Concrete Roofing Tiles

by Bo Johansson

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Bo Johansson was born in 1946 in Visby, Gotland, an island on the east of Sweden, and graduated as an engineer in 1967. He has been employed at Lund University since 1969, mainly carrying out laboratory and applied research with concrete. He has participated in development research projects in Tunisia, Algeria and Ethiopia since 1981, focusing on self-help housing and developing local building materials.

He is an active member of the Swedish Association for Development of Low-Cost Housing, SADEL, an independent organization established by architects and engineers at the Institute of Technology, Lund University.

When he has any free time, he does fine bindings of old books.

1 Introduction

The aim of this document is to present a simple method to produce a roofing material with cement as the binding agent. The method is well established, and the report is based on the experience of persons who have been producing tiles for 50 years. It describes primarily production and quality control of concrete tiles, not roof construction.

What limits the use of concrete tiles is their weight on the roof, which requires a strong load-bearing structure. Changing an existing roof can require strengthening the roof framework.

Advantages of concrete tiles are that they are cheap, require little financial investment and take little energy to make. Production is very simple, and the entire process can take place on the building site or in small units, which can easily be expanded later.

Problem

There is a great shortage of roofing material in almost all developing countries. Local materials are often used, like soil, stone, grass and palm leaves. These roofs require a lot of maintenance and are not always resistant to heavy rain. Materials like corrugated iron sheets (CIS) and asbestos cement sheets have replaced traditional materials. Roofing materials tend to be the biggest expense for individual home builders.

The disadvantages of CIS roofs in tropical areas are that they give a poor indoor climate and make a lot of noise when it rains. They also require a lot of energy to produce.

Asbestos cement sheets should not even be considered, because of the health hazard associated with making them. Production is banned in many countries, which is sufficient reason not to advocate their manufacture or use.

Ceramic tile roofs are good. However, if the kiln does not allow adequate temperature control during firing, the quality of the finished tiles can be very uneven. On the other hand a ceramic tile roof is often lighter in weight than a concrete tile roof, and consequently requires less wood for the trusses.

In Europe concrete tiles have partially replaced ceramic tiles for purely economic reasons. It is also much easier to control the production of concrete tiles. The transition from ceramic tiles to concrete tiles has been a long process, from manual production to modern factories. Early manufacture was very labour intensive and done in small production units. If one is interested in starting small scale production of concrete tiles, the experiences of the early producers are well worth trying. The technique allows profitable small scale production with modest investment costs.

Method

The study began with visits to a number of concrete tile factories and interviews with persons who have practical experience of manual production. Craftsmen who had machines and produced concrete tiles according to the oldest, traditional methods were visited and interviewed.

A survey of the literature was carried out with the help of the Lund University Library and through visits to institutions in Stockholm including the Swedish Cement and Concrete Research Institute and Cementa, a subsidiary of EUROC, Sweden's largest building materials company.

Organization

The report is divided into two parts.

Part 1 consists of

Chapter 1: the description of the problem;

Chapter 2: a general description of how to make concrete tiles;

Chapter 3: practical recommendations for production.

Part 2 includes

Chapter 4: quality control tests;

Chapter 5: proposals for a production unit;

Chapter 6: simple instructions for laying concrete tiles on the roof

Chapter 7: some thoughts on energy consumption and costs for roofing materials.

2 General considerations

Concrete tiles like all other roofing materials are subject to great stress from the weather. It is therefore important to be extra careful in producing the material. Special attention should be paid to the following when making concrete tiles.

- volume of production
- shape of the tile
- aggregate
- binder
- additives
- mixing
- moulding the tile
- curing
- quality control

Volume of production

The first concrete tiles were made in Germany in the 1840s. Production spread rapidly to the rest of Europe and America. Early production was very simple. Plain moulds were used, and all the work was done by hand. This method continued in some parts of Sweden all the way into the 1960s. Automatic machines were built in England in the 1920s. These have been improved, and modern machines are very advanced. With a small number of workers, modern factories can now produce around 10,000 tiles per person per day.

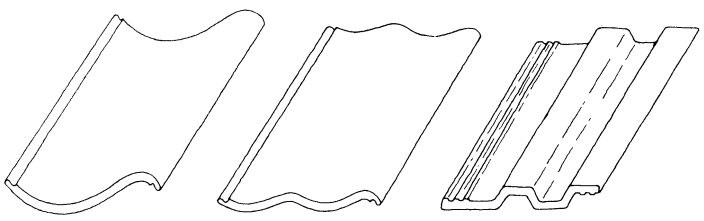
Modern, high-tech equipment mean a high production volume. On the other hand, labour-intensive manufacture with small-scale technology can very well follow the model of the earlier production units. The proposal in this report is for a production of 900 tiles a day.

Shape of the tile

Different shaped tiles give roofs with different characteristics. Ordinary tiles with flat edges must be overlapped, which gives a high weight for area ratio. At the same time, the roof is not particularly watertight. By adding grooves along the edges, to improve watertightness, less overlapping is needed, and the weight for area ratio is lower. An advantage of concrete tiles is that they hold their shape during curing, so that the grooves of the finished tiles fit together and interlock.

Groves should be designed in both sides of the tile and on the edge that will be at the top. There should be a heel on the underside at the top for hanging over the batten. This complicates the manufacture a little. A benefit of the groove at the front and the heel is that it is possible to have a relatively steep roof angle (greater than 14°) which allows better water run-off. The tile also needs little hole to allow fastening.

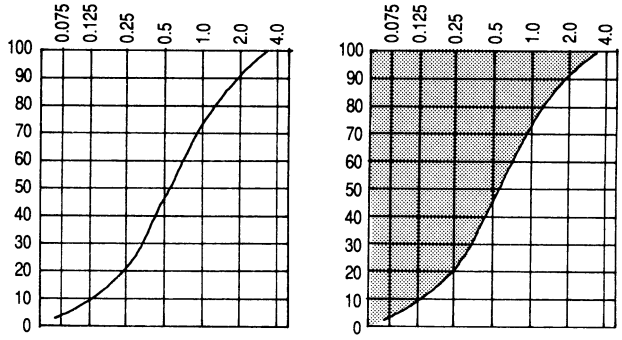
See the drawing on page 7.



Examples of concrete tiles: single tile, double tile, ribbed tile.

Aggregate

Because a suitable thickness for a roofing tile is about 10 mm, the sand used should have a maximum grain size of 4 mm. It is important to determine the particle size distribution curve of the sand. This gives the *fineness modulus* which is equal to the area in the diagram over the distribution curve.



Ideal particle size curve for sand. Fineness modulus.

The lower the fineness modulus, the finer the material. Finer material requires more water and a greater amount of cement.

Binder

The binding material is almost always ordinary Portland cement. Rapid hardening cement might also be used for a shorter stripping time, getting the tiles out of the moulds sooner.

Additives

Possible additives are fine grained inorganic materials added to concrete as a substitute for cement. The amount should be greater than 1% of the cement by weight and function to increase the concrete strength.

The most common additives are fly ash from burning coal, granulated blast furnace slag from making pigiron, and natural silica-rich soils or pozzolanas.

In general, if uniform tiles are wanted, that is tiles that do not discolour, it is better to avoid additives.

Mixing

It must be possible to mix the concrete well into a homogenous mass to produce a good concrete tile. Hand mixing is not recommended. The normal texture of concrete is very firm, possibly *earth-damp* consistency, and this requires a mechanical mixer. The mix ratio between cement and sand varies from 1:2.5 – 1:4 by weight.

Moulding the tiles

The principles for making concrete tiles are based on simple technology and equipment.

After the right quantities of the raw materials are chosen, the cement, sand and water are mixed in a concrete mixer. The tiles are then made by hand on a work table. The underside of the tile is moulded on a base sheet, usually made of pressed steel or cast iron. The base is held in a frame that also moulds the sides of the tile. The top of the tile is formed by a *modelling iron* which is normally separate, but could be mounted on the work table.

There are bins under the work table for the unshaped concrete. There might also be a sifter that can swing out to sprinkle powdered pigment over the tiles.

The base sheet, on which the finished tile rests, is released from the table by pushing it up with a pedal or lever.

There are also work tables to mould two or three tiles at the same time for a higher production rate. Experience shows that around 300 tiles can be made per day with a simple work table. This means that there must be at least that many base sheets. In practice at least double that number are needed, so that the tiles have a chance to harden sufficiently before they are stripped from the moulds.

Curing

After moulding, the concrete tiles should be stored carefully. The tiles are put on shelves in a special store which should be well protected from cold and wind. The tiles should be kept damp during storage. To accelerate curing, the tiles can be put into a chamber and heated up to 45°C. They must not be allowed to dry out, and it might be necessary to add moisture. If the chamber is packed full, the moisture in the tiles could be adequate to maintain sufficient humidity. Depending on the conditions, the tiles should be kept in the chamber for 2–5 days. Concrete tiles should not be used sooner than six weeks after moulding if they have not been heat cured, or if curing has not been accelerated in another way.

Quality control

Of the raw ingredients sand, cement and water, sand is the most important to check carefully. In most cases cement is produced under rigorous quality control, and the only things that might be checked are setting time and development of strength. Water should be of drinking quality. Sand should be clean (free of organic contamination, silt and clay) and contain a mix of grain sizes from the finest to 2–4 mm.

Concrete tiles should be tested regularly during production for water absorption, water permeability and strength.

Water absorption. A concrete tile should not absorb more water than 6% of its dry weight during 24 hours in a water-bath.

Water permeability. A concrete tile should not allow so much water to pass through that there are water drops on the underside.

Strength. This is determined by impact and bending strength tests.

3 Recommendations

The quality of the concrete tiles produced in small Swedish factories was very high. One can still see houses with roofs of concrete tiles that were made and laid around 70 years ago. On closer study the tiles appear completely undamaged by the considerable stresses of the Scandinavian climate.

Their durability, and the fact that the equipment needed to make them are themselves simple to produce, make these tiles very interesting. Capital investment costs are very low in such cases. Naturally some equipment much be acquired: a concrete mixer, transport for the ingredients for the concrete and the finished tiles. The equipment are sturdy and do not require many spare parts; most of them are simple and easy to make.

The concrete tiles that are made should naturally meet the needs of the local market. To satisfy users' requirements, it is necessary to conduct careful sample tests before starting large scale production. These tests give the basis for deciding the proportion of cement and working out the right recipe for the concrete that will be moulded.

Volume of production

Around 300 concrete tiles can be produced per day with a simple work table. A normal roof might need around 900 tiles, which is the equivalent of three days production. This is the basis for the following recommendation.

Even if the "factory" is small, it requires quite a number of workers at different stages of production. Some are needed to handle the raw materials, to make the concrete and deliver it to the work tables. When the tiles are moulded, they must be moved to a temporary area to harden before they can be taken from the mould. Then they must be stored for some weeks before they are cured and ready for delivery. When the tiles are stripped, the base sheets are returned to production.

More specific recommendations for equipment are given below.

The shape of concrete tiles

Ribbed tiles are preferred to curved tiles because they are simpler to make. The base sheets can easily be made by a local blacksmith.

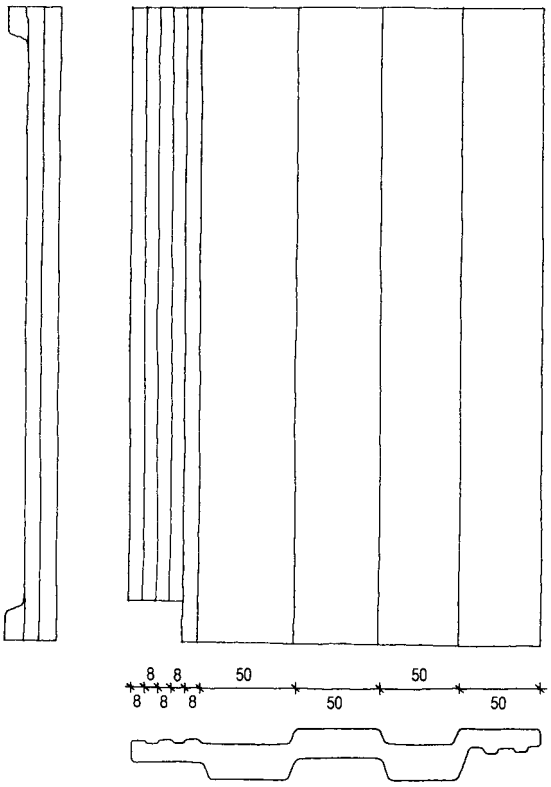
Aggregate

The sand must be clean (containing no humus) and have an even grain size distribution from 0–2 to 4 mm.

Suitable tests are described in Chapter 4.

Binder

Ordinary Portland cement is recommended. A rapid hardening cement might be used.



Dimensions and appearance of a ribbed tile.

Additives

No additives are recommended. If coloured tiles are desired, it is important to test the colouring substances first to avoid discoloration from scaling or the sun.

Mixing

A mechanical mixer is essential for homogenous fresh concrete with controllable quality. The size of the concrete mixer depends on the intended production volume. See Chapter 4 for tests of fresh concrete.

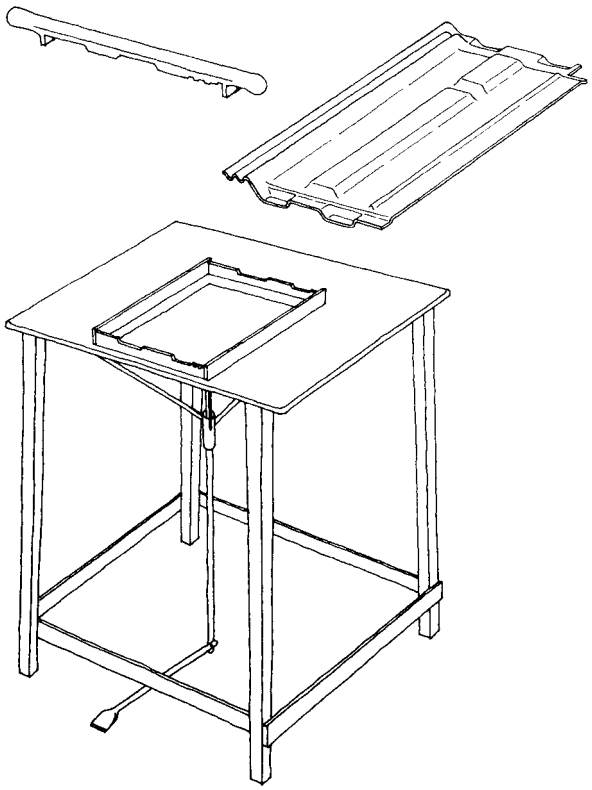
Moulding the tiles

The concrete tiles are hand-moulded on a work table designed to make one or more tiles at a time. A sketch of a work table with moulding frame, base sheet and modelling iron is shown below.

Preliminary concrete mix, water-cement ratio = 0.45

	cement:sand 1:2.5		*cement:sand 1:4*	
	150 l	*1 cu m*	*150 l*	*1 cu m*
cement	84 kg	563 kg	63 kg	420 kg
sand	211 kg	1,408 kg	252 kg	1,682 kg
water	38 kg	253 kg	28 kg	189 kg

To make the tiles, first put the cement and sand in the concrete mixer. Then add enough water to make the mixture a little softer than earth-damp. Mix only as much concrete as can be used in an hour, or as allowed by the cement's setting time. Take the concrete to the work table and fill the bin under the table. Put the base sheet into



Work table, base sheet and modelling iron.

the frame and begin moulding the tile. Use a trowel to fill the mould with concrete. Be very careful to fill the corners. Pack it well with, for example, the trowel handle. Then press the concrete with the modelling iron and even it out, so that the top of the finished tile has the same shape as the base sheet.

After moulding the tile, lift it out from the work table together with the base sheet and cut one corner. See the photographs on page 13. Move it to the curing area. Before the tile hardens, use a nail to make the hole needed to fix it to the batten.

Curing

Store the finished tiles in a room or under a roof. They should be placed on racks or shelves. Do not place them on the ground if possible, because of the danger of discoloration and distortion.

After at least 24 hours, the tiles can be taken from the mould. The base sheets are then cleaned, oiled and returned to production. Lay the tiles on wood pallets or something similar and wet them with water. Dampen very slightly the first day, and relatively more during the rest of the week.

To accelerate hardening, the tiles can be steam-cured. The tiles are stacked in a closed room and heated with steam. Depending on the conditions, they should stay in the room 2–5 days.

Concrete tiles should not be delivered until they have reached the standard of strength and impermeability required by the customer.

For appropriate tests of finished concrete tiles, see Chapter 4.

4 Tests

Preliminary tests

Before beginning production of concrete tiles, careful preliminary tests are necessary. These include:

- testing the aggregate to determine grain size distribution and cleanness of the sand.
- determining the amount of cement suitable for the mix. This is done by casting a few tiles and running quality control tests on them.
- determining the amount of water suitable for the mix. This is done at the same time as the cement content tests.

Detailed reporting forms, to be collected and saved, should be kept in a special place. The forms should be clear and state what and how often the material should be tested. Results should be recorded in special tables.

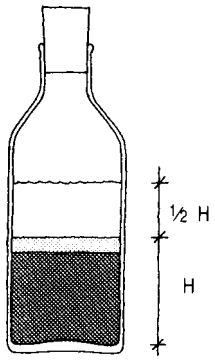
The preliminary tests are the basis for deciding the appropriate recipe for the concrete. The recipe must be clear, and it must be followed when casting the sample tiles. It is especially important to measure the quantity of water. It is better if all materials are weighed and not measured by volume. A detailed list of the quality control tests should accompany the recipe.

The tests proposed here are mainly to be conducted during production and deal with aggregate, fresh concrete and the moulded tile.

Aggregate

The sand used must be clean and have a maximum grain size of 4 mm. If the sand has larger particles, they must be crushed or sifted out. It is also important to sift the material and draw a grain size distribution curve to be sure that no fractions are missing. The sand should include all sizes to pack as “tight” as possible with little space between the grains. The grain size distribution curve also gives the fineness modulus, that is the area over the curve in the diagram. The fineness modulus should lie between 1.2 and 1.8.

To check for dangerous organic contamination, mix the sand with a 3% NaOH solution. When the material has been put into the bottle, shake it hard to mix it well. If the solution discolours after some hours, the sand contains humus, which can keep the concrete from hardenening. If it is difficult to get NaOH solution, humus content can be checked by mixing cement, sand and water in the same proportion as in making concrete. A little of the mixture is spread on, for example, a sheet of glass. Check after four hours to see if the concrete has begun to set. If it has not, the sand must contain humus.



Determination of humus content and proportion of fine particles in sand.

The sand should not contain large amounts of clay or silt. Washing the sand to remove clay and silt is not recommended, since

the valuable finest fractions of sand are lost and the procedure is not reliable. To do a rough check on the quantity of clay or silt, pick up some sand and rub it between the hands. There should not be a lot of fine clay that "falls out". A more precise way to check is to use a humus bottle. Shake the bottle and let it stand for 24 hours. Measure the thickness of fine material lying on top of the sand and divide it by the total height of sand to get the percentage. It should not be greater than 15%. Note that assessing silt content does not require NaOH solution. It works just as well with clean water.

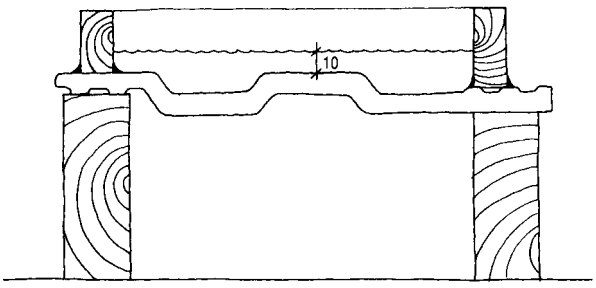
Fresh concrete
According to the grain size distribution, fineness modulus, etc. of the sand, an amount of sand is mixed with cement and water to make a mass that is as dry as possible but that can still be shaped. The texture should be earth-damp or very stiff. The proportion by weight of cement to sand can vary from 1:2.5 to 1:4. To check the texture, roll a ball of concrete between the hands. It should form a firm ball and leave just a trace on the hands.

Quality control of concrete tiles

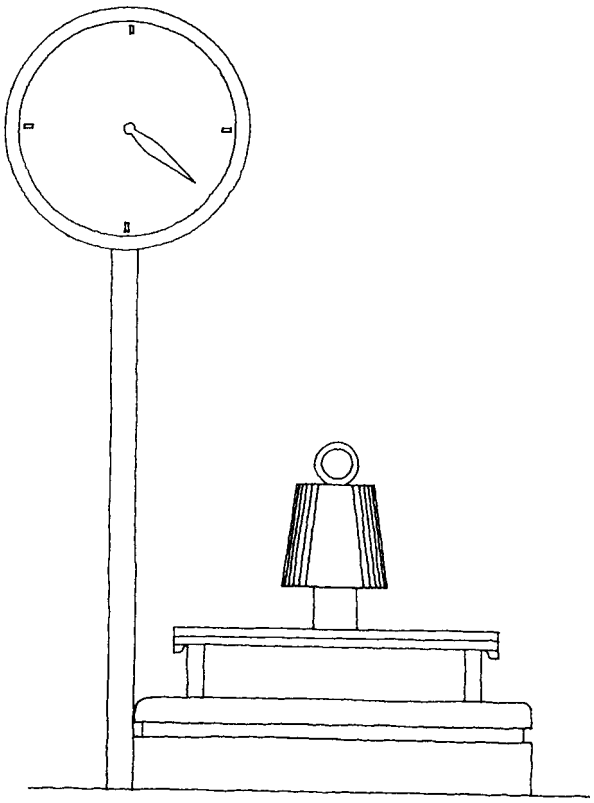
The moulded tiles should cure for 28 days before testing. The characteristics to test are water absorption, impermeability, bending strength and impact strength. If the tiles are to be delivered in less than 28 days after moulding, the tests should be done at that time to be sure that the tiles meet the requirements set. It is also important that the tiles tested are selected at random.

Water absorption
Ten tiles are dried in an oven at a constant 60°C, and then put in a water-bath for 24 hours. The difference in weight is measured and given as a percentage of the tiles dry weight. The tiles should absorb at most 6% after 24 hours in water.

Water permeability
Five tiles are kept at a constant temperature around 20°C without any draught. The tiles are placed horizontally on supports so the undersides are visible. Place a frame on the top that can be sealed to the tile. Fill the frame with water to 10 mm over the highest point of the tile. Let the water sit for 24 hours. Inspect for damp spots or water drops on the underside. If they are found on two or less of the tiles, the tiles are considered sufficiently impermeable.



Test of water permeability.


Test of bending stregth.

Bending strength
Always determine bending strength.

To determine bending strength of concrete tiles, it is necessary to have an apparatus that can increase a load with some degree of accuracy. It could vary significantly in appearance and cost. The instrument described here is very simple. Whichever apparatus used, it is important to be consistent and careful when testing for bending strength.

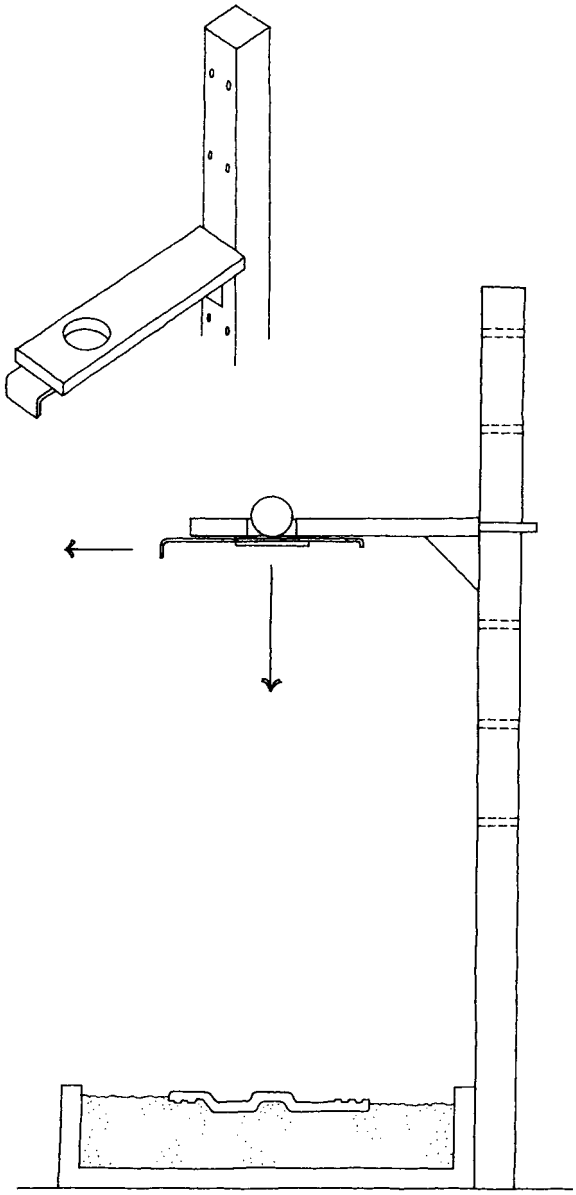
Five concrete tiles are placed in a room with as constant temperature and relative humidity as possible. The test apparatus should be in the same place. It is appropriate to use the same room as for the other laboratory experiments. The tiles are laid right side up on two felt covered bars of wood, one fixed and one moveable. The wood bars should be 25 mm wide and 300 mm apart. The felt covering is to get good contact in case the tile is slightly warped. Loading is done through a 25 mm wide, felt covered wood bar, parallel to and half way between the support bars.

The required bending strength is an average load of at least 60 kg for the five tiles, and a minimum load of 50 kg for any single tile. This assumes that the tiles are not older than six months. If they are, they should support a greater load, 70 and 60 kg respectively.

This requirement is set by the client. The standard should however always be to avoid what is called "punching failure."

Impact strength
Testing for impact strength does not have to be done routinely, only when the client has set this requirement. Here is a simple method to determine impact strength.

The tile is placed horizontally, right side up, on a 100 mm thick layer of sand. Press the tile down so the heel is in the sand and the tile lies flat. Drop a steel ball weighing around 225 g from 500 mm onto the centre of the tile. The position of the ball with respect to the tile is carefully determined by a plumb line. After each drop, the height is raised by 100 mm. Note if the tile breaks or if any cracks develop. Even if it is not possible to give a appropriate standard for the height of the drop, the test gives an indication of variations in production quality. A minimum requirement should be that the tile withstands the first drop without visible cracks or other damage.



Test of impact strength.

5 Proposal for a production unit

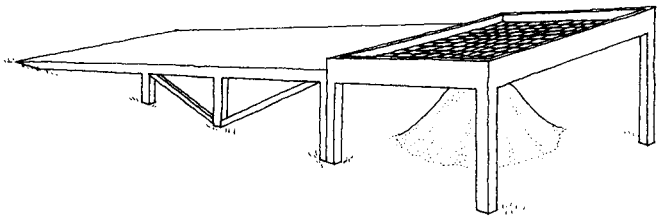
This example assumes production aimed at around 900 concrete tiles a day. The tile in the example measures $390 \times 240 \times 10$ mm, and 14–15 tiles cover 1 sq m of roof. That means 900 tiles cover around 60 sq m of roof. There might be variations caused by roof slope, overlapping, etc.

Production takes place as shown at the bottom of the page.

Sand

Assume that all sand delivered to the factory must be sifted, so that the largest particle size is 4 mm. A production of 900 tiles a day requires around one cubic meter of concrete. This requires about 1500 kg of sifted sand.

A good method is to cast a concrete slab on the ground and fix over it a large sieve (net) with mesh size 4 mm. The sieve should be slanted to give an angle of repose, which reduces the amount of work getting the material through the screen. At this angle the screen no longer allows the sand to pile up through friction.



Sifting sand.

The sifted sand should be covered to protect it from contamination by plants and leaves, etc.

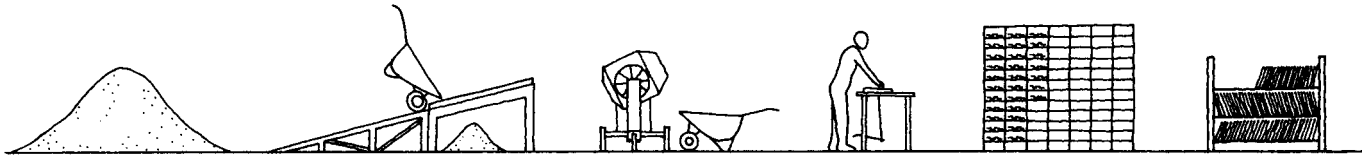
Sand is taken to the concrete mixer as needed.

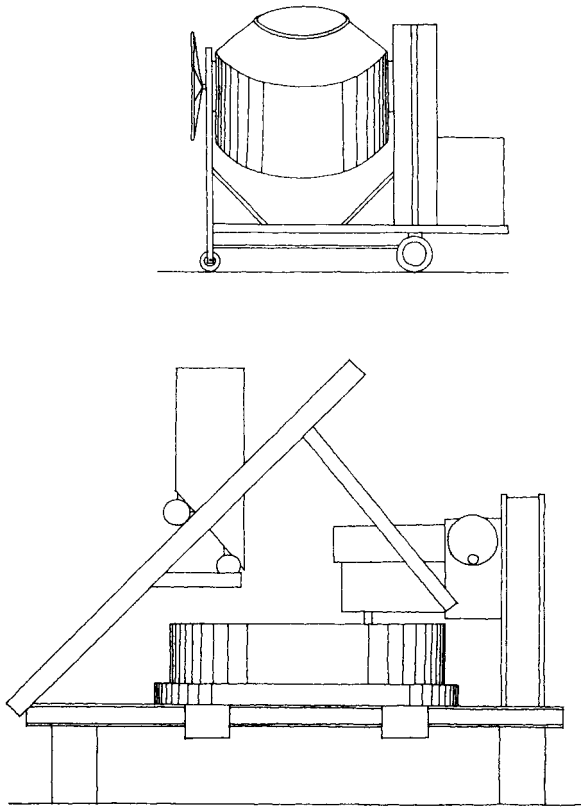
All work with sand can be managed by one or two persons.

Preparing concrete

One day's production of tiles requires around one cubic meter of concrete. The tiles are shaped continuously during the entire day. Only the amount of concrete that can be used within one hour should be delivered to each work table. A maximum of 40 tiles can be formed per hour per work table. That is, the concrete requirement is around 50 l concrete per table per hour. Three work tables would need 150 l of concrete per hour. A concrete mixer with this capacity is recommended. The type of mixer is not so important, since the concrete is fine and easy to handle.

Gathering sand, sifting sand, mixing concrete, moulding tiles, unmoulding, curing and storage.





Examples of concrete mixers: rotating drum mixer and paddle mixer.

The concrete mixer should be placed firmly on the ground, preferably under a roof and on a cast concrete slab.

Wheelbarrows are used as bins to hold the raw concrete and to transport the concrete to the work tables. Five to six wheelbarrows are needed if one reckons on three work tables, one wheelbarrow per table, plus spares being filled to replace them as they are emptied.

It is very important that the cement is stored dry, preferably indoors. It is very important to be careful in mixing the concrete. The selected recipe for the mix must be followed exactly. The material should preferably be weighed. If that is not possible, it can be measured by volume. But then the volume-weight of each component must be carefully established.

Moulding

The three work tables must be placed at least under a roof and on a cast concrete slab. Each work table has a cart or wheelbarrow that holds 50 l of concrete. This is the equivalent on one hours production or 40 tiles. There must be base sheets continuously available. A day's production requires 300 sheets per table.When a mould is filled and shaped, the base sheet with the tile is lifted up and moved from the work table to the curing area on a special cart.

Unmoulding

The carts should be designed so that the base sheet with tile is placed on shelves. The carts should be relatively small and easily manoeuvred. They are managed by the tile maker at the work table. When a cart is full, say 40 tiles or one hour's production, another person moves it to the first curing room. This should be indoors with as constant temperature and humidity as possible. The base sheets with tiles are placed so that they can easily be removed after one or two days for stripping.

The base sheets are cleaned and oiled. After that they are returned to production at the work tables.

Curing

After stripping, the tiles are taken to another room where they cure for one week. During this time they should be sprayed with water so that they remain damp. They are placed standing on shelves or similar. It is important that they are not laid on the ground, because of the risk of distortion. The curing room is separate from the unmoulding room, but easily accessible with a cart through a door. It should be large enough to hold at least one week's production of 4500 tiles.

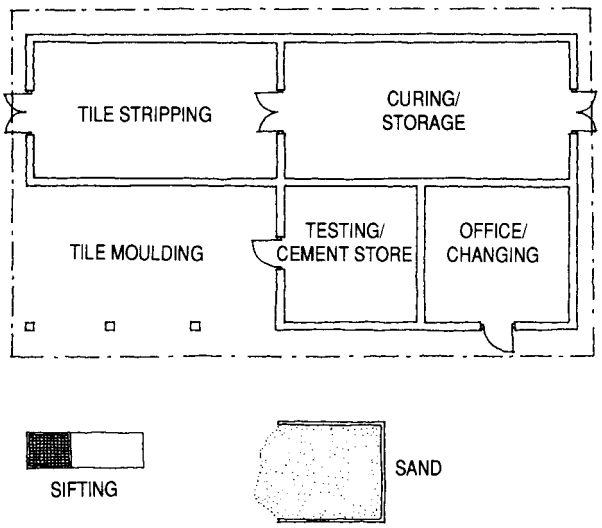
Storing

After one week's curing indoors, the tiles are moved out where they can stand until delivery. The tiles should be placed standing against the factory walls and/or against a wall. They should stand on wooden bars or sheeting, not directly on the ground, to keep them from discolouring.

Testing

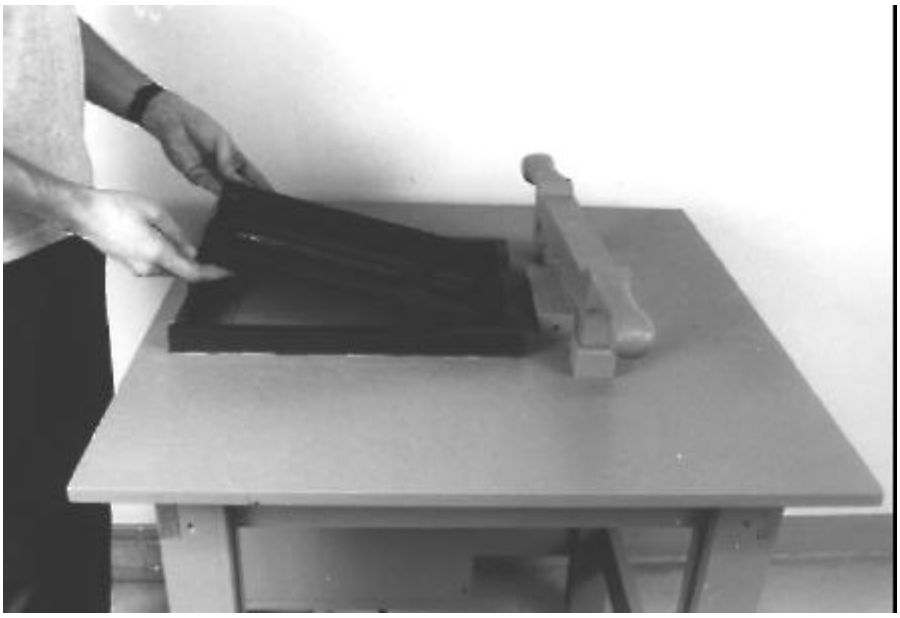
In addition to the areas described above, there should be a space for testing. It should be placed adjacent to production, and should have facilities to sift and dry sand. Other quality control tests of the finished product include water absorption, impermeability and strength.

There should also be a separate room to store the test reports and a changing room.

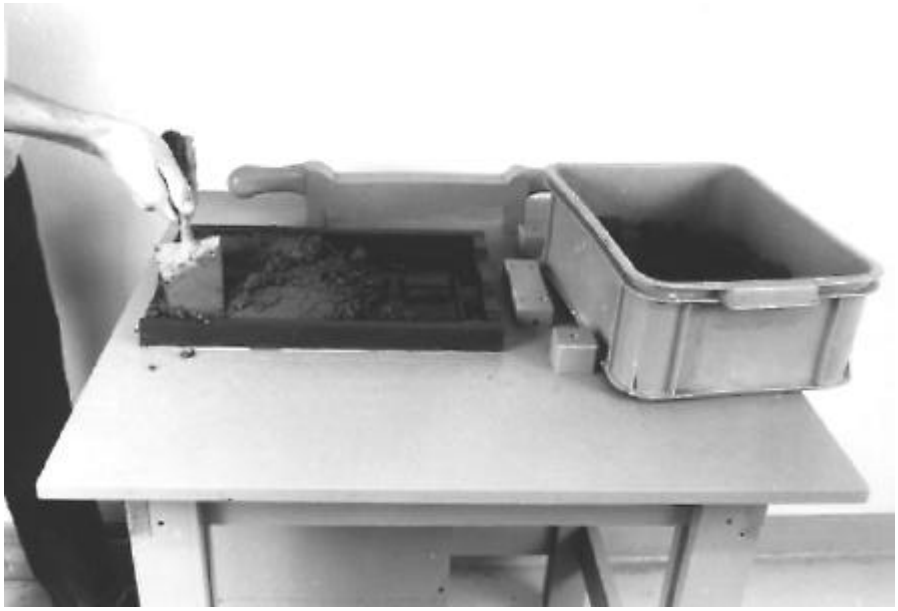


Proposed production unit.

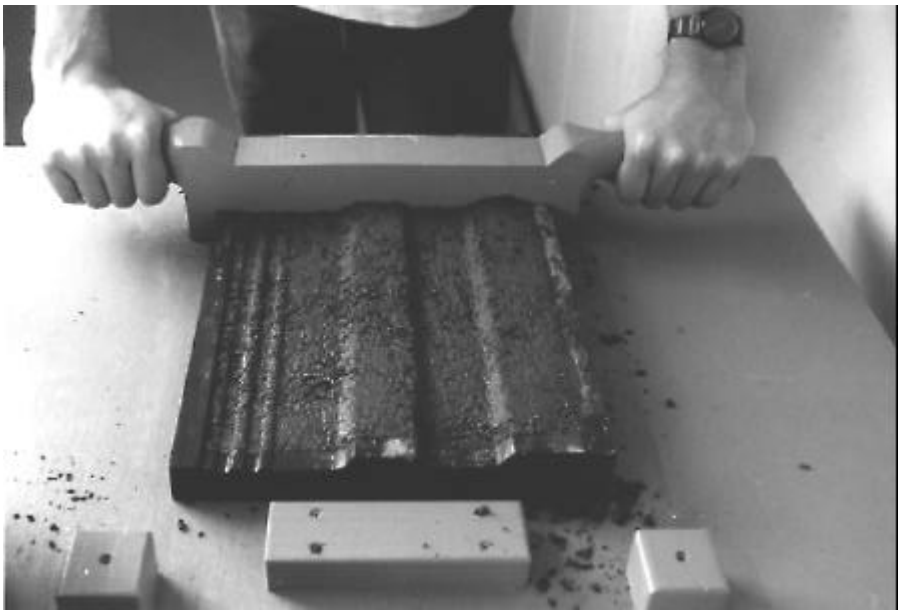
Steps in making a concrete roofing tile



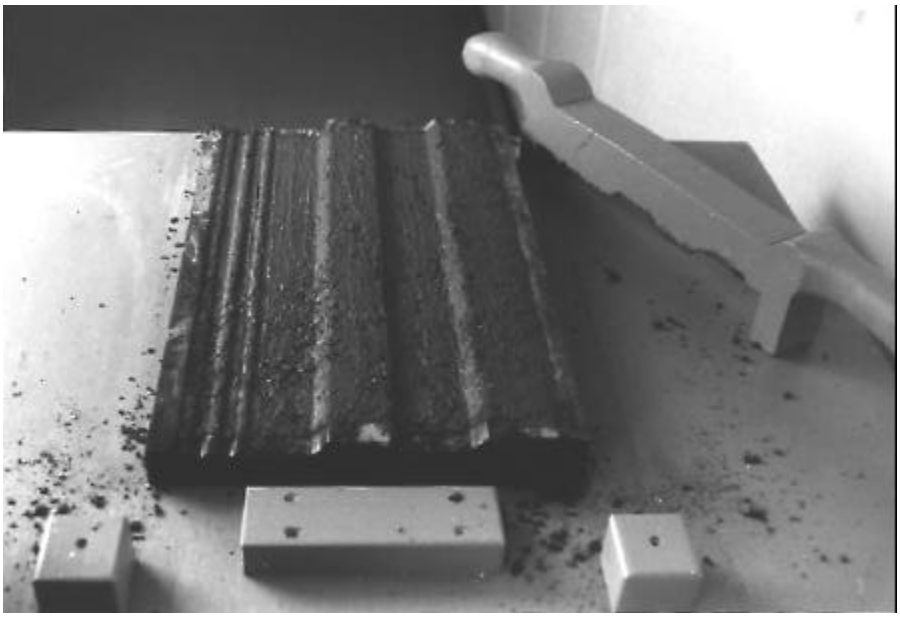
Brush the mould to remove any concrete that sticks. Oil the base sheet well and place it in the mould.



Fill the mould with concrete. Pack it in very carefully, and pay special attention to the corners.

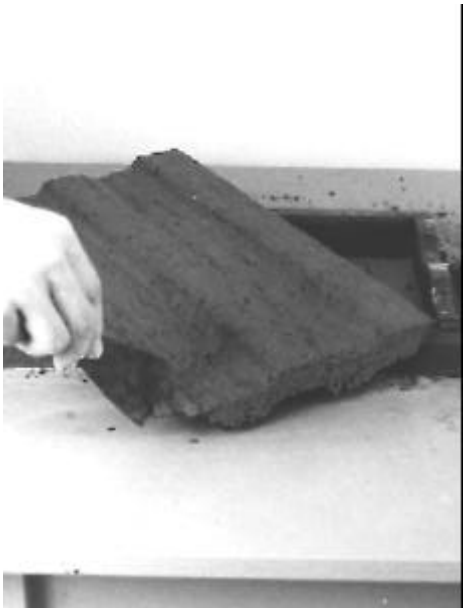


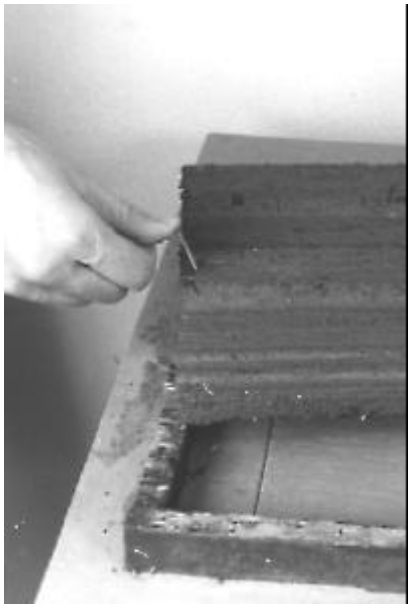
Use the modelling iron to shape and pack the concrete. To get a good finish, slide the iron with slow and deliberate movements.



The moulded concrete tile.

Use the foot pedal to lift the tile together with the base sheet.



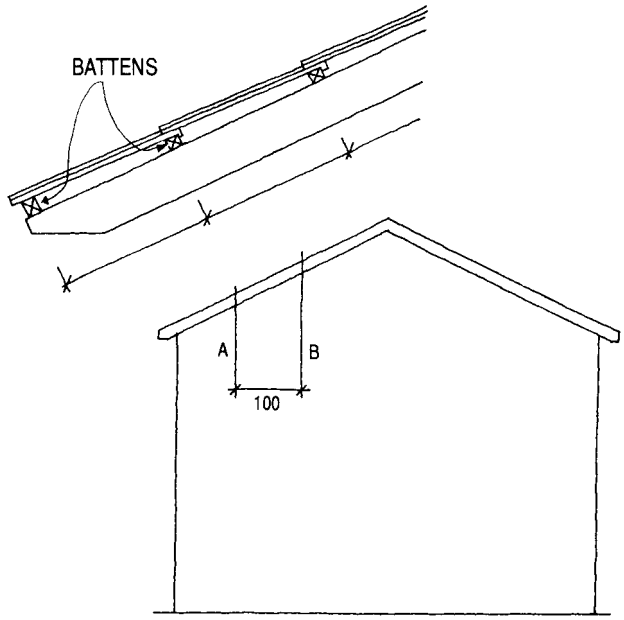


Before taking the tile to the curing room, cut off the corner and, if needed, use a nail to make a hole for fastening the finished tile to the roof batten.

6 Laying a tile roof

Before laying a roof, estimate the number of tiles needed to cover it.

First decide the angle of the roof, which can be done according to the sketch.



Roof angle.

Distance between battens and number of tiles per sq m

Roof angle (°)	*Distance between battens (cm)*	*No. tiles per sq m*	*kg per sq m*
14–18	28–29	17.5	35
18–22	29–31	16.7	33
> 22	34.5	14.5	29

Calculation of roof angle

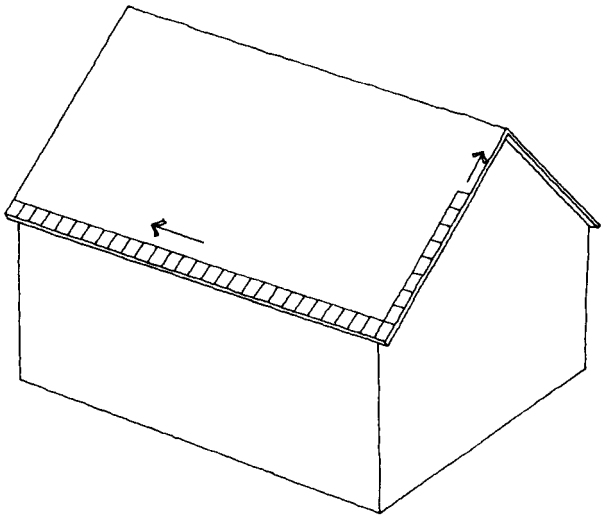
A–B cm	*Roof angle (°)*	*A–B cm*	*Roof angle (°)*	*A–B cm*	*Roof angle (°)*
25	14	58	30	90	42
30	17	62	32	100	45
36	20	67	34	104	46
40	22	73	36	111	48
45	24	75	37	119	50
49	26	78	38	133	53
53	28	84	40	143	55

If the slope of the roof is at least 22°, the full length of the tile can be used (distance between the battens). If the slope is between 14 and 22°, the distance between battens must be shortened and lengthwise overlapping is increased. This is necessary to keep water from seeping under the roof backwards. Water can collect on the roof and then seep under the tiles from beneath. Rain water can even seep under the roof through negative pressure caused by wind.

If the slope is less than 14°, concrete tiles should not be used as roofing.

When the roof angle is decided, the distance between battens is determined, which gives the number of rows of tiles vertically. The number of tiles horizontally is calculated by measuring the roof and dividing it with 200 mm, the effective cover of each tile.

After all the battens are nailed to the roof rafters, the tiles can be laid. Start at a bottom right corner. One row is fixed at the bottom moving towards the left, and then a line of tiles is placed upwards along the right edge. Continue the second line vertically from the right, and add one line of tiles at a time, always starting at the bottom. Continue until the whole roof is covered. A straight-edge should be used to make sure the tiles lie straight. The two outer rows of tiles around the entire roof should be nailed to the battens, as well as all tiles around any openings like a chimney.



7 Energy and costs

Compared to ceramic tiles that must be fired at around 1100°C in rather inefficient, energy consuming kilns, the cement used in concrete tiles requires less energy to produce. Cement is about 25–30% of a tile. Processing of cement is done at 1400°C and is usually very efficient.

In a study conducted by the United Nations Centre for Human Settlements in 1991, comparison was made of energy requirements of different roofs: CIS, ceramic tiles and concrete tiles. It was found that CIS requires over 600 MJ per square meter, and ceramic tiles a little more than 25% of that. Concrete tiles take even less, barely half as much as ceramic tiles, including the wood support structure. See the table.

Comparative energy requirements of alternative roofing assemblies for a pitched roof (per sq m)

Option	*Material*	*Unit*	*Quantity*	*MJ/unit*	*MJ*	*Total*
Corrugated galvanized-iron sheets (30 gauge)	Sheets	kg	10	60	600	
	Timber	m^3	0.009	500	5	605
Clay tiles (12.5 mm)	Clay tiles	kg	50	3	150	
	Timber	m^3	0.015	500	7.5	158
Concrete tiles (12.5 mm)	Cement	kg	8	8	64	
	Sand/agg	kg	32	0.1	3.2	
	Timber	m^3	0.01	500	5	72

It is difficult to do a cost comparison between production of ceramic and concrete tiles. On the other hand, it is clear that concrete tiles can be made with a very simple process, no kiln is necessary and curing occurs without addition of extra energy. As a result, the investment costs are significantly lower than for the equivalent production of ceramic roofing tiles.

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