PRACTICAL ACTION
Technology challenging poverty

MICRO-CONCRETE ROOFING TILE PRODUCTION

Much attention has been paid to developing the small-scale production of concrete roofing tiles as an affordable alternative to both traditional roofing materials, such as thatch, and modern, mass-produced, often inappropriate, galvanized iron sheeting or asbestos cement. These tiles are relatively low in cost, durable (with a life span expected to exceed 20 years in most areas), aesthetically acceptable, able to offer adequate security and comfort, and provide protection from both the heavy rain and the hot sun.

Concrete roofing tiles are now produced by small businesses in a number of countries in Africa, South and Central America, Asia and South-east Asia, and in the former Soviet Union. The key to the success of this technology was the development of equipment and techniques to produce the tiles on a small scale. It typically costs US$5000 (excluding land and buildings) to set up a concrete roofing tile workshop, and can be less than US$1000 in areas where the vibration equipment and the moulds are made locally.

When the technology was first developed it was decided to make large roofing sheets similar in size and shape to the corrugated asbestos or galvanized iron sheets used on many buildings. These were reinforced with natural fibres such as sisal or coir. The fibre-cement mortar mix was simply spread out by hand on a flexible plastic sheet in a large mould. Afterwards the sides of the mould were taken away and the sheet with the mortar on top was gently pulled over onto a corrugated mould where it took its shape.

Problems were experienced with decay of the fibres and cracking of the sheets after only a few years, and so the production of fibre-reinforced concrete roofing sheets has been abandoned in many countries.

The next development was production of fibre-reinforced concrete roofing (FCR) tiles. With tiles (typically about 500 x 250 x 6 or 8mm) the performance of the fibre is less critical than with sheets. The fibres are added largely to control damage caused by impact during handling. Once placed on the roof, tiles are unlikely to crack if the fibres decay. In addition, FCR tiles are vibrated during their production which gives them added strength and durability. It has also been found possible to make fibre-reinforced semi-sheets (of size 600 x 600 x 8mm) by the same method without any adverse effects.

A more recent development has been to make concrete tiles without any fibre at all. These are the so-called micro-concrete roofing (MCR) tiles. Greater care needs to be taken with MCR tile production compared with FCR if the number of damaged or sub-standard tiles is to be kept low. MCR tiles are also more brittle than FCR tiles, and can be damaged if dropped or handled carelessly when transporting them or fixing them to the roof.

technical brief

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Quality control

To produce a good MCR tile, care needs to be taken in the quality of the sand to make the mortar. This should have a regular grain-size grading – without too much material of one size and, particularly, without too much fine silty material. If the sand from one source contains too much material of any one size it should be mixed with a sand of different grading from another source. In addition, the batching of the quantities of sand, cement, and water needs to be done accurately – to ensure that there is enough cement and that the mix is not too wet. The tilemaker needs to mould the tile with care and skill, and it is important that the tiles are properly cured.

With FCR tile production there is some capacity for these quality aspects to be less rigorously exercised, but with MCR production there is no margin to be lax on quality control if large numbers of damaged or sub-standard tiles are not to result. If the potential producer cannot ensure good quality control at all stages of production, then it probably is not a good idea to produce MCR tiles.

Equipment and materials

The equipment and materials needed to produce MCR tiles are the same as for FCR tiles, except that no fibre is used and the sand used needs to be of good quality, as noted above. The essential equipment is:

- a tile vibrator
- moulds
- plastic sheets
- batching boxes
- a water curing tank
- a table to work on

The use of a vibrator is essential for MCR tile production. Vibration helps to consolidate the mortar mix and removes air bubbles, which would otherwise cause weak spots in the hardened tile. The vibrator unit itself consists of a flat metal plate which is suspended on dampers and to which is attached a rotating eccentric cam. It is the rotation of this cam which translates into the up-and-down motion of the plate. A hinged metal cover fits onto the plate. This defines the sides of the tile. The vibrator may be driven manually, electrically with a standard 12-volt truck battery, or on mains electricity.

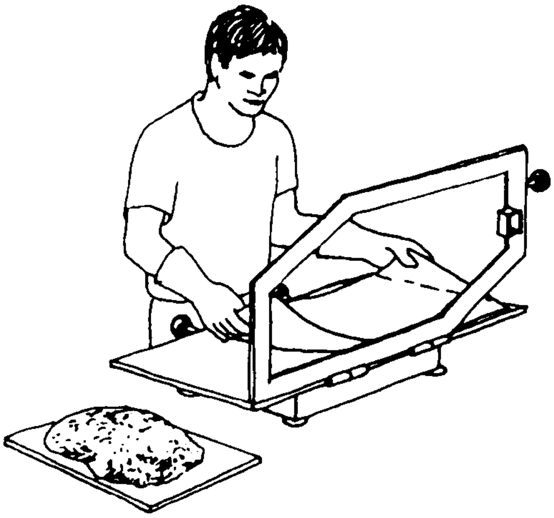

Figure 1: Place the polythene interface sheet

Because cement mortar sets slowly and the tiles need to be left on the moulds at least overnight before they can be removed, the producer will need enough moulds to cover a whole days' production. A single person should comfortably be able to make at least 200 tiles per day, and probably considerably more. (Note: the cost of 200, or more, moulds should not be underestimated – they could cost more in total than the vibrating unit itself.) Because it is important that MCR tiles cure in a damp environment, the enveloping type of mould needs to be used. These moulds are stacked one on top of the other and hence

Figure 2: Work the mortar mix under vibration

cover the curing tiles and prevent them drying out too quickly. Although cheap concrete moulds have been used for FCR tiles, which then cure open to the air, more rigorous standards are needed to cure MCR tiles. The stack-up type of moulds are made of plastic. Note also that out of a batch of 200 moulds, at least 10 should be ridge moulds for making the specially shaped tiles for the ridge of the roof.

Tiles are moulded on top of a plastic sheet on the tile vibrator. After vibration, the tile is removed carefully from the vibrator, still on its plastic sheet, and positioned on the mould which forms its shape. The same number of plastic sheets as moulds will be needed, but some additional sheets should be kept in stock to replace those which wear out.
Accurate batching of sand and cement is essential. For this reason, it is usual to have two batching boxes to measure out exactly the right amount of sand and cement needed for one tile. A measuring jug for water, to ensure that similar amounts of water are added for each tile, would also be useful.

A water tank is needed for curing the tiles. As the tiles are cured in warm water for at least five days, the tank should be large enough to hold 1000 or more tiles. A single tank to accommodate this number of tiles would need to be about 8 metres long, 0.8 metres wide and at least 0.6 metres high, although it probably would be more convenient to use a number of smaller tanks.

The materials needed to make MCR tiles are:
- sand
- cement (Ordinary Portland Cement)
- water
- pigments (optional)

The need for sand with a suitable grading has already been noted. More specifically, the following guidelines are used for sand grading for MCR tiles.

Tile thickness	6mm	8mm	10mm
maximum grain size	4mm	5.5mm	7mm
above 2mm	25-45%	30-50%	35-55%
0.5 to 2mm	20-50%	15-40%	15-40%
below 0.5mm	15-45%	15-45%	15-45%

In addition, the clay and silt content should be less than 4% in all cases. A set of three sieves with openings of approximately the sizes indicated above would be a very useful acquisition for the serious MCR tile producer. These could be used for determining the sand size grading and, possibly, for making sand heaps of different sand sizes, which could afterwards be mixed in appropriate proportions. A clean sharp sand is the best to use.

The water used should be clean and free from significant quantities of dissolved salts, particularly sulphates. If water of good enough quality to drink is available, then this should be used.

Pigments for colouring the tiles are popular in some areas. Red is probably the most common colour used for tiles.

Figure 3: Smooth under vibration

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Pigments tend to be imported and therefore expensive. Their use makes the cost of the tile significantly more expensive, but in some areas a market does exist for more expensive coloured tiles. Pigments add nothing to the strength of a tile and may even reduce it slightly.

The production sequence

The sequence of operations to make MCR tiles is as follows:

- Fill the cement and sand batching boxes fully to the top and level off. It is normal practice to use three volumes of sand to one of cement, so the sand batching box is three times the size of the cement box.
- Tip out the sand and cement onto a wooden, plastic or metal mixing board placed on a table. Mix thoroughly for up to a minute until all the material is of one colour.
- Add water to the mix gradually, turning the mix with a trowel all the time until it becomes wet enough to be workable. Add the water only slowly to ensure that too much is not added. It is best to use a measuring jug and to add a measured amount of water each time. A few trial mixes can be made to find out how much water would normally be needed. If a set of scales is available a standard water-to-cement ratio (by weight) can be determined. First find out how much cement is used per tile by weighing out the cement batching box empty, then full, to obtain the weight of the cement used. Mix the sand and cement and add a measured volume of water until a mix of the required consistency is obtained. The volume of water in millilitres is equal to its weight in grammes and from the weight the water-to-cement ratio can be calculated. A good mix will have added to it a weight of water equal to half the weight of cement (that is the water-to-

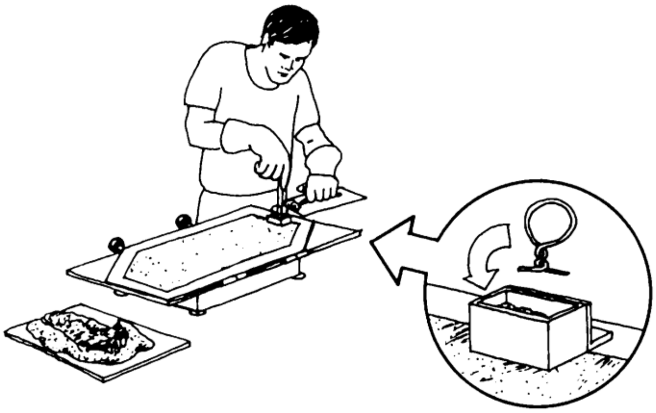

Figure 4: Fill nib forming box and insert loop of wire

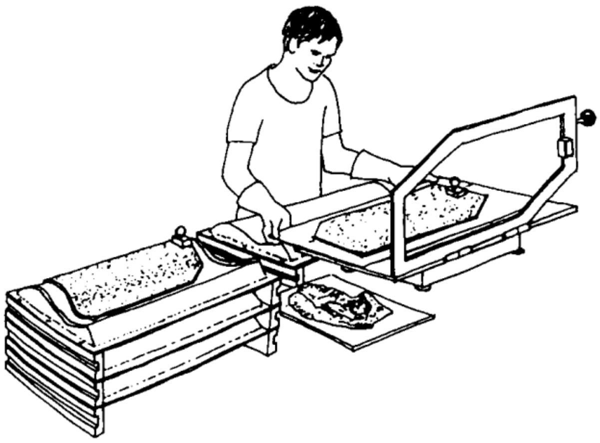

Figure 5: Pull polythene sheet with wet pantile over setting mould

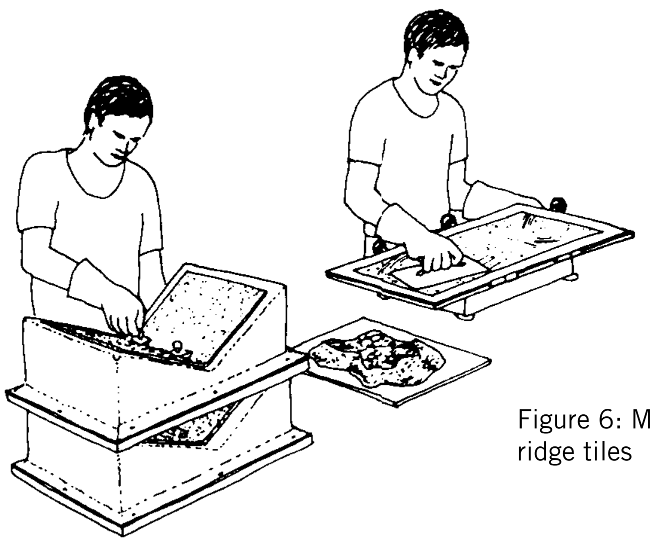

Figure 6: Making ridge tiles

cement ratio is 0.5). One millilitre of water weighs one gramme, so the weight of water in grammes is equal to its volume in millilitres. If, after adding your calculated volume of water, the mix is too stiff, add a little more water but make a note of how much extra is added. If a water-to-cement ratio of more than 0.65 is needed to make the mix workable then the resulting tiles will be of low strength and quality, so stop and re-examine your materials before proceeding.

- Place the plastic sheet onto the vibrator unit and clamp down the sides.
- Transfer the mortar mix onto the vibrator, spreading it out with a trowel.
- Switch on the vibrator unit and continue to spread the mix with the trowel. A vibration time of 30 seconds will usually be sufficient. Vibration for more than a minute is not recommended: it can cause the mix to segregate.
- Add the tile nib, to be used to fix the tile to the roof, manually.
- Remove the sides of the unit and carefully slide the green tile, still on its plastic sheet, onto the mould so that it takes the corrugated or ridge shape of the mould.
- Stack the moulds and leave overnight.
- Next day remove the tiles from the moulds and place them in the water curing tank, leaning the tiles against each other. Leave the tiles in the tank for at least five days.
- Remove the tiles from the tank and leave them to cure in the air for at least 20 days in a cool, shaded place. Sprinkle with water at least twice a day.

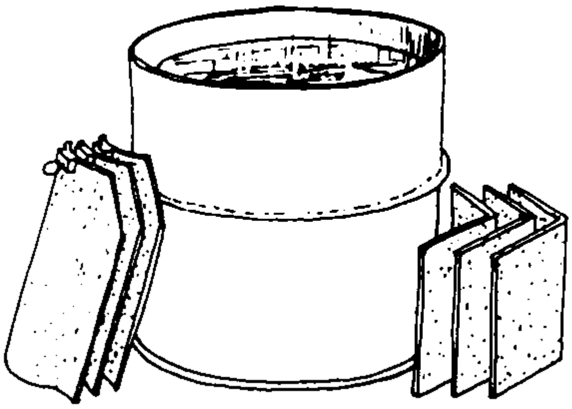

Figure 7: Cure in a water tank, in this case an old oil drum.

References and further reading

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Further advice on MCR production and MCR technology can be obtained from The Roofing Advisory Service within SKAT.

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LCHS constitutes a unit at the School of Architecture at Lund University and acts as an interface for initiating, promoting and co-ordinating international research in construction and development subjects.

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