22

FCR / MCR TOOLKIT

ELEMENT 22

SKAT

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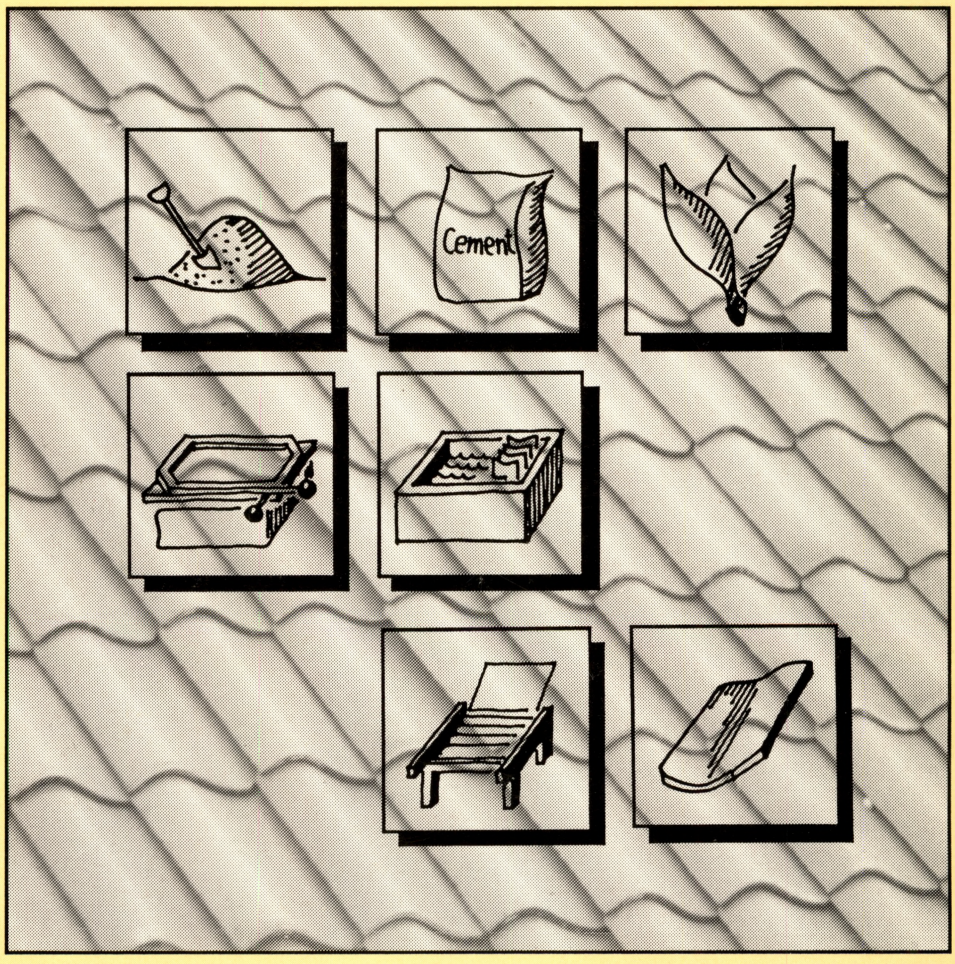
Swiss Centre for Development Cooperation
in Technology and Management
International Labour Office

PRODUCTION GUIDE

Fibre and Micro Concrete Tiles



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**Swiss Centre for Development Cooperation
in Technology and Management
International Labour Office**

PRODUCTION GUIDE FOR FIBRE AND MICRO CONCRETE TILES

Rules and guidelines for the production of Fibre and Micro Concrete Tiles.

A co-publication of the Swiss Centre for Development Cooperation in Technology and Management (SKAT) and the International Labour Office (ILO), supported by the Swiss Development Cooperation (SDC)

FCR / MCR TOOLKIT-DIAGRAM:

NATIONAL CENTER KIT

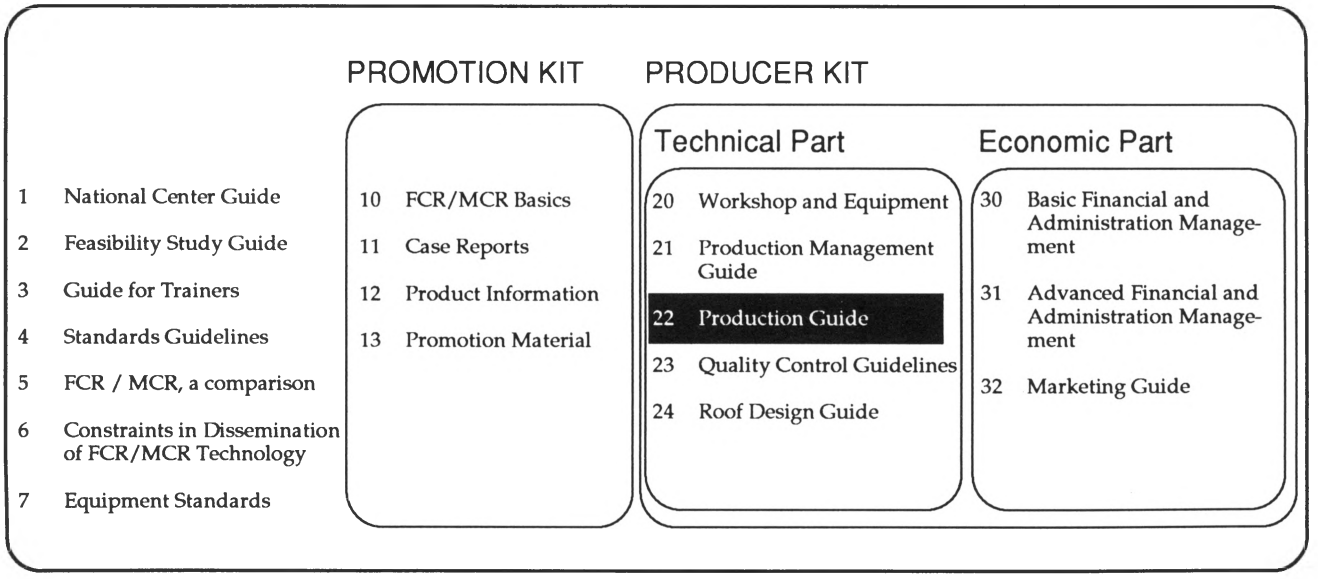

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TABLE OF CONTENTS

1. PREFACE

The history of FCR/MCR

The FCR/MCR technology was developed in the 1970s based on generations of experience with concrete tiles and asbestos cement sheets. During the 1980s this technology has found applications in many countries all over the world. Today it is at a mature stage and experience has shown that it offers a reliable roofing material that can compete with most of the conventional roofing materials.

The roles of BASIN, SKAT and ILO

BASIN

BASIN (Building Advisory Service and Information Network) is a coordinated network of experienced international professionals, set up to provide qualified advice and information in the field of building materials and construction technologies.

The activities of BASIN are divided amongst four leading European, non-profit appropriate technology organizations (GTZ/GATE Germany, ITDG England, SKAT Switzerland, CRATerre France), each of which covers a separate specialized subject area, in order to provide more qualified expertise with greater efficiency.

SKAT

SKAT is an information and documentation center and a consultancy group engaged in promoting and implementing appropriate technology for partner countries worldwide.

Among the BASIN partners, SKAT is specialized in roofing, and in this field is especially familiar with the FCR/MCR technology. Within BASIN, SKAT established the Roofing Advisory Service (RAS). With the commitment to facilitate the promotion and dissemination of the FCR/MCR roofing technology, SKAT/RAS is producing the "FCR/MCR Toolkit" series of which this "Production Guide" is one element.

ILO

A program for the development, the promotion and the application of appropriate building technologies suitable for low-cost construction is currently implemented by the Micro-enterprise and Informal Sector Section of the ILO Entrepreneurship and Management Development Branch.

The objective of this program is to minimize construction costs, maximize the use of locally available raw materials, and generate productive employment. It aims also at developing small and micro-enterprises in this sector of

activities and at demonstrating their commercial viability. This program makes use of an innovative approach whereby some of the activities are carried out within ongoing technical cooperation projects for the development of small and micro-enterprises, executed by ILO or other agencies (e.g. UNDP, multi-bilateral projects, bilateral projects). Various means of action are used by this program: research and development, dissemination of technological information, advisory services to governments and implementation of technical assistance projects.

Network of specialists

A worldwide network of specialists and of specialized institutions provides technical support to new and already established producers of FCR/MCR. This helps to ensure reliability and quality of the products in this growing market.

This FCR/MCR network of specialists is coordinated by the Roofing Advisory Service (RAS) of SKAT.

The FCR-MCR Toolkit

The guide in hand is part of the FCR/MCR Toolkit. This kit imparts the entire know-how that is required in the field of the FCR/MCR technology, covering the technical as well as the economic, organizational, management and marketing aspects. The toolkit diagram shows the structure of its contents.

The kit is now (1991) at its development stage. Many elements are already available; other elements exist in a draft or outline version.

Contact address

This literature, as well as further information, is available from:

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Tigerbergstrasse 2
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1. INTRODUCTION

What are FCR and MCR?

FCR (Fibre Concrete Roofing) is a new technology for roof covering. It consists of concrete tiles made of cement mortar mixed with a small amount of natural or synthetic fibre.

In the case of MCR (Micro Concrete Roofing), fine aggregate is used instead of fibre.

For further basic information please refer to "The Basics of Concrete Roofing Elements".

The advantages of FCR and MCR

The technology provides an inexpensive and reliable roof covering and is especially suited for the needs of developing countries. The main advantages are :

- The raw materials are available locally and thus foreign exchange is saved.
- The appropriate technology that is involved allows for de-centralised and small-scale production.
- The technology involves little investment.
- The production is labour-intensive rather than capital-intensive; it thus creates jobs.
- Compared to metal sheeting, rooms covered with FCR/MCR remain cooler during sun radiation because of better thermal insulation and ventilation.
- FCR/MCR is much less noisy than metal sheeting during rain.
- The product is environmentally well-adapted.
- The technology is easy to learn.

The drawbacks of FCR/MCR

The durability of FCR/MCR is basically as good as that of ordinary concrete tiles, which have shown service lives exceeding 50 years. The FCR/MCR material, however, sometimes has a lower strength compared to modern concrete tiles and AC sheets because the small production units involve a higher risk of quality variations and because of the lack of standards.

Objectives of this guide

The roof constitutes the most important part of a building and special care has to be taken in preparing the roof and the roofing elements. The best available raw materials should be used and throughout the production process it should be kept in mind that a bad quality roofing product will not only result in an inadequate roof, but may also lead to severe damage to the whole building.

To promote FCR/MCR technology, a high and constant quality is required. This is important not only to produce and continue a reputable product, but also to avoid wasted investments. Therefore, adequate technology transfer and comprehensive dissemination of know-how are important tools in the production process of FCR/MCR.

This guide is compiled so as to help advisory centres to transfer this know-how systematically and to help producers to achieve a product of a high standard . The chances of improved production on a broad basis are then increased, benefiting from existing and well-established technological know-how.

What you can find in this guide

The guide provides detailed technical guidelines for daily use in the workshop and rules and hints on how to produce FCR/MCR tiles.

What you CANNOT find in this guide

The guide is intended for persons who already know the basics of FCR/MCR or are already producing FCR/MCR elements.

As a consequence, it does not contain

- the basic information required for newcomers such as advantages and disadvantages, and guidelines to be considered as the first steps towards FCR/MCR production.

It also does not contain

- information on production management;
- specifications of cost and profit;
- information about specific problems in particular countries; and
- guidelines for quality control and the required tests.

If you are interested in basic information we suggest you read the following booklet:

"*The Basics of Concrete Roofing Elements*. Fundamental Information on the Micro Concrete Roofing (MCR) and the Fibre Concrete Roofing (FCR) Technologies for Newcomers, Decisionmakers, Technicians, Field Workers and all those who want to know more about MCR and FCR". (available at SKAT free of charge in English, French and Spanish).

If you are interested in the scientific explanations and justification for specific recommendations, we suggest reading the Technical Memorandum No 16 : *"Fibre or Micro Concrete Tiles, Production Process and Roof Laying"* (available at ILO in English and French).

This guide is not designed as an instrument for self-teaching. For successful production many additional hints and tricks are needed that can only be acquired through comprehensive training.

Other elements of the FCR/MCR toolkit as well as further information are available from SKAT or ILO.

Quality testing

Throughout the process of producing tiles, a quality control procedure should be applied. For this purpose a separate toolkit has been published in this series: "*Quality Control Guidelines*, Toolkit Element

23". In it a comprehensive methodology is proposed and described, including the production process and quality control of raw materials, and the end product. Both toolkit elements 22 and 23 complement each other.

Managing the production

This guide describes the production of the tiles step-by-step. The reality of the production process, however, is much more complex. Many steps are carried out simultaneously, in sequences or in cycles that may be interlinked or overlap. How this production process can be organized is described in the "*Production Management Guide*", element 21 of the Toolkit.

The Production Management Guide uses the same numbering system used in the Production Guide as well as in the Quality Control Guidelines. This facilitates the complementary use of these three elements

General remarks

Validity of the data: The rules and data presented in this guide are based on scientific laboratory research and the long-standing practical experiences of international technology specialists, and represent a general standard. Data such as the mix to be used, compacting and curing time etc. may vary slightly from place to place, depending on the raw material properties and other local factors. Experience in a particular country will provide the exact data that are to be applied.

Range of products: The process described in this guide is basically designed for the production of tiles, both the roman and the pan type. By adapting the rules analogously, the same method can, however, also be applied for the production of semisheets and the various fittings which are required for different roof types.

Responsibility: The sole responsibility for implementing the rules correctly should lie with one person (i.e. the head of the workshop). He should also make records and keep them for at least five years.

Comments

Comments and feedback information are welcome and will help to further improve this guide and with it the technology. They may be sent to SKAT or ILO.

2. RAW MATERIALS

The use of good quality raw materials is vital for the quality of the end product.

The basic raw materials required for the production are:

2.1 Cement

2.2 Sand and aggregate

2.3 Fibre

2.4 Water

2.5 Colorant

2.6 Fixing devices

Material CEMENT

Rule A

Type and Quality

Ordinary Portland cement is used for the production of FCR and MCR. In order to achieve the required result in strength and durability, it is essential that the quality measures up to the standard required for normal concrete work.

Rule B

Pozzolanic Additives

In some cases the use of pozzolanic additives may be taken into consideration. However, the setting and strength development may be slower.

To prove its suitability the tiles should pass the tests described in the quality control guidelines.

It may be possible to mix the cement with a certain amount (up to 20 - 25 %) of pozzolanic additives. The feasibility of this should be tested in practical trials.

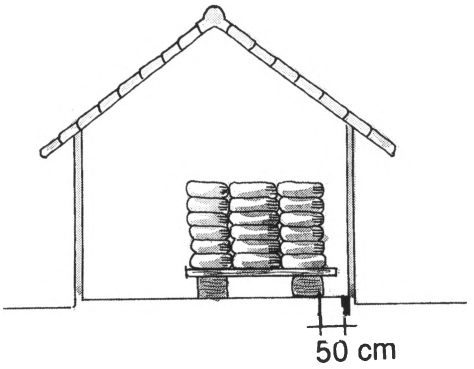
Rule C

Store Cement Dry

Moisture destroys cement; therefore it must be stored dry. If the cement contains lumps it is a clear sign that it has been exposed to moisture.

A storing place with a secure roof and good ventilation is required. It is recommended to use a separate store-room in the workshop.

To avoid rising damp do not store the cement directly on the floor, but for instance on timber pallets.

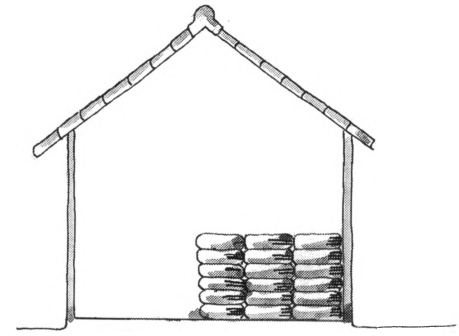


Good
Storing on timber pallets and no contact with outer walls

Tests see Quality Control Guidelines Code 2.1.10 & Code 2.1.20

Avoid contact of the cement bags with outer walls and floor. Walls and floors could be a source of moisture. In addition proper ventilation is prevented.

The cement stack should not be more than 10 bags high.



Wrong:
Storing directly on the floor and on the outer wall

Rule D

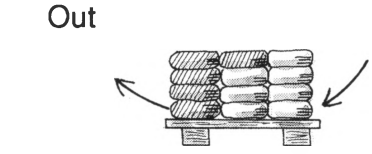
Storing Period

Do not keep cement longer than 1 month. This is especially important in humid climates.

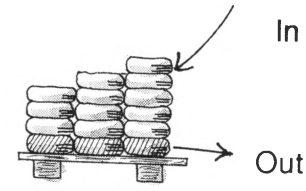
Make sure that the older stock is used up before the new one.

On no account should old and already set cement be used.

To be sure about the age of the cement, it is advisable to buy the cement directly from the producer, with printed dates on the bags.



Good
Finish old stock before new one



Wrong:
Part of the stock gets too old if only new stock is used

Rule E

Cement with Defects

If the cement has lumps, the bags are hard or if the quality of the cement is doubtful in any way, it should not be used.

Cement with lumps may still contain some quantities which can be used. In this case it should be sieved through a 0.5 mm sieve and used together with good quality cement (see Quality Control Guidelines).

Tests see Quality Control Guidelines Code 2.1.10 & Code 2.1.20

Rule F **Special Additives**

Special additives may increase the workability, accelerate the setting speed or lower the water/cement ratio. Such materials should only be used if they do not affect the strength of the tiles. They usually add significantly to the price of the tiles.

Remark Keep strict control over the cement stock by a proper stock record (Reporting Format "Cement" in Quality Control Guidelines).

Material SAND AND AGGREGATE

Rule A

Silicious Origin

The sand and aggregate should be of silicious origin or have similar characteristics. They should not contain minerals which may react chemically with the cement.

If the properties of the materials are not known, they should first be tested by a laboratory.

Rule B

Grading of Material for FCR

Where fibre is used for the production of the tiles, only sand and no aggregate is used.

Product thickness		6 - 12 mm
Maximum grain size		2 - 3 mm
Component above	2 mm	0 - 10%
Component	0.5 - 2 mm	35 - 75%
Component below	0.5 mm	25 - 55%

Rule C

Grading of Material for MCR

If the tiles are produced without fibre (MCR), a defined quantity of fine aggregate is used. The following ratio is recommended:

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

No single piece of aggregate should exceed the tile thickness minus 1mm.

Tests see Quality Control Guidelines Code 2.2.10 & Code 2.2.20
Further reading regarding Sand and Aggregate see Lit [01]

Rule D

Grading and Cleanness

Sand and aggregate should be well graded, clean and free of organic material. The clay and silt content should normally not exceed 4%.

(See also: Quality Control Guidelines, grading test)

Rule E

Porous Material

If the sand or aggregate is porous, more water and cement is required. The water/cement ratio should remain unchanged.

Rule F

Protection from Rain

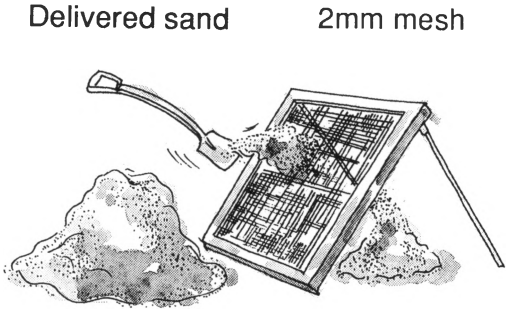
Protect the sand and aggregate stock from rain, because the moisture content should not vary during the production period.
Increased or decreased moisture would change the water / cement ratio of the mix.
The cement / sand ratio would also change, because the volume of the sand changes (honey-comb effect).

Rule G

Sieving and Separation

Before sand is stored, it should be sieved.

The fine aggregate used for MCR is kept in a separate place.



Only sieved sand to be stored

Remark

The rules and range of possible grading as given above should be understood as general guidelines. Test results of different proportions would tell the producer the best grading for his material.

Tests see Quality Control Guidelines Code 2.2.10 & Code 2.2.20

Material FIBRE

Remarks

Advantages of Fibre

The main role of chopped fibre is to improve the cohesion of the fresh mix, thus making the molding process easier by reducing the danger of cracking during molding.
In the case of tile damage on the roof, fibre prevents tiles from falling into pieces.

Disadvantages

The use of fibre adds to the costs and involves more labour.
Careless workmanship carries the risk of lumps that can cause leaking.

Production Without Fibre

Research and production experience have shown that this type of tile can also be produced without fibre (MCR). This technology requires more care in the selection of raw materials (e.g. grading of sand and aggregate). However, the quality of MCR is comparable to that of FCR.

Rule A

Type and Quality of Fibre

Many types of natural or synthetic fibre can be used in concrete roofing elements as long as they are clean. Coconut husk fibre, stem fibre (for example jute) or leaf fibre (such as sisal) are the most common examples which have been used so far.

The fibre should not contain loose particles, soft pith etc. and should be well separated. This can be checked visually.

Rule B

Size of Fibre

The length of the cut fibre should be between 15 and 25mm, with 20mm as an average. No single piece should be longer than 30mm.

Tests see Quality Control Guidelines Code 2.3.20

Material WATER

Remarks

The quality of the tiles also depends on the quality of the water used for the mix. Dirty and chemically contaminated water may have a negative effect on the setting process and on the strength.

A reliable water supply is essential. Where shortages occur, a water tank must be installed.

Rule A

Kind of Water

Water should be clean and fresh, preferably standard potable water.

Rule B

Salt Content

If black iron wire (not galvanized) is cast into the tile as a fixing device, the water must not contain salt.

(If the iron parts are galvanized, salty water up to a maximum of 4% by weight, e.g. sea water, may be used.)

Rule C

Control

At the workshop the water can be controlled visually. It should have a clear appearance.

In the laboratory it can be tested for salt content and other chemical contamination.

Rule D

Testing

If the water quality is doubtful, it can be tested by comparing the setting time and strength properties of a tile produced with potable water and a tile produced with the water in question.The results should be the same.

Material COLORANT

Remarks

Advantages

Tiles without added colorant are of a darker or lighter grey color. To achieve a more attractive product they may be colored. Color may be a selling feature.

A bright color increases the reflection of solar radiation and thus improves the thermal performance of the roof.

Rule A

Colorant Added to the Mix

The most commonly used additive is red oxide (iron oxide). Use a high quality, synthetic grade at the rate of 3 - 10% of the cement weight, depending on the type of color wanted.

White cement may also be used to achieve a bright color. However, in many cases this material may be prohibitively expensive.

Rule B

Colorant Applied as Paint

Ordinary grey tiles may be painted with color after the water curing process. This color preferably consists of a colorant powder mixed with cement and water to make a paste that is applied with a brush. The cement brings about a good cohesion of the paint. The color should not contain any plastics (latex etc.) and should be based solely on silicates. Otherwise it will peel off in time.

Under certain climatic conditions it is advantageous to whitewash the roof with a lime paste at the beginning of the hot and dry season. The effect is a better reflectivity of solar radiation. During the rainy season and the subsequent cooler season the tiles turn grey, thus absorbing more heat. This is a cheap and labour-intensive method suitable to a climate where cooling is desired during a certain season only. In cases where drinking water is collected from the roof, this method should not be applied.

Material FIXING DEVICES

Rule A

Recommended Types

The following types of devices for fixing the tiles to the roof are recommended:

- Galvanized steel wire with a diameter of at least 0.9mm. If the galvanization is of poor quality the diameter should be larger.
- Black wire may be used where galvanized wire is not available. The diameter should then be more than 2 mm to guarantee a reasonable life span.
- Copper wire (or other non-ferrous wire of a metal that is compatible with concrete) with a diameter of at least 1.2mm.
- Stainless steel wire with a diameter of at least 0.9mm.
- String of a material that does not rot (synthetic, e.g. nylon).

The wire should be flexible enough to be twisted by hand without breaking.

Rule B

Avoid Organic Materials

No organic strings of jute, hemp and the like should be used because of rotting.

Rule C

Preparation of Holes

If holes are required in the tiles, they should not be drilled when the tiles are dry. This may cause hair cracks which can be a source of damage at a later stage. Holes should be made during the casting process, when the tiles are still fresh.

Rule D

Avoid Fixing by Nails

The tiles sould not be attached by nails or screws through a hole in the surface. This carries the risk of cracks and leakage. Instead, put a wire through the hole and fix the wire with a nail or screw.

3. PRODUCTION PROCESS

Besides the quality of the raw materials, a careful production procedure is the other important guarantee for a product of a high standard. The steps of the production process are:

3.1 Mortar preparation

3.2 Vibrating and molding

3.3 Mold curing

3.4 Demolding

3.5 Tank curing (in water tanks or vapour atmosphere)

3.6 Air curing, storage

3.7 Transport

1st Step MORTAR PREPARATION

Rule A

Proportion of Components

The proportion of cement, sand, water and fibre or fine aggregate in a mix is based on the properties of the actual raw materials and can vary from place to place. It should be defined during the prototype production and again when the properties of the raw materials change.

Rule B

Cement / Sand / Aggregate Ratio

For FCR, the cement to sand ratio is normally between 1:2 and 1:3. For MCR, the cement to sand to aggregate ratio is around 1:2:1. The proportions are measured by volume.
Too much cement results in fine cracks in the tile and also in high costs.
Too little cement results in a weak and porous product.

Rule C

Ratio of Fibre

The ratio of fibre is usually between 0.3 and 1.2 % of the wet mortar by weight.
Too much fibre results in a low strength and high porosity. Omitting fibre may result in cracks during molding.

Rule D

Workability

A good workability of the mix is important so as to obtain a good production result. The following indicators show if the right workability has been chosen:

- A practical instant method is to squeeze the mortar by hand. No water drops should come out and the mortar should not crumble.
- Water appearing on the surface after a short vibration period is a clear sign that too much water is being used.

Record the data on the reporting format **Code 3.1**
Tests see Quality Control Guidelines **Code 3.1.10 & Code 3.1.20**

- An easy test to maintain the correct ratio is the workability test (see Quality Control Guidelines).

Rule E

Water / Cement Ratio

The water to cement ratio of the mortar (as well as curing, especially during the first 24 hours before demolding) is a major factor governing tile quality.

The correct ratio:
A good quality mix has a water to cement ratio of 0.5 by weight (1 l water = 1 kg) and results in a mortar which hardens in the correct time, is easy to demold and does not have to be cured in water for more than 5 to 7 days.

The strength and watertightness of FCR/MCR products are sufficient if the water to cement ratio is below 0.65, but the risk of breakages during demolding is greater and longer water curing times may be required compared to products made of mortar with a water to cement ratio of 0.5.

A water to cement ratio higher than 0.65 will result in low quality products, and if the water to cement ratio of the mortar exceeds 0.7, the watertightness and durability of the FCR/MCR products are not ensured. Products with a water to cement ratio exceeding 0.65 should not be used as roofing material. Such products may ruin the good reputation of cement-based roofing products.

When calculating the water to cement ratio, the moisture content of the sand also has to be taken into account. When using wet sand, less water should be added.

The water to cement ratio also varies according to the sand quality. A mix with porous sand requires more water than a mix with non-porous sand.
The following rule is generally valid:

Suitable water to cement ratio : 0.5 - 0.65 (by weight)
Never use a water to cement ratio above 0.65

Record the data on the reporting format **Code 3.1**
Tests see Quality Control Guidelines **Code 3.1.10 & Code 3.1.20**

Rule F

Mixing

The mortar has to be mixed well, so that no lumps of fibre, aggregate and cement remain.

First mix sand, fibre and aggregate; then add cement and colorant and mix again thoroughly. Add water.

Rule G

Use Fresh Wet Mix

Every hour fresh mix has to be prepared.

The mortar mix has to be fresh when cast. The acceptable maximum time between mixing with water and casting depends somewhat on the properties of the cement and also on the temperature and air humidity. However, it should not exceed one hour.
(see also Production Management Guide)

Rule H

Stiff Mix

If the mix stiffens during the production process, do not add water. Prepare a new, smaller quantity of mix instead.

Remarks

The method of mixing a large quantitiy of cement, sand and aggregate at a time and then adding water to a small portion of that dry mix should be practiced only in areas with low humidity or with very dry sand and aggregate. Moisture in the mix will cause the setting process to start.

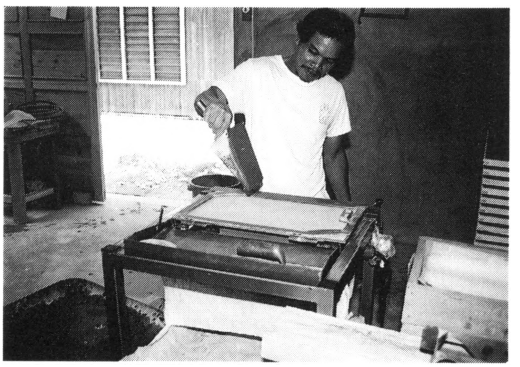
The rules and the range of possible mixes as given above should be understood as general guidelines. Testing of different mix proportions would tell you what the best mix for your material is.

Record the data on the reporting format **Code 3.1**
Tests see Quality Control Guidelines **Code 3.1.10 & Code 3.1.20**

2nd Step VIBRATING AND MOLDING

Rule A

Placing the Mortar



Put a clean plastic interface sheet on the vibrating table, close the frame and put the accurate quantity of mortar on the table by the use of a measuring scoop. Spread the mortar roughly with a trowel before vibrating.

Rule B

Cleanness

The equipment used (especially the plastic interface sheets) must be clean. The vibrating table and the frame must be free of any old mortar.

Rule C

Free from Defects

The interface sheet must not have any holes.

Rule D

Fresh Mix

The mortar has to be used within one hour after water is added to the mix.

Rule E

Accurate Vibration Time

The vibration time depends on the equipment used and the workability of the mortar. It varies between 20 and 50 seconds.

Vibration is sufficient when water starts to appear on the surface, provided the water to cement ratio is correct. At the end of the vibration, there should be:

- no water film on the surface;
- no cracks, holes or air bubbles in the matrix;
- no lumps of fibre;

and the matrix should have:

- an even thickness and
- a uniform surface.

Too long a vibration leads to a reduction in the quality of the tiles due to the segregation of the mix components.

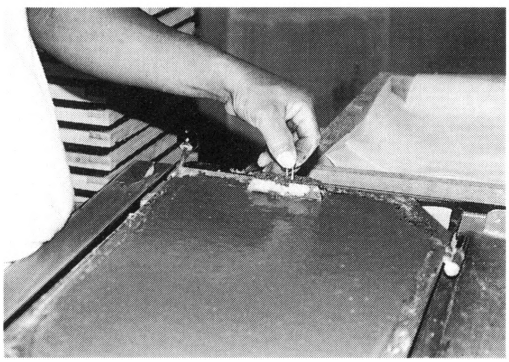
Rule F

Nib Molding and Placing of Fixing Device

When the vibration is stopped, the nib is mounted. The nib mold is filled with mortar which is then tightly connected to the tile by another short vibration.

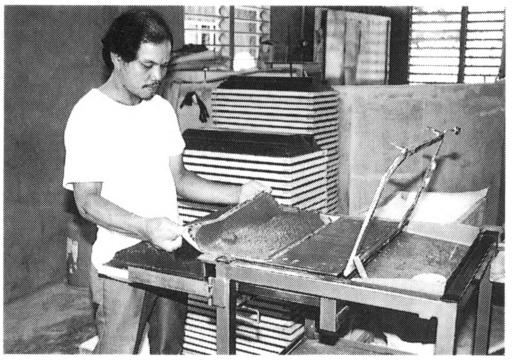
Hereafter the fixing device is inserted and the tile is again vibrated for a few seconds; then the mortar flush to the nib is cut off with a trowel.

When opening the nib frame, the nib has to be kept down by pressing with a finger.



Rule G

Molding



After vibration the matrix is moved to the mold, where it must be placed exactly in the correct position, otherwise the shape of the tile will not be correct and this could result in a leaking roof. To ensure the correct positioning the molds should have marks.

During this process no cracks should appear on the surface. Fine hair cracks that may appear are closed by a trowel or a brush.

(The photos show the method using the equipment of J.P.M. Parry & Associates).

3rd Step MOLD CURING

Rule A

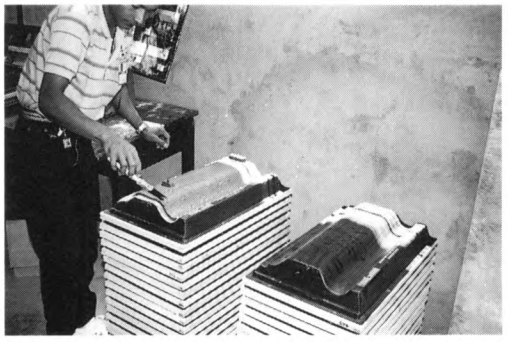
Cure Immediately

The proper setting of the mortar is only possible if the tiles are cured correctly. The curing procedure should start immediately after the product has been cast. The tiles have to be stacked in an airtight manner or covered within **5 minutes** after casting. Neglecting this would result in drastically weakened tiles and cracking.

Rule B

Curing Method

During this period the tiles are cured in a horizontal position while still on the mold, by covering their surface with a plastic sheet or by stacking with molds that guarantee airtight and dampproof stacking.



If during this step cracks develop on the surface, it is a sign of too much air circulation.

Rule C

Curing Period

The most important curing period is during the first 24 hours.

For organizational reasons it is difficult to keep the tiles on the stack for exactly 24 hours. However, a minimum of 20 hours must be allowed.
(See also Production Management Guide)

4th Step DEMOLDING

Rule A

Time of Demolding

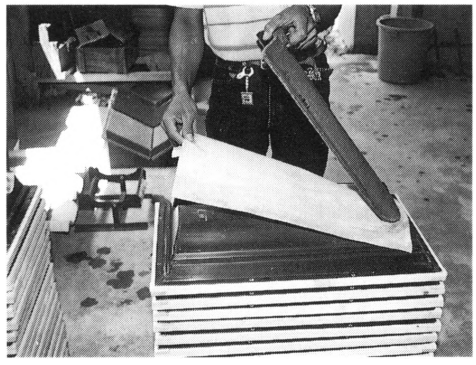
After 24 hours the strength of the tiles is sufficient for demolding. Do not demold earlier than 20 hours after vibrating.

Rule B

Demolding

This operation can be done by tilting the mold with the tile over a jig (method using the equipment of J.P.M. Parry). Instead of the jig a mold specially made for this purpose may also be used.

Demolding can also be done by sliding the tile and the interface sheet from the mold and holding the tile gently in the palm of the hand. Care should be taken to avoid holding the tile by the corners or between two fingers only.



Remove the interface sheet by pulling it across the tile (short dimension) and remove any fresh mortar. Then place the tile on the test mold.

Rule C

Testing

Check if the demolded roofing product fits on the jig or test mold without wobbling and with all the edges in the right position. The size and shape should also be checked.
(See also Quality Control Guidelines)

Rule D

Cleaning of the Molds and the Interface Sheet

So that good quality tiles can be produced later, it is most important to immediately clean the molds and plastic interface sheets with a brush and water. They should be checked for holes and stored properly (see also 5.1).

Rule E

Tile Marking

The tiles should be marked with

- the production date,
- the name of the company and
- the name of the worker.

This helps to observe the correct curing time, determine the right time for the end control and to relate the service performance of installed tiles to the production data and the producer.

Marking can also be done during the vibrating process.

5th Step TANK CURING

Rule A

Curing Time

After tiles have been cured for 24 hours in a horizontal position, they are carefully moved to the curing tank where they are kept completely under water in a vertical position for at least 5 days, provided the water temperature is above 20°C.

Mark the date on the curing tank to avoid confusion. (See also Production Management Guide)

Rule B

Immediate Curing

After demolding, the tiles must immediately be moved to the curing tank. Never allow the tiles to dry in the sun or wind before water curing.

Rule C

Water Level

The water level in the curing tank should be checked daily. The tiles should be covered by at least 20mm.

Rule D

Curing at Low Temperature

If the water temperature is below 20°C, the curing time must be increased.

For a temperature of 15°C, the curing time must be at least 7 days.
For a temperature of 10°C, the curing time must be at least 11 days.

Make sure that the water temperature is measured because it is lower than the average daytime air temperature.

Rule E

Curing Time for Tiles Cast with a high Water to Cement Ratio

If the water to cement ratio is higher than 0.5, the curing time must be increased as well.

Rule F

Change of Water

If the water becomes too aggressive on the skin, it should be changed, this may be once a week, but at least every two months. At the same time the tank should be cleaned.

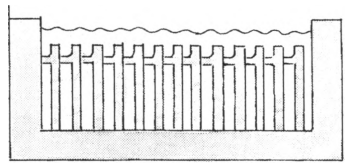
Curing in clean water is especially important when producing colored tiles. Old water may cause white stains.

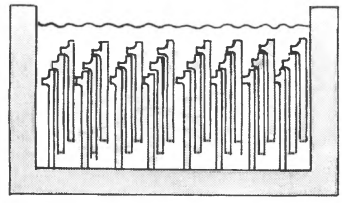
Rule G

Storing Method

There are different possibilities for storing the tiles in the tank:

- Stacking the tiles in a row
- Stacking the tiles in sets of three tiles.



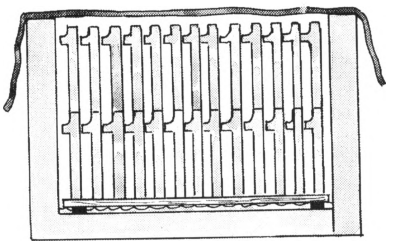


Stacking in sets is a space and time saving method, but is only possible with tiles that have a nib at the top. It involves a certain risk of damage to the nibs.

Rule H

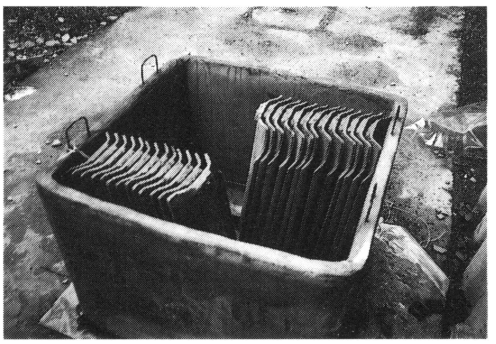
Vapour Curing

Another method is to cure the tiles above water in air saturated with water vapour.



This can be achieved by placing only a little water in the curing tank. The tiles are stored above the water level. The tank is then made airtight by covering it with a black plastic sheet. As the tank is exposed to the sun, the enclosed air becomes saturated with humidity and the temperature rises, thus accelerating the setting process.

The water level must be checked at least every morning.



This environment, where the curing temperature is higher, favours the curing process. The result is a strong product with a smooth and clean surface.
The method is especially advantageous for colored tiles, giving a proper coloring without white stains.

Rule I

Batch Marking

Properly mark the daily batches with the date of production and product number so that the curing time can be checked.

(See also Production Management Guide)

6th Step AIR CURING, STORAGE

Rule A

Curing Time

After the water curing period the cement setting process is not yet completed. 28 days after casting only 80% of the final strength of the tiles has been reached.

After the tank curing, another 20 days must be allowed for air curing.

Rule B

Shaded and Windprotected Storing

During this time the tiles must be protected from direct sun radiation and air circulation, which would result in too fast a moisture evaporation.

Rule C

Water Sprinkling

In dry climates the tiles should also be sprinkled with water twice a day to avoid complete evaporation of moisture.

Rule D

Protection from Mechanical Damage

To avoid mechanical damage the tiles are stored in a vertical position on properly built racks or on sand.

Rule E

Batch Marking

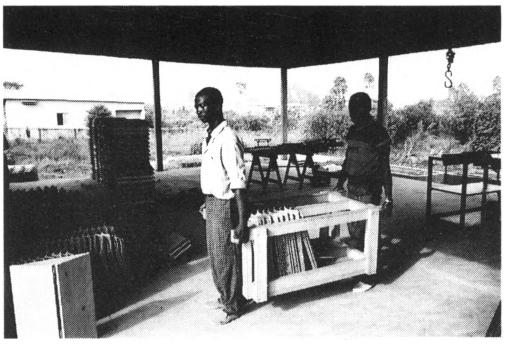
Properly mark the daily batches with the date of production and product number so that the curing time can be checked.

(See also Production Management Guide)

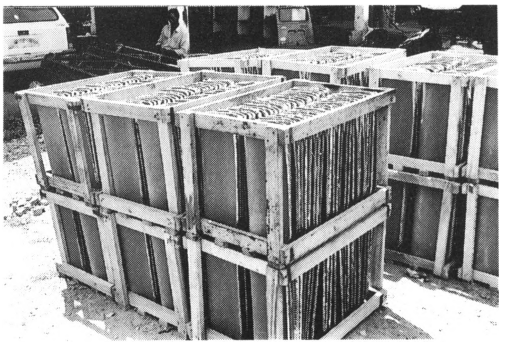
7th Step TRANSPORT

Rule A

Careful Shipment



The last step in the production process is the shipment.
The means of transport varies from a lorry, a bullock cart, a ricksha to people carrying the tiles on their backs. The roads are often extremely rough.
To avoid damage during transportation, careful handling is required. Proper packing methods adapted to the means of transport have to be used.



- The tiles have to be transported in a vertical position, preferably in packages of three pieces.
- They must be tightly stacked, with no scope for knocking each other during transportation.
- Proper racks should be used when carrying tiles.
- When transporting in a vehicle, sand, sawdust or fibre rejects should be used at the bottom to cushion the tiles. The direction of stacking must be the same as the direction of movement of the vehicle.

Rule B

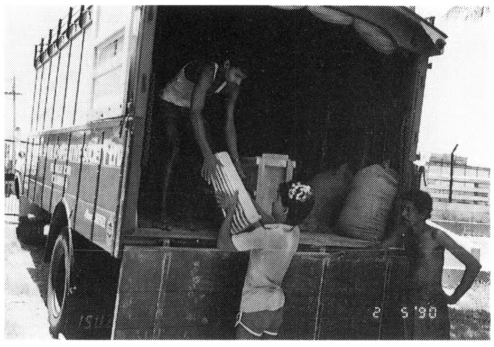
Instruction of Customers

Often the tiles are transported by the customer. He must be properly instructed how to handle and transport the tiles.

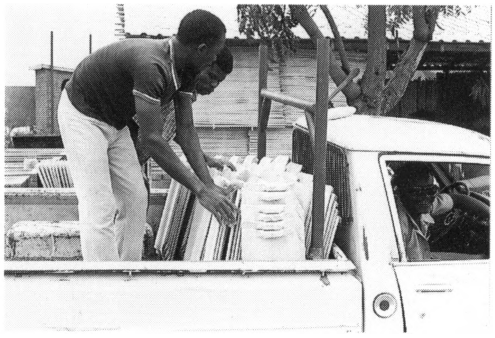
A simple leaflet can be designed for this purpose and distributed to the customer.

Examples

Transport by Lorry



Transport by Pick-up



4. END CONTROL

An end control must be done shortly before the tiles are sold or, if the producer installs the tiles himself, just before installation.

This testing at the last possible moment ensures that all damages which occurred during storing, handling and possibly transportation are discovered, and the customer can be supplied with a reliable product.

Some tests have to be done with every single tile; others can be done on a random sample basis.

The tests are:

4.1 Pore and crack test

4.2 Ring test

4.3 Bending test

4.4 Nib tensile test

4.5 Watertightness test

4.6 Weight test

These tests as well as the consequences or action to be taken when the tiles fail a test are described in the Quality Control Guidelines, Toolkit element 23.

Tests see Quality Control Guidelines, Codes **4.1.10** **4.4.10**
4.2.10 **4.5.10**
4.3.10 **4.6.20**

5. MAINTENANCE OF THE EQUIPMENT

Maintenance of the equipment is an important aspect in FCR/MCR production.

The proper functioning of the equipment - which is a vital factor in producing a good and constant product quality - depends much on maintenance. Maintenance also saves time, reduces damage and increases staff motivation.
As a consequence it can substantially reduce the production costs. Loss or breakdown of equipment can lead to high financial losses or even to a production standstill.

Note : For the maintenance of equipment, also follow the instructions of the manufacturer.

The main components are:

5.1 The battery

5.2 Vibrating device and tools

5.3 Molds and plastic interface sheets

5.4 The scale

5.5 The workshop

Equipment THE BATTERY

Rule A

Regular Control

The battery should be controlled daily to ensure the long life of this costly item.

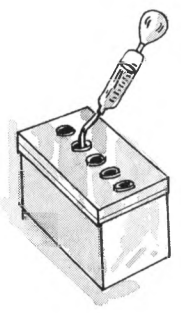
The checks should be done on a routine basis after every shift or working day.

Rule B

Battery charge level

The battery charge level should be checked regularly by using a hydrometer. The battery should never be allowed to lose more than half its capacity before reloading.

Charge the battery immediately. If repeatedly allowed to fully discharge, the battery is damaged and would have to be replaced.



Control water levels and charging status after every shift

Rule C

Water Level

Check the water level of the battery at the same time. The plates must always be covered by a few millimetres of water. Make sure that only distilled water is used.

Remarks

Type of Battery

Preferably use a strong battery (12 Volt truck battery, 16 cells). It will not be necessary to charge it as often as a car battery.

Direct Mains

A reliable direct current supply, if available, and used with a transformer, is preferable to a battery.

However, a professional installation is important in the interests of reducing the danger of accidents.

Record the checks on the reporting format Code 5.1

Equipment VIBRATING DEVICE AND TOOLS

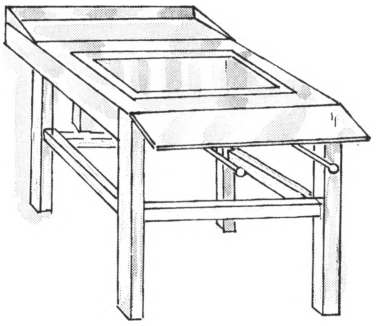
Rule A

Cleaning Before Any Interruption of Work

The life span of the vibrating device and tools depends to a great extent on regular cleaning.

All vital parts of the vibrating device and all tools should be kept clean.

The vibrating table top, the screeding frame, the transfer frame, the hinges and the frame lock handles have to be carefully cleaned and oiled before any work break which is longer than half an hour.



The same maintenance is also needed for tools.

Rule B

Cleaning After Every Tile

Only on a clean table can proper tiles be produced.

The surface of the table and the frame have to be wiped after producing every tile.

Rule C

The Table Must be Level

For tiles of uniform thickness, the table must be level.
Check once a day with a water-level.

If no water-level is available, one can also place mortar on the middle of the vibrating table top, start the vibrator and see if the mortar spreads faster in any direction. If so, the level of the table has to be adjusted.

Equipment MOLDS AND PLASTIC INTERFACE SHEETS

Rule A

Cleaning After Every Tile

Immediately after demolding every single tile the mold and plastic interface sheet have to be carefully examined and cleaned. Defective pieces have to be replaced.

The cleaning is most easily done with water and a fibre bundle or brush.

Rule B

No Time Saving

Do not try to save time by avoiding or neglecting cleaning interface sheets and molds. The quality of the product and the lifetime of the equipment would suffer too much.

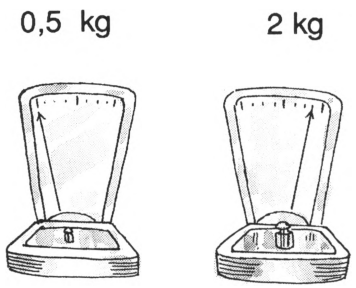
Equipment THE SCALE

Rule A

Check Weekly

Only a reliable scale provides information that is useful to draw conclusions from the tests. The function of the scale should be checked regularly by using two different standard weights.

If the readings are not exact anymore, try to adjust the scale or replace it.



Rule B

Cleaning

Always keep the scale clean.

Equipment THE WORKSHOP

Rule A

Keep in Order

The workshop should be put in order after every working day. This is important for the motivation of the staff and to avoid loss of equipment. In the long run it saves time.

Rule B

Cleaning

The workshop should be cleaned and swept at the end of every working day. Dirt and breakage must be properly disposed of or transported away.

Rule C

Curing Tank

Clean the curing tank and change the water every week or at least every 2 months.

6. FURTHER READING

(E) = English; (F) = French; (S) = Spanish

01 Brys, Gilbert: Tuiles en fibromortier. Procédé de production et pose en toiture, Technology Series, Memorandum No. 16, International Labour Office (ILO), Geneva, 1988 (F,E)

02 Evans, Barrie: Understanding Natural Fibre Concrete, Its Application as a Building Material, IT Publications Ltd., London, 1986 (E)

03 Gram, H.-E.; Parry, J.P.M.; Rhyner, K.; Schaffner, B.; Stulz, R.; Wehrle K.; Wehrli, H.: FCR - Fibre Concrete Roofing. A comprehensive report on: The Possibilities of Fibre Concrete Roofing. The Limits of Application, and The State of the Art, SKAT, St. Gall, 1986 (E)

04 Heierli, Urs; Beck, Victor: FCR - Fibre Concrete Roofing, Feasibility and Market Study Guides, SKAT, St. Gall, 1987 (E)

05 Lola, Carlos R.: Fibre Reinforced Concrete Roofing Sheets, Technology Appraisal Report, AT International, Washington, D.C., 1985 (E)

06 Parry, John: Fibre Concrete Roofing, Intermediate Technology Workshops, Cradley Heath, 1985 (E)

07 Parry, John: Users Manual (E)

08 SKAT: The Basics of Concrete Roofing Elements, Fundamental Information on the Micro Concrete Roofing (MCR) and Fibre Concrete Roofing (FCR) Technology for Newcomers, Decisionmakers, Technicians, Field Workers and all those who want to know more about MCR and FCR, SKAT, St. Gall, 1989 (E)

09 SKAT: Información Básica Sobre Techos de Micro Concreto (TMC) y Fibro Concreto (TFC), Introducción para Arquitectos, Técnicos, Epresarios, Instituciones de Desarollo y el Público Interesado en TMC y TFC, SKAT, ST. Gallen, 1989 (S)

10 Stulz, Roland; Mukerji, Kiran: Appropriate Building Materials, A Catalogue of Potential Solutions, SKAT, St. Gall, GATE, Eschborn, IT Publications Ltd., London, 1988 (E)

11 Twigt, Fred Jan: Fibre Concrete Roofing in Malawi, Kenya, Tanzania, Zambia and Uganda, FCR Advisory Services, SKAT, St. Gall, 1988 (E)

12 Gram, Hans-Erik; Gut, Paul: FCR/MCR Toolkit Element 23, Quality Control Guidelines, SKAT, St Gall, 1991 (E)

13 Gut, Paul: FCR/MCR Toolkit Element 4, Standards Guidelines, SKAT, St Gall, 1992 (E)

Audio-Visual Material

14 Macwhinnie, Ian: An Introduction to FCR/MCR Production, A BASIN Video, ITDG/GTZ-GATE, Eschborn, 1990 (E)

Reporting Format

MORTAR PREPARATION

Use this data when evaluating the results of the end control.
It may give you indicators for possible failures.

Mix No	Date	Time when water added	Cement (kg) A	Sand (kg) B	Moisture content (1) (%) C	Water (litre) D	Water/ Cement ratio (2)	Time when last unit was cast

(1) Moisture content = Moisture content of sand and aggregate

(2) Water / Cement ratio $= \dfrac{D + (C \times 0{,}01 \times B)}{A}$

Reporting Format **BATTERY**

Date of control	Charging status (1)	Date of filling water	Date of charging

(1) Charge the battery if more than half of the capacity has been used.

Reporting Format **THE SCALE**

Date of control	Weight shown with 0,5 kg standard weight	Weight shown with 2,0 kg standard weight

The roof constitutes the most important part of a building and special care has to be taken in preparing the roof and the roofing elements. The best available raw materials should be used and throughout the production process it should be kept in mind that a bad quality roofing product will not only result in an inadequate roof, but may also lead to severe damage to the whole building.

To promote FCR/MCR technology, a high and constant quality is required. This is important not only to produce and continue a reputable product, but also to avoid wasted investments. Therefore, adequate technology transfer and comprehensive dissemination of know-how are important tools in the production process of FCR/MCR.

This guide is compiled so as to help advisory centres to transfer this know-how systematically and to help producers to achieve a product of a high standard . The chances of improved production on a broad basis are then increased, benefiting from existing and well-established technological know-how.