THE CONSTRUCTION OF
CORRUGATED ROOFING SHEETS
USING
SISAL-CEMENT

D.G. Swift and R.B.L. Smith
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1. GENERAL INFORMATION

This brochure describes a method of making and fixing sisal-cement corrugated roofing sheets. It also gives details of their properties and cost. The process described has been developed and tested by the authors at Kenyatta University College, Physics Department and Nairobi University Department of Civil Engineering.

The present brochure is intended for those who may wish to make the sheets either for themselves or to sell on a village-industry basis. It is assumed that the reader has some basic skills, for example, in joinery, enough to make a few boxes and similar items using a saw, hammer and nails, glue, and so forth. This is for the construction of the initial apparatus, for which a carpenter could be hired if necessary. Some familiarity with plastering and concrete making will also help, although these are skills that will be soon picked up, sufficiently for present purposes, with experience of making the sheets.

Sisal-cement roofing sheets are similar to asbestos roofing sheets and, like asbestos sheets, are cooler than metal in sunny weather, quieter under heavy storms including hailstorms, and lighter than concrete tiles. They are slightly heavier and weaker than asbestos sheets for sustained loads. However, they are not so easily damaged by knocks, and are much cheaper, costing less than corrugated iron sheets. The process for making them is also simple and cheap.

Sisal-cement sheets use a very rich concrete mix: two parts of cement to one of sand. This makes them strong and waterproof (provided not too much water is used when making them). Sisal fibres, added both as long fibres and as short, chopped fibres, make the concrete very tough (i.e. not brittle) and improve the strength. If well made, the sheets are strong enough, when supported on a span of one metre, easily carry two men without being damaged. They can be nailed, and when bent until they break by a very large load, do so only after considerable bending and cracking; they do not suddenly fail as asbestos sheets do when heavily loaded.

At the outset, however, it should be stressed that the sisal-cement sheets described in this book are new materials. They appear to be satisfactory according to the tests carried out so far. However, they have not been fully tested, especially for long-term behaviour, and so we cannot guarantee how long they will last or that the present process of making the sheets is the best possible method. On the other hand, because of the present favourable results from tests, the very low cost of the sheets, and their other advantages, we feel that people should now be given the opportunity of making them. The authors would welcome any comments or queries concerning the sheets, especially from those who find problems with their construction or use, and from those who can suggest improvements. Please address such comments to:

Dr. D.G. Swift,
Physics Department,
Kenyatta University College,
P.O. Box 43844,
Nairobi, Kenya.
2. SUMMARY OF STEPS TO BE TAKEN IN SETTING UP THE PROCESS

The following is a brief summary of the steps that would need to be taken by someone setting up a construction unit to make sisal-cement sheets, whether for himself or to sell. Details of the various steps are given in subsequent sections.

A. Identifying or constructing basic facilities

These include dry storage areas for the cement and sisal, shaded areas for constructing the sheets and storing them during the initial curing period, a clean and reasonably dry storage area for the sand, a water supply, a water curing tank if possible, and places for chopping the fibres and mixing the cement.

B. Obtaining the tools and materials

These include:

(a) tools for making the wooden moulds,
(b) tools and containers for use when making the cement sheets,
(c) materials for making the construction apparatus
(d) materials for making the sheets themselves

The quantities of tools and materials will depend on how many sheets are to be made each day, how long the sheets are to be cured, and which method of fixing to a roof is to be used.

C. Making the construction apparatus

The basic apparatus consists of:

(a) a flat wooden moulding board
(b) measuring boxes for measuring out cement and sand
(c) a polythene moulding envelope for making the initial flat sheet and transferring it to the corrugated mould
(d) the corrugated moulding block
(e) a sieve to obtain fine sand

plus the tools mentioned in B. above.

D. Preparing to cast a sheet

This involves:

(a) weighing, or measuring out, and chopping the sisal fibres
(b) measuring the correct quantities of cement, sand and water,
(c) mixing the mortar

E. Making the initial flat sheet

Alternate layers of mortar containing chopped fibres, and long fibres arranged in two directions as a loose, unwoven mat, are placed on the polythene moulding sheet on the flat wooden board. The layers are then covered with the top polythene sheet of the moulding envelope, and the surface is smoothed flat.

F. Corrugating the sheet

The wet, newly-made sheet is pulled from the board onto an asbestos sheet with a concrete backing. This is performed by fitting one end of the moulding envelope to an end of the asbestos sheet "moulding block" using wire, and pressing the wet sheet into the asbestos corrugations using drain pipe whilst at the same time sliding over the flat moulding board.
G. Devices for fixing

Once the sisal-cement sheets have dried and hardened sufficiently, they are tough enough to be nailed directly to roofing purlins. We do not, however, recommend this; it requires expensive masonry nails to penetrate the sheets without bending and some damage occurs around the nail hole, and this may be a source at which cracks can develop and spoil the sheets.

Better methods of fixing the sheets are:

(a) to make small holes in the wet sheet where the sheet, when it has hardened, is to be nailed to the purlin. For example, pieces of wood, including twigs, can be pushed into the sheet in these positions and left in place, since they are easy to nail through. The sheets are then fixed to the roof by first nailing through a bottle top, and, possibly, a rubber washer made from car tyre inner tube, and then through the sisal-cement sheet to the purlin.

(b) to drill holes in the final sheet using a masonry bit and then to nail the sheet as in (a) above.

(c) to add to the wet sheet wire fixing loops that will remain firmly fixed in the sheet as it hardens.

II Curing, storing and transporting

Like any other concrete, the sheets should be kept moist for a long period and then slowly dried. The polythene moulding envelope will keep them sufficiently moist for at least 24 hours. If possible, they should then be placed in a water tank and kept there, fully submerged, for four weeks. However, this may be impracticable or uneconomic and then some compromise must be made.

After this curing, the sheets must be dried slowly or they are liable to crack. Once dry, they are strong and tough. Even so, reasonable precautions should be taken when handling, transporting and storing them.

I Laying the sheets on a roof

The order and manner in which the sheets are laid on a roof will depend on the direction of the prevailing wind. Overlaps will depend on the slope and size of the roof. As with asbestos sheeting, it is necessary to mitre the sheets at the corners to avoid having more than three layers of the relatively thick sheets at any point. Purlin and rafter sizes and spacing must be in accordance with the weight of the sheets.

The above steps are described in detail in the main body of this pamphlet. Those who have tried making a few roofing sheets and wish to set up a small business to make and sell them will also need to consider costing, labour, production flow, planning of layout and quality control. These topics are included in an appendix. Also included are suggestions for those who are unable to obtain all the items mentioned in this pamphlet, or who may wish to try modifications to improve the process.
3. EQUIPMENT AND MATERIALS NEEDED

A. Tools and ancillary equipment

For constructing the apparatus, you will need to borrow or purchase a few basic carpentry tools including a hammer, pliers, saw, hacksaw, large screwdriver, a smoothing plane or sharp knife, a rule, a straight edge and a try-square (or a triangle of wood having sides in the ratio 3:4:5, eg. 30 cm, 40 cm and 50 cm). A drill will also be helpful, and necessary if you intend to drill through the sheets to fix them — in this case you will need a 6 mm masonry bit.

For making the sheets you will need a plastering trowel or float (preferably both). A paint roller as used for lino-cuts is also useful if one can be obtained (eg. from a shop selling school equipment).

For cutting the sisal, sharp scissors can be used, but a paper guillotine, obtainable from shops selling office supplies, is much easier to use. A good-quality paper-stapler is also useful for making the polythene envelopes, and can be obtained at the same place.

When mixing the mortar, an ideal container is a large plastic washing bowl of at least 20 litres. A strong stick or piece of dowelling at least 12 mm thick is sufficient to stir the mix. Water can be carried and measured using empty litre or half-litre tin cans (eg. empty Kimbo tins). These can also be used to hold the chopped fibres.

For transferring the sheets onto the corrugated mould, you will need some drain pipe (eg. P.V.C.) of about 90 mm diameter. You will need at least two lengths of about 1100 mm.

For corrugating the sheets, you will need one-metre long asbestos sheets having deep corrugations (eg. "Super seven" or "Super Six"). It may be necessary to buy two-metre lengths and cut them using a hacksaw. Obtain sufficient sheets for the number of sisal-cement sheets you intend to make in one day.

A water tank is the best way of curing the sheets, but if this is felt to be inconvenient or too costly, a watering can may be useful to keep the sheets moist during curing.

Summary

Essential items: hammer, pliers, saw, hacksaw, drill, large screwdriver, Knife or smoothing plane, rule, straight edge, try-square, plastering trowel or float, scissors or paper guillotine, several old tin cans, plastic washing bowl, strong stick or dowelling, asbestos sheets, drainpipe.

Optional items: paint roller, paper stapler, watering can, water curing tank, 6mm masonry bit.
B. Materials for making the construction apparatus

For the moulding board:

1 sheet of 1.2 m by 1.2 m by 8 mm plywood
1 sheet of 1.2 m by 1.2 m by 18 mm plywood or blockboard
2 of 25 mm screws
4 washers to fit the screws
15 of 20 mm nails

For the measuring boxes:

8 mm plywood (remainder of that used for the moulding board)
2 pieces of wood 220 mm by 20 mm by 20 mm
4 pieces of wood 200 mm by 20 mm by 20 mm
4 pieces of wood 180 mm by 20 mm by 20 mm
4 pieces of wood 160 mm by 20 mm by 20 mm
2 pieces of wood 140 mm by 20 mm by 20 mm
56 of 20 mm nails

For the polythene moulding envelope (for each envelope):

1 sheet of heavy duty transparent polythene, minimum size 2255 mm by 1000 mm
1 piece of 1100 mm by 12 mm by 8 mm plywood
8 staples (paper staples or small fencing staples)

For the moulding block:

1 sheet of "Super 7" or "Super 6" (i.e. deeply corrugated) asbestos roofing one metre long
4 pieces of wood 1 m by 100 mm by 25 mm
1 piece of wood 1 m by 25 mm by 25 mm
2 pieces of wood 1.1 m by 25 mm by 25 mm
12 of 35 mm screws

A sheet heavy duty polythene 1.2 m by 1 m

Small quantity of oil (for oiling the mould - old used motor oil is adequate)
1 of 50 kg bag of cement
150 kg sand

Tamping beam (e.g. piece of wood 1.2 m by 50 mm by 50 mm)

About 1 m of thin iron wire

For the sand sieve:

piece of wire mesh with 1.5 mm holes, size 1 metre by 600 mm
2 pieces of wood 1 m by 100 mm by 25 mm
2 pieces of wood 50 mm by 100 mm by 25 mm
8 of 35 mm wood screws.
C. Materials for making the sisal-cement sheets

For each sheet to be made, allow 10 kg of cement, 5 kg of sieved sand, 0.4 kg of sisal and about 5 litres of water. This allows a wide margin for wastage.

(a) Cement

This should be bought not more than 3 months in advance, and must be stored in a dry place. Do not open bags until necessary, and reject cement which contains many hard lumps (use this cement for other purposes such as paving).

(b) Sand

This should not contain too much dust, silt or vegetable matter. To check this, fill a bottle three-quarters full of sand, add a little salt, and fill the remainder of the bottle with water. Shake the bottle vigorously and allow to settle. If the water becomes very muddy during shaking and a layer of more than 1.5 mm thickness forms above the sand as the water clears after shaking, the sand is too dirty to use as it is. If better sand cannot be found, wash the sand thoroughly before use. If there are a lot of large grains which will not pass through the 1.5 mm wire mesh, provide extra sand to allow for this wastage (the 'wasted' sand can again probably be used for other concreting jobs).

(c) Sisal

The sisal used must be line fibre of length about 1 m and must be perfectly clean with no leaf, pulp, juice, bark, tow (i.e. frayed, short fibres), knots or other imperfections. That is to say, it must be fully and carefully decorticated, thoroughly washed and sun dried before use, with the hanks finally being lightly beaten on 'brushed' to free the individual fibres and remove short fibres. If purchasing from a sisal estate, choose grade 'B' if possible. (Grades 'U.C.', and 2 or 3 are short but reasonably satisfactory, and grades 1 and A are perfectly acceptable but a little more expensive with no additional advantages). The sisal should be stored dry, for example, with the cement.

(d) Water

This must be clean. That is to say, it must not contain salt, silt, or appreciable quantities of plant juices, oil or chemicals. If it is good enough to drink it will certainly be adequately clean.
4. MAKING THE CONSTRUCTION APPARATUS

(a) Moulding Board

1. Cut two strips of 8mm plywood 50mm by 40mm and drill or burn a hole in the middle of each.

Two 50mm x 40mm strips of 8mm thick plywood drilled or burnt hole for screw

2. Nail 3 strips of 8mm plywood of dimensions shown to an 18mm board, checking with a try-square that they are nailed squarely.

Nail the two pieces containing the holes as shown.

Plywood or blockboard
18mm thick, size 1200mm x 1200mm

Dimensions

1150mm 16mm
1110mm
1.2m
1200mm

Dimensions

40mm wide strips of 8mm thick plywood
Cut two further strips of 8mm plywood, this time 64mm by 40mm. Drill or burn holes in each 18mm from one end as shown.

Screw these two new strips down onto the other strips that had holes made in them, passing the screw through each hole, and putting washers above and below the top strip as shown. The top strip should now rotate in each case, bridging the 16mm gap.
Measuring boxes

1. Nail four strips of any small square section wood (say 20 x 20mm) cut to length so as to leave 8mm round the edge of the board.

2. Nail four further pieces of the same square section wood as shown.
Finally nail two pieces of 8 mm plywood of size 236 mm by 200 mm, and pieces of 8 mm plywood of size 220 mm by 200 mm on as shown to make the sides of the box. This box is now ready to be used for measuring out cement so write the word CEMENT on it.

Make a box for the sand in the same way, but with base 196 mm square instead of 236 mm square, and height 160 mm instead of 200 mm.
(c) Polythene moulding envelope

Take a 1 m wide strip of heavy duty transparent polythene sheeting 2255 mm long and lay it in the moulding board as shown.

slot covered by rotatable strip of wood.

Insert a piece of 8 mm thick plywood 12 mm wide and 1100 mm long into the slots on the moulding board, moving aside the rotatable strips to enable you to do this.

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Fold back the polythene sheet over the piece of wood and staple it to the wood using a paper-stapling machine (or small nails folded over).

The moulding envelope is now ready and can be removed from the moulding board.
(d) Concrete moulding block.

1. Take four pieces of wood 100mm by 25mm by 1 metre long.

2. Take one piece of wood 25mm by 25mm by 1m long, and chamfer the two top edges using a knife or plane to give the shape shown, i.e. so that when seen from one end it looks like a house with a centre ridge and two sloping roofs.

3. Nail the 25mm by 25mm strip to one of the 100mm by 25mm pieces as shown below.

4. In two of the remaining 100mm by 25mm pieces cut slots as shown below.

piece 1

piece 2, cut the same way as piece 1.
Join the four pieces of 100mm by 25mm by 1m wood together as shown below using wood screws.

Fit an asbestos sheet (1m by 1m) inside the mould to form its base. It must fit exactly against the strip as shown, so that the bottom surface of the asbestos as it rises to meet the strip is level with and touching the edge of the sloping "roof" of the shaped strip.

To make it do this, pack under the asbestos sheet with sand and stones until it is correct.
1100mm by 25mm by 25mm wooden pieces placed in the slots in the mould

- oil the sides of the mould

- lay polythene on the asbestos sheet in the bottom of the mould

Lay polythene in the base of the mould, oil the wooden sides of the mould with a rag or sisal dipped in, eg., spen engine oil, and slide in the two pieces of wood as shown.

Fill the mould with mortar made from:

(i) One 50kg bag of cement
(ii) Three cement bags full of sand (approx 150kg)
(iii) About 25 litres of water to give a fairly stiff mix.

Push the mortar carefully into all corners of the mould, press it down firmly with a stick, and bang the top with a tamping rod (ie. a thick stick) to fully compress before levelling off.

Cover the mould with a polythene sheet, and leave under some shade for one week (or at least three days)

Remove the polythene sheet, turn the mould carefully upside down, remove the wooden sides and the asbestos sheet and polythene from the top. The mould is now ready to use.
(e) Sand sieve

1m

wire mesh
1.5mm wire mesh
stapled or nailed
onto wooden frame
made from 100mm by
25mm wooden boards.
5. **MAKING THE ROOFING SHEETS**

(a) Preparing to cast a sheet.

**If you have a suitable weighing machine or balance:**

Weigh 150 grams of sisal ready to be chopped
250 grams of sisal ready to be laid in the mould

Do not tangle the sisal: keep it straight and dry.

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**If you do not have a suitable weighing machine:**

Take a large enough bundle of sisal so that, when twisted as tightly as possible, it is as thick as your little finger.

For grade 3L sisal, this bundle will weigh 100g. Lay out one and one half of these bundles to give 150g of sisal to be chopped later. Lay out two and one half bundles to give 250g ready to be laid in the mould.

If using U.G. grade, take two bundles instead of 1½ and 3½ bundles instead of 2½.
Cut the 150g of sisal to lengths of 25mm (the length of the end of your finger) using scissors, or, better still, a paper guillotine if you have one.
Put the chopped sisal in a dry, empty tin.

Arrange the long sisal in four equal bundles (about 60g in each). Keep the bundles straight. Do not tangle them.

Sieve enough sand to fill the smaller wooden box.
Make sure that the measuring box is pressed full of sieved sand. Press down and level off with a trowel.

Empty the sand into a mixing bowl (eg. a plastic washing bowl).
Fill the larger box with cement, removing any hard lumps. Press down and level off with the trowel.

Add the cement to the sand in the mixing bowl and stir well using a stick.
Take a few of the chopped fibres at a time and sprinkle them into the mixing bowl.

Stir well. Continue until all the chopped fibres have been well stirred in.

(N.B. Do NOT add water yet).
You are now nearly ready to cast a sheet.

Before you begin, have the following ready to use:

** (i) The moulding block and moulding board with moulding envelope fitted, all laid out on top of each other as already mentioned (see item 12 above).

** (ii) The mixing bowl containing the sand, cement and chopped sisal, plus the mixing stick.

** (iii) The four 60 gram bundles of sisal fibre.

** (iv) A bucket of water containing more than 5 litres of water, and a one-litre can (eg. an empty one-kilo tin of Kimbo). Extra tins can be used to hold the water if you do not have a bucket.

** (v) A mason's float and trowel.

** (vi) At least two lengths of drain-pipe (eg. P.V.C.) which should be about 90mm in diameter and longer than one metre (eg. 1100mm).

either

** (vii) A reel of thin iron wire and some pliers or wire cutters (if using wire loops for fixing the sheets to a roof — see section 5d).

or

**(viii) A few 8mm long pieces of thin stick (if leaving these in the sheet to provide fixing holes — see section 5d).

or

**(ix) A long thin stick for making fixing holes in the sheet (if using this method — see section 5d)

and

**(x) A lino paint roller (if you have one or can get one
Pour sufficient water into the mixing bowl to form a smooth creamy mixture. This will normally require about 4½ litres of water (eg. 4½ one-kilo empty Kimbo tins). Make sure the mixture is fully stirred with no dry parts remaining. This sisal-cement mix is now ready to use.

Using the trowel and float, carry some of the sisal-cement mix from the mixing bowl to the lower polythene sheet on the moulding board. Spread this mix out evenly. It is very important that the whole sheet is covered - no gaps are left - and that the layer is as thin as possible.
Take one of the four sisal fibre bundles and carefully lay the fibres across the mould. The fibres should lie singly and evenly cover the surface, as far as possible. They should be straight, all in the same direction.

Gently press the fibres into the sisal-cement layer using a trowel or float.

Take the second bundle of sisal fibres and lay these in the same way but this time along the mould, at right angles to the first layer of fibres. Again gently press them in using the trowel and float.
Plaster another layer of sisal-cement mix from the mixing bowl onto the fibres you have just laid. Cover them all - the whole sheet - with a very thin layer.

Now lay more fibres across and along the mould as before using the two remaining sisal fibre bundles.

Finish off with a final layer of sisal-cement mix, using all that remains in the mixing bowl. Make sure all the long sisal fibres are covered and that the surface is as level as possible.

Now cover the sisal-cement sheet you have made with the top layer of the polythene envelope. Smooth it down carefully with your hands and make it completely level with no creases or dips.
If you have a lino paint roller, run over the surface of the polythene with it to remove any bubbles from under the polythene and give a level surface.

Trim round the three open edges of the envelope using the trowel or float to leave a thin space between the sisal-cement sheet and the edges of the mould. This will prevent the edges of the sisal-cement sheet from being damaged as you slide it off the moulding board.
Slide the moulding board so that the edge of the asbestos sheet next to the concrete groove can just be seen when looking down at the mould. Make sure the corners of the asbestos sheet that can be seen are in-line with the edge of the sisal-cement sheet.

Rotate the movable strips of wood on the moulding board and lift the moulding-envelope stick out of the slots. Gently slide the sisal-cement sheet over the edge of the moulding board until the moulding-envelope stick rests in the groove of the concrete moulding block. Fasten the stick down with the iron wire attached to the sticks in the moulding block.