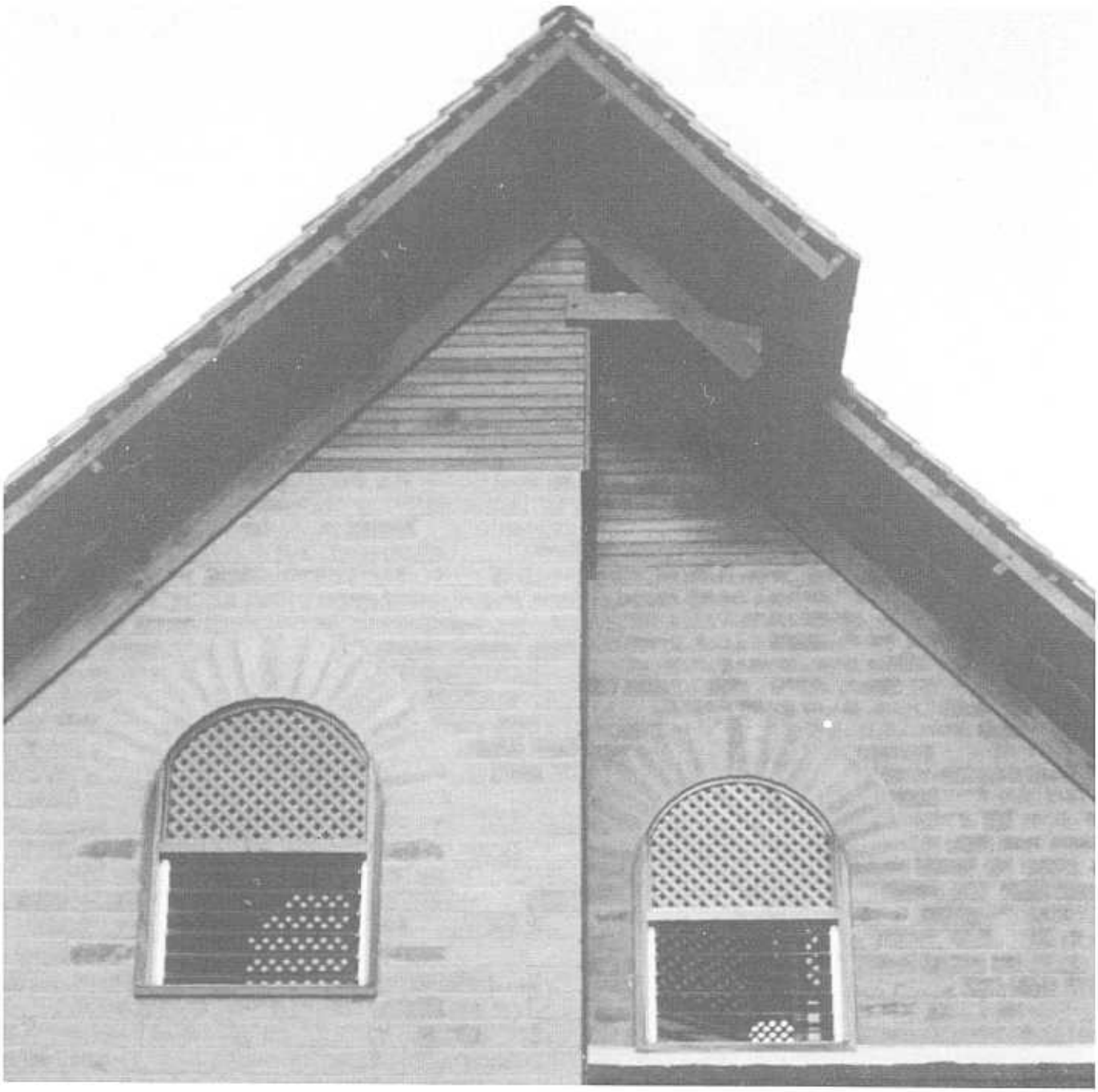
CRATerre

The Basics of

# Compressed Earth Blocks

Aus der Arbeit von GTZ



**GATE** - stands for German Appropriate Technology Exchange. GATE is a division of Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, a federal organization commissioned by the Government of the Federal Republic of Germany with the planning and implementation of Technical Cooperation activities with countries of the Third World.
GATE currently works in the fields of dissemination of appropriate technologies, environmental protection, conservation of natural resources and research and development. Within the GTZ, GATE is responsible for these activities on a cross-sectoral basis. GATE is divided into three sections :

1) **Dissemination of appropriate technologies**
   Dissemination and application of appropriate technologies, especially in connection with self-help activities :
   - Cooperation with non-governmental appropriate technology groups : cooperation agreements with NGO's in Africa, Asia, Oceania and Latin America.
   - Information service : documentation (appropriate technologies), exchange of information, question and answer service, publication of technical brochures, articles and a technical journal.

   Implementation of supraregional projects and programmes which serve as models for the adaptation and dissemination of technologies.
   Key activities at present :
   - Supraregional stove dissemination programme.
   - Supraregional biogas dissemination programme.
   - Micro hydro-power programme
   - Dissemination programme for animal drawn implements and machinery (gin technology).
   - Fund for small-scale appropriate technology projects.
2) **Environmental protection and conservation of natural resources**
   - Coordination of environmental protection activities at the GTZ.
   - Further development of methods and instruments for environmental impact assessment.
   - Technical backstopping and coordination of interdisciplinary and multisectoral projects in the fields of environmental protection and conservation of natural resources.
   - Cooperation with the relevant national and international organizations, associations and offices concerned with this sector.
3) **Research and development (R & D)**
   - Preparation of multisectoral and strategic R & D plans.
   - Coordination of ongoing R & D activities and planning.
   - Coordination of cooperation with R & D institutions.
   - Innovations management.
   - Implementation of selected R & D projects and programmes.

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# CRATerre

**CRATerre** - The International Center of Earth Construction, is an international non-governmental organization. The members of CRATerre are high-level professionals from various countries. Since 1973, CRATerre has been involved full time in all aspects of earthen architecture from the preservation of historic monuments to the setting up of modern production lines. CRATerre's five inter-related fields of activity are :

- Research : as an officially recognized research team, CRATerre carries out several research programs at fundamental and practical levels in various fields such as ethnology, economy, mineralogy, soil mechanics, technology, etc.
- Consultancy : CRATerre's missions in this field cover the project formulation, feasibility and investment studies, setting up of programs, building design, raw material prospection, planning and evaluation.
- Application : CRATerre members are currently engaged in field operations from architectural design to site supervision of social or educational building on behalf of governmental or non-governmental organizations.
- Training : in collaboration with the School of Architecture of Grenoble (EAG) and Grenoble University (USTMG), CRATerre runs post-graduate courses for architects and building engineers. CRATerre also organizes vocational training courses and thematic intensive training sessions in collaboration with organizations such as the International Union of Testing and Research Laboratories for Materials and Structures (RILEM), International Council for Building Research Studies and Documentation (CIB), United Nations Industrial Development Organization (UNIDO), International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and others.
- Dissemination : through the publication of scientific and technical books and manuals, an active participation in international meetings and a "question-and-answer" service, CRATerre contributes greatly to the promotion of earthen architecture and the dissemination of technical information.

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CRATerre

**The Basics of**

# Compressed Earth Blocks

Fundamental Information for :

Decision-makers
Building materials producers
Building contractors
Technicians
and all those who want
to know more about the CEBs

A publication of
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Cover illustration : © ROBIN Catherine, House construction with compressed earth blocks - SIMKO, Guyana

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# THE COMPRESSED EARTH BLOCK

**Earth construction**

For 10 000 years, earth has been used as a building material. Today, one third of the world population is living in earth buildings. There are twelve principal well-known methods using earth as a building material. Amongst these, eight are currently employed and constitute the major techniques.

- **Adobe :** the earth, in a malleable state, often improved by addition of straw or other fibres, is moulded into a brick form and dried in the sun. (11, 12 13)
- **Rammed earth :** the earth is massively dumped into formworks, compacted by means of a rammer, layer by layer, and formwork by formwork. (5)
- **Straw clay :** the earth is spread out in water until a homogeneous thick liquid state is attained. This muddy liquid is mixed with straw in order to form a film on every wisp. The building material obtained conserves its strawlike aspect. It is put into place by means of a formwork in order to erect a monolithic wall which necessitates a primary support structure. (16)
- **Wattle and daub :** clayey material, mixed with straw or other fibres, is layered on top of wattles that fill in a timber structure. (14, 15)
- **Shaped earth :** the earth, often improved by the addition of straw or other fibres, is shaped into a wall using the same technique as that used for pottery, without tools. This ancient technique is still widely used. (4)
- **Extruded earth :** the earth is extruded by a powerful machine similar to, or derived from, the machines used for the manufacture of fired brick. (10)
- **Cob :** the earth, often improved by the addition of straw or other fibres, is shaped into big balls, which are piled on top of one another and lightly packed, by hand or foot, in order to erect shaped monolithic walls. In other cases, the cob is incorporated into a timber framework or structure. (3)
- **Compressed earth :** the earth is compressed, in block form, in a mould. In the past, the earth was compressed in the mould by means of a small pestle, or by tamping a very heavy lid forcefully on the mould. Nowadays, a wide variety of presses is used. (6, 7)

**Compressed earth blocks (CEBs)**

In view of the history of earth construction, the compressed block technique is a new technique. It has been developed in the fifties in the frame of a research program concerning rural housing in Colombia. It is an improvement of the adobe technique. Instead of being moulded by hand in a wooden frame, the blocks are formed by compressing earth, slightly moistened, in a steel press. Compared to the hand-moulded block, the CEB is very regular in size and shape, and much denser. It has better resistance to compressive stresses and to water.

**From village to town**

CEBs can be produced in small scale village workshops as well as in medium or large scale urban plants.

**At all levels of society**

CEBs are of regular shape and size, making the production of fine masonry easy. The CEB can be used in prestigious buildings as well as in social building programmes.

**National industry**

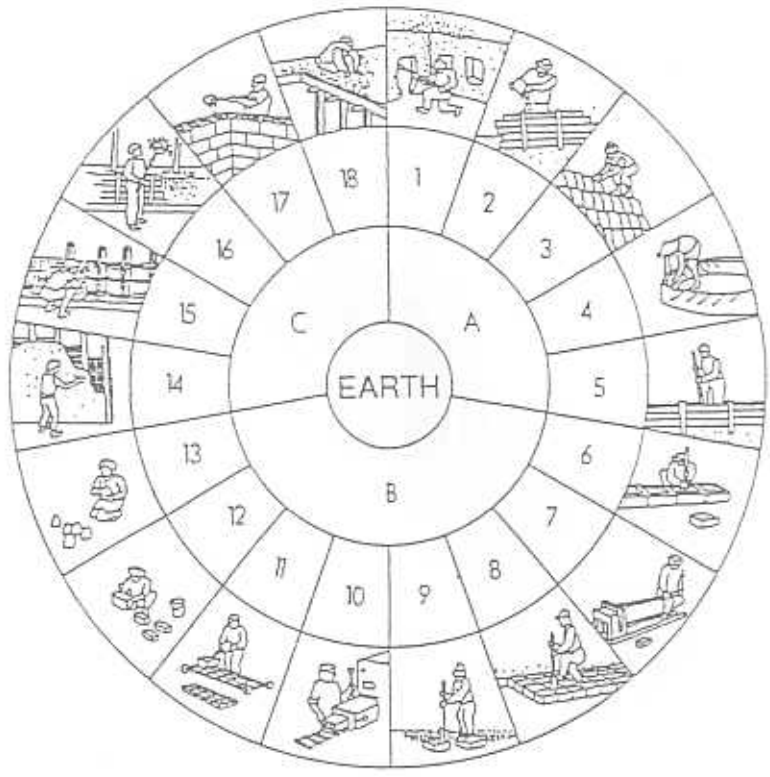
Between traditional and low grade techniques and imported modern materials, the CEB provides an alternative and its production may constitute a first step in setting up a national industry in the building materials sector, using national labour and local resources.

**Failures and improvements**

In the early stages of the development of the CEB technique, the attention of researchers was focussed mainly on the strength of the blocks and the design of presses. But experience has shown the importance of other production parameters such as selection and preparation of the soil. Failures were generally due to an underestimation of some production parameters or due to an improper building design. Since the beginning of the 80' s great stress has been laid on vocational training in the field of production and building techniques at every level. Technical data obtained on sites or from researches have been put into practice. When properly managed, building programs involving CEBs have been a success.

**Further development**

Improving existing equipment and developing new tools specific to the CEB is one way of assisting the spread of the technique. Another key to a successful dissemination is the development of managerial tools at workshop level as well as for the implementation of large scale programs. Furthermore, research and further development has still to be done in the field of building norms, standards and technical manuals to facilitate the introduction of the technique to the formal building sector.



# ADVANTAGES OF THE CEB

### Improving traditional techniques
Where there is a demand for improving traditional building materials made of raw earth, CEB may provide an answer because the production methods are technically accessible to the local labour, and because laying CEBs requires only elementary masonry skills.

### Building programs
Setting up large scale building programs or building in urban areas means using standard designs for the houses. Standardized building materials of known size and tested quality such as CEBs are needed for construction. And if the houses have been designed using a modular system consistent with the CEB size and shape, much time and money can be saved.

### Building techniques
The CEB is a very practical building material suitable for a beam-and-post system as well as for a load bearing wall system. It is easy to make arches over openings to save on concrete or wooden lintels. When the blocks are laid properly and the outside of the wall is not too exposed, the wall does not need any rendering. The CEB is economical not just in itself but also because it makes the application of economical building techniques and designs possible.

### Reducing imports
In regions and countries where building materials like cement have to be imported and transported over long distances or under difficult conditions, the CEB is often an economically attractive alternative.

### Market opportunities
Financially, the profit to be earned from marketing CEBs depends on the local situation : the cost of the stabilizer, labour, raw material. A feasibility study has to be carried out to establish the profitability of a CEB production unit in every particular case. But in most cases, CEB buildings are cheaper than buildings made of sand-cement blocks.

### Flexible production scale
CEB production equipment exists for the small scale as well as industrial scale units, thus, CEBs can be used in a wide variety of contexts.

### Social acceptance
In its early stages, the CEB was associated with social housing or village housing i.e. habitat for the low-income population or the poor. Since that time, it has been convincingly demonstrated that the CEB can also be introduced in buildings such as houses for the better-off. Compared to traditional materials, the CEB is a vast improvement.

### Limiting deforestation
In regions where building involves materials produced using firewood, the CEB contributes to limiting deforestation.

### On the building site
The standardized shape and size of the CEB make bricklaying, handling and storage easy. Saving time means saving money. The CEB facilitates savings on the general management of a site.

### Constraints
The main limitations to the production and application of the CEB are :
- lack of proper soil;
- big spans;
- high rise building design;
- high cost of some production inputs;
- low social acceptance;
- restricted or out-dated building codes.

### Failures
Experience in many countries has shown that when failures occur with CEBs, it is often due to lack of preparation in the projects and a poor understanding of the basic principles of CEB production. The most common mistakes are :
- Wrong selection and bad preparation of soil.
- Bad choice of production equipment.
- Bad curing.
- Lack of knowledge about the CEB specific principles of design and bricklaying.
- Untrained production teams.
- Lack of quality control.
- Lack of reliable preliminary feasibility studies.
- Overestimation of CEB technical performances.

### Technical performances
Compared to other modern building materials, the CEBs have lower compressive strength but their performances are still good enough to plan 2-3 storey buildings with CEB load bearing walls. Thermal performance is good and durability can be very good if the specific building principles are respected. The energy involved in producing a CEB wall is very low.

*Improving the housing standards*

# CEB PRODUCTION

### Three stage process
Producing a CEB is a 3-stage process:
- preparation of the soil,
- compression of the mix,
- curing the blocks.

### Preparation of the soil
Selection of a soil with a good grain size distribution and good cohesive performances is essential. Generally, the raw material has to be prepared before compression. The principal operations are:
- pulverizing the raw material and sieving out the largest clay lumps, gravel and stones to obtain a powdery material with which the stabilizer can mix most efficiently;
- mixing the prepared soil and the stabilizer and then moistening the mix.

### Compression
It is not necessary to exert a high pressure to obtain a good block as long as the soil has been chosen correctly. A producer must remember that a press is as good as the earth that is put in it. The strength of a compressed block depends not only on the quality of the raw material, the press design, but also on the size and shape of the block and the care with which the production team is operating, as well as on many other parameters.

### Curing
A CEB can be handled and stacked immediately after being compressed but it does not attain its complete strength immediately and needs a curing period under particular conditions. A hot and humid atmosphere gives the best results. Preventing rapid drying out by keeping the CEB moist is essential. The time needed to achieve a proper cure depends on the weather conditions and on the type of stabilizer. When cement is used as a stabilizer, the recommended curing period is four weeks. Some equipment producers claim that it is possible to use the CEBs produced with their equipment directly, without any drying beforehand. While this technique is attractive from an economical point of view, the technical results are less convincing.

### Manual or motorized production lines
Depending on the production scale and the local cost of labour, preparation of the soil and compression can be achieved with manual or motorized equipment.

### Fixed or mobile production lines
Production equipment, with the exception of industrial machinery, is generally fitted with wheels or light enough to be moved by hand. Thus CEBs can be produced in a permanent workshop and then transported, or the equipment can be moved from one building site to the other.

*A CEB production site in France*

### Light infrastructure
The production of CEBs requires some space for storing the raw material and for curing the blocks. The production itself, however, does not require too much infrastructure. If no rain is expected, the production can be set up in the open. But the stabilizer and small tools have to be kept in a closed storeroom.

### Team work
As the soil is processed in several stages, it is important to have good coordination in the production team, i.e. good labor management. With a manual press (300 to 600 blocks per day) 3 workers are needed for pressing and storing the blocks, and 2-4 workers are needed for preparing the soil. On a small motorized production line, as many workers are needed but production can reach 2 000 CEBs daily

### Basic skill
The basic know-how to operate the equipment is easy to accumulate even for unskilled labor. But the production team has to master the general principles of the process (importance of soil selection, moisture content, curing conditions, etc.) to be able to produce good quality products. Vocational training is necessary at the start.

### Quality control
Good appearance does not always mean good quality and durability. At each stage of the process, quality needs to be checked. Simple but efficient procedures and tools have been designed for that purpose.

### Production management
Production management has a direct influence upon the productivity and the profitability of a workshop. For example, the raw material must be ordered in time to be delivered before the stock is exhausted, or the stock of curing blocks must be stacked in such a way as not to congest the production area.

### Financial monitoring
Financial monitoring of the activity is as necessary as production management. Understanding the financial consequences of technical decisions is essential.

# CEB FOR ORGANIZATIONS

### Housing programs

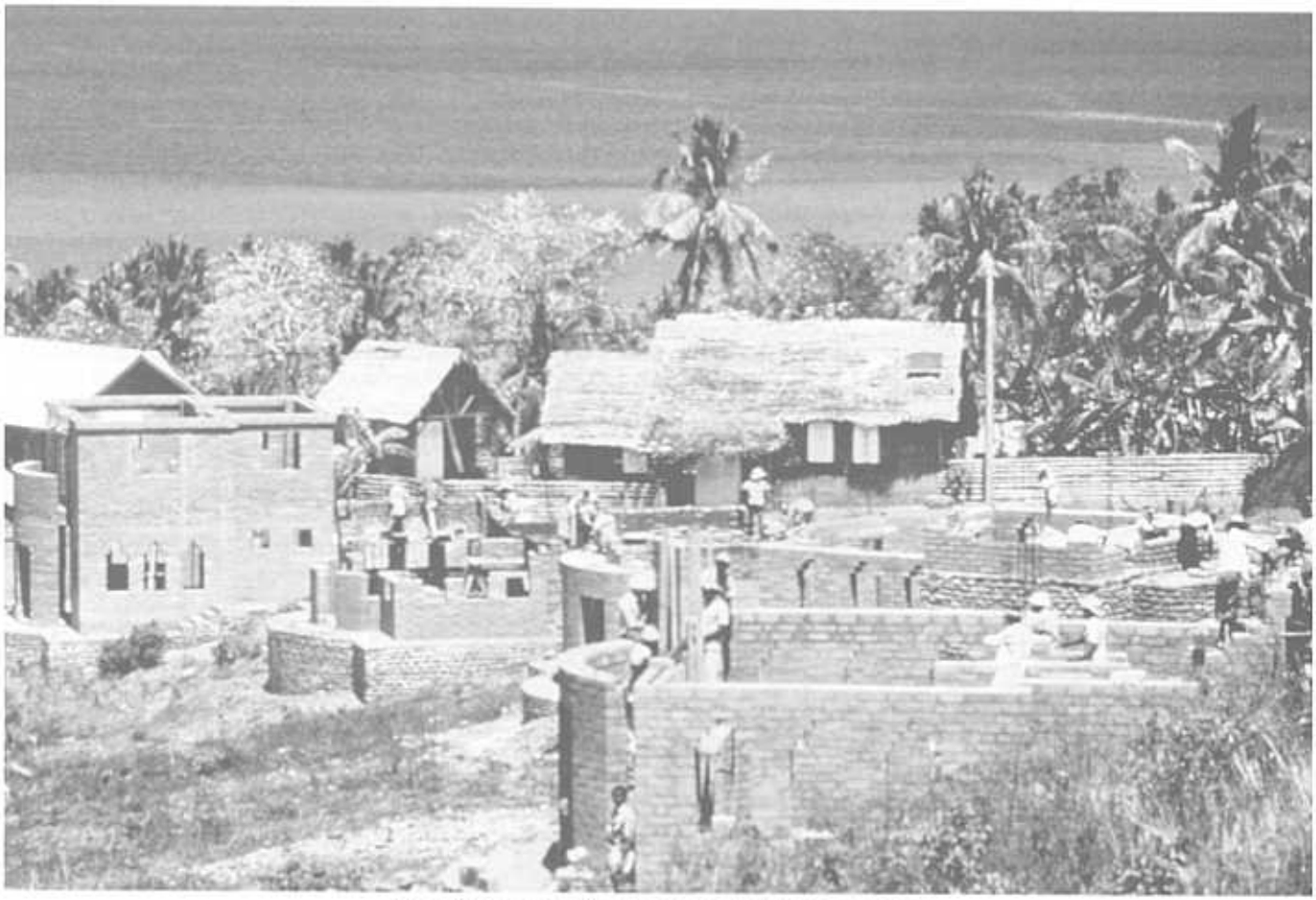
Governmental and Non-Governmental Organizations are often in charge of housing programs. The success of such operations is mainly a question of management. The CEB is a standardized product. An optimum block size and shape can be determined before starting work and standard designs can also be prepared. Production and delivery of building materials can be planned. Monitoring the progress in the brickwork is easy and so is the financial evaluation. Controlling quality is also easy. Standardization of products is often a reason for using imported, modern materials even if they are more expensive. In that respect, the CEB provides the same advantages as modern materials, but at the low-cost of a locally made product.

### Social acceptance

Another key to success in a housing scheme is the social acceptance of the dwellings by their future inhabitants. They generally ask for a "modern" look, i.e. a house made of sand cement blocks. But at the same time, the traditional way of life must be preserved and attention has to be paid to the local climatic conditions, especially in hot countries. The CEB looks modern. Its flexible size and shape allows it to be used to achieve many different types of masonry and so to build houses of any style. In hot countries, and even more in those with a wide thermal diurnal variation, a CEB wall creates a truly comfortable living environment compared to sand-cement based materials. Occasionally, a social reluctance to use the CEB can be encountered when the CEB has been too strongly associated with low cost or "cheap" building. Social acceptance depends a great deal on how it is presented to the population. Organizations have an active part to play in this respect, as well as political decision makers. The involvement of architects and planners in this process is also necessary.

### Development

Housing programs are often integrated into a strategy of development. One must consider not only the direct benefits of the program (number of improved dwellings) but also its effects on the local economy. An organization can produce CEBs on the site itself or encourage local entrepreneurship by subcontracting the production to local production teams. In any case, vocational training provided during a program is a benefit for the community. Housing programs can provide an opportunity to set up a local industry if appropriate materials such as CEBs are preferred to materials based on imported components.



*A social program in Mayotte island : 1 000 houses per year*

# CEB FOR PRIVATE CONTRACTORS AND ENTREPRENEURS

**Building contractors**
When they are involved in medium scale construction sites, where they are asked to use CEBs, building contractors can integrate the production of CEBs into their activities. In this way they save on transport and become independent of the building materials retailers. But they will have to prove the quality of their product. Individual customers would perhaps be reluctant to have the building contractor producing the blocks on the spot because it would be difficult for them to assess the quality of the product. But if the owner or the contracting authority of the site is a large organization which can set up a procedure of acceptance for the materials, there should be no problem in integrating the production in the building site.

**Entrepreneurs**
A small and, occasionally, a fairly big business can be set up producing CEBs. The activity can be set up step-by-step, according to the means of the producer and the growth of the market. Profitability might not be immediate but would come soon if the producer were keen to succeed. Selling CEBs is possible only if the market is open. Participating in or organizing pilot operations to promote the CEB is therefore essential. The producer then has to maintain the technical credibility of CEB products if he wants to broaden the market. At the early stages, it would be wise to supply only builders with a proven skill, especially with respect to appropriate building design. Otherwise, failures can be expected and the CEB will fall into disrepute, even if the quality of the block itself is not the actual reason for the failure.

**Quality**
Facilities must exist locally to perform quality control which gives the users a guarantee and the producers credibility. Quality control is more often a benefit for the entrepreneurs concerned than a handicap. If advisory services are provided at the same time as quality control, conditions are optimized for developing the activity. Advisory services must include production, management and basic accounting training.

**Building materials range**
Producing and marketing different but complementary building materials like CEBs and micro concrete or fibre concrete roofing tiles might benefit the entrepreneur as it would draw more customers into his workshop and diversify his sources of income.

*A private manufacture in Cameroon*

# INVESTMENT AND PRODUCTION COST

**Investment**

The investment depends mainly on the size and the type of equipment :

| | Class 1 manual | Class 2 manual | Class 3 motorized | Class 4 motorized | Class 5 motorized |
|---|---|---|---|---|---|
| **Production/day** solid blocks 29,5 x 14 x 9 | 600-700 | 1 200-1 400 | 1 400-2 000 | 1 400-2 000 | 2 800-4 000 |
| **Equipment :** press<br>mixer<br>pulverizer<br>conveyor belt<br>manual trolley<br>fork-lift truck | 1 manual | 2 manual<br>1 x 250 l | 1 motorized | 1 motorized<br>1 x 250 l<br><br><br>1 manual | 2 motorized<br>1 x 500 l<br>1<br>3<br>1 manual<br>1 |
| **Workers** | 9-10 | 11-13 | 12-14 | 9-10 | 9-12 |
| **Workshop area** | | | | | |
| total (sq.m) | 380 | 530 | 800 | 800 | 3 250 |
| closed area | 10 | 15 | 20 | 15 | 30 |
| weather-proof shed | 30 | 100 | 80 | 40 | 90 |
| open area | 340 | 515 | 700 | 745 | 3 130 |
| **Investment in equipment**(USD) | 2 600 | 12 600 | 14 500 | 30 600 | 75 440 |
| **Investment in Infrastructure**(USD) | 860 | 1 950 | 2 100 | 1 500 | 8 900 |
| **Total Investment**(USD) | 3 460 | 14 650 | 16 600 | 32 100 | 84 340 |

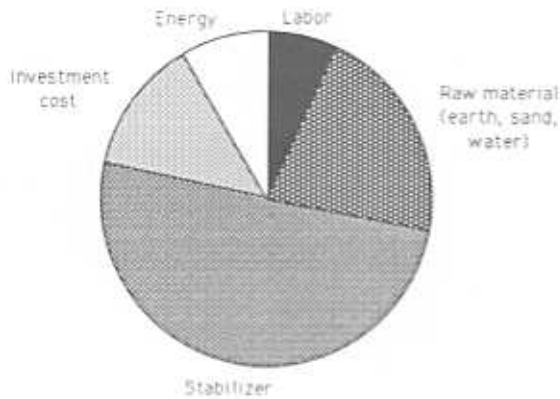
(feasibility study, Ivory Coast, 1987)

**Production cost**

The production cost of a compressed block is very dependent on the local cost of the main inputs : stabilizer, raw material and labour. A feasibility study is essential to determine the best set up for a production line, as the following example from Chad shows :

- production of CEBs of standard size and shape (29.5 x 14 x 9 cm) stabilized with 6 % cement.
- equipment : one motorized press (2 000 blocks/day), one 500 l mixer and one motorized pulverizer.
- labor : 7 laborers, 1 supervisor.

| | | |
|---|---|---|
| Type of production line | : | mechanized |
| Production (blocks per day ) | : | 2 000 |
| Production cost for 1 000 blocks (USD) | : | 186 |




In this particular case, the feasibility study shows that the stabilizer is the most important item in the total cost of the block. The producer should look for a more economical stabilizer than cement. Lime, if it is locally produced, could be an alternative. The labor accounts for only a small proportion of the total cost; thus if the producer wants to achieve better productivity or to ensure good quality, he can distribute incentive bonusses to the workers without greatly affecting the final cost.

# COST OF CEB BUILDING

**Building with CEBs**

The first question a potential user will ask is whether a building built with CEBs is more economical than one built with any other material. First of all, one must consider the type of building. In a luxury villa, the cost of the wall building materials accounts for very little, about 10 % or less, of the total cost. In that instance, carpentry, plumbing, electricity, flooring, etc. will represent a large part of the cost. Choosing the CEB to build a prestige villa is mainly a question of thermal comfort and of taste. Money will be saved on the consumption of electricity, because air conditioners will work less than in a hot sand-cement blocks villa. But in low cost houses, such as those of social housing programs, the cost of walls is a major component of the total cost. In that case the choice of the wall building materials and the wall building techniques are more critical. The CEB is often preferred because it is more economic in itself and permits the use of economical building techniques, such as a block arch instead of a concrete lintel, as shown in the example below.

**Types of wall**

To make realistic comparisons, one must consider a complete section of wall. For example, a wall made of sand-cement blocks is generally plastered on both sides with a cement based render and has a reinforced concrete post every three or four meters. A CEB wall will be rendered, at most, on one side and concrete posts are not necessary. The cost of plastering and of structural elements have to be introduced into the calculation for the sand-cement blocks wall. In a well designed CEB wall, where rendering is not necessary, the advantages of the CEB are obvious.

**Traditional earth materials**

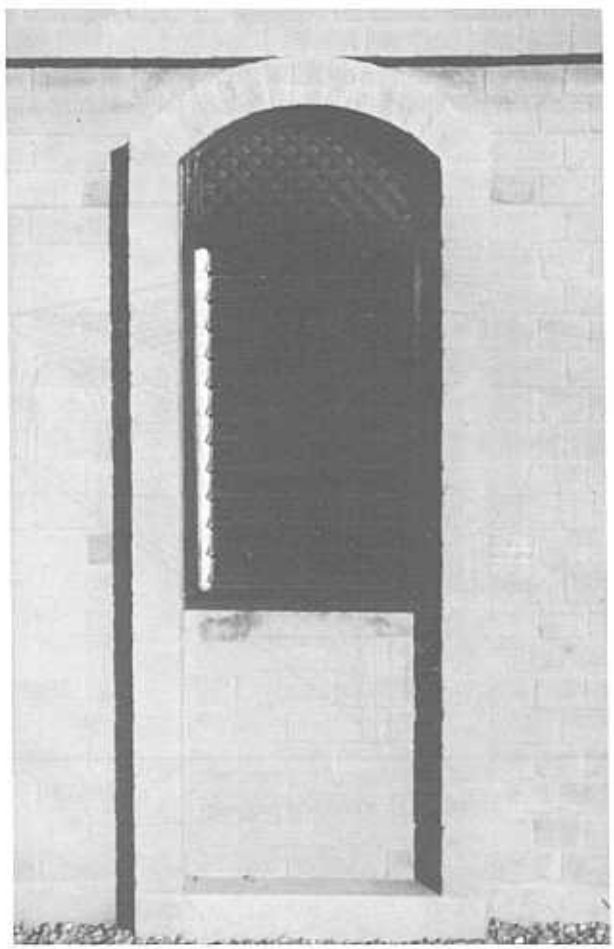
CEBs are always more expensive per unit than traditional hand moulded earth blocks, because of the cost of the equipment and the use of a stabilizer. But, in the long term and in particular circumstances, it can be cheaper to use CEBs. Buildings made of CEBs need less maintenance and in a large building program the standardized size and shape of the CEB allows rationalization of supplies and handling.

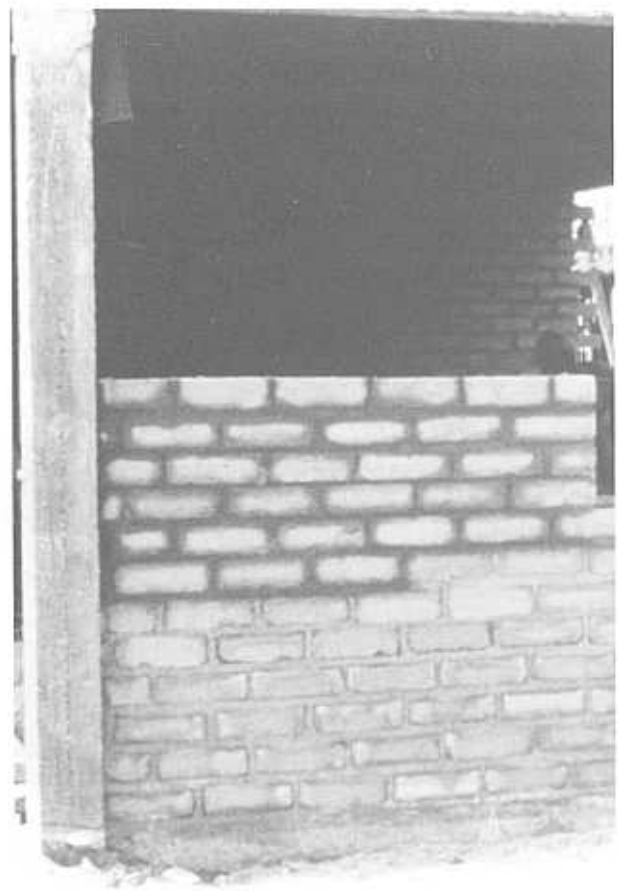
**Modern materials**

The use of sand-cement blocks is increasing rapidly in every part of the world. But their thermal performance is poor, and their cost very dependant on the local cost and availability of cement. Furthermore, a sand-cement block wall always requires rendering and so, in most cases, a building made of CEBs is cheaper.

**Compatibility**

Experience has shown that a preliminary feasibility study is always advisable to compare different building materials. But in the field, it is common to design buildings where exposed parts are made of concrete or sand-cement blocks while the main walls are made of more economical CEBs. Trying to build only with CEBs, including foundations and roofing, can prove difficult. Complementarity rather than competition should be sought when investigating the potential of building materials for a project. The most durable and economical houses are generally the result of a skilful combination of several building materials. For example, some contractors on building with a concrete frame and CEB as filling material.





# KEY QUESTIONS FOR A POTENTIAL PRODUCER

If you are considering setting up a production unit for compressed earth blocks, or want to work with CEBs, you have to pay great attention to the following key points :

- mastering a new production technique
- mastering new building principles
- managing a production process
- marketing a building material

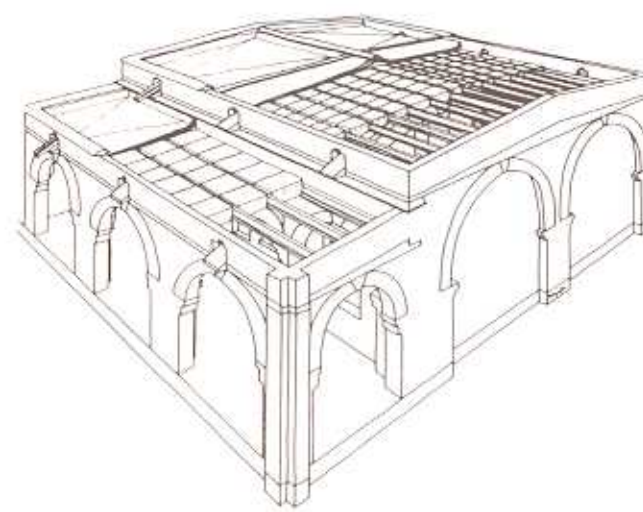
To evaluate your project, please work through the following checklist.

### Ten key questions

| yes | no | |
|---|---|---|
| ◊ | ◊ | Do you know if the local soil is suitable for construction ? |
| ◊ | ◊ | Do you already have a building program and on what scale ? How many CEBs of standard size ( 33 CEBs per square meter ) would that mean ? |
| ◊ | ◊ | If you plan to sell your blocks, do you have figures about the demand for building materials in your area ? Do you have positive indications about the social acceptance of CEBs from potential buyers ? |
| ◊ | ◊ | Are you aware that design and appropriate use are important besides making good blocks ? Do you know any builders who have mastered the CEB design principles and CEB bricklaying techniques ? |
| ◊ | ◊ | Do you know where to get help for training and an advisory service ? |
| ◊ | ◊ | Have you collected information about different types of equipment and tried to make comparisons ? |
| ◊ | ◊ | Do you have information about the local availability of a stabilizer ? |
| ◊ | ◊ | Have you made an estimation of the investment needed and does it match your own financial capacity ? |
| ◊ | ◊ | Do you have experience in workshop management and accounting ? |
| ◊ | ◊ | Are you aware that it would take a while before all your efforts and investments are paid off ? |

If you have answered every question with "yes", you have the potential to undertake the production of CEBs. If not, you must continue to prepare your project more thoroughly and you would be wise to contact one of the specialist organizations for assistance in decision-making.

*Availability of local resources*



*Plans for a building program*

# TEN STEPS TO SET UP A SUCCESSFUL PRODUCTION UNIT

1 Local availability of sufficient suitable soil and the possibility of organizing its extraction easily must be checked.

2 If a supply of soil is established, a feasibility study should be carried out to prepare the project. This feasibility study should comprise a technical study including an analysis of the local soils, a description of the best production methods in the local context, a description of the equipment needed and where it would be available, a study of production costs. A market survey will complete the technical study; it should include figures about the demand for building materials and the opportunities for using CEBs, the size and shape of the product and the maximum price for the CEB to be more attractive than other building materials.

3 Local building regulations, and if they allow the use of CEBs, must be checked, as must requirements about technical performance.

4 Securing the capital to cover the investment required and the first month's expenditure is the next step before the laying out of the workshop.

5 Ordering the equipment can be done simultaneously with the preparation of the production area and the construction of the few buildings necessary : storerooms, office, etc.

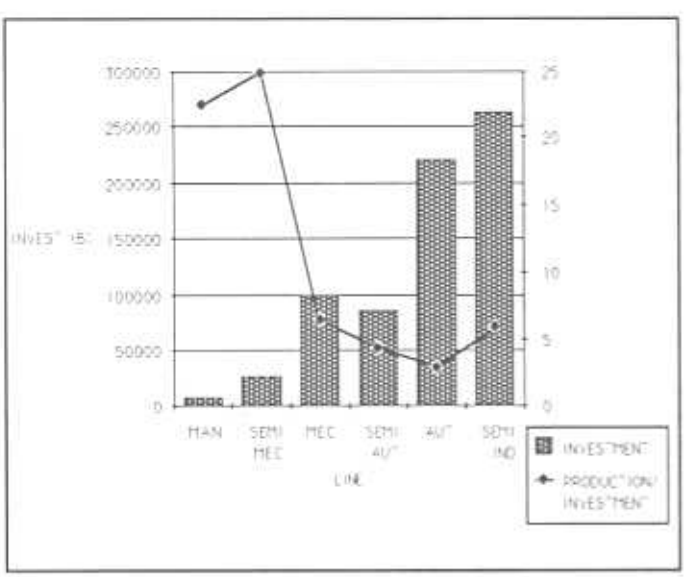
6 A training course on production and workshop management must be carried out by an experienced organization during the installation of the production equipment. Production tests can then be undertaken.

7 As soon as the results of the production tests on the production process are available, commercial production can start. Quality control procedures must be set up as soon as commercial production is underway.

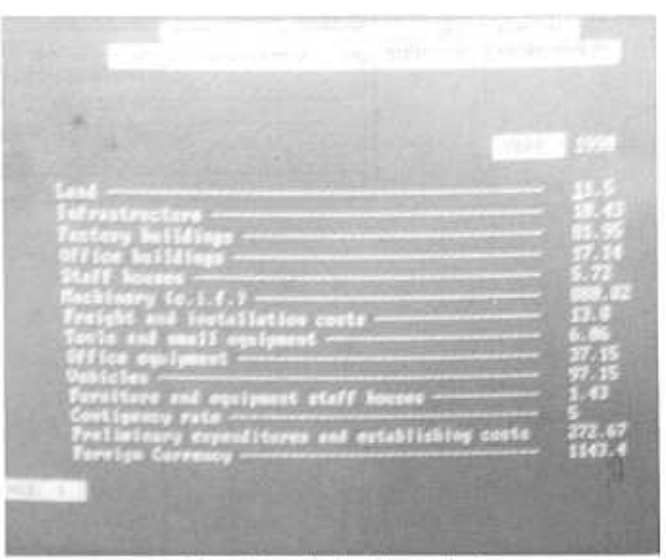
8 Before or as soon as production starts, the entrepreneur or the workshop manager must become suitably qualified in marketing, accounting and production monitoring.

9 The workshop manager or a qualified technician must check how the CEBs are used and give technical advice if anything goes wrong.

10 During the first months, a producer would be wise to keep in touch with one or more competent associates from whom he can get technical or marketing advice.




*Selection of a production scale*
*Estimation of the part of investment*




*Financial analysis of the project*

# THE WORKSHOP AND PRODUCTION SITE

### Selection of a site
The production of CEBs needs space because it is necessary to store raw materials and to cure the blocks. A production site has to be of a good size. An expansion of activities is always possible and provision should be made for this.

### Building sites
If the workshop is not located directly on the building site, one must take into consideration the average distance for delivering the blocks to the potential buyers. CEBs are heavy and the cost of their transportation is not without effect on their total cost to the customer. Marketing criteria of this kind have to be taken into account to select the best location for the workshop.

### Access and circulation
To enable the supply of raw materials and the delivery of the blocks, provision must be made for sufficient room for carts or lorries to have direct access both to the area where raw materials are to be stored, and to the area where dry bricks are stacked. If production is intended to be run all year round, access must be possible at any time of the year, even under bad weather conditions.

### Water
The production of CEBs does not require a lot of water but the availability of water on the site is of great help.

### Organizing the production line
Depending on the equipment in use and the local context, one can choose to locate the production equipment either as near as possible to the raw materials or closer to the curing area, in order to minimize the distance which the workers have to carry the blocks after pressing. This means that when production is high and the stock of curing blocks is growing quickly, it could be necessary to move the equipment more than once a day. This option is available only if mobile equipment has been chosen.

### Making room
Working out the area needed at each stage of the production process is essential to minimize transport and handling and to facilitate circulation or activities. The production site has to be divided into four areas :

- *raw material* : depending on whether it is delivered daily or periodically, the space needed will be small or large.
- *soil preparation* : the working area must be sufficient to operate a pulverizer and a mixer. This area must be close to the raw material stocks so that the pulverizer can be fed directly.
- *compression* : the space needed to operate the press is very little.
- *curing* : this area can be subdivided into two : a small area used to store a few rows of blocks for a day after compaction, and another, much larger, area for final curing taking 15 or 20 rows, each comprising one day's production. But it is preferable to have enough room to allow for 5 to 10 rows to be cured directly next to the production area.

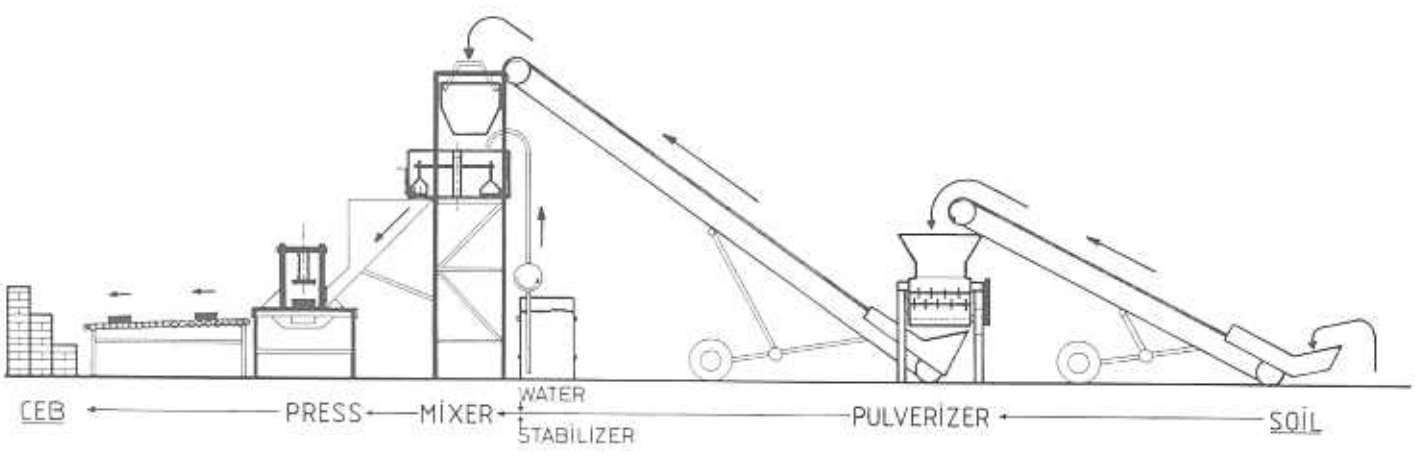
### Base
It is not necessary to have a concrete floor throughout but the ground must at least be flat and hard. In the long term, it is preferable to prepare a concrete or stabilized earth base for the production area.

### Storerooms
The stabilizer has to be stored in a dry and secure room. Another room is needed to store tools, maintenance equipment and spare parts. Facilities for maintenance and minor repairs such as a bench, welding set, etc. would be very useful.

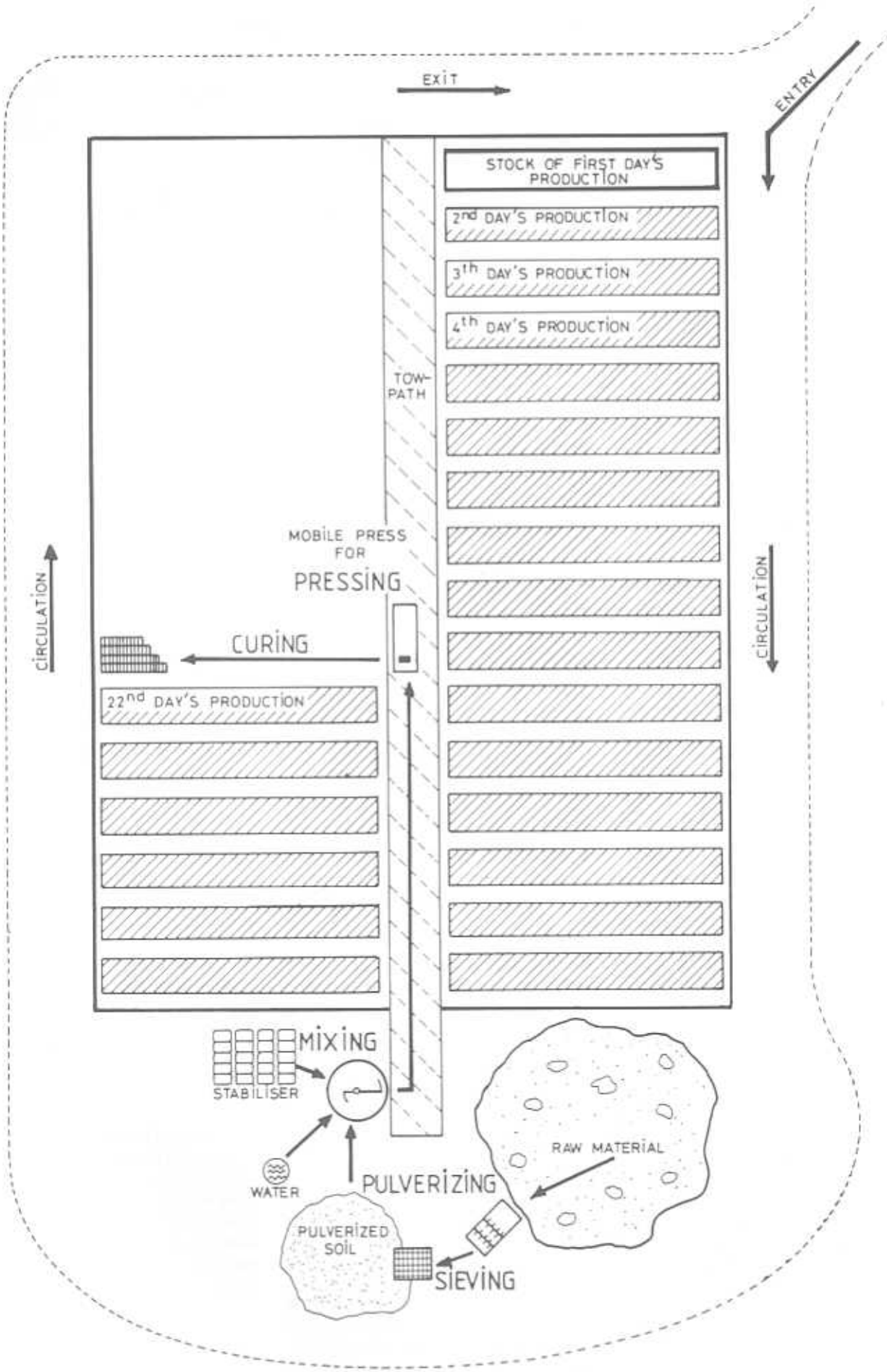
### Office
It is advisable to include some room for a small office to do the administration. Books and documents must be kept secure.

### Mini-lab
Space is also needed to perform identification and control tests. It is preferable to set aside a specific area in the workshop for that purpose.

### Working conditions
In hot countries, handling dusty materials all day long may become very arduous and productivity will soon fall if no action is taken to protect the workers against the wind or the sun. Hence roof cover should be provided for the main working areas.

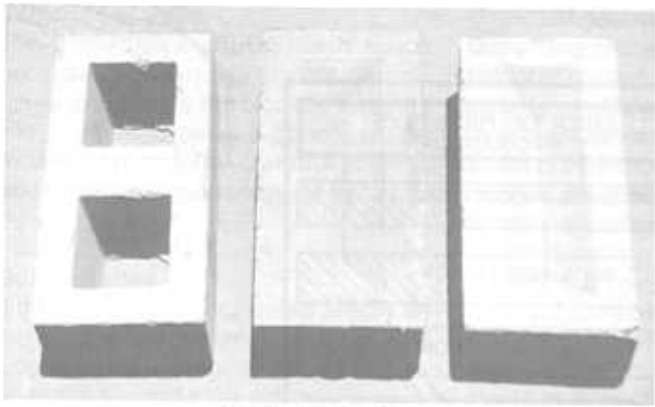



*Lining the equipment according to the production sequence*




*The production site : a question of room management*

# IDENTIFYING THE RIGHT PRODUCT



*Solid and hollow blocks*

*Interlocking blocks*

### Building and marketing

Before starting production and even before purchasing a press, deciding on the type of block to be produced is essential for both technical and commercial reasons. The quality of a block and its acceptance by the bricklayers depend on its size and shape, which are also important for the designer and builder in applying economical modular building systems.

### Compression

The larger the block, the more energy is needed for compression. This is why the volume of a block produced with a manual press is limited to a maximum of 40 x 20 x 10 cms and such a large block would have poor compressive strength. Generally the recommended size is 29.5 x 14 x 9 cms. With a motorized press, it could be possible to produce bigger blocks but they would soon be too heavy to be handled easily on a building site. Small blocks of 22 x 14 x 7.5 cms are sometimes preferred by masons as they are lighter and can be handled with one hand.

### Standard block

The exact dimensions of a block must be calculated in the light of the required bonding pattern. To obtain a proper result with any bond without difficulty, there must be an optimum ratio between the length and the width of a block: the length must be twice the width plus one mortar joint. This will allow the blocks to be laid in header and stretcher patterns. The most common dimensions, sometimes called CEB standard dimensions, are 29.5 x 14 x 9 cms. 29.5 cm is equal to 2 x 14 cms + 1.5 cm for the middle joint. For example, a block of 30 x 15 x 10 cms proves to be very impractical on the site when the blocks are laid in double rows.

*Coordination of the block dimensions to achieve a proper bond*

### Block format

Architects and designers work with a masonry unit of given dimensions. This unit takes into account the dimensions of the block itself plus half a mortar joint on either side. Thus for a standard block of 29.5 x 14 x 9 cms, the unit dimensions are 30.5 x 15 x 10 cms. This unit is very useful for coordinating the dimensions of a building. But the producer must not confuse the dimensions of the block itself and those of the design unit, called the block format. When he selects a mould, he must check the dimensions of the block itself and whether it complies with the block format that designers use locally. Selecting a mould for an impractical block of 30 x 15 x 10 cms is often due to a misunderstanding of the difference between the dimensions of a block itself and those of the block format.

### Bond

A proper bond cannot be obtained with only full-size blocks; half or three-quarter size blocks are often needed. It is possible to get these blocks by cutting standard blocks, but this is time consuming and uneconomical. It is therefore recommended to produce machine-made small blocks using special moulds. The facility for a quick change of moulds is another criterion to consider in selecting a suitable press.

### Types

The most common type of block is the solid block, generally a parallelepiped. But it can also be hexagonal or any other prismatic shape. It is also very common to have an indentation known as a "frog" in the blocks. This not only saves a bit of raw materials for the producer, but also makes the block lighter and easier to handle, and improves masonry bonds.

### Hollow blocks

With sophisticated moulds, it is possible to produce hollow blocks, but they require more energy and expensive moulds to produce.

### Interlocking blocks

Interlocking blocks are shaped in such a way that they can be laid without mortar. They are, however, more difficult to produce, need a higher compression ratio than ordinary blocks and their production requires additional skill and strict quality control.

# RAW MATERIALS

*Selecting a suitable soil : a key parameter*

*Checking the grain size distribution*

### Soil selection

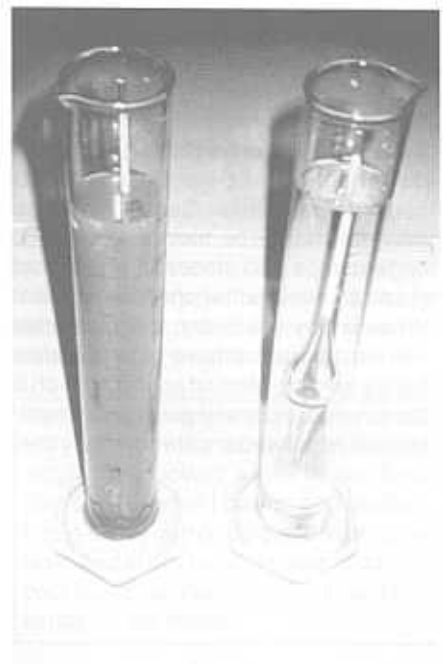
Not every soil is suitable for the production of CEBs. Selection of the best soil is critical. The principal criteria for selecting a soil are grain size distribution and cohesive performance. At the same time, the presence of salts or organic matter must also be taken into account. Simple field tests can be performed by the producer, but, if large scale production is planned, the testing of samples by a competent laboratory is essential.

### Sand and gravel

When a natural soil is not suitable because it is too clayey, it is possible to improve its qualities by adding some sand and small-sized gravel to reduce the proportion of clay and to improve the grain size distribution. Other inert materials such as pozzolanas can also be used instead of sand.

### Stabilizer

There is a wide range of stabilizers to choose from. Many organic or industrial products could help to improve the characteristics of soil blocks under wet conditions. Some of these stabilizing products are specific to particular conditions. Some are of more general use. The choice of a stabilizer depends on its local availability and its cost but also on which kind of soil has been chosen for the production. A very clayey soil requires lime as stabilizer rather than cement, which is more suitable for sandy-clay soils. Depending on the type of stabilizer used, production methods differ. For example, a cement stabilized CEB takes four weeks to cure whereas a lime stabilized CEB would take twice as long.



*Measuring the clay content*

### Absence of stabilizer

Stabilization is in most cases performed only to improve the characteristics of a soil block under wet conditions. When CEBs are used in a particular situation, such as interior partition walls, where there is no risk of humidification, it is not necessary to stabilize the blocks.

### Chemical stabilizers

The publicity for certain chemical stabilizers makes them sound very attractive. It must be remembered, however, that practical experience is far more valuable than any advertising on paper. Before selecting a stabilizer, a CEB producer should seek the advice of competent technicians.

### Stabilizer proportions

Increasing the proportion of stabilizer used means increasing the performance of the block under wet conditions, but also the production cost. This is why producers try to limit the proportion of stabilizer used. But below a certain level, it is difficult - from a mechanical point of view - to obtain a homogeneous mixture of soil and stabilizer, and the blocks made from such a mix do not last very long under wet conditions. Small proportions, such as 3 or 4 % for cement stabilization, can give effective results under laboratory mixing conditions, but would prove to be less efficient under site conditions where a 5 to 8 % proportion is often required to secure the quality of the product. The proportion of stabilizer is always given as a percentage by weight.

### Fibres

Fibrous materials are generally used to produce traditional hand moulded bricks (adobe). People therefore sometimes imagine that they are necessary for CEBs. In fact, fibres are elastic, making their use incompatible with the compression process.

### Water

The production of CEBs does not require much water and water consumption can be as low as 8 % for the weight of soil. As a general rule, clean water is always more advisable. Salty water must in any event be avoided.

# EQUIPMENT

*A rotating sieve*

*A soil pulverizer*

**Specialized equipment**
Working with earth requires the use of specialized equipment. All attempts to produce CEBs with equipment designed for cement blocks or for concrete have failed. Today, one can find a very wide range of equipment appropriate to the production of CEBs on the market.

**Selection**
Equipment represents a large proportion of the investment to set up a workshop. The buyer must make his choice with care, following existing checklists of criteria given in specialized literature. It must be remembered that the best equipment is not always the most attractive financially, but the one which suits the project in question.

**Soil preparation**
If the soil is to be be stabilized, it should contain no big lumps which the stabilizer could not penetrate. Generally, the raw material has to be sieved to eliminate larger lumps and stones, if any. Locally made sieves are the cheapest solution. When a clay soil is dry, it agglomerates into hard clods that have to be pulverized before sieving. Manual pounding to crush the lumps is slow and gives poor results. Motorized pulverizers are generally used.

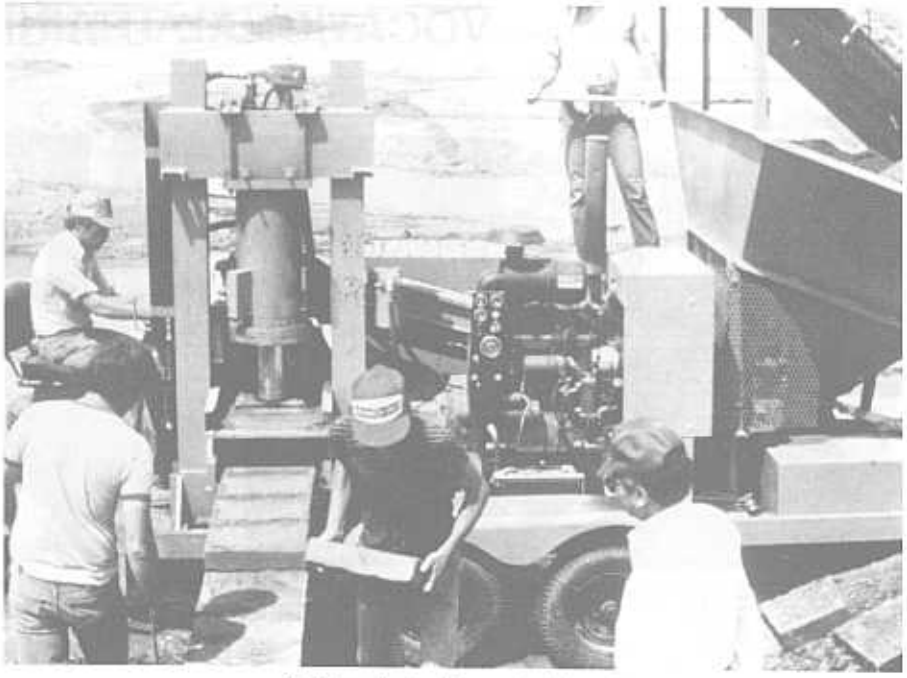
**Mixing**
Mixing soil and stabilizer and then moistening the mix can be done by hand. For commercial and larger scale production lines, it is often preferable to use a motorized mixer, which guarantees good productivity and consistent quality of the mix. This equipment can also be used to prepare mortar or rendering mix on a site.

**Curing**
Curing CEBs in the open is difficult, particularly in hot countries. Sheets of plastic or plastic textile covers for lorries are effective in slowing down the drying out of the blocks. The cost of these protective covers has to be included in the investment calculation.

*A planetary type mixer*

*Curing under a plastic film*

*A manual press*



*An integrated mobile production unit*

### Compression

Many types of presses have been developed. Some are manual and some are motorized. Motorized presses are fitted either with a mechanical system or with a more sophisticated hydraulic device. A potential buyer has to look at the purchase price, productivity, but also at reliability in the long term. The quality, size and shape of the blocks must match the characteristics he has defined during the feasibility study of his project. Other criteria must not be forgotten such as mobility, ease of maintenance, etc. Particularly in the case of presses, the buyer is advised to follow a check list if he wishes to make a systematic and thorough comparison.

### Handling equipment

Handling problems are often underestimated even though they can affect productivity. Some are due to lack of organization but others could be solved by using handling tools such as flat bottom wheelbarrows to carry the blocks or conveyor belts to transport soil between the various pieces of equipment.

We strongly recommend that you do not "re-invent the wheel" and, for example, try to invent a new design for a press. Equipment design and production is a very demanding and expensive task. And in any case, a press matching your particular needs probably already exists on the market.

### Quality control devices

Simple devices can help to maintain optimum quality. A measuring tape, a scale, a watch, plastic basins, a bending test block-breaker, a penetrometer are the basic tools needed. If the producer is purchasing soil from outside, he also must have simple tools, such as knives and spatulas, a glass jar, a graduated flask, a rubber tube, moulds for linear and volumetric shrink tests and a few others, for performing identification tests.

### Accessory tools

A set of hand tools such as a spade, pick, a wheelbarrow, a trowel, measuring and batching boxes, grease pump, must be provided.

*An industrial production unit*

*A motorized press*

# VOCATIONAL TRAINING

*Assimilating the basic principles of CEB production*

*Detailling the basic principles of construction with CEBs*

### Production methods

CEB production is not highly skilled, but there is a minimum that one needs to know in order to achieve good productivity without sacrificing quality. Training must include practical sessions so that the workers understand the key parameters of production: soil selection, pulverization, choice and proportion of stabilizer, mixing, moisture content, compression, curing. If these basic principles are assimilated, there will be fewer quality problems. The workers then have to learn how to use the equipment and be able to practice for a while to familiarize themselves with its functioning. Detailed instructions on equipment maintenance and the most common breakdowns is essential. Safety rules also have to be explained. Finally, workers must understand the importance of coordinating work with each other and organizing the work to reduce laborious handling operations.

### How to use CEBs

CEBs do not differ greatly from common building materials but attention must be paid to certain points such as the choice of mortar or renderings, and bonding principles. Participating in pilot building projects where there is reliable supervision is the best way for bricklayers to gain practical experience.

### Management

As with any other activity, CEB production involves book-keeping and some marketing. These tasks must not be neglected since they are critical in the long term. If the workshop manager does not have experience in this field, he must obtain suitable training.

### Designing CEB buildings

The design of a building is as important as the quality of the CEBs. Those responsible for the building project must be trained in the specific principles of earth construction. Technical guidelines must be put into practice.

### Looking to the future

No activity can afford to stand still. Adopting new production methods, purchasing more efficient equipment, changing the size and shape of the products, has always to be considered. To be able to improve productivity or to penetrate new markets, an entrepreneur or a production manager must always be willing to get more training for himself or his workers and must try to keep abreast of new developments.

*Practical training*

*Training site*

# MANAGEMENT

### Productivity
Workshop profitability cannot be achieved if productivity is not maintained above a minimum level and at a regular pace. And that cannot be achieved if the workshop is not properly organized.

### Production management
If no attention is paid to where to store raw materials, how to set up the production line, how to stock the blocks to dry, very soon the workshop will be congested with soil or blocks and production will have to stop.

### Equipment maintenance
A good worker must have good tools. If it is not maintained, equipment will soon break down. When selecting equipment, reliability and ease of maintenance or repair under local conditions and with local tools must also be taken into account.

### Team work
Productivity is highly related to production team coordination. The training, guidance and encouragement of the production team must be one of the workshop manager's ongoing tasks.

### Focus on quality
A faulty CEB means there is a problem on the production line. Permanent control must be exercised throughout the process : the quality of every delivery of raw material, the proportion of stabilizer, the moisture content, mixing, etc.

### Book-keeping
Keeping up-to-date with production records, orders, stock account books, is the only way to monitor the financial progress of the activity and to be in a position to assess profits.


CEB PRODUCTION WORKSHOP "....."

MONTH ..... 19..

| DATE | SUPPLIES (PER DAY) I | II | III | IV | SUPPLIES (CUMULATIVE) I | II | III | IV | CONSUMPTION (PER DAY) I | II | III | IV | CONSUMPTION (CUMULATIVE) I | II | III | IV | STOCK I | II | III | IV |
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I SOIL
II STABILIZER
III PETROL
IV WATER

NOTES

INVENTORY

DIFFERENCE BETWEEN INV.

*Monitoring the supply and consumption of stabilizer*


CEB PRODUCTION WORKSHOP "....."

MONTH ..... 19..

| DATE | PRODUCTION (PER DAY) I | II | III | IV | PRODUCTION (CUMULATIVE) I | II | III | IV | DELIVERIES (PER DAY) I | II | III | IV | DELIVERIES (CUMULATIVE) I | II | III | IV | STOCK I | II | III | IV |
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| TOTAL | | | | | | | | | | | | | | | | | | | | |

I 295 x 145 x 95 cm
II 292 x 142 x 95 cm
III 147 x 145 x 95 cm
IV 295 x 142 x 95 cm

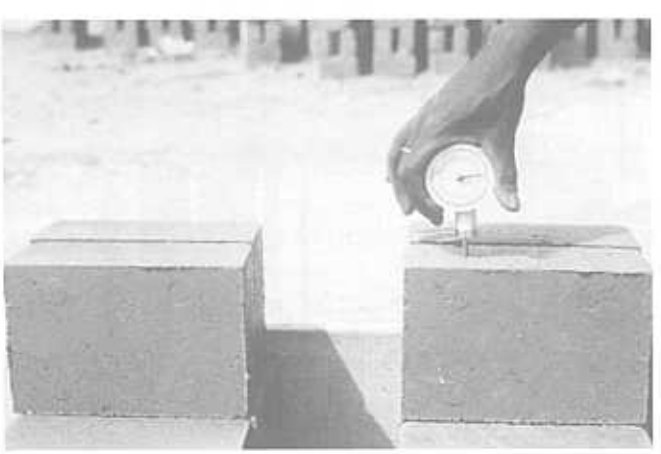
NOTES

INVENTORY

DIFFERENCE BETWEEN INV.

*Keeping the books up to date*

*Maintaining the production equipment*



*Checking the quality of the product*

# MARKETING

### The right market

The new producer has to select his marketing strategy, since his initial moves could determine the future of his activity. If he starts by supplying only some social housing programs, customers and potential buyers will associate the CEB with low income populations, and more wealthy clients will not wish to be seen buying CEBs. On the other hand, if the entrepreneur's first orders are for luxury villas or larger public buildings, such as schools, institutions and the like, the CEB will soon become socially desirable.

### Information

If the CEB is a new product in the area, spreading information amongst the potential users is the first step. Information leaflets can be printed with a description of the product (size and shape), its use and its price.

### Demonstration

Nobody will buy CEBs until they have seen them in the wall of a building. Even before starting commercial production, pilot building opportunities must be secured. These demonstration sites are also a chance to organize vocational training courses about how to use CEBs.

### User confidence

The producer must gain the users' confidence. He must therefore be able to offer reliable and demonstrable quality, by setting up efficient and permanent procedures for quality control. Furthermore, users will have more confidence if the product has gained official acceptance. The producer has to establish and maintain a good working relationship with the local building authorities.

### After sales

The producer has to be careful of the way his customers use CEBs. If a customer does not respect the specific guidelines for using CEBs and the building fails, the tendency will be to blame the quality of the CEBs. The producer would be well advised to obtain some first hand experience in CEB building principles to be in position to advise his customers and if necessary to supply them with technical books, standard plans and drawings.

*Promoting CEB through pilot building projects*

# BUILDING DESIGN

### Durability
The design of buildings constructed of CEBs is very important. A well designed building can do without external rendering, thus saving money, time and energy. Non-stabilized blocks can also be used in protected parts of the building. One of the major principles of earth construction is to limit the damaging action of water.

### Good boots...
A building made of CEBs is said to need good boots, i.e. to need good foundations,or at the very least the lower part of the walls must be totally waterproof.

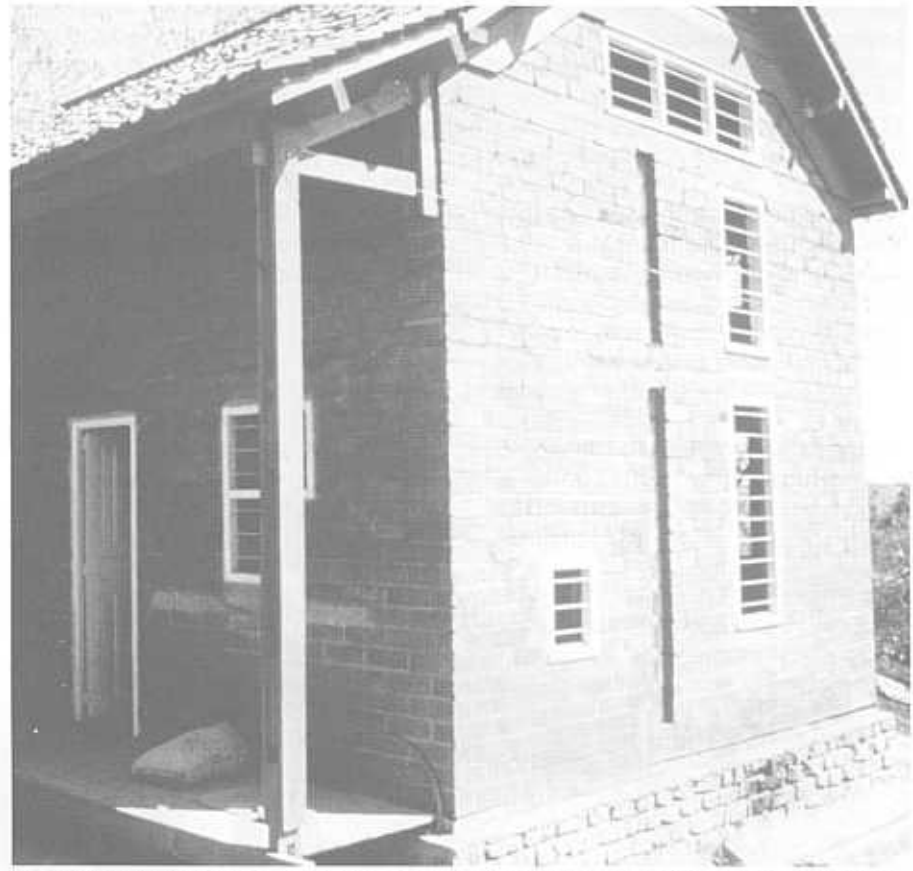
### ...and a good hat.
A good roof will keep the rain away from the wall and so limit damage caused by water running down the walls.

### Above the ground
Except under very special conditions, CEBs, even if they are stabilized, must not be used in the ground for foundations or for lining a well pit or gutter. Any earth block has a limited resistance to periodic wetting and drying.

### Compressed blocks
CEBs have limited tensile strength. The structural design must exercise only compression forces. This is why architects use arches. It is also why a minimum distance between openings, or between an opening and a corner, should be respected.

### Standardization
CEBs are standardized products, so the dimensions of buildings must take into account the block size and shape. Otherwise, the brickwork will be complicated and the final quality compromised.

### Bricklaying
The way the blocks are laid has a major influence on the strength of a wall. First, the bond must be regular, with a minimum shift between vertical cross joints. The mortar must be of the same strength as the blocks. All the vertical joints have to be filled with mortar. And, of course, the bricklayer is supposed to know how to use a plumb line.



*Respecting the specific rules of earth construction is essential for the durability of the buildings*

### Multi-storey
Building houses with 2 or 3 floors poses no problem, if the CEBs are of good quality. Reinforced concrete beams are laid at every level to support the floor and to tie the walls.

### Thick walls
Traditional walls are generally over-dimensioned to counteract the poor quality of the building materials. With the CEB, it is possible to modulate the thickness of a wall by laying the blocks in a single row or double rows.

### Concrete posts
It is very common nowadays to use a post-and-beam structure. If CEBs are used instead of sand-cement blocks, there is a chance that a shrinkage gap develops after a while between the block wall and the concrete post. In fact, concrete posts are not necessary with CEBs, because the latter are solid building materials and so they can be used in load bearing walls. If a post and beam structure is still preferred, the posts should be made with a groove into which the blocks of the wall can slot.

### Nailing, fixing
It is said to be difficult to use nails in an earth wall. To hang a light item like a picture frame, a long nail is enough to provide sufficient strength. To fix hinges, it is advisable to lay amongst the CEBs some special sand-cement blocks as fixing-bricks : these can then be drilled and plugged with a cement mortar.

### Rendering
If the roof provides a good overhang and protection against rain and if the blocks have been laid with care, it is not indispensable to plaster the walls. Rendering is necessary only on the most exposed walls or for the sake of appearance. Hard cement based renderings are not suitable for CEB walls because they are too rigid. Lime based renderings are preferable and inside traditional gypsum plaster can be used without difficulty.

### Painting
A CEB wall can be painted but the type of paint used must be selected with care. Acrylic paints should be avoided. Colored or white lime wash are the cheapest way to obtain the desired decorative effect.

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(E) = English; (F) = French

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**An information network on building materials**
BASIN (Building Advisory Service and Information Network) is a service available to all institutions and individuals concerned with housing, building and planning in developing countries. GATE, ITDG, SKAT and CRATerre are jointly responsible for the documentation, evaluation and dissemination of information in four subject areas.
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The Earth Building Materials Advisory Service also undertakes research and development programs in the field of building materials and their application. This activity includes project monitoring and evaluation.

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- Are you planning to set up a production workshop and do you need more information ?
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# WHO MIGHT BE INTERESTED IN THIS BOOKLET?

Decision-makers : building program managers who have to decide whether to work with CEBs or not, planners who have to prepare strategies in the building materials industry sector.
Building contractors : contractors involved in building sites where they are asked to use CEBs.
Building materials producers : workshop or plant managers who want to develop CEB production lines.
Anyone interested in CEBs and wishing to know more about them.

# WHAT YOU CAN FIND IN THIS BOOKLET:

Basic information about CEBs.
Some advantages and disadvantages of CEBs.
Guidelines that you should consider and first steps towards CEB.
Tips and particular details to help you to avoid mistakes.
Addresses and further reading for you to obtain more detailed information.

# WHAT YOU WILL NOT FIND IN THIS BOOKLET :

No detailed technical information.
No detail instructions on how to produce CEBs.
No specifications of costs and profit for your particular circumstances.
No information about particular problems in individual countries.