Modular insulated Warré hive

The Aim:
To insulate a Warré hive to the equivalent thermal resistance of a Warré-sized cavity in a cedar tree whose trunk is approximately 30 inches in diameter, which would determine cavity "walls" that are 8 inches thick.

The Plan:
To insulate each Warré hive box individually so boxes can be added, removed or manipulated without disrupting the insulation of their neighbours, over the annual cycle of growth and reduction of the number of hive boxes.

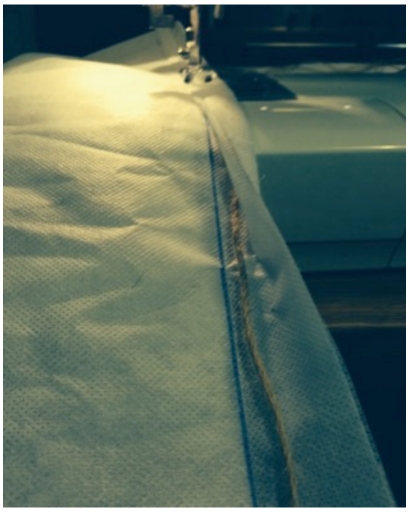
Weather proofing would have to overlap the boxes to make the insulation waterproof, but "disconnecting" a box from the weather proofing system should take less than a minute, and "reconnecting" similar. The weather proofing materials and insulation should remain attached during the process.

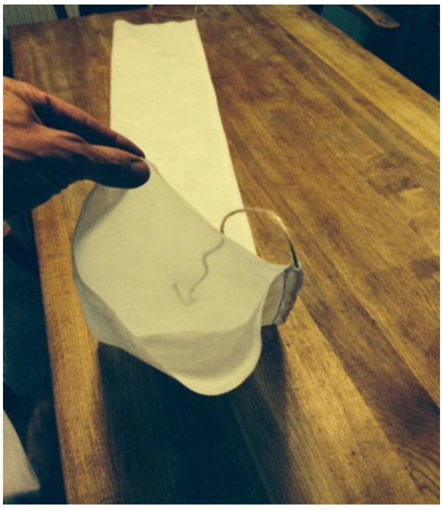
The Attempt:
It was calculated that a thickness of 2.75 inches of sheepswool would be adequate to raise the thermal resistance of the 1 inch thick walls of a Warré hive box from R1.4 to R11 – the equivalent of 8 inches of cedar. [see Note 1]

Sheepswool was sourced in the UK from Woolcool, https://www.woolcool.com a company that makes woollen insulating packaging used by organic food suppliers to keep their products fresh in transit. It's also used to keep human organs and vaccines chilled in transit. Woolcool thoroughly clean their wool!

It came on a roll whose width turned out to be exactly 6 times the height of a Warré box. A double thickness of the wool was 2.75 inches. Three strips were cut long enough to comfortably wrap around a Warré box, and folded over to make double thickness. Cheap non-woven polyester fabric was cut to make a cover, like a pillowslip, for the strips

When the fabric was sewn into a sleeve, the hem was stitched to allow a sisal drawstring to be inserted, and move freely, the length of the sleeve:





An identical length of sisal was placed inside the fold of the strip of wool when it was folded over double, and the wool was inserted into the sleeve. The ends were then sewn closed, ensuring that both lengths of sisal could slide freely and act as drawstrings:

Breathable roofing membrane was attached as weather proofer.
http://www.protectmembranes.com/uploads/ddd45e1cb3584a908c2ffb62079b4bb1.pdf

Strips were cut 13 inches wide (to allow an overhang) and 10 inches longer than the woollen sleeves. Using a needle strong enough for denim, the membrane was sewn to the hem of the sleeve with 5 inches extending either end:

The stitching stopped short of the ends of the sleeve by 3 inches to allow for more convenient tying of the drawstrings:

(End of woollen sleeve open in this photo for illustrative purposes)

Stationery was used to help attach the sheepswool sleeve to a Warré box, and seal the roofing membrane:

Each hive box needs 2 large paperclips and one plastic slide binder. Trim the slide binder with a hacksaw so it's a little shorter than the height of a hive box – and preserve the end with the curved guide. The bulldog grip is an essential third hand!

The woollen sleeve was tied in place with the two drawstrings:

The bulldog grip was used to hold one end of the woollen sleeve onto the corner of a box while the sleeve was tightly wrapped around. The drawstrings were tied together:

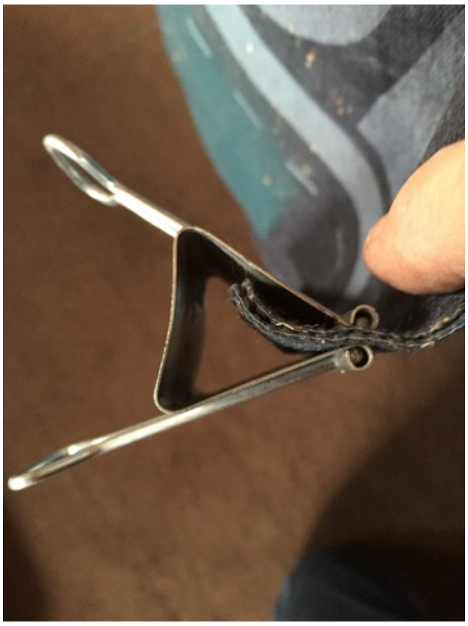
 

The top drawstring needs to be as near to the top of the hive box as possible. A good way to achieve this is to tie it tightly in place with one corner of the box slightly covered - and then use your thumbs to prise the drawstring back down onto the vertical corner edge: it's hard work, but the drawstring becomes very tight indeed, allows for precise manipulation, and will stay where you put it!

The bottom drawstring should similarly be as near as possible to the bottom of the hive box.

<u>Sealing the roofing membrane:</u>

The two ends of the membrane were aligned and carefully held with the bulldog grip:

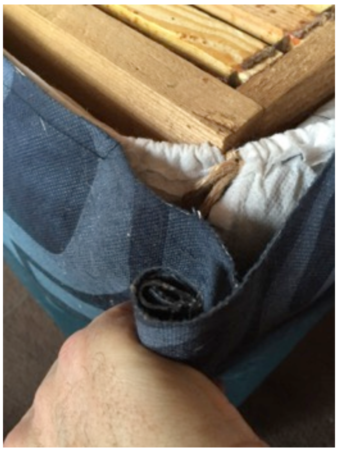
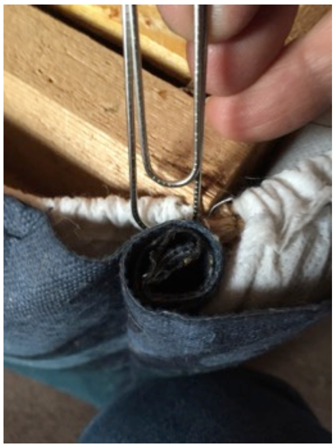


And then the slide binder was slid down through the bulldog to grip the ends together:

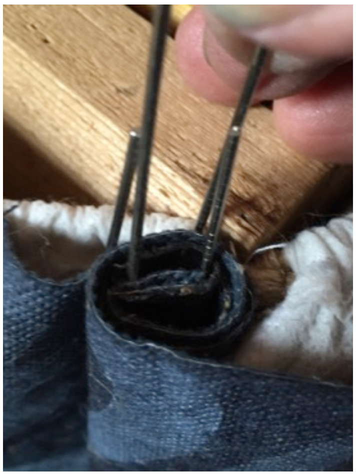


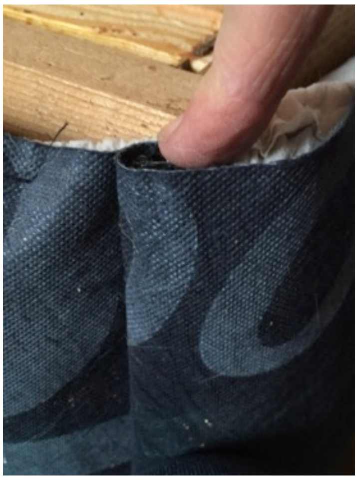


The slide binder was then wound towards the hive box making a tight roll of membrane:

And the roll was held in place by paperclips – at the top of the membrane the small loop of a paperclip was inserted inside the slide binder in the middle of the roll, the large loop between the roll and the woollen sleeve:





Making sure the roll at the bottom was as tight as possible (it's beyond the full influence of the slide binder which is too short to reach the bottom), the large loop of a paper clip was inserted into the centre of the roll and the small loop between the membrane and the hive box:


This hive box is now insulated, and the sealed roofing membrane which overhangs the box below can keep the insulation wind and waterproof.

To remove this box from the hive, simply extract the bottom paperclip, loosen the roll of overhang, and fold it up (paperclip in photo is just making sure it doesn't get lost!). The slide binder ensures that the roofing membrane covering the insulation stays in place, and only the overhanging membrane is flipped up:

The insulation drawstrings can be nudged up and down at the corners to expose the bottom of the hive box:

The first time you perform this task it might take all of a minute, but subsequently it's difficult to make it last more than 30 seconds!

The hive box can now be treated in the conventional way, and lifted by the handles gripped through the insulation. The top and the bottom surfaces of the box are unencumbered by the insulating process:

After replacing the box, the insulation draw strings are edged up and down to where the hive boxes meet, and the overhang membrane is folded down. The bottom of the rolled join in the membrane is reconfigured and tightened to match with the roll still firmly held by the slide binder, and the paperclip reinserted. The process will come to take less than a minute with practice.

The insulating component of this hive box could now be considered as integral to it as its top bars: put in place before that box is nadired into the hive, and then hopefully left alone until the box rises to be harvested some years later, when any need for maintenance could be assessed. The insulation, membrane and paperclip fastening on my boxes have survived 3 winters and still going strong.

<u>The quilt box</u>

In an attempt to emulate the thermal resistance of what might be as much as 20 feet of tree trunk above the feral colony living in the Warré sized cavity in our hypothetical cedar tree, the height of the quilt box was doubled from 4 to 8 inches – the size of a hive box.

20 feet of cedar has a thermal resistance of R336. 8 inches of wool is R28 – the equivalent of 20 inches of cedar above our feral cavity. Not a flagrantly excessive amount of tree to be emulating.

So while some might feel 8 inches of wool in the quilt box is only needed during the kind of winters bees encounter in Siberia, it's worth noting that even in the temperate Soft South of the UK, current building regulations stipulate a minimum of 8 inches loft insulation for human dwellings - in suburban homes clad with wisteria, 8 inches is not thermal hysteria! They'd want more in Siberia!

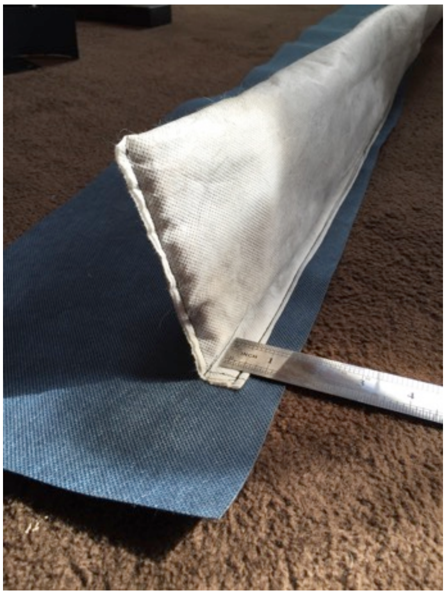
Here's how the 8 inch quilt box connects the Warré roof to the top hive box: a hessian bottom and four simple swivel stays are added to a hive box that's filled with sheepswool:


The stays do not need to waterproof the join between quilt and hive box, they're just stopping it sliding off.


Back to the sewing machine for a slightly different woollen sleeve: same length as before, but this time the wool is a single thickness and only 4 inches wide:


There's a very wide hem of a good half inch, but no drawstrings.

The roofing membrane water proofing is the same length as before but narrower – about 10 inches – and this time the sleeve is stitched right up to its ends, but about half an inch from the top of the membrane:



Fit the Warré roof onto the 8 inch quilt box and draw a line around its bottom edge, then draw another line 1.5 inches above it:

With a thumb tack, pin the middle of the quilt woollen sleeve to the middle of the front of the quilt box, so the top of the membrane follows the top line:

Move onto a side and pull the membrane as tight as you can whilst still following the line with the top edge: because of the thickness of the insulation, this will create a pleat/fold in the membrane at the corner. This is fine, just keep it to a minimum. Pin the membrane in place on the line in the middle of the side.

Repeat with the other side, and at the back:


Pin down the pleats/folds and check that the two ends of the membrane align:


Once you're satisfied it's tight and following your line, roll the two ends of the membrane together as tightly as you can towards the quilt box and staple the roll to the quilt box. Then staple the rest of the top of the membrane to the line and remove the thumb tacks:


Make the bottom of the membrane roll as tight as possible and fix with a paperclip as before:

The roof overhangs the top of the quilt's roofing membrane:

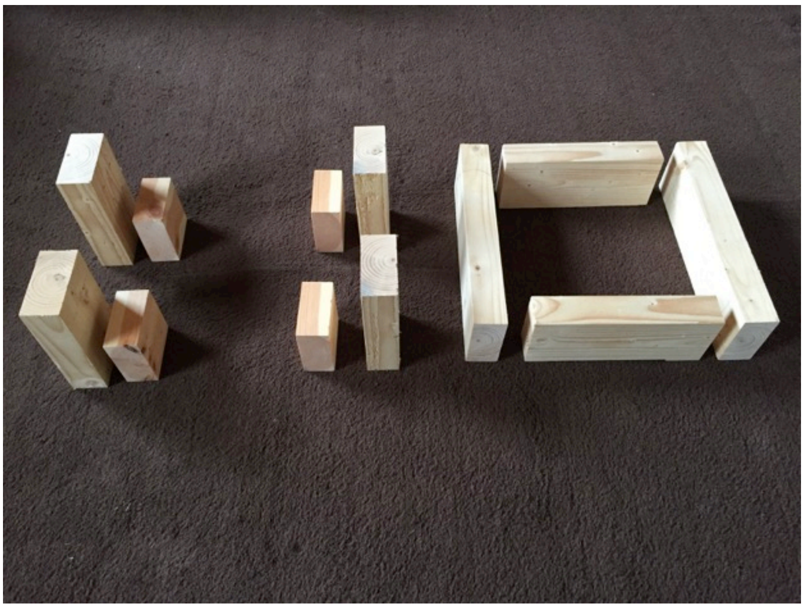
To remove the quilt box the bottom paperclip is taken out and the membrane and insulation folded up. The stays can then be rotated to the unlocked position and the quilt box lifted away:

When replacing the quilt box, after locking the stays, fold down the woollen sleeve first and make sure it's properly in place with the two ends meeting squarely, before folding down the membrane, reinstating the roll and reinserting the paperclip – it won't take a minute:

The hive base

In pursuit of thermal equivalence, a very modest 4 inches of sheepswool have been incorporated into the hive base – emulating a mere 14 inches of cedar tree beneath our Warré sized feral cavity, but of some thermal significance on the many windless days and nights in both winter and summer.

The base is designed around using 4 x 2 inch timber in a way that maximises the accuracy of the specification provided by the sawmill:



The 8 pieces of wood in the above photo with horizontal grain all have the same 4 x 2 cross section as provided by the saw mill: parallel and perpendicular.
So resting them on a flat surface next to a vertical wall allows for reasonably precise assembly, without clamps or jigs: screws are more expensive than nails, but minimise plaster damage to the wall from banging!

Before fitting the legs to the main base, breathable roofing membrane is positioned on the bottom:


And then breathably clad in an attempt to keep out insects and hibernators:


Wool is added inside the main base which is covered with a standard hive floor:



(This hive base is a modification of an attempt at a more ventilated "eco" version I can no longer convince myself is tree-like [see Note 2])

To prevent any possibility of the insulation on the bottom box sagging and blocking the hive entrance, two "tent poles" are added at the sides of the landing board:


These "tent poles" only need to be tall enough to be flush with the surface of the hive floor, but slightly taller could be useful when nadiring – acting as guides to align the front of the bottom hive box. The potential value of this, set against a reduction in manoeuvrability of the bottom hive box, remains to be seen.

Space is still available either side of the entrance for fixing a mouse guard.

The overhang at the front of the bottom box must be tucked up under the woollen sleeve:

Side view

The walls of this Warré hive now emulate the thermal resistance of our hypothetical cedar tree, but they're not identical: the layer of wool cannot carry the thermal mass of 8 inches of cedar.

But the cedar never naturally evolved to be an insulator. Whereas the wool spent around 8 million years evolving to help keep an organism alive at a constant temperature of 39C. We are now discovering all sorts of clever ways wool does this - much of the significance of the breathability of the materials covering the wool in this hive insulation system is to allow the wool to proactively respond to the changing atmospheric humidity

And while 39C isn't perfect for the 35C the bees need to maintain for their young, it's pretty close…

Note 1:

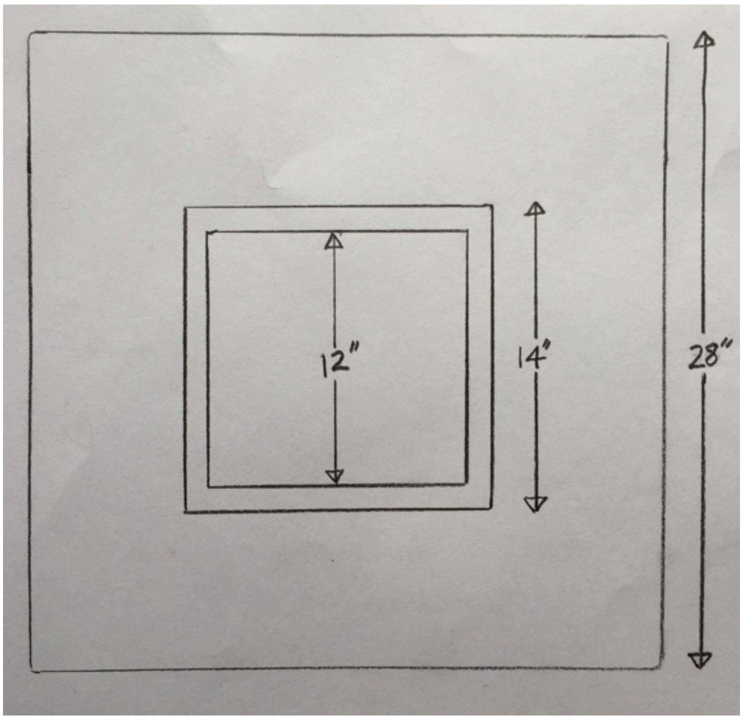
Cedar has a Thermal Resistance of R1.4 per inch
http://energy.gov/energysaver/articles/energy-efficiency-log-homes
Wool's is R3.5 per inch
http://energy.gov/energysaver/articles/insulation-materials

Professor Tom Seeley found feral hives' Thermal Resistance in the range R5 – R15

Two 35mm layers of wool = 70mm = 2.75 inches x R3.5 = R9.6
(In addition to R1.4 of 1 inch cedar)

Total Thermal Resistance of wool-clad box = R11.2
(Slightly above Seeley's median R10)

To achieve the R9.6 added by the wool, 9.6 divided by 1.4 inches of additional cedar would be required = 7 inches. So to achieve the same Thermal resistance of R11.2 the solid cedar hive walls would need to be 8 inches thick.



Weight of R11.2 Hive Box:
Cross-sectional area of 1 inch thick box = 14x14 – 12x12 = 52
Cross-sectional area of 8 inch thick box = 28x28 – 12x12 = 640

The 8 inch thick cedar box is heavier by a factor of **12.3 -** 25kg empty – potentially 50kg full of honey

The thermally equivalent 1 inch thick cedar box wrapped in wool weighs 2kg.

Note 2:

An earlier version of the hive base was designed to incorporate insulation, allow condensation to drain from the hive, and provide a more "eco" hive floor for the bees. I no longer think draining condensation from the hive emulates a tree cavity, and the hives on my roof are separated from the soil by 4 storeys of bricks and mortar – too great an "eco" disconnect I fear.

A double layer of stainless steel mesh was fixed to the bottom to keep out hibernators:

Wool was added inside the base and topped with a layer for shredded tree from a bee-friendly local tree surgeon:

Initially cedar shavings were used instead of the shredded tree, but they were light enough for the bees to carry, and they assiduously removed them from the hive!

https://drive.google.com/open?id=0Bw5eG71kwvhZMmxnNVNCWjhmNU0