FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

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A comprehensive report on The potential of Fibre Concrete Roofing The limits of application The state of the art

SKAT
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2. Producer organization

In chapter 2 Beat Schaffner is treating the aspects

- **Self-help organisations**
- **Non governmental organisations (NGO)**
- **Possible forms of organisations**
- **Eight different cases**

Please note: By using the term "NGO's and public" we mean aid-organisations, funding agencies, governmental services or organisations subsidized by the public.

2.1 Conclusions

The way FCR production is organised is in two main categories which will to be looked at separately where producer and user are the same where producer and user are different

- In the case of producer and user (customer) being the same individual or organisation, the problems are more production orientated. The aim of this type of organisation will be to get products at a good standard for its own use.

- Acceptance of the product is easier in such cases, because the users are involved in the production process. The marketing problem does not have to be faced.

- Economics are not purely valued in profit but in socio-economic benefits such as

- **job creation**
- **foreign currency savings**
- **use of local materials**

- **improvement of roofing-technology**

- In the case where the producer and user are not the same, marketing becomes the main problem; quality standards and costs will be judged by the market. In this case, FCR is in competition with other roofing materials such as clay tiles, asbestos-cement, galvanized corrugated iron-sheets. Transport adds another special problem to this form of organisational set-up.

- The buyer will ask for guarantees from the producer. The producer might be able to give guarantees for the product but he has no influence on how the roofing materials are mounted on the roof.

- Acceptance by the users which are not involved in the production process will be much more difficult to obtain.

- There is not a definitive answer of how production should be organized. Successful production and self-use or production for the open market depend on the local situation of course. Nevertheless, the preconditions for success seem to be better, if producer and user are the same.

- The various forms that producer - user relationships might take will influence both the potential scope for the organisation and in particular, the constraints upon it. It is important for it to be aware of this.

- A licensing system has not yet been established for FCR technology.

2.2 Evaluation of experiences

In the questionnaire, there were two paragraphs which should give a picture of how FC-production is organised and who is using FCR products. Besides the organisational form,

we were interested to know, if FCR is produced or used mainly in rural or mainly in urban areas.

The results give evidence, that FCR is produced first of all by NGO's or public organisations and that it is used mainly in rural areas.

This result has to be interpreted with caution. SKAT as originator of the questionnaire is also a NGO and the collection of addresses was based on information received from institutions within the AT-network. Also most of the answers came from organisations producing sheets. The results might be different for FCR tile production. All these groups which have started FCR production on their own after having seen it at NGO's workshops or got hold of a manual somewhere are not known to us.

Their number is large and the rate of failure will also be large. In the future a high potential for FCR and private entrepreneurs will probably arise in periurban areas due to the existence of wage employment and sales of cash crops.

The following tables give a picture on the data received:

	Rural	Urban
Self-help	many cases	few cases
NGO's & Public		
- On Site	most cases	many cases
- Mobile	few cases	very few cases
small-scale industry	few cases	very few cases

Table 1: Producer organisations (Answers to question: What type of FCR production do you use and in what areas?)

	Rural	Urban
self-help	high potential	high potential
NGO's & Public		
- On Site	highest potential	high potential
- Mobile	high potential	high potential
small-scale-industry	medium potential	medium potential

Table 2: User organisation (Answers to the question: For which type of market is FCR an appropriate technology and for what areas?)

2.3 Comments

Fig. 1 shows the range of main possible forms of organisation for the production of FC-products. The key question is first of all, if the producer organisation Is Identical with the user or not.

If producer and user are not Identical, the whole problem of marketing has to be solved: A mobile team of craftsmen has to find its potential customers or the producer has to promote his product for sale.

Another main question is whether production is done on site or at a central workshop; if it is done at a central workshop, there have - besides production - two main problems to be solved.

One is transport and the other is supervision and co-ordination when it comes to the installation on the roof structure.

The possible forms of organisation are shown below and they are commented on the following pages.

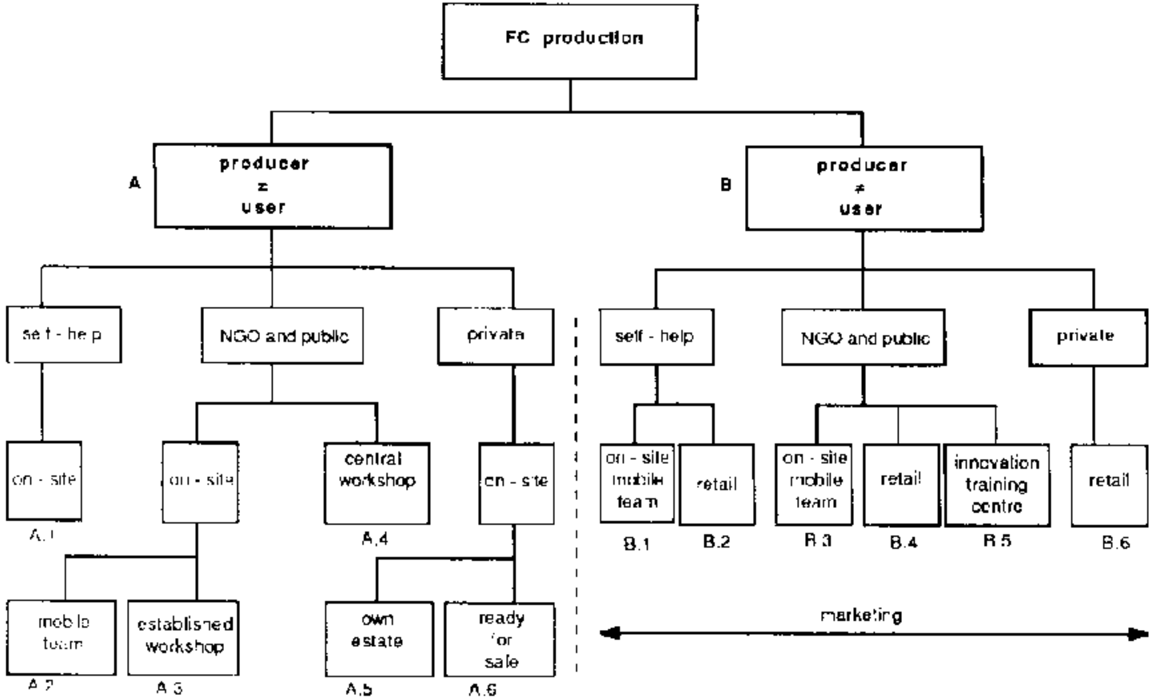
The main criterias to evaluate appropriate forms of organisation are in our opinion:

- acceptance of product
- maintenance of quality control In production and installation
- transport problems.

Not solved yet are the problems of licensing. At the moment, almost everybody is entitled to start

FC-production, whether or not suitable resources are available.

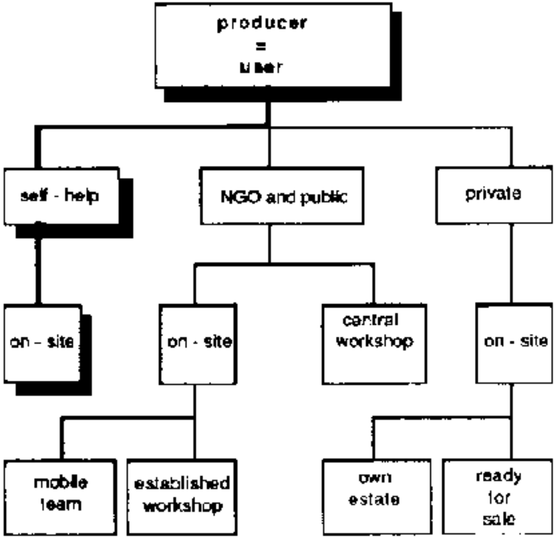
Design and construction of the roof structure as well as the installation of the FCR elements on the roof should be supervised and co-ordinated by the FCR producers at least until the FCR has become a commonly used technology.



Possible forms of organisation

Case A.1

This seems to be the easiest pattern for an organisation to set-up FCR production. A typical example for this kind of organisation would be an agricultural cooperative which is planning to roof their animal-houses or their grainstores with FCR products.



Case A.1

The main problem for the co-operative will be how to start: Where to get the know-how from and how to finance the initial investment for setting up a plant.

An advantage in these forms of projects is the fact, that the production team will participate In the installation of the roofing elements. This ensures a quality self- control and also acceptance of the product.

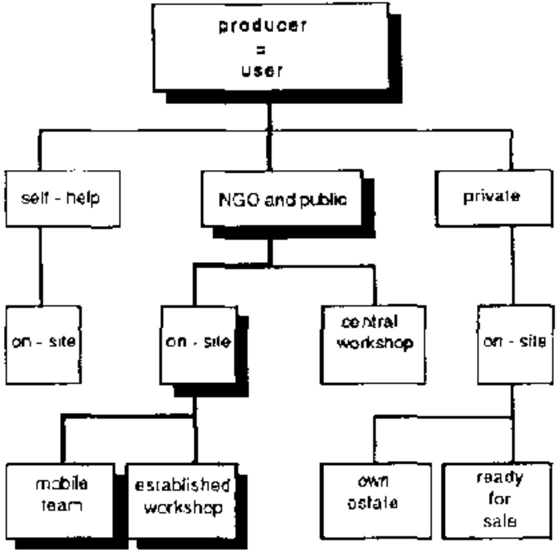
Nevertheless, the risk of this kind of organisational set-up is in an often observed decline of quality. Once the production has started and achieved a certain standard, quality control might seem to be unnecessary.

Of course, FCR production is designed for this kind of group. It Is the responsibility of the FCR promoters (as manufacturers of equipment or knowhow-pool), to see that the initial knowhow-transfer is followed-up.

If the own demand for roofing materials is satisfied, these projects of course have the potential to become a producer group for others later on (see case B.1, B.2).

Case A.2 and A.3

This is a very frequent organisational set-up. NGO's such as aid-organisations, AT-institutions, large co-operatives or government services initiate the production in their projects. This can be done either by establishing a workshop on-site or by sending a team of skilled, already trained workers to the site.



Case A.2 and A.3

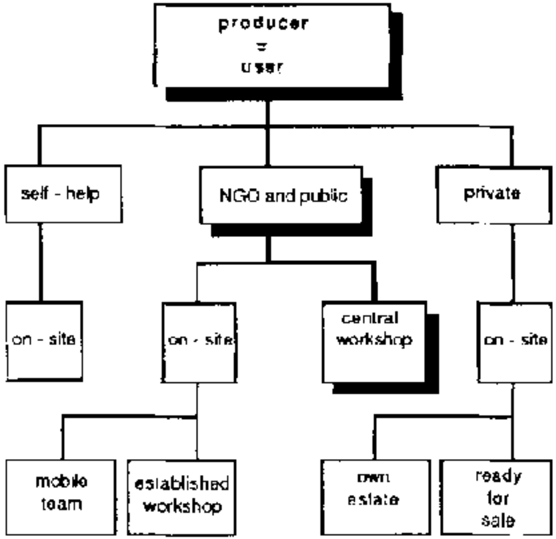
Initial Investment will mostly be paid by the organisation as well as starting capital. This kind of scheme Involves the users in the process, if not directly as producers, at least as partners in the production process. They can do FCR related work such as fibre preparation, sand collection or roof carpentry.

Acceptance of the product will be easier, If people are somehow Involved in the making of their roofs.

Case A.4

Adoption of this model of FCR production has many advantages. It ensures the NGO or

public-service will supervise production centrally and to see, that standards are kept high and according to the latest knowhow. If the products are used in different projects, the central workshop can produce a large number of tiles or sheets. This should allow the producer to Invest more In good equipment and know- how-transfer (training) as this initial investment can be paid back.

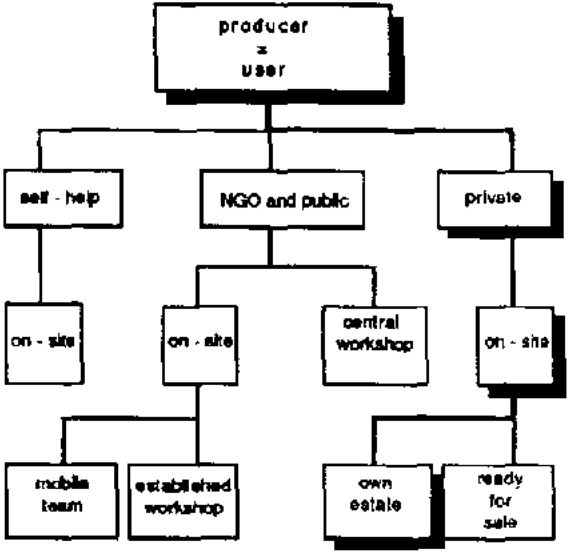


Case A.4

The problem in this case is of course mostly in transport (which is not easy and becomes a cost factor) and in a potential risk of product damage if the people who are producing are not identical with the people installing the sheets or tiles on the roof.

Case A.5

The economics of FCR can also be of Inter-rest for private entrepreneurs. If a private investor such as an industrial estate has its own large demand e.g. for their own housing project, it might be interesting for it to start a FCR production.



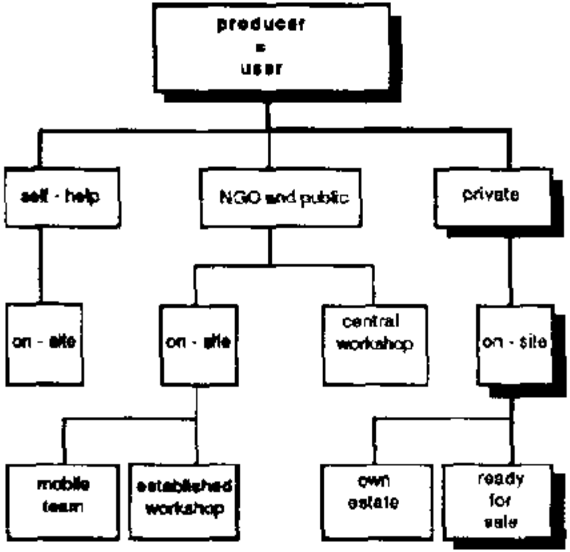
Case A.5

An entrepreneur will later on think about how he could enter the market with this product. His private project will serve him as a reference and pilot project.

Case A.6

A building contractor, who is selling buildings for immediate occupation might use FCR products as a roofing material. As he has to give a guarantee for the house he is selling, he

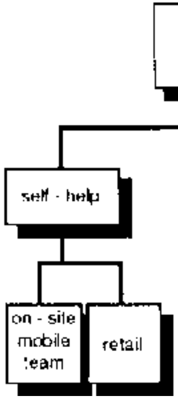
will be interested in having a good quality roof.



Case A.6

Case B.1 and B.2

If self-help groups are trying to enter the roofing market, they can either form a mobile team of craftsmen or sell their products as retailers.



Case B.1 and B.2

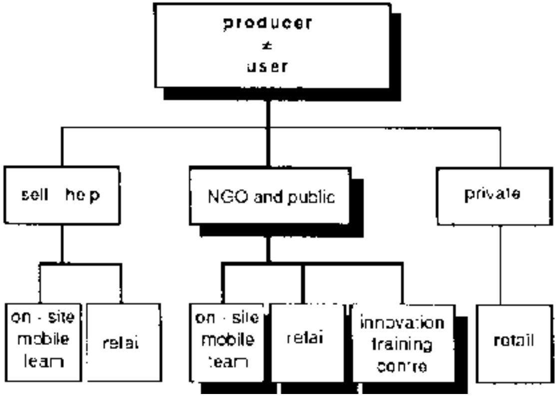
If they have been producing FCR products for their own use before, they might have a reasonable chance of success.

But if beginners try to enter the market, it might be rather difficult. The product might be suitable of good standard, but transport and assembling of the roofing materials will cause a lot of problems to the buyer. Setting up a reference roof at the point of sale will be very essential to illustrate to all customers the way FCR should be installed, indicating that no guarantee would be assumed If the construction does not fill minimum requirements.

As a mobile team of craftsmen is seeking their customers, they need a reference project to encourage potential customers. On site production will again have the advantage of better acceptance if the future users are somehow involved in the making of the products and observe and understand the process.

Case B.3. B.4. B.5

These cases are proven In the field. The advantages of having a NGO or government organisation backing the project are obvious:



Case B.3, B.4, B.5

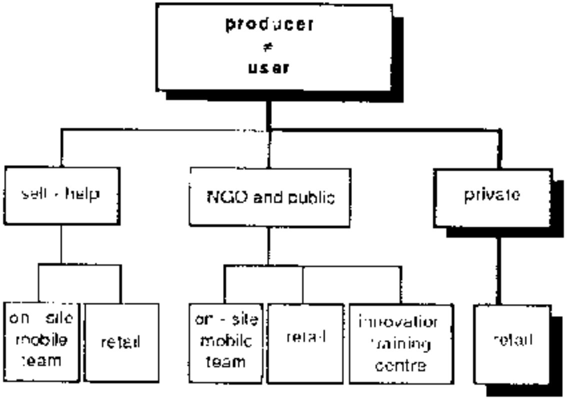
They can assure training facilities and technical assistance as well as working capital in the beginning.

On site production, backed by the NGO or public will be the most appropriate case, central retail has again to face transport and installation problems.

Supported Innovation centres play an important role as information pools for latest knowhow, quality control and follow-up services.

Case B.6

Commercial type of FCR production with private investors: if FCR production enters this field, it faces serious marketing problems.



Case B.6

It will be considered as an industrial product and as an alternative to asbestos- cement and galvanised iron roofing materials. Therefore it has to satisfy high quality standards.

The price of the product will be its best selling feature

There is a risk in this case, that a private producer will try to reduce his cost by reducing the cement ratio which will result in a decline of quality.

Nevertheless there is a reasonable chance for this kind of commercial FCR production in circumstances where other materials are scarce or where the economic advantages of FCR are obvious and If quality control is maintained

It would be an important task for suppliers of FCR equipment to follow-up their sales and to keep a check upon private FCR- producers

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3. Technical rationale

In chapter 3 Hans Erik Gram is treating the aspects

- Composition of matrix and type of fibres used
- Rejection rates
- The matrix
- The role of the fibre
- The composite
- The tile
- The sheet
- The load on roofing structures
- Quality control
- References

3.1 Conclusions

Roofing elements of natural fibre concrete have been in use since 1977. The experiences so far include both success and failures. To secure a good quality roofing material made of concrete or mortar with natural fibres one has to keep the following in mind:

The cement matrix

- The properties of the hardened concrete are affected by the mix proportions, the mixing procedure, the compaction and the curing during the first 7 days.

The fibres

- The chopped fibre plays its main role in giving the fresh mix a better cohesion and it enables the moulding of corrugated products.

- Fibre length less than 25 mm is recommended.

• All types of natural fibres are possible to use in FC as long as they are clean so that they do not have a negative influence on the setting and hardening of the concrete.

The composite

- Concrete with long natural fibres may be improved in flexural strength but this effect is lost when the fibres are decomposed.

- Concrete with chopped natural fibres is a material with properties more like burned clay than asbestos cement and it has to be looked upon as an unreinforced material. The addition of 1 percent by volume of chopped fibres does not improve the properties of the hardened concrete with exception of a slight increase in toughness.

- The natural fibre is decomposed in the alkaline environment of the concrete . This has the effect of a reduction in toughness but not of the other strength properties.

- The durability of natural fibre concrete is good if the batching, mixing, compaction and curing are done properly and if the material is not subjected to stresses exceeding its capacity. There is need for a good quality control program for the production of natural fibre concrete elements.

- The stresses within the roofing element are dependent on its dimensions and how it is fixed. In this respect the roofing tile seems to have an advantage compared with the roofing sheet.

3.2 Evaluation of experience

16 answered questionnaires and discussions with practitioners as well as earlier evaluations made, give the base for this evaluation. In table 1 basic data from the questionnaires are given

Country and /Reference	Dimension product width, length, thickness [mm]	Pro-duced since	Number of elements produced	Number of elements installed in roofing	Production capacity [m^2/day]
Africa					
Mocambique /67/	240x500x7 ITW-tile	1985	1'500	1'000	4
Zambia /68/	670x1000x6	1984	2'000	2'000	13
Tanzania /69/	750x750x7.5	1978	5'000	5'000	20
Kenya /70/	Parry ITW-tile	1983	100'000	48'000	18
Kenya /71/	"	1985	20'000	1'500	17
Zimbabwe /84/	700x1000x6 7.5	1979	2'000	200	15
Zambia /86/	sheets (NA)	1982	-	-	10
Ghana /89/	tiles (NA)	1985	500	150	NA*

Malawi /93/	760x1000x10-15	1980	34´000	21´000	15-60
Asia					
Bangladesh /72/	795x1000x6.5	1983	880	530	9
" "	Parry ITW tile	1983	80	-	-
India /73/	650x1000x10	1982	10´000	9´500	2*
India /74/	1000x2000x7	NA	FEW	FEW	-
Indonesia /75/	920x1150x7	1982	2´000	1´800	
Bangladesh /88/	790x1000xNA	1983	1´070	834	8
Sri Lanka /45, 80/	390x1000x10-15	1984	15´000	14´000	NA
America and Australia					
Dominican /76/ Republic	750x1350x6-9	1984	3´000	1´500	16
Dominican /77/ Republic	1000x1450x10-15	1982	1´000	900	-
Nicaragua /78/	840x1000x6-9	1984	14´000	8´000	80
Solomon /79/ Islands	Parry ITW-tile	1984	1´000	1´000	4
Haiti /87/	Parry ITW-tile	1984	42´000	34´000	40
Guatemala /45, 80/	770x990x6-9	1981	1´500	1´500	NA
Colombia /45, 80/	610x1140x10	1982	300	200	NA

*NA = No Answer

Table 1: Basic data on FC roofing.

Country and / / Reference	Type of element	Cement sand ratio	Water/cement ratio	Type of fibre and length [mm]	Fibre volume [%]	type of compaction
Africa						
Mocambique /67/	Tile	1:2	0.52	Sisal 12	1.7	vibration
Zambia /68/	Sheet	1:1	-	Sisal 10-20	1.1	"tamping"
Tanzania /69/	Sheet	1:1	0.56	Sisal 20-50	3.0	vibration
Kenya /70/	Tile	1:3	-	Sisal 12	1.5	"
Kenya /71/	Tile	1:3		Sisal 12	1.1	"

Kenya /71/	Tile	1:3	-	Sisal 12	1.1	
Zimbabwe /84/	Sheet	1:1	-	Sisal 15-20	0.9	"tamping"
Zambia /86/	Sheet	NA	-	Sisal 20-50	NA *	NA
				Elephant gr20-50	NA	NA
Ghana /89/	Tile	NA	-	Palm nut 60	NA	NA
Malawi /93/	Sheet	1:2	0.6	Sisal 20 30	ca.1.0	"tamping"
Asia						
Bangladesh /72/	Sheet	1:0.8		Jute 18-25	1.1	"tamping"
Bangladesh *	Tile	-	-	- -		-
India /73/	Sheet	1:1	-	Coir12	1.9	"
India /74/	Sheet	1:0	-	Coir 100-200	16	vibration + pressure
Indonesia /75/	Sheet	1:0.67	-	Ijuk 30	3.4	"tamping"
Bangladesh /88/	Sheet	1:0.8	-	Jute 15	1.5	NA
Sri Lanka /45, 80/	Sheet	NA		Coir 20-30	NA	vibration
America and Australia						
Dominican /76/ Republic	Sheet	1:1	-	Sisal 25	1.2	"tamping"
Dominican /77/ Republic	Sheet	1:1	-	Sisal 50-75	12?	"
Nicaragua /78/	Sheet	1:1		Sisal 25	3.5	"
Solomon /79/ Islands	Tile	1:3	-	Coir 20	1.1	vibration
Haiti /97/	Tile	1:2.5	-	Sisal 20	NA	vibration
Guatemala /45, 80/	Sheet	NA	-	Sisal 20-30	NA	vibration
Colombia /45, 80/	Sheet	1:1.2		Sisal 20-30	0.5	vibration

*NA = No Answer

Table 2: Composition of matrix and type of fibre used. Compaction method used.

Country and // Reference	Type of element	Rejection rate before shipment [%]	Damage rate after shipment [%]	Way of fixing	Crack pattern	Expected durability [years]

Africa						
Mocambique /67/	Tile	0.5	0	Wire loops	none	-
Zambia /68/	Sheet	4.5	5.5	"	longitude	6-10
Tanzania /69/	Sheet	1.0	1.0	Nail, screw	"	30
Kenya /70/	Tile	4.0	1.0	Wire loops	"	20-25
Kenya /71/	Tile	0	2.0	"	none	15
Zimbabwe /84/	Sheet	5	10	Wire loops	long + trans	20
Zambia /86/	Sheet	20	30	"	NA*	7-10
Ghana /89/	Tile	2	0	"	NA	-
Malawi /93/	Sheet	2-20	2-10	"	longitude	10-70
Asia						
Bangladesh /72/	Sheet	5.0	5.0	Wire loops	long + trans	15
India /73/	Sheet	5.0	-	"	longitude	10
India /74/	Sheet	5.0	5.0	J-hooks	long + trans	30
Indonesia /75/	Sheet	x[1])	x[1])	Wire loops	"	-
Bangladesh /88/	Sheet	6	2	J-hooks + wire loops	long + trans	10
Sri Lanka /45, 80/	Sheet		2	J-hooks	long + trans	4-6
America and Australia						
Dominican Republic /76/	Sheet	3.0	2.0	Screws	long + trans	8
Dominican Republic /77/	Sheet	-	-	Nails	"	5-10
Nicaragua /78/	Sheet	6.0	8.0	J-hooks	"	10
Solomon Islands /79/	Tile	1.0	1.0	Nails	longitude	10
Haiti /87/	Tile	1.0	NA	Wire loops	corners	-
Guatemala /45, 80/	Sheet	-	20	J-hooks	long + trans	4-6
Colombia /45, 80/	Sheet	-	53	J-hooks	long + trans	-

*NA = No answer

[1] Figure not given, but the roofing structure classed as failure because of many problems with cracks.

Table 3: Rejection rate before shipment, damage after shipment, mode of fixing, type of

observed cracking and expected durability.

From data given in table 3 one can conclude that the rejection rate before shipment and damage rate after shipment is lower for tiles than for sheets. Cracks have been observed in most cases. The sheets seem to have both longitudinal and transverse cracks. Two out of four tile producers report no cracking. The tile has been in use for only 2 years, but the experience so far shows better performance than it is the case for the sheet.

Not too wide cracks can be mended according to the answers in the questionnaire: In reference /69, 72, 75, 78, 93 / the use of mortar is recommended. In reference /72, 75-79, 88 / white PVC glue, asphalt, cement paste or painting with oil are suggested.

The reason for observed cracks are according to reference /71, 78, 93/ poor curing. Other reasons such as not homogenenous mortar mix and not evenly distributed fibres /72, 74, 93 / ,bad properties of constituents (cement, sand or fibres) /72, 74, 78, 93 /, to high water /cement ratio /72, 93/ or bad compaction /72, 76, 78, 93/ have also been mentioned.

Deteriorated fibres in roofing structures have been reported in reference /69/ (Sisal). No sign of fibre deterioration has been reported in references /67, 68, 70, 72-74, 76-79, 87, 88, 93/.

Investigations in the field /45, 85/ give evidence of both successes and failures. In these examples up to 45 % of installed roofing sheets are cracked after a few years. The roofing tile has only been in use for two years and has less tendency to cracking compared with the sheet.

A control of cement, sand and fibre quality on reception and in stock is reported in 14 questionnaires. A control of the correctness of weighing and batching equipment is reported in questionnaires. The product shape is controlled according to 13

questionnaires.

The product thick-ness is controlled according to 10 questionnaires. The surface finish is controlled according to 13 questionnaires. The Impact resistance is controlled by 7 producers. The stiffness and /or strength of the products are controlled by 4 producers. The pull-out strength of fixings is controlled by 5 producers. The porosity and/or water tightness is controlled by 9 producers. The condition of the production equipment is controlled according to 8 questionnaires. "Good housekeeping" of the production area is kept according to 9 questionnaires. The frequency with which controls are undertaken, varies between dally and monthly, depending on type of control (8 questionnaires). The proportion of tested samples depends also on the type of test. Non destructive tests may include 100%of products and the destructive test includes normally 1 %or less of the production (data from 10 questionnaires).

3.3 Comments

The matrix

The matrix is formed by the binder and the aggregate. The binder, cement, consists mainly of lime, silica, alumina and iron oxide. During hydration heat develops during the acceleration stage, which lasts about 24 hours.

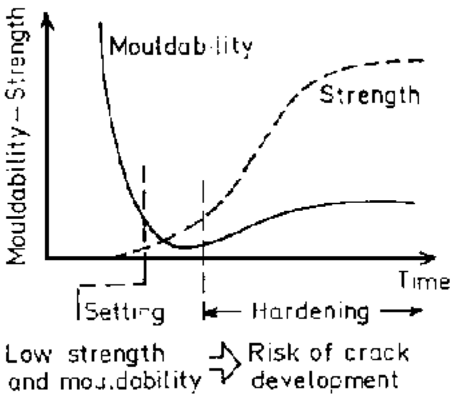
During the retardation stage, which lasts about 28 days, the hydration sequence is retarded. About 1/3 of the hydration products consist of calcium hydroxide which does not take part in forming the cement gel, the binder.

Normally about three-quarters of the volume of the matrix is occupied by aggregate. The properties of the matrix are of course influenced by the properties of the aggregate. The properties depend on the petrology, mineralogy, particle shape and texture, mechanical properties, specific gravity and porosity. The aggregate may contain deleterious

substances like organic impurities, clay and other fine material, salt, and unsound particles.

The aggregate shall be graded so that the matrix gets maximum density. The voids between the coarse aggregate shall be filled with smaller particles. The grading shall also result In a good workability of the fresh mix.

The properties of the hardened concrete are affected by the properties of the mix in the fresh stage. The fresh mix shall be workable, be possible to compact, surround the reinforcement and fill out the mould without segregation of the constituents and have as little bleeding as possible. The fresh mix gradually converts to the hardened stage, the workability decreases and the strength of the matrix is built up. Cracks can develop very easily during this phase (see the figure). The cracks can be initiated by outer or inner forces. One example of an inner force is plastic shrinkage caused by rapid evaporation.



Relation between mouldability and age and relation between strength and age.

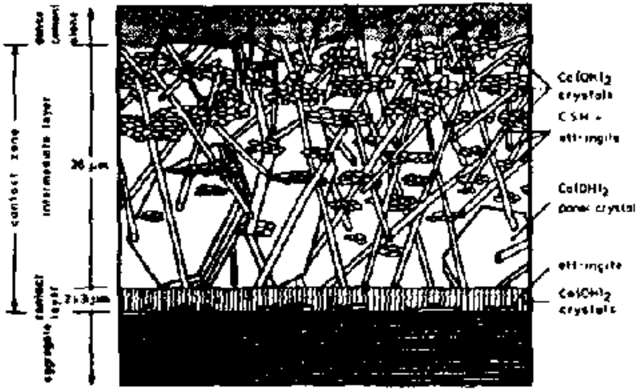
The setting depends on the evaporation and the hydration of cement. Factors as cement content, water content, the temperature of the mix and the temperature and relative humidity of the ambient air, admixtures and porosity of the aggregate are all affecting the setting.

For a 1: 3 mortar with a water/coment ratio of 0.5, the shriakage Is 0.4 % if the temperature is 520 ° C and the relative humidity 50 percent and the wind velocity 1.0 m/s.

During this setting time, the modulus of elasticity increases with increasing strength.

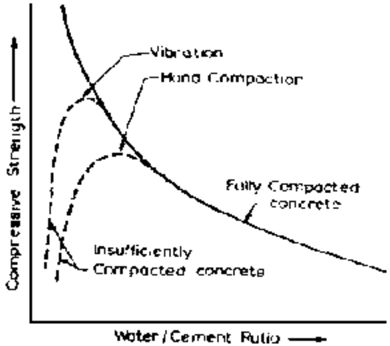
During curia´', keeping the concrete saturated or as nearly saturated as possible during the setting time, is very essential for the properties of the hardened product.

The cement paste is not homogeneous. It contains pores of different sizes and weak zones can develop for instance in the phase boundaries between cement paste and aggregate particles or reinforcement material, inter alia, due to water segregation in the fresh concrete state.



Structure of the phase boundary between cement paste and an aggregate.

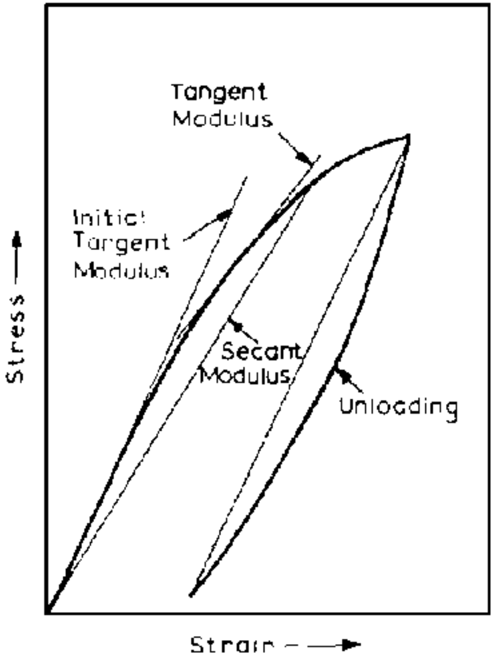
When concrete is fully compacted, its strength is taken to be inversely proportional to the water/cement ratio.



The relation between strength and water/cement ratio.

The tensile strength of concrete is low, less than 10 % of the compressive strength. The type of aggregate and the moisture content have influence on the tensile strength. The tensile strength of concrete is about 2 MPa. The flexural strength of concrete is affected by the dimension of the tested specimen, the surface of the aggregate maximum aggregate size, temperature and moisture gradients. The flexural strength of concrete is about 5 MPa.

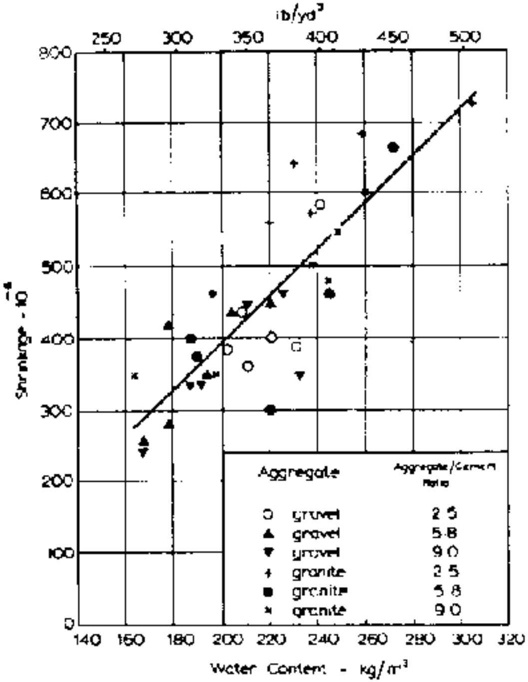
The impact strength is related to the tensile strength of concrete and the brittle behaviour of the material. The impact strength can be increased by lower water/cement ratio, high volume of aggregate, small maximum aggregate size and crushed aggregates. The impact strength of concrete is about 2 kJ/m^2.



Typical stress-strain curve for concrete.

A characteristic value of the modulus of elasticity for concrete is 30 GPa. The strain at failure is 0,01 - 0,02 %.

The drying shrinkage is caused by withdrawal of water. The main factor affecting shrinkage Is the amount of water available for evaporation from the concrete, i.e. how much water has been added to the mix.



Relation between the water content of fresh concrete and drying shrinkage.

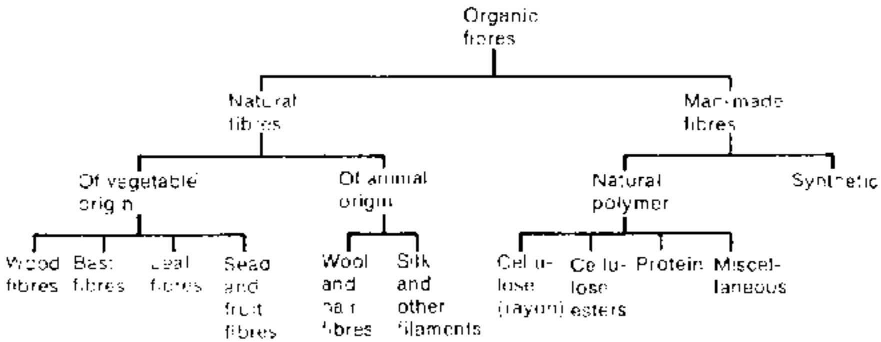
The dimension of the concrete structure, the relative humidity of the ambient air, and the time affect the shrinkage.

Concrete also undergoes shrinkage due to carbonation and this shrinkage is in the same order of magnitude as the drying shrinkage.

The thermal coefficient of expansion of concrete is in the magnitude of 13 x 10(-6)/°C.

The fibre

Fibres can be classified as shown below.



Fibre classification chart.

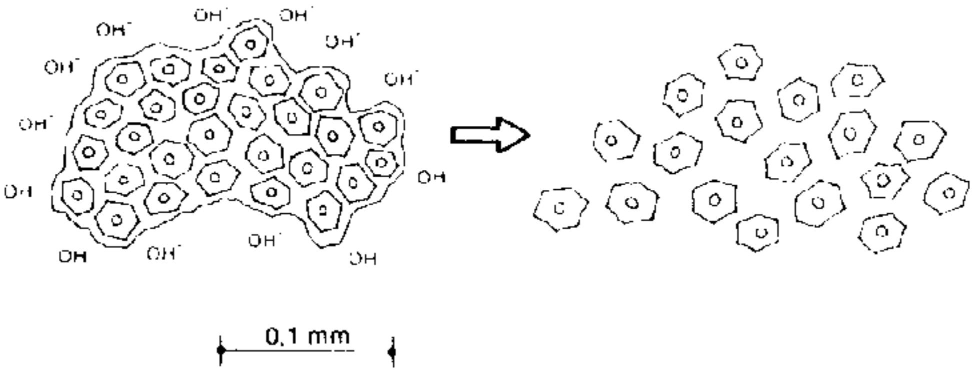
Fibre type	Length mm	Diameter mm	Density kg/m³	Youngs Modulus GPa	Tensile Strength MPa	Elongation at break %	Water absorption %
Kenaf	30-750	0.04-0.09	NA	22	295	NA	NA
Coir	50-350	0.1-0.4	1440	0.9	200	29	130-180
Sisal	1000-1300	0.2-0.3	1450	26	570	3	60-70
Bagasse	NA	0.2-0.4	1250	17	290	NA	70-75
Bamboo	NA	0.1-0.4	1500	27	575	3	40-45
Jute	1800-3000	0.1-0.2	1500	32	350	1.7	NA
Flax	500	NA	1540	100	1000	2.0	NA
Elephant Grass	NA	NA	NA	5	178	3.6	NA
Water-reed	NA	NA	NA	5	70	1.2	NA
Plantain	NA	NA	NA	1.4	92	5.9	NA
Musamba	NA	NA	NA	0.9	83	9.7	NA
Piassava	NA	NA	NA	6	143	6.0	110
Polypropylene	NA	NA	910	6.8	586	210	2
Glass	NA	NA	2700	76	1240	3.5	4
Steel	5-200	0.1-0.4	7860	207	700-2100	3.5	NA
Asbestos	<15	<0.2	2550	159	210 2000	2.5	7-18
Concrete	NA	NA	2300	32	5	0.02	NA

Table 4. Properties of some fibres.

There are three main factors which can cause partial or complete deterioration of the natural fibre. They include:

- **long exposure to moisture**
- **stress corrosion and**
- **exposure to aggressive environment.**

The concrete is aggressive. Its alkalinity is high.



Schematic sketch of the decomposition of sisal fibres In concrete. The middle lamella Is dissolved by the alkaline pore water In the concrete.

In carbonated concrete, the alkalinity is low and therefore the fibre is not decomposed. Fibres are added to concrete In length up to 25 mm (in some cases even 75 mm) in the mix or as long fibres between layers of matrix.

The composite

The properties of fresh fibre concrete are dependent on the properties of the matrix, the type of fibre added, the fibre length and the fibre volume. The workability of the mix is changed, compared to the workability of matrix without fibres. Extra water is needed to maintain constant workability. If the volume of added fibres is high, balling of the fibres may occur. The fibre length and thickness do also influence the balling. The thinner the fibre, the shorter must it be to avoid balling.

The addition of fibres enhances the cohesion of the fresh concrete and makes It possible to mould a product In a simple manner. Depending on the properties of the matrix and of

the fibre, the suitable fibre volume and fibre length can be found In pretests. If, for instance, the intended product is a corrugated roofing sheet, it should be established that the thickness does not change during the setting time. Concrete Is extra weak during the first few hours, before the hardening process has given the material a certain strength. Water evaporation can cause cracking, due to plastic shrinkage. It is the same process which occurs when mud dries. It has been known for thousands of years, that this cracking can be limited or completely avoided by reinforcing the material, for instance sun-dried bricks with straw. The incorporation of fibres in concrete can have a similar effect. But it is important to point out that concrete can be protected against plastic shrinkage by stopping the water evaporation by an effective cover or by water spraying on the surface of the concrete.

Constituents in the fibre material or on the fibre surface can cause retardation of the cement hydration, and even affect the resulting strength of the fibre concrete. The harmful substances can be removed by properly cleaning the fibres, but in most cases it appears that the normal fibre processing will give satisfactorily clean material. The main advantage of fibre reinforcement of concrete is the improvement of the fracture toughness, the impact, flexural and tensile strength.

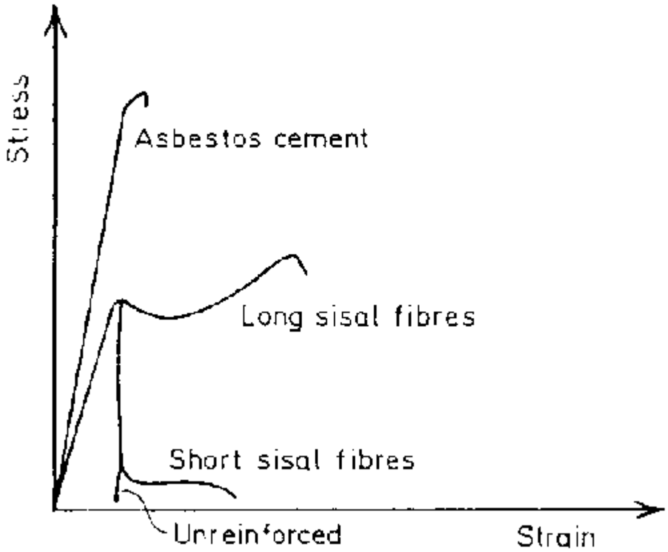


Diagram of composite

The composite Is elastic until the first crack has developed. This point, the limit of proportionality, is not influenced by the fibres or only very limited. The occurrence of the first crack is therefore mainly determined by the properties of the matrix. If we use chopped fibres, the flexural strength or modulus of rupture of the composite will be the same as the value obtained at the limit of proportionality, i.e. the flexural strength of the unreinforced concrete.

As can be seen in the figure, the modulus of rupture and the flexural strength of the composite reinforced with long fibres can exceed the limit of proportionality or flexural strength of the matrix. But this means that the composite is cracked and the design load

should therefore not exceed the limit of proportionality. The fracture toughness and impact strength of the composite is considerably higher than in the case of short fibres, compare the area under the stress- strain curves.

The compressive strength of the composite Is not at all affected by the addition of natural fibres. If fibres which are not clean are used, the compressive strength can decrease. The incorporation of fibres may require extra addition of water which results in a higher water/cement ratio and therefore a lower compressive strength.

The water tightness of the composite Is not affected by the incorporation of fibres.

But as is the case with the compressive strength, the water tightness can be Influenced in a negative way If the water/ cement ratio Is Increased to achieve a good workability of the fresh mortar mix.

Drying shrinkage of the hardened composite Is only linked to the water content of the fresh matrix.

The fibres can give a better crack distribution, smaller crack widths, but larger number of cracks. Again, it should be pointed out that the incorporation of short fibres may require more water in the mix to obtain good workability which will increase the shrinkage.

Properties like thermal conductivity, sound transmission, fire resistance, water absorption, linear expansion. moisture movements and temperature movements are not influenced by the incorporation of a few percent by volume of natural fibres.

The natural fibres are protected against microbiological decay in the matrix because of the high alkalinity of the pore water. Constituents of the pore water, for instance calcium hydroxide, penetrate the fibre and “mineralize” it. it is not known what happens to a fibre in a crack, possibly there is a crack width limit within which the fibre is protected against

microbiological decay.

The high alkalinity of the pore water results In a chemical attack on the fibre and causes a reduction or even nullisation of Its strength. Fibres In carbonated concrete, where the alkalinity of the pore water is low, are not decomposed chemically and seem to be protected against microbiological decay.

The carbonation of the matrix is linked with a shrinkage. This shrinkage is of the same size as the drying shrinkage. The carbonation process is slow and this allows the creep of the matrix to play a role. The carbonation shrinkage causes micro - cracking and cracks can sometimes be seen on the surface of the carbonated concrete. The natural fibre does not play any or only a very limited role in this crack formation. With time the carbonation front moves Inwards Into the concrete and if we have a thin concrete product, it can be completely carbonated within a few years. The microcracking can have a negative Influence on the flexural and tensile strength of the composite. The addition of fibres in the fresh mortar may require more water In the mix to obtain good workability and this leads to a higher water/cement ratio, a faster carbonation process and a bigger carbonation shrinkage. Research in this field to clear the effects of the carbonation on the properties of thin natural fibre concrete products is recommended.

The tile

Concrete tiles have been used on buildings for at least 80 years and the experience with them has been good. The concrete tile is not reinforced. Nowadays, they are normally manufactured of a very dry sand- cement mix with very low water / cement ratios. The thickness varies between 10 and 20 mm. Extrusion is used in the production process.

In 1983 Parry introduced a S-shaped pantile with the dimensions 500 x 250 x 6 mm. The tile is light and easy to handle. The production process Includes the use of a vibro-screeding machine which secures a good compaction of the product. Short fibres are

included in the fresh mortar mix to give higher cohesion.

The long term behaviour of this thin product is not yet known. Two out of four producers of this tile report no cracking. In Sri Lanka and Brazil thicker tiles, 10 - 30 mm, are produced. The concrete tile seems to be an Interesting rooting element. Further development concerning the shape of the tile and the need of fibres in the tile is recommended.

The sheet

Natural fibre concrete cannot directly substitute for asbestos cement. The flexural strength of natural fibre concrete is only 25 per cent of that of asbestos cement. Many sheets have been produced with dimensions common for asbestos cement products. Several instances of cracking have been reported and the dimension of sheets have changed to smaller sizes and thicker products. Still the cracking seems to cause problems and the need for repair or replacement of roofing streets already placed on a roof. The roofing sheet must be regarded as an unreinforced element.

The use of short or long fibres seems not to have any different Influence on the long term behaviour. In Tanzania production of 70 000 m2 roofing sheets per year will be initiated in 1986, using a concept with long fibres and a manufacturers guarantee of durability. Further development concerning the roofing sheet, suitable dimensions and properties, is recommended.

The load on roofing structures

A roofing element is subjected to many different types of loads. During production and curing we have the plastic shrinkage phenomena due to water evaporation. Later, the drying shrinkage of maybe 0.5 % may cause internal stresses and cracking. During handling, demoulding and transport cracking can occur. Storing and transporting In the

wrong way, for instance piled on each other, may also result in too high stresses and cracking. During installation on the roof, the element also has to take static and dynamic loads. On the roof, stresses may be concentrated at different points or lines on the roofing elements.

Deformations in the timber support may also cause stress concentrations in the element. For Instance, a temperature cycle from maybe + 10° C in the night and + 70° C on the day results in a movement of 0.7 mm per meter. The moisture movements caused by rain and sun also initiate movements in the elements which have to be taken into consideration. These movements may cause too high stresses and therefore cracks. The moisture movement of the natural fibres is bigger than that of the matrix, which may result in internal stresses, especially if the volume of fibres is high and the fibres are utilized as reinforcement (long fibres). If the fibres are decomposed due to chemical attack, also new stress situations may occur. Finally, the carbonation process in the matrix also leads to a shrinkage and micro crack development.

The quality control

The control should comprise a check on the cement (no lumps), on the fibres (clean so that they do not contain "sugar"), that an account on the addition of constituents to the mix is made that the compaction is well done, that product shape, thickness and surface finish are acceptable, that the curing Is started immediately after casting in a proper manner and continued for one week, that possibly 10 percent of the products are tested in a non-destructive load bearing test and maybe 1 percent of the products are tested to failure. The fixings should always be checked. If the water/cement ratio is below 0.6, there is no need for a control of water tightness.

For further research

The following items should be the subject of further research:

- What is the optimal shape of a roofing element made of concrete considering the non existence of a reinforcement? The stresses which occur must be identified and taken care of.

- Might the tile be produced without fibres? What consequences would this have on the shape of the tile?

- Is it possible to use locally available pozzolanas as a partial substitute of cement?

- Can the curing procedure be improved in an appropriate way?

- Is it possible to use natural fibre as a reinforcement in the long term and to produce self supporting roof structures?

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4. Manufacturing technology

In chapter 4 Kurt Rhyner is treating the aspects

- Equipment
- Working procedure
- Sheets
- Tiles
- Worksite
- Quality control

4.1 Conclusions

- The production of FCR is a sound technique and much practical experience is available.

- Failures are identified and are usually due to production errors.

-Tilemaking can tee started in most places with fair chance of success, if professional training is provided and if the appropriate method is chosen.

- Also the production of sheets is possible but much attention has to be given to the roof structure.

- A lot of experimentation has been done and documented and future experiments should take into account the history and state-of-the-art and not simply be in the spirit of "Appropriate Technology Enthusiasm".

4.2 Evaluation of experiences

The 13 questionnaires reporting on sheetmaking, refer not 10 one single method, but rather a variety of slightly different processes. However, with the exception of one respondent who produces fibre-cement sheets without sand (not fibre-concrete) all the

others can be treated similarly, as they are variations of one process.

The 4 reports on tiles work according to the specifications of the manufacturer of the equipment.

Equipment

Simple masonry tools- shovels, sieves, trowels - are the basic equipment needed. In addition, some kind of work platform, frame, plastic sheets and moulds are needed.

Most sheetmakers report using manual tables, though three use vibrating tables. The design of the table does not determine the quality of the product, with the possible exception of a vibrating table which would be an important improvement if it works according to specifications.

Working procedures

Again in sheetmaking several slightly different modes working are reported, but it may be said that it is not the fact how the components were mixed, but rather that they were well mixed which determines the quality of the product.

It is in the field of quality control where the answers are very different from one questionnaire to another and it is obvious that here much has to be improved.

Only two questionnaires report on daily quality control, in one case they do it weekly and in one biweekly. The other reports are spacing the controls wider apart or do not do them regularly. Coconut con and sisal are the most widely used fibres, jute or Indigenous grasses being used In three Instances.

4.3 Comments

In the past most people have believed that the making of FCR-sheets was something simple and easy to learn. Furthermore, it was believed that it depended upon the right kind of apparatus or table used. In fact, there exists a large number of publications which describe the production of FCR sheets and there are as many technical differences as there are producers.

Most technicians confronted with FCR first think of making the sheets bigger; it seems to be an automatic reaction. At the same time, one tries to make them of better quality by seeking to improve raw materials, mix-proportions, and even the form of the sheets. Most manufacturers though eventually come to the conclusion that the elements should be smaller end that the decisive factor in production is the quality of workmanship.

Raw materials

The availability of the materials has to be assured, but this seldom presents problems. Portland cement according to international specifications seems to be available in most countries, and complaints usually centre on the age and possible poor storage of the cement (moisture) rather than of its ex-works quality.

Sand is available in most places: it must be clean, but its granulometry does not seem to influence the quality of the streets es much as one first assumes. Tests in the Dominican Republic have shown that the difference of workmanship from one workman to another have a greater Influence on test results than the difference between sands of varied granulometry. However some more recent tests seem to alter this finding slighty.

Whether sisal or coconut con Is used does not seem to cause much difference, once the basic cleanliness and the good cutting of the fibre Is guaranteed. Other fibres like Jute are somewhat more difficult to work with and fit Is not recommended to use grasses without proper testing.

Batching and mixing of the components can be done by hand and with simple batch-box methods though preferably by weight. The fibre should be measured by weight.

There is much controversy about whether the fibre should be added to the dry or wet mixture, but it can be said that In both cases It works just about the same.

Sheets

For sheet production generally a sand-cement ratio of 1:1 by volume is used . Small deviations
(25%)did not alter test results in the Dominican Republic to a significant degree. Much of the discussions center upon the type of table which is used to hold the mould and serve as the working surface for the making of the sheet. However, it can be said that it Is not decisive what kind of table one uses since one of the more efficient workteams known prefers to fabricate their sheets on the floor.

The more complicated and perfect the table is, the easier for the workteam, but the slower the work.

The crucial moment In the sheet fabrication Is when the wet mixture Is placed on the mould. If the mixture does not have the proper degree of stiffness, this will make the Job more difficult and result In inferior quality.

The workteam has to act simultaneously and any minor error will show up. The bigger the sheet is, the more difficult is this procedure, and the better the two or three workers have to be coordinated.

A good part of the quality Is determined by the curing procedure. The task is to keep the newly manufactured sheets humid as long as possible and not to disturb them for at least 24 hours. In some places they are left for 72 hours between plastic on the moulds;

however, if they can be immersed In a wafer basin they can tee carefully demoulded after 24 hours. They should stay immersed In water between 3 and 15 days, the final quality depends to a large extent on this water curing.

Where no water tank is available, the dally molsterning of the product and covering with plastic does help somewhat, but the immersion in water is better. Even if the sheets are produced perfectly, there is no guarantee that they will do well on the roof, as the roof structure and the installation of the sheets still can be imperfect. Most cracks appear within the first days after installation or after a significant change of the support structure (warping of the wood, bending) and usually cracks are lengthwise. The cracking is due to either uneven supporting structure, to incorrect fixing of the sheets to the rafters or to inner stresses, which are much greater in sheets than in tiles.

Another very Important point Is the handling of the product, where much of the later failure on the roof Is being Induced by putting too much stress on the sheets, either by rough handling or by stacking them Incorrectly.

Tiles

Tiles can be manufactured safely with a much poorer mixture, and therefore economize on cement. The strain upon each tile placed on the roof is several times smaller than upon a sheet.

For tilemaking there exists a manual that instructs in the procedures, and if this is applied, using the standard tile-kit, production Is of a general uniformity. The preparation of the materials and the mixing is much the same as for sheets (only with a lower cement proportion), but mainly in the complicated moment of forming the tile presents clear advantages compared to the sheet. The unit can be worked by just one person and therefore no co-ordination of movements between workers is needed.

Compaction of the mix Is much better shanks to the vibrating table,which guarantees better formations of the matrix. Also the handling involved Is much easier than with the sheets, mainly at the demoulding stage when the fragile elements have to be stacked in water to cure.

Curing has the same Importance as in the production of sheets and should be done whenever possible through immersion in water for several, whenever possible 10 to 14 days. The tiles are less susceptible to cracking than the sheets.

Worksite

The worksite can be almost anywhere, as long as there is access for raw material delivery and some shade, but It is recommended to have some roofed area for all-wheather production and a closed room for storage of cement, fibre and tools.

Quality control

This is the one area where the production process varies greatly from one site to another depending on the interest management takes in it. If we list the main failures within the production process, which determine the later appearance of cracks on the finished roof, we see that all of them could be avoided by good management and most of them could still be detected on a quality-check before the element leaves the production area.

The most common production errors are:

- bad or inconsistent raw materials
- Incorrect batching
- deficient equipment
- bad compaction
- variation In the thickness of the product

- uneven elements (Incorrect positioning on moulds)
- Insufficient curing
- rough handling

If strict quality control is applied, one can not only detect deficient products, but also motivate the workteam to take more care and to improve their performance not only in quantity but also in quality. Several projects deduct wages for deficient products.

A visual check has to be done with every single element, some more thorough procedures have to be applied to a certain proportion of the output. A very successful commercial producer in Nicaragua (workshop of the Regional Government in Granada)tests a certain percentage of the sheets dally for the following aspects (random samples):

- load bearing capacity
- water Impermeability
- Impact resistance
- detail of exact overlap/underlap

If all sheets perform well, production goes on, if any one of them is deficient, the error is looked for and the guilty worker is punished financially by a discount system. One of the mayor tasks for the near future will be to establish reasonable common standards of quality for both streets end tiles, but meanwhile we strongly recommend all producers (and buyers) to establish a routine quality-check for FC products.

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FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)
5. Installation

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5. Installation

In chapter 5 Heinz Wehrli is treating the aspects

- Roof structure
- Protection against insects and decay
- Structural demands, wind loads
- Overlaps
- Fixing the elements
- Ridge tiles
- Who is installing the elements
- Repair
- Maintenance

5.1 Conclusions

General remarks

- It ist not possible to consider the FC technology in isolation of the roof structure.

- Most damages to FC products on roofs can be tracked down to faults in the roof structure and in the way the products were placed and fixed.

- The smaller the element, the more easily it adapts to the structure.

- The tile presents several advantages over the sheet, but usually needs imported equipment and electricity. On the other hand there is still room for improvement of the sheet technology.

Roof structure

- The design should be simple, e.g. gable roof with rafters and purling, or prefabricated trusses and purling. Minimum pitch of 20°, but up to 30° is required in areas where torrential driving rain occurs. Imposed loads, especially wind suction, may produce higher forces than self weight.

- Good quality timber is desirable but wood is getting scarce and expensive.

- FC tiles need approximately the same quantity of timber as FC sheets.

- Craftsmanship: Carpenters who traditionally build roofs for C.I. sheets will need special training to achieve a more demanding qualify execution. Purlins and tile laths must be straigt and parallel. FCR elements, particularly sheets, cannot adapt to inaccuracies of supports without risk of cracking.

Installation of roof cover

- Prior to installation on roof, check FC elements for good quality, exact size, properly fitting overlaps, correctly formed mitres, etc. The laying of sheets should preferably be done by a team of carpenters and sheetmakers. Edges and overlaps should be well aligned. The installation of the ridge tiles requires careful attention too.

- Sheets should be handled with great care.

- Fixing: the driving of nails through elements should be discouraged. If screws or J-hook bolts are used they must not be overtightened. Cast-in wire loops which allow fixing from underneath prove to be the best solution so far. Sheets should rest on both purlin and bottom sheet at each corrugation.

General rule:	TREAT FC PRODUCTS LIKE CLAY TILES! NEVER GO ONTO A ROOF WITHOUT CRAWLING BOARDS!

5.2 Evaluation of experiences

14 questionnaires were scrutinized with regard to roof structure and installation of FC elements.

Roof structure

Most respondents build gable roots, usually with trusses and purlins. A few prefer rafters to trusses. No material other than timber is used. There is little information available on truss assembly. Two participants mention bolts, otherwise nails are used.

The span of the trusses, or width of building varies from 5 to 10 m, the distance between rafters, or trusses, from 0.8 m to 2.5 m; minimum required roof pitches mentioned are between 14° and 26°.

Protection against insects and decay

Only halt of the participants think that some sort of protection Is necessary. Usually, waste engine oil is applied.

Structural demands towards the roof

There is little awareness of the necessity to build a strong roof. Three of the questionnaires mention wind speed of 120-200 km/in. One participant thinks that the roof has to support only the self weight of FCR tiles; another one mentions earthquakes in his area. One mentions, that the roof should be able to support the weight of people installing or repairing the roofing elements.

FCR: sheets or tiles?

Ten participants make sheets, four make tiles. If given a choice, six would continue with sheets, but eight would prefer tiles.

How do the elements overlap?

Only five participants give a clear answer. For sheets the normal end overlaps are 6", and side overlaps probably according to the available asbestos moulds. For tiles the overlaps are as per standard I.T.W. specifications.

Method of fixing the elements

For sheets, two participants install J-hooks, two others fix them with nails, another one uses screws. Fixing through cast-in wire loops is used for both sheets and tiles.

Ridge tiles

Except three participants who install either galvanized iron sheet ridges, concrete ridges or clay tiles, all the others manufacture their own V-shaped FCR ridge tiles.

By whom are the elements Installed on the roof?

Eight participants say that the elements are installed by an experienced work group, in five instances this group being identical with the producers' team. Five others go along with "do-it-yourself" methods. As for guidance, practical on-the-pb training as well as written guidelines are applied.

Repairs

Ten participants claim that it is fairly easy to carry out repairs. Four participants, working with sheets, maintain that repairing is difficult. Commonly used repair methods are:

- very fine cracks are sealed with paint or cement slurry

- on small cracks, first paint with PVC glue (white carpenter's glue), then apply a strip of FC mortar, approx. 1/4" thick
- if cracks are large the element has to be replaced.

Maintenance

Five participants claim that no maintenance is needed. The others mention checking of the wooden structure, e.g. sagging or badly warped purling. The fixings need to be checked, and cracks may need repairs. The roof cover should be kept clear of leaves, accumulated dirt, etc.

5.3 Comments

Roof structure

This chapter deals only with timber roofs. Steel structures, for a number of reasons, would not be regarded as appropriate technology (import of material, mechanical workshop facilities, special rust protection paint, higher cost).

Roof design

The design should be simple and limit itself to lean-to roofs i.e. single pitch, and gable roofs i.e. double pitch.

Lean-to roof (fig. 1)

It comprises mainly rafters and purling. The span of the rafters i.e. the width of the building should normally not exceed 3,5 m. The advantages are: no trusses required, no ridge, simple construction. But on the other hand it might be difficult to get adequate timber sizes.

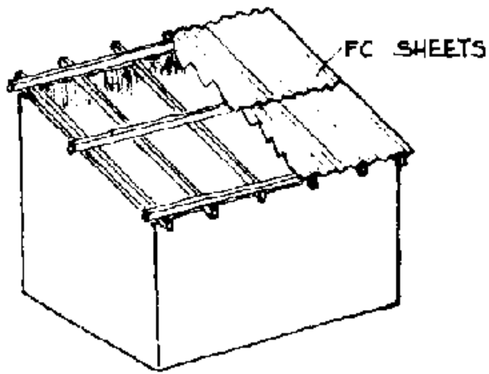


Fig. 1 Lean - to roof

Gable roof (fig. 2)

The traditional design consists of rafters and purling, the rafters resting either on a ridge purlin or spine wall, and on a wall plate. This system is suitable for buildings of approx. up to 6,0 m width. For wider buildings, triangular trusses provide an economical solution. (fig. 3)

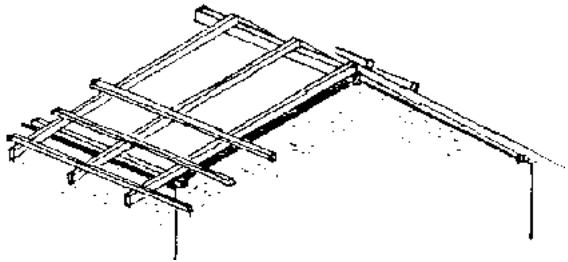


Fig. 2 Gable roof

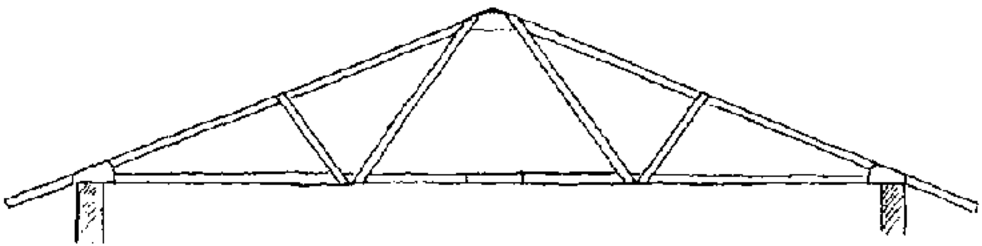


Fig. 3 Example of roof truss

Properly designed trusses are able to span very wide buildings. But for usual FCR purposes the practical limit would be around 10 m. The truss presents several advantages compared to the simple rafter, such as smaller timber sizes, a more stable roof structure and absence of horizontal loads on top of walls. But their manufacture require more professional skills. The distance between trusses or rafters will depend on the imposed

loads, the purlin size and the quality of the available timber.

For usual conditions, using 2" x 3" purilns on edge, a span of about 1.5-1.7 m will be suitable for sheets. If tiles are used, the laths (small "purlins") are of smaller size, and the distance between trusses or rafters is reduced. The roof pitch, or slope, should be approx. 4:10, or 22°, for average climatic conditions, with end overlaps of sheets of at least 6". A steeper pitch of up to 30° or even more Is necessary in regions of torrential driving rain to prevent water from entering between overlaps.

Loads on roof

It is commonly held that the roof structure to support FCR must be heavier than that to support a lighter cladding, e.g. G.C.I. sheet. In fact, It Is the Imposed loads (wind or people), not self weight, which produces the main forces in the roof structure. Very often traditional roofs intended for G.C.I. sheets are built too weak to carry Imposed loads.

Wind load

It is useful to obtain climatic data on maximum wind speed, to refer to local building codes, if any, and to the experience of the inhabitants, e.g. local farmers, carpenters. In many cases the wind pressure is lower than the wind suction, the latter leading to considerable uplift forces, particulary on low-pitched roofs. (fig. 4)

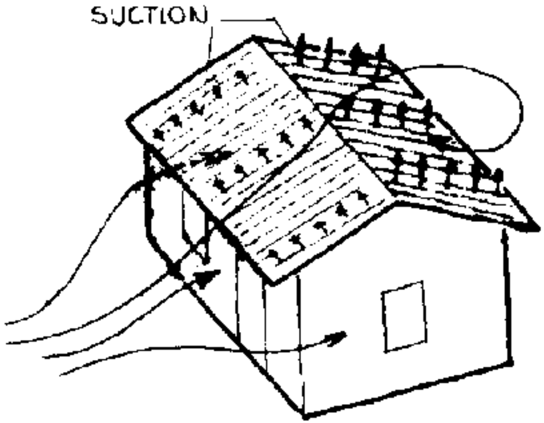


Fig. 4 Wind load

An example of loads that may act on a gable roof, with a 22° pitch, covering a closed one-storey building with windows, and assuming a max. wind speed of 100 mph (160 km/h):

- self weight of timber roof structure: approx. 20 kg/m2

- self weight of FCR: sheets 30 kg/m2; tiles 22 kg/m2

- self weight of ceiling, if any: 10-20 kg/m2

- live load (e.g. workers during construction or repairs): 100 kg on mid - span of purlin 2x50 kg on 1/4th span of tile laths

- snow load depending on altitude (rare in the case of 3rd world countries)

- wind pressure on windward slope: practically nil

- wind suction on lee slope: 60-80 kg/m2

It should be noted, that at roof overhangs, ridges, protruding edges and corners, the suction forces are much higher (fig. 5). These must be resisted by especially firm fixing of the roof structure and coverings in these areas (see fig. 6, 7, 8, 14). Moreover, if a building has large openings. or in the case of an open shed, the wind forces increase further.

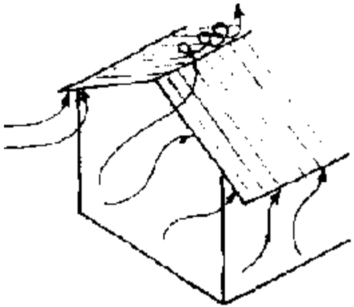


Fig. 5 Areas of more severe suction

Overhangs

A large overhang is good building practice. It increases the life of the walls by preventing the flow of rainwater and it helps to reduce the Inside temperature. For practical purposes, such as timber sizes, overhangs have to be limited to approx. 3 ft. at eaves and 2 ft at verges.

Roof dimensions

The size of sheets, or tiles, determines the lengths along the ridge and along the slope, overlaps being deducted. Whereas there is no limit to the lengt of the roof, its width is limited and for practical purposes each roof slope should not exceed 6-7 m.

Materials

The availability and the properties of the required materials should be taken into account already when designing the roof. Wood. Usually sawn timber is used, but reportedly poles have also been used. Depending on its species, bamboo too may have good structural properties, but connections (joints), accurate dimensions and preservative treatment are more of a problem than with timber. For purlins it will always be preferable to use sawn timber. It is wise to choose a wood species that has a proven record with local builders.

The timber has to be selected carefully. Cheap, low grade timber might not be economical in the long run. Bolts, nails or other devices for assembly (e.g. tin sheet connectors) should match the timber sizes.

Assembly and erection

This work should be done by skilled carpenters. The various parts of the truss are connected solidly. Often bolts are used, but properly designed and executed nailed joints provide better and more rigid connections. Multi-nailed galvanized tin sheet or plywood gussets may also be used. It should be noted that any inaccurancies in the roof structure can be accommodated much less by FC sheets than by FC tiles, asbestos cement or G.C.I. sheets. To ensure uniformity when assembling the trusses, the use of a template may be of help, e.g. wooden pegs driven into the ground, or pencil marks on the floor. For nailed hardwood joints it is necessary to drill pilot holes. A separate plywood template for each type of joint is of great help when positioning the nails.

The trusses must be securely fastened to the building by means of anchors resisting the wind uplift forces mentioned above (fig. 6). In the case of wallplates, they themselves should be fixed well to the wall (fig. 7). Anchors consisting of iron rods that penetrate just into a couple of rows of brickwork would be insufficient. In cyclon-prone areas it is not unusual that complete roofs are lifted and torn from the building.

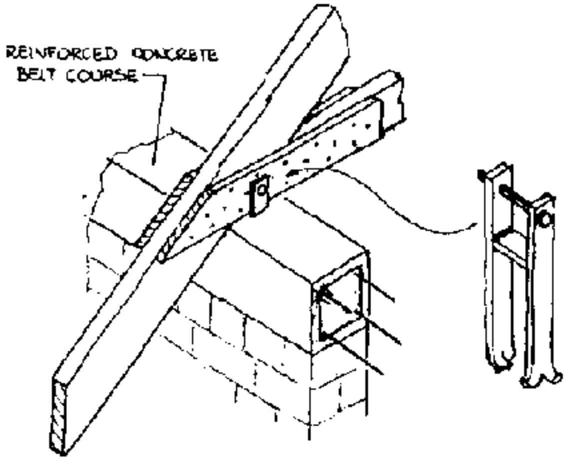


Fig. 6 Example of anchoring a truss

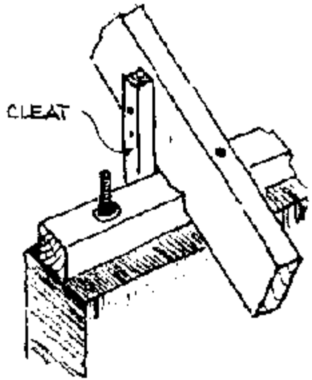


Fig. 7 Fixing of wallplate and rafter

The purlins should be in line and correctly spaced according to sheet or tile lengths minus overlaps. As the timber is usually rough sawn it is helpful to plane the top edges straight, at least in the case of FCR sheets. When fixing the purlins make sure the top edges are parallel, for example by sighting over the purlins from the ground or from the scaffold. Typical purlin spacings for 1 m-sheets: 85 cm, for standard tiles: 40 cm.

The purlins should be well fastened to the rafters. Driving just a nail into the rafter is not sufficient in regions with high wind speeds. Adding tin straps, or wooden cleats about 1 1/2" x 1 1/2" size, nailed to both purlin and rafter are a good solution (fig. 8). They also prevent the purlin from tilting in the case of a greater roof pitch.

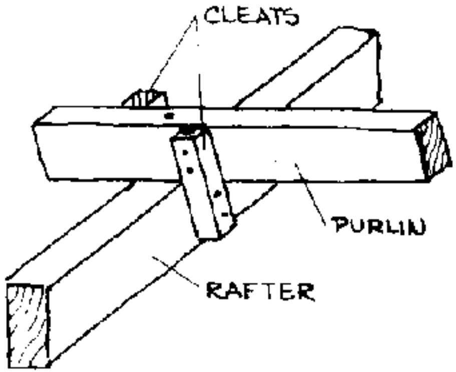


Fig. 8 Fastening of purlin to rafter

Wind bracing should not be omitted. It would be wrong to rely on the FCR sheets or tiles to stiffen the roof structure. The wind braces, approx. 3" x 1 1/2" size, are fastened diagonally onto the purling, adjoining both gable walls. All metal parts should be protected with a good red oxide primer paint.

Protection of timber

- Insects

In tropical regions it is not easy to protect timber against attack by wood boring beetles, white ants, etc. Suitable wood preservation insecticides are often not readily available. <Dieldrln> or <Lindane>- type emulsion concentrates are very persistent and toxic to insects in extremely small quantities. The usual safety precautions when handling poisonous liquids should be taken.

- Decay, fungi

Whereas decay (rot) cannot take place in dry wood, a preservative treatment should be applied to all parts exposed to humidity and weathering, especially roof overhangs. Methods using pressure to ensure deep penetration are the most suitable but access to such installations will normally not be possible. A reasonably good protection can be achieved by two or three applications of <Creosote> on all exposed parts. Used motor oil can also be applied. End grain should be treated with special care. Coal tar too provides a good protection, but it is unsightly. It should be used on all wood surfaces in contact with masonry.

Installation of roof cover

- Preliminary remarks
The installation of FCR sheets is a delicate job and should be done by skilled workers. It is of advantage to have a team composed of sheetmakers and carpenters from the roof construction gang. They will be confronted with the various practical problems and thus be able to effect improvements during future roof building and sheet manufacturing.

- Overlaps, mitres

A precondition for proper installation is to have well made sheets of good quality. Properly fitting side and end overlaps are very important. Note that with thicker sheets the end overlaps will not fit as well as with thinner sheets. Rough <flashings> of cement along edges should be removed by running a wet mosaic stone along all arrises. Since cutting the corners of finished sheets is practically impossible, the mitres are usually "incorporated" during forming. This means that mitres are present also in unwanted positions, such as along eaves, ridges and verges. It is of course possible to make several types of sheets with mitres only at those corners where actually required. But this would lead to complications such as special frames for each type of sheet (costly), risk of errors during production, increased number of spare sheets, etc. Several trials at the manufacturing stage may be necessary in order to achieve correctly shaped mitres, i.e. with a clearance of 1/8" - 3/8". It is easier, and also cheaper, to use wooden screeding frames for these trials.

- Laying of sheets

In order to improve waterproofing some technicians recommend laying the courses by advancing toward the prevailing wind direction. This system makes it necessary to have at least two types of mitred sheets ("left" and "right"). But in many regions the prevailing wind direction may change with the seasons, thus making this complication fruitless.

Coming back to the simple method with just one type of sheet one starts with each row from bottom to top. Each side overlap should be checked for good fit. This is done by sighting from the ground or from the scaffold because the workers who place the sheets are unable to see the overlap without climbing onto the sheets (which should be stronly discouraged).

As a general rule, walking on the roof cover must be avoided. In exceptional cases, i.e. for repairs or cleaning, crawling boards should be laid carefully above the purling. Sliding of

the boards can be prevented by placing jute cloth or similar material between boards and FCR. With sheets made true to size and square it should not be a problem to align the edges of the eaves sheets. For better appearance and fit, the eaves purlin should be approx. 1/2" higher than the other purling.

Once all sheets have been laid on one slope the work continues on the other slope, but in the opposite direction.

At this stage it is necessary to install the ridge tiles (fig. 9), gradually with each row of sheets. This in order to avoid the need of later on climbing onto the roof for ridge tile installation.

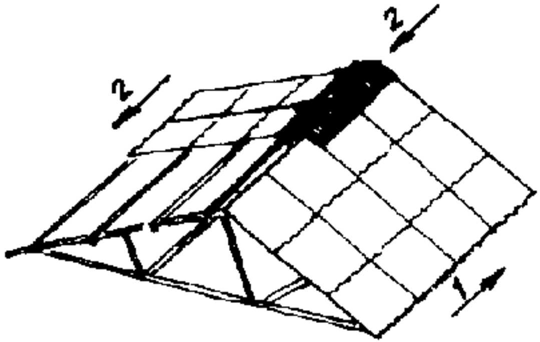


Fig. 9 Laying of ridge tiles

- Laying of ridge tiles

The FC ridge tiles are manufactured at the same time an the sheets or pantiles. The simple V-shape type is a good design. As it has no corrugations it should cover the sheet by about 10", or more, in regions of torrential driving rain.

The ridge tile can be made with an off-set at one end so as to be able to overlap, or by simply butt-jointing with FC mortar. To improve water-tightness the butt joint will be covered with a FC mortar strip. It is necessary to water each gap before applying mortar, and to cover the finished joint with wet rags for curing. A <weir, of cement mortar may be added at the top end of the rolls at the ridge sheet to prevent rain water being driven up into the building.

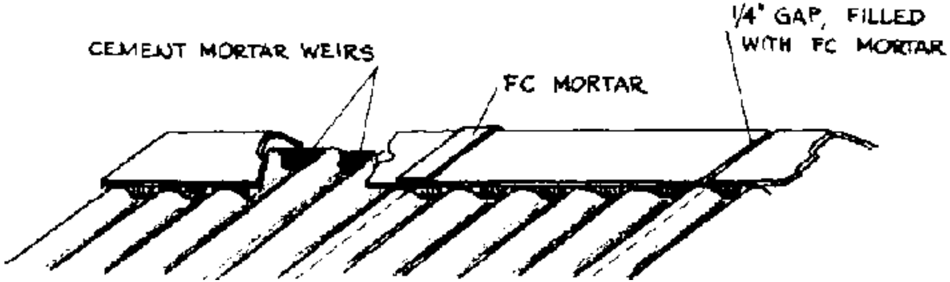


Fig. 10 Grouting together of ridge tiles

Fixing of the elements

The fixing can be done by means of nails, screws, bolts or cast-in wire loops.

- Nailing

In some countries, sheets are apparently nailed to the purlins. This practice Is however not to be recommended.

- Fixing of sheets with screws or bolts

This is best done right after the laying of each row, thus avoiding the need of climbing onto the sheets. Round head screws (preferably galvanized) of sufficient length, i.e. min. 4

1/2", are usually not available. The same applies to carriage bolts. It is preferable to fix the elements on the bottom rather than the top to avoid flapping in high winds. J-hook bolts can be made fairly easily from 6 mm (1/4") dia. M.S. rod. (mild steel bars). Great care should be taken when drilling the holes for screws or bolts:

- Mark hole exactly on top of corrugation, and above purlin center for screws, or purlin edge for bolts.

- Choose a masonry drill bit of a diameter about 2-3 mm larger than the screw or bolt. If a hand drill is used it may be easier to make a pilot hole first with a thinner bit.

- Protect FC sheet from sudden Impact shock of drill by a buffer material, e.g. a piece of 3/4" thick softwood board with a 3/4" dia. hole in its centre.

Water proofing of the hole requires special attention too. The J-hook bolt should sit at a right angle to the sheet, or the head just slightly inclined towards the apex of the roof. Besides a galvanized iron flat or cup washer,a bitumen or plastic or rubber washer should be fitted. Suitable thick rubber washers can be made from truck tire inner tubes. The nut should be tightened gently, using a spanner in preference to an oversize sliding wrench. Overtightening may result in cracks. For normal cases two fixing points per sheet suffice (see fig. 14).

Cast-In fixings:

This system, developed by JPA, presents several advantages:

- No holes in sheet: no waterproofing problems
- Work done from underneath: no temptation to climb onto roof cover
- No extra stresses in sheet because of overtightening
- Lower cost than screws or J-hook bolts

The cast-in fixing, usually a pair of galvanized wires, gauge 18 or 16, shaped into a loop, is well anchored in a small rib during sheet manufacture (fig. 11). One loop in every other corrugation (i.e. 3 loops per sheet) will be sufficient except in hurricane areas.

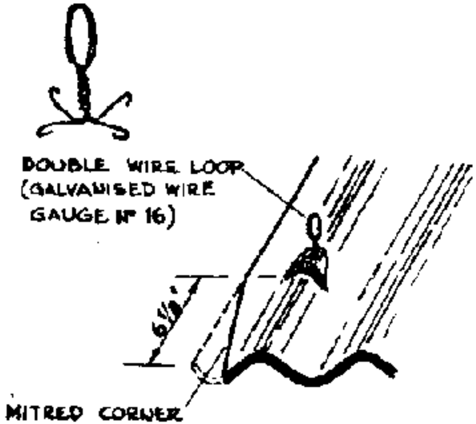


Fig . 11 Cast - in fixing (sheet)

From manufacturing of the sheets through curing, storing, transport and handling stages, the wire loops should be treated with care. They should not be touched until the concrete has set (place wooden <bridges> above freshly moulded sheet before covering it with polythene for curing), and should not be twisted unnecessarily afterwards. Fig. 12 shows a simple V-shaped ridge tile with cast-in ties

Fig. 12 Ridge tile with cast-In wire loops

The loop may be tied to the purlin with a pair of wires, although with this system there is the risk of the wires snapping because of overtwisting, or directly with a screw (fig. 13). The wire loop should be straightened first and care should be taken to avoid damaging It when drilling or punching the pilot hole for the screw.

The tied-down wire loops should not have any play, i.e. each fixing point should be tight, otherwise at high wind speeds the suction forces might cause the sheets to clatter. This could result in cracking of the sheets. As already mentioned before, roof overhangs are subject to severe wind uplift. Moreover, the wireloops along the overhangs are accessible from the outside of the building, thus making it easy for burglars to enter the house by lifting a couple of sheets.

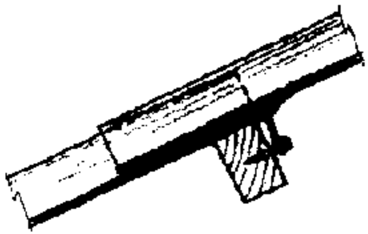


Fig. 13 Fixing of sheets

For the above reasons it is advisable to Install one line of J-hook bolts (fig. 14) all along

eaves and verges. Water- proofing will not be a major problem since occasional leaks will not affect the interior of the building.

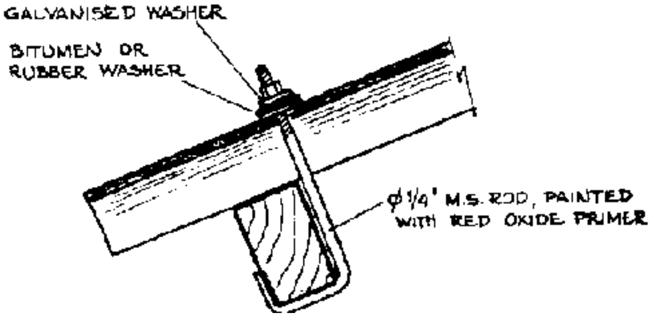


Fig. 14 Installation of J-hook bolt

The ridge tiles too need to be fastened carefully, e.g. as shown in fig. 15

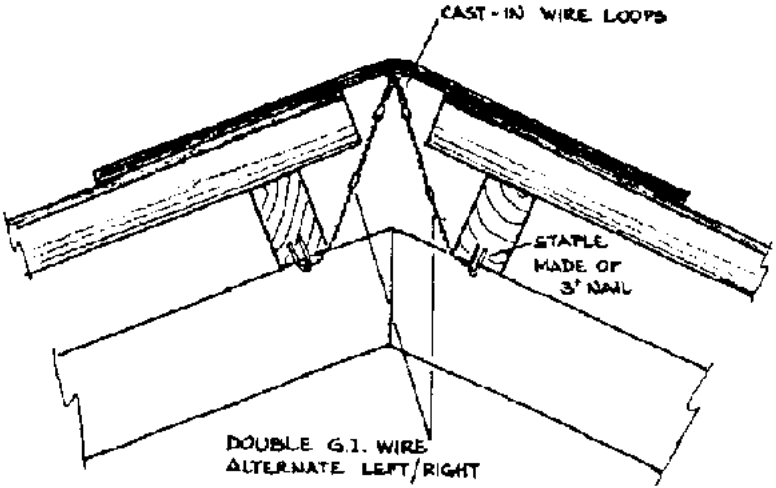


Fig. 15 Fixing of ridge tiles

Damages to FCR products due to faulty Installation and fixing

FCR elements have very litte flexibility and are therefore easily prone to cracking. Therefore, handbooks and practitioners insist on the necessity for each corrugation to touch the purlin. This is quite easily achieved with FC tiles, each one of them having only two supporting points, whereas in the case of FC shoots, the above requirement is usually not met for practical reasons:

- sheets cannot possibly be made with industrial precision

- the top edges of the purlins are never perfectly straight, or they do not remain so due to bending under load and natural movements of wood (warping etc.) There are other

reasons for the sheets not being proferly supported:

- at the end overlap the lower sheet supports the upper sheet: inaccurately moulded corrugations will make it impossible for the two sheets to overlap properly.

- Poorly fitting sided overlaps will either leak (wind blown rain) or make the sheet crack if the overlap roll is forced down on the underlap roll but still leaving a gap between purlin and sheet.

Now, at each point where the lower roll of the sheet does not rest on its support, when pressed down either by self- weigth, wind pressure, fastening points such as J-hook bolts, the sheet tries to bend, and since it is quite rigid, this will lead to cracks.

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw

FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

6. Costs and economics

In chapter 6 Beat Schaffner is treating the aspects

- Cost factors
- Elements of costs
- Comparison with other roofing materials
- Advantages and drawbacks from

FCR-use

Please note:

Costs and economics of FCR products cannot be given as exact figures.
There are many factors which determine coatings and economics. It is not only the cost one has to study before implementing FCR but also its impact on the local building material market and its consequences regarding the raw-material situation.

Costs given here date to 1985; if reference is made to 1 m² of roofing, it means 1 m² of roof-surface (roof-skin).

6.1 Conclusions

Costs

- In most countries, FC-sheets or FC-tiles can be produced at a cost of 2 US $ to 4 US $ per square meter. This includes costs for raw-materials, labour, depreciation and interest for initial investment.

- A square meter of a FC-roof including cost for the roof structure varies between 4 US $ to 8 US $, depending on the local situation.

- Our analysis of field-experiences allows the following statement: Compared with other roofing-methods, a FC-roof including roof structure can be built at 2/3 to 3/4 of the cost of a similar roof covered with Asbestos-Cement- or Galvanised-Corrugated- Iron (GCI)-sheets. - The roof-structure will consume half of the investment, the FC-roofing-material the other half. There is no apparent difference in the costs of the roof structure whether FC-tiles or FC-sheets are used.

Economics

- The economics of FCR products depend largely on the life-span of the tiles or sheets and therefore on the quality of production.

- Both, the manufacturer of FCR products and the roof-builder by their actions fundamentally influence the lifespan of the products whether they be sheets or tiles.

- From the technical point of view the life-span of FCR products can be 10 years or more.

- From the economic point of view the life-span of FCR products should be at least 4 years, in order to justify the investment at all

- Economics of FCR are not only valued in costs but in other benefits to a local economy such as: Use of local resources, low initial investment, job creation for both men and women, less involvement of foreign currency than other roofing materials, low transport costs.

- The import component in a FCR product - if any - is in the cement and the plastic for moulds. It is typicially between 30 % and 50 % of the costs of the FCR product, e.g. 0.6 to 2 US $; comparable roofing materials such as GCI-sheets may have an import value of 3 to 6 US $/m²

6.2 Evaluation of experiences

Costs

The questionnaires which were returned by 17 projects had different paragraphs to evaluate the costs and economics of FCR products.

The answers should give a picture about the following aspects:

- Costs of production (fixed and variable costs)
- Costs of fixings and roof-structure
- Costs of transport
- Importance of costs and economics
- Comparison with other roofing materials

Even though most persons answering the questionnaire gave a high importance to the economic aspects, there seems to be a lack of information and awareness about costs and economics.

Almost everybody could give exact figures of the costs for raw-materials. Once the composite is known and practical experience is made, it is easy to calculate the costs of raw materials. The other cost factors which will incur from the investment such as interest on loans, depreciation (of capital, equipment and training costs) e.g. the fixed costs seem not to be taken into account by most of the project responsibles. This might origin mostly from the way FCR projects are supported.

Labour-costs, the other main cost factor, are also given very rarely. The reason may be the- fact, that FCR Is still In a phase of development and often the work Is done by free labour or self-help-groups. There seem to be very few cases, where FCR production is done on a commercial basis by entrepreneurs and contract labour.

As a general figure, 80 % of the people answering the questionnaire stated costs of production per one square meter of roofing elements at 2 US $ to 4 US $. No indication was given on transport costs.

The costs of fixings and roof-structure could be given by most of the participants. It varies between 2 US $ to 4 US $ per square meter of roof surface. There Is no apparent difference in costs of roof-structure whether FC-tiles or- sheets are used. The timber consumption Is almost the same for both a "truss and purlin" or a "rafter and purlin" structure.

The figures given by the field-workers have verified the statement made by the promoters of FCR technology:

In comparison with similar roofing materials such as GCI-sheets or asbestos-cement sheets, the costs of production for a FC-element can be 50 % to 60 % less.

Economics of FCR as a product ex-works

FCR products are, generally speaking, not a commercial product yet. In very few cases, FCR has entered the building material market as a profitable trade.

Advantages (+) or disadvantages (-) of FCR production is given in catchwords only:

+ Low initial investment
+ No direct import of raw-materials (foreign currency involved only indirectly for cement and plastic if at all)
+ Communities producing their own building materials
+ On site production (no transport)
+ Low energy input for production process
+ Low costs for maintenance of equipment

- **Use of cement which might be scarce anyway**
- **Energy input for cement production**
- **Need of foreign currency to buy equipment**
- **Training courses overseas or expatriate trainers are expensive**

Another problem to determine the economics of FCR is the lack of knowledge about the products life-span and a lack of marketing experience. A comparison with other roofing materials has to consider the different life spans as well as the fact, that prices of other materials known are retail prices which include profits of wholesalers and marketing costs . Estimates of life span of a FCR product vary from 4 to 30 years, depending on experiences of succes or failure so far made by the people answering the questionnaire. Empiric experiences date back to 1978. Reported failures are mostly caused by bad production or bad roof-structure and less by material properties.

Economics of FCR-products including roof-structure

There Is no evidence in the questionnaires, that FCR products require a more expensive roof-structure than other roofing-methods. No special comments are made on the system of roof-structure. It seems, that most projects are using a traditional local roof-structure technology, adapting it to the dimensions determined by their FCR product.

The scarce information given on structural problems of the roof asks for more clarification of how a FCR roof should be built.

6.3 Comments

Abstract of cost factors (How to calculate a FCR project)

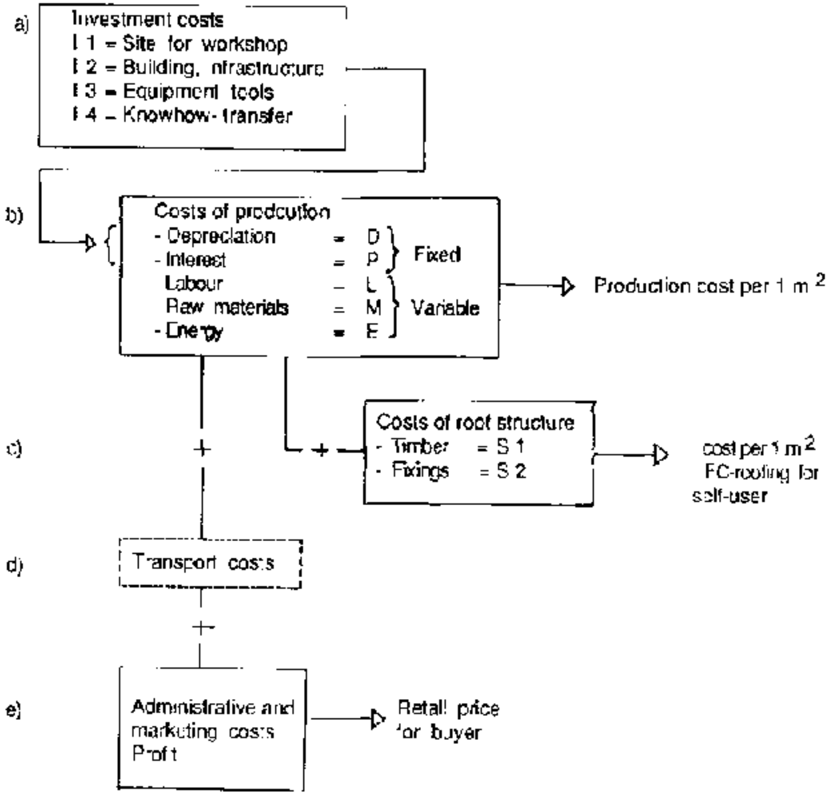


Diagram of calculate a FCR project

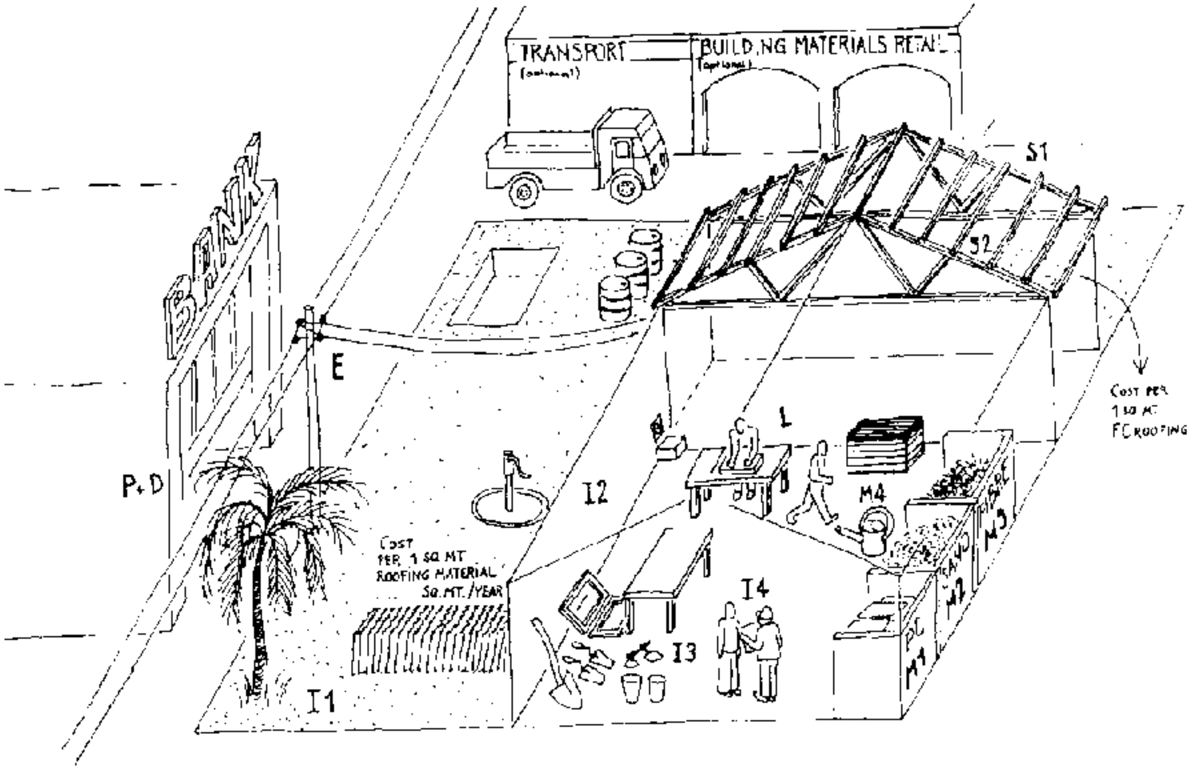
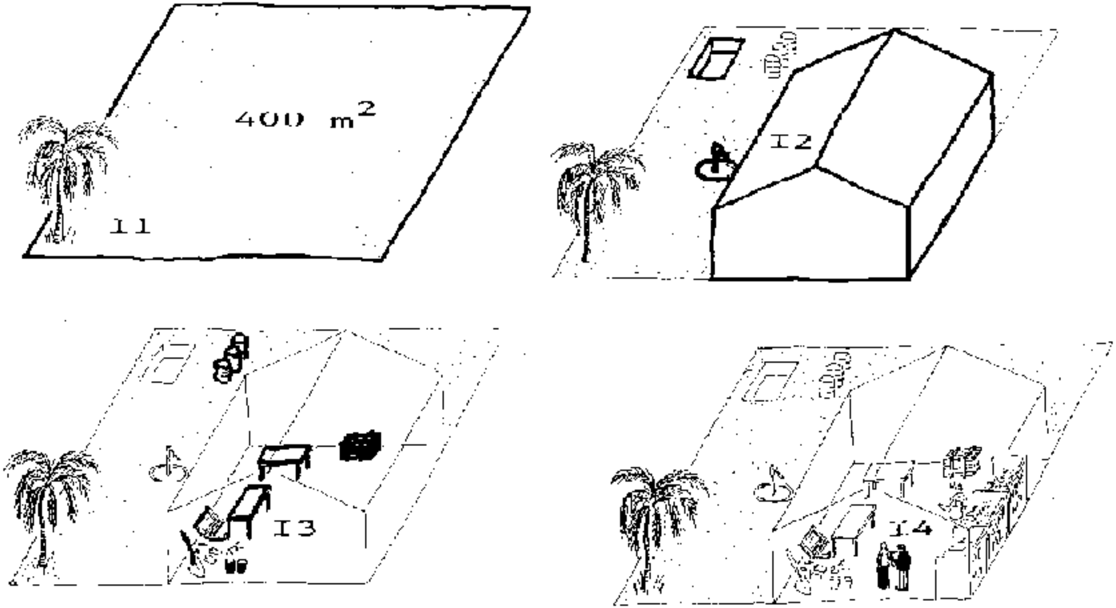


Table 1: Synoptic view of cost factors In a FCR project

Elements of costs



Elements of cost

a) Investment costs

(Estimates: 3’000 - 30’000 US $)

I 1: Site for workshop

These costs will depend on various circumstances, mainly wether it is in a rural or urban area 400 square meters is the minimum requirement for a production plot. (Estimates 0-

5’000 US $)

I 2: Building, Infrastructure

Simple workshop. Water facilities (well, hand pump), curing devices (pool or drums), light, office furniture, typewriter, calculator, drawing equipment, etc. (Estimates 3’000 - 10’000 US $)

I 3: Equipment, tools

Costs vary whether you use

- imported kits
- locally made kits
- self made equipment

(Estimates 200 - 2000 US $)

Additional costs may be necessary for miscellaneous hardware plastic sheeting, shovels, stacking and transport devices, etc.

I 4: Knowhow-Transfer Costs vary wether knowhow-aquisition is done by

- manual
- training at regional center
- training abroad
- trainer from abroad

(Estimates 1 -15’000 US $)

Please note:

Initial investment in setting up a plant may well add up to 3 - 6 months production costs. This requires a substantial amount of working capital.

b) Production costs

The term < production costs > has meaning only when it is related to output. Output in FCR-production will be measured in square meters of roofing elements produced during a certain period. Production costs should be divided up In <fixed costs> and <variable costs>. The diagram below should help to make this clearer. The elements of fixed costs can be given as yearly costs; when divided by yearly production in square meters, the part of fixed costs in one square meter can be calculated. Fixed costs and variable costs added will give the total costs of production per one square meter of FC-roofing material.

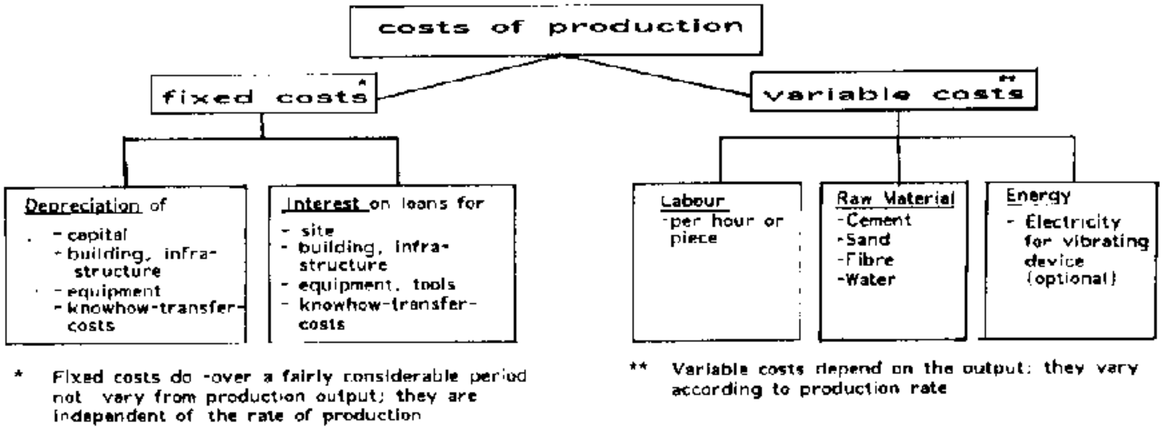
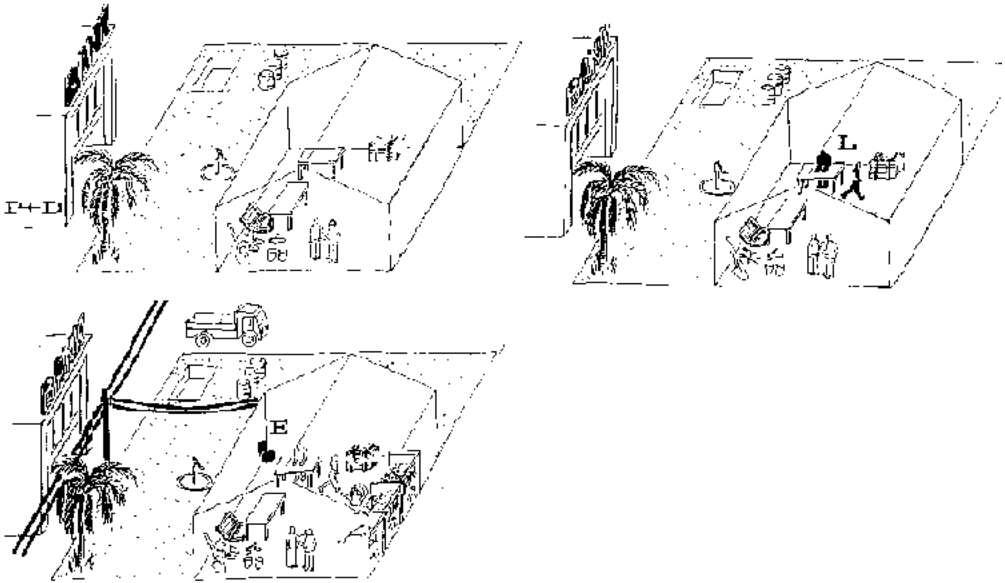


Table 2: Diagram of production costs

Fixed costs are:



P+D, L, and E figure

P: Interest for Investment

Depending on the interest rate and the initial investment, interest costs can add up to some 300 to 3’000 US $ per year.

D: Annual depreciation

Building, infrastructure, equipment, tools and knowhow-transfer costs must be paid back within 5 to 10 years. Depreciation will therefore add some 500 to 5’000 US $ per year, depending on initial investment and life span of facilities.

Variable costs are:

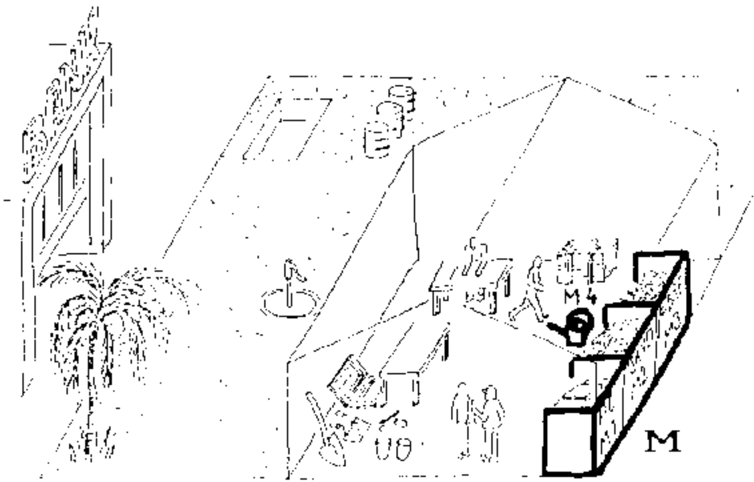
L: Labour costs

FCR is a labour intensive production. As a rough estimate it can be said, that an experienced team of 4 workers can produce 2’000 to 4’000 m 2 a year.

E: Energy costs

Depending on the production process, energy may be used for vibrating devices. Nevertheless, the energy bill will be within some 50 to 100 US $ per year and therefore it can be almost disregarded

M: Raw material costs



M figure

Roughly estimated the costs of raw material may vary between 1 and 2,5 US$ for 1 m 2 of FC-roofing product.

M 1: Cement

According to proven standards cement requirements for 1 m 2 of roofing is either 5 kg or 14 kg depending on whether tiles or sheets are produced.

M 2: Sand

Sand is usually not an important cost factor in FCR-production. Nevertheless, where it has to be transported to the site, It will add 5 % to 20 % to the cement cost.

M 3: Natural fibres

The availability of natural fibres will determine its price. For a rough calculation, cost of fibre will be 10 to 20 % of the cement cost. FCR tiles require 0,2 kg of fibres per m2 of roofing, sheets 0.25 kg per m². Fibre cost will increase, if removal of contamination is necessary.

M 4: Water

Water is used not only for production but also for curing. In most cases it can however be disregarded as a cost factor except for cases, where it has to be transported to the site.

M 5: Plastic sheets

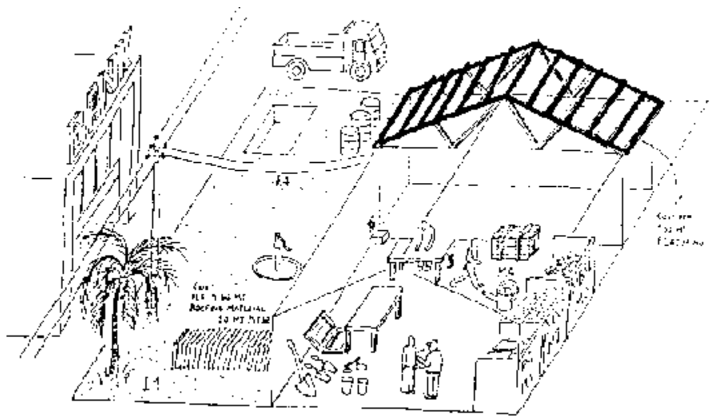
Plastic sheets have to be replaced frequently to maintain a good top surface.

Please note:

Raw material costs are not the only cost factor of FCR production. For proper calculation and comparison with other roofing materials, all cost factors have to be taken into account.

c) Cost for roof structure

S1: Cost for supporting structure



S1 figure

The costs do not vary that much whether tiles or sheets are used. Also the difference in the roof system -whether trusses and purlins or rafter and purlins - is not very significant.

The timber demand for the supporting structure per m² of roofing is between 0.005 to 0.015 m³. A rough calculation for a rafter and purlin construction can be done as follows:

Demand for rafters (in cubic meters):

L/D + 1 x y x (H x W)

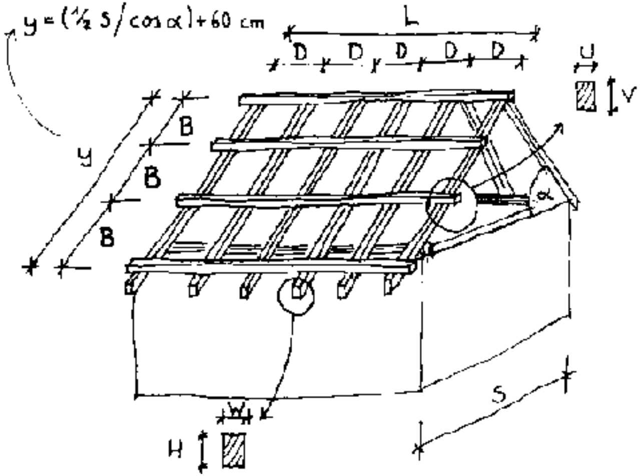
number of	dimension
rafters:	of rafter
to be rounded	
to full number	

Demand for purlins:

y/B + 1 x L x (U x V) in cubic meters

number of purling: to be rounded to full number

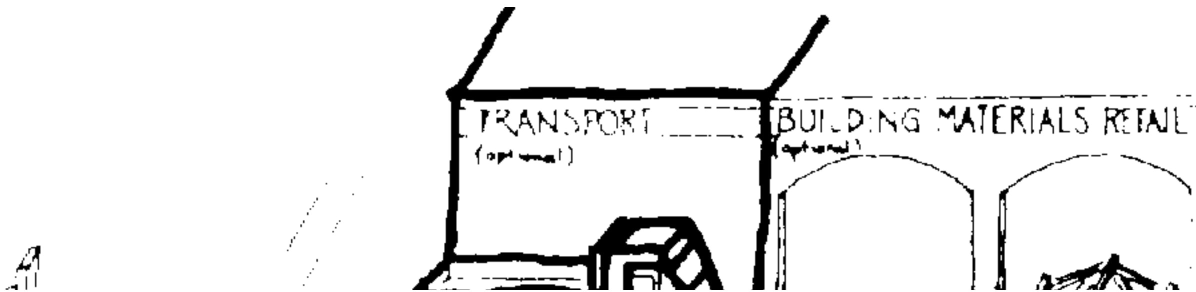
S 2: Fixing costs

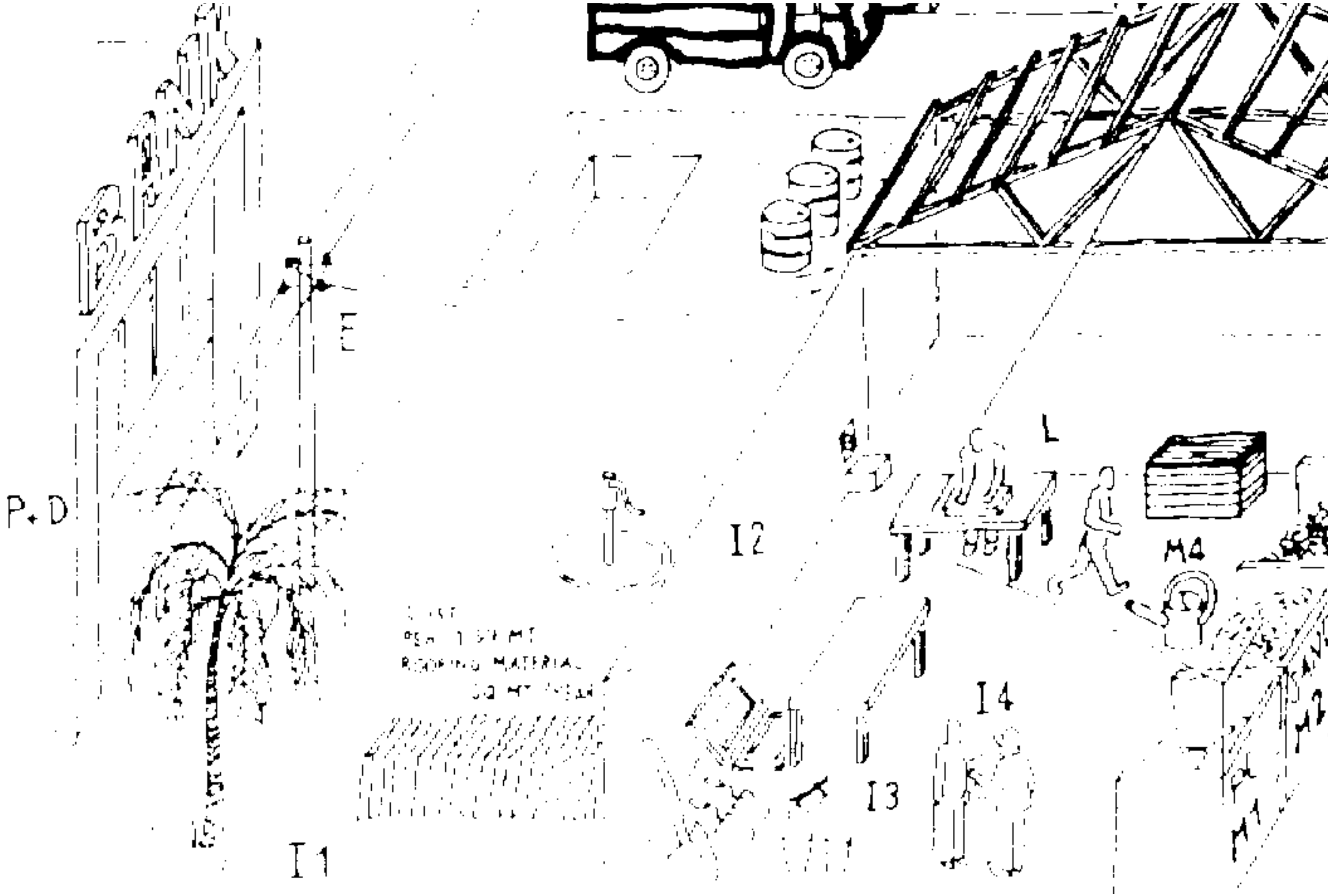


S2 figure

Includes labour for installation and material cost. As a general rule, this will be 8 % to 15 % of the cost for the supporting structure.

d) Transport costs




E
L
P+D
I2
M4
ROOFING MATERIAL
I4
I3
I1
M1

Figure

Transport of FCR-products is a crucial affair. If possible, it should be avoided. The simple equipment makes FCR production mobile . If there is a large demand for FCR products, it might be better to have it produced on site. For tiles, however, a permanent workshop looks like a better solution.

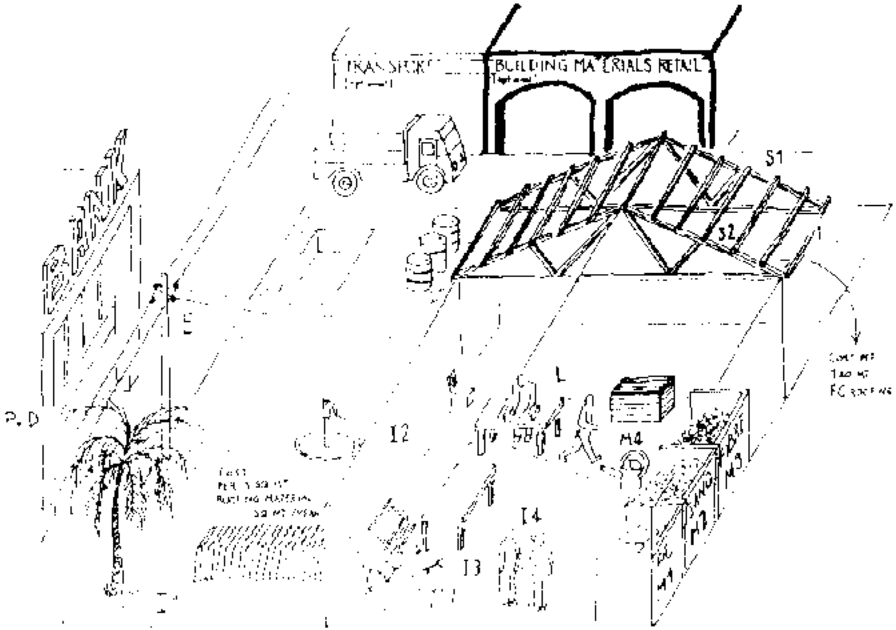
If transport is necessary, the following dimensions and weights have to be considered.

Dimension in meters	Units per sq. meter of roofing	Weight of sq. meter
Tiles		
0.50x0.25	13	21kg
Sheets		
1.00 x 0.78	1.5	30 kg

Example:

If you have to cover a roof surface of 60 square meters with sheets, you will have to transport 90 sheets with a total weight of 2,7 metric tons.

e) Royaltles, administrative and marketing costs, profit



Figure

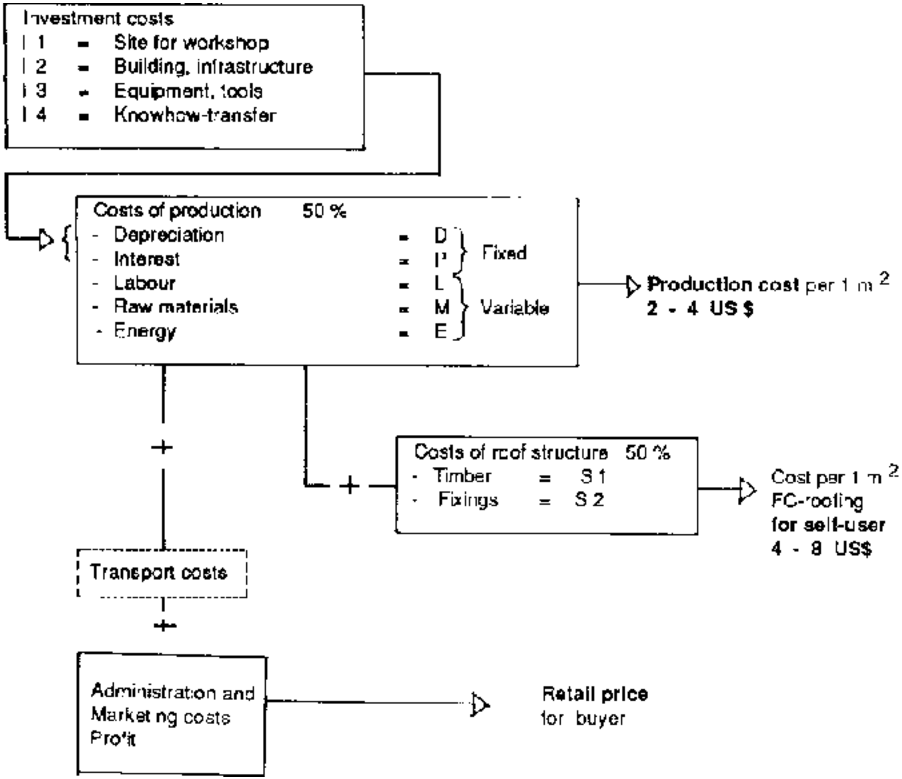
A private entrepreneur will have to calculate an additional amount to the costs of production to cover royalties, administrative and marketing costs and to make his profit. The market situation in building materials will be a constraint to his calculation. A margin of 30 % seems to be possible In most cases.

Total costs

If FCR production is calculated with all the elements showed before, the total cost for one

square meter of roofing including roof-structure, will be - in most cases- 4 US $ to 8 US $.

As a recapitulation a comprehensive coat-model might look as follows:



Compreshensive cost-model

As a simple rule it can be said that the roof-skin will be 50% of the costs, the roof-structure the other 50%.

The material costs of the roof skin -which are only part of the costs- will be 50% to 60% of the costs of production.

Comparison with other roofing-materials

The foregoing paragraph was about how FCR-products should be calculated if a comparison with other roofing-materials is made. Costs of other roofing materials are mostly given as retail-price in the market.

Table 3 shows, that FCR - as a product ex works - will be positioned between the traditional roofing materiels end the industrial products if it enters the market.

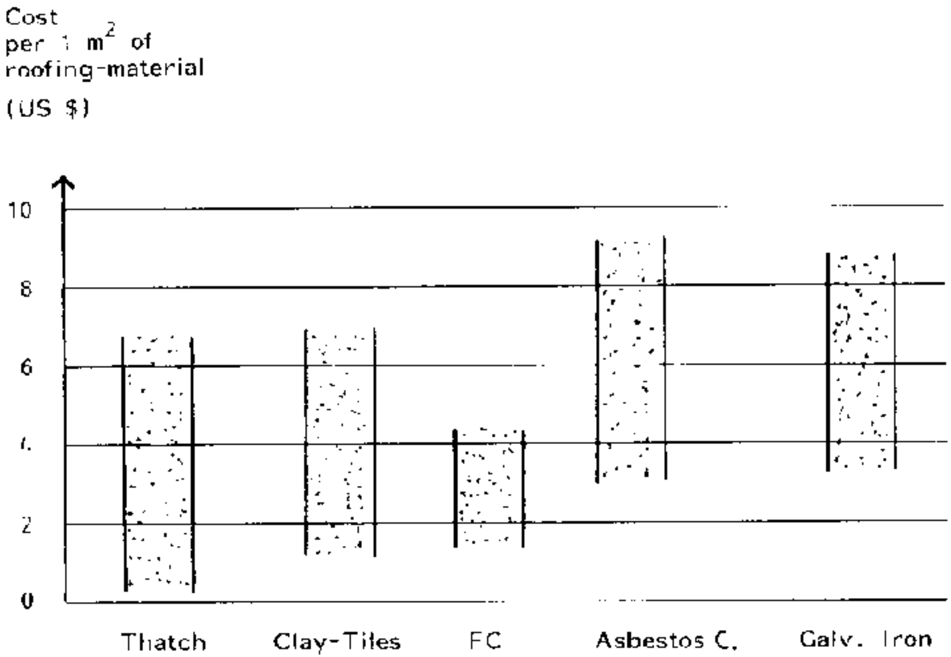


Table 3

This cost-comparison must be taken with caution. It compares roofing materials prices which are derived from production costs, with other prices which were determined by market forces. By itself it cannot be used to determine which is the most economical roofing material. No account has yet been taken of the life-span of the products and other economic criteria (see following pages).

Is the roof structure for a FCR roof more expensive than for other roofing materials?

It is obvious that the self-weight of roof cladding in FCR Is more than the weight of competing materials such as Asbestos Cement (AC) or Galvanised Corrugated Iron (GCI).

Nevertheless, the roof structure will in most cases have to be similar, as the critical dimensioning criteria is not the self-weight of the cladding but the ability to withstand imposed loads, such as people (e.g. workmen) or wind forces (pressure or suction).

A detailed cost comparison of different roof structures has already been made). In many countries one will find of course GCI end AC roofs using very timber saving methods. They are dimensioned according to the self-weight of the cladding and to critical loads during construction. Accordingly they will not be able to withstand strong wind uplift .

The following table compares the timber consumption of typically dimensioned roof-structures (wall plates are not included).

1) Ortiz, F: Experiencia en la investigacin de planchas de sisal-cemento en CII-Viviendas Cetavip, Repblica Dominicana.

	Clay-tiles	FC-sheets	FC-tiles	Galvanised-corr.-iron	Asbestos-cement sheets
self weight of roof-cladding:	60 kg/m2	30 kg /m2	21 kg/m2	10 kg/m2	20 kg/m2
Spacing of rafters: (center)	70 cm	140 cm	120cm	110 cm	150cm
Dimension of rafter:	6 x 12	6 x 12	5 x 10	6 x 12	5 x 10
Spacing of purlins or laths (center):	30 cm	85 cm	40 cm	100 cm	90 cm
Dimension of purlins or laths: (in centimetres)	4 x 3 lath	5 x 8 purlin	3 x 4 lath	3 x 5 purlin	5 x 7.5 purlin
Timber consumption per one square meter of roof slope:*	0,015 m3	0,010 m3	0,008 m3	0,009 m3	0,009 m3

* For a simple rafter and purlin roof, wall plates and bracings not included

Table

Assumptions:

Wind speed = 90 mph
Rafters as shown
Timber: pine, spruce or wood with similar properties.
Deflection f = i /200 = 2 cm for rafter

Which economic criterias determine the use of FC-products?

a) Demand for a roofing alternative

FCR will be valued by its price as a roofing product on the market, respectively by the demand for this type of product.

Where roofing materials can be produced locally, e.g. in a clay-tile region or in an environment where thatched roofs are at a good standard, it will be difficult for FCR to become a competitive roofing solution against traditional roofing.

Where it competes with industrial products such as Asbestos Cement or Galvanized Iron-sheets, not only its price will be used as a deciding factor but also its social prestige. Competition is also difficult if a country subsidizes the industrial products.

b) Availability of cement

There might be circumstances, where FCR is not appropriate because of the national economics. If cement has to be imported, FCR should be promoted only if there is no other alternative.

c) Life span of FCR products A comparison between the manufacturing costs of FCR products and other products shows that FCR products are more economical In most cases. However, If the products have a different lifespan, the picture changes.

In general, if the cost of FCR products is half the cost of AC products, they should have at least half the lifespan to be more economical. If we assume that the cost of FCR products Is half the cost of AC products, and if the lifespan of AC products Is 25 years, then FCR products should at least have a life-span of 12,5 years.

But, the real considerations of a third-world customer are certainly different: even if he knows, that FCR products will last only half the time of AC products, he may prefer to buy the cheaper option, and he will not bother too much, if he has to replace the roofing

sheets after 12,5 years, a time horizon, which he may consider as close to eternity. He may also simply not have the money to buy the more expensive products, even if the lifespan would be shorter and if he would end up with higher costs.

The choice between a cheaper product with a short life and a more expensive product with a longer lifespan depends basically upon the availability of capital. If capital is easily available, an investment in the long-lasting more expensive product becomes economical; if capital is very scarce - or not available at all - the short-term option is the only solution. The usual expression for the difficulty to have access to capital - or, in other words, the scarcity of capital - Is the prevalling interest rate in real terms of an economy. If inflation rate is higher than the nominal interest rate, interest in real terms becomes negative. This makes it attractive for the customer to invest his money in solid values which do not loose their value with inflation; he may buy a tile every week whenever he has some money left.

This interest rate can vary quite significantly from an official banking rate In a specific case; if the customer of FCR products has only access to credits from money lenders, his subjective interest rate can be on a short-term base, so that his effective interest rate would be absolutely prohibitive. The following table shows a comparison between AC- and FC-products in relation to the prevailing or individual interest rate. The basic assumptions are that FC-products cost US $ 4,00 per m², while AC-products cost US $ 8,00 per m² and have a life-span of 25 years. Flow long should FC-products last at least, If different Interest rates are taken Into consideration? In order to calculate the minimum life-span, both investments for AC- and FC-products were discounted with the method of the Net Present Value (NPV) at different interest rates. The results show the following relations:

Prevailing or Individual Interest Rate p.a.	Minimum ("breakeven") Iife-span for FC-products
0 %	12.5 years
5 %	approx. 9.0 years

[illegible]	[illegible]
10 %	approx. 7.0 years
20 %	approx. 4.0 years

If interest rates are above 20% p.a., the minimum life-span drops down to 1 to 2 years, and decision-making will not any more depend on such considerations, but much more follow a subjective rationality; financing of the long-lasting option will get so troublesome (over a period of 25 years), that the customers preference will opt anyhow for the cheaper solution, providing that the life-span is acceptable. As a subjective impression, the life-span of FCR products should at least be 4 years, In order to Justify the Investment at all.

However, only the market can prove if the customer looks at FCR products this way. If money is scarce, to opt for the alternative with a lower initial investment seems logical. But It may also happen that the customer will prefer the alternative which he considers more long-lasting, and he will pay whatever costs if he is sure not to loose the money. Many poor people will spend the money very carefully; they may prefer not to have a solid roof for a long time and may slowly buy the tiles for a definitive roof which they consider as an investment for the "eternity". In this case their perception of money fits with the zero-interest or the negative-interest option.

d) Producer organisation

FCR-production is a very tempting trade because it requires a low initial investment and first results are achieved with almost no capital input. Nevertheless this temptation is a risk if production at a low quality standard is started and maintained. The product will fail after some time and then it can become a loss maker.

FCR-production therefore needs to be backed by organisations which will take over the responsability for regular quality control.

Advantages from FC-use

FCR is not only a more economical roofing material but it can have also additional positive effects on a local economy. Except for the cement - which might be imported - FCR uses local resources such as sand, fibres, labour and reduces therefore the ecological stress on a region. The energy Input for the manufacturing process Is very low.

FCR is a labour intensive product and it creates Jobs not only for the people in the manufacturing unit but also for preparation-work such as fibre collection and preparation, sand collection or for installation on the roofs.

Except for the cement FCR does not require foreign currency for the raw-materials. The low initial investment allows to weak sections in society to start a production. It can be a real "If-help activity with a potential to become a regular Income source.

Drawbacks from FCR-use

If production Is not at a good standard, FCR can become a painful loss for the people involved.

Should the products turn out to crack after two years, a two years production can be lost and there is no way to recycle the material and the labour. However with the knowledge accumulated up to now, this can be avoided.

The failures reported so far in FCR projects do not dismiss the method as such. FCR is an alternative to the traditional roofing methods or the more industrial roofing material if the criteria described before are checked according to the local situation.

FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

7. Knowhow transfer

In chapter 7 Roland Stulz is treating the aspects

- Lack of information
- The ITW information monopoly
- The best way of knowhow transfer
- Information sources
- Continued education
- The “kit and manual” philosophy
- Decision making
- Knowhow transfer package
- Regional centres

7.1 Conclusions

Knowhow is available

- Knowhow for proper production and application of FCR elements is ready and available to potential users. But there exists a gap in the provision of knowhow and technical rationale representing the actual state-of-the-art to the practitioners.

- Most failures in FCR production and application so far were due to no or bad knowhow transfer and insufficient professional training.

- Since the technical rationale of FCR is still in a process of development, and marketing and management methods have to be improved also, the decision-makers and practitioners should be kept conversant with the most up-to-date data and facts.

Lack of continued support and education

- There exists a remarkable lack of continued support and service for FCR producers, and little ongoing professional education seems to exist. Continued knowhow transfer which transmits the actual results of research and technical rationale will be essential for the FCR producers mainly in the future. This will be the only way to avoid further discrimination against FCR technology caused by failures due to bad service and insufficient professional training.

Regional centres

- The dissemination of knowhow adapted to the local demands could be done through several regional FCR centres The role of such regional centres would be to:

- provide the FCR producers with planning help for the establishment of new production

plants

- inform the producers of the findings of the FCR panel, mainly concerning the technical rationale, management and marketing

- help the producers with continued technical support and with troubleshooting if problems or mistakes occur

Production kit and "decision making package"

- A good FCR hardware kit must be accompanied by a well adapted knowhow transfer package (and if possible professional training) if the FCR production is to be successful in the long run. This fact has not been taken into consideration sufficiently so far.

- The decision makers need better instruments which allow them to make their decision whether or not to adopt production of FCR in a specific case based on objective criteria. Within this report we include some aspects which can be of help for better decision making A complete "decision making package" should be prepared within the FCR follow-up study.

Knowhow transfer package

- There are different forms of FCR knowhow transfer. One has to choose the appropriate form for each specific case. The formulation of an easy-to-understand knowhow transfer package needs additional research data (technical rationale) and close collaboration with regional training centers.

- The most efficient training seems to be possible at regional training centers or on the job, but there appears to be a lack of qualified teachers and money available for knowhow transfer and professional training

Quality control by the market

- In many cases of the introduction of new products into new markets it is the dynamic (acceptance) of the market, which decides whether a product is appropriate for a given situation. With simple words, the producer has to improve the product if the market refuses it. Our analysis shows that the FCR technology does not (yet) fit into this self-control by the market, because of the following reasons:

- FCR elements should last for ten or more years. Instances of inferior quality causing reduced lifespan will tend to mislead the market into assuming properly made products to be less durable than they are.

- FCR is not yet a well understood common technology. Therefore failures because of inappropriate production or application may discredit the technology itself for the future.

- FCR is a roofing method which should not only serve the interest of individual manufacturers, but create additional jobs and save foreign exchange at the same time.

The language problem

Due to differences in materials, conditions, construction styles, competing materials, culture and economics between countries, manuals in the language of the target country need to be produced. Imported manuals are too foreign to be followed completely. They would necessarily generalize, leaving too much room for interpretation by the user.

7.2 Evaluation of experiences

Lack of information

Most answers in the questionnaires concerning knowhow-transfer do not include specific

or detailed information on the how and where of the FCR professional education. It seems that knowhow-transfer of the FCR technology so tar has not been considered as a main problem. In most cases the crucial point Is to get enough money to purchase the hardware for FCR production; in consequence the "software" for the professional training is treated more like an extra of lower priority. There also exists a lack of continued knowhow-transfer concerning mainly management, marketing, installation and up-to-date results of research and technical rationale.

Even in cases where initial training of the workers of a new FCR production plant has taken place, this one training course seems not to be sufficient for succesful production and application in the long nun. Many problems and mistakes occur after a certain period of production has elapsed. If in such cases nobody is around to help the producers or users of FCR to overcome their problems, there is a great risk that these people will be disappointed and discredit the FCR technology as a whole.

Therefore it seems necessary to set up a system of continued technical support and troubleshooting.

The ITW "information monopoly"

For the production of FCR corrugated roofing sheets several information papers or manuals seem to exist exist -most of them copies of Intermediate Technology Workshop ITW (John Parry) manuals or articles. So far we know of more than 12 different existing manuals. Most of them deal with single aspects of FCR technology only, like e.g. production methods, installation, etc. Only very few of them give indications on limits of application, professional training, knowhow transfer, local production of equipment, etc. For FC tile production John Parry's ITW (Great Britain and Kenya) and "Action Aid" in Kenya (Roger Bonner and Solomon Mwangi) appear to be the only institutions providing knowhow and professional training. Some other Institutions and private persons are

beginning tile production plants and offering professional training at the present time.

These institutions offer 1 to 12 weeks training courses at their producers headquarters, on the job or at a regional training center. These training courses include:

- Training of how to make sheets and tiles
- Management of a FCR production plant
- Building of a demonstration house on the job
- etc.

In Kenya "Action Aid" too are now setting up groups consisting of four primary school leavers who are given training in tile making and how to manage themselves.

The best way of knowhow transfer

The question "Which is the best way of knowhow transfer" and "which way did you use" has been answered in the questionnaires as follows:

	The best way	The way I used
By manual	(6)	(1)
Training course on the job	3 + (7)	7 + (3)
Training course at an institute in the country of FCR production	3 + (3)	2
Training course at an institute in an industrialized country		2 + (1)
Special training for installing of sheets	(1)	

( ) : These questionnaires have given several different answers.

The best way of knowhow transfer

From these heterogeneous answers it is difficult to extract a clear answer or trend. It seems that a combination of training courses and manuals is the most appropriate method.

Planning of FCR production

The question "How has the FCR production and marketing been planned" has been answered as follows:

Planning method	Number of answers
By a technical adviser (expert)	10
With the help of a FCR manual	8
Feasibility study	6
Trial and error	5
Contacts with local contractors	3
Training at equipment suppliers headquarter	2
Contacts with equipment supplier	1
Research at local university	1
Participation in industrial fair	1

All respondents gave multiple combined answers.

Planning of FCR production

In most cases marketing has not been planned at all; either because the FCR elements were produced for the own demand of the producing organisation or because marketing was considered a problem of second priority.

In general the technical advice ended after an initial installation and training course. This

initial phase was followed by a time of trial and error, which led to improvements or disappointments.

Training at the equipment suppliers headquarter was mentioned twice only though many persons from developing countries visited such training courses so far. Most of the respondents are NGOs who can afford some investment. This may explain the rather great number of cases in which planning has been done by technical advisers. Private entrepreneurs would probably hesitate to engage an (expensive) expert and be more interested in the planning of marketing.

Constraints on wider application

The question “What are the constraints on wider application of FCR” has been answered as follows:

	Number of answers
Lack of knowhow for application	8
Bad transportability and workability	8
Lack of knowhow for production	7
Low durability, breakability	7
Bad acceptance by the market	6
Lack of local raw materials (sand, sisal)	5
Bad physical qualities	2
Size of sheets too small	1
Lack of quality control	1
Lack of production equipment	1
No information in other languages than English	1
Decomposition of fibres	1
Expensive roofing timber	1
Low prestige	1

All respondents gave multiple combined answers

Constraints on wider application

The lack of knowhow seems to be a serious constraint on wider application of the FCR technology. As Carlos Lola of ATI points out: "Because of the components of FC roofing, especially cement, a level of training and knowledge should be required to initiate any new project and to avoid the unsuccessful stories".

Low durability and bad transportability too are serious problems to overcome. On these two items better information about how to handle, to install and to maintain the FCR elements is a must.

The acceptance by the market is not a problem of first priority for the respondents (who are mostly NGOs). It may be of greater importance for private entrepreneurs who are confronted with conservative market behaviour and competition with other roofing materials. The lack of raw material, mainly good sand and fibres, seems to be a problem In several cases.

Content of a knowhow transfer package

The question "What information should a technical manual or a training course provide?" has been answered as follows:

	Number of answers
Limits of application of FCR	19
Quality control	19
Tools and equipment	19
Technical rationale	18
Manufacturing methods	18
Storage of materials	18
Transport and handling	18
Installation of roofing elements	16
Types of products	14
Management	12
Feasibility study	9
Marketing	8
Simple roof structures	2
Maintenance	2
Repair methods	1
How to produce equipment locally	1

All respondents gave multiple combined answers.

Content of a knowhow transfer package

This table shows that a technical manual or a training course should be as comprehensive as possible, cover meinly the technical aspects and, with second priority, management and marketing aspects. For a private entrepreneur management and marketing surely would be as important as the technical aspects.

Information sources

The question "Which information sources on FCR do you know" has shown that there exist quite a few AT centres and reports, manuals and leaflets which provide knowhow on FCR. They all cover certain aspects of this technology, but only a few of them give comprehensive information on how to achieve successful planning, production, marketing and application of FCR technology. The indications given by the respondents of the questionnaires lead to the following list of information sources. It was not possible to evaluate the quality of each of them. Therefore we only can present an overview of these sources. This list is certainly not complete; it may just give an impression on how heterogenous the information sources are already, though a consistent fund of FCR knowhow is just emerging but has not yet consolidated. For the future this means, that the dissemination of FCR infromation should be done more carefully and based upon reliable knowhow and technical rationale. The publications mentioned in the questionnaires are:

- SAREC Report. Natural Fibre Concrete. By H.E. Gram et al. Sweden 1984.

- Fibre reinforced concrete roofing sheets. Technology appraisal report, by Carlos R. Lola, ATI and Save the Children Federation, USA 1985.

- Fibre Concrete Roofing. The complete text book by John Parry. UK 1986.

- Roof construction for housing in developing countries. By GATE / GTZ / Institut fur Tropenbau. West Germany.

- Sisal cement roof sheets manual. By Hlekweni Friends Rural Service Centre, Dept. of Appropriate Technology. Bulawayo, Zimbabwe.

- How to make a durable cement roof. By Rural Housing Project, UNDP. Lilongwe, Malawi.

- Manual. By Instituto de la Vivienda. Tegucicalpa, Honduras.

- Report and seminar on FCR in Eastern Africa at Kenyatta University, Kenya.

- Telhas de fibro-cemento "Pembalite". By Direccao Provincial de Construao e Aguas. Pemba, Mozambique.

- Reinforcement of concrete with sisal and other vegetable fibres (SCBR). By H. Persson, A. Skarendahl (SIDA), Sweden.

- NFC for roofing. By NFC AB, Stockholm, Sweden and A. S. Mawenza, University of Dar-es-Salaam, Tanzania.

- Cement based composites with mixtures of fibres. By BRS. U.K.

- Roof sheets made of sisal reinforced concrete. By BRU. U.K.

The importance of knowhow transfer

The question 'What is, in decreasing order of Importance, the role you give to different criterias" has been answered as follows:

	Priority
Durability	1
Acceptance	2
Manufacturing method	3
Economics	4
Quality control	5
Raw material	6
Knowhow transfer / professional training	7
Limits of application	8
Installation of FCR elements	9
Research and development	10
Transport and handling	11
Supporting structure / maintenance	12
Marketing	13

"Attractive appearance", "producer organisation", "mobile production plant" and "equipment" have also been mentioned as aspects of some importance.

The importance of knowhow transfer

Knowhow transfer and professional training are mentioned as priority 7 only. This judgement is in contradiction with the answers to the question "What are the constraints to wider application of FCR There the respondents expressed that the lack of knowhow was one of the main constraints on wider application of FCR.

This may be explained by the tact that the items "durability", "acceptance", "production method", "economico", "quality control" which have been indicated as more important criterias, are all somehow aspects of knowhow transfer: If the knowledge about these criterias is to be Improved, better training and information Is needed.

Continued education

Ongoing professional education In developing countries does not exist yet, though the FCR production is still based on rather limited empirical know-how. As the FCR technology needs further research the problem of continued knowhow transfer to FCR producers will be of great importance for the future.

In several projects problems with continued training, with respect to provision of specific information to overcome problems during FCR production occurred. Many FCR producers feel that they get unsatisfactory service and support (trouble-shooting) by promoters of the FCR technology or the seller of the hardware.

The "kit and manual" philosophy

From 1983 to 1985 ITW has sold over 100 production kits for FCR tiles. In many cases the customers did not request professional training by the ITW group. The evaluation of the first experiences with this system of selling a kit with a manual without additional training by the seller has shown limitations in this way of knowhow transfer.

It seems that kit and manual can be recommended only If a talented and serious person with good theoretical and practical professional background Is using them.

Otherwise there appears to be a great risk of failure for the FCR production. In some places in Kenya the moulds for tile production have been criticized by customers for their rather mediocre quality and high price. Although the supplier has improved the quality and

prices have fallen in the meanwhile, there may occur a trend towards local production of the production kits In the future. This may or should also mean a demand for more local professional training facilities.

A personal opinion

One conclusion of an expert after visiting several FCR production plants in Kenya is, that FCR tiles are a highly suitable technology for village level production”,,,, If we accept this we need to consider ways of accelerating their dissemination through local manufacture of the hardware together with supplementary promotional activities such as training courses for small manufacturers, demonstrations for building authorities and contractors, etc.”

Open questions

Many questions have been arising which could not be answered during the evaluation of the questionnaires and available reports. The answering of the following questions would help to establish a better know-how transfer network and improved professional training:

- What manuals on FCR exist besides the ITW manuals? Which of them need to be upgraded?

- What training courses exist?

- Where are the existing training centers located?

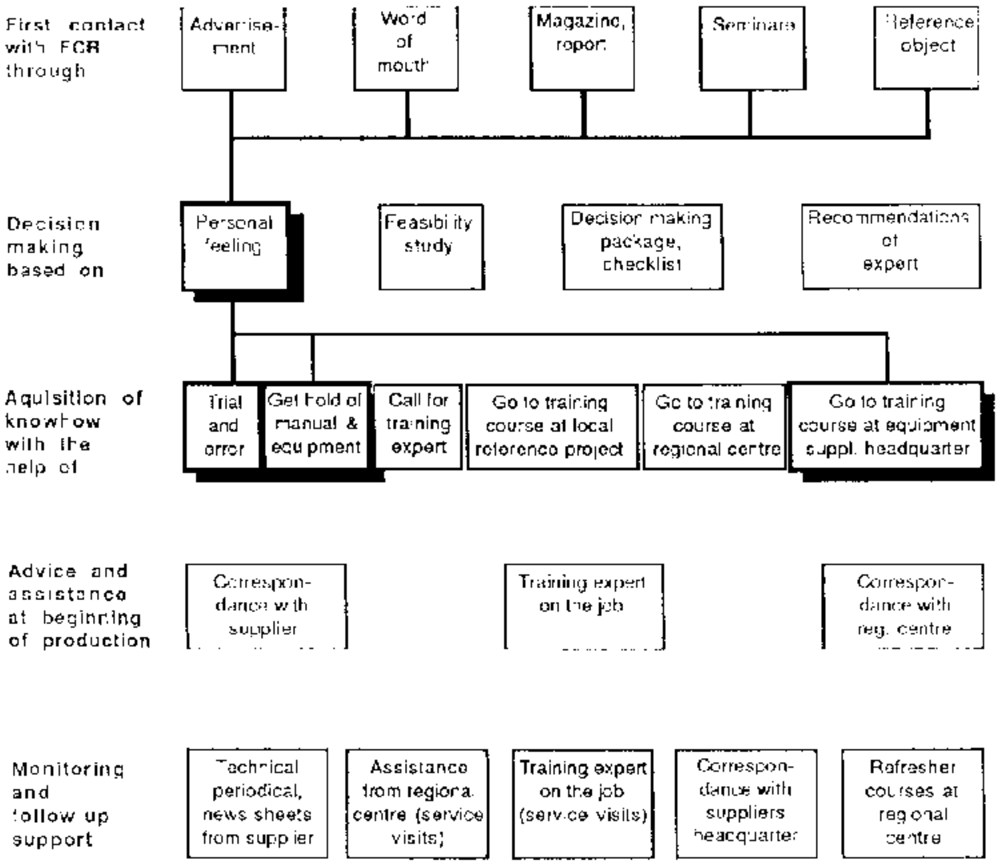
- How are the training courses organized, what manuals do they use?

- Where are suppliers headquarters?

- Where are regional centers?

7.3 Comments

There exist many different possibilities for FCR knowhow transfer. On the diagrams below we set out four ways of knowhow transfer which are applicable to most situations.

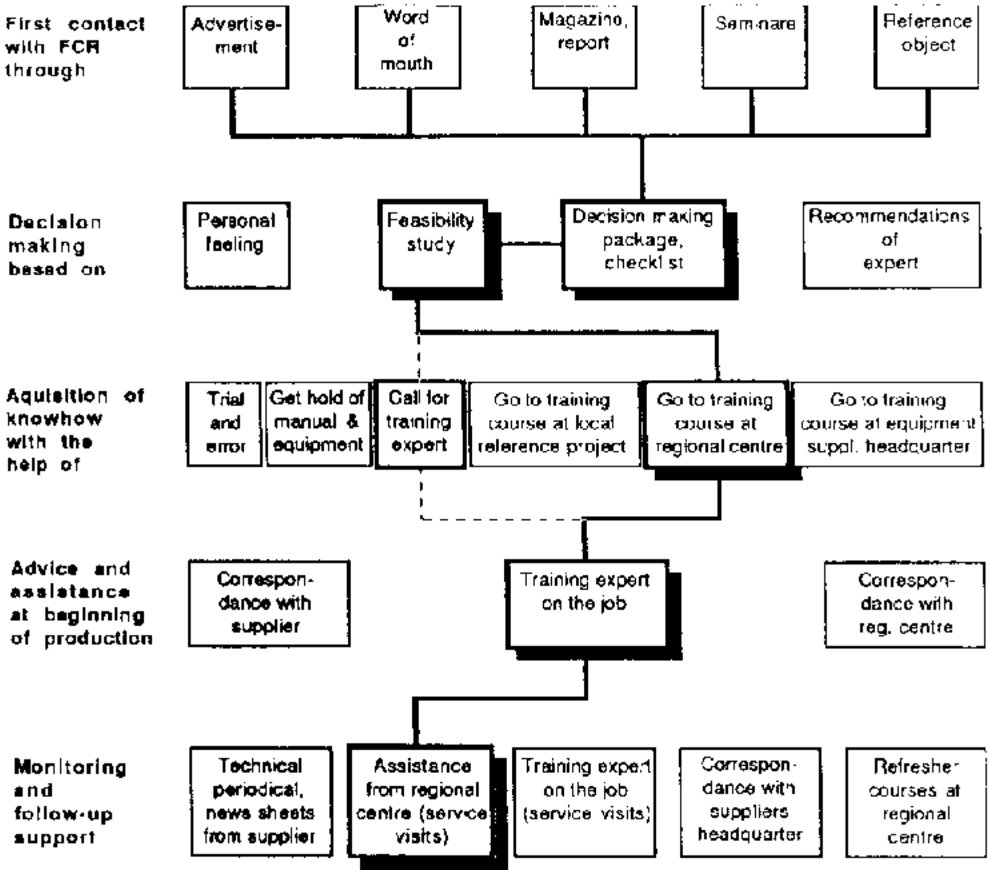


A. The most widely used way so far

This is certainly the cheapest, but also the most risky way of knowhow transfer and

planning of FCR production, since there exists neither professional nor follow-up support and assistance in this method. Nil or insufficient knowledge of recent and improved methods and technical rationale, no competent troubleshooting if problems occur and a lack of continued technical service and support are the main reasons which indicate that this method should be avoided in most cases in the future.

In the past and in the present this way of knowhow transfer has led to misunderstandings and in consequence to deficient manufacturing and application of FCR products in many cases.

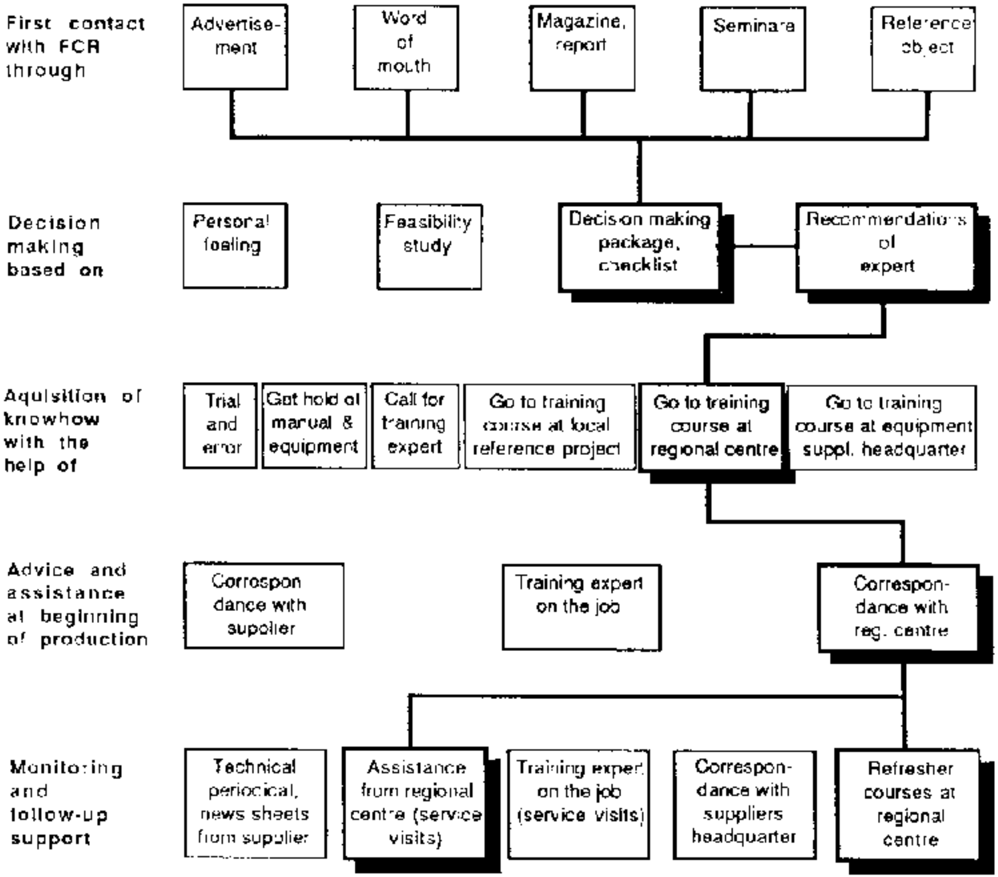


B. A good way for Non Governmental Organisations (NGO) and public Institutions.

This method permits establishment of FCR project on a solid basis. Competent initial

planning and professional training are combined with continued technical support and troubleshooting.

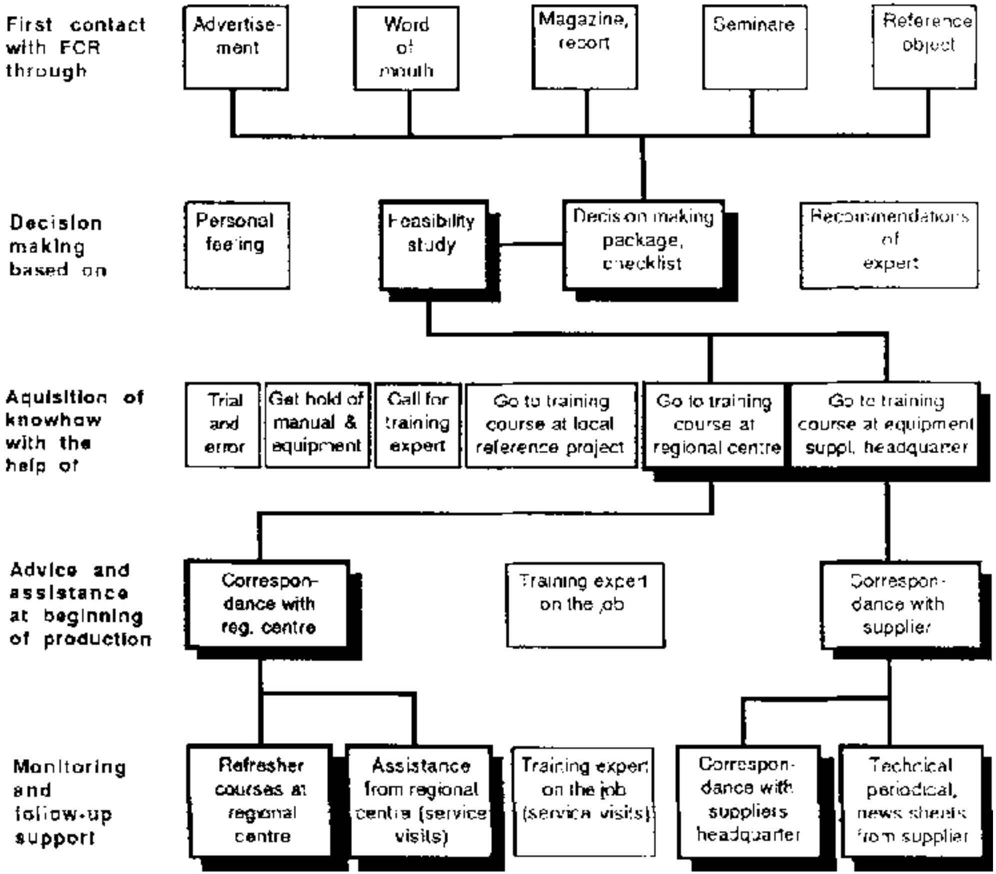
This way of knowhow transfer needs financial investment for planning, professional training and monitoring. Higher efficiency of production and marketing as well as better quality of the FCR products should pay back this Investment within a short time.



C. A good way for self-help initiatives.

This is the method which requires the least amount of financial Investment, still offering a rather good basis for planning and professional training. The main risk factor is that the continued support depends much of the initiative of the project director: he has to contact the regional centre to get the information and help he needs. Monitoring and continued technical assistance are not institutionalized.

This method will work well if the project director is an active person and If the regional centre is well established and can offer prompt and efficient help if required and if problems occur in a production plant.



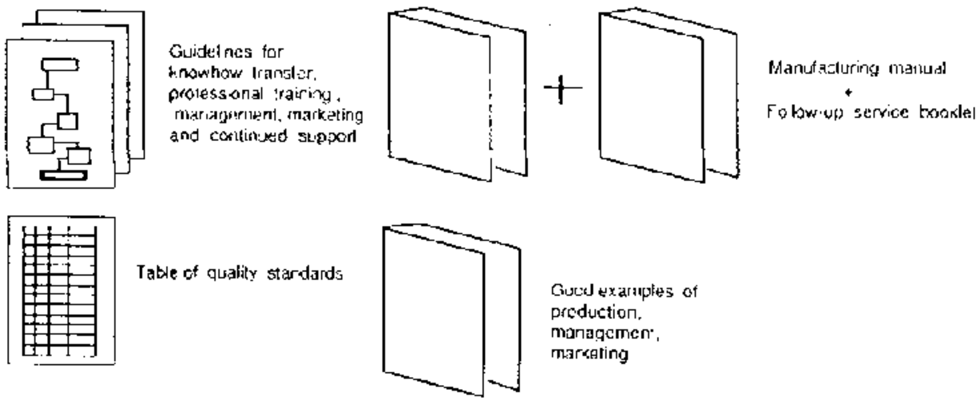
D. A good way for commercial entrepreneurs.

The private entrepreneur has to be an active person anyway if he wants to be successful. That is why he does not depend so much on institutionalized support. But he still needs competent technical advice if problems too difficult to overcome by himself occur. Therefore he needs a regional centre he can contact and ask for help. He should be able to contact by his own initiative the regional centre or the equipment supplier to get the help he needs.

Decision making

The decision makers in the aid agencies and on the Job need better Instruments. Therefore we would have to prepare a checkilst and recommendations for the decision makers In an easy-to-understand form. By answering the checklist the potential FCR producer should be able to find out whether to undertake a FCR project or not.

"Knowhow transfer package"



This package may include the following items:

Regional centres.

When we consider the findings of this report, the establishment of regional centres which promote the FCR technology and knowhow and which guarantee continued technical support, appears to be essential if this technology Is to become successful In the long range.

In a midterm range these regional centres should be supported financially and technically from outside aid agencies. In the long term, competition and improved technical standards as well as profitable marketing of the FCR products should allow the self-support of the regional centres.

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FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

8. Fallow-up programme

In chapter 8 Roland Stulz and Karl Wehrle are treating the aspects

- Two different scenarios
- Proceeding and organisation models
- Financing model

8.1 The aim of a follow-up programme

A follow-up programme should help to make FCR a mature technology with the help of further analysis and detail studies concerning

- **Monitoring**
- **Technical rationale**
- **Manufacturing**
- **Installation**
- **Costs and economics**
- **Knowhow transfer**
- **Decision making package**

There exist several possibilities to aim at this goal. In the following pages we present two scenarios which show how a worldwide FCR knowhow network and technical assistance could be established (scenario 1) or how FCR knowhow can be desseminated by more improvised methods.

This study has shown that a follow-up programme is a must if FCR is to become a mature technology and if misunderstandings and failures are to be avoided. Mainly with regard to the growing demand for low-cost roofing materials it is essential that potential and existing producers and users of FCR get additional information and technical assistance.

8.2 First scenario

Scenario 1 shows the establishment of several regional knowhow centres which

- **provide the producers with knowhow for the establishment of new production plants**

- **provide the producers with the latest knowhow and findings of the FCR panel, mainly concerning technical rationale, management and marketing**

- **provide the producers with troubleshooting and technical assistance if problems or mistakes occur during production and application**

- **provide the FCR panel with monitoring and with new facts and experience arising from research and development.**

Operating and organisation model.

The scenario 1 is set up with the goal to arrive at a consistent and equal level of knowhow and technical understanding in all main AT organisations. This seems to be necessary to avoid misunderstandings and deficiencies in knowhow transfer in the dissemination process of FCR technology. Further failures and disappointments through bad FCR experience should tee minimised by this approach.

The advantages of this scenario are:

+ Coordinated dissemination of the new FCR technology.

+ Coordinated monitoring and feedback of experiences for analysis and improvement of knowhow. Effective further research and development.

+ New findings through further analysis and detail studies are available for all panel

members and their associate regional centres and producers.

+ Consistent and equal level of knowhow and quality standards world wide.

+ Improvement of the partially flawed Image of FCR through coordinated support by major organisations.

+ After a time-limited introductory phase FCR technology becomes a "mature technology" which "stands on its own feet". The financial involvement and technical assistance of the donor organisations becomes unnecessary after the intensive Introductory phase.

+ In consequence time-limited financial engagement of donor organisations.

+ Elimination of the confusion caused by conflicting advice by different consultants because an international panel can be approached for a ruling.

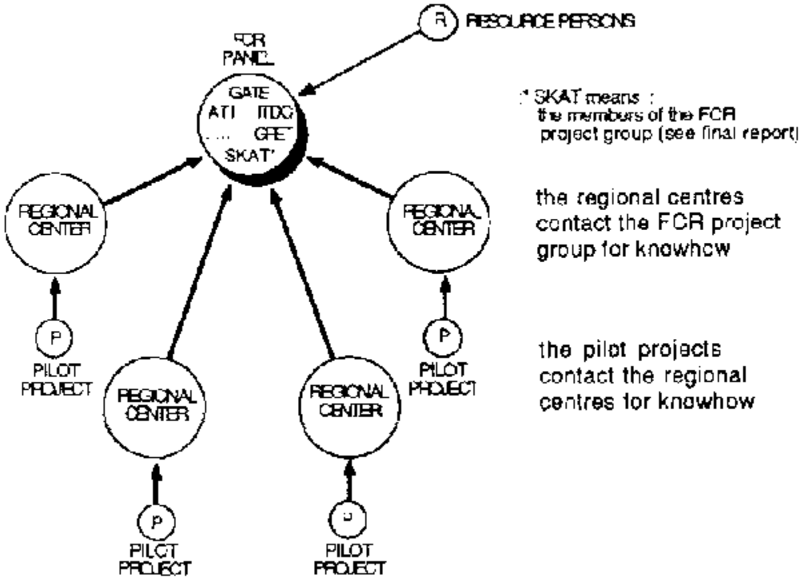
The disadvantages of scenario 1 are:

- Rather high financial Investment of donor organisations In the Introductory phase. Considering the potential reduction of failures, this Investment is economically justified in the long term.

- Organising and coordinating the regional centres needs a certain time.

- The FCR panel needs some coordination and possibly administration.

First phase



First phase

Several organisations - e.g. GATE, ITDG, ATI, DEH, GRETetc. - select or establish a regional centre of their choice. Jointly with this regional centre they establish new pilot projects or collaborate with existing FCR producers.

The role of such regional centres would be to:

- provide the FCR producers with planning help for the establishment of new production plants

- provide the producers with the most valid findings of the FCR panel, mainly concerning

the technical rationale, management and marketing

- help the producers with continued technical support and with troubleshooting if problems or mistakes occur.

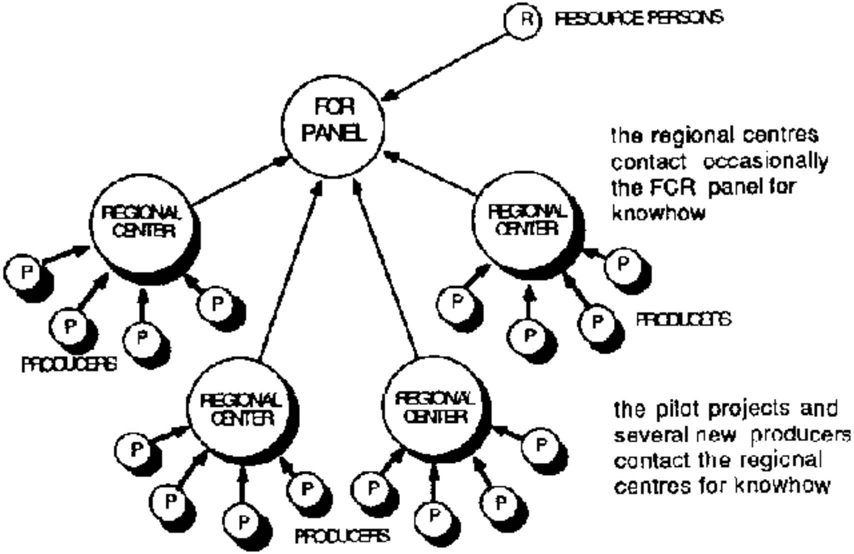
The organisations coordinate their planning and monitoring of the regional centres and pilot projects within a FCR panel to be set up.

This panel consists of the representatives of the donor organisations and of the FCR project group (or part of it) which procured this report.

The panel designates the persons who are responsible for the technical contacts with the regional centers and producers and for their provision with latest technical knowhow, technical and management assistance as well as trouble shooting.

The producers are associate members of the regional centres according to guidelines which have to be established by the FCR panel.

Second phase

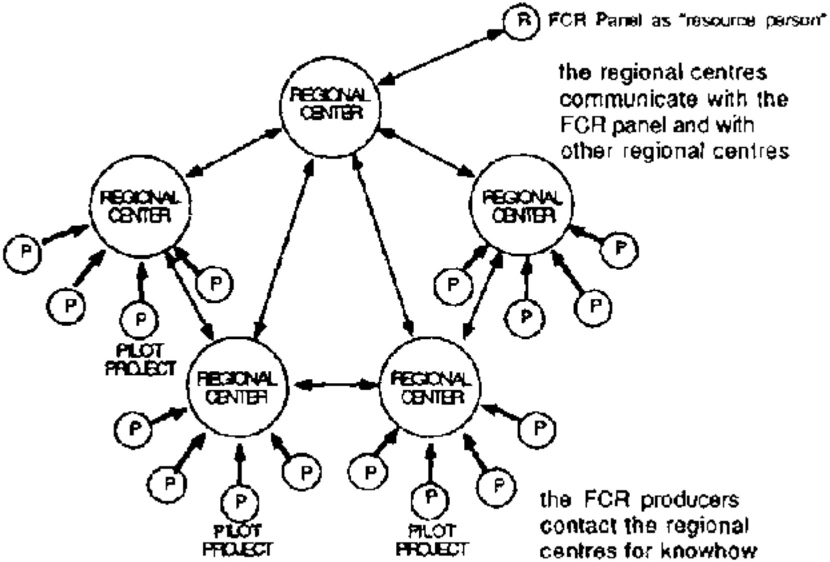


Second phase

The regional centres take over the role of disseminating FCR knowhow and assisting the producers.

The FCR panel has completed its initial task. Now it takes a background role as an information pool and an enquiry and answer service œntre.

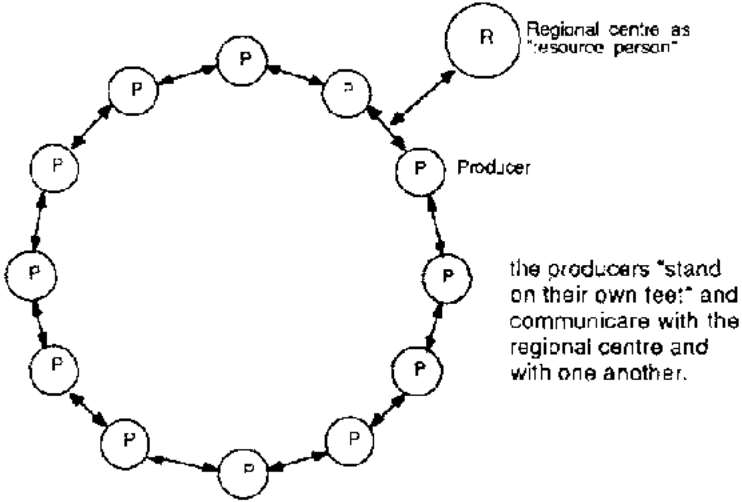
Third phase



Third phase

The regional centres communicate one with another. One of the regional centres takes over the role as information and enquiry and answer service from the FCR panel.

Fourth phase



Fourth phase

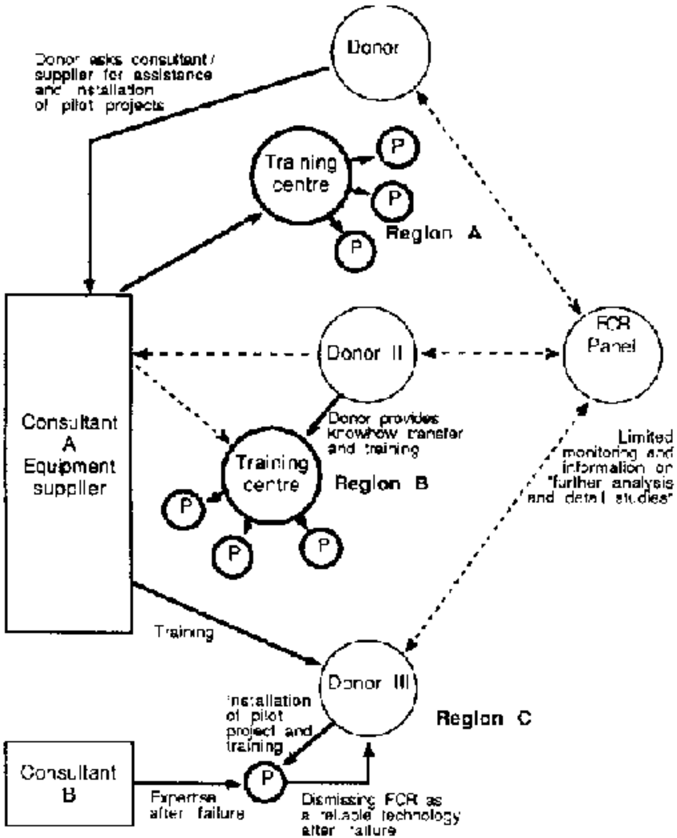
The FCR technology has become a mature and self-reliant technology which is supported by a network of local producers of equipment. It works mainly on a commercial basis like other small industrial processes.

8.3 Second scenario

Scenario 2 shows the "improvisation method" of how the FCR technology can be disseminated with the help of

- **one main private equipment and knowhow supplier.**
- **several consultants assisting independently diverse FCR producers.**
- **"trial and error reaming method for FCR producers who start production without having**

the money to finance proper initial training and technical assistance by consultants.



Figure

Operating and organisation model

The scenario 2 is more or less the extrapolation into the future of how FCR technology has been disseminated so far.

This scenario allows each organisation and FCR producer to go his own way without worrying about what happens to others. The advantages of this scenario 2 are:

+ No coordination with other organisations is necessary. Fast reaction of donor is possible.

+ Each organisation or producer can start production right away without being involved in a process of "further analysis and detail studies".

+ Each donor can act Individually.

+ No FCR panel (with administration) has to be established.

+ The costs for disseminating the FCR knowhow can be limited to a minimum.

+ Every consultant can develop his own "specialities"; he is not limited by common quality standards.

The disadvantages of this scenario 2 are:

- Monitoring as well as exchange and evaluation of experiences are rendered more difficult.

- New findings through "further analysis and detail studies" cannot be disseminated to all producers because no information network exists.

- No consistent and equal level of knowhow.

- No common quality standards.

- Risk of damage to the FCR Image due to failures and misunderstandings with the "trial and error" method.

- Risk of long term costs for donor organisations due to consultancies and closing down of deficient production plants after production failures, wrong application and insufficient management and marketing.

- The FCR knowhow can be monopolised by one single equipment supplier.

- Conflicts of Interest may occur if the equipment supplier is consultant at the same time. As equipment supplier he will hardly accept local alternatives to his methods.

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FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

9. The questionnaires

In this part you can find the addresses of the persons and organisations who have been answering the questionnaires.

9.1 Africa

Address of person answering the questionnaire	Address of FCR production unit
N.D. Court P.O. Box 2756 Accra Ghana	Peri-Shelter LTD P.O. Box 696 Dansoman Estate Accra, Ghana
Roger Bonner + Solomon Mwangi Actionaid-Kenya P.O.Box 42 814 Nairobi Kenya	Kibwezi Kenya (Rural) Kariobangi Nairobi Kenya (Urban) Webuye Kenya (Rural) Kibosa Kenya (Rural)
Mc Neil Mamboleo 4th Ngong Avenue P.O. Box 45 156 Nairobi Kenya	IT-Workshops
A. Beamish+Will Donovan	Maria Cristina Dias Lay Projecto Telhas de Fibro Cimento C.P. 292

	Pemba, Cabo Delgado Mozambique
Prime Minister's Office Building and Research Unit P.O.Box 1964 Dar es Salaam, Tanzania	J.S. Baradyana BSC
Steffen Knak-Nielson P.O. Box 30 500 Lusaka Zambia	
Wolfram Pforte Ottersfuhrstr. 17 D 6050 Offenbach/M - Bieber	
Kim Parmand/Phillip Newenya Departement of Appropriate Technology Hlekwewi Friends Rural Service Centre P.O. Box 708 Bulawayo Zimbabwe	

9.2 Asia

Adress of person answering the questionnaire	**Adress of FCR production unit**
Heinz Wehrli 34, rue de la Gabelle CH1227 Carouge	BASWAP Bangladesh
Gulam Mostafa	Dacca Bangladesh

Beat Schaffner Ringstr. 39 CH 8057 Zrich	A.M.G. Leprosy Relief Project Post Box No. 18 Titilagarh 767 033 Bolangir Dt.-Orissa India
T.N. Gupta Acting Director CBRI Roorkee India	
Christian Vollmin Proyek Act Swiss Jalan Diponegoro Praya Lombok-NRB Indonesia	

9.3 Latin America

Address of person answering the questionnaire	**Address of FCR production unit**
Carlos R. Lola A.T. International 1331 “H” street N.W. Washington DC 20005 USA	Several projects in Latin America
Felix Ortiz CII-Viviendas / Cetavip Ciudad Ganadera Apartado Postal No. 20 328	CII-Viviendas/Cetavip Ciudad Ganadera Apartado Postal No. Santo Domingo

Santo Domingo Repblica Dominicana	Repblica Dominicana
Martin Malandez Calla 5 Esq. Bovaire # 20, Al Ma Rosa Santo Domingo Repblica Dominicana	Comunidad Los Boncos Barrio la Libertad San Juan de La Maguova Repblica Dominicana
Tom Adamson Port-au-Prince Haiti	
Kurt Rhyner Glarnerstr. 12 CH 8755 Ennenda	Grupo Sofonias San Juan del Sur Nicaragua
Lic. Ernesto Ortega Contiguo al cine Plaza San Mros, Barazo Nicaragua	Empresa Regional de Fibralix Gobierno Regional Granada Nicaragua
St. Dominics R.T.C. P.O. Box 22 Gizo/Solomon Islands	

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Comments:

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Summary

In this part you can find

- How to read this report
- Introduction

- **Why this study**
- **The aim of this project**
- **The project group**
- **The questionnaires**
- **An international consensus**
- **The need for a follow-up programme**

- Executive summary
- Tiles or sheets?
- 10 key questions for decision makers

How to read this report

For the executive

If you have only 15 minutes to get an idea of what Fibre Concrete Roofing is and how it

can be implemented, you just read the

- executive summary
- 10 key questions.

For decision makers and potential users

You may read

- the "conclusions" of each chapter
- the "10 key questions".

To get a more detailed idea of the different aspects of Fibre Concrete Roofing you may also read the bold printed words of the "evaluation of experiences" of each chapter.

For the practitioner and technician

You may read

- the "conclusions"
- the "evaluation of experiences"
- the "comments" of the chapters you are interested in.

For easy understanding you may just read the bold printed words.

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FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)
(introduction...)

Introduction

What is FCR?

Fibre Concrete Roofing (FCR) is a building material which has been developed for the covering of roofs mainly in low cost building construction. The roofing elements are shaped and sized in the form of either tiles or sheets. The appearance of the FC sheets is much like that of asbestos cement sheets. The FC tiles look like clay or concrete tiles of grey or red colour. The FCR elements are made of mortar which is a mixture of sand,

cement, water and - natural or artificial - fibres.

Roofing - a target for low-cost techniques

The roof is - beside foundations, walls and ceilings - one of the main important construction elements. Therefore it is an important target for finding appropriate technical solutions, especially for the housing of low income groups. The need for alternative methods and materials is increasing since conventional building materials like timber and energy sources (firewood) for clay tile production are in limited quantifies and not available in many places. Also a cementitious material like FCR is less deteriorated by salt or industrially polluted air than steel. This gives the FCR tiles an advantage compared to the corrugated iron sheets.

Why this study?

When we started this study in 1985, the FCR technology was very successful in many projects; on the other hand FCR was harshly criticised in other places. Everybody was talking of fibre-cement roofing, but only few people knew by then that it was in reality fibre-concrete. This little difference of the words "concrete" and "cement", which makes in the reality of building houses such a big difference is typical for the situation of this technology at this stage.

Only few people really knew how to produce good qualify FCR products. Many people and organisations made bad experiences with improper production- and installation- methods. Mainly the unsatisfactory results of FCR production in some projects in the Dominican Republic lead to justified criticism. The result of these criticism was that FCR acquired a rather bad image and aid organisations hesitated to apply FCR in their projects, though it is not the technology or product which failed but its application.

Various parties (institutions and private persons) are active in developing and improving

new methods to produce and apply roofing elements made of fibre concrete. Raw materials, production methods, size and shape of the roofing elements differ from site to site. As far as we can judge success or failure of a production plant seems to depend strongly on the personal initiative of the individuals involved. Long term experience with this new technology seems to be very limited, though it is widely used all over the world. Besides many positive experiences the FCR method has also failed in many other places.

At that point of confusion we found it helpful and necessary for the FCR technology and its potential users to get a clear idea of the potential and the constraints of FCR.

We believe that positive criticism of FCR is necessary and that many mistakes

- mainly nonprofessional manufacturing - have been made so far.

On the other hand FCR is a technology which still needs research and development, information, professional training and investigation to become a mature technology which can be helpful in very many housing projects all over the world.

The aim of this study

With this study we want to:

- improve the knowledge of the technical rationale,

- help avoid financial investment into incorrectly planned FCR projects,

- present the latest state of the art of the year 1986,

- evaluate the experience of a large number of existing FCR projects in Latin America, Africa, Asia, etc.

- show the deficiencies of FCR knowhow, application, training, etc.

- show the possibilities of knowhow transfer,

- give clear answers to the questions of the practitioner,

- show the potential and the constraints of FCR,

- show the importance of the aspects "marketing", "management", "economics", "acceptance",

- present a follow-up programme.

To help avoid further failures with the useful and in many cases appropriate "FCR technology" we set out to elaborate a comprehensive package of knowhow transfer mechanisms. The result of this project consists in the presentation of the most up-to-date state of the art, based upon a large number of field experience reports - including good and bad experiences - as well as on laboratory test results. We also intended to show which items need further research and development. The main goal of the project is to propose methods of better "knowhow transfer" in this field, including professional training facilities.

The project group

In order for SKAT to carry out the study as scrupulously as possible, leading FCR experts were invited to collaborate within a project group. Fortunately some of the best experts - both critics and advocates of FCR - accepted the invitation. The collaboration of advocates and critics within the project group and with outside experts resulted in an impartial presentation of the state of the art of FCR.

The questionnaires

To get a relevant number of experiences which could be evaluated, SKAT sent over 50 very detailed questionnaires to sites of FCR production known to the group so far . 20 questionnaires were sent back to SKAT and provided the project group with very valuable facts.

The report

The evaluation of the questionnaires and of the FCR group-members experience as well as several detailed studies and tough discussions within the project group and with outside experts lead to the facts and statements presented in this report . The statements presented in this report are supported by all project group members jointly.

This report is not a manual for FCR production and application. Other publications on FCR - e.g. like "The complete text book by John Parry" - show how to produce, to manage and to apply FCR. The SKAT FCR report on the other hand shows clearly the limits of application of FCR and the findings which could be drawn out of the experience of FCR producers and users all over the world.

An international consensus

It seems that a consensus of judging the possibilities and the limits of FCR has been found with this study.

The general conclusion may be summarized in the statement, that FCR is a promising technology provided that its knowhow is adequately and comprehensively communicated to all users and followed-up with the help of a world wide network of regional centres specialised in FCR.

The failures so far seem to be the result of insufficient knowhow -transfer, use of faulty production methods and incorrect installation of FCR.

It is our hope that this report will help to show the way in which FCR can con tribute to the implementation of durable and satisfactory low-cost roofing while creating jobs and using local resources.

The need for a follow-up programme

This study has shown that a follow-up is a must if FCR shall become a mature technology and if misunderstanding and failures shall be avoided. Mainly with regard to the growing demand for low-cost roofing materials it is essential that potential and existing producers and users of FCR get additional information on the technical rationale - which also has to be improved. An FCR information network has to be established according to the importance of this technology and to the extremely large number of potential and existing producers and users of this technology.

A follow-up programme has to cover the aspects

- further research and scientific monitoring of FCR to mature the technology,
- qualified dissemination of the knowhow as well as appropriate training and technical assistance.

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Executive summary

Limits of application and acceptance

- The future users of FCR have to make a conscious decision to adopt FCR, in order to ensure their identification with the material and to prevent subsequent rejection which may happen for social reasons.

- Emphasis is needed on good training of the workteam and on quality control.

- A basic management organization is essential to undertake production, transport and use

of the FCR elements.

- FC roofing can be cheaper than any comparable material, but only if it is manufactured fulfilling accepted quality standards. Otherwise limited lifespan will destroy the economic advantage.

- The following points can be considered as the limits of application:

- **Insufficient standard of craftmanship in manufacture and installation**
- **Deficient roof structure**
- **Lack of good management**
- **Extreme weather conditions like hailstorms and hurricanes**
- **Vandalism, certain ballgames and fruit trees dropping heavy fruits**
- **Deficient raw materials**
- **Deficient tools and equipment**
- **Uncertain social prestige**
- **Public does not trust the new material**

It has to be noted however, that the same limits apply to other materials to a varying degree, particularly in the case of hurricanes.

Producer organization

- Economics are not purely valued in profit but in socio-economic benefits such as

- **Job creation**
- **Import savings**
- **Use of local materials**
- **Improvement of roofing technology**

**- If the producer and user are the same organization, the problems are more production orientated. Acceptance of the product Is easier In such cases, because the users are involved
In the production process.**

- In the case where the producer and user are separate, marketing becomes the first problem; quality standards and costs will be judged by the market.

- The buyer will ask for guarantees from the producer. But the quality of the roof depends also on the appropriateness of the substructure as well as on how the roofing elements are mounted on the roof. In cases where the producer sells directly to the user he might be In position to provide assistance and advice on these aspects. The producer should be able to give guarantees for the product; but in many cases he has no Influence on how the roofing elements are Installed on the roof substructure.

Technical rationale

- The chopped fibre plays Its main role In giving the fresh mix a better cohesion and It enables the moulding of corrugated products.

- All types of natural fibres are possible to use in FC as long as they are clean.

- Concrete with chopped natural fibres is a material with properties more like burnt clay than asbestos cement and it has to be looked upon as an unreinforced material.

- The durability of natural fibre concrete is good if the batching, mixing, compaction and curing are done properly.

- The stresses within the roofing element are dependent on its dimensions and how it is fixed. In this respect the roofing tile seems to have an advantage compared with the

roofing sheet.

Manufacturing technology

- The production of FCR is a sound technique and much practical experience is available.

- Failures are identified and are usually due to production errors.

- Tilemaking can be started in most places with fair chance of success, if professional training is provided and if the appropriate method is chosen.

- Future experiments should take into account the history and the state-of-the-art and not simply be in the spirit of "appropriate technology enthusiasm".

Installation

- The design of the roof structure should be simple.

- The minimum pitch should be 20°, but up to 30° is required in areas where torrential driving rains occur.

- Wind suction may produce higher forces than self weight.

- Good quality timber is desirable for the roof substructure though wood is getting scarce and expensive.

- FC tiles need approximately the same quantity of timber as FC sheets.

- Carpenters who traditionally build roofs for C.I. sheeting will need special training to achieve the more demanding quality execution required for FC roofing.

- Prior to installation on the roof, check FC elements for good quality.

- The laying of the sheets should be done by a team of carpenters and sheetmakers.

- FCR elements should be handled with great care.

- The driving of nails through the elements must be discouraged. If screws or "J"-hook bolts or nails through predrilled holes are used they must not be overtightened. Cast-in wire-loops which allow fixing from underneath seem to be a good solution as well.

- Treat FC products like clay tiles!

- Never go on a roof without crawling boards!

Costs and economics

- In most countries FC sheets or tiles can be produced at a cost of 2 to 4 US$ per square metre.

- A square metre of FC roof including cost for the roof structure varies between 4 and 8 US$, depending on the local situation.

- A FC roof Including roof structure can be built at 2/3 to 3/4 of the cost of a similar roof covered with asbestos-cement or galvanized corrugated Iron (GCI) sheets.

- The roof structure will consume half of the investment, the FC roofing material the other half.

- The economics of FC products depend largely on the life span of the sheets or tiles.

- From the technical point of view the life-span of FC pro ducts can be ten years or more.

- Both the manufacturer of FC products and the roof builder influence the lifespan of the products by their actions.

- Economics of FC are not only valued In costs but in other benefits to a local economy such as

- **Use of local resources**
- **Low Initial Investment**
- **Job creation for men and women**
- **Less foreign currency necessary**
- **Low transport costs.**

- The import component In a FC product - if any - is in the cement and the plastic for the moulds. It Is typically between 30% and 50% of the costs of the FC product.

Knowhow transfer

- Knowhow for proper production and application of FCR elements Is ready and available. But there exists a lack of provision of knowhow and technical rationale representing the actual state-of-the-art to the practitioners.

- Most failures in FCR production and application so far were due to no or bad knowhow transfer and insufficient professional training.

- Since the technical rationale of FCR is still in a process of development, the decision-makers and practitioners should be kept up-to-date with the provision of the most up-to-date data and facts.

- No continued professional education seems to exist. Continued knowhow transfer Is essential for the FCR producer.

- The dissemination of knowhow and continued support of the producer, adapted to the local demands, should be done through several regional FCR centres.

- A good FCR hardware kit must be accompanied by a well adapted knowhow transfer package.

- The decision makers need better Instruments to make their decision based on objective criterias.

- A complete "decision making package" should be prepared within the FCR follow-up study.

- The most efficient training seems to be possible at regional training centers or on the job, but there appears to be a lack of qualified teachers and money available for knowhow transfer and professional training.

- In many cases of the introduction of new products into new markets it is the dynamic (acceptance) of the market, which decides whether a product is appropriate for a given situation.

The producer has to Improve the product It the market refuses it. Our analysis shows that the FCR technology does not (yet) fit into this self-control by the market, because: FCR is not yet a well understood common technology. Therefore failures because of inappropriate production or application may discredit the technology Itself for the future. FCR is a roofing method which should not only serve the interest of a single manufacturer, but create additional jobs and save foreign exchange.

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Tiles or sheets?

This report is about Fibre Concrete Roofing. This includes both of the roofing elements “tiles” and “sheets”, the first being a further development of the latter. The comparison between FC-tiles and FC-sheets is a bit like a comparison between a truck and an oxcart: it is obvious, that the FC-tiles are the most developed product, and in most aspects they are superior to the sheets. Nevertheless, as there are situations where an oxcart is more

adapted than a truck, there can be cases, where sheets are the better choice than tiles. In most cases however the FC tiles will be the more appropriate product and cause less problems than the FC sheets.

Sheets	Tiles
FC sheets will be compared to asbestos or corrugated iron sheets; expectations will be difficult to meet.	FC tiles will be compared to clay tiles; expectations are easier to meet.
Only a good workteam will be able to guarantee a good overall esthetic appearance of a finished roof.	Good esthetic appearance is easy to achieve, as minor errors do not show easily.
Moulding needs a very well coordinated team of at least two workers.	One qualified worker can do the moulding .
Tamping or vibrating are difficult to standardize.	Vibration is standardised.
Production is possible without electricity and with very simple equipment.	Production process needs electrical or manual vibration.
Handling of the fresh product is difficult; risk of breakage.	Easy handling; almost no breakage of one day old tiles.
Curing in water tanks is difficult because of the big size of sheets.	Curing in many kinds of water tanks is easily possible.
Transport is rather difficult and risky.	Transport is less difficult.
Lower costs for equipment.	Higher investment for production equipment.
Higher cement content (1: 1); therefore more cement per square meter and higher material costs.	Lower cement content (1: 3); therefore less cement per square meter and lower material costs.
Heavier self-weight and less overlaps will withstand stronger wind forces.	Lighter cladding; easier to tee removed by wind if not tied down.

Handling of the sheets on the roof is breakage. difficult and may lead to	Easy handling on the roof.
Traditional craftsmen (used to GCI sheet and clay tile roof laying) need special training for FC sheets installation.	Where clay tiles are common, most craftsmen will be able to install FC tiles.
Bad supporting structure or warping of timber leads often to leakage.	Uneven parts of the roof structure can be absorbed to a certain extent by the tiles.
Replacing of sheets on the roof is difficult; other sheets may brake in the process of replacement.	Replacing of tiles is easier though not without problems.
Training is essential and has to be done by a qualified instructor. Minimum training time 2 to 3 weeks.	Initial training can be achieved in a shorter time but follow-up is required at initial stage of technology.
The stresses within the sheets are higher than in the tiles. Sheets are therefore more susceptible to cracking.	Due to its smaller size the stress within a tile is smaller and less cracking occurs.

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10 Key questions

Is there a genuine demand for a roofing alternative?

Are all the following materials available in your locality:

- cement
- sand
- water
- vegetable fibres
- good timber or metal supporting structures?

Are you aware that there is expenditure involved before you can even try out this technology?

Can you use or sell a FCR product that costs 2 to 4 US$ per m² in production?

Are you interested in creating jobs and saving foreign exchange?

Are you aware that FCR manufacturing may present some initial problems like any other production method? These problems can be mastered by good workers and good management.

Are you equipped for careful manufacturing with close supervision, maintenance of equipment and quality control?

Are you prepared to pay high attention to the initial knowhow transfer and professional training as well as to continued education and service?

Do you have a secure, dry site with good access?

Do you realize that all building materials have a limit to their service life?

If you answer every question with yes, you have the potential to go into FRC technology.

If not, you are advised to contact one of the specialist organizations.

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FCR: Fibre Concrete Roofing (SKAT, 1987, 185 p.)

1. Limits of application and acceptance

In chapter 1 Kurt Rhyner is treating the aspects

- **Social acceptance**
- **Economical limits**
- **Technical limits**
- **Competitive materials**
- **Material properties**
- **Transport problems**

Please note: Detailed information on all practical questions with regard to production, installation, costs and economics is presented in subsequent chapters.

1.1 Conclusions

The production and use of FCR is not a field for amateurism or experiments in the cause of

promoting Appropriate Technology.

Social aspects

- The future users of the FC-roofed buildings have to make a conscious decision to adopt FCR, in order to ensure their identification with the material and to prevent subsequent rejection which may happen for social reasons.

Technical aspects

- Consistent quality levels of raw materials, standardized production routines including handling and transport as well as correctly designed and constructed roof structures are essential.

- Emphasis is needed on good training of the workteam and on quality control. If any of those aspects is deficient, the consequence is a bad roof.

Management aspects

- A basic management organization is essential to undertake production, transport and use of the FC-elements, involving such aspects as marketing, production, training, maintenance of equipment, workers safety and welfare as well as financial control.

Economic aspects

- FC roofing can be cheaper than any comparable material, but only If it is manufactured fulfilling accepted quality standards, otherwise limited lifespan will destroy the economic advantage.

- It should not be encouraged where it could damage an existing appropriate local industry, such as most small scale clay tile producers.

The limits

The following points have been found to be the main reasons for problems and can be considered as the limits of application:

- lack of good management
- uncertain social prestige of the material
- public does not trust in the new material (conservative market behaviour)
- deficient raw materials
- deficient tools and equipment
- insufficient standard of craftmanship in manufacture and installation
- deficient roof structure
- vandalism, certain ballgames and fruit trees dropping heavy fruits
- extreme weather conditions like hurricanes and hailstorms

It has to be noted however, that the same limits apply to other materials to a varying degree, particularly in the case of hurricanes

1.2 Evaluation of experiences

Social aspects

While the questionnaire did not enquire directly in this area, it is evident that social factors have influenced greatly the answers to several questions, as it is the response by the public that determines a project success or failure.

It is in this area where some of the more severe limitations to the use of FCR have been found. Many of the big differences in appreciation from one project to another have their roots in social factors and not in the technical sector. The same quality of product can be a failure or a success, according to social factors.

When the user has a deep Identification with the material, It will almost always be a success. We have seen projects where the FCR apparently is a failure, but the rejected sheets that have been collected by poor people seem to make perfect roofs.

Economic aspects

According to almost all questionnaires FCR is cheaper on the market than just about any other roofing material in most countries and under most circumstances. Only in countries where a certain product is subsidized by the government may this be as cheap as FCR. It is however difficult to generalize anything about price relationships, and exact figures from one country may not reflect the situation of another.

However it can be said, that the price for tiles and sheets Is comparable, furthermore most marketed roofing materials have a substantially larger component of foreign exchange in their cost, with the exception of clay tiles if they are made by hand.

But dependent upon the timber supply situation in that country, that may be offset (clay tile roofs do need more timber).

The fact that 4 of the questionnaires report on commercial production and are describing it as a success, at least two of which are making considerable profits stands on its own. It is interesting that they do perform quality control, while generally little real quality check-up seems to be done in other projects which may lead to sloppy workmanship.

Technical aspects

Evaluating the questionnaires, we find that 13 cases refer to the production of large sheets (typically around 1 m long), using locally produced equipment, most often with asbestos cement moulds (9) though some have produced their own moulds out of cement (3) or metal (1). 4 questionnaires report on tile production (standard Parry method) and are

therefore using imported equipment.

In only three instances the experience with FCR was termed an outright failure and in three it was considered a mixed experience, all of these reporting on projects producing large sheets without proper training for production and installation.

On the FC tile production we hear only of experiences termed "successful".

While the low rejection rate of elements after production and transports seems to support these claims for success (only one report states more than 10% of loss, this one being an experimental station), this has to be taken with caution as these were mostly producers who answered the questionnaire and not all of them are also users.

While most sheet producers see many constraints to the wider application of their product (mainly low durability, problems with cracks and transport, lack of expertise in both production and application), the tile producers are very confident and see very few constraints (transportability, availability of good fibre) which it should be possible to overcome.

Tiles	Sheets	
4	7	success
-	3	failure
	3	mixed experience
1	3	economic venture
		type of moulds used
-	9	asbestos
4	-	PVC
	3	cement
-	1	metal
0 - 7 %	1 - 30 %	breakage total (inc. transport)

Summary of questionnaires

1.3 Comments

Social aspects

FCR is a material that does present technical problems, mainly when made in the form of sheets, and social factors determine whether those problems are being resolved quickly or whether they are allowed to develop into big problems.

Generally the experiences are positive where the owners of the roof had something to do with the decision and the manufacture of the material, as well as the installation, and where the form of payment of the houses is clear. Often pretexts are sought to not pay for

houses in government or NGO sponsored projects and minimal problems In the roof construction are exaggerated for this reason.

In public buildings, experiences range from total success all the way to total failure, often for social reasons such as maintenance or a resentment because the government or NGO did not provide a more prestigious material. Again, if the users made a conscious decision to use FCR the chances for success are far greater.

Often projects which use FCR are termed a success by some visitors and failure by others. This very often simply reflects the reaction of users, who are more or less identified with the product. For example during a meeting with the future inhabitants of a housing colony the people complained about the deficient roofing material, but a workman, who didn't have a house yet, asked permission to use the moulds to make some sheets for himself.

Not only direct physical involvement can bring about an identification. Probably even more important is the fact that the people have consciously taken the decision to use FCR, and this criteria basically applies to any material. Ifthe choke of the roofing material is sound, and In a guided project it should be, then the users can and must be Included In that decision.

Often we find that less than- perfect roofs are accepted and even defended by the owners If they feel that the work and the choice was really theirs, whereas practically perfect roofs sometimes a rejected in order to gain some social or economic pay-off if the beneficiaries do not have a real identification with the project.

Only those purely social factors explain why one group happily repairs the leaks in the roofs and meets repayments on the house, while another group nearby uses any defects in the roofs to justify their not paying their quotas Even after this latter group received new corrugated zinc roofs they still found another reason to not pay their quotas.

Projects where FCR is imposed for financial or philosophical reasons (Appropriate Technology) by the leadership will seldom work.

Care should be taken to not disrupt or endanger the trade of other local producers of existing
“appropiate” roofing materials such as clay tiles.

Technical aspects

It was about 1980 when the news about FCR started to spread and in many countries interested people began to experiment or called upon others for training.

A wide variety of procedures were invented and subsequently modified, a great deal of resources and time were spent, and often poor quality products were placed on roofs. But there are also several well-documented experiences which testify to the real possibilities for FCR.

Unfortunately, among those technicians and project directors interested in appropriate technology, many are very doctrinal and often apply manuals and instruction papers without adequate practical experience and, thereby, cause much damage.

Competitive materials

If a variety of roofing materials is freely available and the cost is not a direct and immediate concern of the users (aid programs etc) they will rarely make a deliberate choice to adopt FCR. However, FCR can compete in many markets because of its price or where other materials are scarce. Again, tiles seem superior to large sheets, for their appearance, uniformity and tradition.

In relation to organic (thatch) roofing materials, FCR Is more durable, more wholesome as

it does not attract insects, mice and rats, minimizes fire hazards, and usually is preferred for its appearance. But it has several negative factors because of foreign exchange element, technical dependence and usually higher cash cost.

FCR when compared with galvanized corrugated Iron sheets, Is usually cheaper, better for physiological reasons and has a relatively low foreign exchange content, but usually the public prefers metal sheeting if given the choice. Durability depends upon the gauge and quality of the corrugated iron.

Compared with asbestos cement, FCR usually is cheaper and because transport problems to the rural area can be avoided by production on-site, less foreign exchange is needed. But asbestos sheets are more certain to be durable, easier to handle and have more resistance to cracking.

Clay tiles need a much stronger wooden structure than FCR and they often are of poor quality. But usually they are cheaper, use less (almost nil) foreign exchange and are physiologically better, more durable and more aesthetically pleasing.

While the large sheets have the appearance of asbestos cement and therefore get treated as such, or, even worse, are treated like metal-sheeting, the FCR tiles are compared to clay tiles and, therefore, they receive more careful handling.

Nobody will try to walk on tiles, but one expects to be able to walk on a sheet, at least along the purling.

It is known that tiles crack if one throws stones at them and baseball is never played near tile roofs. But all those precautions which are inherent in many societies do not apply for FCR sheets, so the sheets often are subjected to much more wear and tear than the tiles.

Material properties

FCR sheets are far more rigid and fragile than most other types of roofing sheets and probably this is their greatest drawback, as the sheets are often treated Incorrectly.

Tiles have the advantage of being compared to and treated like traditional clay tiles and, therefore, can more easily fulfil or even surpass expectations. Because the stress within the tiles is smaller than in the sheets, tiles are less susceptible to cracking.

Mechanical damage Is the main problem affecting FCR products. It is often a deficient roof structure that causes cracking, through warping or bending of wood.

But also vandalism (stone-throwing) and baseball have caused much damage. Moreover, from Bangladesh there is a report that a hailstorm, with hailstones as big as fists caused severe damage. There has been no damage reported which seems to indicate deterioration of the sheets either through Influence of weathering, sun or other rays, heat, cold or ageing.

Some eight years of practical experience reveal that life expectancy may be high If no mechanical damage occurs from causes such as those discussed above. Repairs to minor cracks can be done by painting them from the inside with white glue or even oil paint. Larger forms of damage require that the sheet be changed and it has been discovered that, in order to do this, the remaining sheets have to be removed. If the sheets were nailed to the wooden Structure, heavy losses will occur, but if they have been fixed with wire loops or J-hooks only a few sheets should be damaged in this procedure. Again, the tiles are much easier to handle and breakage is minimal.

Economic aspects

While it seems unwise to produce FCR sheets for the free market, the sheets are widely used in development projects because of their low production cost. However, where the construction material market is tight and the public possesses the means to purchase, the

technique will spread to supply the free market. Such has been the case In Nicaragua, which situation has resulted in extreme differences in quality from one producer to another.

The use of tiles instead of large sheets appears to ease that situation, as the technique is more uniform and the possibilities for error much smaller. In Africa there exist several successful tile businesses that do compete on the free market. The cost advantage of FCR tiles over Gil sheets is primarily obvious for for small buildings with spans of up to 7.5 m. In Nepal, a 4m x 7m FCR roof costs 40 % less than a corrugated iron sheet roof. The reducing cost advantage for spans over 7.5 m is due to the closer spacing of rafters and the extra structures needed.

Transport problems

While breakage of sheets in transport according to the questionnaires does not seem to be a large problem (1 to 5 % breakage) it is established that in certain cases this figure may be much higher.

It can be said, that It depends almost totally on the driver of the vehicle, whether it be a truck or an oxcart, and certain precautions taken, like stacking the sheets vertically and with some soft packing material (grass, husk, old tires etc). There are many reports where no breakage occurred, but only If the driver is interested in his load, or if the owner is directly involved in the transport. The same holds true in most cases for asbestos cement sheets, though to a lesser degree.

Assessment

FCR is a real alternative to other roofing materials, with its limitations like any other material and should be used selectively. Generally, FCR is more suitable to small roofs and it is more difficult to use it on large structures because of the roof pitch necessary.

Also, the social integration of the community can place limitations and where vandalism is common, FCR might not be suitable.

Tiles are usually a better choice than large sheets, but there are places where sheets are better suited, mainly when the production facilities are adverse and the battery powered vibration table can be a problem because of the lack of electricity. In the near future hand operated vibrating tables for tile production will be available. By then the tiles will be the better choice in almost all cases.

Great care should be taken before embarking on a sheet production. Training and follow-up assistance have to be more extensive for sheets than for tiles.

Often, it is a deficient roof structure or social problems (including carelessness) which cause the cracks which determine the life span of a roofing sheet.