy, 6 or 7 metre long sticks. I got all the best poles ready, fanning out from their uprights, and drilled a 28mm hole in each about 3"/75mm deep, at a slight angle, and allowing at least half a metre or more for the eaves. I also made a slight notch in what would be the underside of the rafters to allow a good sit on the henge (*diagram 5*).

It is at this point that good pole selection pays off; each pole must be thick enough at the centre to be capable of holding a considerable weight at its thinnest part, where it meets the others at the centre. If a pole is too long, you can always cut off the surplus at either end, so in this process it is always best to use good strong poles that are too long. The surplus length at the eaves is actually quite useful, as you can manipulate a pole much easier around the fulcrum of the henge if you have 2 metres or more of heavy end to play with. Several of my poles had this much spare, so I drilled the pin hole accordingly further from the end. The outstanding ends were again useful, when we clad the roof, to clamber up on to the roof and to lean secondary rafters against. The houses built by our ancestors from cob and thatch, such as the ones at Castell Henllys, often had huge spacious eaves coming down almost to the ground. These would provide dry cover for animals, firewood, hay etc. and would of course protect the outside wall from the elements. These days, long rafters would also provide the basis for greenhouse extensions in the sunny sectors. Between you and me, I have often found our generous eaves also of use for keeping dry while peeing in the rain.

Right, so our rafters are drilled, and ready. The Charlie stick is waiting.



(diagram 4) Reciprical roof frame rafter layout and placing sequence.



(diagram 5) Rafter detail for fixing at henge crosspiece.

I had a spare, smaller Charlie of about 2.5 metres long (let's call it Ajusta) for adjusting the rafters once they were up. So I lifted up the first rafter (in the South; no reason, but Willow would probably approve), heaved the thin end up onto the henge, climbed the tripod holding the end of the pole, and, on tiptoe, lifted the first pole up and into the Charlie Y. I was not actually being assisted that day, so that ten minutes or so was the nearest I have ever got to being a circus performer. I got a bit of birdsong for applause, and tied the pole loosely, to allow some movement, with baler twine. (Baler twine? We use it as currency here. I once assumed it's minted somewhere and planted by God in hedgerows and on old farm machinery the world over, but find that you can buy it in big rolls from agricultural Co-ops.) I then returned to the ground, lifted the heavy end until the hole was over the peg in the support, and let it down. With each junction at the henge, I use a piece of builders' galvanised steel fixing strap, which comes in 5 metre lengths. I cut off about a metre, and half fix it with a couple of nails on the upright, then one nail on the top of the rafter. That stops the rafter rolling anywhere, which is what they sometimes try to do. Stop to take a photograph. Note the pegs sticking up from the henge, the Charlie stick and the tripod.

Henge, tripod, Charlie stick and first rafter laid in position.

From here it is logical and straight forward, going round the circle adding each rafter, aligning each to the appropriate place across the circle, adjusting each one at the centre with Ajusta, tying with baler twine and half fixing with fixing strap.

1996 field marquee structure.

If you are likely to be building one of these yourself, may I recommend that you do this process with a scale model of sticks first, say tenth or one fifth scale. There is no substitute for experience in making the small adjustments of each rafter as it goes on so that the central hole becomes regular, and it is much better to get the hang of it with, say, 1m sticks than with giant 7m ones. Having said that, I still believe this system is perfect for people with virtually no building experience, so long as you have played with long poles, levers etc. a bit. Now we come to the last two stages of the reciprocal frame skeleton, which are The Last Pole and Taking Charlie Out.

The last pole fits under the first and over the second to last. If Charlie is too short there will be no room for the last few poles. If he's too long the poles will keep trying to roll away down each other and Taking Charlie Out will be a bit dramatic. With Charlie at formula length I had just enough space to squeeze the last pole into its space and lower it down onto the peg with a bit of grunting and groaning. It is now just a matter of removing Charlie. Of course Charlie, by now, has come to realise that he, and he alone, has been holding up about half a ton of woodwork, and is indispensable to the entire project. He is well rooted in thick clay. Removing him feels hazardous, even if it is not. I will always remember when we were at this point putting up our field marquee structure in 1996. One of the observers, wringing her hands in dismay at the apparent certainty of imminent loss of life, wailed, "What does it say in the book?" Well, here's the book, four years late, and it says Don't Panic, take it slowly, and dig down under the Charlie gently until, bit by bit, the structure takes the weight, the poles settle, and Charlie can be removed, preferably to carry out a ceremonial function somewhere. I adjust the circle with Ajusta, then finish pinning down all the fixing straps across the tops of the rafters and down to the top of the upright on the other side. I then fixed the poles at the centre with short lengths of fixing strap on the top sides of the poles, and by my favourite fixing system - a metre of telephone wire wrapped round several times and stapled two or three times. The basic skeleton is now complete.

Detail of telephone wire strapping around the skylight hole.

The Full Skeleton

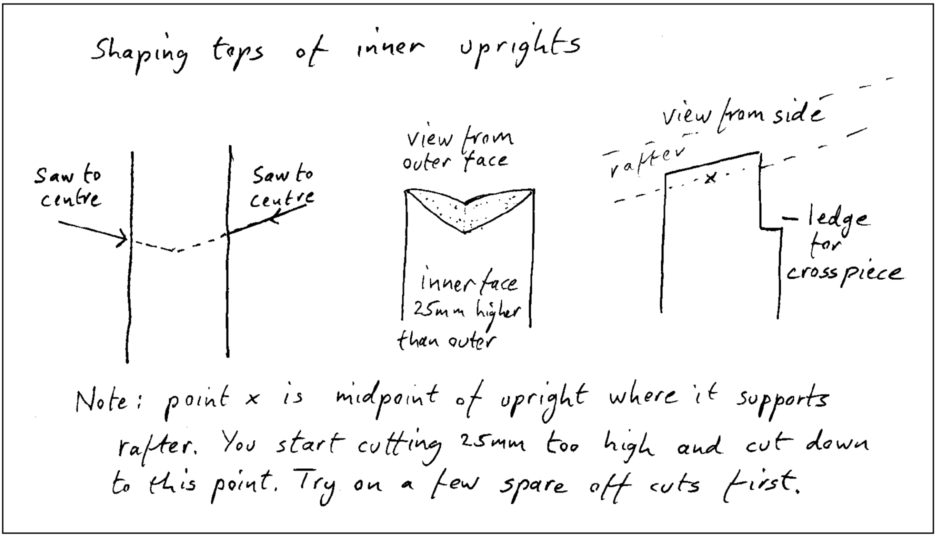
The roof with a typical light snowload.

Turf roofs are heavier than almost any other kind of roof. If your house is to be built in a region where winters bring heavy snowfalls, you need to estimate how much strength you need in your roof to hold up not just a thousand or more wet turves, but also a layer of snow. Heavy snow falls are very rare here in this part of West Wales, so this roof is not built for the worst case scenario. I also did not intend to use turves much thicker than about 3.5 inches, or 9cm, as it rains often enough in the summer to prevent the turf totally drying out. Still, a circular roof 12m/40ft across gives me approx 1400 turves of one square foot. Each turf weighs from 1kilo (2.2lbs) to a max of 10 kilos, averaging about 5 kilos, so for this roof we are talking about something like 7 tons of turf when wet, plus insulation of about a ton. Looking again at accounts of ethnic round houses, I noted that usually there were inner posts to bear the extra weight of a thick roof. The circular earth lodges of the early British, and North American Native peoples, the Mandan, the Pomo and the Miwok, all used an inner henge of strong poles to support heavy roofs. This house therefore also has an inner henge of strong uprights and crosspieces to support the load-bearing rafters near their mid point. If you are worried about load bearing capacity of roofs, there are experts who can calculate these things, so consult one. My basic rule of thumb with this house was: (*a*) to build with the strongest members I could actually lift, because in this site and weather it would be silly to have always to rely on one or more extra helpers all the time; (*b*) to use experience of building with this type of roof on seven or eight previous structures; and (*c*) to trust the designs of our ancestors who built and refined roundwood and turf designs over thousands of years. Overall, this whole structure feels strong, but in a soft way, as a visitor once put it. As in a basket, there's a bit of give in everything; it's not completely rigid.

Inner Uprights

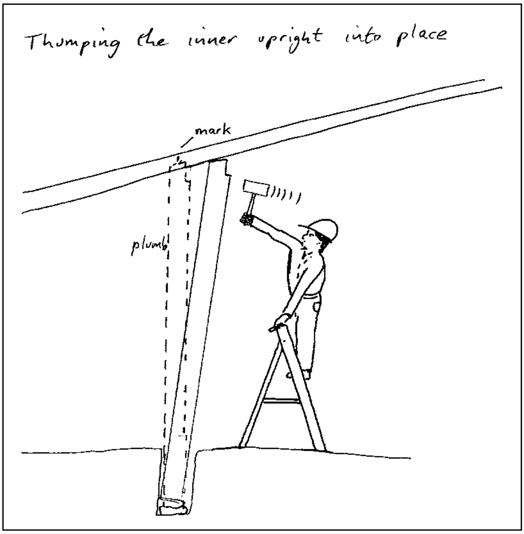
There are thirteen inner uprights, each supporting one of the main rafters. For the exact location of each, Jane and I walked around the inside of the structure we had erected, and imagined how much space would be required for each sector. As we felt OK about the space for that, we put a stick in the ground and moved on round. We went round clockwise talking it through: "Here we are in the coats area; we come in the door, kick off our boots, hang a wet coat on the post... here. Now we are in the clothes storage area - two racks of clothes hang from the wall to a low partition... here." etc. We wanted an inner room big enough to dance in, and have band practices or meetings, so we tried to keep the outer ring reasonably narrow. In practice this worked out at the inner circle being about 2m in from the outer one, widening a bit in the north and narrowing a bit in the south sun bit/bath area. I've never actually measured it all the way round. Hard to believe, isn't it, but I didn't need to.

The way we built the inner henge was to put each upright in first, then fit the crosspieces in situ. Kit form would have been possible, but this way each piece is custom made to its own rafters - less chance for the working of the great Murphy's Law ("Yea, if something can go wrong, it will"). Going round to each rafter in turn with a ladder, I moved a plumb line up or down the rafter until the lead was at its closest to our stick marks. Jane then put a new marker stick to mark the place exactly; I marked the rafter where the new upright would meet it, measured how long the support would be, marking it down on a piece of paper, and we moved clockwise to the next. When we had finished, Jane started digging the holes a cubit deep, and I started dragging the poles into position, their bottom ends already debarked and creosoted. These poles are the heaviest in the structure, because of their length, and they are all at least a hand span thick, so each one must weigh at least 100 kilos. I cut them to length with an angled saw cut (*diagram 6*) to give a better fit at the rafter, and also debarked and flattened the rafter at this point. If you want to be ethnic and use a good scrabble word here, pick up your adze. If you don't have an adze, you can do this kind of job quite adequately with a hand axe tapped like a chisel with a hammer or mallet.



(diagram 6) Shaping detail for inner uprights.

When all was ready, and stones placed in the bottoms of the holes, three of us put each pole in its hole and raised it up from the centre of the circle to take advantage of the rafter's slope. (*diagram 7*) When the pole was touching the rafter, but still at a slight angle, I went up the ladder and thumped the pole into place with a heavy mallet until the pole was plumb vertical. If the pole is 1 or 2 cm too long, there is enough play in the long rafter to accommodate it. If the pole is too short, put stones in the hole until it is a tiny bit too long. In our case, miraculously, the poles were all just right, and after they had been thumped very satisfyingly to the vertical I fastened them with fixing strap to the rafters. Don't make this a final fixing - just a temporary fixing on the sides (although hammer 2 or 3 nails well in on the top of the rafter) so that the cross pieces can later use the same fixing strap.



(diagram 7) Installing inner uprights.