Construction in Developing Countries

A Guide for the Planning and Implementation of Building Project

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Preface

to the English Edition

This is a translation of **Att bygga i u-land**, published by The Swedish Mission Council in 1994. The original book was published in 1986. The 1994 edition included substantial revisions to incorporate technical developments and eight more years of practical experience, but it was still addressed to a Swedish-reading audience. There are further additions and modifications in the translated version, particularly to the technical standards, to make the material relevant in more countries.

Preface to the 1994 Edition

After more than 30 years of international development aid, Swedish builders have accumulated invaluable experience of construction in developing countries. Over the years there have been both mistakes and good solutions.

Construction in Developing Countries is meant primarily for engineers, architects and others working with construction in developing countries. The aim is to provide guidance in planning and implementation of construction projects. It is hoped that the book can also illuminate the problems and possibilities of construction for those who are perhaps not directly involved in the building process, such as decision makers.

This is a revised version of a book compiled for the Swedish Mission Council (SMR) in 1986 and reprinted in 1990. The original was based on the results of a questionnaire sent to 220 builders and 15 interviews, and has been used in training development aid experts, schools and universities, courses and seminars.

This edition was revised by SADEL (Swedish Association for Development of Low-cost Housing) in cooperation with SMR. Each chapter was revised by an expert, and the entire text was compiled and edited by Johnny Åstrand.

I would like to thank all who contributed to making this new edition possible. I hope that it can promote, in a clear and easily understood way, better construction in the future. Special thanks to Hartmut Schmetzer, Göran Tannerfeldt, Tor Forsman, Varis Bokalders and Cecilia Pering for their valuable comments that helped to improve the book.

Karl-Erik Lundgren
Swedish Mission Council

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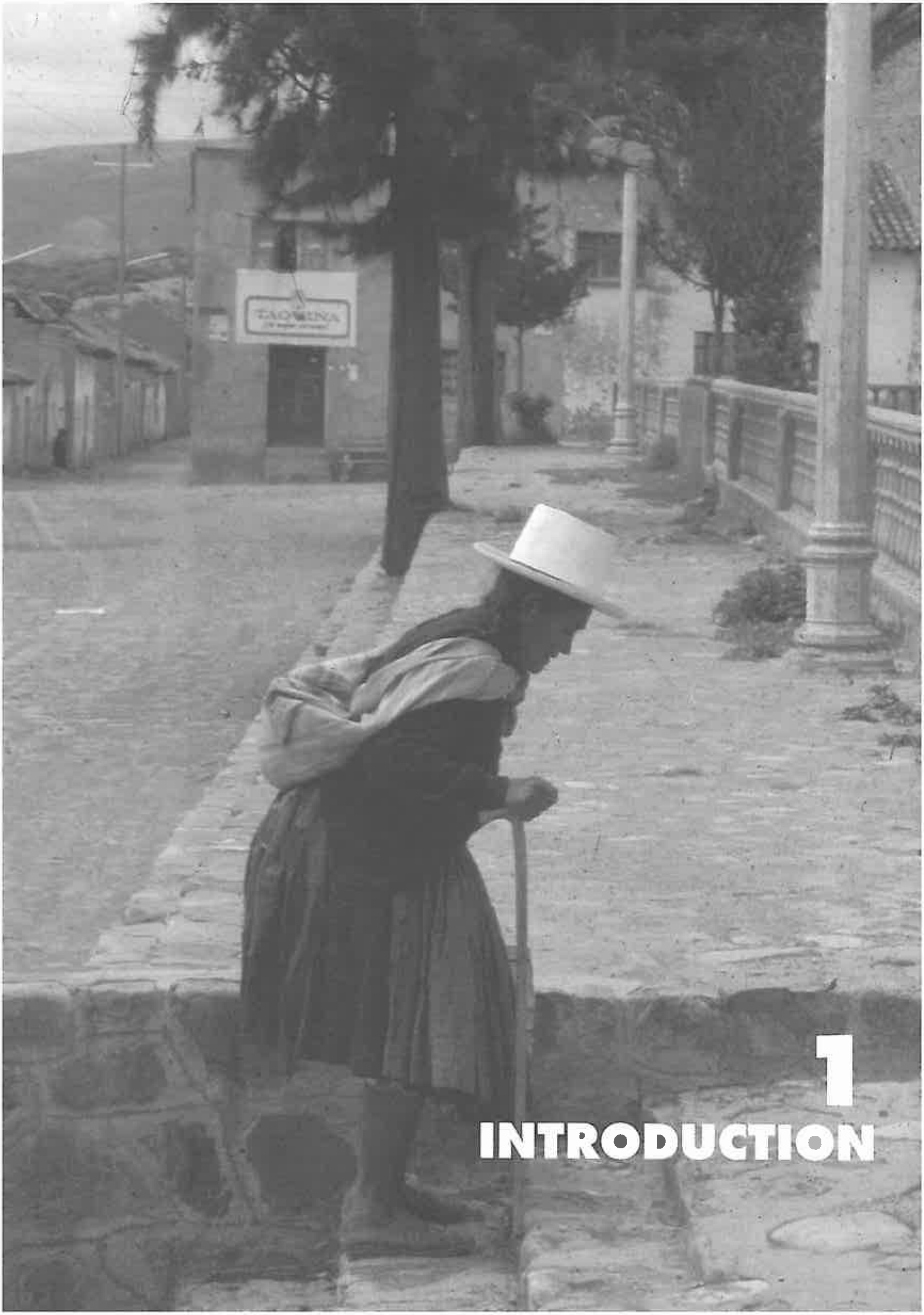


1 INTRODUCTION

Introduction

Construction is an integral part of national development, not a separate independent activity, so it is essential to plan and prepare any building project carefully.

To be able to make a good contribution to construction in a developing country, one needs technical training, practical competence and experience. Most countries require formal certification as a structural engineer, civil engineer or architect for any position of responsibility in a construction project.

It is important to be able to take initiatives, but one must also have the patience to listen to local users and respect their knowledge.

Cultural and Social Behaviour

The expression "culture shock" is often used to describe the experience of a first meeting with a developing country. This varies greatly among individuals and countries. It can be stressful for a professional from an industrial country to confront open poverty and misery. Others feel frustrated because they are not as efficient as they would like to be, because everything seems to take a little longer than they expect. The climate can be a strain, especially if one must work under difficult conditions. Communications function badly in many developing countries, and one is often expected to solve problems alone.

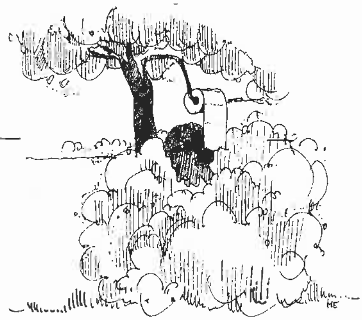
Culture shock might also be experienced by a national of a developing country who grew up in a city, perhaps attended university or conferences abroad, and lives an "international" everyday life, when he meets a group of homeless rural workers. The daily exposure to urban structures and the international media gives another perspective than might be held by many others in the country. Just living in the same country does not mean people share the same culture, even if they have much in common.

Although the external conditions might often be difficult, working in a developing country is a positive experience for most people. Much of this is due to the great friendliness and optimism that one meets among ordinary people, who seem to share a greater belief in development and the future than is common in developed countries. It is wrong to assume that poor people are always miserable and pessimistic. People with adequate food and reasonably tolerable living conditions consciously strive to improve the life of their families and children.

To work successfully with development aid requires an understanding of the local culture, religion, social patterns and economic conditions. One can more easily adapt oneself to the local situation by listening and respecting the unfamiliar. It is especially important to show respect for local social and cultural patterns in rural areas and smaller communities, since as a rule one is more visible there. Ones choice of clothing can be important for acceptance. In some countries an expert is expected to dress formally, while in other countries this is seen as snobbery. It is important to be sensitive to such issues, and to learn the traditional ways to greet and behave in public.

One is received with great hospitality in all developing countries. It is almost as if the poorer the people, the greater their generosity. It might be difficult to know if one should accept gifts of food and crafts. If one declines, it might insult the giver; but if one accepts, the family might be without food that day.

Aesthetics, a need for beautiful buildings, is seldom discussed. Yet we know that attractive buildings are better maintained, more respected, and that people are willing to use them for additional purposes than originally intended. For example, a simple primary school could be used as a community centre. Beauty is important!



The concept of toilet differs from place to place.

Buildings – Value and Use

Buildings are valued and used differently according to the climate, traditions and religion in the country. In many places an outdoor space serves important functions. It is a multi-purpose area for work, socializing and preparing meals. There is often a public outdoor space at the front of the house and a private space at the back. The design and placement of kitchen and toilets might be a sensitive issue that must be considered with extra care. If one introduces a new solution for the toilet, one must be certain that it is acceptable to the users.

In some countries school children sit on carpets on the floor. This of course affects the design and size of the class room, if no benches and desks are installed. Hospitals and clinics are heavily used and have many more patients per day than is normal in an industrial country. Patients may have travelled far and must have somewhere to sleep, cook and meet sanitary needs. One can also expect relatives or friends to accompany the patient, and that mothers will bring other children with them.

The routines for cleaning buildings differ among countries. It is common to wash floors with a lot of water, which means that floors and the lower parts of walls must be designed to withstand water. There are many cases of prefabricated houses exported to developing countries that do not meet this basic requirement.

A building tradition: mosque in Kairoan, Tunisa.

Local building materials, Tunisia.

PHOTO: MONICA ERIKSSON

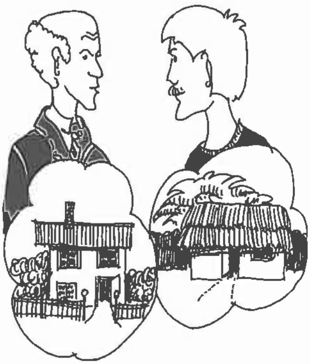
Ethiopia

The Local Building Tradition

There is much to learn from traditional construction, developed over centuries and shaped by the life style, climate, availability of materials and technical skills. Traditional construction uses local building materials and local labour, which means lower costs, since transport costs, among others, are very low.

Traditionally built houses often require more maintenance than modern buildings, but maintenance is easy since the building materials are locally available. Maintenance might be impossible if a new material, that is not locally available, is introduced. It should always be possible to maintain buildings, even after the end of the project and the formal hand over to the local cooperating partner.

One should always try to follow a local building tradition that works well. Certain solutions can be very good and worth copying, while other can be completely unsuitable. Traditional materials and methods are often opposed by local professionals and decision makers who consider them inferior. The local users might also be reluctant, since they aspire to development and higher status, often represented by modern building materials.

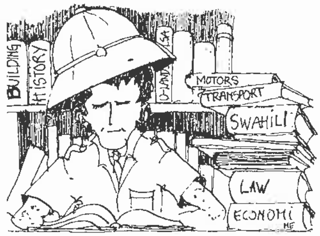


Sometimes we have different assumptions about what is appropriate construction.

It is difficult to use simple techniques, to improve traditional building methods, to produce cheaper and more durable houses that conform to the local style. Nevertheless, this should be the aim, since it leads to sustainable development. It is also necessary to study conventional construction, how local contractors build. A foreign builder has a great responsibility. Local users often have a lot of respect for the "foreign expert," and many will later copy whatever is built, even if they might be critical during the actual construction.

Preparations

Construction is a central part of national development. Therefore one should try to see the individual project in a wider context, and form a personal perspective on development issues and aid. It is important for outsiders to study the country, its political system, social conditions, economy, religion and building traditions, to be better prepared before landing in the middle of the project. Talking with people who have worked in the region is often the best way to get information about the local construction situation.



It is important to get as clear and complete a job description as possible from the future employer. Too often as soon as funding is granted, a builder is quickly recruited to begin work immediately, without a chance of participating in project preparation.

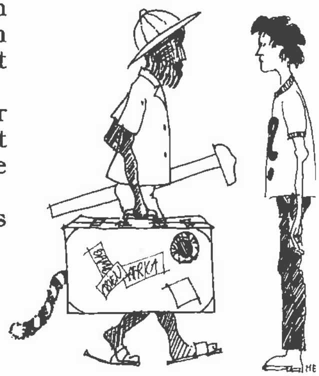
United Nations agencies, bilateral aid agencies and some non-governmental organizations arrange courses for their staff. There might also be courses on development aid issues and languages through community colleges and education centres. People who have worked abroad are important sources of information on climate, conditions of work, customs and habits, etc. They might also be able to provide useful contacts.

Try to meet experienced people who have worked in the area.

It is important to have good working competence in English, French, Spanish or Portuguese, depending on the country one will work in. It is also useful to learn some of the local language(s), even if only common greetings and expressions. Of course one can work with a translator, but it is easier and one earns more respect from the local people if one speaks their language.

Since the availability of materials, tools and other equipment can change a lot from year to year, it is best to talk with someone who has recently worked in the country.

Construction in developing countries requires knowledge, preparation and motivation.



It happens all too often that as soon as the funds are granted, there is a rush to find a builder who can leave immediately and start construction, without having been involved in designing the project. It is an advantage if the builder can participate in the planning.

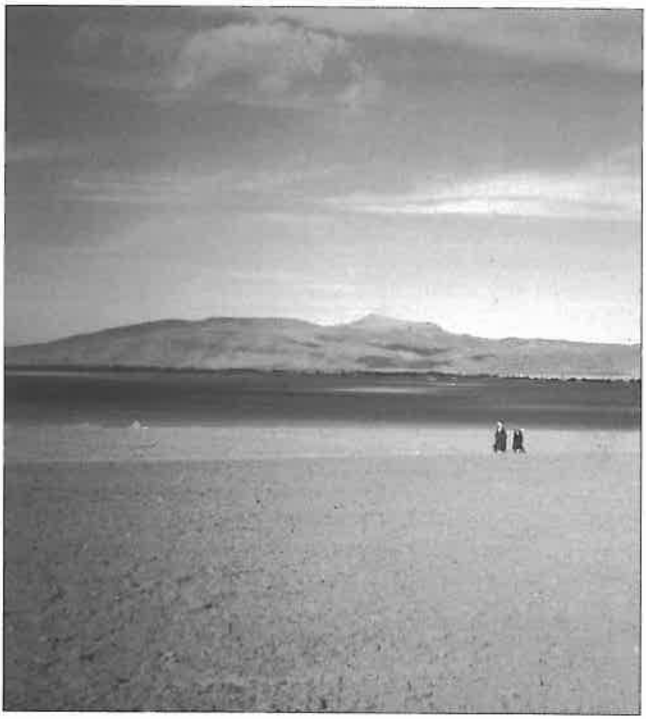
Organization of the Book

The aim of this book is to provide advice for the planning and implementation of construction projects in developing countries. The basic premise is that design, building methods, choice of material and organization of construction should be adapted to the local conditions as much as possible.

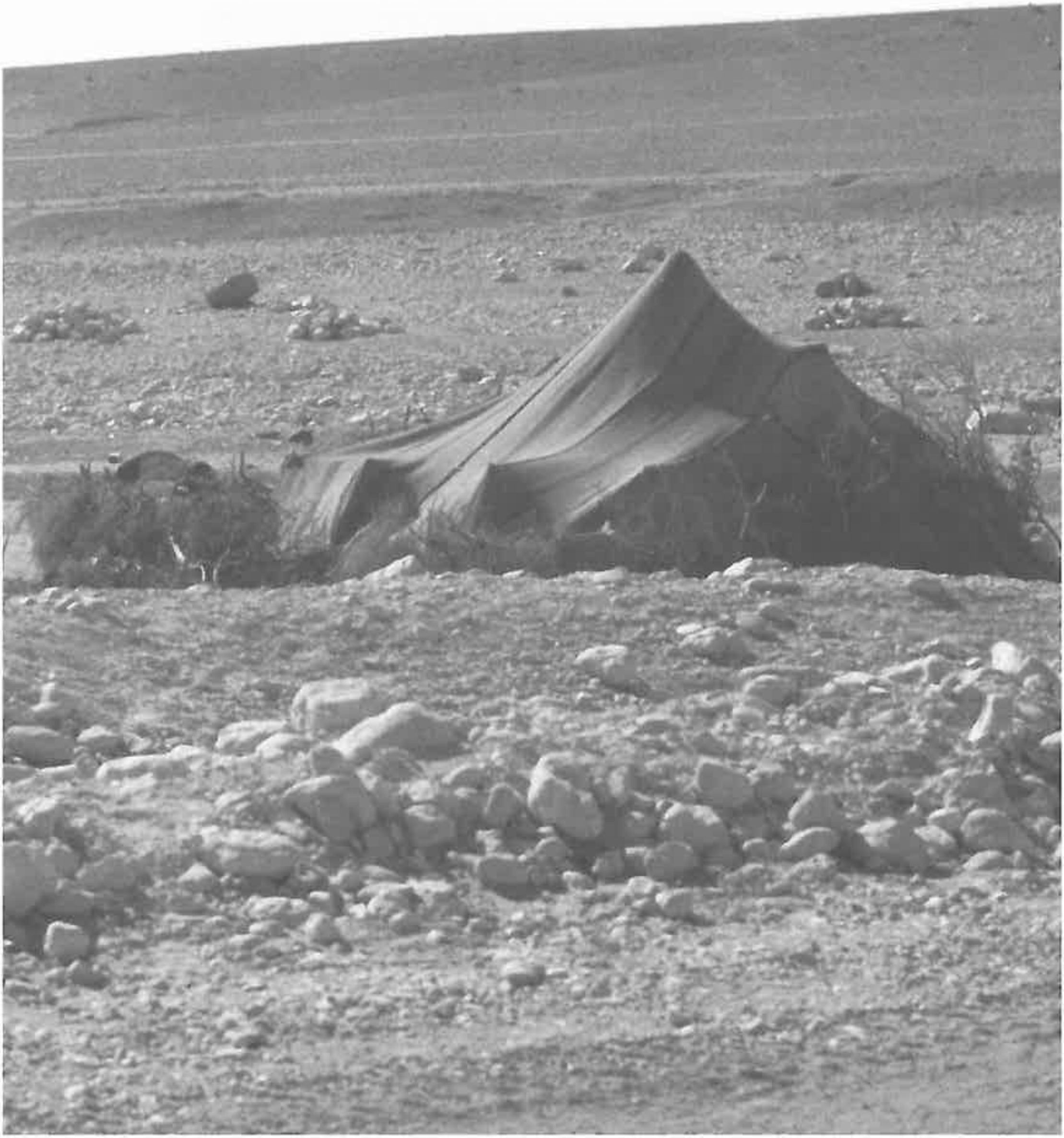
Based on this premise, the building materials and methods commonly found in developing countries, and that are considered appropriate, are described in Chapters 2–7. The steps in the building process from basic study and project development to construction and evaluation as described briefly in Chapters 8–9. Attention is mainly given to construction of institutional buildings such as schools, vocational training centres and clinics.

Chapter 10 addresses housing in developing countries and gives some general advice on how to work with improving housing for low-income families. This chapter is based on the book **11 Successful Housing Projects** published in 1990 by SMR and SADEL.

Sahara



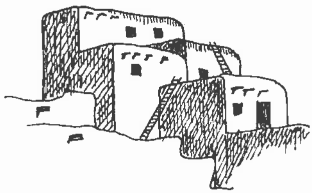
2 CLIMATIC DESIGN



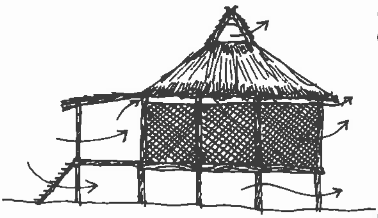
Climatic Design

Modern architecture based on international models has resulted in poorer adaptation to local conditions, such as the climate. The passive, energy efficient technology found in traditional construction has been abandoned for active, energy-consuming, climatization. In developing countries building norms are often established according to European or international standards and are rarely appropriate for the existing economy of the country.

A study of traditional buildings can give many good ideas for climatic design. These must then be interpreted in terms of contemporary building techniques, economic resources and cultural values.



Hot and dry climate

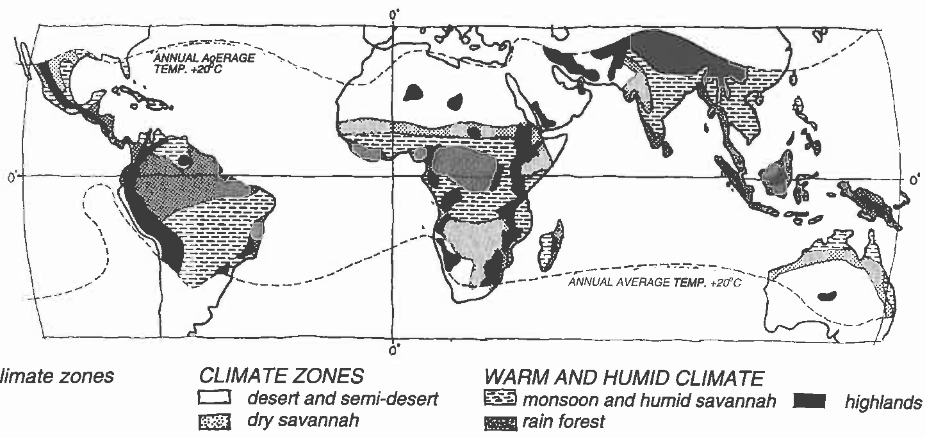


Warm and humid climate

Climate Zones

The world can be divided into climate zones according to criteria such as temperature, precipitation, humidity and wind. General information about these factors is found in any world atlas. More detailed information about a specific microclimate can be sought from a weather station, often found at airports. Other sources of information are agricultural and forestry schools or farming cooperatives, which usually keep some weather statistics. The residents often know a lot about the local climate.

- A **cold climate** requires indoor heating all year round. The thermal insulation of buildings is important for comfort and to reduce the amount of energy used for heating. The potential for solar heating may be limited.
- A **temperate climate** requires both heating and



Climate zones

Source: LIPPSMEIER: BUILDING IN THE TROPICS.

cooling of buildings. This means that there is a need for both thermal insulation and some thermal storage capacity (heavy mass). Correctly placed windows can take advantage of the sun for heating.

- A **hot and dry climate** has great differences in day and night temperatures. These temperature changes can be utilized by incorporating heavy materials to help moderate the indoor climate. Compact, heavy structures with small openings are common in this climate. Some thermal insulation is advantageous, particularly of the roof, which receives the most solar radiation.
- A **warm and humid climate** has a fairly constant temperature. Shading and ventilation are the most important factors for comfort. Buildings should be light with large openings and roof overhangs or verandas.

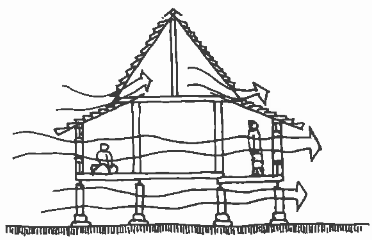
These climate types are only a very rough simplification. Monsoon winds, created by temperature differences between the air over water and over land, also affect the climate. These winds have the greatest importance in Asia and East Africa. There are many variations and combinations, such as a mountain or coastal desert climate.

It is important to consider the seasonal variations in any climate. Even if the desert makes one think of unbearable heat, desert temperatures can drop below freezing during winter nights.

The outdoor environment is also important. With correct design of the buildings and the site, it is possible to create a microclimate in streets and open areas that is significantly different from the surrounding "free" climate. Topography and the proximity of plants and water play a large role. This is not only important when people are outdoors – the buildings themselves stand in this microclimate and interact with it.

Comfort

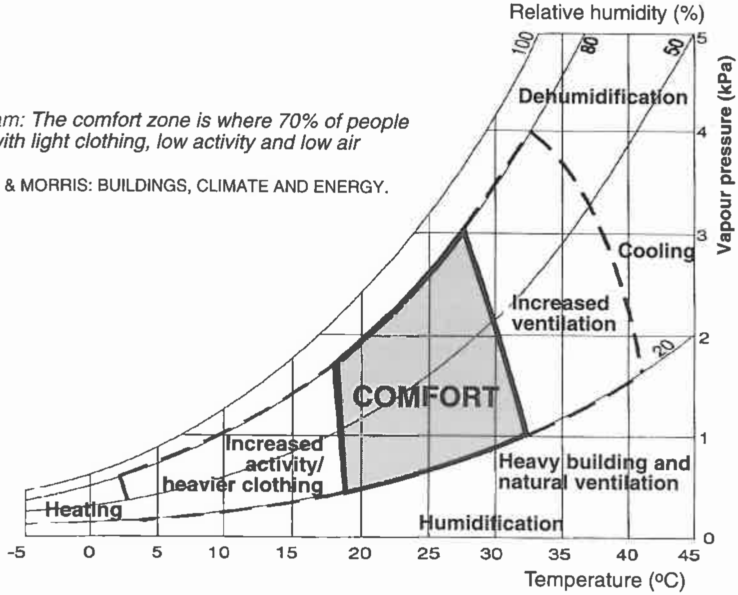
Our perceptions of the climate depend on several factors: air temperature and humidity, air velocity, radiation absorbed from the sun and exchanged with hot or cold objects around us. At the same air temperature the climate can be perceived differently depending on the relative humidity or wind velocity. Even behaviour has effects: clothing, body position and type of activity. A classroom where children must concentrate has different climatic requirements from a workshop requiring physical labour.



Ventilation is an important factor for comfort

Comfort is a subjective experience of satisfaction, which is individual. One often defines the comfort zone

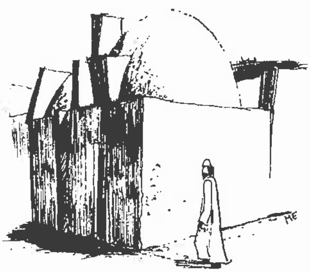
Comfort diagram: The comfort zone is where 70% of people are satisfied: with light clothing, low activity and low air velocity.
Source: MARKUS & MORRIS: BUILDINGS, CLIMATE AND ENERGY.



as the area where 70–80% of people are satisfied. See the comfort diagram above.

Thermal comfort may be related to other aspects of satisfaction, such as if one likes the surroundings or what one is doing in them. Comfort is also a question of economy. One cannot always afford to achieve comfort, but perhaps must be satisfied with the tolerable.

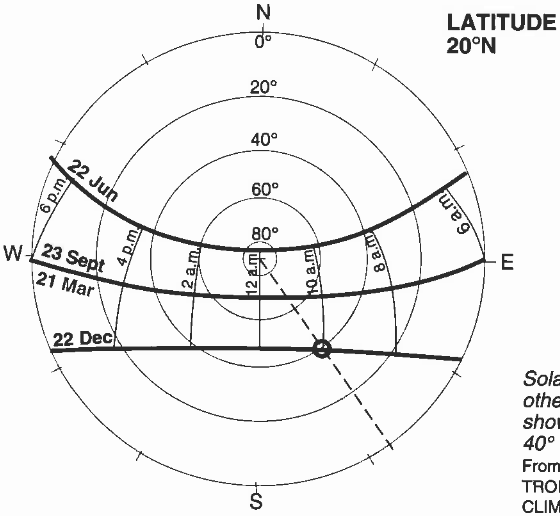
Sun



The sun is the "engine" of climate. Solar radiation warms the earth, and the distance and angle to the sun determine the seasons. Even winds are affected by the solar heating of land, seas, etc.

The sun rises in the east and sets in the west. At noon the sun is toward the south in the northern hemisphere, and toward the north in the southern hemisphere. During summer the midday sun might be in the opposite direction between the tropical circles (23.5°), but even far from the equator, the morning and evening sun are toward the pole. A solar diagram is a simple, useful tool to study solar angles in more detail. It allows one to define the position of the sun at all times of the day, every day of the year.

In a hot climate one must shade or minimize the east and west facades. The south facade in the northern hemisphere (north facade in the southern hemisphere) allows the possibility of free supplementary heating in



Solar diagram for latitude 20°N. There are other diagrams in the literature. The example shows that at 10.00 in December, the sun is 40° over the horizon in the south-east.
From KOENINGSBERGER ET AL: MANUAL OF TROPICAL HOUSING AND BUILDING, PART 1: CLIMATE DESIGN.

the winter, because the sun follows a lower path as one moves away from the equator. During summer, and close to the equator, the sun passes high in the sky, and a correctly designed solar screen, such as a roof overhang, shades the facade.

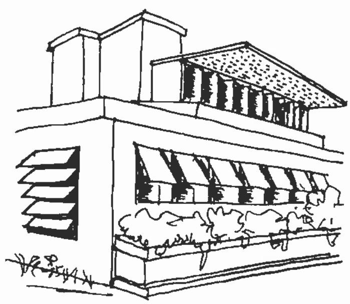
The visible short-wave solar radiation is affected by the colour of the surface it strikes. A white surface reflects about three quarters, while a darker surface absorbs most of the solar radiation. The colour, of a roof for example, is crucial for protection from solar heat.

When solar radiation strikes an object, say a wall, the energy is absorbed and converted to heat, that then re-radiates from the object. This heat radiation is largely independent of the colour (absorptivity) of the surface, but depends on another property, the readiness to absorb and release long-wave radiation (emissivity). Most building materials absorb and release about 90% of the heat radiation striking them. This quality can be useful in a desert region. The roof surface is white-washed to reflect solar radiation during the day, while at night the materials release whatever heat that was absorbed toward the cold, cloudless sky.

Arcades for shading

Window panes allow most of the short wave solar radiation to enter the house as light. Inside the room the energy is absorbed by walls and floors and converted into long-wave radiation or heat, which is trapped in the room and cannot pass back through the window. (This is known as the hothouse effect.)

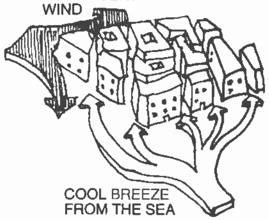
Windows should be placed according to the principles above concerning the orientation of the building. To avoid solar radiation, one can use shutters, blinds and various types of shading devices, often fixed. Horizontal



shades, such as roof overhangs, are effective over north and south facing windows, while vertical or angled shades protect against the sun striking from the east and west. Internal shades, such as Venetian blinds, are less efficient than external.

Plants can also be used for shading. Some trees drop their leaves during winter and thus allow more solar heating.

Wind

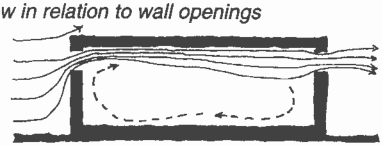


The dominant wind direction should be considered in orienting buildings.

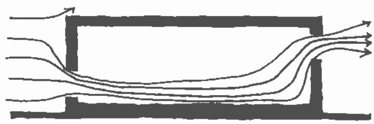
The direction and velocity of the wind affect both indoor and outdoor climates in built areas. The dominant wind directions during the different seasons must be considered in planning houses and neighbourhoods. Some winds are desirable, such as warm winter winds, while one wants to be protected from others, such as hot desert winds.

Important factors are the orientation of the buildings, their placement in relation to and their distance from each other, and the placement and size of the openings. It is necessary to place openings opposite each other to allow good cross ventilation. Openings should be designed to create a flow of air in the zones that are normally occupied by people.

Air flow in relation to wall openings



High openings give no air flow at body height

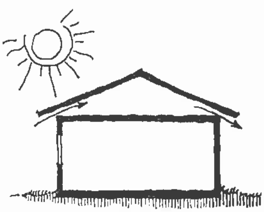


Low inlet and high outlet give a low flow of air

Low openings create air movements that can cool

A high inlet give a high flow of air that is not affected by the low outlet

From EVANS: HOUSING, CLIMATE AND COMFORT.



A roof and ceiling allow the solar heat to be ventilated away

In some cases, where wind velocity is low, the chimney effect might be used. This is based on the principle that heat rises. Placing the air intake low in the room, and the exhaust opening high up, promotes this kind of ventilation.

In a hot and dry climate, night ventilation can improve indoor climate significantly. The cool night air lowers the temperature of the indoor surfaces, and the effect remains the next day if the building is kept closed.

Ventilation of the building envelope is also effective, for example a double roof construction, where the warm air between the roof and the ceiling is ventilated out and the heat removed.

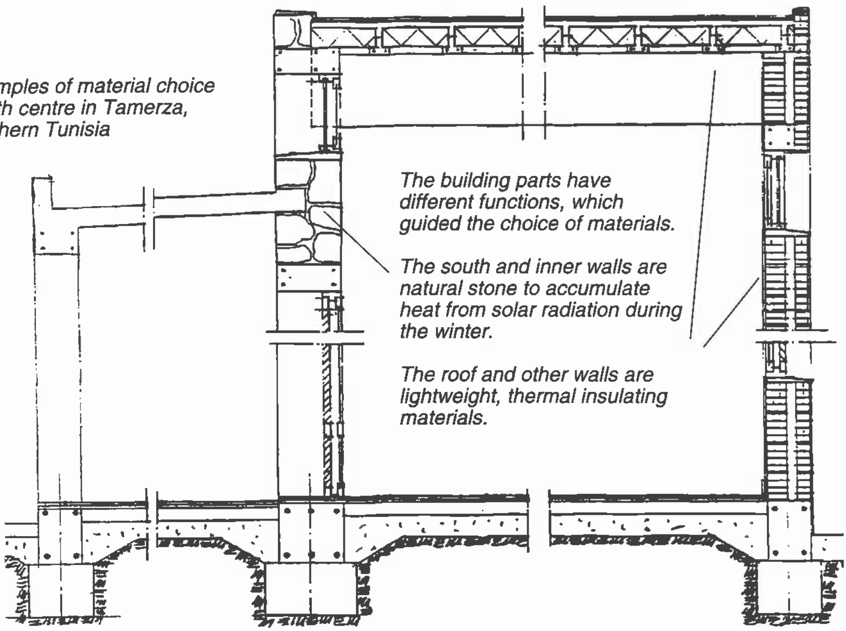
Observe that ventilation openings should be covered by mosquito net or a grill to keep out insects, vermin, sand and dust.

Materials

There are two principal ways building materials provide thermal protection from the climate. Either a material is light and insulating and prevents heat from passing; or it is heavy and heat-storing and moderates tempe-

Exterior and interior, youth centre, Tamerza

Examples of material choice Youth centre in Tamerza, southern Tunisia



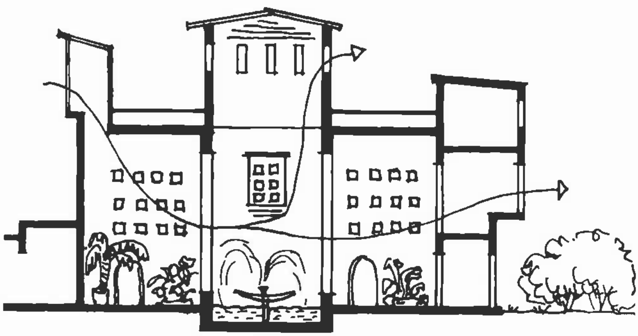
ratures by attenuating and delaying the effects of temperature changes. All building materials have varying amounts of both qualities.

In a hot and dry climate where night ventilation is feasible, it is important to have a heavy interior mass, while the outer shell, especially the roof, should be well insulated. The choice of building material must be based on the intended use of the space. A heavy construction that is heated during the day gives off most of its warmth at night, and is less suitable for bedrooms.

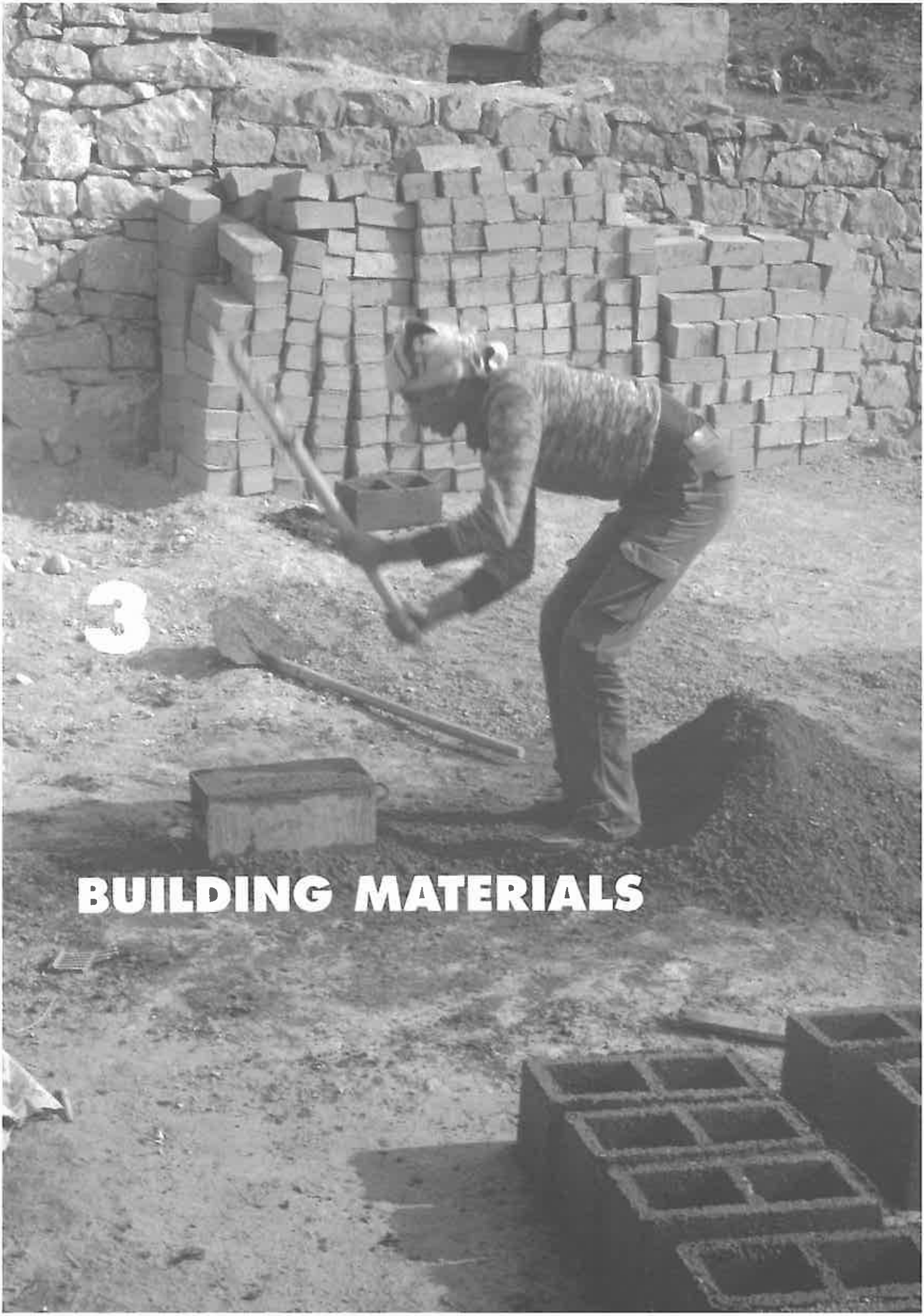
Climatization

The term might mean many things. The first thought that comes to mind is perhaps air-conditioning, and other sophisticated, energy-consuming systems. But it is possible to climatize with simpler techniques. Evaporation of water removes heat: this principle can be applied through fountains, or unglazed water jars and damp curtains in ventilation openings. In some parts of the world ventilation chimneys are built, often together with some air moistening device, to catch the wind and draw it into the house. In climates with great differences between day and night temperatures, increased night ventilation cools the building mass, giving lower indoor temperatures during the day as well.

The most important form of climatization is passive – through building design. The materials, orientation, placement of doors and windows, and other aspects of design discussed above should be carefully considered and chosen to give the best possible adaptation to the climate. If active climatization is necessary to achieve the required level of comfort, the passive and active systems should be designed to work together. This is a difficult and complicated task, because techniques that support one system may be detrimental in the other. (See Adamson and Åberg 1993.)



A traditional Egyptian house with a malkaf (wind catcher on the roof) and indoor fountain for cooling through ventilation and evaporation.



3

BUILDING MATERIALS

Building Materials

Locally available building materials should be chosen, as far as possible. This is often a basic condition for maintenance of a building. If building materials that have not previously been used in the region are imported, one must be certain about their properties and performance in the local conditions. Avoid materials that carry health risks or can lead to problems with moisture and mould. Extreme climates can reduce the durability of a material.

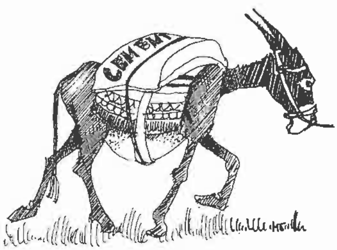
Casting the strip footing.

Concrete

Concrete is used for foundations, walls, columns, beams, floors and roofs. The material withstands high compressive stress, but has only relatively low tensile strength, so concrete structures are often reinforced. Concrete is a mixture of aggregate (stone and sand), cement and water. The cement and water mixture – cement paste – acts as a binder between grains of sand and crushed stone or gravel. The cement paste should contain as little water as possible. Too much water thins the binder and reduces the strength of the concrete.

The sand should not include humus. It is important that the sand and stone are mixed in the correct proportions, and the sand is a continuous graded (not uniformly graded) grain size distribution. In this way one can produce a strong concrete without using unnecessarily much cement.

Cement and Pozzolans



Delayed by transport difficulties

Cement mixed with water is used as a binder in concrete, masonry mortar and renders. Cement acts as a glue between gravel and/or stone particles. Cement is expensive both to purchase and transport, and should be protected from moisture during storage. When cement is used, it releases a light dust that is dangerous to breathe; be sure there is good ventilation.

The most common type of cement is ordinary Portland cement (OPC). Freshly produced cement is normally of good quality, but it can deteriorate quickly with poor storage or transport.

Where rice is grown, cement can be produced with rice husks. The husks are burnt in ovens at 450–750°C. The ash is ground into a fine powder. Rice husk ash is mixed with lime in the proportion 1:2 to give a strong binder. It is also possible to stretch Portland cement by adding rice husk ash.

There are natural pozzolans in volcanic ash, and they can be produced by heating certain clays to 700°C. Pozzolans do not function as cement, but both cement and lime can be expanded somewhat with pozzolans without significantly reducing strength. Even fly ash, a waste product from, among other things, coal fired power generators, can be mixed with cement or directly in concrete. No more than 25% fly ash should be added, to retain acceptable strength.

Water

Access to water is often restricted on building sites outside the main cities. The transport of water is expensive. One might need to conserve water by protecting concrete floors, masonry walls, and other structures with fresh concrete from drying out through evaporation, instead of keeping them damp by sprinkling with water. Water costs for construction can become very high, and must be considered already during planning.

A rule of thumb is that water that is good enough to drink can be used for concrete. If there is any uncertainty, it would be wise to test the strength of a sample concrete cube. One can also run simple tests of setting time by comparing the setting time of cement pastes made with pure water (distilled) and the water available on the site.

Water containing salt should not be used for reinforced concrete because of the risk for corrosion. It can also lead to salt efflorescence (bloom) on rendering and masonry. Water is often salty in desert areas, while surface water from lakes and rivers can often be used. Surface foam might be a sign that the water is contaminated, and is a reason to conduct a test. By sprinkling some cement over a sample of water, such as in a barrel, one can make the visible water contamination sink to the bottom, since it binds with the cement.

Water transport.

Aggregate

The border between coarse and fine aggregates as defined by the American Society for Testing Materials (ASTM) is not sharp. However, in practice aggregate with particles under 9.5 mm are called fine aggregates. They normally consist of sand and natural or crushed gravel. Coarse aggregates consist of natural gravel, crushed stone, crushed rock or crushed gravel. The definition and limits vary, according to the different sieve standards. For instance in Sweden the limit between coarse and fine aggregates is 8 mm.

According to ASTM D653, gravel is rounded or semi-rounded particles of rock that will pass a 3 inch (76.2 mm) sieve and be retained on a No 4 US standard sieve (4.75 mm). Sand is particles of rock that will pass a No. 4 sieve and be retained on the No 200 (0.075 mm) sieve. The equivalent Swedish limits are 4 mm and 0.075 mm.

Name	Size of particles (in mm)
Coarse gravels	60.0 - 20.0
Medium gravels	20.0 - 6.0
Fine gravels	6.0 - 2.0
Coarse sand	2.0 - 0.6
Medium sand	0.6 – 0.2
Fine sand	0.2 – 0.06
Coarse silt	0.06 – 0.02
Medium silt	0.02 – 0.006
Fine silt	0.006 – 0.002
Clay	≤ 0.002

Source: BRITISH STANDARDS INSTITUTION *BS 1377*, 1975.

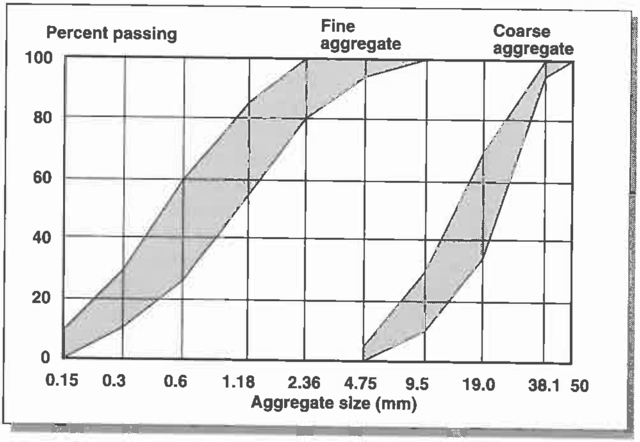
Material passing sieve No 200 are called silt. Silt can be both organic and inorganic. High silt content may jeopardize the quality of the concrete, therefore the silt content of fine aggregates must be limited. A simple way of determining silt content is described in the section of Soil, i.e. use the method described for determining the clay content in soil. If the factor 100 A/B is less than 15%, the silt content of the fine aggregate is acceptable. The reader is also referred to ASTM-C 177, "Standard Test Method for Materials finer than 0.075 mm Sieve in Mineral Aggregates by Washing."

It should be noted that these definitions are according to ASTM for use in concrete technology. There are other standards and applications of soil that use different definitions of its constituents. For instance, Table A shows the grading of soil by the constituents according to the British Standards Institution BS 1377, 1975.

The grading of the aggregates is very important, since it governs the workability of the fresh concrete, which is very important during casting, and the watertightness of the hardened concrete. Grading is determined by sieve analysis, i.e. a representative sample of the aggregate is passed through a stack of sieves arranged in order of decreasing size of opening of the sieve. The figure shows the grading curves indicating the specified grading limits (ASTM C33) for fine aggregate and one size of coarse aggregate. It should be noted that the sieve sizes in the figure are according to ASTM.

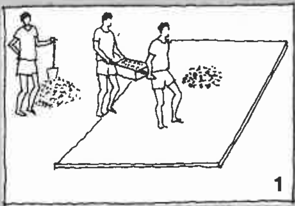
The natural fine aggregates may contain humus which can jeopardize the quality of the concrete. A test method to make a preliminary determination of the acceptability of fine aggregates is briefly described below. ASTM C40 gives a detailed description of the test method.

Grain size for concrete

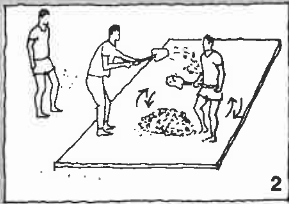


Source: MINDESS, SIDNEY AND J. FRANCIS YOUNG, *CONCRETE*.

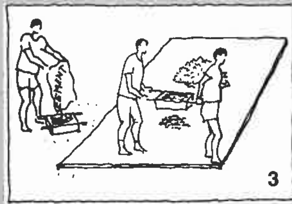
MIXING CONCRETE



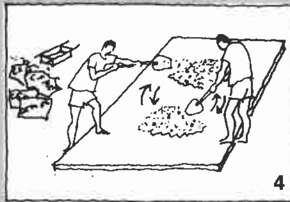
Measure the aggregate (sand and gravel).



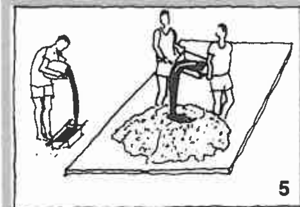
Mix the aggregate, move the material twice.



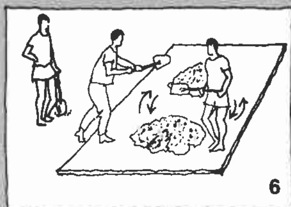
Measure the cement and add.



Mix in the cement, move the material at least three times.



Measure and add the water, be sure that none runs out.



Mix well, move the material at least three times. Ready concrete.

Take a colourless graduated glass bottle (350–470 ml) with a watertight stopper or cap. Fill the bottle to the 130 ml level with the sample of fine aggregate to be tested. Add 3% sodium hydroxide (NaOH) solution (3 parts by mass sodium hydroxide in 97 parts water) until the total volume of fine aggregate and liquid, after shaking, is 200 ml. Set the stopper in the bottle, shake vigorously and let stand for 24 hours. If the colour of the liquid is

- yellow – the sand is clean enough.
- light brown – the aggregate can be used only if a strength test shows that the strength of the concrete is not affected.
- dark brown – the fine aggregate should not be used.

Mixing Concrete

Mixing can be done by hand or machine. First the aggregate (sand and gravel or stone) is mixed. Then the cement is added and mixed well until the colour is even. Finally water is added and mixed in until the concrete has the desired consistency. A rule of thumb is to be economical with water during mixing, and extravagant on the finished structure.

If measuring is done by volume instead of weight, it is important to use the same container to measure all the ingredients. Otherwise there is a risk that the proportions of ingredients will vary between different batches.

Proportions of components in concrete

Strength grade	Quantities by Weight kg per m3 concrete				Quantities by Weight kg per 50 kg sack of cement			Quantities by Volume			
	cement	water	fine aggregate	coarse aggregate	water	fine aggregate	coarse aggregate	cement	water	fine aggregate	coarse aggregate
30 MPa	360	212	980	850	30	140	120	1	0.75	2.0	2.0
25 MPa	320	221	1010	850	35	160	135	1	0.90	2.5	2.0
20 MPa	280	232	1040	850	42	185	150	1	1.05	3.0	2.5
15 MPa	245	250	1070	850	51	215	170	1	1.30	3.0	3.0

In situ Cast Concrete

Concrete is an easily worked material and can be cast in moulds. The concrete should be stiff for normal casting. Soft or semi-fluid concrete is less strong. The cast concrete should be vibrated or consolidated in some other way. Reinforcement bars must not be vibrated, and vibration should not continue for too long; it can lead to separation of the components of the fresh concrete, resulting in a non-uniform mix.

After casting, the concrete must be kept wet to avoid cracks, often for at least two weeks. This can be achieved by covering or watering. Extreme temperatures reduce the concrete strength, so one should avoid casting concrete that is 30°C or warmer during mixing. It might be better to cast the concrete during the coolest part of the day, or at night, and shade the water tank and aggregate from direct sun.

In temperatures between 10 and 30°C, the formwork can be removed at earliest two days after casting. The formwork for structural elements should not be removed for 2–3 weeks. The strength class of concrete is normally based on its strength after 28 days. At 14 days the strength is 75% and after 21 days it is 90% of its 28 day strength.

If a high concrete quality is required, it is wise to run compression tests on cubes (200´200´200 mm or 150´150´150 mm) or cylinders (Ø 150, 300 or Ø 100, 200) of the proposed mixture, to determine its actual strength.

PHOTO: KARL-ERIK LUNDGREN

Precast concrete elements.

Concrete Elements

Concrete elements are used for foundation and building columns, beams, walls, floor structures and roofs. They can be bought ready made or produced on the site. An element should not weigh more than about 150 kg to allow it to be moved and raised by 3–4 persons.

Concrete elements are cast is wood or steel moulds. The mould should be reusable to keep the costs low.

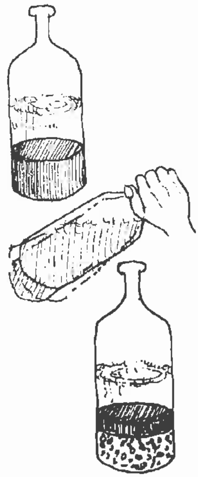
Lightweight Concrete

Lightweight concrete consists of a binder mixed with water and aggregate or additive. Cement and lime are the most common binders. There are several types of lightweight concrete, all of which are less dense than normal concrete. The advantages of the material are that it is both thermal insulating and capable of bearing loads.

The simplest type of lightweight concrete is produced by replacing some of the normal aggregate with a lighter material, such as expanded clay, blast furnace slag, cork or sawdust. These materials can be produced on site at relatively low cost, and each has different properties and uses.

Autoclaved aerated concrete is an industrial product, made by allowing a cement or lime paste to expand through a chemical reaction, then curing it under steam pressure. Production requires a fairly high investment, so the material is found in few developing countries.

Foamed concrete is a cement paste that is expanded with air, mixed in as foam. It is produced on the site in one of two ways. In the first, a foaming agent is whipped into the water in a mixer; when it is foamy, the cement is added. In the second, the foam is produced separately in a foam generator and added to a cement paste. Foamed concrete is produced in densities between 200–600 kg/m³. Sand can be added to reach a density of 1,800 kg/m³. Foamed concrete has lower strength and greater shrinkage than autoclaved aerated concrete. Production is however much simpler, and the investment costs for the mixer and foam generator are relatively low.



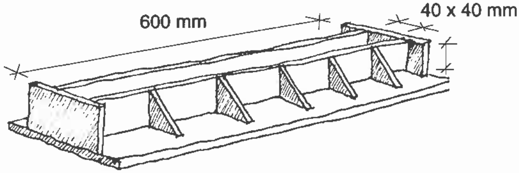
TEST FOR CLAY
- *Fill a bottle 1/3 full with soil.*
- *Add water to 2/3 of the volume and put on the cap.*
- *Shake the bottle thoroughly and let it sit for 30 minutes to allow the material to separate. A teaspoon of salt speeds the process.*
- *Shake the bottle thoroughly again and let it stand. After a few minutes the water should clear and leave two layers, clay (and silt) and sand (and gravel).*
- *Measure the total thickness of the soil (layer A + layer B), and the thickness of layer A. If the clay content (layer A) is between 5 and 30% of the volume of soil (A+B), the material is probably suitable for making blocks.*

Soil

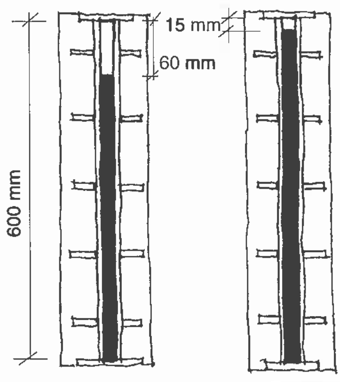
Soil is used as the ground floor, for walls and sometime for roofs. Not all types of soil are suitable for construction, and it should not contain any humus. One must be able to choose the right soil, or improve it, for good building quality. The building technique used is also important.

One can determine if a sample contains humus by smelling it. Soil that smells "earthy" contains humus. Use the soil test above. One can check for clay by rubbing the soil with a thumb nail. It the surface is shiny, the soil contains a lot of clay, while a matt surface shows there are coarser particles.

Clayey sand or sandy clay are excellent building materials. If such soil is not naturally available, one can



TEST OF SHRINKAGE
- *Mix soil and water to a stiff paste and pack into the mould. Use a rod to compress the material, remove air bubbles and even the surface.*
- *Let the sample dry for several days.*
- *Let the sample fall to one end of the mould and measure the empty part. If the shrinkage is between 15 and 60 mm, the material is probably suitable to make blocks. If shrinkage is less than 15 mm, the material contains too much sand. If the shrinkage is greater than 60 mm, the material contains too much clay.*



mix sandy and clayey soils. Clay consists of particles with a grain size up to 0.002 mm. Pure sand and pure clay are not good building materials, but soil with little clay is often suitable. Laterite is an iron and aluminium rich clay that is very suitable for building. Sandy laterite should be stabilized with cement, while clayey laterite should be stabilized with lime. Clayey silt (silt = grain size between clay and sand) is best stabilized with lime or asphalt.

Soil is often reinforced with straw to distribute cracking and achieve a strong structure.

Making hollow concrete blocks

Masonry Units

Concrete

Concrete bricks and blocks are very common building materials in developing countries. A common size is 400x200x200 mm. Concrete units can be solid or contain holes (concrete hollow block). Both types are simple to make, and production is often on the building site.

If there is a good supply of clean sand, solid or hollow units can be made with a simple, motor driven machine or a hand press. There are also electrical machines that vibrate each block during production.

The common proportions are 1 part by volume cement to 5 parts by volume sand for hollow blocks, but this can vary from 1:4 to 1:8 depending on how the blocks will be used. The mixture can be lean. The consistency should be earth damp, that is rather stiff. The mix should be packed carefully into the moulds and kept damp for about three weeks before using.

Moulding clay bricks by hand

Burnt Clay Units

Burnt clay bricks and blocks have been used as building materials for more than 5000 years. The raw material can be found almost anywhere, and production is relatively simple. Firing clay (to about 1000°C) takes energy. Smaller brickyards usually burn wood or another solid fuel. Industrial producers use modern kilns that are larger and more technically advanced, and require significantly less energy.

Burnt clay is a hard and brittle material with good compressive strength. The material does not change its shape after firing, and retains its dimensions when subjected to changes in moisture and temperature. Burnt clay is also heat resistant and immune to most chemical and biological agents.

Units from smaller producers are usually hand-made. They might be solid and attractive, but there can also be variations in size, strength and durability. There is usually no quality control of these units.

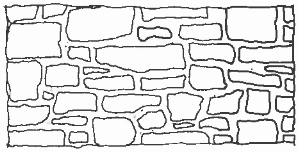
As a rule, industrially produced units are extruded. The size and shape depends on the intended use. Solid or perforated units are used for facades and in load bearing structures. Thin walled units are common, and they can vary in size from small "traditional" bricks to large hollow blocks. These units are used in non-load bearing interior walls and as a filler in a concrete frame wall. Sometimes hollow blocks are placed in cast concrete floors. Thin walled units offer different climatic qualities from solid units; they provide better thermal insulation but have lower heat storage capacity.

Production of hollow clay blocks

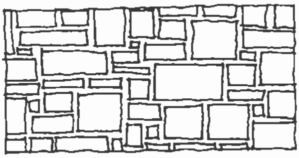
Stone

Stone is an excellent building material that can well be used where available. Most types of stone are suitable for foundations, walls and roofs. A natural stone facade is attractive and long lasting. Stone walls are maintenance free, and therefore an economical alternative to burnt clay or concrete units, but in some part of the world they have lower status.

Hard stone is difficult to work. It can be used for foundation walls, for walls that will be rendered, and for crushed aggregates. Softer varieties of stone can be worked and used in walls and columns without rendering. Natural stone used in foundation and building walls should be clean and not so porous that they absorb water. Stone walls are often rendered to give them more status, but then the render requires regular maintenance, repair and painting. All types of stone can be used as a base for the ground floor.



Natural stone wall



Cut stone wall

Adobe and Stabilized Earth

Adobe is soil shaped into a block and air dried for about one week. A common size is 400x400x100 mm. Straw can be mixed into the soil for reinforcement.

It is difficult to give simple rules for choosing the soil. It is best to make sample blocks and let them dry. Test them by placing weights on them. This test will show which soils or mixtures should be used. The soil can be reinforced with straw, cement, lime or bitumen, and thus made more water resistant.

There are machines that mechanically press blocks of stabilized soil. The strongest units are of soil stabilized with cement. Normally the blocks are somewhat larger than a burnt clay unit. The most common size today is 295x140x90 mm.

Making cement stabilized earth/ soil blocks

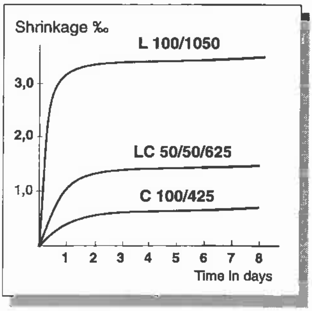
Sifting sand

Mortar for Masonry and Rendering

Clay has been used as both mortar and render for stone and burnt clay walls. If the clay is mixed with straw for reinforcement, the structures can last for decades, provided they are not exposed to direct rain. Soil from termite stacks, mixed with water, can be used in a similar way. Much more common, and more durable, are standard mortars composed of binder, aggregate (and mixing water): cement and sand; lime and sand; or lime, cement and sand.

Mortar is named by its binder, such as lime mortar, lime cement mortar or cement mortar. (This section is quoted from Sandin 1995.) The amounts of binder and aggregate should always be expressed as parts by weight; for example LC 50/50/650 means 50 kg lime, 50 kg cement and 650 kg sand. As an alternative the components can be expressed in volumes; that is LC 2:1:12 which means 2 parts lime by volume, 1 part cement by volume, and 12 parts sand by volume.

Binder and Shrinkage

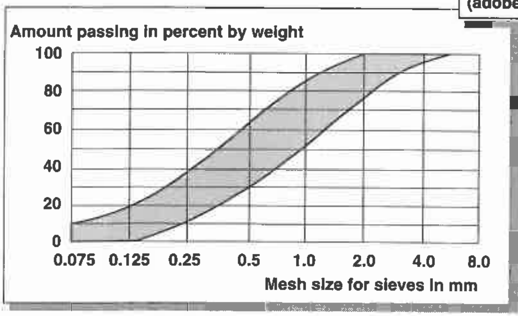


L = lime, C = cement. For example, LC 35/65/550 means the proportion of lime/cement/sand by weight
LC 1:1:8 means the proportion of lime:cement:sand by volume

Examples of Mortars for Units of Different Absorbencies and Strengths

	High absorption Low strength	**Low absorption High strength**
Solid and hollow concrete blocks, natural stone	LC 35/65/550 (LC 1:1:8)	C 100/450 (C 1:4)
Bricks and hollow blocks of burnt clay, calcium silicate units	LC 50/50/650 (LC 2:1:12)	LC 35/65/650 (LC 1:1:10)
Aerated lightweight concrete Cement stabilized soil blocks	LC 60/40/700 (LC 3:1:16)	LC 50/50/650 (LC 2:1:12)
Sun dried clay units (adobe)	L 100/800 (L 1:4)L	C 60/40/700) (LC 3:1:16)

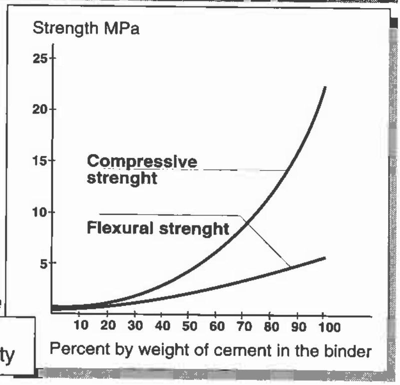
Grain Size Distribution for Mortars.



Source: SANDIN 1995.

Cement and Strength of Concrete

Binder:aggregate = 1:4
3 months curing at 70% relative humidity



A pure cement mortar is stronger than a pure lime mortar, but significantly more brittle, and not as workable. In most cases a lime cement is preferred.

The sand, cement and lime should be well mixed before water is added. The ingredients should be weighed if possible, or use a marked measuring container, and add enough water to reach the correct consistency. The largest grain size in the sand may not be greater than 1/3 of the thickness of the layer.

Render

For a long lasting render, the background material must work well with the mortar. This means that the mortar must never be stronger than the background. A burnt clay brick wall, laid with lime mortar, should also be rendered with lime mortar to avoid cracks.

Lime cement mortar is often preferable, because it provides a combination of strength and workability with less risk for cracking. Cement mortar is brittle. If the surface will be subject to movement, the rendering should be reinforced with galvanized steel wire netting or reed mats.

A rendered surface must be protected from heavy wetting.

External rendering should not be done on natural stone, concrete block or solid burnt clay, if they are good quality, since these materials require less maintenance than a rendered surface.

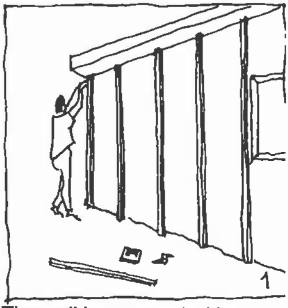
Cement and lime mortars should not be used on a clay background. Clay mixed with straw is however suitable as a render on earth walls.

Lime

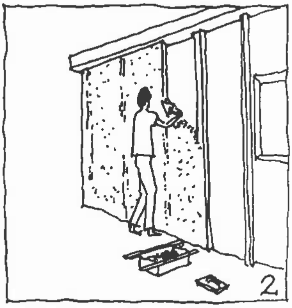
Lime has been used for hundreds of years as a binder in mortar. Lime is produced by burning calcium carbonate, found naturally as chalk, marble and limestone. Limestone is burnt in shaft furnaces at a temperature of 1100–1300°C, using wood, coal or oil as fuel.

The burnt (quick) lime reacts with water to form calcium hydroxide (slaked lime). There is wet-slaked and dry-slaked lime. The final product in wet-slaking is a thick paste, three times the volume of the original material. This paste, mixed with sand and water, becomes lime mortar. Wet-slaked lime is often made by hand, and is being replaced by dry slaked lime, which is made industrially. Dry-slaking produces a fine powder, usually sold in bags.

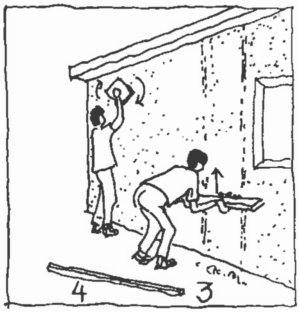
Lime can be either non-hydraulic or hydraulic. Non-hydraulic lime cures only in air, and these are used in lime cement mortars. Hydraulic lime resembles cement: curing begins as soon as water is added and the mortar is relatively hard and brittle.



The wall is prepared with a spatterdash coat. Wooden strips, the same thickness as the intended coat of render, are fastened vertically one metre apart, using mortar.



When the strips are firmly attached (about 1 hour), the render is laid between the strips beginning at the bottom and moving upwards.



Excess mortar is removed by drawing a board horizontally, back and forth, from the bottom toward the top. Remove wooden strips and for a smooth and water resistant finish, polish the surface with a float.

Timber and Plant Materials

Timber

PHOTO: KARL-ERIK LUNDGREN

Pole wall

The availability and quality of timber varies greatly by region. Sawn timber is either hand or machine sawn. The classification and quality control of timber is often poor, and one should check especially carefully.

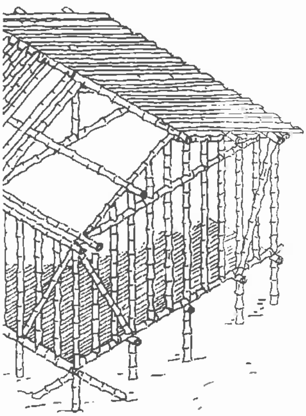
Some types of wood are so hard that they are difficult to work with (plane, split, nail, etc.). They can be resistant to rot and termites, and therefore very suitable for the building frame or for doors and windows. Hardwoods are more easily worked when damp. More easily worked wood is used for furniture. Poorer quality soft woods can be used for formwork.

Timber should be dried well before use, by stacking and sheltering it from rain. In some climates wooden constructions are not suitable in exposed places. Humid climates might pose a problem with mould. Therefore it is important to design the building details to minimize the entry of rain and moisture into the structure, and to allow drying. Termites and other insects can destroy wooden buildings. See the chapter on termites for advice on reducing the risks.

Boards

The production of boards has expanded rapidly in many developing countries. Boards are made of wood, such as plywood, wood fibre and chipboard, and also asbestos cement and fibre cement. Avoid using materials containing asbestos because of the health risk.

Boards are mainly used for ceilings, interior walls and fittings. The quality might be uneven, and they are not usually termite and water resistant. Some chipboard is treated in the factory to be termite resistant. Cement-bonded wood particle boards are resistant to moisture and termites.



Bamboo

Bamboo is a relatively strong and light building material. It is completely different from other sorts of timber and requires special techniques. Once one has learned these techniques, it is possible to build very complicated and durable structures. In some areas entire houses are built of bamboo: walls, trusses and roofing. Bamboo cannot be nailed without first drilling holes, so it is often woven or tied together.

Moisture and insects weaken bamboo, and shorten its service life. Bamboo, therefore, does not have very high status, and is used in store house walls, gable ends and such. Bamboo can be treated like ordinary timber, by pressure impregnation, painting or soaking with copper, chrome arsenic and similar compounds. Bamboo should be treated when it is still green, before it has dried.

Straw

Straw, reeds and palm leaves are used as traditional building materials in roofs, walls and as reinforcement in adobe walls. The material is often cheap and locally available, but it is flammable and attractive to insects and vermin.

The most common use of grass and palm leaves is roof covering. It requires regular maintenance. Depending on the skill of the craftsman, and the quality of the material, a thatched roof might last between 3 and 30 years.

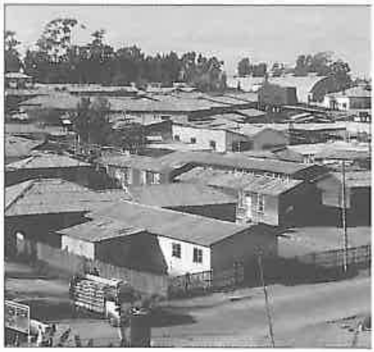

PHOTO: MONICA ERIKSSON

Metal

The most common metal materials are CIS and reinforcement bars.

Corrugated Iron Sheets (CIS)

Galvanized, sinus corrugated, steel sheet roofs are found all over tropical areas. The sheets can be bought locally in most countries, but are normally imported or manufactured locally with imported raw materials.. The thickness of the steel varies from 0.2 to about 1 mm. The sheets rust quickly, especially in coastal and industrial areas. The service life can be extended by painting.

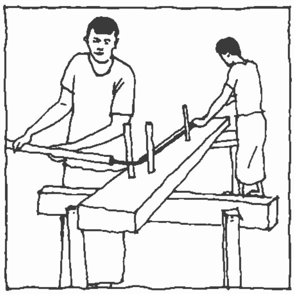
PHOTO: MONICA ERIKSSON


Aluminium

Aluminium sheets have become more common recently. The advantage of aluminium is that it does not rust, but it is usually more expensive.

Reinforcement Bars

Ribbed and smooth bars are usually made locally. The quality varies. Before using the bars in a reinforced concrete structure, they should be tested for tensile strength in a laboratory. New reinforcement steel has a thin oxide scale that must rust away before the bars can be used.


Bending a reinforcement bar

Profiles, Pipes and Nails

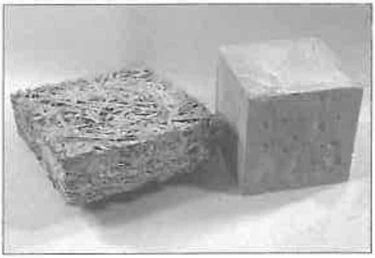
Some locally made profiles of pipe, angle iron, flat steel, window profile can usually be found, but they often have relatively low strength. Galvanizing is also done locally. The availability of imported steel products depends on the country. Aluminium profiles are becoming more common for fittings and doors and windows. Galvanized pipe is being replaced by plastic pipe in water systems.

There is usually a limited selection of nails, the most common is round and soft. Nails are expensive, and bent nails are reused. If the timber is very hard, one should drill before nailing, otherwise the wood splits.

Thermal Insulation Materials

There is justification for using thermal insulation materials in developing countries, for protection against both heat and cold. In air conditioned buildings, one can conserve energy with thermal insulation. Even in passively climatized buildings, thermal insulation improves the indoor climate. The benefits are especially great in hot and dry climates. (See Chapter 2).

All thermal insulation materials hold air, which is itself a poor heat conductor. High value insulating materials contain a lot of air, are light, and have low strength. Heavier materials have higher strength and greater heat storage capacity, but somewhat lower thermal insulation capacity. These factors must be considered when choosing the material. It is preferable if the thermal insulation material can be used without requiring changes in the local building techniques.



Woodwool slab and foamed concrete

Imported mineral wool is used in a few high cost projects, mainly to insulate cool rooms, hot water pipes or ventilation pipes for air conditioning. Cellular plastics are used about as much and in a similar way.

Cork is common in North Africa, where cork is heated to produce expanded cork. It is used in sheets between 20 and 150 mm thick. The most common sheets are 50 mm thick and used to insulate floors of the terraces since they tolerate relatively heavy loads.

Woodwool slabs are found in a number of developing countries, mainly in East Asia and Latin America, but also in some countries in Africa. The material is made of woodwool, cement and water in the proportion by weight 1:2:1. Woodwool is mainly produced from conifers, fir and pine, but wood from some deciduous trees can be used. The material is not attacked by mould and rot and has good resistance to termites. Woodwool slabs are well suited for concrete structures, as permanent formwork, and is an excellent background for rendering. It can be used for thermal insulation of walls and roofs. (See chapter 4). The slabs have excellent sound absorption properties and is often used as a ceiling. When the slabs will be visible, they can be painted.

Woodwool slabs are an interesting material for the future in countries that lack their own thermal insulation material, since it is normally easily adapted to local building techniques. The material can be produced in labour intensive factories, and the investment costs are significantly lower than for mineral wool or cellular plastic plants.

In countries where wood is scarce, cement-bonded straw slabs might be considered. These are produced along the same principles as woodwool slabs, although the straw must be pre-soaked for two days in a calcium chloride solution.

Autoclaved aerated and foamed concrete are somewhat heavier thermal insulating materials, described in the section on concrete.

The thermal conductivity of a material varies with its moisture content. The table compares some materials with normal moisture content.

Material	Density (kg/m3)	Thermal Conductivity (W/mK)
Mineral wool	15–200	0.04
Cellular plastic foam	12–40	0.04
Cork	140–200	0.05
Woodwool slab	200–300	0.07–0.09
Foamed concrete	200–1800	0.08–0.8
Autoclaved aerated concrete	400–650	0.10–0.18

Surface Treatment

Paint

Painted surfaces require regular maintenance, so one should choose locally available paints. External walls exposed to rain, and made of materials that absorb water, should be painted for protection. Painted interior walls should have a surface that is easy to keep clean. Wood details should be protected with wood oil or oil paint, especially on the outside of the building. In wet areas the wall can be protected from damp by oil based paint.

Lime paints are common on both exterior and interior walls, but it gradually washes away when exposed to rain, and must be repainted. To get the most out of the lime, mix it into boiling hot water. Adding 2 kg of table salt to 100 litre of lime paint will keep the paint from rubbing off the painted surface. Adding animal based glue (horn glue) to the lime gives a harder surface and a somewhat more durable paint.

Shutters and doors can be oiled or painted with oil based paint. Timber can be brushed twice with waste oil mixed with 1/3 diesel. This gives a cheap wood protection, but is not widely used.

Acrylic paints are produced in more and more countries. There are different qualities for interior and exteriors. Do not paint both sides of a wall with tight plastic paint, since most wall materials need to breath. In humid climates this can be a disaster, leading to rapid growth of mould and rot, so avoid plastic paint if possible.

PHOTO: KARL-ERIK LUNDGREN

A problem with lime paint is that it washes away in rain.

Waterproofing

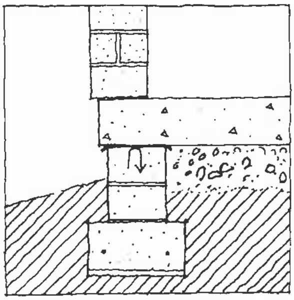
A watertight layer is very important in some parts of a building, such as the damp-proof course between the foundation wall and an outer wall, or between masonry or concrete and wood in exterior parts of the building. Damp proof courses are often made of plastic sheeting, asphalt or bitumen felt. Plastic sheeting is sensitive to ultraviolet radiation (sunshine), which breaks down the material.

It is not simple to build in a humid, tropical climate. Acrylic paints dry badly and mould often. "Maintenance free" plastic floor coverings shrink.

Waterproofing for Flat Roofs

Waterproofing should be seen as a system consisting of a waterproofing membrane and a protective layer. The layer is to shield the membrane from solar radiation and mechanical stress such as foot traffic.

The waterproofing membrane of a flat roof is usually some form of mastic asphalt, roofing felts or rubber sheets.



A damp-proof course keeps the ground moisture from being absorbed by the floor slab and the wall.

Mastic asphalt (a mix of bitumen, filler, sand and gravel) is laid a few centimetres thick. The asphalt is spread over a base layer of bitumen reinforced with, for example, jute sacking. Spreading asphalt requires equipment to heat and mix the material, and trained labour, which makes it a relatively expensive solution.

Roofing felts of bitumen impregnated paper (bitumen felt) work very well as waterproofing, and can be laid several layers deep. Because the elasticity of bitumen is destroyed by ultraviolet rays, the surface must be shielded from the sun. The protective layer might be tiles, sand or coarse gravel, mortar or lime paint.

Lime works well as waterproofing where there is little precipitation, but requires annual maintenance.

A weatherproofing membrane of polymer-modified bitumen – a sort of rubber sheeting sold by roll – is becoming more common in developing countries. The sheets are rolled out on the roof with a slight overlap, and the joints are sealed by fusing with a blowlamp. The material is sometimes protected from the sun by a reflective aluminium paint. This material is expensive, requires experienced workmen to lay, and does not tolerate foot traffic (and is thus not suitable for a roof used as a living area). The aluminium paint does not give complete UV protection, since it easily cracks and fragments loosen.

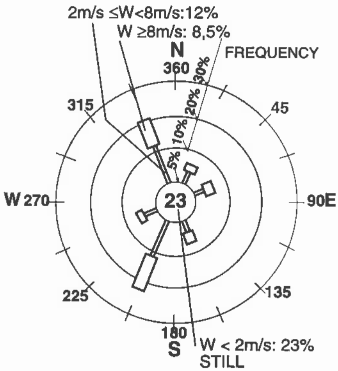
Laying a waterproofing membrane on a flat roof.

An economical waterproofing membrane is bitumen emulsion – a type of unheated asphalt. It is easy to work with, since it is applied when cold. The tools can be washed in water. Bitumen emulsion should be reinforced with fine gauge plastic mesh or a similar material to bridge any cracks better. It can be covered with a protective layer of mortar, which should be reinforced against cracking with steel net.

4 BUILDING TECHNOLOGY

Building Technology

The quality and durability of a building depends to a large extent on its foundation. Any faults in the foundation can lead to irreparable damages. The roof, walls and foundation should be well fixed together to withstand the expected wind-force and possible earthquakes. All construction should be designed to allow drying-out to avoid problems with moisture and mould, especially in areas with heavy rains.



Example of a wind rose. The circle in the centre represents wind velocity below 2 m/s (still), which occurs 23% of the time. The vectors show wind directions, wind velocity and frequency. The narrow part of each vector represents the wind velocities between 2 and 8 m/s. The thick parts represent wind velocities over 8 m/s. The length of each part of the vector gives the frequency in %.

Source: GRET, BIOCLIMATISME EN ZONE TROPICAL

Natural Forces

Strong Winds

It is important to design the building to withstand strong winds. When calculating the dimensions of the building components, one should allow a margin of safety over the strongest winds likely during the building's expected lifetime. Special measures must be taken in areas where there is risk for cyclones (also called hurricanes or typhoons in different parts of the world).

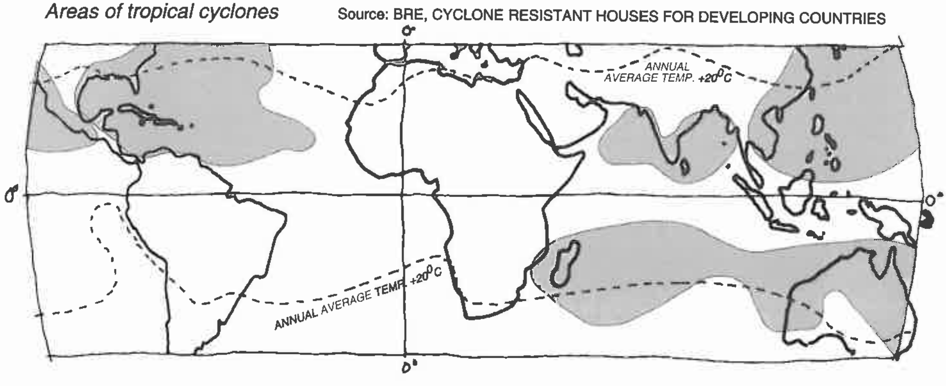
Wind Loads

In some countries the wind load requirements are stated in the building codes. If this information is not available, data from weather stations, or a climate atlas, can be used to estimate wind velocity as a basis for calculations. Climate atlases include wind-roses showing the directions and velocities of winds. These diagrams are based on many years of measurements. The local population can also give important information about wind directions and strengths.

When wind strikes a structure, it produces a wind load; some parts of the building are subject to pressure and others to suction. Wind loads are especially great

Areas of tropical cyclones

Source: BRE, CYCLONE RESISTANT HOUSES FOR DEVELOPING COUNTRIES



at corners and roof projections. Flat roofs, and roofs with slight inclines, are always subject to suction. A gable roof with a slope over 20–25° has pressure on the windward side and suction on the lee side.

Wind-safe Construction

Building damage related to wind is largely caused by inadequate fastening. It is important to attach the roofing material to the battens and the rafters to the walls. In areas with very strong winds, it might be necessary to anchor all the way down to the foundation. See the section on walls and roofs.

Another cause of damage is the *shape* of the building. High, long and narrow buildings are more exposed to wind than low square structures. The most exposed part of the building is the roof. Wind has the least effect on a roof with a slope of 30–40°, and less effect on a hipped than a gable roof.

Where there is a risk for cyclones, the roof overhang should not be longer than 800 mm. Windows should be small and placed away from corners. Hurricane shutters help protect the windowpanes from cracking.

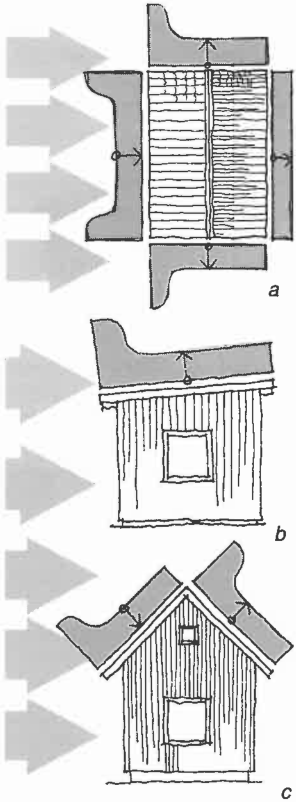
The *placement* of the building on the site also affects safety in wind. One should avoid:

- tops of cliffs and hills,
- deep valleys opening towards the sea,
- flat coastal strips.

The wind speed in these areas can be 10–20% higher than normal.

Instead one should choose:

- well protected valleys
- placing the buildings in a cluster surrounded by plants.



The distribution of wind pressure on a) walls, b) roof with little or no slope, c) pitched roof. The wind is blowing from left to right.

Rain

Rain often falls very intensely in tropical areas, and even in some dry climates with a low total annual rainfall. Intense rain can cause great damage, because the ground cannot absorb the water fast enough. Therefore one must plan for efficient drainage of rainwater.

Local rain patterns and potential flood risks should be investigated before deciding where the building is to be placed, what kind of foundation and design to use.

It is important where the building is placed on the site. The ground should slope away so surface water can run off. It can be expensive to put buildings on very steep sites, because the ground might require terracing and it

Rainwater damage

PHOTO: BJÖRN MOSSBERG

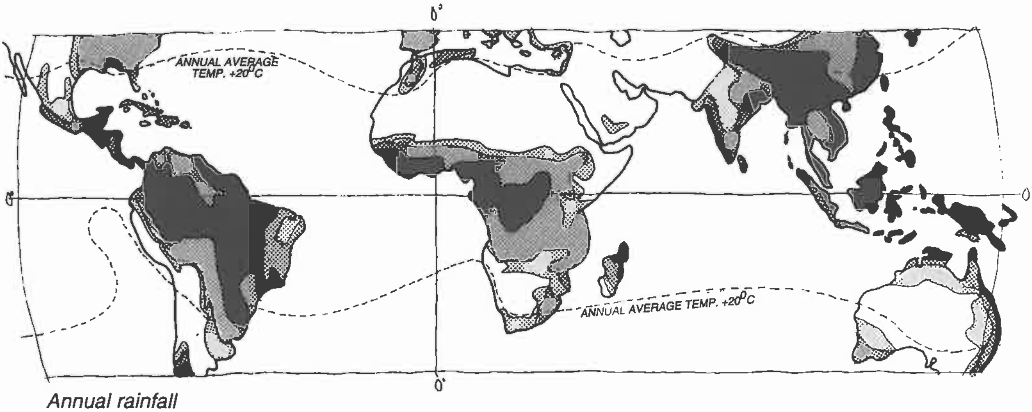
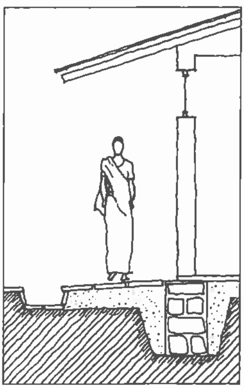


PHOTO: KARL-ERIK LUNDGREN

Long overhangs and hard paving against the building protect it from rain



might be necessary to build large drainage ditches because of the fast-running water.

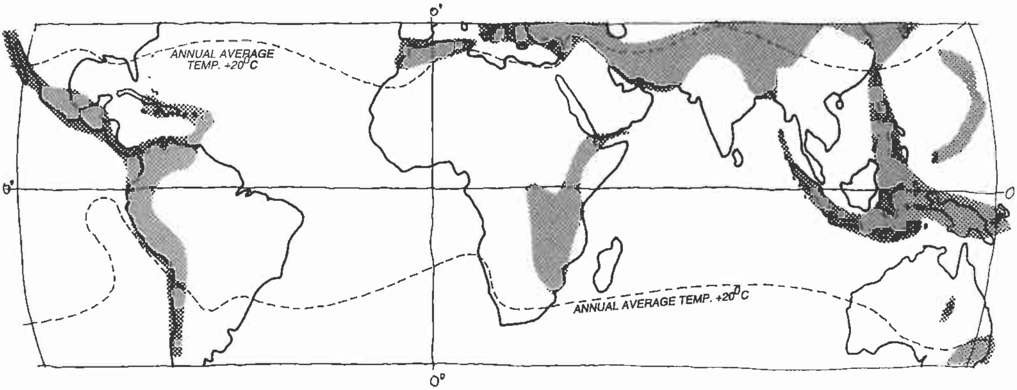
Some rivers are dry most of the year and fill only during the rain period or after heavy cloudbursts. A building should never be placed where there is a risk for such flood rivers, which can be very wide and difficult to see. These rivers might even change their flood path from year to year.

The foundations must be protected from rainwater. This can be achieved by long roof overhangs, hard paving close to the building, and drainage channels to lead away ground water. A lot of rain strikes the roof, and the water should be removed by gutters and downpipes. It is important that the gutters and drainpipes are big enough, durable and easy to clean. The floor should be above ground level. If there is a risk of flooding, the foundation should be made of a water resistant material, and it should extend some distance above the ground.

> The first rule is to lead the rainwater away from the building so that it does not seep into the soil or collect in the ground. If this rule is broken, there is no solution. Pay special attention to the area close to the building. Assume that the annual rainfall is 3000 mm. If a roof is 200m², it means that 600,000 litres of water must be removed. If this is not done, the ground loosens and the building sinks where the soil is softest.

With a combination of wind and rain – known as driving rain – even the walls are exposed. Long roof overhangs protect walls from driving rain. Hipped roofs also protect the gable ends.

The watertightness of a roof depends on its slope and how it was covered. The flatter the roof, the more difficult to keep watertight. Flat roofs have proven to be particularly difficult to keep tight. Therefore such roofs should be avoided in areas with high rainfall.



Earthquake zones

Soil Erosion

Foundations can be washed away by rain, so it is important to protect the soil from erosion before, during and after construction. Erosion might also be caused by wind, streams or groundwater.

The most common protection against erosion is planting trees and shrubs. Leaves and branches reduce the effect of heavy rains, and roots hold the soil together. Erosion caused by rain water can be alleviated by terracing and surface drainage.

PHOTO: KARL-ERIK LUNDGREN

Soil erosion

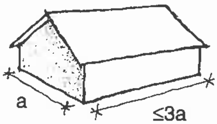
Earthquakes

Where there is risk for earthquakes, it is very important to test the ground. The quality of the soil and the likely strength of potential earthquakes are crucial for dimensioning the building components. Avoid building on soils that might become fluid during an earthquake.

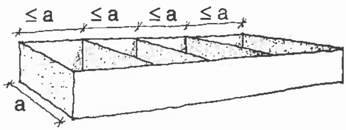
The strength of an earthquake is measured on the Richter scale, which expresses the energy released at the focus of the earthquake. The focus for most earthquakes is 0–70 km under ground. The Richter scale is logarithmic, which means that a one point increase on the scale is equivalent to a 10 times stronger quake. At 5 on the scale there might be slight damage to buildings. At 6 on the scale there will be cracks in masonry walls. At Richter 7, masonry and wooden structures suffer extensive damage.

The site should be chosen to reduce the risk for sliding. The ground should be well drained. The structure should be placed high in coastal regions. Generally lightweight buildings are preferable to heavy buildings. The roof, walls and foundation should all be well fastened to each other. Avoid building a storey that projects out from storey under (continuous corbel).

In earthquake areas the following building materials are recommended: steel, timber and reinforced concrete.



Appropriate proportions between the length and width of a building to improve safety during an earthquake.



Stabilization of a long, narrow building with inner walls.

Source ARYA: PROTECTION OF EDUCATIONAL BUILDINGS AGAINST EARTHQUAKES

Unsuitable materials are unreinforced masonry walls with weak mortar and unreinforced soil walls.

To be as earthquake resistant as possible, the building should be symmetrical along both axes. Best is a rectangular design with a length:width ratio < 3:1. Avoid long, narrow structures.

A long, narrow building can be stabilized by walls that break the space into nearly square boxes. If this is not possible, the walls can be raised as a system of rigid frames, with columns and beams of reinforced concrete (maximum distance of 6 m between the columns).

It is expensive to make a building completely earthquake-proof. The aim is to avoid the collapse of the building in an earthquake. One must accept that there might be cracks and other damages to repair after a strong earthquake. One way to reduce costs is to have a lower level of safety in parts of the building that are not often occupied, such as stores and laundry rooms. (About earthquakes see also pages 51, 56 and 65.)

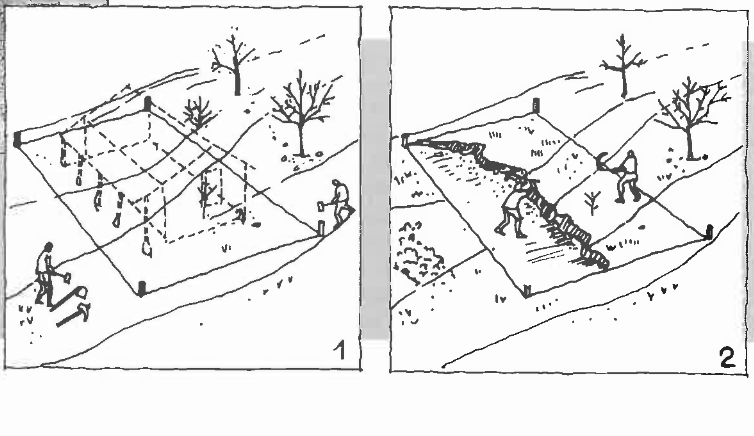
Ground Work

The importance of ground work is often underestimated. It should always be planned early to make the construction easier. One must reserve adequate resources not only for work related to the construction itself, but also the work required after, such as paving and landscaping.

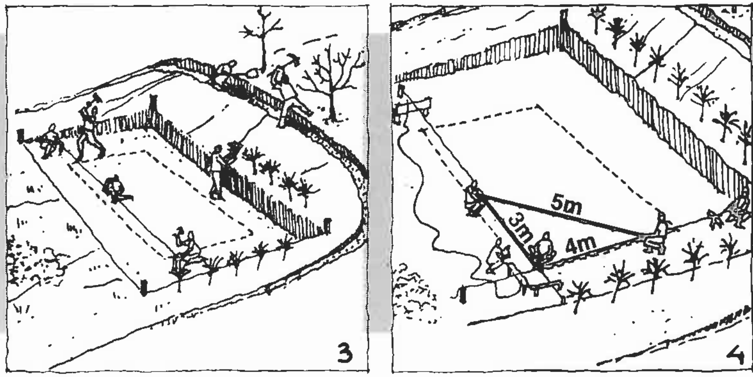
The amount of work depends on the ground conditions, such as the type of soil. Soil types and testing are discussed in the section on Foundations.

Setting-out

Setting-out is an important step in construction. Before it can be done, the site must be cleared of any plants, trees, roots, termite mounds, etc. The top soil is removed to a depth of 150 mm and saved for later planting.



SETTING OUT
1) Setting out for excavation
2) Excavation

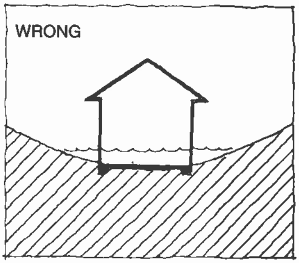


3) The exact dimensions of the building are marked
4) Setting out a right angle

First the finished floor level is determined, considering precipitation, soil moisture and the risk of floods. To mark the corners of the building, solid profiles are set at a slight distance from the facade. These are linked by steel wire or any string that is not affected by damp (such as nylon). These corner profiles and lines can then be used as guides during excavation, setting-out footings, walls, etc.

There are advantages to setting-out the corners with a theodolite. If there is none available, determine a right angle with a 3:4:5 triangle. Check that the plan is rectangular by measuring the diagonals.

To assure that the building is horizontal and at the right height, use a level or a transparent hose filled with water. A spirit level may be enough for a smaller building.

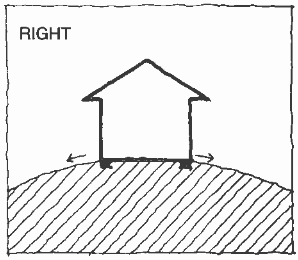


Be sure the excavated site does not collect water.

Excavation

An excavator is necessary for some kinds of foundation work. If there is none available, or if it costs too must to hire, manual excavation must be considered.

When excavating near the edge of the site, consider the angle of repose, which varies with the type of soil. For deep excavation near the site boundary, or near existing buildings, sheet piles might be required, and are very expensive.



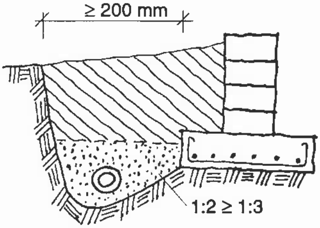
The ground should slope away from the building.

Drainage

The ground around the building must normally be protected, especially in tropical areas where rain falls in heavy cloudbursts.

Subsoil Drainage

If heavy tropical rain is not a problem, it might be enough to have a subsoil drain. An advantage is that it also gives some protection against rising ground water.



Subsoil drainage of the ground near the foundation wall.

A correctly placed and constructed subsoil drain improves the soil stability, which reduces the risk of settling and serious damage during an earthquake.

The subsoil drain may be plastic, burnt clay or concrete. It is laid below the foundation and around the building with an even decline of at least 1:200. At its lowest point it is connected to a natural gully or sewer. The subsoil drain is placed on 50 mm of packed gravel and covered by the same material to 100 mm over the top edge. Fill with a pervious material up to the level of the foundation. The trench of material should extend at least 200 mm from the foundation wall.

Concrete slab pathways, Nicaragua

Surface-water Drainage

If there are heavy tropical rains, the ground surface around the building must be paved and drained. The drainage channels should also be surfaced to prevent collapsing. It is almost impossible to construct channels that withstand an abnormally heavy rain, but by leading the water in the best possible way, it is possible to limit the damage.

The ground and the channels can be paved with in-situ cast concrete, asphalt concrete, oiled gravel or tiles. The paving should extend at least 1.5 meters from the wall, at a slope of at least 2.5%, preferably 10%.

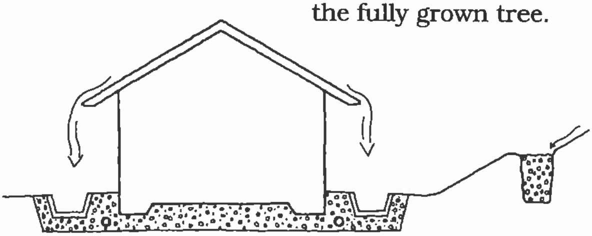
The ground might also be treated by cement or lime stabilization. Cement is used for non-cohesive soils (sand, clean silt), while lime is used for cohesive soils (clay, clayey silt). Note that lime stabilization does not withstand heavy tropical rain, so the surface must be protected with a bituminous layer or tiles.

If the site is very sloped, a French drain should be built along the upper side, above the building. A steeply sloped channel should have steps to slow the flow of water.

Landscaping

Trees, bushes and lawns provide protection against erosion. Trees also block the wind and sun, and should be planted as early as possible.

Tree roots absorb moisture, which can cause subsidence in clay soils. In such cases trees should not be planted close to the building. A rule of thumb is the tree should be as far from the building as the height of the fully grown tree.



Drainage for surface and roof water. A French drain is placed above the building

Source: ADAMSON AND ÅBERG 1993

Foundations

The quality and service life of a building is greatly depended on how the foundation is laid. A poor foundation can lead to damages that a impossible or very expensive to repair.

Soil Properties

Soil is grouped into two classes: frictional (non-cohesive) and cohesive.

Frictional Soils

Frictional soils (sand, gravel, clean silt) consist of large particles. They can have good strength, depending on how well they are compacted. Their strength is largely independent of water content.

A frictional soil will settle immediately under a load, but after the building is constructed, there is normally no further settlement.

Cohesive Soils

Cohesive soils (clay, clayey silt) consist of fine particles and have less strength than frictional soils. The properties of clay soils vary greatly with their water content. When water content goes down, the clay shrinks and becomes stronger. When water content increases, the clay swells and losses compressive strength.

Any plants nearby, particularly trees, can have a large effect on the shrinking and swelling of clay soils. A tree absorbs a lot of water, causing shrinkage in the surrounding ground. Cutting down a tree, so that the roots no longer take up water, will cause ground swelling. Local swelling can also occur where there is run-off from roofs and leakage from water supply and sewer pipes.

If clay is subjected to a load, such as by a building, water is extruded and the soil is compressed. This process of consolidation is very gradual and settlement can occur for several years.

Expansive soils, such as black cotton soils, contain clay that expands and contracts *very greatly* when water is added or withdrawn. This kind of soil causes most difficulty in climates with distinct rain and dry seasons. The transition from dry to rain period can imply swelling pressures of about 100 kPa, sometimes even greater.

Soil Investigation

The cost of the foundation is closely tied to the soil conditions, so it is important to investigate these carefully, early in the planning. If the ground conditions prove to be worse than reckoned, it might be necessary to modify the design of the building.

In addition to soil quality, it is also important to know the variations in groundwater levels. Laying a foundation under the groundwater level is more complicated, so the location of the groundwater can be crucial for the bottom level of the building.

A soil investigation determines the levels of the soil layers, their properties and thickness. In the case of pile foundations, the study also determines the depth of the firm base.

It is enough to take soil samples in the corners of the site for smaller structures. Tests should be done at least to the depth that the ground is affected by the building.

Inspection pits can be dug when laying shallow foundations for light buildings. Other techniques are normally used for deeper foundations. A simple test method is the static penetration test, suitable for cohesive soils and frictional soils with a low degree of compaction. This is done with a steel rod that is driven into the ground. The rod is loaded, and the ratio of weight to depth helps determine the type of soil and its thickness.

A safer method is to take up core samples of undisturbed soil from boreholes with a soil auger. A hand held posthole auger can reach a depth of 7–8 m in soft or firm clays. For frictional soils, or if one needs to go deeper, special truck-mounted drills are used. This test is done by specialists and the samples are analysed in a laboratory.

Soil Stabilization

Weak ground can be stabilized in different ways. One is to excavate and backfill with soil of greater supporting capacity. The replacement soil must be packed to reach the required strength.

One can pre-compress clay soils, such as by laying a thick layer of soil on the ground. The load should be greater than the weight of the building itself.

Soil can also be stabilized with cement or lime. The binding agent is mixed with the soil by a rotary cultivator or injected by drilling.

Choice of Foundation

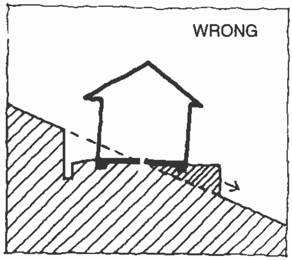
The function of the foundation is to transfer the weight of the building to the ground. The type of foundation must be decided early in the planning process, since it can affect the design of the building. When deciding on the foundation, one must consider:

- ground properties
- load
- sensitivity of the building to settlement
- availability of equipment and labour.

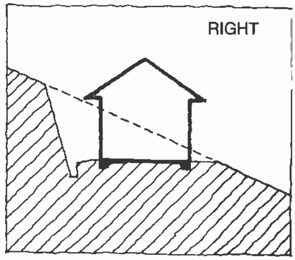
Ground properties are normally determined by the soil investigation, as described above. The sensitivity to settlement depends entirely on the type of construction; a masonry structure, for example, is significantly more sensitive than a timber structure.

Choose a foundation that provides good assurance that the ground will not give way, and lessens the risk for settlement. Normally there is no problem setting a foundation on rock or packed frictional soil, but clay has poor carrying capacity. Earth slides can occur on slopes, or where different types of soil meet, especially if the building is heavy or the soil clayey. One should never build a foundation on filled or partially filled ground.

Avoid laying a foundation during the rain period, if it is not possible to protect the excavated ground.



Avoid putting a house on different foundation materials



The foundation under the entire building should be the same kind of material

Foundation Wall

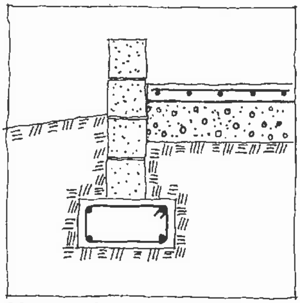
If the ground is rock or packed frictional soil, the load of the building can be transferred directly to the ground with a foundation wall. This can be cast concrete or masonry units: stone, concrete block, etc.

Strip and Pad Foundations

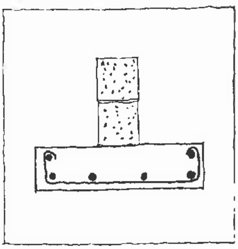
If the ground cannot support the load transferred by the building's walls, the weight can be distributed on strip or pad footings. Strip footing are used under walls and pad footings under columns. The method is relatively cheap and allows a simple building design. However, it is not suitable if the properties of the ground under the building varies greatly, since uneven settlement can occur.

The foundation wall, that transfers the load from the wall to the strip footing, is cast concrete or masonry. Columns are usually made of reinforced concrete.

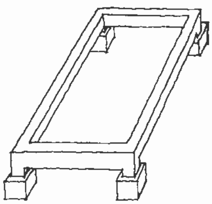
Strip and pad footing are dimensioned to avoid ground collapse and to lessen the risk for ground settlement. If the load is great and/or the strip and pad footings are very broad, they must be reinforced to resist shear and bending stress. If the load on strip and pad footings is uneven, consider the risk for tilting.


Masonry foundation wall on a reinforced concrete strip footing

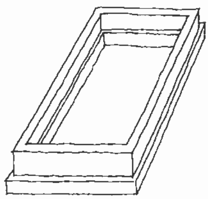
Pad footing with bottom reinforcement

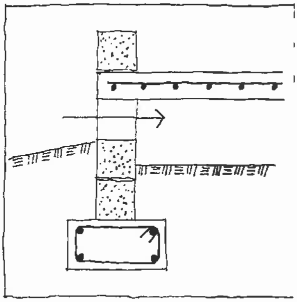


Pad footing

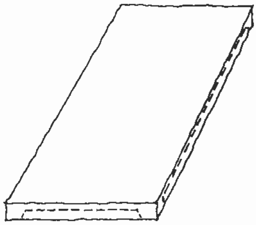


Strip footing

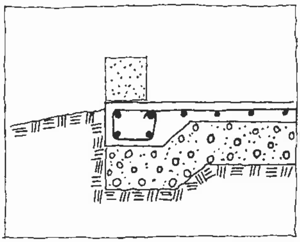




Crawl spaces should always be ventilated



Slab on the ground



Slab on the ground. The slab is thicker under the outer wall and cast on a bed of packed gravel.

The floor can be laid directly on the ground or be suspended with a crawl space between the floor and the ground. The crawl space must be well ventilated, which can be achieved by having ventilation holes in the foundation wall or by building the foundation of columns and leaving the space open.

Slab on the Ground

A slab on the ground is a solid concrete slab under the entire building. The advantage is that it settles less than pad and strip footings, since the load is distributed over a greater area. If the ground conditions under the building vary, giving the risk of differential settlements, a slab has clear advantages.

A slab on the ground is thicker under the outer and the inner structural walls.

To prevent ground moisture from capillary suction, the slab should be cast on a bed of packed gravel, at least 200 mm thick.

Basement

A basement with a concrete slab floor and retaining walls has the advantage that the weight of the excavated soil can be roughly equivalent to the weight of the building itself, which reduces the risk of settlement to a minimum. This is a great advantage when building on expansive soil and ground that is prone to settlement.

Basements, however, are expensive to construct, and the method requires excavation of large volumes of soil. Further, the floor and walls must be protected from rising damp.

Pile Foundation

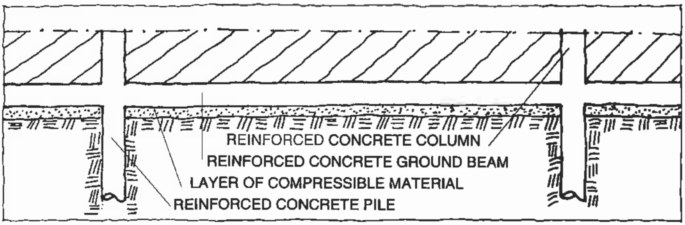
If the bearing layer of soil is far down in the ground, the load must be transferred by piles. These rest either on solid ground or on pads. The holes for the piles must be bored with an auger. Piles are normally made of concrete, either cast in the bored holes or prefabricated, but they might also be made of wood. Wood carries the risk of rot and termite attack.

The distance to solid ground might be so great that friction or cohesion piles must be used. These are made of concrete or wood, and gain strength from friction/cohesion against the surface of the pile, and by bearing forces acting at its base.

The ground beams laid between the piles to support the outer walls are normally made of reinforced concrete.

Foundations on Expansive Soils

Special measure must be taken. Trees must never be planted closer to a building than the height of the tree. Surfaces within two metres of the walls must be paved and slope away from the building.



Pile foundation for expansive soils. The ground beams are laid on a layer of compressible material.
Source: LONGWORTH ET AL 1984

To avoid settlement, the foundation depth should be deep enough that the movements caused by changes in moisture content are negligible. Appropriate foundations are pile or pad foundations at a depth of 3–5 metres. It is however important that the ground beams are not in direct contact with the clay. There must be a layer of compressible material between the beams and the ground to absorb the movement of swelling clay. The floor should not be laid directly on clay, but should rather be suspended. Another solution is a basement at a depth of 3–5 metres.

Foundations in Areas of Flood Risk

If there is a risk for flooding, the foundation should be built of reinforced concrete or masonry walls laid with cement mortar. It is a good idea to use pad or pile foundations. The upper level of the foundation should be 0.75–1 metre over the ground surface.

Foundations in Earthquake Areas

For light timber buildings it is most suitable to fix the superstructure rigidly to concrete piers in each corner.

Heavier buildings are most suitably based on strip footings of reinforced concrete, with wall columns fixed to the strip. The strips should be fixed together at the corners of the building and at other joints. The width of the strip should be at least 450 mm (and at least 300 mm wider than the wall) and at least 200 mm deep. In severe seismic conditions the strip should be reinforced with at least four bars placed in the corners. Pad foundations should be made of reinforced concrete and fixed to each other (alternatively, the columns may be fixed to each other) by a reinforced concrete beam.

In pile foundations the piles should be fastened together under ground level. On loose, saturated sand, which can behave like a fluid during strong earthquakes, the piles might have to be 10 metres long.

Floors

The choice of construction method and surface cover of floors depends on their use. Factors to consider include expected load, wear, cleaning, slipperiness and resistance to moisture.

The bottom floor should lie at least 150 mm above the surrounding ground to avoid moisture problems. If rains are extremely heavy, the floor should be at least 300 mm above ground.

Concrete Floors

Construction


Compacting the gravel before casting a concrete floor.

Ground floors are cast 75–100 mm thick and protected from cracking with, for example, welded mesh reinforcement. The ground under the floor is at least 200 mm of gravel to decrease the risk of moisture absorption. Another way to protect against rising damp is to put a damp-proof membrane under the concrete slab. It is preferable to use machine mixed concrete and an electric vibrator for the sake of quality. It is important to keep the water:cement ratio (weight of water divided by the weight of cement) low, because high water content might lead to cracking. Cracks occur with too fast drying, so the concrete should be kept damp the first week. (See Chapter 3 Building Materials).

Suspended floors can be made in several ways: an in situ cast concrete slab, either solid or hollow block construction, or pre-cast units. See the section on flat roofs. The floor must be 150–250 mm thick to sustain normal loads.

Finishing

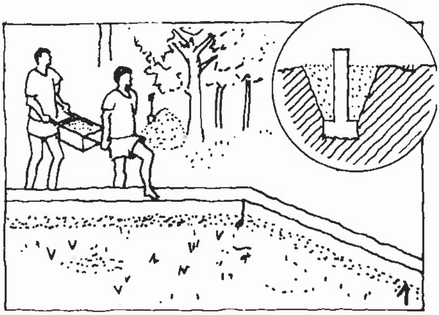
A common finish for concrete floors is a 20–40 mm, steel trowelled, cement and sand screed. The background should be carefully cleaned and dampened before laying. The cement mortar should be floated so that the surface is even before steel trowelling. After curing for one day, the surface is watered and kept damp for at least a week. If the sun if strong, the surface should be covered for the first week. Sprinkling cement on the surface while trowelling gives a hard and shiny surface. A reddish surface is obtained by mixing 10% iron oxide with the cement.

Another common finish is tiles: ceramic, terrazzo, concrete or natural stone. The tiles are laid onto a damp screed with or without joints. Any joints are filled after the screed has cured.

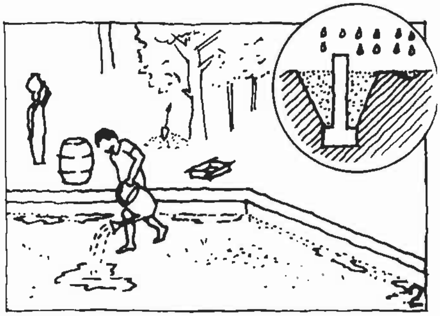
Another method is to lay burnt clay bricks in 20–40 mm of sand. The units are laid without joints, and sand is brushed into any gaps to hold the bricks.

A warmer floor can be built by gluing plastic (vinyl), textile or linoleum floor coverings directly onto the concrete or onto a screed. The method is very susceptible to ground moisture: high moisture levels in the concrete can cause the adhesive to loosen and create a bad smell. Floor covers, therefore, should not be glued before the concrete has dried for at least a month.

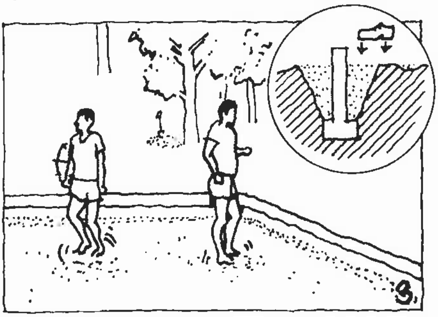
HOW TO CAST A CONCRETE FLOOR MANUALLY:



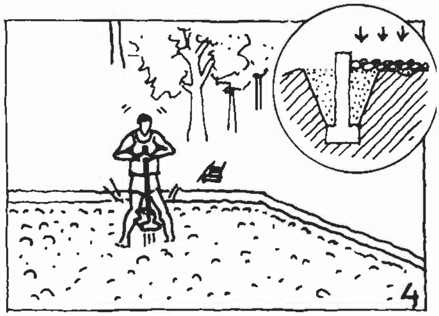
Spread the filler



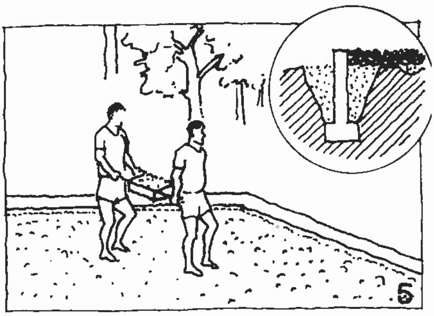
Water the filler



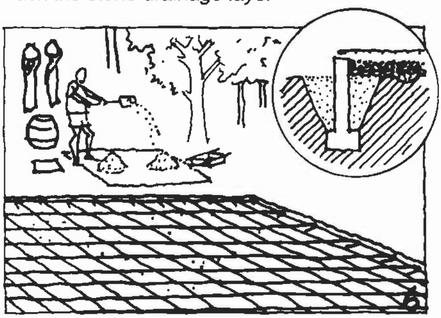
Pack the filler



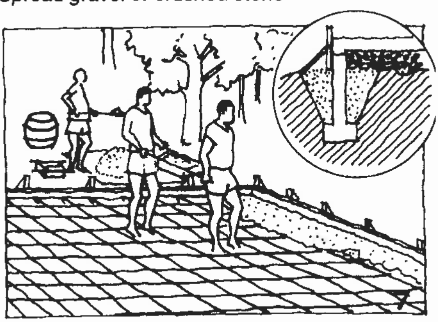
Pack the stone drainage layer



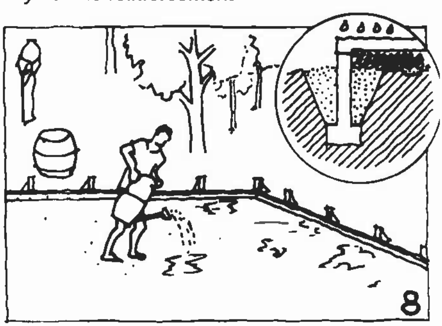
Spread gravel or crushed stone



Lay out the reinforcement



Cast the concrete



Water generously when the surface is firm

A surfacing of floorboards or parquet also gives a warm and pleasant floor. On a ground floor, where there is a risk for mould and discoloration if ground moisture is absorbed, all timber components should be insulated from the concrete slab by a damp proof membrane.

Timber Floors

Timber floors are suspended with floor joists 400–600 mm apart resting on timber wall plates attached to the foundation walls (at the ground floor) or the building walls.

At the ground floor it is important to insulate the wall plate from the foundation wall with a damp-proof course such as bituminous felt or tar paper to avoid moisture damage. It is also important that the crawl space under the floor is well ventilated to avoid moisture damage to the timber construction. If the underlying ground is saturated, it must be covered by a damp-proof membrane or a gravel layer.

Special measures must be taken when using timber floors in areas with termites. See Chapter 7.

The floor joists are covered by floorboards or chipboard. The surface finish is the floorboards themselves, parquet or a vinyl or linoleum covering. Avoid tight coverings such as vinyl floorings on ground floors, since they make it more difficult for any construction moisture to dry out.

Earth Floors

Earth floors are normally about 100 mm of rammed earth. They are cheap but require maintenance to retain a smooth surface.

A method to make a stronger earth floor is to mix in about 10% ordinary Portland cement (if the soil is fat, sand must be added as well). Such a floor should be rammed and polished within 30 minutes of laying, and kept damp during curing. Some slight cracking is unavoidable, but the cracking can be controlled by pressing a mould with a pattern like tiles into the surface. The cracks will arise in the "joints" between the "tiles." The floor is then painted with linseed oil that permeates the "joints."

Earth floors can also be covered by burnt clay bricks laid in sand.

As all ground floors, the earth floor must be protected from ground moisture. This can be done by covering the soil under the floor with a damp-proof membrane, covering it with a thick layer of gravel, or a combination of both.

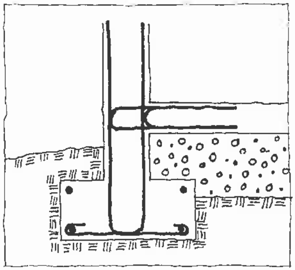
Designing for Earthquakes and Cyclones

Concrete floors

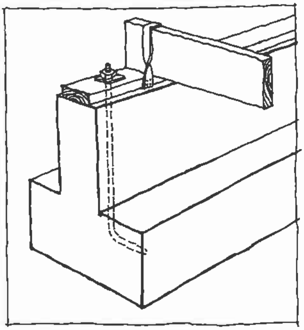
Concrete ground floors should be well fixed to the foundation and the concrete wall columns. Suspended concrete floors should be anchored above and below into the concrete wall columns.

Timber Floors

Every floor joist should be fixed to the ground beam with metal straps or angle iron nailed or screwed to the wall plates. To prevent the floor joists from twisting, struts can be placed between them. Floorboards (or chipboard) should be well nailed to each joist.



Anchoring a concrete floor in the foundation wall and the outer wall.



Anchoring a timber floor in the foundation wall.
Source: BRE, CYCLONE RESISTANT HOUSES FOR DEVELOPING COUNTRIES

Thermal Insulation

Thermal insulation is only required where there is active heating and cooling, to reduce energy consumption.

Thermal insulation can be laid as a base to the floor covering. Suitable materials are cork boards, woodwool slabs or cellular plastic boards.

In suspended floors over a crawl space, thermal insulation can be placed within the construction. See the section of flat roofs.

Ground floors cast on soil can be insulated from under with insulating slabs, in situ cast foamed concrete or loose fill insulation such as pellets of expanded clay.

Walls

The construction method depends on factors such as the number of floors, loads and risk for earthquakes or cyclones. The choice is also greatly influenced by the availability of building materials and skilled labour. Walls should be adapted to the local climate and require little maintenance. In areas with heavy rain, wall should be protected by long overhangs.

Where there is a risk of rising damp, a damp proof course must be laid between the foundation and the wall (see Chapter 3).

> Be careful about changing local construction techniques. These were often developed over a long period and are as a rule appropriate to local conditions.

Concrete Structures

Reinforced concrete structures should always be calculated by a structural engineer. In principle they can be any height. Concrete for walls should always be mixed and vibrated mechanically. The work requires well trained craftsmen. Mixing and casting concrete is described in the chapter on building materials.

Solid Walls Cast in Situ

Solid concrete walls are expensive and are used where great strength is required. Extreme care must be taken in setting-out; corrections after casting are difficult and expensive.

A concrete wall is normally 150–200 mm thick. The timber or metal forms are held together by steel formwork ties or are supported externally. The forms must be designed to support the weight of the cast concrete so that they do not burst or warp. They must also be well anchored and supported so that the walls stand vertically in the correct position.

The fresh concrete should be transferred to the form with a plastic hose or a pipe. The free fall from the bottom edge of the hose should not be greater than 1.5 m to avoid separation of the components. The concrete is spread in layers that are not more than 0.5 m thick. Each layer is vibrated with an internal vibrator to fill out the form and be sure the concrete completely surrounds the reinforcement. For the second, and each subsequent layer, push the vibrator about 100 mm into the underlying layer to work the two layers together.

Formwork for walls that support only their own weight can be removed at earliest two days after casting, with a normal temperature (10–30°C). The formwork for load bearing constructions cannot be removed for 2–3 weeks. Concrete reaches its full strength after 28 days. At 14 days its strength is about 70%, and at 21 days it is about 90% of its final strength.

Formwork for casting of concrete columns

PHOTO: KARL-ERIK LUNDGREN

Wall of precast concrete elements, Ethiopia

Column and Beam Structures

A very common type of wall is the column and beam construction where the elements are cast together in a frame system. The gaps between beams is filled with brickwork or blockwork. The thickness of walls varies between 150 and 300 mm. To improve thermal insulation capacity, two leaves can be laid with a cavity between; then the thickness could be 350–400 mm.

The columns and beams are cast in the same way as solid walls. Casting is done either before or after laying the bricks or blocks. In the latter case, it is easier to set the forms, and less timber is needed, since part of the masonry wall is used as formwork.

Walls of Prefabricated Elements

Prefabricated concrete elements are often better quality than those cast on site, since production can be more carefully regulated. Construction with wall modules is rather complicated however, especially for taller buildings, and requires good planning and high precision.

A type of prefabricated element is a small slab mounted horizontally between I beams of steel or concrete. The elements are bonded with mortar. The assembly is simple and can be done by unskilled labour.

Load bearing wall elements are also made of autoclaved aerated concrete. These elements have significantly better thermal insulation capacity than ordinary concrete and are about 3000 mm high, 500 mm wide and 150–300 mm thick. The can be assembled either horizontally or vertically.

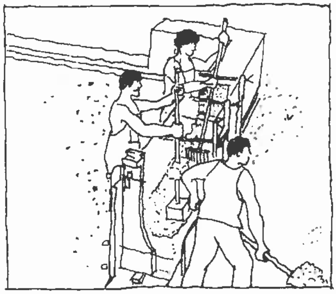
Earth Walls

Earth construction was and is still very common in many countries. There are many building techniques. Two of the most common are rammed earth and wattle and daub. Sun-dried blocks and stabilized soil blocks, which are also common, are addressed under Masonry Walls.

Earth walls, particularly unstabilized, must be protected with long roof overhangs. The bottom part of the wall, up to 500 mm above ground, must be made of a water resistant material.

Rammed Earth

Rammed earth (pisé) walls are packed in horizontal layers and allowed to dry before the next layer is added. Moulds of wood or metal are used. The mould is moved up as a new layer is added. The soil, which should have a high sand content (45–75%), is compressed with manual rammers, that normally have a metal striking head and weigh 7–10 kg.



Earth wall rammed in a mould (pisé technique)

Normal wall thickness for single storey buildings is 400–500 mm. Thicker walls are necessary for multi-storey buildings; with the walls getting thinner towards the top. Lintels of timber or concrete are placed over door and window openings. They should extend at least 250 mm into the wall on both sides of the opening.

Rendering is normally with mud. Lime mortar, perhaps with a small amount of cement added, might also be used. A lime mortar is more durable but must be anchored to the wall with wooden pegs or nails. It could also be reinforced with galvanized steel wire netting nailed to the wall.

Wattle and Daub

The earth is held by vertical wooden posts placed in the ground or on a foundation wall. The poles are normally thin and fairly close together. They are supported by diagonal braces and bound together with branches or reeds. Wet mud is plastered onto both sides of the wall in several layers. Often the mud is mixed with plant fibre, straw or cow dung to improve binding. The walls are then rendered, usually with some kind of mud mortar. Wattle and daub structures are normally only single storied, and the wall thickness is 100–150 mm.

Wattle and daub walls are earthquake resistant, but the require a lot of maintenance and are susceptible to termites and fungal decay.

Masonry Walls

Masonry is the most common wall material, and masonry units include fired clay, stone, adobe, etc. A masonry wall will support itself, but masonry units might also be used as infill between concrete columns (see Column and Beam Structures above).

Recipes for mortars suitable for masonry and rendering are given in Chapter 3.

Concrete

Walls are often made of concrete blocks, either solid or hollow. Blocks might also be made of lightweight concrete. The blocks are set with lime cement or cement mortar. The surface is usually rendered. The walls vary between 150–400 mm in thickness.

A concrete hollow block wall can be built with the cavities over each other. The shafts created can be used to cast vertical, reinforced concrete columns to strengthen the structure. There should be lintels over door and window openings, made of plain reinforced concrete or reinforced concrete cast in special U formed hollow blocks.

Hollow clay block wall before rendering

PHOTO: KARL-ERIK LUNDGREN

Burnt Clay

Solid or perforated bricks are used for loadbearing walls. They are set with lime cement mortar. The walls might be five or six storeys high. The thickness of brick walls varies greatly according to the load, anything from 100–800 mm. In high buildings, the thickness of the walls usually decreased with height.

A wall of good quality bricks can well be left as it is. If the wall is rendered, the bricks do not have to be as even or have as good a finish.

Loadbearing walls of burnt clay bricks are very expensive. Instead hollow blocks are often used, since they are cheaper and give somewhat better thermal insulation. These units are significantly weaker than the solid and perforated bricks, and are used in column and beam construction.

There should be arches or lintels over windows and doors. Arches are normally made of the same bricks as the wall and can be anything from straight to pointed. An arch creates horizontal stress in the wall. In larger openings the arch must be reinforced with a steel rod which can be hidden or visible. Instead of an arch, it is common to use brickwork beams, steel, stone or concrete lintels.

PHOTO: BJÖRN MOSSBERG

Stone wall

Natural Stone

Stone walls are made of cut or undressed stone, and are often 400–500 mm thick. It is difficult to make the walls thinner, considering the method of construction and the size of the stones. Natural stone walls are very strong if they are laid with a rain resistant mortar. If the mortar is not water resistant, the joints should be filled with lime cement or cement mortar, or the wall should be rendered.

It is important that the units are well fixed together, particularly at corners and openings. Local masons are often experts at this technique. Some kind of lintel, such as reinforced concrete, is necessary to take the load over windows and doors.

Stone walls can be made several storeys high, but it is not recommended to build more than two stories because of lower stability and the great weight.

Laying a stone wall

Adobe and Stabilized Soil Blocks

Soil blocks can be unstabilized (adobe) or stabilized with a binder such as cement or lime. Stabilized blocks are normally compressed by machine and are stronger than adobe.

Load bearing walls of adobe can be 300–500 mm thick. The mortar is usually the same mixture as the blocks, but lime mortar can also be used. An adobe wall must be rendered for rain protection. This is done in the same way as for a wall of rammed earth. There should be wood or concrete lintels over windows and doors.

Walls of stabilized soil blocks can be laid with lime or lime cement mortar, with or without rendering. When calculating a load bearing wall, remember that stabilized soil blocks often lose strength when wet, down to 1/3 of their strength when dry. There should be either an arch or lintel made of wood or concrete over window and door openings.

Timber Structures

Wood is a strong material for its weight. Timber structures can be made light and flexible, which makes them appropriate for earthquake areas. Since wood is attractive to termites, timber structures should be

Wall material	Density (kg/m^3)	Compressive strength (MPa)
Concrete	2300	15–60
Hollow concrete block	1000–1500	2–10
Autoclaved aerated concrete	400–800	1.5–7
Rammed earth	1800–2000	1.5–3
Adobe block	1000–1700	1–2
Stabilized soil block	1200–2200	1–20
Natural stone	2300–2900	50–350
Calcium silicate brick	1600–2100	10–50
Burnt clay brick	1300–1800	2–50
Timber	500–900	40–60

Adobe house under construction, Bolivia

avoided in areas with lots of termites unless it is possible to use treated timber or protect the structure (Chapter 7).

Wood can also be attacked by mould and rot where there is high humidity. A timber building must be designed to stay as dry as possible. Occasional wetting, such as during a rain, is acceptable if the moisture can dry out in between. In humid climates, it is important to have good ventilation in buildings.

All timber should be seasoned before use, that is, it should be allowed to dry to the moisture level of timber in standing structures. Otherwise there is a risk that the timber dries and warps, causing damage to the wall.

Timber frame walls consist of vertical studs between the sole plate and the wall plate. The stability of the wall in its own plane is provided either by diagonal timber braces or rigid boarding such as plywood, nailed or screwed to the frame. A timber frame wall is usually 100–150 mm thick.

External cladding can be of timber panels, corrugated metal sheets, cement-bonded particle boards, rendered reed matting or moisture treated plywood. Asbestos cement sheets should be avoided because of their risks for health. Timber materials and galvanized steel sheets should be regularly painted to lengthen their service life.

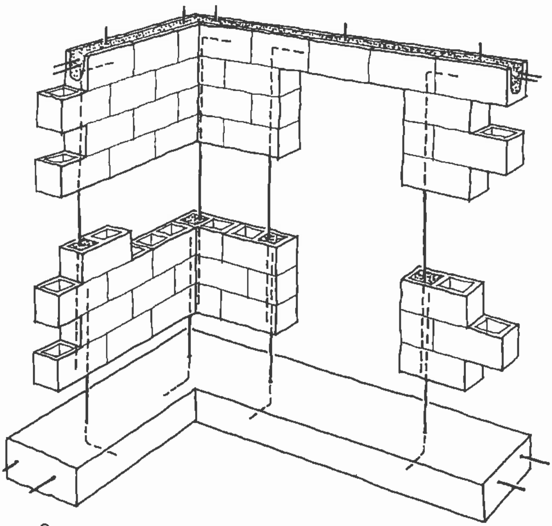
Internal lining can be made of chipboard or plywood.

Designing for Earthquakes and Cyclones

Concrete walls or column and beam structures must be fixed to the foundation, the floors and the roof. All joints should be reinforced so that they are rigid.

Earth and masonry walls are less safe in earthquakes. A masonry wall can be somewhat improved by avoiding joint angles of 45° to the ground, since this is a common angle for cracks during earthquakes. To withstand strong earthquakes and cyclones, the walls must be stabilized with reinforced concrete columns and beams. The columns are placed in the corners of the building, where the inner walls meet the outer walls, and along the sides of doors and windows. If hollow concrete blocks are used, the holes could be used to cast vertical columns. Masonry walls can also be stabilized with buttresses.

Concrete hollow block wall stabilized with vertical columns and a ring beam of reinforced concrete. Note the anchoring of the columns in the foundation and in the ring beam.



Source:
BRE, CYCLONE RESISTANT HOUSES FOR DEVELOPING COUNTRIES

Continuous, horizontal ring beams are placed at ground level (a ground beam), along the top of the wall, and, if possible, over window and door openings. It is important that the joints between columns and beams are adequately reinforced, to make stiff joints.

A timber frame wall is stabilized by anchoring the studs to the wall plate and the sole plate with galvanized steel U straps. Stability in the plane of the wall is created with diagonal timber bracing, metal straps or closely nailed rigid boarding. The wall is anchored to the foundation with metal straps, steel brackets or bolts cast in the ground beam or footings.

Thermal Insulation

Thermal insulation of walls can improve indoor climate in some passively climatized buildings. Walls should be thermally insulated in actively climatized buildings to reduce energy consumption. Note that uninsulated walls of natural stone and concrete have very poor thermal insulation capacity, that is a high U-value. Earth walls and hollow clay walls have a somewhat lower U-value.

Walls in an air-conditioned building should have a U-value of 1.0 W/m^2°C. Thermal insulation materials are usually necessary to reach this level.

Column and beam structures can be built with woodwool slabs or lightweight concrete as infill. Woodwool slabs can also be nailed to timber frames. Boards or loose fill of cork, mineral wool and cellular plastic can be used as cavity insulation in masonry walls or between studs in timber framed walls.

Earth walls can be made more insulated by mixing in more straw. Clay straw can be produced in densities down to 300 kg/m^3. The material is not load bearing, but must be used with timber studs, for example.

Avoid allowing materials that conduct heat, such as steel and concrete, to penetrate insulated walls, because they create thermal bridges.

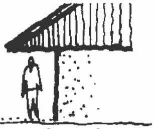
Wall type	U-value (W/m^2 °C)
500 mm natural stone	3.0
150 mm concrete	3.8
200 mm concrete hollow block	2.7
500 mm rammed earth	1.5
400 mm adobe	1.2
300 mm clay-straw (500 kg/m^3)	0.5
250 mm solid clay brick	1.8
200 mm hollow clay block	1.7
100 + 200 mm hollow clay block + 50 mm cavity	1.0
100 + 200 mm hollow clay block + 50 mm cork board	0.6
200 mm lightweight concrete (400 kg/m^3)	0.7
75 mm woodwool slab	1.0

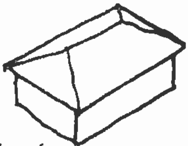
Approximate U-values for some outer walls. If the walls are rendered and plastered, the U-values will be slightly reduced.

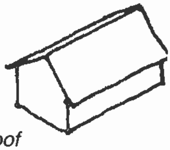
Roofs

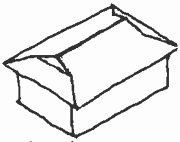
The roof, like the foundation, is a component that most affects the service life of the building. The roof protects against weather and wind, heat and cold. Roofs often protect the outer walls from sun and rain. The roof is normally the most expensive part of a building.

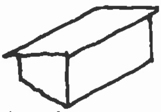
Traditionally roofs were made of whatever was available locally: burnt clay, thatch or earth. For many reasons thatch and earth are used less frequently. The craft is disappearing and good raw materials are less readily available. Traditional roofs require a lot of maintenance and are often not suitable in towns, in particular thatch roofs which are a fire hazard.

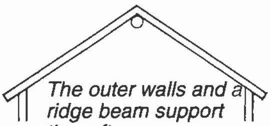

Generous roof overhangs

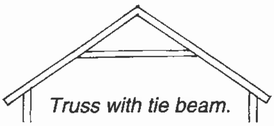

Hipped roof

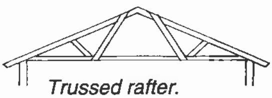

Gable roof

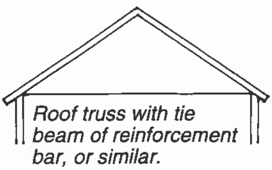

Half-hipped roof


Monopitch roof


The outer walls and a ridge beam support the rafters.


Truss with tie beam.


Trussed rafter.


Roof truss with tie beam of reinforcement bar, or similar.

Flat roofs should be avoided in rainy areas, because it is difficult to make them watertight.

Pitched Roofs

The gable roof is the most common type of pitched roof. The overhangs are usually long to protect the walls from rain and sun. Overhangs of 0.8–1 metre are common.

A hipped roof is more complicated than a gable roof, but protects the end walls. This roof is less susceptible to wind, but more difficult to ventilate than the gable roof. The half-hipped roof is traditional in many countries. It allows ventilation through a gablet (small gable) under the ridge.

The monopitch roof has the disadvantage that three wall are relatively unprotected.

Roof Trusses

The most common type of roof truss is a sawn timber frame, held together by nail joints or special nail plates. Trusses can also be made of round timber (poles) or welded steel sections.

Timber can be saved by letting the rafters rest on the walls and a beam in the ridge. The beam rests on the gable walls, which extend up to the ridge.

When calculating the dimensions of trusses, one must consider the dead-weight of the roof, wind loads and, if relevant, snow loads. Most types of trusses can be designed on the basis of manual calculations. The nail joints and welded joints must also be calculated.

Wind causes both lateral and lift stresses on the roof. Therefore the trusses should always be well fixed to the walls, or directly in the foundation, and stabilized laterally. The purlins and battens must be well fastened to the trusses. When putting up a roof, the trusses can be stabilized with diagonals at the gable ends. Such reinforcement might also be needed after the building is finished if there is a risk of earthquakes.

Clay Tiles

Tiles made of suitable clay and correctly burnt are strong and durable. The material has good aesthetic qualities, and it ages in a beautiful way.

Clay tiles can have many shapes such as Spanish tiles, Roman tiles, pantiles and plain tiles. Spanish tiles are shaped like a half cylinder, and are traditional in many countries. Since a roof of Spanish tiles consists of under-tiles and over-tiles, it becomes very heavy. This can be an advantage in some climates since the good thermal storage capacity helps to moderate temperature variations.

The battens for clay tiles must be of sawn timer or steel, and the distance between them is rather short, 300–400 mm.

Clay tile roof, Nicaragua

Roofing Material	Lowest Pitch (°)	Weight (kg/m²)
Clay tiles	22	30–80
Concrete tiles	15	40–50
FCR/MCR tiles	22	25–30
Steel sheets	5	2–7
Aluminium sheets	5	2
Fibre cement sheets	15	15–30
Shingles	45	5–10
Thatch	45	20–40

Roofing Materials

The main disadvantage of clay tiles is that production is very energy consuming, and raises their cost, but locally made tiles are normally competitive in price with imported metal sheets.

Concrete Roofing Tiles

Concrete roofing tiles have documented high strength and durability, and they are becoming more common in developing countries. Local materials can be used, and production can be manual or automated.

Concrete tiles are made in similar shapes to clay tiles. They can be coloured by adding pigments (iron oxides) during production. They have interlocking grooves on the side of the tiles which improves watertightness and resistance to seismic movement.

The same types of battens used for clay tiles are used for concrete roofing tiles.

Concrete tiles are normally cheaper than clay tiles.

Fibre/Micro Concrete Roofing Tiles

Roofing tiles made of fibre concrete (FCR tiles) or micro concrete (MCR tiles) are produced in many developing countries today. Both materials are made in the same way on small scale, mainly by self-builder.

FCR and MCR tiles are produced as tiles or semi-sheets, a larger type of tile. They are normally 8 mm thick, thinner than ordinary concrete tiles.

FCR tiles, containing natural fibres such as sisal, have been made since the beginning of the 1980s. There are reports of these tiles in good conditions after 10 years exposure to the climate, but there are also many examples of tiles with poor durability. It appears that the addition of fibres has more disadvantages than advantages (see Fibre Cement Sheets below), so there is a change toward production of MCR tiles.

Fibre concrete roofing tiles, Tanzania

Battens of sawn timber or steel are used, and the distance between them should be 400 mm for tiles or 500 mm for semi-sheets.

FCR and MCR tiles are a cheap material and easy to make. A disadvantage is that the tiles are weak, which makes transportation difficult.

Fibre Cement Sheets

The oldest type of fibre cement sheets is based on asbestos. The material is made in large corrugated sheets that have good flexural strength and require little support. Asbestos cement is also known for excellent fire resistance and good durability. A very serious drawback is that it is a health hazard during production and installation. For this reason, the production and use of materials based on asbestos should be avoided.

Inhalation of asbestos fibres can cause diseases such as lung cancer. Often these diseases to not arise until 10–15 years of exposure to the fibres. The health risks of asbestos cement are mainly linked to the production of the material, and to some extent sawing, drilling, grinding and breaking the material.

Today fibre cement sheets are made with plastic fibres in many developed countries. These can be used in the same way as asbestos cement sheets.

Fibre concrete roofing sheets (FCR), based on natural fibres, were introduced in many developing countries in the 1970s. However, these sheets, which were as large as asbestos cement sheets, broke after some years when the natural fibres deteriorated. Sheets based on natural fibres can be produced only if the cement mix is made less alkaline. This requires replacing some of the cement with a pozzolan such as rice husk ask. This kind of fibre cement sheet has been made in some developing countries since the end of the 1980s. The material is strong and the distance between purlins, which must be sawn timber, is about 1 metre.

Galvanized iron sheets, Cuba

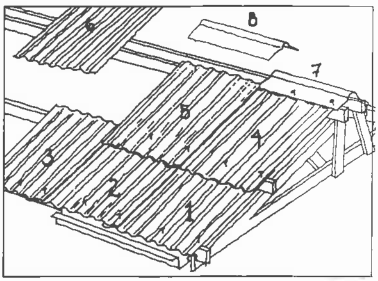
Galvanized Iron Sheets

Corrugated iron sheets (CIS) is one of the most common roofing materials in developing countries. It is available in a range of sizes, thicknesses and shapes.

CIS is flexible, which allows for some irregularities in the support; purlins do not have to be sawn but can be round timber. The distance between purlins can be up to 1 metre, which saves timber. The sheets can be fixed by unskilled labourers. CIS can be transported on bad roads without damage.

CIS has, however, poor thermal and acoustic properties. The material is normally imported, either as a finished or semi-finished product, and thus requires hard currency. Furthermore, production is very energy consuming, which makes the material expensive.

Durability is poor, especially the thin sheets (down to 0.2 mm thick) which are cheapest and most common. In coastal areas, and in heavily industrialized regions, corrosion occurs very fast, and thin sheets might rust through within a few years. The sheets must be painted regularly to extend their service life. A light coloured paint will reflect more sunlight. The thermal and acoustic qualities indoors are much improved by adding a ceiling and by using double sheets in the roof.



The steps in laying a metal sheet roof

Aluminium Sheets

Corrugated aluminium sheets are used in the same way as CIS. Aluminium sheets require extremely large amounts of energy to produce, and are significantly more expensive than CIS. The material has greater durability and might be a good alternative in coastal climates where CIS rusts quickly. Aluminium sheets give a better indoor climate than CIS, because they radiate far less heat to the interior.

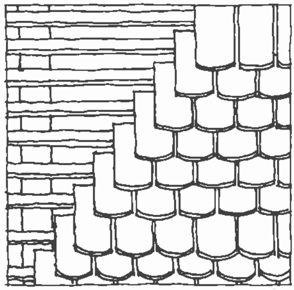
Aluminium corrodes when it comes into contact with cement, copper or steel. Therefore one must be careful when sealing between the wall and roof. If cement is used as sealing material, the sheet must be painted with bitumen. An alternative is to seal with clay. Nails used to fix aluminium sheets must also be aluminium.

Shingles

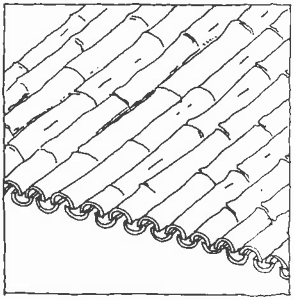
Shingle roofs have low weight but require a steep slope. The shingles are nailed or tied down so the each layer overlaps the one under. Laying requires skilled craftsmen. Some types of timber, such as cedar, can be used untreated. Shingles of wood with low durability must be chemically impregnated.

Shingles can also be made of large bamboo split in half and tied with string to purlins of bamboo or poles. This roof must have a relatively steep slope.

Shingle roofs are a fire risk, and are not suitable in densely built neighbourhoods. Singles should not be used where there is a termite risk, unless the roof can be protected.



Shingle roof



Roof of split bamboo

Thatch

Roofs of grass, straw, reeds or palm leaves are cheap and can be constructed and maintained from local materials with local labour. The service life depends on the type of grass, the skill of the roofer, and regular maintenance. A well maintained roof can last up to 30 years. Thatch roofs require a steep slope, at least 45°, with battens set close together. They give a good indoor climate, but they are a fire risk.

Professional skill is required to lay a thatched roof, and is therefore most suitable where they are traditional and there are local craftsmen. It is getting more difficult to find good quality raw materials, partly because of overgrazing and cultivation of land.

Thatched roof have a short service life in are areas with termites.

Thatched roof, Ethiopia

Flat Roofs

Flat roofs are common in areas with little precipitation. They do not protect the walls from weather and wind, but their advantages include functioning as a terrace and a base for adding another storey. There are normally three parts to a flat roof: a load bearing floor structure, a gently sloping cover for drainage and a waterproofing membrane. These roofs are usually surrounded by a parapet. Rainwater spouts at the lowest edge of the roof lead water away through the parapet.

The waterproofing membrane is described in Chap.3.

Earth Roofs

These are traditional in warm, dry regions. They have a structural frame of timber beams covered by boards, round timber or flat stones. This layer is first lined with leaves, straw, or similar and then covered with 100–300 mm of rammed earth. Traditionally the watertight layer was rammed clayey soil, but it could also be stabilized soil or a lime screed. The surface is often whitewashed, to increase both tightness and the ability to reflect sunlight. Earth roofs require constant maintenance to remain watertight.

Jack Arch Roofs

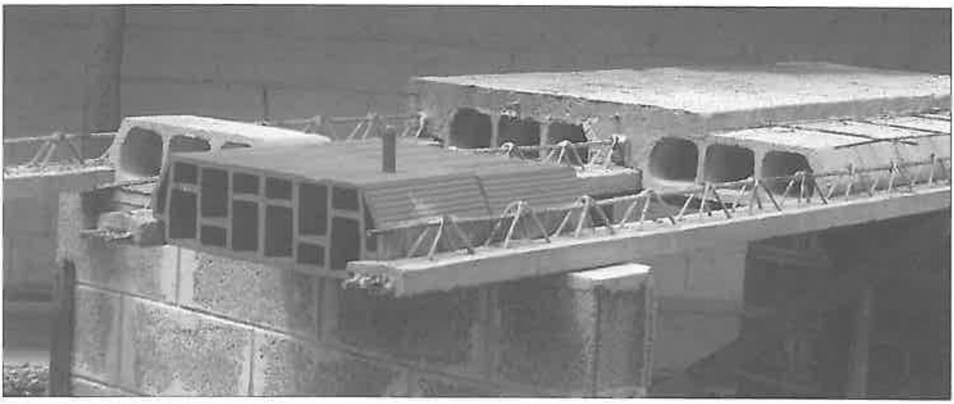
These roofs are clay brick arches between rolled-steel joists. The arches are evened with a screed of concrete, mortar or earth. The roof is made waterproof with some kind of roofing membrane (see Chapter 3). Like soil roofs, this roof is not suitable in earthquake zones.

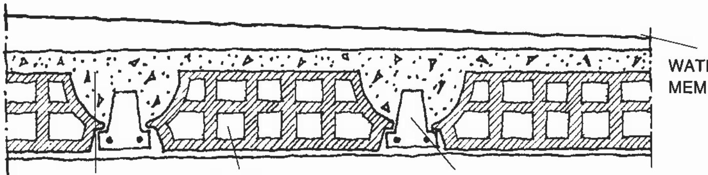
Concrete Roofs

Concrete roofs consist either of a solid reinforced concrete slab or a hollow block construction. Hollow blocks, either clay or concrete, simplify formwork and the roof is lighter.

In one type of construction the hollow blocks function as permanent shuttering, allowing tensile reinforcement to be laid between the blocks. When the concrete is cast, it becomes a T-beam deck made up of a 50 mm slab and tensile reinforced beams. It is, however, more common to lay the hollow blocks between precast beams before casting the concrete. This construction, which requires only a few braces during casting, sometimes uses prestressed beams, which permits wider spans.

Burnt clay and concrete hollow blocks





Flat roof of reinforced concrete with hollow blocks of burnt clay (or concrete) laid on precast concrete beams.

A screed of mortar or lean concrete is spread over the load bearing structure, at a slight slope towards the rainwater spouts. The waterproofing membrane is laid on top. If it is bituminous, it must be protected from UV-radiation.

The very gentle slope means that flat roofs often leak. The causes of the leakage are a poor waterproofing membrane – or a poorly laid membrane – together with a water permeable load bearing structure.

To avoid leakage in flat concrete roofs, one should:

- Cast the reinforced concrete in the supporting floor carefully to avoid cracks. That is, do not cast the concrete if it is too warm, and keep the surface wet during curing. Reinforce the concrete with welded mesh.
- Slope the roof at least 20 mm per metre toward the water spouts. The spouts should not be too short. When making the slope, observe the same rules as for the supporting floor above.
- Choose a suitable waterproofing membrane.

Timber Roofs

Timber roofs consist of joists of sawn timber covered by timber boarding. The roof should slope slightly for rainwater drainage.

The roof deck is normally made watertight with some kind of bituminous material. If bituminous felt is used, a bottom layer is nailed on and a cover layer is attached with hot applied bitumen.

Vaults and Domes

Their advantage is that they do not require a timber or steel supporting structure, but they can only be built by skilled craftsmen, which means they have become less common in many countries where they are traditional.

The roof is usually made of burnt clay bricks, adobe or stabilized soil blocks. A mould is often used to shape vaults and domes, but they can be built freehand.

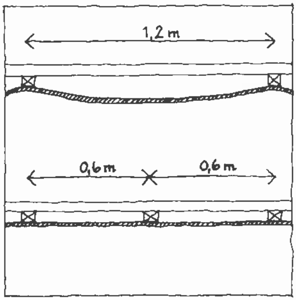
Vaults and domes create horizontal forces in the supporting walls. This outward pressure is balanced by thicker walls or buttresses, or a tie rod. The forces increase as the vault or dome become flatter.

They are made water resistant by rendering with a mortar suitable for the masonry units.

Building a vault roof with cement stabilized earth blocks, Tunisia

Vaults and domes are not suitable for areas subject to earth tremors, or where is a risk for settling, since these roofs are sensitive to movement and vibration.

False Ceilings



Too wide spacing between the battens allows the chipboard ceiling to sag.

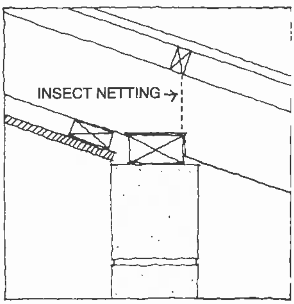
A false ceiling costs more, but can improve the thermal, acoustic and aesthetic qualities of the indoor environment, especially in buildings with metal or asbestos cement roofs.

A false ceiling is a lining material fastened to battens on the ceiling joists. They can also be suspended, by hanging a lightweight grid with laid-in tiles.

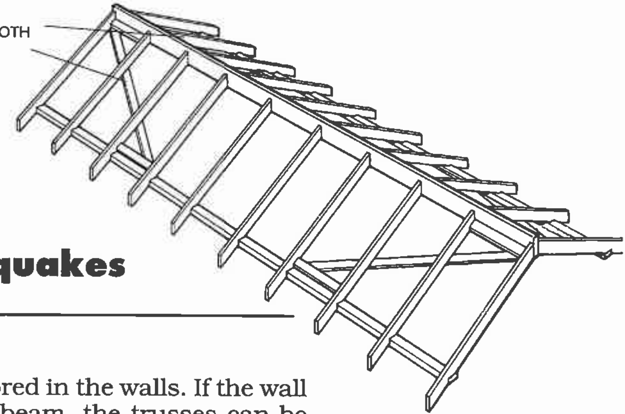
They can be made of many materials. Chipboard is relatively cheap. It is nailed to battens placed a maximum of 600 mm apart, so that the sheets do not sag. Another material is porous fibre board, which is less durable than chipboard. Natural materials such as cloth, bamboo and papyrus might be used. Laid-in tiles include woodwool slab, cork, plaster and plastics.

Woodwool slab ceilings improve both thermal insulation and the sound absorption of the roof. They are not attractive to termites, and are not attacked by mould or rot. They are also hard to ignite. Cork boards have better thermal insulation capacity than woodwool slabs, but worse acoustic qualities. The same is true of cellular plastic sheets. These are resistant to termites and mould, but can release poisonous gases in a fire.

A problem with false ceilings is that insects, birds and bats invade and occupy the space between the ceiling and the roof, especially if it is dark and damp. Their waste products create bad smells and poor sanitary conditions. Good ventilation, openings for light and strong netting over all openings can reduce this problem.



Detail of the ventilation opening at the eaves. Insect netting.



Roof structure strengthened by diagonal braces

Source: BRE: CYCLONE RESISTANT HOUSES FOR DEVELOPING COUNTRIES.

Design for Earthquakes and Cyclones

Pitched Roofs

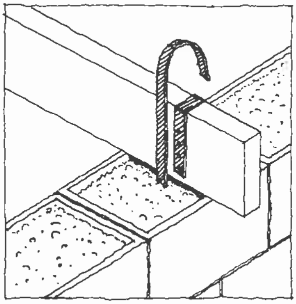
The roof must be well anchored in the walls. If the wall finishes in a concrete ring beam, the trusses can be fastened by metal straps, reinforcement bars or bolts cast in the concrete. Metal straps are used to fasten trusses to a timber wall plate.

The structural members of the roof truss should be carefully nailed together.

Wind stability is improved by diagonal braces linking the trusses at the ends of the roof.

Purlins and battens should be well fastened to the trusses, for example with metal straps.

The roofing material must be well fastened to the structure. If the roof is subject to strong winds, the binding should be stronger at the eaves and ridge. Sheet material should be nailed closely or fastened with hook bolts; roofing tiles should be tied with steel wires around the battens.



The roof trusses should be securely fixed to the walls.

Flat Roofs

For soil roofs, the load bearing poles should be anchored to the wall ring beam.

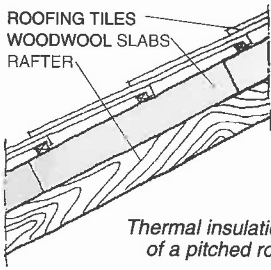
Concrete roofs must be fixed with reinforcement bars to the wall columns. Good concrete workmanship is important.

The joists of timber roofs should be well fastened to the wall plates (see Timber Floors).

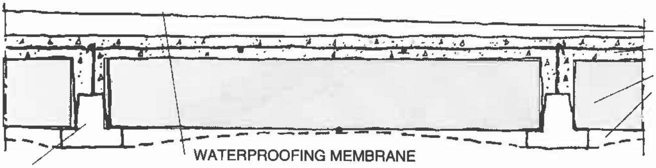
Thermal Insulation

In hot climates with high solar elevation and strong solar radiation, much of the heat transmission is through the roof. In air conditioned houses the U-value should be at most 0.5 W/m^2 °C.

In pitched roofs the thermal insulation can be placed either on the level of the rafters or on the level of the ceiling joists. Woodwool slabs can be used as a base for roofing tiles or sheets, or as ceiling panels. Mineral wool is placed between the rafters or between the ceiling joists.



Thermal insulation of a pitched roof



Thermal insulation of a flat concrete roof using woodwool slabs instead of hollow blocks. This lowers the U-value from 2 to 0.5 W/m² °C.

Approximate U-values for roofs

Roof type	U-value (W/m² °C)
Metal roofing sheet + air space + chipboard ceiling	3.2
Metal roofing sheet + 100 mm mineral wool	0.4
200 mm thatched roof	0.7
Poles + 200 mm rammed earth	1.8
150 mm concrete	4.3
200 mm concrete/hollow block construction	2.0
200 mm concrete/woodwool slab construction	0.5
200 mm hollow block construction + 100 mm foamed concrete	0.7

In flat roofs, the insulation can be put over, inside or under the roof construction. Foamed concrete is an excellent insulating roof screed. Even woodwool slabs and cork boards can be used over the roof construction. Woodwool slabs and cellular plastic sheets can replace hollow blocks in concrete roofs. Ceiling panels, fixed to the roof or suspended, can be made of materials as woodwool slabs or cork board.

Flat timber roofs can be insulated with mineral wool, for example, between the joists or by replacing the timber boarding with woodwool slabs.

The thermal insulation capacity of earth roofs can be improved by mixing straw in the soil.

Doors, Windows and Furniture

Windows and doors provide natural light, ventilation and communication with the outside. They are relatively expensive details in a building, so great care must be

PHOTO: BJÖRN MOSSBERG

taken in choosing the type and workmanship. They are made of wood, steel, aluminium or PVC plastics. Wood and steel are the most common in developing countries. Steel doors and windows are more expensive to buy than wood, but they have a longer service life and require less maintenance.

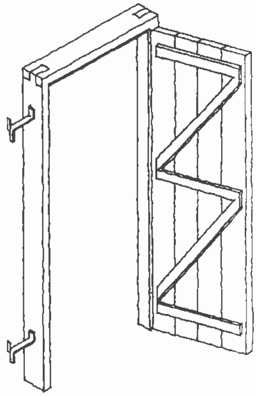
Doors

Wood Doors

The simplest wooden door is made of standing battens held together by horizontal bars at the top and bottom and diagonal braces. There is often a bar in the centre of the door as well. The braces should point down toward the hinges so the door does not sag. Adding a frame gives a better door. A panelled door is a framed door without braces; the battens may be replaced with wooden boards or window panes.

In warm and humid climates, where high ventilation is desired, louvers are often used. This door consists of a frame with wood (fixed) or glass (moveable) louvers instead of panels.

The best possible timber should be used for doors: straight and without irregularities, preferably hardwood. The timber should be seasoned to the mean moisture content in the local climate. A wooden door can be left untreated, oiled with linseed oil or painted with an oil based paint. Avoid acrylic paints. If there is a risk of termites, choose a termite resistant timber, treat the timber with a termiticide, or use another material such as steel.



A simple timber door without a frame.

Metal Doors

The advantage of metal doors is that they hold their shape and they are not attacked by mould, rot or termites.

Steel doors are normally made as a welded casement with an infill of metal sheet. They are subject to rust and must be rust-proofed and painted regularly.

Outer Doors

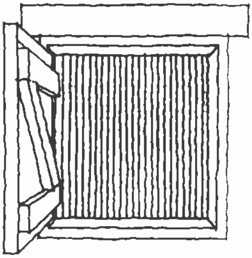
There might be special requirements for security, if there is a burglary risk. The door frame should be well anchored in the wall. Locks should be sturdy since they are subject to stress. Avoid importing door handles and locks. Local fixtures are cheaper and easier to maintain. In smaller buildings, simple bars and padlocks might be adequate.

Any glass in outer doors should be burglar proof, that is reinforced with steel wires inside the pane.

Windows

Windows are exposed to weather and wind, and require a lot of maintenance. Glass is relatively expensive, and using only a few sizes makes it easier to replace broken window panes. If glass is not necessary, one can use wooden shutters instead.

Windows provide a risk for break ins, especially if they are near street level. Metal burglar bars built into the window opening offer protection. The bars might be reinforcement bars, welded mesh or forged steel.

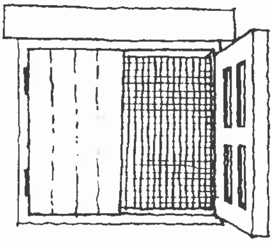


Simple wooden shutters

Wooden Windows

There are many styles and the most common is the casement window, with a sash set with hinges into an outer frame. For the sake of watertightness, the window should open outwards.

Wooden windows require continuous maintenance. See the section on Wooden Doors for the quality of wood and surface treatment required.

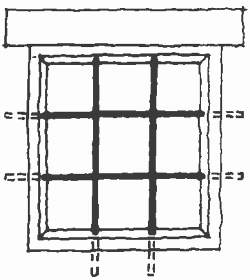


A panelled shutter

Metal Windows

Metal requires less maintenance than wood, and metal is suitable for large windows.

Steel windows are usually made locally, and are thus more affordable. Check their quality. The hinges should be greased often so that they do not rust solid. Steel windows have a long service life if they are painted regularly, about every five years.

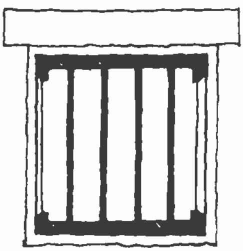


Reinforcement bars fixed in the wall

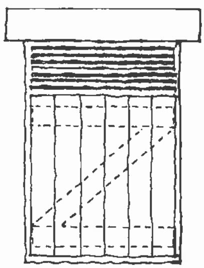
Ventilation

To provide ventilation without large windows, one can use horizontal glass louvers. They permit control of the air flow through the room. They are expensive and fragile (the glass pieces should be at least 5 mm thick). A disadvantage is that it is difficult to close them tight against dust and driving rain.

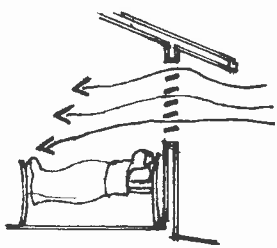
Another way to provide ventilation is to build openings adjacent to or over windows.



Reinforcement bars welded in an angle iron frame



Ventilation over a window opening



Louver window

PHOTO: BJÖRN MOSSBERG

Simple wooden shutters

Insect nets are often necessary in windows and other openings to the outside. These nets are made of galvanized steel, aluminium or nylon and block the ventilation somewhat, which should be considered when calculating the size of the ventilation openings.

Make your own window putty. It consists of heated linseed oil mixed with chalk powder to the right consistency. Varnish can be used instead of linseed oil.

Airtightness and Thermal Insulation

The airtightness of the window and door openings is important in actively climatized buildings. Involuntary ventilation greatly increases energy consumption. Use a draught strip, of foam rubber for example, to tighten between the sash and the outer frame. It is also important to tighten between the outer frame and the wall. Louvers are unsuitable because they cannot be closed tight.

Windows normally have poorer thermal insulation capacity than walls, and cause high energy losses. Single pane windows have a very high U-value: 5.9 W/m^2 °C; double pane windows have double the thermal insulation capacity: 2.9 W/m^2 °C. Double pane windows are, however, more expensive and they block some of the sunlight. Avoid metal windows in actively climatized buildings since they create strong thermal bridges.

Furniture

Try to use locally made shelves, cabinets and furniture, instead of importing pieces that are very different in design, since these are often inappropriate for the local climate and are difficult to repair. Local production and simple, solid designs are preferable. Avoid details with a short service life, such as adjustable shelves and magnetic catches in cabinet doors.

In isolated areas without a carpentry shop, it might be necessary to produce doors, windows, cabinets, etc. on site oneself. If electricity is available, one can make good use of electrical saws for cross-cutting and ripping, a surface planer and a thicknessing machine (panel planer).

Wood Products

Wood must be seasoned so that its moisture content is in equilibrium with the surrounding air. If the relative humidity varies greatly, the wood will alternately swell and shrink. These moisture movements can be reduced by surface treatments such as painting or lacquering.

Wood can be attacked by mould and rot where relative humidity is high. The risk varies greatly between types of wood, and is lower where there is good ventilation.

Wood is also attacked by termites. Where there is a termite risk, use termite resistant, or impregnated, timber. Shelves and cabinets that stand on the floor should have metal legs.

Cement bonded wood particle boards are more expensive than glued wooden boards, but they are more resistant to both moisture and termites.

Other Materials

Nearly all furnishings include metal as hinges, screws and nails. There is also furniture entirely of metal. Stainless steel and brass are very durable, and expensive. Ordinary steel rusts and must be protected by galvanizing or painting with rust-proofing compounds.

Concrete resists moisture and termites. The material is strong, easily shaped and suitable for sturdy shelves, cabinets and work surfaces.

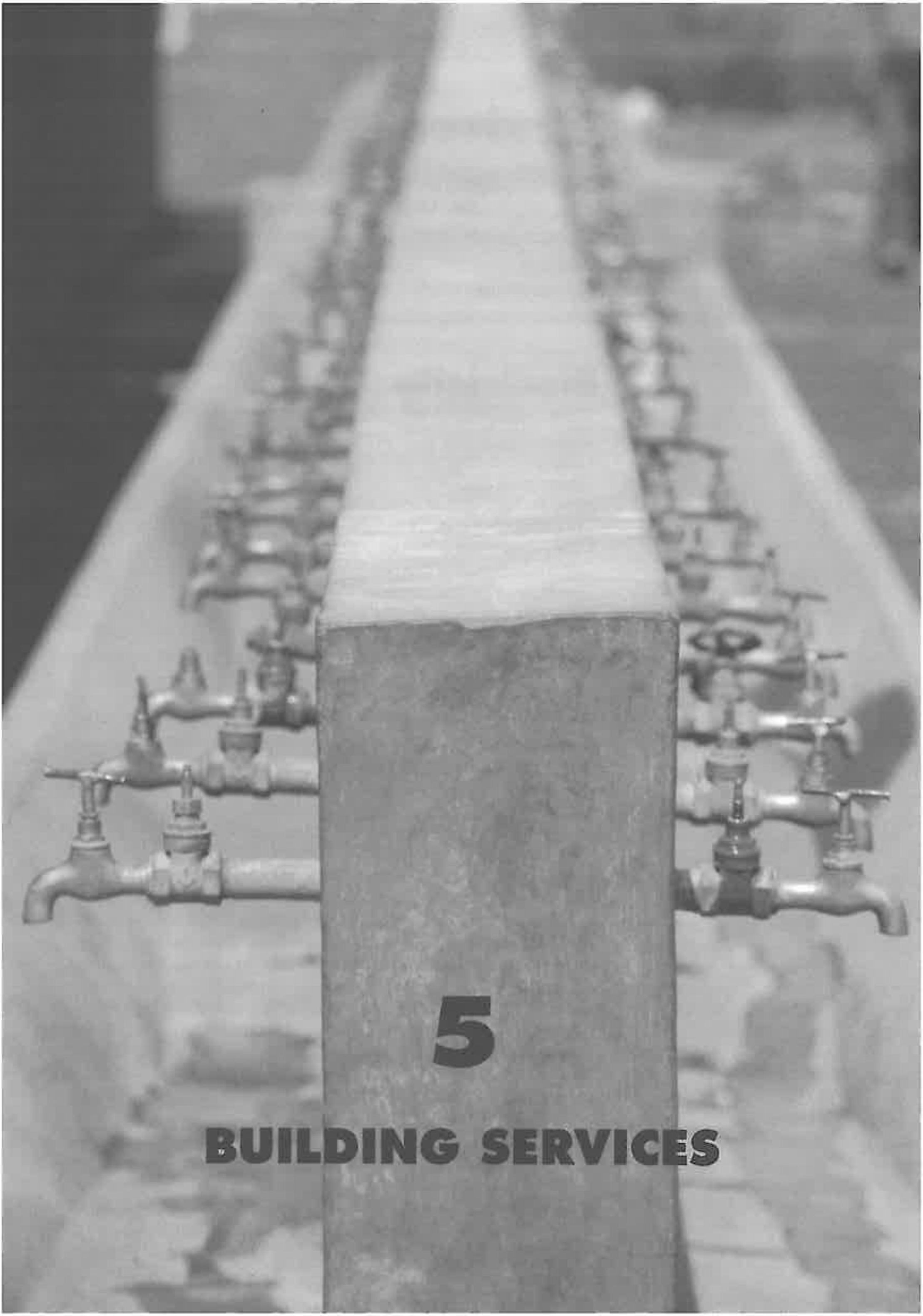
Adobe is used for simple, cheap furniture.

Design in Hot and Humid Climates

Poor durability is a great problem in a hot and humid climate. Rapid deterioration of glues and surface finishes is common. The deterioration causes unhygienic conditions which can create problems in health clinics and schools. It is especially important to take care in the choice of materials and design in these climates.

One should use the most durable material possible. Wood should have as little moisture movement as possible and have natural resistance to mould. Adhesives used in composite boards, such as plywood, and to glue together furniture should have good durability in heat and humidity. It is advantageous to use materials such as concrete, rattan and non-corrosive materials.

To reduce the risk of moisture damage and mould, wardrobes, cupboards and drawers can have small holes for ventilation, or even be made without doors.



5

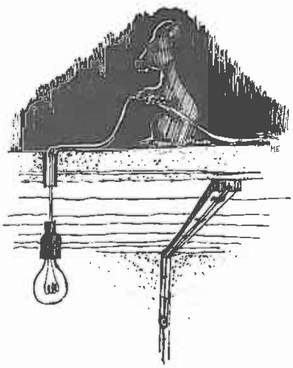
BUILDING SERVICES

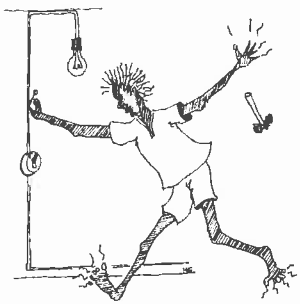
PHOTO ON PREVIOUS PAGE: BJÖRN MOSSBERG

Building Services

Installation of electricity, water and sewage improves a building significantly and gives it more status. It is important that the installations are designed for local conditions, that they function well and are acceptable to the users. This is especially important for toilets and washing facilities.

Reliability and long service life are more likely if the installations are robust, simple in construction, and contain as few imported materials as possible.





Electricity

When designing electrical installations, particularly with costs in mind, the following should be considered:

- the possibility of installing exterior light, to improve personal and material security,
- the possibility of installing lights and power in public buildings such as schools, hospitals and clinics,
- the possibility of supporting income earning production at home, social activities and adult education.

The cost of installing electricity in a small settlement in a developing country is about 10–20% of the total cost of infrastructure (roads, water, sewerage and electricity). Electrical installations incur significantly lower running costs and better safety than other light sources, such as kerosene lamps.

Materials for electrical installations should be selected with consideration for the effects of temperature, humidity, solar radiation and lightning. Short circuits are common where there is high humidity. Acid air pollution can cause corrosion damages. Strong sunlight makes plastic sheathed cables brittle with a high risk for short circuits. Cables and outlets must be placed and designed to be protected from physical damage and attacks by insects and other animals.

The cables should allow a good margin in the cross section to avoid overheating from the current. The electrical installation must be able to tolerate frequent short term voltage swings and power failures. Ordinary fuses often tolerate higher voltages than they are designed for, for short periods, which reduces protection for the equipment. A supplementary voltage regulator should be supplied with sensitive equipment. Always connect equipment such as refrigerators and engines to earth.

All wiring should be done by professionals, because a faulty job could result in bodily harm or fire.

If lightning is frequent, protection should be installed on buildings, particularly those that rise above their surroundings. A copper lightning rod should have a cross section area of at least 50 mm^2, with at least two down conductors of at least 20 mm^2 in cross section. These should be connected to an earth electrode: either a cable buried around the building, or a rod or pipe reaching the ground water table.

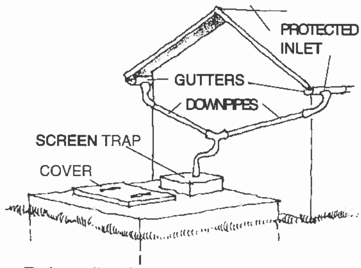
All installations must meet local codes and regulations, and a local electrical engineer must sometimes be responsible for the design.

Water

Access to clean water is one of the most important requirements for good health. The minimum consumption for rural families collecting water at a distance is 3–5 litres of clean water per person and day for drinking and food preparation. Reasonably clean water is also needed for washing and laundry. An average daily requirement in a developing country is 15–30 litres per person and day.

Surface water is often contaminated and can cause life-threatening diseases, such as diarrhoea, especially among young children. Other diseases are spread by water-borne parasites or insects living near water.

Rain Water



Rain collection system

One way to obtain clean water is to collect the rain off a roof and let in flow into a storage container. The first rain washes the dust off the roof and should not be collected. The container must be kept clean and covered. There should be a cover to keep out rubbish and insects, such as disease carrying mosquitos. The inflow should be provided with a screen to prevent leaves and other rubbish from entering the container.

The container can be built underground to keep the water cool in hot climates, and to protect it from freezing in cold climates. It can be made of cast concrete or masonry. It should be rendered on the inside or, if possible, surfaced with glazed or ordinary tiles to make it easier to keep clean. Water is lifted with a bucket or simple hand pump, and it could be pumped to a small, raised container for daily use. A 100 mm rainfall on a roof of 50 m^2 gives 5000 litres. With a consumption of 5 litres a day and person, this will suffice for a family of six persons almost half a year.

An above ground water tank

PHOTO: KARL-ERIK LUNDGREN

Water Sources

The availability of water can be a determining factor in the placement of a building project. Usually the first choice is groundwater, which is clean, free of bacteria, and a constant temperature. In hot countries the temperature of groundwater can be much lower than the temperature of surface water.

The well should be placed to minimize the risk of reaching contaminated water, at least 30 m from areas that might be polluted by sewage or toilets. Look for water in depressions with large catchments, and with permeable soils such as sand and gravel, not clay. The water well should be protected with a fence and a cover.

Sale of drinking water in Kenya

Distribution

In large systems water is pumped directly from the source, with or without purification, to a storage reservoir built high over the ground, from which it is distributed by gravity.

Small or medium systems often use a pressure tank consisting of a pump and a cylindrical galvanized steel tank, partly filled with pressurized air. The water is pumped into the tank until it reaches a pressure that triggers a power switch. When the water is consumed and the pressure drops in the tank, the switch is triggered again and the pump starts. There is normally a pressure difference of 1–2 kg/cm^2 between start and stop in the pumping.

The simplest system is to lift the water with a bucket and crank or a simple hand pump. There are wind driven pumps in rural areas for agricultural irrigation.

Water is distributed by underground pipes, dug sufficiently deep to be protected by the soil. The pipes might be galvanized steel or plastic. Galvanized pipes cannot be considered completely rustproof, and should be given further protection, such as painting them with an asphalt compound (Flintkote), wrapping with jute or strips of plastic, and painting again with asphalt compound.

Purification

Surface water must normally be treated to be used as drinking water, particularly in hot countries. First mechanical treatment and sterilization are necessary. Surface water contains many small particles, mostly organic, often of a jelly-like consistency. Pathogenic bacteria flourish in these.

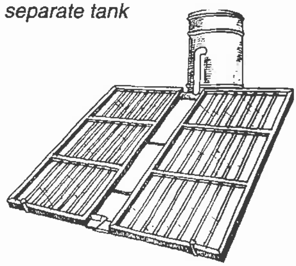
The simplest treatment is to let the water flow through an open sedimentation tank. The water passes very slowly, and the particles sink to the bottom creating a sludge, which is removed regularly with a bottom scraper. If sedimentation is poor, a coagulation agent is added, usually aluminium sulphate, that causes the particles to form gelatinous clumps. These clumps are removed by rapid filtering, which means the water in a closed steel tanks passes a bed of sand with the finish grain size on the surface and larger grains at the bottom. The impurities are caught on the surface; when they start to clog the filter, water is pressed back from the bottom toward the top and overflows into the sewer with the impurities.

Slow sand filtration a more effective method to purify water, but the water must be fairly clear. If it is cloudy, preliminary sedimentation is necessary. The water flows slowly through a large open tank filled with find sand and with a very fine top layer. The water flows through the filter bed and our through a drain at the bottom of the tank. While the rapid filter requires daily cleaning, the slow filter works up to two months, and when clogged only a thin surface layer need to be removed. The sand must be refilled at intervals, which is not required for the rapid filter.

Sterilization of water usually involves addition of liquid or gaseous chlorine to kill the bacteria.

The presence of iron and magnesium in groundwater affects the taste. Large quantities of lime give "hard water," which causes pipes to clog and requires using large amounts of soaps and detergents. Iron and manganese might be removed in simple cases by aeration and rapid filtering. The hardness in water is eliminated in a filter with zeolite, a mineral that serves as a catalyst to initiate an ion exchange between calcium and sodium, when the filter is charged with common salt.

Solar water heater with separate tank

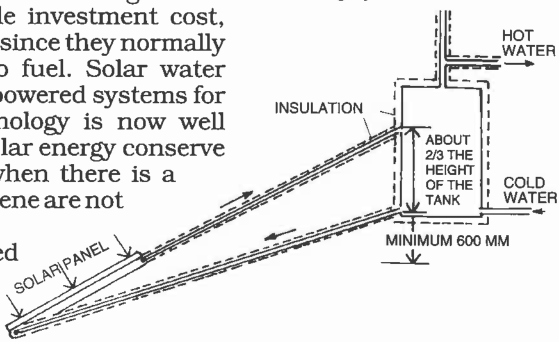


Heating Water

Solar heating should be considered. Although solar heating systems have considerable investment cost, they are economical in the long run since they normally require little maintenance and no fuel. Solar water heating could be a complement to powered systems for larger institutions, and the technology is now well established. Not only does using solar energy conserve resources, it provides a backup when there is a power break, or when gas and kerosene are not available.

Water heating can be combined with the central heating system in a building, or it can be separate: warmed by electricity, gas or solid fuel.

The principles of a self-circulating system



Indoor Water Installations

The water installations should provide

- clean water
- whenever needed
- at the desired temperature
- with a steady pressure.

The installation should be designed to allow easy access for repair and replacement of components. The pipe sizes are determined by the number and capacity

Washbasin **Bidet** **Toilet** **(water closet)** **Urinal (separate)**	0.10 l/s
Kitchen Sink	0.20 l/s
Bathtub	0.35 l/s
Shower	0.25 l/s
Water tap	0.15 l/s
Garden tap (min 20 mm)	0.70 l/s

of outlets, water velocity and the length of the pipes. The adjacent table provides the approximate flow in liters per second for different outlets, and these values can be used to estimate the total requirement. Hot and cold water should be calculated separately.

If there are only two components, add the given figures. However, if there are several components, multiply the total flow in branch of the system with a coefficient of simultaneity, related to the likelihood that not all components are open at the same time. The curve below can be used to calculate the volume requirements when designing the system.

For example:There is one line with connections to two wash basins with hot and cold water, one wash basin with cold water, two toilets, a kitchen sink and a bathtub. The total flow would be:

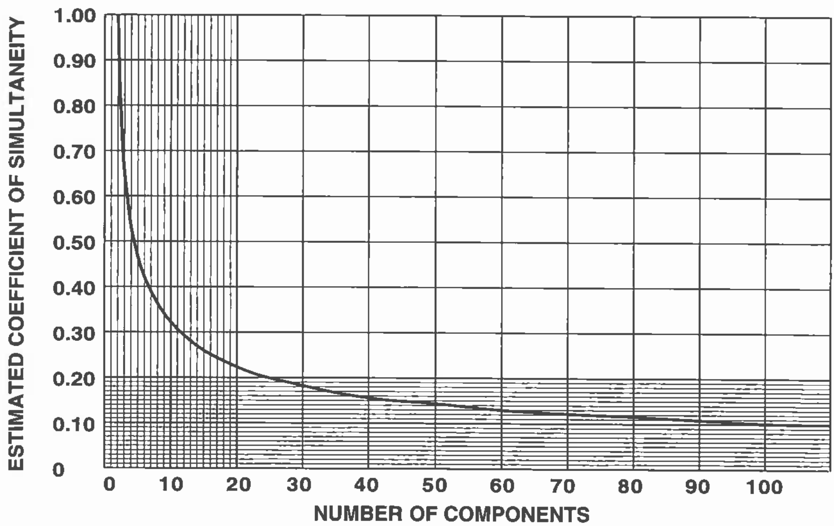
2x2x0.1 + 1x0.1 + 2x0.1 + 1x2x0.2 + 1x2x0.35 = 1.8 litres per sec

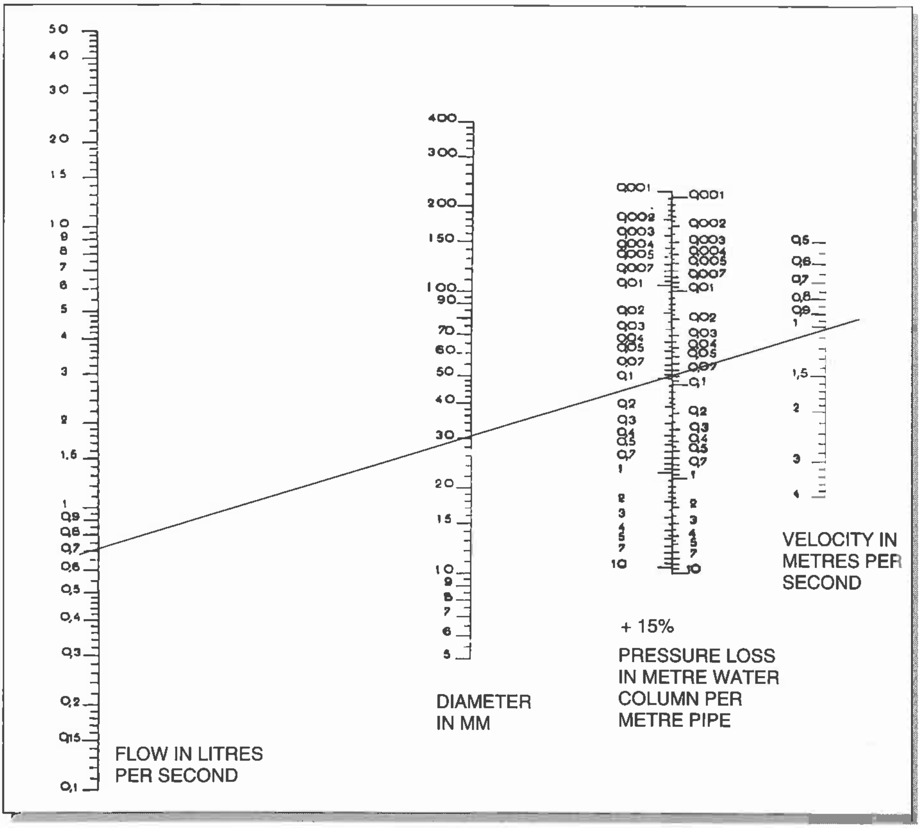
2 washbasins (h+c)	2x2x0.1	=0.4
1 washbasin (c)	1x0.1	=0.1
2 toilets (c)	2x0.1	=0.2
1 kitchen sink (h+c))	1x2x0.2	=0.4
1 bathtub (h+c)	1x2x0.35	=0.7
7 items		1.8

Since there are 7 componentss, the coefficient of simultaneity according to the curve is 0.40, and the calculated flow is 0.40 x 1.8 = 0.72 litres per second.

In the design, one must also proceed from a certain water velocity. High velocity allows smaller, and cheaper, pipes, but causes large losses in pressure, so that the system cannot pass the intended volume. An appropriate velocity is 1 metre per second.

To calculate the correct pipe diameter. In the diagram above a line has been drawn for a flow of 0.72 litres per second at a velocity of 1 metre per second, giving a pipe diameter of 30 mm. If the calculated result is not consistent with pipe available, chose the next larger diameter, but consider the loss of pressure that will result.





From the pressure in the inlet pipe, calculate the pressure in the highest outlet (or component) in the building. If the incoming pressure is at least 3 kg per cm^2 (30 m of water column), the highest outlet 7 m above the incoming pipe, and the total loss of pressure between inlet and outlet equivalent to 12 m, the remaining pressure in the outlet is 30 - (7+12) = 11 m, which is the minimum required to flush a toilet.

The pressure loss per metre pipe is given in the table. Use the values on the left side (+15%) which takes bends and valves into consideration.

If the water in the area is very hard (has a high lime content), deposits build up inside the pipes. It might be appropriate to install slightly larger diameter pipes to increase the service life of the system; even with some furring, reasonable amounts of water could still pass.

There should be a stopvalve where the water enters the building. A tap to allow rapid draining of the system should sit over a floor drain. Both taps should always be easy to reach.

The highest tap in each vertical section of the system releases any air that collects, so any pipe that goes up and then down must have a manual or automatic air release valve at its highest point.

Low points in systems without a stopvalve should have manual taps, situated as close to drains as possible. In a multi-storey building, there should be a stopvalve where the water enters each floor. Each component should have a stopvalve.


PHOTO: BJÖRN MOSSBERG

Hot Water System

The water should flow hot soon after the tap is opened. The pipes should be at least 5 cm from the wall and floor for thermal insulation. Attach the pipes to allow for movement caused by temperature changes. Hot water pipes that go through floors and walls should be placed in larger protective pipes that allow for thermal movement. Water heaters connected directly to the water mains should be fitted with a non-return valve and a safety valve for high pressure.

Piping

Common materials are

- Galvanized steel
- Copper
- Plastics such as polyvinyl chloride (PVC) and polyethylene (PE).

Galvanized steel Pipe

Galvanized steel should not be used for temperatures over 60°C, that is not for hot water systems, and not in diameters under 20 mm.

Galvanized steel pipes are fixed in threaded sleeve couplings of malleable cast iron or forged steel galvanized both inside and outside. They can be brazed (hard soldered with a solder containing copper) at a temperature far under the melting point of zinc. Threaded joints are tightened with hemp fibres and a sealing compound.

The stop ends on the pipes at delivery should never be used for couplings, because they are too short and are not galvanized on the inside.

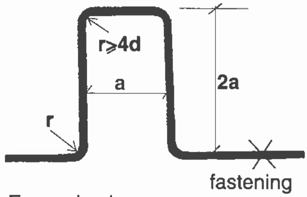
Bends are short lengths of pipe for turning corners. In exceptional cases pipes can be cold bent with special tools to keep their diameter. Galvanized pipe must not be heated and bent.

Branches are normally added with special connection pieces, but might also be done by cutting a hole and brazing. Care must be taken not to damage the galvanizing, since the unprotected surface can begin to rust. Galvanized pipe may never be welded.

Pipes should be covered with a rubber strip, at least 2 mm thick, at attachment points, to prevent the transfer of noise to the building structure. If there are likely to be large temperature swings, put expansion bends or loops into long, straight sections.

Galvanized pipe should be protected from corrosive (acid) attack on both inside and outside. If the water is very acid, equipment should be installed to neutralize it.

Because steel is so rigid, it is not well suited for direct connection to taps embedded in ceramic fixtures. It is better to use softer copper pipe for the tailpiece.



Expansion loop

Copper Pipe

Copper pipe is used for both hot and cold water. Pipes are joined by brazing (preferably with a solder containing silver, and a melting point under 800°C) or with bronze connectors. Brazing should always allow the larger pipe to overlap by three times the thickness of the thinner pipe. If the pipes have the same diameter, one pipe end is reamed to allow the overlap.

When laying copper pipe, pay special attention to thermal expansion, which is 50% greater than with steel. On straight sections, expansion loops must be included to compensate for the calculated expansion in length.

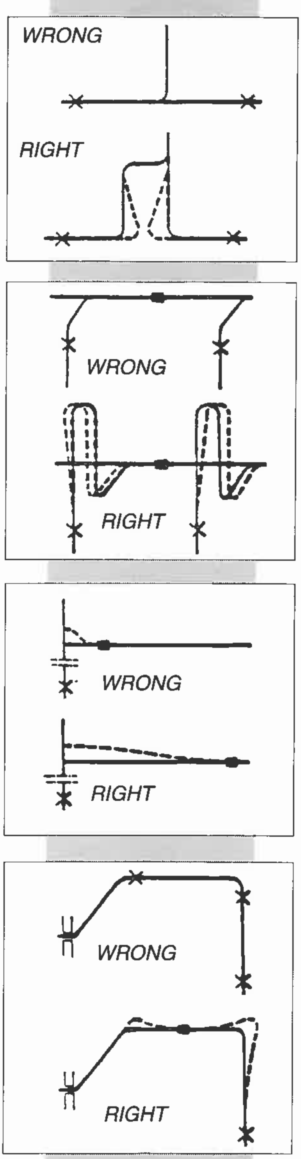
Branches can be made with pipe fittings or brazing. Joints and branches between galvanized steel and copper pipes should use special bronze connectors. Never connect a galvanized pipe directly after (with respect to the water flow) a copper pipe, because it results in electro-chemical corrosion that destroys the joint.

Plastic Pipe

Plastic pipes should not be subject to temperatures over 65°C and are more difficult to fit than copper pipes. There are plastic and metal connectors, but pipes are often joined by gluing. Testing under pressure can be done after at least 24 hours drying.

Pipes are laid in removable, wide plastic or metal union pieces that allow the pipe to slide in its guides in case of temperature changes. Plastic pipes have high thermal movement, 5–12 times that of steel, which must be considered in the design. The figures show how pipes should be laid to allow for thermal movement. If the pipe is set vertically, the sheet is set under a sleeve or a pipe piece attached by glue. The pipe is held in place by the union piece when it is fastened.

Only hardwood tools should be used to work plastic pipe, although a flat steel file might be used when chamfering pipe ends. The only shaping that occurs is pipe bending and making sleeves. The pipe is heated by hot air to 120–140°C. Never place plastic pipe near an open fire.



Laying plastic pipe

× Fastening
= Guide

When bending the pipe, fill it with dry sand, a spiral or an inflated hose-pipe to retain the round section. The minimum radius of the bend is 3xdiameter (d) for pipe with an external diameter £ 50 mm, 3.5xd for pipe 63–110 mm, and 4.5xd for pipe >125 mm.

End sleeves are made by bevelling the outside of a pipe end at a 45° angle, heating another pipe and slipping it over the bevelled end to the minimum overlap specified in the table below.

Outside diameter mm	12	16	20	25	32	40	50	63	75	90	110
Overlap mm	23	28	31	35	40	45	50	55	60	65	75

When joining pipe, the surfaces should be cleaned and degreased. A suitable glue is spread thinly on both the pipe end and the inside of the end sleeve, and the pie is pushed into the coupling. If hot air welding is used, it should be in a workshop, not on the site.

Components

A bath tub should have a pin under it to connect to earth in the electric system. If there is none, the cold water system should be earthed.

Stainless steel components, such as sinks, should be at least 1 mm thick and be backed with sound insulation material.

Valves and taps should withstand water pressures of 20 kg/cm^2 and be easy to open and close. A mixing tap should work well even with a pressure difference of up to 2 kg/cm^2 between the hot and cold water.

It is very important, especially in warm countries, that there is a water seal at least 50 mm high on all components. The water seal prevents sewerage gases from escaping into the building, and it should be able to withstand the suction that arises in the system when a toilet is flushed or a bath emptied.

Laying Pipe

The longest distance between fastenings is as follows

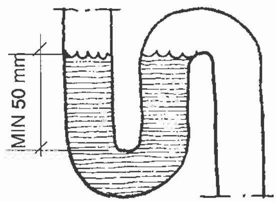
	Maximum distance in m	
	Copper	Steel
Inside d < 20 mm	1.25	1.50
Inside d 20–40 mm	1.80	2.25
Inside d > 40 mm	2.50	3.00

Plastic pipe is fastened at the following maximum distance

Outside d mm	12–20	25–32	40–50	63–75
Distance between supports m	0.50	0.65	1.00	1.30

Solid fittings, fixings and guides should resist thermal movements and compressive tests. The pipes should not come into contact with any other service system. All pipes should run through a protective pipe where they penetrate the floor or wall.

The plumbing contractor may not make a hole in the structure or the waterproof course, such as the roof insulation. There should be no joints or welds where the pipe penetrates floors or walls. Pipe should be laid straight with no unnecessary bends. Pipe should be laid at a slope of 2 mm/m to allow emptying.



A water seal.

The system should be designed and constructed so that it does not create or transmit noise. Cantilevered fixtures should be fastened with bolts that go through the wall. Standing components should be anchored to the floor with stainless steel screws in plastic plugs.

Taps are attached to ceramic components with special connectors and circular rubber seals. There should be at least 1.5 m between the bottom of the water tank and the toilet seat, for toilets with separate tanks. The flush pipe should be of a rustproof material and with at least 30 mm inner diameter.

Inspection and Test

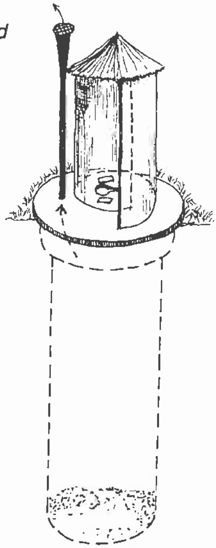
During the inspection check the workmanship, the time to fill and empty each component, see that it withstands the force of a compression test, and there are no noises. Then run a compression test with all taps closed and all joints visible. The entire system should be dry on the outside. Check that all air is removed from the system; raise the pressure to 5 kg/cm^2 over the intended working pressure and allow it to stand for 4 hours. Check the pressure with a metre accurate to 0.1 kg/cm^2. If during this time there are no visible leaks, no lasting distortion, and the pressure holds, the system can be approved for pressure.

A record should be made of the inspection and signed by all parties. When the job is complete, the contractor should hand over a drawing of the system.

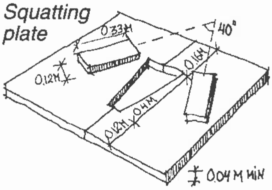
Sewage

Human waste causes disastrous pollution in towns, but is less of a problem in sparsely populated rural areas. The earth can absorb some amount of waste that is washed away and/or broken down to harmless components bu aerobic fermentation or by putrification. The goal is to dispose the human waste in a hygienic and culturally acceptable manner, that is technically and economically feasible.

Ventilated pit latrine



Squatting plate



Pit Latrines

The most common latrine is a pit latrine with a surface of about 1 m^2 and a depth of 3–4 metres. The pit is usually covered by a reinforced concrete squatting plate with an inlet hole for the waste, possibly with foot rests and a superstructure for privacy and protection from the weather. Liquid waste disappears quickly through infiltration, and the dry remains are not more than 25–30 litres per person and year. This means that a cubic metre pit should suffice for 30 person years, or five years for a family of 6. The pit should be well-ventilated to reduce bad smells inside the superstructure and to lessen the attraction for flies and mosquitoes. The simplest ventilation is a pipe that extends at least 0.5 m above the roof, with its end covered with stainless steel mesh. There should also be a cover for the inlet hole. When the pit contents rise to about a half metre from the surface, cover it with soil and dig a new pit.

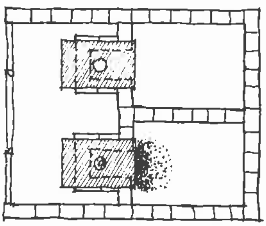
Composting Latrines

There are different types of composting latrines and their main characteristic is that the compost is kept. The latrine illustrated is the Vietnamese latrine with two underground chambers of 0.5–1 m^3 each. Through a groove under the inlet hole leading to the chambers, the waste is led to one or the other chamber. The two chambers are used alternately. One chamber is filled to a certain level and then the other is used. When the latter chamber is filled, the compost in the firs one is ready, and it is emptied before the chamber is used again.

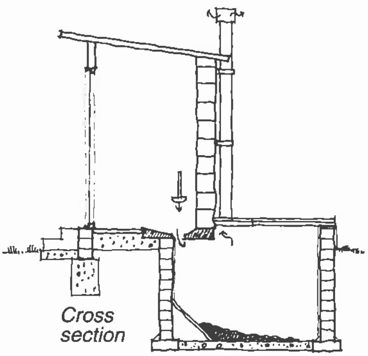
A version of the composting latrine was developed by the Building Research Establishment and is widely used in site and services schemes in Botswana and Lesotho.

Before using any kind of composted waste, check how long it takes for the harmful bacteria to disappear. This varies greatly according to local conditions. Using the sludge from treatment plants should be restricted to before the crop begins to develop, to reduce the risk of contaminating the harvest.

Composting latrine



Layout

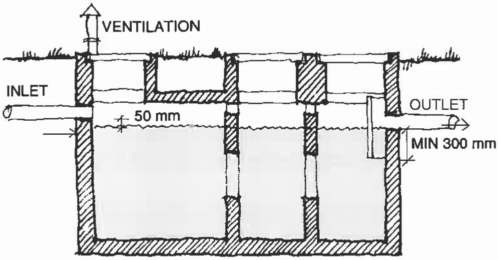


Cross section

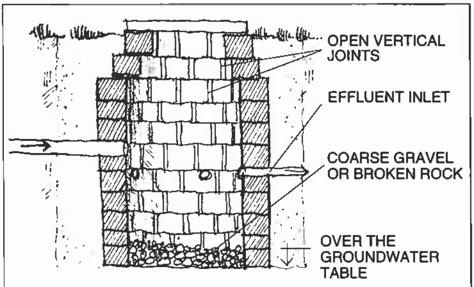
Septic Tanks

Among the small systems the three chambered septic tank is the most common, best and simplest for water-borne sanitation. It is designed with a volume of 200 litres per user, a little less in hot climates, but the minimum total volume should be 2000 litres.

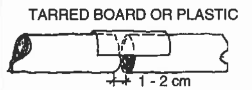
After sedimentation in the chambers of the septic tank, the water flows to a soakaway to seep into the soil. This can only occur above the ground water level. A



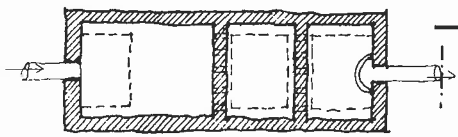
Septic tank, cross section



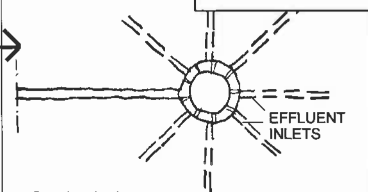
Soak pit, cross section



Joint in the effluent inlet



Septic tank, layout



Soak pit, layout

soakaway chamber usually has open vertical joints and a permeable bottom. If the soil at the base is not adequately permeable, seepage can be improved by running horizontal infiltration pipes from the chamber into coarse gravel. In this way the effective surface of infiltration is multiplied. Most of the sludge will collect in the first chamber, and should be removed regularly. It is important to allow space for a suction tanker to drive in to empty the tank. The sludge can be dried on a drying bed and used as a soil improver.

Sewage Ponds

Sewage ponds are large, shallow bodies where two processes occur. Organic pollutants are oxidized by non-pathogenic bacteria to produce carbon dioxide, in the same way as when water is held in tanks. The other process is that algae and water plants bind the inorganic salts with the help of sunlight. These salts would otherwise pollute lakes and rivers. The algae and water plants can be harvested and composted to return the nitrogen to the fields. A pond that 1000 m^2 and 0.5–1.5 m deep functions well for 300–1500 people; the higher value applies in hot countries.

From the Romans

Flush toilet	80 mm	1.5 l/s
Bath tub	40	1.5
Wash basin	30	0.75
Kitchen sink	40	0.75
Bidet	30	0.5
Urinal (single)	30	0.5
Shower	30	0.5

Sewer Systems

A sewer system should remove liquid and solid waste quickly and continuously. Sewer gases should not escape into occupied areas.

The pipes should be large enough for the calculated flow, and small enough that they are washed by the waste water. Bends should have a large enough radius that they do not slow the flow. The angle of joints should be less than 75°. Provide access openings for cleaning. The minimum slope of a sewer system should be at least 1:50.

The sewer system usually consists of a main pipe in the cellar, or under the ground, that empties into a sink connected to the municipal system by a service pipe. This main pipe is fed by one or more vertical pipes leading directly, or indirectly through horizontal branch lines, from sanitary components. In multi-storey buildings, the vertical pipes should extend through the roof and be left unsealed as air inlets, to reduce negative pressure (suction) and prevent the emptying of water seals, which would allow sewer gases to escape into the building. If the branch lines are long or heavily used, they should also be connected to an air inlet system. The main pipe should be at least 100 mm in diameter, which is adequate for a single family home. Pipes for larger buildings must be calculated according to the expected flow. The table gives some standard figures for the minimum outlet and water seal diameters in mm and the design flow in litres per second.

Using the same example as above (three basins, two toilets, a sink and a bath), the design flow is:

$$3x0.75 + 2x1.5 + 0.75+1.5 = 7.5 \text{ l/sec}$$

Note that for two components, the flow is reckoned as the same for one or two taps.

This is a significantly larger load than the water supply into these components (1.8 l/sec), and explains why for the same set of components, the outlet pipes should always be larger than the inlet pipes.

The chart on next page can be used to calculate the pipe diameter required. Locate the total calculated flow on one of the two scales at the bottom: the top scale is for a normal household and the bottom scale allows some margin for public buildings. There is a coefficient of simultaneity built into the chart, since not all components are used at the same time, so the flow approximates the probable volume of waste water. To take an example: a household calculated to need 7.5 l/sec total flow probably uses 1.5 l/sec at any time; with a slope of 1/50 (2 cm per metre) the pipe diameter should be 75 mm, but chose 100 mm, since this is the minimum diameter for a main. Vertical pipes should have at least the diameter specified in the table adjacent.

Toilet	100 mm
Bath tub and sink	75 mm
Other components	65 mm

If vertical main pipes are more than a metre to the side, with an angle of maximum 75°, increase the diameter one step. Branch lines without ventilation at the end should not be over 3 metres long. Calculate their diameter according to the chart above, using the minimum diameters given in the adjacent table.

Toilet	100 mm
Bath tub	75 mm
Sink	65 mm
Wash basin, bidet, urinal	40 mm

Sewer Pipes

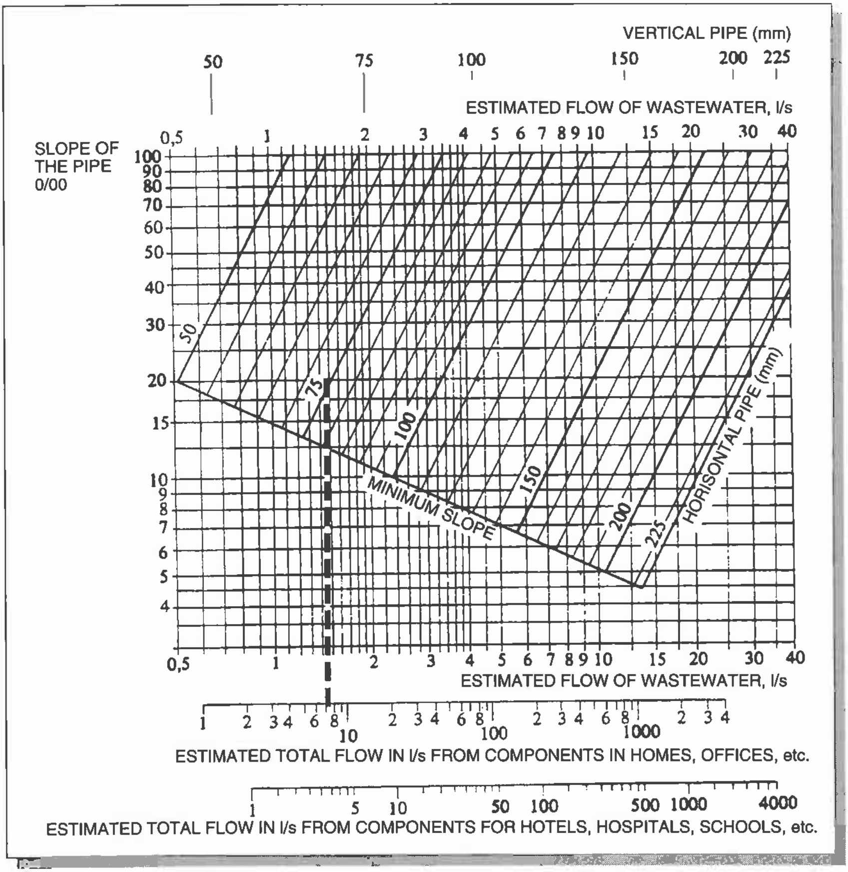
Concrete and stoneware are used only outdoors and in cellars. Cast iron is now too expensive to be common. Asbestos cement is found in some countries.

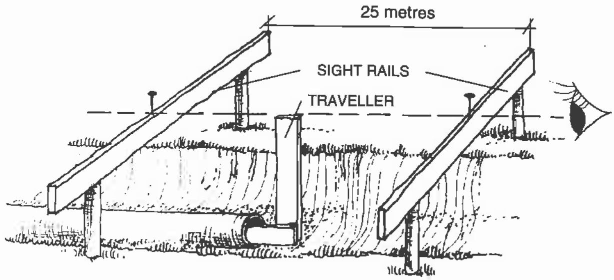
PVC is the most common material. Pipes are spliced with special couplings or glued like water pipes. The following is the maximum distance between supports for horizontal pipes.

The maximum distance between supports for vertical pipes is 2.7 m.

External diameter mm	32– – 63	75– – 125	140– – 250
Distance m	0.5	0.8	1.0

Concrete and stoneware pipes are sealed between the sleeve and the pipe with mortar, jointing compound or rubber rings.





Pipeline Trenches

Outdoor trenches are dug with straight sides, if the soil allows. There should be a layout and an elevation showing the slope of the pipes. Pipes should be laid at least 60 cm deep where there is no risk of freezing. If there is a risk of freezing, the pipes should be under the frost depth. Smooth the bottom of the trench with a spade. In rocky or clayey soils, lay the pipes on a bed of sand, and fill sand to the top of the pipe.

To ensure that the pipes have a constant and correct slope, use sight rails and a traveller. A sight rail is a horizontal plank resting on two posts, straddling the trench. The top of the plank should be exactly 2 m over the inside of the pipe bottom. Place sight rails 25 m apart, and hammer a nail in the plank over the centre of the pipe. The traveller is a lath with a 2 m board set at right angles at one end. Push the it into the end of the pipe. If the top the traveller lines up with the tops of the sight rails, the pipe is vertically correct. If the traveller is in the same line as the two nails in the sight rails, it is horizontally in place. The sight rails and traveller can be made at any height, such as 1.5 or 2.5 metres, depending on the depth of the pipe. After laying a pipe, be sure it is cleaned of soil before the next pipe is laid.

Inspection and Testing

Check that the pipes are at the correct slope, that the fastenings allow thermal expansion in plastic pipes, that the components are correctly connected and that the entire pipe assembly is well finished.

The vertical sections, in particular, can be tested for tightness with smoke cartridges. All joints should be visible to see if any smoke escapes.

A report and a drawing of the finished system should be made, as for the inspection of the water installations.

6 KITCHEN AND STOVE

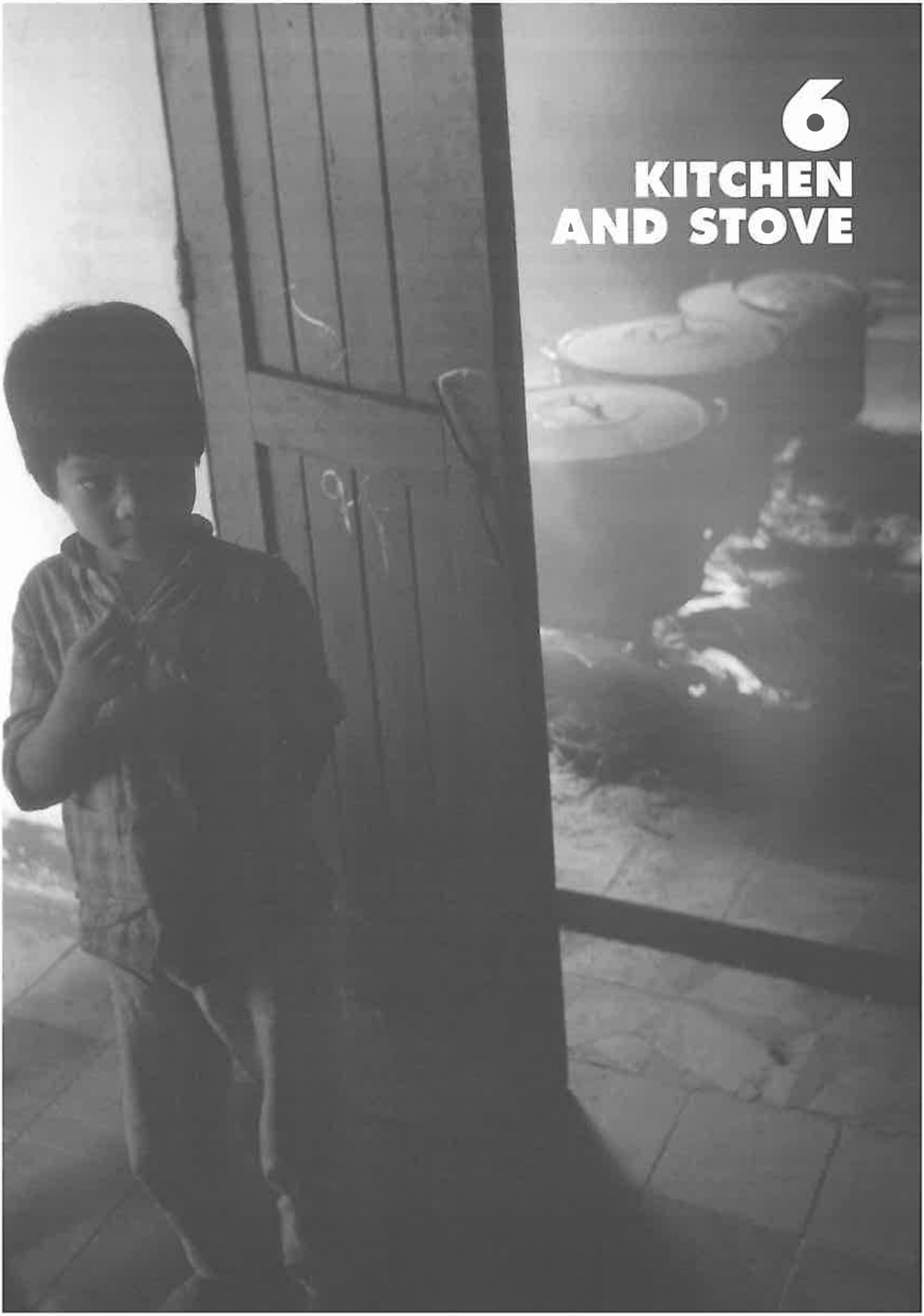


PHOTO ON PREVIOUS PAGE: MARIA NYSTRÖM

Kitchen and Stove

Kitchens in developing countries are often sooty, dirty, unhealthy and badly lit because inadequate attention is given to their placement and design. By planning the kitchen carefully, it is possible to improve hygiene in homes and institutions, and to make the indoor environment, where women and children spend most of the day, safer and more pleasant. Further, the correct stove uses energy more efficiently , lowering the cost of cooking.

This text is based on KITCHEN AND STOVE: The Selection of Technology and Design.

Why Priority on Kitchen and Stove

The placement and design of the kitchen seem to be neglected, even in new urban houses. People building their homes construct fine residential buildings, but seldom pay any attention to improving the kitchen. Rats and insects rapidly infest areas where food is prepared and stored.

Many institutions such as kindergartens and schools may not have a kitchen, so that meals must be cooked over an open fire outdoors or in one of the rooms. The converse might also be found. A kitchen built by donor aid and equipped with modern technology might be impossible to use if the stoves and refrigerators are inappropriate for the local fuel, or if the traditional diet is cooked in special pots that do not fit on the stove; perhaps the oven in unnecessary because the cooks do not know how to use it, etc.

The kitchen is often dangerous for those working or spending time there. In developing countries many women and children are found there. Burns caused by hot water or open fires are common in kitchens. Modern cookers have made electric shocks more common. Slippery floors lead to falls, and incorrect working positions cause wear on the body. Everyone in the kitchen is exposed to air pollution, and with the risk of illnesses such as carbon monoxide poisoning, respiratory infections, chronic bronchitis and cancer. The climate in the kitchen is stressful, with high temperature and air humidity generated by the stove.

Not only is the kitchen a risk-filled workplace, the kitchen is where most of a household's energy is consumed in developing countries. This is why stove projects have been implemented all over the world. There is an international stove network *The Foundation for Woodstove Dissemination* (FWD) based in Nairobi, Kenya. This forum collects news, spreads information about improved stoves, supports stove activities and tries to stimulate developing in the area of household energy. Institutional stoves: for clinics, schools, kindergartens and restaurants are also of interest. There has been some progress in producing baking ovens and stoves for brewing. HEDON is another network for organizations working with household energy, supporting household energy programmes in developing countries and developing professional competence in the area.

It is difficult to spread innovations into homes and have women accept the new stoves. There are many reasons to use an improved domestic stove, but energy savings is not a convincing argument in itself. A stove should save time, be safe, attractive, easily cleaned, etc. It is also difficult to get the new user to operate the stove correctly, so a stove that saves energy in the laboratory may not do so in the home. The wood is not cut into small enough pieces, or too much is put on the fire; the ashes are not removed or the chimney swept. Improving the kitchen has a positive effect on the acceptance and spread of new stoves.

It is easier to use arguments for energy efficiency in an institutional kitchen, since the energy saved is more visible with the large volume of cooking. It is also easier to reach the users to teach them how the stove works and how it should be operated.

PHOTO: MARIA NYSTRÖM

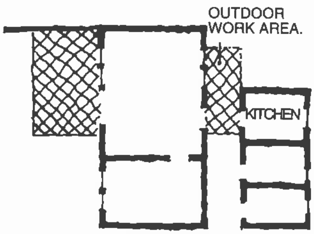
Kitchen with an improved stove in India.

Kitchen Design and Choice of Stove

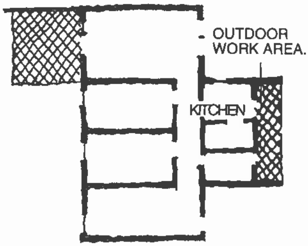
The design of the kitchen and its relationship to other dwelling spaces is closely linked to the choice of stove and where it is placed. It is not possible to give general solutions, since there is no universal model of a good and well functioning kitchen with an appropriate stove. Instead there is a series of questions that one should address before building a new kitchen or improving an old one.

Technically, the kitchen is perhaps the most complicated part of the dwelling. Building a kitchen that is comfortable and practical to work in, with as few inconveniences as possible, requires the integration of the stove.

Kitchen



A separate kitchen in a modern house.



Another solution is to let the kitchen open onto an outdoor work area.

Type, Location and Orientation

Will the kitchen be used by a single family, shared by many families or used to prepare meals in an institution? Where should the kitchen be placed in relation to the rest of the dwelling or to other spaces such as dining and service areas? It is important to know the requirements for location in relation to other areas and functions, since the kitchen affects the rest of the building in terms of both function and climate. In some parts of the world the kitchen might be outdoors, or both indoors and outdoor, according to the weather, season or culture.

It is important to consider whether the dining area will be in the kitchen, next to it or completely separate. This is particularly important for single family kitchens, but the position of the dining room in relation to the kitchen is also important in institutions.

There are several advantages to separating the kitchen from other areas, such as classrooms or a bedroom, to avoid subjecting them to offensive smoke, soot, heat, moisture, cooking smells and noise. These problems are more difficult to address in developing countries, where power is unreliable or too expensive to support technical solutions such as mechanical ventilation. It is particularly important in hot climates to ***orient*** the kitchen correctly with the prevailing winds, to take advantage of cross-ventilation, while preventing the spread of the problems. In orienting the kitchen, attention must be paid to any seasonal changes in climate that might affect ventilation.

Kitchen as Production Unit

The kitchen might have many functions, which vary during the year. It serves as a storage area for fuel, water, bicycles, tools and even the family livestock. The family might use it to bathe, do the laundry and ironing, or as a bedroom. It is important to find out what takes place in the local kitchen. What functions take place outside the kitchen, and in that case where? What are the requirements for access? This is perhaps more important for a domestic kitchen, but there might also be several functions in an institutional kitchen that should be separated from cooking.

Where does the family eat? Often meals are served the main dwelling because the kitchen is considered not fine enough. Perhaps this attitude would change if the kitchen were cleaner.

Cooking is a ***flow of activities or operations***, that must be identified locally. This flow could be broken into, for example: preparation of the ingredients, cooking, frying, grilling, dishing up, serving and eating, washing up and drying, and garbage disposal. Each activity requires a ***work area***. There are some steps that could advantageously performed outdoors, such as plucking fowl, washing rice and vegetables.

Some activities require ***equipment*** such as a stove, sink, dish rack, pots, utensils, etc. The number and size of the equipment must be decided and placed in relation to the flow of activities. Refuse is produced in the kitchen, and the types must be identified so disposal can be planned. Different fuels produce different residues that can be used in different ways. For example, wood ash is used as fertilizer in the garden. The choice of equipment should be appropriate for local needs, traditions and economy.

What are the possibilities to store water near the sink, the stove and the food preparation area? How can raw ingredients be stored at a reasonable temperature, safe from rats and insects?

The ***size*** of the kitchen is determined by the work steps in the food preparation process, required work areas and the amount of equipment. A rearrangement of the traditional kitchen might save space and building materials. The standard of the kitchen does not depend only on its size, but also how efficient and comfortable it is to work in.

Cooking frame of reinforcement bars in a rural Vietnamese kitchen house. Rice and sauce pots and a kettle for drinking water.

PHOTO: MARIA NYSTRÖM

Squat –

– sit or stand

Stand, Sit or Squat

Many women squat or sit on a low stool to cook. A basic question is whether the work should remain on the ground or be lifted to counter level. Therefore it is important to observe what position is taken in each activity. Some types of stove require one to stand, while others that one sits. The main advantages of raising cooking to a counter are better ergonomics, improved hygiene and less risk of accident. Other reasons are to save space in the kitchen by using counters and walls, and to keep food off the dust and dirt on the floor. The disadvantages are that it might be contrary to local traditions, and that children who often help in the kitchen find it difficult to see into the pots. The issue is complex and it important to agree with the user on the most appropriate solution. A general rule is that the height of the kitchen follows the requirements of the stove; that is, if the stove is placed for sitting or standing, the rest of the furnishings and fittings should be placed to avoid unnecessary bending or lifting.

Clean, Comfortable and Safe

The kitchen has high requirements for **cleanliness** in handling food, preparation and purchasing, etc. An important aspect of hygiene is to separate toilets and animals from the kitchen. Water should be readily available in the kitchen, and its floor, work surfaces and the wall over the counters should be easy to wash. This requires water resistant materials. Walls of ceramic tile can be a good choice, and they are usually produced locally. An alternative to tile can be a finish of steel-polished concrete or shiny paint, for example as a splashback behind the sink. Wet floors offer a risk for

PHOTOS: MARIA NYSTRÖM

Safety – Vietnamese girls learn early to help in the kitchen.

slipping, and a non-slip material should chosen. Drainage should be arranged by sloping the floor and building floor drains in institutional kitchens.

The kitchen should have good lighting, and it is important to see that there is natural light through windows and doors. Even if there are electric lights, they may not be completely reliable because of power breaks.

The kitchen should also be a safe workplace, designed to avoid burns and slipping. The stove and fuel should therefore be chosen carefully. If an electric burner is used, the electrical outlets and drawing of cables should be planned with consideration for water and use, to reduce accidents.

Electric cookers are becoming more common in Vietnam.

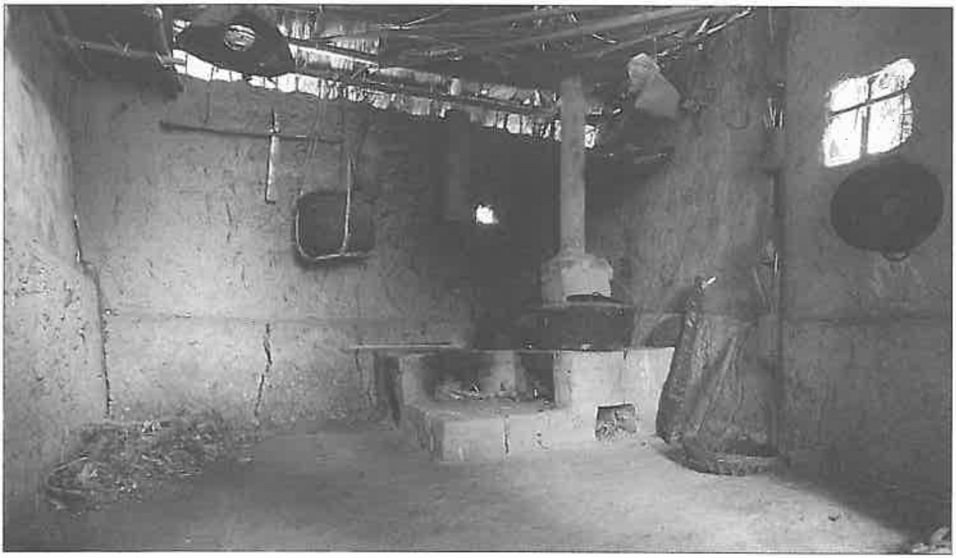
Well Ventilated and Smokeless

The ventilation of the kitchen should be separate from the rest of the building. It should be well ventilated, and at the same time the smoke should be extracted. Mould growth can be inhibited by good ventilation and cleanliness. The smoke extraction system for the stove should be designed to complement the total ventilation of the kitchen. The problem is not solved simply by putting a chimney on the stove. The location of the stove in the room is important for its efficient functioning. It should not be in a draught.

The height of the ceiling and the total volume of the kitchen are important. Traditional kitchen houses often have lower ceilings than the dwelling, and this is not suitable for ventilation.

Current research shows that women in developing countries who spend much time in smoky kitchens inhale more carbon monoxide, formaldehyde and cancer-causing compounds than heavy smokers.

Rural Vietnamese kitchen with a fixed stove and ventilation.



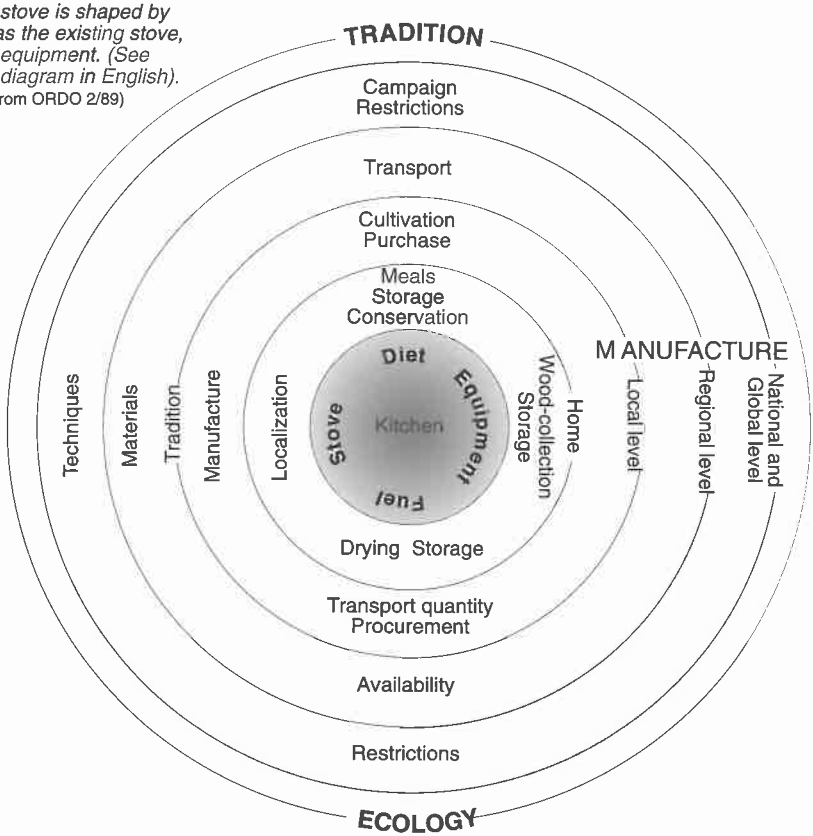
Stoves

Choice of Stove

There are many aspects to consider in choosing a suitable stove. The four components **diet – equipment – fuel – current stove** each set requirements or give the conditions for the choice of a specific stove. The stove is also related to the user and her requirements, which are specific in each case. Who is responsible for cooking and who assists? What are the other activities in the kitchen? Who shops or collects food, fuel, cooking utensils, pots and other equipment?

It is important to get to know the user of the stove, and to be sure that she understands why changes such as a new stove or a new kitchen are introduced. That is when changes for the better can take place.

Factors influencing cooking are described on different levels, from kitchen and home to global. The inside circle describes how the design of the stove is shaped by factors such as the existing stove, diet, fuel and equipment. (See photocopy of diagram in English).
M. NYSTRÖM (from ORDO 2/89)



Clearly a different stove would be chosen for an institutional kitchen and a domestic kitchen. The stoves meet different requirements. The four components and the user's requirements are found in both cases, but they result in different basic prerequisites.

• **DIET**

What requirements does the diet put on the stove: will the stove be used for long or short cooking periods (e.g. boiling water or pot roasting meat), frying, boiling or steaming, roasting, variations in diet? Are there any campaigns to change the diet or introduce new foods that might affect the choice of stove? What volumes of food are cooked? It is important to identify the food preparation process and its components.

What will be Cooked on the Stove

It is important to learn what kind of food is prepared by the family or institution over a day. The dishes might vary with the season. During holidays the preparation of special dishes might need completely different arrangements than normal. Attention should also be given to meeting these requirements.

Boiling water before drinking is often recommended, although it is often not done because of ignorance or a lack of fuel. Water is also heated for bathing and laundry. Pre-warming with solar energy could be a good solution.

Beer brewing is common in some countries, and often uses fuel very inefficiently. It must be decided whether brewing should be separated from ordinary cooking and done on a different type of stove. Similarly there might be large quantities of animal food cook in separate pots. Should one encourage the continued cooking for animals, or are their other solutions, such as feeding the animals uncooked food or cooking the food collectively in the village, etc.

Meat and fish are smoked, and other items such as tea are dried. Should these be processed with special stoves or ovens?

Thus there are different preparations of dishes and other food that one should note. What are the possibilities of combining different types of stoves? Perhaps it is necessary to have several stoves. Large, heavy stoves that store heat can be suitable for long cooking, while boiling or quick cooking are better on a metal stove that does not retain heat.

PHOTO: KARL-ERIK LUNDGREN

Impractical injera oven in Ethiopia.

PHOTO: MARIA NYSTRÖM

Beer brewing in Burkina Faso – baby at risk.

PHOTO: MARIA NYSTRÖM

Kitchen in India.

Bread in Rice Country

In some rice-eating countries, there are attempts to introduce other grains to reduce dependence on a single crop, so it important to know, through contacts with agricultural, health and education authorities, if any changes are planned that could affect the diet. If there is a shift from rice to wheat, it may be necessary to introduce ovens for home baking. There may be campaigns planned to revive food conservation techniques, since often valuable food traditions are dying out. A reason might be the changed working situation of women to take paid jobs outside the home. Changing from cooking on wood to using an electric cooker might also mean a new diet. Maize porridge might be replaced by pasta, if the round bottomed porridge pot cannot be used on an electric burner, or it porridge is considered old-fashioned.

Preparation of a Typical Meal

Institutional and domestic kitchens vary in size, and the stove(s) must be appropriate to both what is cooked and how much. Important questions are what is the daily menu and how many portions are prepared.

It is important to note how each dish is cooked, what are the steps, in what order are they executed, how long does each take, etc. It is recommended that the work process in the kitchen be studied for some days (see also the section Kitchen as Production Unit above, with special attention to how the dishes are cooked on the stove. What is the menu of a typical meal, and how is it prepared traditionally? Do a time study of what, how, when and how long for each dish. What pots and utensils are needed? How is a stove with several potholes or burners used? When, and for what dishes, are the different burners or stoves used?

• EQUIPMENT

Cooking requires tools. The choice of pot is most important, next to selecting a stove. What pots are used and how are the acquired? It is very important is the pot has a round or flat bottom. What are the made of, and what are the common sizes? How are pots bought; where are they made; and how much do they cost?

Dishes, Pots and Type of Stove

Tradition dictates which pot to use for each dish. Maize porridge may always be cooked in a round bottomed pot, and animal food in a huge boiling pan. Changing the type of stove might require a change in the type of size of pot. A stove cannot be accommodate all pot sizes efficiently. A comparison can be made with a traditional Swedish wood stove. The openings in the metal top had a set of rings to allow the hole to be adjusted to the pot. The pot also had a collar, so it could hang stably on the ring into the cooking hole. These pots are unusable on an electric cooker, which requires a flat bottomed pot.

In changing or developing stoves, pots are an important component, and pot manufacturers should be involved in the process. A good recommendation is to supply pots with lids for more efficient cooking.

PHOTO: KARL-ERIK LUNDGREN

Stoves must be able to accommodate different pot sizes.

Hot Box and Sand Box

A hot box is a basket, a paper carton or wooden crate filled with insulation such as hay, sawdust, cloth strips or newspaper. It is a good complement to the stove, and is useful to finish the cooking of roots, grains or porridge. The advantages are that it saves energy, and the cook is free to do other tasks. It seems to be difficult to introduce the hot box and convince people of its merits. They argue that the food does not taste as good as when it is finished over the open fire. But the hot box might be used for cooking animal food or keeping dishes warm. The hot box was widely used in Sweden during the Second World war, so there is wide practical experience.

Another complement to the stove is a box filled with sand to slake burning wood. Instead of allowing the fire to burn out, or pouring water on it, the coals can be smothered in sand and reused. This conserves energy.

A type of hot box in the basket in the background.

PHOTO: KARL-ERIK LUNDGREN

• FUEL

What fuel(s) is currently used, and what are the long and short term probabilities. How much energy is consumed in total and for each of the stove's component functions: heating water, brewing, tea drying and cooking? How is fuel obtained during different seasons? Are different fuels used for different purposes? How is fuel stored and are there any special storage requirements?

PHOTO: MARIA NYSTRÖM

Kitchen in Vietnam

Type of Fuel and Stove

Choosing a multi- or single fuel stove depends on the long and short term fuel supply, acceptance by the user, etc. Normally a stove is more efficient technically if it is designed for a single fuel. This might not be possible since the fuel situation might change continuously, between seasons or according to the market. This must be considered carefully, in contact with the local and national authorities responsible for energy supply.

In many kitchens in developing countries today, one finds several types of stove, using different fuels, such as wood, charcoal, electricity and gas. This may be related to variations in fuel availability, prices, or that some dishes require a certain fuel.

Briquettes

It could be worth investigating the feasibility of briquetting waste materials such as rice husks, straw, hay or sawdust. Briquettes withstand moisture better,

A traditional three stone stove on the right, and a modern improved three stone stove.

PHOTO: ANTOINE LEMA

and the energy content of a sawdust briquette is greater than in unpacked sawdust. However, it costs to produce briquettes, and the drying process may be difficult and expensive in a humid tropical climate.

Production of briquettes may be practical if the materials are found near the place of use, such as a sawmill, paper or furniture factory.

Coal briquettes, known as honey combs, are already widely used, particularly in Asia. The disadvantage of them is that it is difficult to adjust the fire. They might be more suitable for institutional than domestic kitchens.

Vietnamese stove using coal briquettes.

PHOTO: MARIA NYSTRÖM

Biogas

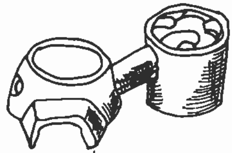
Biogas has been widely discussed as an alternative. It is widely used in India and China. Animal manure is necessary for the system to work well, so it is less suitable for urban areas. A biogas generator requires competent and careful maintenance, so it might be better suited for large consumers who can provide careful supervision.

Solar Energy

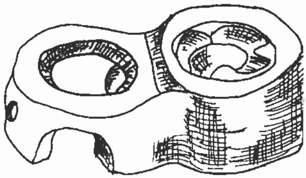
Solar cookers have been widely discussed, and there are many negative voices. The general conclusion is that the lack of success with solar cookers is because the wrong technology was used in the wrong situation for the wrong user. The comment that can be offered is that there are areas in the world where the sun should be a natural source of energy, where is a great shortage of fuel and many days of sunshine.

A solar cooker should be seen as a complement to a more traditional stove. It cannot be used at night or when it rains. Partial preheating of water could be a good use of solar energy.

There are many varieties of solar box cooker, that can well be used for cooking. The same box can be used to sterilize water and medical equipment at health centres.



Ceramic stove lining made by local artisans in Indonesia and elsewhere.



People buy the lining and cover it with clay to make a finished stove.

• CURRENT STOVES

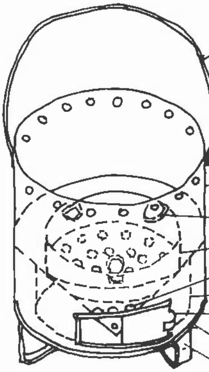
What sort or sorts of stove are currently in use: portable or fixed, with or without chimneys, how many cooking holes or burners, and what is the efficiency. Where are the stoves: indoors or outdoors, at what height? What other functions does the stove serve besides cooking? Are they built on site or prefabricated? What material? How much do they cost?

Thai bucket stove, Vietnam.

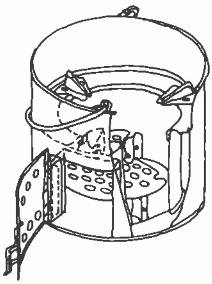
PHOTO: MARIA NYSTROM

Stove Functions

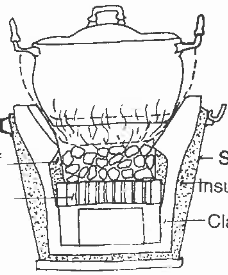
Besides cooking, the stove provides heat and light, warms water and acts as a focus for social activities. If the open fire is replaced by a closed stove, it loses its function as a source of light, and must be complemented by daylight and electric or gas lamps. The functions of the stove in the home or institutions should be mapped.



UNICEF's charcoal stove in double walled metal with a wind shield.



A metal stove from Botswana with double walls and wind shield.



Thai charcoal stove with a ceramic lining (improved Thai bucket).

Types of Stoves

Stoves might be portable, fixed, or prefabricated and assembled on site. The choice of type largely depends on the cooking tradition.

Portable stoves are probably most common in domestic kitchens, but also in simple, sidewalk cafes. They are made of metal or clay and are single or double walled. Examples of improved **portable** stoves are:

— The Thailand bucket stove and similar models all over Asia,

— The improved jiko in Kenya, made of metal with a ceramic liner.

Some **built on site or fixed** stoves are:

— Versions of the Chula (Nada Chula, Mangan Chula), widely used in India, made of clay, cow dung and straw, fitted with a soot door, grill and chimney,

— The brick Lorena stove in Latin America,

— The protected three stone stove in the Sahel.

Examples of **prefabricated** stoves are:

— The portable Mangan Chula,

— *The New Nepali Cooking Stove* introduced by UNICEF, delivered with full instructions, ready to assemble on the site.

Institutional stoves are designed and produced by

— The Renewable Energy Development Institute, Geneva,

— Bellerive Foundation, Nairobi and Geneva,

— The German Agency for Technical Cooperation (in Kenya).

PHOTO: MARIA NYSTRÖM

Improved stove in India. (Nada Chula)

Quality Control

It is crucial to spread only good, well-functioning stoves. A defective stove can create resistance to adopting any improved stoves. It can be difficult to test stoves built on site in individual homes, but stoves produced in a factory or workshop should be subject to regular quality control.

PHOTO: MARIA NYSTRÖM

Improved ceramic stove for round bottomed pots, Burkina Faso.

Stove Efficiency

Technical efficiency is not perceived as important by a household as an institution. It has been shown that priority at home is put on other qualities than energy efficiency and cost: ease of use, risk for burns and time savings. Economy is more important in institutional kitchens, since fuel and food are often together in the same budget. In both cases the placement of the stove in the kitchen is important to allow energy saving; the fire or stove must be shielded from draft, weather and wind.

The cook should learn to use and maintain the stove correctly: use the correct amount of fuel, empty the ashes and keep it clean. Any chimney should be cleaned regularly to avoid chimney fires, and so that the stove works well. All cooking utensils should be clean of soot for efficient heating.

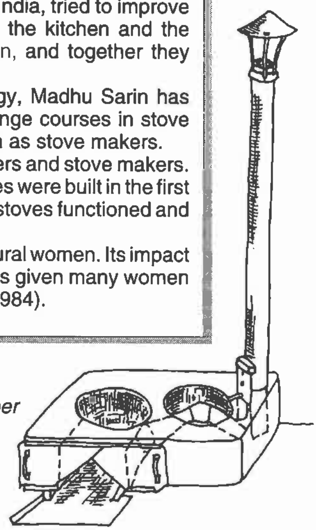
NADA CHULA – A women's project in India

Sheila, a woman in the casteless part of Nada Village in north-west India, tried to improve her stove some years ago. The problems were the smoke filling the kitchen and the increasingly difficult fuel situation. She got help from Madhu Sarin, and together they developed what later became known as Nada Chula.

With support from SIDA's special fund for environment and energy, Madhu Sarin has worked with other non-governmental organizations in India to arrange courses in stove making, to produce teaching aids and to train poor, illiterate women as stove makers.

So far 120 women have been trained directly by the project as teachers and stove makers. They in turn have trained hundreds of others More than 100,000 stoves were built in the first two years of the project. A recent evaluation showed that 84% of the stoves functioned and were in use.

This is an example of a small project initiated by and directed to poor rural women. Its impact reaches far beyond energy savings and better health: the project has given many women their own income, self-confidence, and a chance to learn to read (1984).



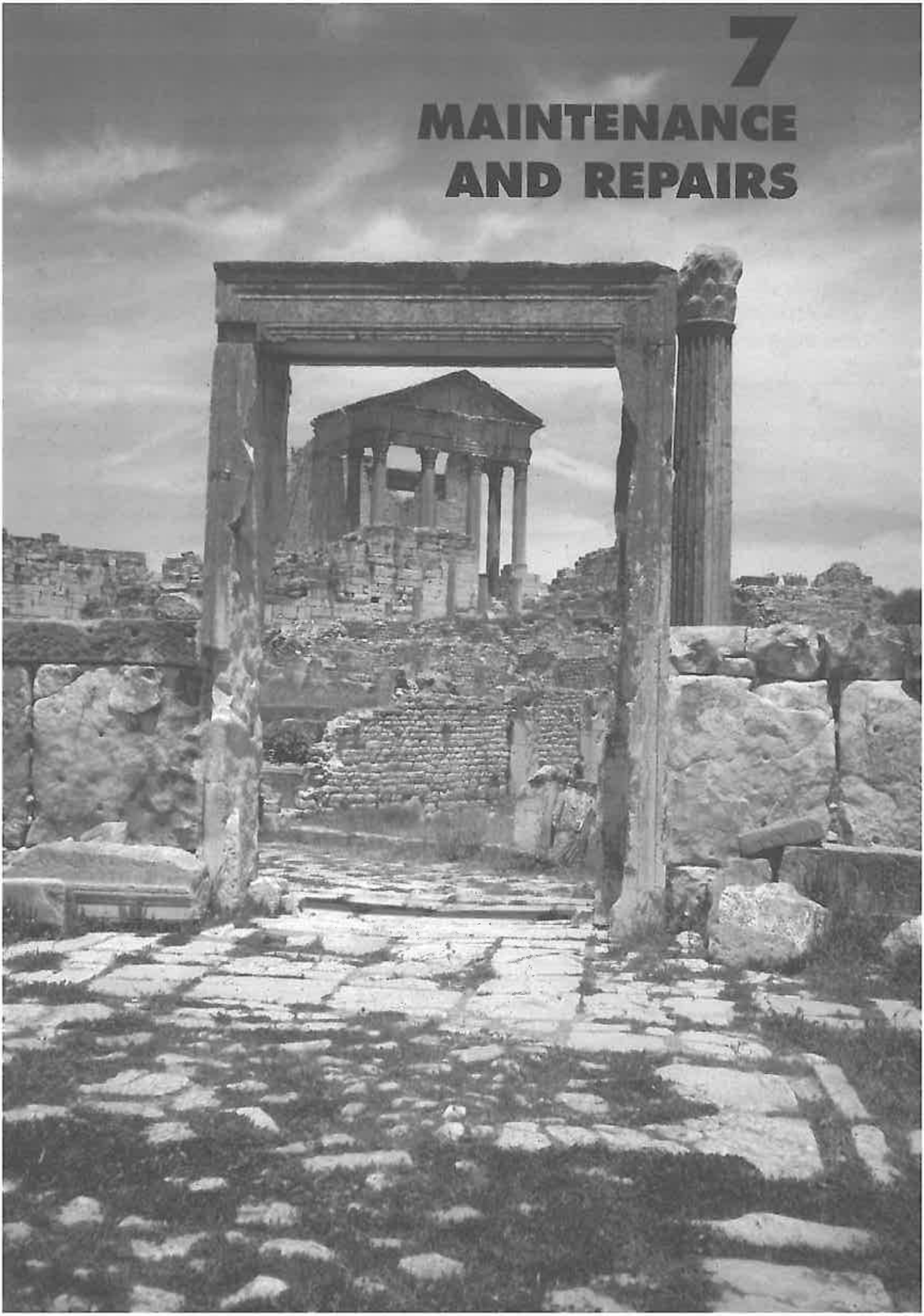
Nada Chula, an Indian clay stove with metal damper and chimney.

Dissemination of Ideas

Improved stoves in institutional kitchens are a good way to spread the new ideas to ordinary people. Schools, health centres and restaurants can reach many people and spread the message about improved kitchens and the importance of investing in the kitchen. Institutional kitchens reach also into the formal building sector, which often serves as a model for the individual household, which might build its own dwelling in the informal building sector.

PHOTO: MARIA NYSTRÖM

7
MAINTENANCE AND REPAIRS



Maintenance and Repairs

Buildings are large investments and an important resource for the users. Maintenance is the management of this resource, and the better one takes care of a building, the longer it remains a good investment.

Good maintenance requires responsibility, knowledge, planning and resources. Unclear allocation of responsibilities, and a shortage of resources, often results in the neglect of maintenance. Lack of knowledge and poor planning lead to inappropriate and expensive repairs.

Maintenance

Donors and recipients of development aid have only recently begun to understand the importance of maintenance, but a lot more information and education are necessary before the issue receives the priority it deserves. Donors can insist on the need for maintenance, but there will not be functioning systems until the recipients understand its importance.

Maintenance requires continuous inspection, economic resources and knowledge. It is a good investment to include a training component for maintenance in aid programmes. Donors often think that maintenance and running costs are the responsibility of the local organization. One can gain a lot by assigning the responsibility early during project planning.

PHOTO: BJÖRN MOSSBERG

Poor maintenance

Common reasons why maintenance does not work

- **Maintenance has low priority and insufficient resources.** It is often easier to obtain financial support for new investment, instead of improvement of an existing one.
- **Organizations for maintenance are often too small for the task.** The staff is poorly paid, have low status and there is little chance for promotion, which lead to a high staff turnover.
- **Wrong level of technology.** Maintenance requires good familiarity with the technology used. One must understand how things work to be able to take care of them.
- **A poor sense of responsibility.** If it is possible to engage teachers and students in the upkeep of a school, for example, there would be less vandalism and theft. Teaching maintenance to school children gives them useful knowledge for their future.
- **Limited understanding of the advantages of maintenance.** Maintenance should not become mechanical. At the same time one constructs a building, one must build up a consciousness and sense of responsibility.

PHOTO: BJÖRN MOSSBERG

Lack of maintenance

To make it easier to accept maintenance, one should

- Solve the issue of responsibility.
- Use well known, locally available building materials.
- Train the users, staff and students in maintenance.
- Allocate adequate budget.

To raise awareness of the need for maintenance, one can:

- Make a cost comparison between a well-maintained house and the cost to repair a run-down house of similar size and construction. Show this to the decision makers.
- Publish articles in newspapers.
- Conduct non-formal education on radio and TV.
- Include maintenance in the curriculum of schools and teacher training colleges.
- Arrange seminars on maintenance: they permit exchange of experiences and raise the status of maintenance. (Courses are often popular with external donors.)

Maintenance ***costs*** *but lack of maintenance* ***costs more***

Maintenance ***pays*** *and it reduces expensive repairs*

Inspection, Inventory, Tender and Budget

Maintenance might be repair of normal wear and tear or repair of a damage, such as a water leak. Preventive maintenance, to avoid damage, is the most economical. This is done by regular inspection of different parts of the building, such as gutters and downpipes before the start of the rainy season, to see if any remedial measures are necessary. It is advisable to follow a checklist so that nothing is overlooked.

When there is damage, it might be necessary to ask for expert advice on the best steps to take. This is especially true for electrical and plumbing installations. Settlement of the foundation, or anything else that might affect the structure should always be inspected by an expert.

Inspection

PART OF THE BUILDING: Inspect/remedy

PHOTO: BJÖRN MOSSBERG

A floor crack

GENERAL SETTLEMENT: Settling of foundation and walls might have a number of causes: insufficiently compressed soil under the foundation, erosion from underground streams, reduced ground water table due to nearby construction, or leaking pipes. If a downpipe empties water into the substructure, there might be problems. Foundation settlements should be investigated by an expert.

Is the settling so severe that the house might collapse? Call an expert immediately.

Is it continuing or has it stopped? Check by measuring the width of the crack every other week for 2–3 months. It is best to deal with the problem when the settling has stopped.

If the settling has caused the floor to slope, it can be very expensive to restore a horizontal surface. Decide if it is possible to use the building in spite of the damage.

FOUNDATION: Check for cracks and settling, which are most common at the corners. Extensions tend to sink in relation to the original structure. Check the jointing of stone foundations. If mortar is missing, stones can fall out of the foundation through erosion. To repair cracks well, it might be necessary to dig out the larger cracks so that the mortar has a large surface area to fasten to.

White painted foundations are not practical in areas with heavy rains, since rain striking the ground can splash up to about 300 mm and leave a layer of dirt.

FLOORS – EARTH: Earth floors require regular maintenance and should normally be polished once a week. Earth floors are often on the same level as the surrounding ground. Raising the floor at least 150 mm above ground level will make them drier, harder, and longer lasting. A raised floor also reduces the risk for flooding. If concrete is laid on an existing earth floor, it should be at least 75 mm thick, and reinforced. The concrete surface should be steel trowelled.

FLOORS – CONCRETE: Inspect for cracks and settling. Cracks must be filled. Settlement of concrete tiles can be evened with cement mortar if the floor must be completely flat.

Check to see that floor tiles sit firmly and that they are not damaged. Loose concrete tiles break quickly and make the floor hard to clean. Remove old mortar or glue before refastening the tiles. Check that they are at the same level as surrounding tiles.

FLOORS – WOOD: Check that the wood is sound. Any wood that is attacked by rot or insects should be removed to stop the damage from spreading. Find the reasons for the damage to be able to prevent it from happening again. Wood should never be in direct contact with concrete or soil, if it is not pressure impregnated against rot. Rot and termites attack both hard and soft woods.

The structure should be designed to keep wood components dry. Structural wood should be treated against insects and rot (leaking water). End wood and cracks are the most common entry point for rot and insects. The bark must be removed. Wood in exterior cladding should stop 300 mm above the ground and be cut at an angle at the bottom to prevent rain drops from being absorbed by the end wood.

PHOTO: MONICA ERIKSSON

Termite attacked timber

WALLS – GENERAL: Building extensions often suffer from cracks caused by settling, especially when they are built of different materials from the original building, and since the older part has already settled in.

Discoloration is common on walls if the eaves are too short to protect the wall from rain.

If a hole is to be filled, such as after a window or door, it is best to use the same material as the rest of the wall.

WALLS – EARTH: Earth walls erode if they are not protected from rain. Driving rain can damage an earth wall very quickly, especially unprotected gables. It is difficult to render an earth wall with lime or cement plaster, and get it to last. The earth wall is a weak material and moves more than the rendering, so the surface plaster falls off in large flakes. Earth walls can be protected by a covering such as bamboo mats or corrugated iron sheets (CIS). Such sheets might quickly be stolen, however, since they are so easy to remove.

If the outer corner of a house is damaged, one can reinforce it by setting in bricks or concrete blocks up to 120 cm. This also protects against animals that like to rub themselves against corners.

The render falling off the wall

PHOTO: BJÖRN MOSSBERG

WALLS – MASONRY: Check for settling and cracks, as for the foundation. Check if the lintels over windows and doors bend or show cracks. It might be necessary to reinforce them, or to put in larger beams.

If a brick wall flakes, the damaged unit should be repaired with mortar or replaced, and the cause for the damage found. Perhaps it is a broken gutter or a leaking downpipe.

How do the joints look? Open joints collect rain water. Joints should be made with a pressed top edge to encourage the off-flow of water.

Mortars containing lime are elastic and therefore better for repairing walls than pure cement mortar. Cement mortar should never be used on walls set with lime mortar, to avoid cracking.

Unplastered outer walls of 150 mm concrete hollow blocks can show water damage on the inside in driving rain. Such a wall should be rendered and perhaps painted on the outside.

Check the wall for paint flakes. Bubbles mean either that there is moisture damage or that the background was wet when it was painted (such as when the previous layer of paint had not dried before the top coat was applied).

METAL WORKS: Check the gutters and downpipes before rainy periods. They should be clean, free of leaves and rubbish and should not leak. Paint them if necessary and replace damaged sections. Check all flashing on the roof, particularly around chimneys and other penetrations of the roof.

Check the window sills to see if they need to be painted or repaired, and that they slope outwards.

Panama

ROOFS – GENERAL: Flat roofs require more maintenance than sloped roofs in rainy areas. Many flat roofs leak because of inadequate drainage during heavy rain. There is often leakage where downpipes penetrate the roof. One way to deal with a leaking flat roof is to construct a sloped roof over it.

Is the roof ventilated? Good ventilation can lower the indoor temperature and reduce the risk for mould and insect attacks on wood buildings.

FLAT ROOFS: Check extra carefully for cracks around the downpipe and in corners. Water damage to the ceiling can be very difficult to trace because the water runs inside the structure.

Solar radiation causes deterioration of the asphalt layer, a common sealant. This surface should therefor be protected with lime paint, render or tiles.

INCLINED ROOFS: Check that the roof is even. If it has subsided, it might mean that the roof structure is structurally underdimensioned. A wet thatch roof weighs as much as a tile roof, and a CIS roof weighs about 1/5 of that. See that the ridge and eaves are intact.

Thatch: Check for leakage and insect infestation. Special thatching grass should be used for repairs. Asphalt impregnated rope should be used to tie the grass, because it is durable and resistant to insect attack. A correctly built thatch roof lasts 15–20 years.

Tile: Check for leakage and broken tiles, and see that all the tiles lie straight and are well fastened to the purlins.

Corrugated Iron Sheets (CIS): Check for leakage and that the sheets are firmly attached . Each sheet should be fastened with 12 roofing nails, preferable galvanised steel. Check that new sheets have the same corrugation pattern and thickness (gauge). Overlap sheets: 1.5 curves on the sides and 20 cm above and below. When sheets are replaced, take great care not to damage them. Lay a long piece of wood under the hammer to spread the pressure when pulling out a nail.

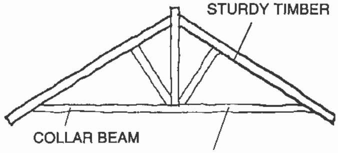
If rusty roofs are common in the area, paint the sheets. It will lengthen their lifetime.

PHOTO: BJÖRN MOSSBERG

Ethiopia

ROOF TRUSSES: If the roof is uneven, the trusses might be overloaded. It is common for sloped roofs to deflect because of underdimensioning and poor connections. Trusses constructed with wet wood loosen in the joints when they dry.

Is there insect infestation such as termites and bumble-bees?. Wood for trusses should be treated to resist insects. Individual bumble-bees attack certain types of wood, and choosing the correct timber will



avoid the problem. Are the battens well fastened to the trusses, and the trusses to the walls? On a saddle roof, is there a collar beam? The trusses of a saddle roof should look like the sketch to the left.

WINDOWS: Check that windows can be opened and closed and that the fittings to hold them open or closed work. Are the hinges intact? Check the frame and sill. Are they intact, is the paint flaking, is there rust, rot or insect infestation? Replace rotten or infested wood. Are glass panes and shutters intact?

Windows that open inward last longer, since they are less exposed to wind and cannot be slammed open or shut. However, it is harder to keep them tight against rain, and they need space inside the room when open.

DOORS: Check that the door can be opened and closed and that fittings to hold them open or closed work. Are the hinges intact? Are doorstops needed to protect the walls?

Check the frame and the door leaf. Are they intact, is the paint flaking, is there rust, rot or insect infestation. Replace rotten or infested wood. Outer doors that open inwards are less likely to be slammed by the wind, and the hinges last longer, but all emergency exits should open outwards.

CEILING: Check for water damage, insects and painting. Is there an inspection hatch to the attic? A ceiling makes it more difficult to inspect trusses, to see that there are no animals (such as rats and bats) or insects, and to discover leaks. A ceiling in a houses with a CIS roof helps reduce indoor heat during the day and the noise from rain.

PAINTING: Check that the paint is not flaking and that it covers the surface. The basic rules for good painting are: **1)** The paint must adhere well to the surface; (use a primer and be sure the surface is clean and dry). **2)** Use several thin coats instead of one thick coat.

OTHER – INSIDE: Check that all fittings are firmly attached (cupboards, bulletin boards, etc.). If furniture is infested with insects or damaged in any way, replace the affected parts. Check balustrades and handrails.

OUTSIDE – GENERAL: Check that drainage around the building is intact, leads the water away and does not slope in the wrong direction because of settling. The surrounding ground should slope away from the house.

Are there plants near the house that need to be trimmed? Branches touching the building can serve as entrances for insects, and large trees develop root systems that may affect the foundations and cause settling. The root system of a tree is often as large as the tree itself.

Check that fences and paths are intact.

Inventory

When inspecting the different parts of the house, one should keep a record of the findings. The recording schedule can be divided into interior and exterior parts of the house, to make it easier to handle.

It is easier to do an inventory of the interior one room at a time. Make a sketch if there are no drawings of the house. Number each room including entrances and corridors. This is an example of a recording sheet for an indoor inventory.

ENTRANCE

Item	Material/fittings	Surface finish	Damage/comments
F	Concrete floor	Vinyl tiles	Settling, cracks, loose tiles
S	Wood	Painted	Lose. Paint flaking
W	Concrete hollow block	Painted render	Cracks, paint flaking
C	Fibre board	Painted	Water damage, paint flaking
M	Window frame – wood	Painted	Window hook broken
	Window sill	Painted	Good condition
	Door – metal	Painted	Damaged hinge
	Bulletin board	Untreated	Falling off wall
E	Circuit breaker		Missing
P	Basin		Tap missing

F = floor, stairs
S = skirting
W = walls, columns, window reveals (parts of the opening not covered by the frame)
C = ceiling, beams
M = miscellaneous, i.e. doors, windows, built in fittings
E = electrical fittings
P = plumbing

A similar recording form for an inventory of the exterior might use **F** = foundation, **S** = skirting, **F** = facade, **R** = roof, **M** = misc.: doors, windows, gutters

One should also record what is in good condition, to show that everything was inspected, and nothing forgotten. Electricity and plumbing should be inspected by an expert.

Photographs can make it easier to decide what measure to take, and one can use them to consult an expert who may not be able to visit the site. The pictures also provide documentation when seeking funds.

Tendering

When the inventory is complete, it must decided what to do. If tenders are put out for the repair work, there must be written specifications, preferably with quantities stated. Even if the repairs will be done by the organization itself, it is useful to have the specification. Write up the points on the check list and what should be done

Building Component/Action
Roof
Roof ridge: nail fast. Replace rusty ridge sheets with new.
Roofing sheets: nail fast. Replace rusty roof sheets with new.
Gutters, Downpipe
Gutters: clean and paint

It is useful to state the quantities involved, such as the number of square meters of wall to paint, or the length of the gutters to clean and paint. By asking for a unit price, one avoids later discussion about additional work.

For the work done in different spaces, one can use a room description based on the inventory.

ENTRANCE

Item	Material/fittings	Action
F	Concrete floor	Fill cracks. Glue loose tiles. Replace broken tiles with (type):
S	Wood	Fasten to wall. Touch up paint, colour:
W	Concrete hollow block	Fill cracks. Touch up paint, colour:
C	Fibre board	Replace damaged sections. Touch up paint, colour:
M	Window frame – wood	Change hook
	Window sill	No action required.
	Door – metal	Replace broken hinge, weld into place.
	Bulletin board	Fasten to wall. Paint, colour:

It is best to have a separate sheet for each room, and post it in the room. Then everyone knows what is to be done and where.

If one puts out tenders, it should be clear who is responsible for acquiring the building materials. Some materials might have to be imported by the client. The builder that wins the bid should make a list of all materials that will be ordered by the client, to avoid any misunderstanding about who is to supply what. It is also the responsibility of the builder to order the right quantities, while the client should check that this is not more than necessary.

A bid should state how the work will be done and how long it will take. When repairing an existing building, consideration must be given to the users.

Schools should be repaired during term breaks. For other buildings, it might be best to do the job in stages to cause as little disturbance as possible.

Consider the weather, and avoid rainy periods: external work must stop often, or even be redone; paint dries badly and transport can be difficult.

PHOTO: BJÖRN MOSSBERG

Budget

Maintenance costs are related to the materials used and whether labour is free. The building's use and location (exposure to weather and wind) affect how much maintenance is required. Normally one can budget maintenance costs (work and materials) at 2% of the value of the building per year, for a new building of durable material. The cost can be lower if there is well functioning preventive maintenance and immediate repair of any acute damage, such as water leaks. It is possible to keep maintenance costs down to 1% of the building value for some years, but not in the long run. When repairing old buildings, there are often unexpected costs, and one can add up to 20–25% for contingencies.

When applying for funds for maintenance, one must estimate the cost of labour, which is impossible to know accurately until the job is done. Consult experts to make an estimate based on experience. Even professionals may find it difficult to give an accurate estimate, especially when there are extensive repairs. Remember also that it might take a long time between the application and the granting of funds, and building costs may have gone up during that time.

Insect Infestation

Termites

The risk of termite attack varies from place to place. They get into almost anything to find cellulose, their main diet. They can destroy nearly everything: clothes, plastic, even lead-sheathed electrical cables, in their search for food.

There are two ways to stop termites: physical barriers or poison.

There are two main types of termites. Dry wood termites live in humid climates, in coastal areas, and often build nests in the roof structure. Ground termites only fly during the mating season, and normally live underground.

Different woods are more or less susceptible to termites, but no wood is completely safe. Avoid timber with cracks or any other damage. Pine, fir, birch and eucalyptus are easily attacked by termites, while some

PHOTO: BJÖRN MOSSBERG

Wall attacked by termites

hardwoods such as teak, rosewood and redwood are more resistant. These can be hard to obtain, and are usually very expensive. Heartwood, from the centre of the tree, is the most resistant, but can lose this quality, especially if it is in contact with the ground, and its naturally protective substances are leached from the wood by moisture.

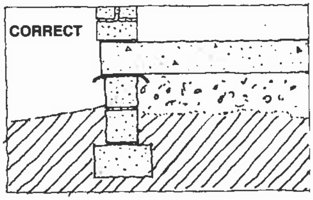
Treating the ground under the foundation with chemicals can protect the building for many years, but it must be done by trained staff. The building codes in some countries require soil poisoning. Wood impregnation can be very effective. Pressure impregnation is more effective for soft woods than hardwoods, and it gives more protection than brushing on or soaking in chemicals.

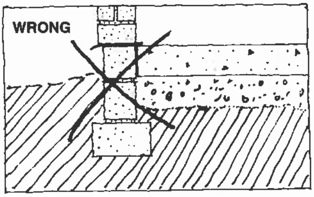
To avoid termite attacks

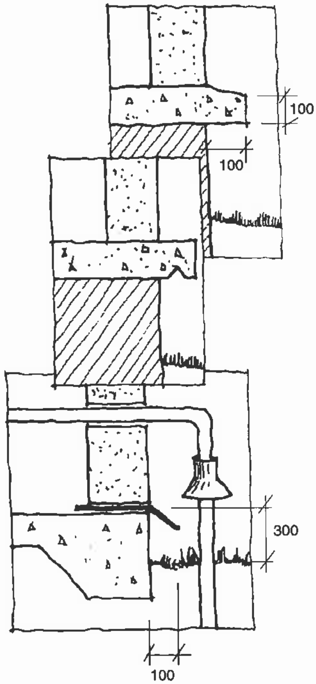
- Clean the site around the building and remove any tree stump, roots, bits of wood, paper or other material that might attract termites.
- Destroy any termite nests within 50 metres from the building and remove the queen.
- The site should be well drained and the building located on high, dry ground. The ground should slope away from the building (1:10). Water from downpipes, gutters and air conditioning should be led away from the building. Termites seek moisture, which they need to digest cellulose.
- Avoid setting untreated wood in the ground (such as poles) and quickly remove all scaffolding used during construction.
- Slab on ground foundations should be made before the rain period when the ground is hard. After the rains, the soil loosens which might cause settlement cracks. Foundation slabs of concrete crack easily if the ingredients (sand/cement/water) are contaminated, the proportions are wrong or the slab is not well dampened after casting. Some termites can enter a building through a crack only 0.75 mm wide.
- Avoid expansion joints by limiting the building to 20–25 metres long, or building several 25 metre long envelopes instead of one long structure. Expansion joints allow termites to enter freely.
- Cast the concrete beyond the foundation wall. See the illustration.
- Set a metal collar (shield) around the foundation, as in the illustration below. Alternatively a concrete slab can be cast to extend beyond the foundation, but an overhanging slab requires more formwork. A metal or concrete collar forces the termites to build out and

over to reach the walls, and they are easier to detect.

- Lay termi-mesh™ when available under the the entire foundation before casting the slab. Termi-mesh is a very fine, stainless steel mesh, which has shown good protective properties against termite infestation in buildings. It is probably the best alternative to soil poisoning.
- Build generous roof overhangs to protect the facade against rain. A hipped roof gives better protection to the gable ends.
- Place rooms with running water against an exterior wall so the pipes can enter through the wall. Pipes coming through the concrete foundation provide an entry for termites. For the same reason, over-ground electrical lines are preferred.
- Design any wooden components so that they stay dry. Timber should never be in direct contact with the ground or cast in concrete. All timber should be well dried before use. Damp, mouldy timber is an open invitation to termites.
- Consider building with termite safe materials, such as steel trusses, metal doors and window frames. The door leaf may be wooden. Hollow concrete blocks make good walls, but the holes provide excellent protected passageways for termites up to the roof.
- Treated timber should be pressure impregnated. A mixture of arsenic, copper and chrome (CCA) is very effective and long lasting. Imported pressure impregnated timber should be soft wood, conifers, because CCA permeates the material well.
- Soil constructions using earth from termite stacks are often immune to termite attack. The main components of wood are cellulose and lignin, that termites cannot digest. Soil from termite nests has high lignin content, which gives it good compressive strength and makes it less attractive to termites. Such soil is excellent for construction, but is hard to extract and mix.
- Conduct inspections several times to check that the building is termite-free, especially during and after rain periods, when termites are most active.







Other Insects

Some bumble-bees bore into timber, such as in trusses, and leave it like a sieve. There is not much one can do about this, except to use other materials than timber, such as steel trusses, or by using resistant type of wood, such as eucalyptus. Inspect wood used in existing buildings and avoid wood species that seem attractive to bumble-bees.

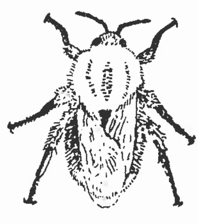


PHOTO: BJÖRN MOSSBERG

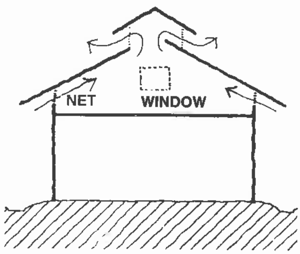
Holes in a timber beam caused by bumble-bees

A white powder coming from the timber is a sign of infestation by woodworm or beetles. If a plank or beam is producing dust, be very careful, because it might appear solid while it is hollow inside. When a board or layer of wood shows a white powder, remove it immediately to prevent the attack from spreading. All infected wood should be burnt.

Bats

Bats are a problem in most of Africa, and elsewhere. They nest in attics and create a terrible stench; their urine and faeces also destroy ceilings. They are very social and gather in large colonies, which very quickly produce large volumes of waste. Bats are second to termites as pests. Once bats have moved into a building, it is very difficult to get rid of the them. They prefer dark, warm spaces where they gather in thousands.

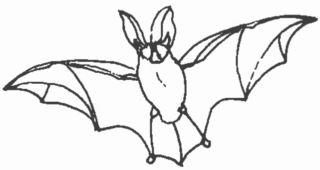
It is almost impossible to seal all openings with insect nets or bars to keep out bats. But they avoid light and draft, and it might be possible to avoid bats by keeping the attic well lighted, by installing skylights, and well ventilated.



Replace some of the roofing tiles with clear corrugated plastic, or set windows at the top of the gavel ends. Ventilate the attic well. One method is to leave a gap between the top of the walls and the roofing sheets, and cover the space with fine gauge netting.

Sometimes this has no effect, and one can see bats hanging from the net, or next to an opening, during the day. The best way to avoid bat damage is to remove the ceiling, but this is not possible with CIS roofs, where the ceiling is necessary to insulate from solar heat and the noise of rain.

Poisonous paints against insects also work against bats, but this is not recommended. It is not good for the environment and the protection lasts only about six months.



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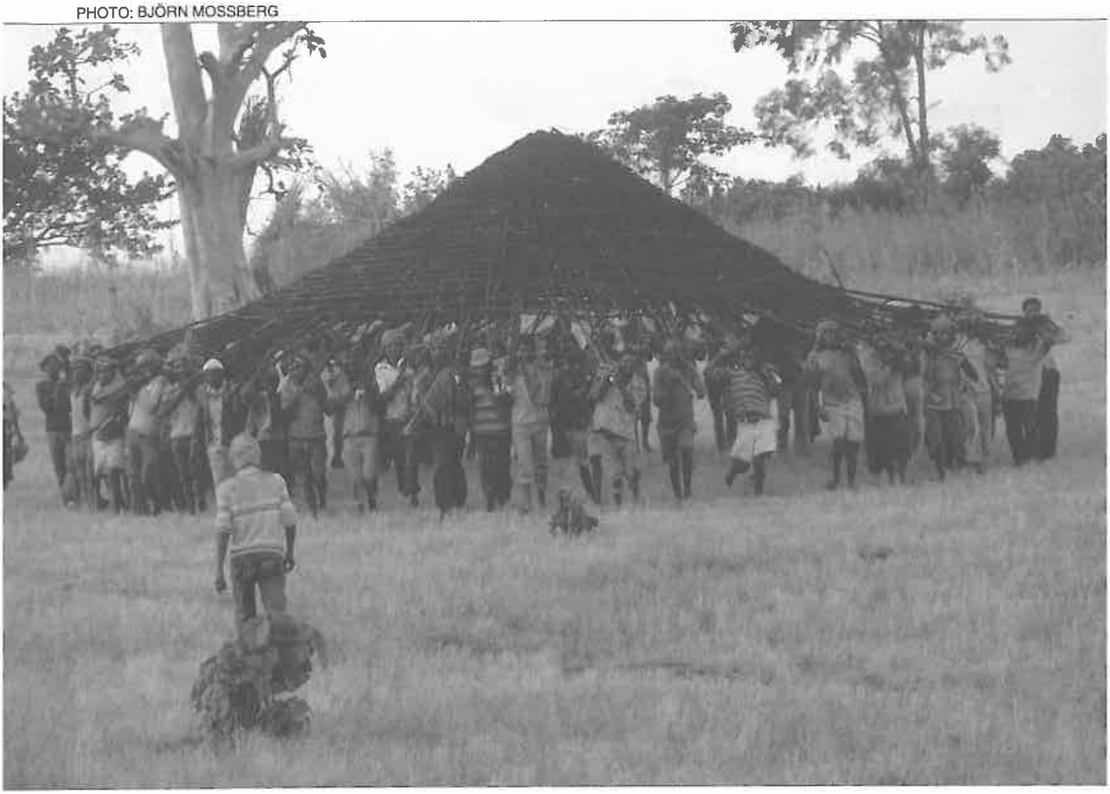


8 THE BUILDING PROCESS

The Building Process

During any building project, a number of decisions are made in consultation with the parties involved. The decisions are based on documents produced at the different stages. It is important that this material can be understood by a layman. The final building documents are used for tendering and construction, and should be as precise and clear as possible.

The creation and use of a building can be divided into the following stages.

- Preliminary study of the needs and conditions[1]
- Building programme[2]
- Designprocess
  - — preliminary design
  - — contract documents
- Construction
- Use and property management

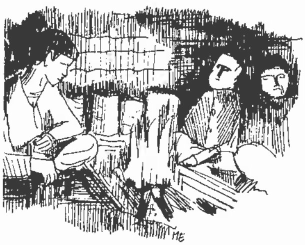
1 Also called the *architect's brief* or *project brief* stage.

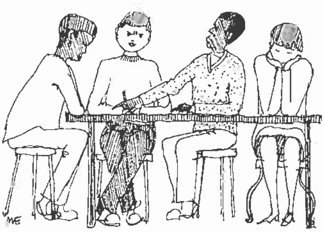
2 Also called *schedule of accommodation.*

The documentation requirements vary somewhat according to the type of contract. When the client and the contractor are the same, the documents can be simple. But when a contractor is hired, the documents must be complete to assure that the building is constructed as the client wants it, and that the tendering process is correct. The building documents can be crucial if a dispute arises over how the work was done.

The following steps are described below: preliminary study, building programme, design process and construction.

All documentation should be produced in the language best understood by all the actors.





Preliminary Study

The aim of this first phase is to collect information about the needs and conditions for implementing the project, as the basis for the building programme.

The study **is usually done** by the persons responsible for the activities in the future building, such as the director of a vocational school. A careful analysis is needed to determine the needs. A new building is not always the solution. The problems might be entirely different, such as staffing or finances. What does not work? Can the problems be solved best by alterations, additions or new construction? Those involved in the activities can give a good picture of the needs, but it is important to distinguish between what is necessary and what would be nice to have.

Informing local people in this early phase improves the chances that they will participate in implementation.

This is a basic condition for them to take responsibility for the use and maintenance of the building later. It is a good idea to establish a building committee to give the project a local base and increase the sense of responsibility.

The study results in a written description of the functions and requirements to be met. If the building is a school, report should describe how the classrooms are to be used, if there are different types of classrooms, and the furniture and fittings needed. One should also calculate the total space required, the construction time, and if possible, a rough estimate of the cost. It is important at this stage that one tries to specify the needs as clearly as possible, rather than consider solutions. Proposing designs this early often causes one to become committed to a position that is difficult to escape, as the design process develops.

An important target group

Building Programme

The aim of the building programme is to provide the basis for decisions on whether, and how, the project will be implemented. It is usually good to offer at least two solutions. This document is also the basis for the preliminary design.

A building always exists in a social, cultural and political context. Who will gain and who will lose in the project? How are the local population affected? It is important for an outsider to listen to all the views before making a proposal. This takes time and patience, but leads to more sustainable solutions.

The building programme **should be produced** by an architect or another professional planner in cooperation with the client's representative. The knowledge and needs of the users should also be considered at this stage, both through spontaneous discussions and formal meetings of a building committee. It is important that the document is done professionally, so that the needs expressed in the preliminary study can be addressed rationally and satisfactorily. A number of questions must be addressed in the building programme. The following checklist might be useful.

Checklist for the Building Programme

- Description of activities
- Local area detailed development plan and regulations
- Site
- Climate
- Topography
- Services to the site
- Relationship between the functional spaces in the future building, alternatives

- Room plan
- Building structure
- Description of the building parts/standards
- Financing
- Maintenance and property management
- Timetable

Some of these questions can be answered by discussions with the future users and local professionals. One should also try to see the project in a broader development perspective, how it fits into national and regional priorities and plans.

The building programme **should include** a plan with a description of how each room will be used, preliminary designs and an estimate of the cost. Describe the activities that will occur in each space and any functional links between them. The plan should list each room and the floor area required. Note any special requirements for each room. Sketches should offer several solutions for the given site. If the site is not decided, specify the requirements for the plot, such as location, area, slope, potential connections to power, water and sewers. It is also necessary to consider needs for future expansion. The cost estimate should include the cost of the new construction, recurrent costs for use and maintenance. The building programme should also include the responsibilities of the parties involved and a list of the authorities and persons affected by the project.

The Design Process

Preliminary Design

The main purpose of the preliminary design is to give the client enough information to decide whether to go ahead with the project, and in what form. It is also the basis for an application for a building permit and other permits required by government authorities, trade unions and others who might be involved. This process might require several steps, depending on the complexity of the project and local regulations. Work on the preliminary design begins when the client has decided to go ahead, on the basis of the building programme.

Preliminary designs should always be **made by** an architect or building engineer to assure a high quality project at an acceptable price. Competent preliminary designs make it easier to produce the contract documents, and help keep down the total project cost.

The goals of the project should be discussed again with the client. Initial ideas often change in the light of

If a project is financed through development aid, a special application is normally required.

Application for Financial Support

Each donor agency has its own application procedure for financial support, often with its own rules and forms. Most applications include the following headings.

Background

Describe the conditions and the problem, particularly the general living conditions in the area. The relevant sector should be described in detail, such as the educational situation if the proposal is for a school. Summarize the background information about the country: type of government, population, culture, religion, language, literacy and anything that describes the living conditions and feasibility of implementing a project in the country.

Aims

State the aim of the project as clearly and concisely as possible. Identify the target group and how they will benefit from the project.

Description

Describe the content and dimensions of the project as thoroughly and systematically as possible. Identify the actors and their responsibilities. Try to assess the potential benefits and any negative consequences. The project description is often the main part of the application.

Budget

Make a detailed summary of all project costs. A bid from a contractor might be required for larger projects.

Implementation

Describe how the project will be carried out and who will do what. Include a detailed timetable showing each step of the construction process with dates for progress reports and the final report.

Evaluation

Evaluation should be an integral part of the project, so plan from the beginning how it should be done, what it should cover and when it should be done. Include the costs for evaluation in the budget, if it is not covered elsewhere.

Attachments

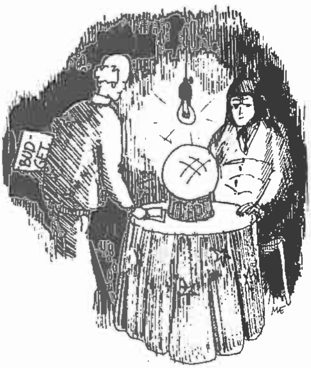
Attach certificates from authorities, drawings, maps, bids, etc. at the end to make it easier to read the project proposal.

local conditions, building traditions, financing, knowledge, etc. Issues of running costs and maintenance should be raised. If the preliminary designs are done by a local consultant, there are better chances for involving the users and the a local building committee.

On the basis of the building programme, preliminary designs are made for a specific site. The designs should be sufficiently detailed to show the proposed use of each space. A model is easier to understand. Services to the site such as roads, water, sewage and electricity should be indicated. The proposals are discussed with the building committee to reach a final design.

The preliminary designs should **result** in drawings, descriptions and a cost estimate that establishes the content, quality and size of the project. A drawing for new fittings and fixtures, a list of new equipment and furniture, and their cost should be appended to the preliminary design. Often furnishings and equipment are financed through a separate budget. It is important to take all the time needed at this stage to find a solution that satisfies everyone, because no significant alterations are permitted after this.

The size of the project is decided in the preliminary design, and good local knowledge is required to calculate the total cost. Since this stage is crucial for the continuation of the project, allow enough time and care to get as realistic a cost estimate as possible.



One calculates the total cost using known local building costs, on the basis of bills of quantities for site work, mains connections, built area, building services, fixtures and fittings. It might be necessary to get figures for equipment and materials that are not commonly used locally. Inflation might be high, and it might be wise to express the calculations to an international currency, especially if the project is financed by development aid. If construction will be done in stages, the costs should also be divided into these stages. Monitoring each stage separately gives a good control that allows constant improvements and savings. This is especially important in developing countries where the basic conditions for a project can change rapidly.

See that the cost estimates allow easy separation of the planning and construction stages. This makes it easier to prepare the final report.

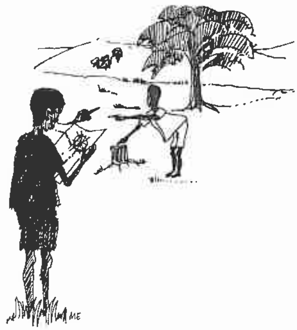
If one is managing the construction oneself, the cost estimates made during the preliminary design are important to assure that costs do not run away during construction. If the client hires a contractor, the cost estimates help in evaluating contractors' bids.

Regulations

It is important to be acquainted with national and local regulations and who issues permission. Building permits are normally required, but the application process varies as do the requirements for documentation. Certain buildings, such as hospitals and schools, might require approval from national authorities, such as the Ministry of Health or Education. It is important that all permits are approved before going out on tender, to avoid risks of changes and delays.

Regulations and by-laws governing the relationship between employer and employee vary from country to country. As a foreign employer, it is especially important to be clear on the content of these regulations, even if they are not always observed by local companies and organizations. One should also establish who is responsible for accidents on the building site. It might be necessary to take insurance if one is managing the construction.

The Site



Disputes about who legally owns a site often lead to problems and delays, so this must be clear before starting a project. There should always be a legally valid deed, issued by the correct authority.

It might be hard to know where the line goes between properties, especially if there are no boundary marks or maps. Land is regarded differently in different cultures. In some countries land is not sold, only leased for fixed periods. Sometimes one only learns who has claims to the land when one sets up a fence.

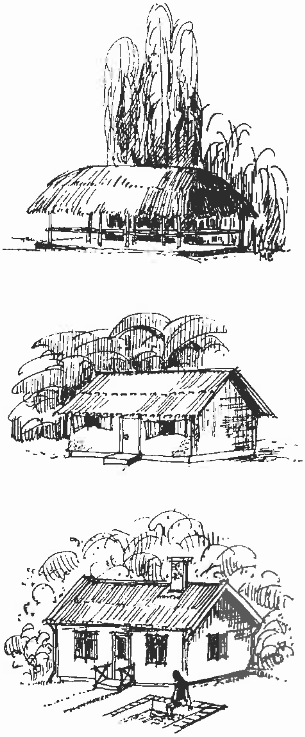
The cost for connections to roads, water, sewage and electricity should always be considered in choosing a site, as should the risk for flooding during the rains. It might be more economical to buy a good site than to build on one that is allocated for free.

Transportation differs

Local Building Conditions

When developing the preliminary design, study local construction carefully before deciding on the building technique and materials. Local builders have a lot of knowledge, and in many countries building research centres can provide information. It is wise to check on the availability of workers, materials and equipment, and the current salaries and prices.

One should exercise caution in introducing building techniques and materials that have not been used previously in the region, especially if they have not been tested in a similar climate. On the other hand, one should introduce improvements if they are well considered and carefully implemented.



Choice of standard

Standards

Decide early in planning if the building should be solid to last 50 years or if it could be simpler with a shorter service life.

Buildings have widely varying standards in developing countries. The informal building sector mainly consists of self-built housing using cheap local materials such a soil blocks, poles, recycled material and corrugated iron sheets. The formal sector, including institutions, industries and a few dwellings, uses more substantial materials such as steel, concrete and burnt clay. Aid organizations often build in durable materials, often imported, especially institutions such as clinics and schools.

Agreeing on the standard can be difficult, and often leads to conflicts. Some want to keep the traditional standards, while others want "modern" structures, often concrete, that have higher status. The aim should be to achieve good quality at the lowest reasonable price.

A basic mistake in development aid has been to use too high standards, inappropriate for the country's level of development. This only raises expectations for development. There are many examples of buildings that the recipients cannot afford, or do not know how, to maintain. It is, however, not wrong to chose a more expensive, durable material where there is heavy wear, such as ceramic tiles for bathrooms, concrete floor tiles in a dining room, etc.

Unfortunately there is a common belief among local agencies that bilateral and non-governmental organizations have unlimited resources, and one should take the chance to choose the highest standard, since it is "free."

Project Administration

There are many actors in a building project. It is important to decide who is responsible for what, so that the project can follow the timetable without conflicts. The actors in a building project are as follows.

Client: the person who will normally own the completed building and who has the authority to approve and decide on a project. It might be a local church, a cooperative or a government agency. Sometimes an aid organization is the client and later hands over the building to the agency or organization that will have responsibility for use and property management. The client might be represented by a board or an individual. It is easier if the client's representative is familiar with the region and the kind of activities the building will serve.

Users are those who will use, and perhaps maintain, the building. They are the most important actors since they will use and live with the building. One should be aware that even if an organization is both the client and the user, there might be different individuals in the two roles. A building committee represents the users and the local community.

Designers transform the client's needs and wishes in the building programme to preliminary designs and contract documents. Architects and structural engineers are usually in charge on this work. Depending on the size of the project, it might also involve electricity, water and sanitation consultants, geologists, interior designers, among others.

Actors

Sometimes the client hires a **project manager**, who is responsible for coordination of the design process, sending out tenders to contractors and monitoring during construction in larger projects. In smaller projects the project manager is responsible to see that the timetable and budget are followed, and that the construction is done according to the agreed drawings. The project manager should always report regularly to the client on the progress of the construction and monitor the costs.

There are two types of **inspectors**, from government agencies and from private inspection companies. The government inspectors check that the building is constructed according to the contract documents and applicable regulations. Their main role is to protect the public, assuring that construction will not cause any risk for the users or the surroundings. The inspectors from a private inspection company are hired by the client to assure that construction proceeds according to the contract documents, and includes quality control of the construction itself and the contractor's work. Monitoring by the private inspection company is usually required for insuring the building and for the contractor's guarantee to be valid. They also review the contract documents before the start of construction.

A **contractor** is hired if the construction is not done by the owner. In large projects there might be several contractors: for construction, water and sanitation, electricity etc.

The **donor or financer** often has comment on the design of the project. A decision to fund is based on a review of a project application. They often require progress reports before each payment and a final report.

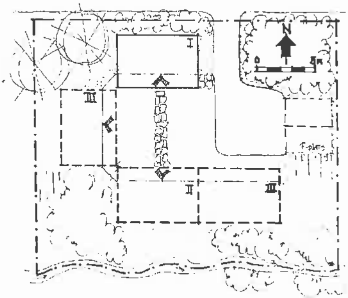
Various **authorities** must be contacted to get a building permit, and the rules vary from country to country.

Contract Documents

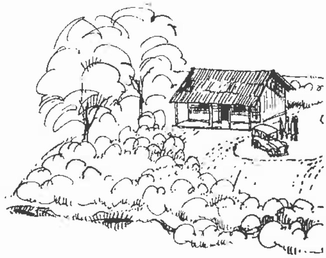
When the preliminary design is complete, the building permit issued and financing assured, the contract documents are prepared. Their **purpose** is to describe the implementation of the project in enough detail for everyone involved. These documents serve as the basis for tendering for a contractor, and thus have economic and legal importance. If the building is done through self-construction, the documents are the basis for detailed cost estimates and in tendering for materials and sub-contracting work.

These documents must always be **prepared by** professionals. Well prepared documents are the key to quality and effective cost control. A lot of experience is necessary to produce good documents, so the task should not be left to an inexperienced colleague. Sometimes the final building is not what was designed, because the contract documents were done by someone sitting in another country, without sufficient experience of the project country, or without contact with the users and the project manager.

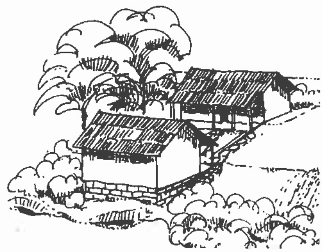
The contract documents **lead to** drawings and written descriptions that specify the dimensions and quality for each part of the project. All information necessary to construct the building must be found in these documents.



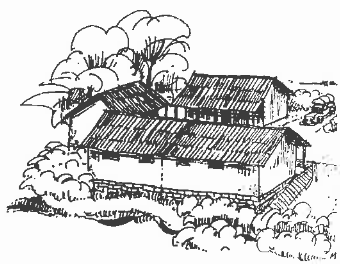
The number of drawings needed depends on the complexity of the structure and if it will be built by self-construction, with a project manager or through a contractor. Simple buildings may not require more than architectural and structural drawings including a site plan, floor plans, sections, facades, structural design and some details. Electrical and water services can be shown directly on these drawings. Larger or more complex projects require separate ground, electricity, water and sanitation drawings.



The site plan should show where the building should be placed on the plot and how services should be laid. It should also indicate possible extensions, since one often builds in stages. Without a general plan at the beginning, a building can become rather unstructured and expensive. There are advantages of smaller drawing formats that are easily handled on the site. Plans, sections and facades are drawn on a scale 1:200, 1:100 or 1:50 depending on what is to be shown. The scales should be specified and a measuring rule put on the drawing to prevent mistakes on the site. Detail drawings (scale 1:20) are needed to show solutions to construction details. Difficult details are shown with perspective drawings or in full scale (1:1). Write explanatory text about dimensions, qualities, etc. directly on the drawing instead to referring to the standard agreements.



Descriptions should include technical descriptions, bills of quantities and room descriptions. These can be combined for small projects. Bills of quantities are often the basis for contractors' tenders, when they are expressed in unit costs for each activity. The technical description should clearly specify how each activity should be executed, with the activity quantified through a bill of quantity. Each room should be described separately: surfaces of floors, skirting boards, walls and ceiling, fittings and furnishings. Quantities are particularly important if a fixed unit price per activity is used in the contract.



It is unwise and expensive to begin construction before all the documents are ready. It is cheaper to solve problems on the drawing board than on the building site.

Budget

Permits, financing and most of the drawing and descriptions should be ready before doing the cost calculation at this stage. This is the last chance to reallocate costs within the total budget frame before tendering and beginning construction.

Divide the project budget into sub-posts, which could correspond to the main categories used in the cost estimates during the preliminary design. This sub-posts should correspond to easily identified construction stages such as site work, construction, electrical wiring, plumbing and sanitation. The budget follow-up is one of the most important controls during the project.

If inflation is high, check against the time schedule how inflation affects the budget. One way of reducing the effects of inflation is to buy all building materials as soon as possible. How are any foreign consultants, project managers, etc. paid? Do their costs come on the project budget or are they paid separately? About 10% of the building costs should be reserved on contingencies.

Keeping the books

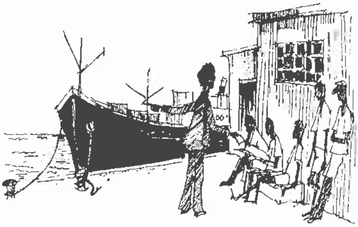
Time Schedule

It is a necessary tool to plan, prepare and execute a building project. The schedule should cover the entire construction period and all sub-activities, so that it is possible to anticipate and avoid potential disturbances. Important points in the schedule are when the permit is issued and when funds become available.

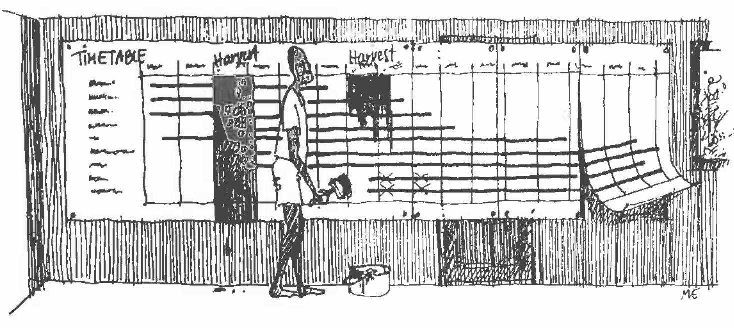
Two main issues are availability of building materials and transport. Careful planning and early attention to purchasing are thus important. Since the availability of certain building materials is often uncertain, it can be wise to purchase them early and build up stores. Imported material can take a long time to arrive, and one should check on import regulations and transport in good time.

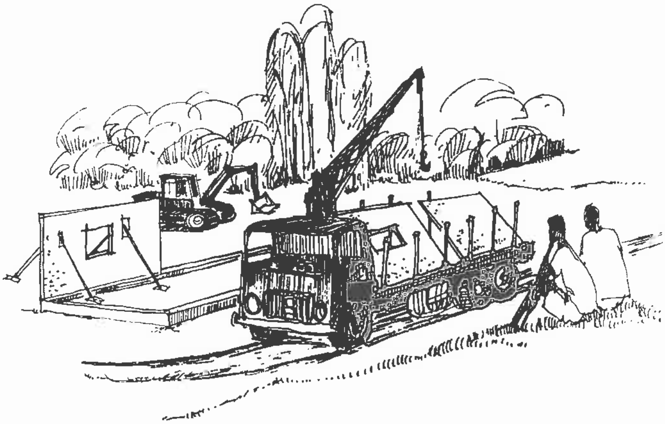
There a number of external factors that affect the schedule. In some areas it is not possible to build during rain periods. During seasons of high agricultural activity, it might be difficult to find workers and arrange transport.

Everything takes at least twice as long as one expects



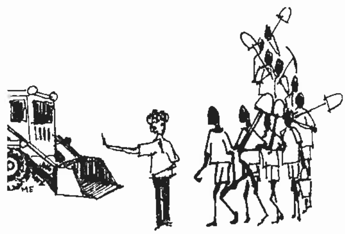
Time and the clock are not always a priority!





Building Method

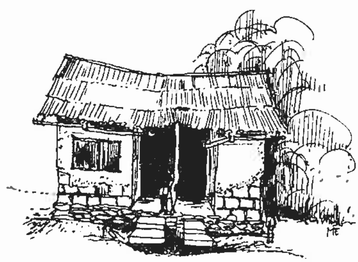
The choice of the method should be seen in a development perspective. Techniques used in industrial countries are often capital intensive and automated. It is appropriate where capital is relatively cheap and labour is expensive. The opposite applies in developing countries. It is not therefore obvious that imported techniques are more efficient in a national economic perspective. These techniques often require extensive and expensive maintenance. One should be very careful about deviating from local building techniques, which are certainly more appropriate for the local conditions than a technique imported from an industrial country. One can however consider improvements that will help develop the local building industry, but these must be introduced in consultation with the local workers. This has an educational effect and makes it easier for the people to adopt and develop construction.



Chose local building materials, with consideration for maintenance and later additions. It also supports the local economy and saves the money that would be used for transport. Designing a building that harmonizes with its surroundings is easier with local materials. Of course one should use local labour if possible.

Maintenance

Maintenance is neglected in most developing countries. There might be external funds for new construction, but maintenance is a local responsibility. Maintenance costs can be reduced by good design and choice of materials to keep maintenance simple and cheap. In the long run it might be better to spend more on construction to reduce maintenance. Even traditional techniques require regular maintenance, but people are familiar with local materials and techniques, it is more possible for them to carry out the maintenance.



Think about maintenance during planning. When choosing the building technique and materials, include the costs of both construction and maintenance in the comparison of the technical solutions.

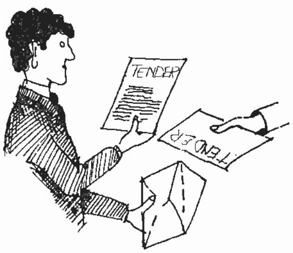
Air conditioners, lifts and other mechanical equipment require technical knowledge and spare parts for maintenance and repair. If it is not possible to build without such equipment, choose well-known manufacturers and sturdy designs. Their purchase price might be higher, but they may be more economical over time.

Construction

The size of the project and the client's experience are crucial for deciding how to execute a building project. One can either hire a contractor or manage the construction oneself. An experienced client with good staff might choose to participate in the administration and management of the project and save money. Clients without these resources or experience should rather give the responsibility to a professional builder.

It is always important to make explicit how responsibilities are divided among the actors, and to have all agreements in writing. Some countries have rules for execution of building projects and standard agreements that must be used, especially for public buildings.

Tendering



If one will not supervise the construction oneself, contractors are invited to tender. An exception is when one has a well established relationship with a contractor who sends regular bills for work done. If there is only one contractor available, there is not much economic reason for going through the tendering process.

It is always better to go out on tender to save project resources. Tendering can either be selective, limited to a number of contractors, or open to all. Some projects might require a public invitation to tender, as is normal for public buildings financed by government.

The contract documents are the basis for a public invitation to tender. They should be as unambiguous as possible to allow comparison of the offers from different contractors. The tender time should long enough to allow the contractors to calculate their offers carefully. The invitation should state when the tender is to be submitted and what documents are required. The tenderer normally specifies a period of validity for the offer, if it is not clearly stated in the invitation.

The whole tendering process should follow establis-hed rules with complete confidentiality until the sealed

Building in Ethiopia

offers are opened. There should be a register of all the bids.

In evaluating the tenders, look at more than the total cost. Decide if the offer is realistic considering the contractor's resources. Will the schedule hold? Is the contractor financially secure? The lowest offer is seldom the best.

When a contractor is selected, a contract is written to establish the division of responsibility between the client and the contractor. Important issues in addition to the costs are the starting date for construction, the schedule, responsibility for delays, responsibility on the building site and payment for extra work. The contact should also include a payment schedule, which the client follows in paying the contractor.

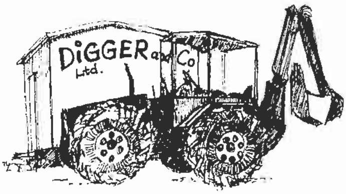
Contracts

There are three main types of contract
- All-in contract
- General contract
- Sub-contract

An **all-in contract** covers both design and construction, sees that the project is executed according to applicable laws and regulations, and that the requirements in the tender specification are met. The contract documents are developed by the contractor, and are not available before the contract is awarded. Instead offers for an all-in contract might be based on a preliminary design with a simple description of what the client wants, without going into technical details of solutions.

For the client, an all-in contract is the simplest solution, since only one other party is involved. It might mean that building costs are a little higher, and it is more difficult for the client to control details of the design.

A **general contract** covers construction and the coordination of any sub-contractors, while the client is responsible for the design. This is a common form of contract and gives the client full control over design, while construction does not require so much administrative involvement.



With **sub-contracts** the client retains responsibility for both design and construction. The number of sub-contractors depends on the project. This type of contract requires that the client has the competence and resources to plan and administer the project. It can give lower building costs and complete control over construction. Sub-contracting is not recommended if the client does not have previous construction experience.

Self-building

A requirement for success is that one can be understood and that one understands.

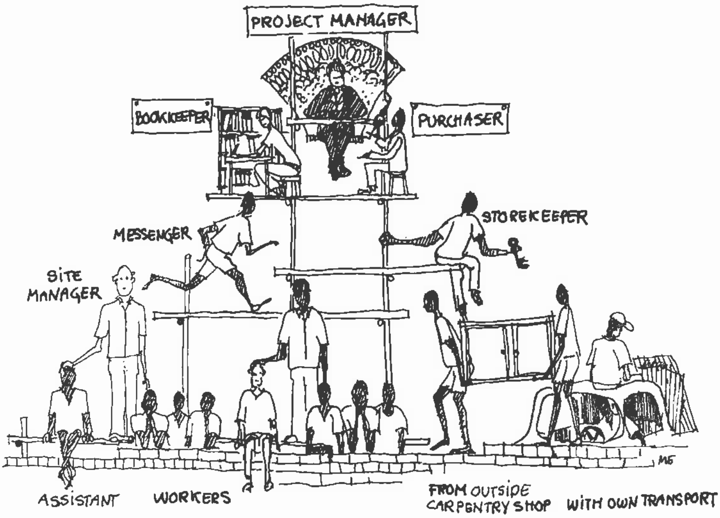
If the project leader is a "foreigner" knowledge of the local language is essential. Try to learn at least a few words.

Building with ones own labour and organization is suitable for smaller projects and where there is no interested contractor. With self-building, the client is repressible for purchasing and employing the labourers on the site. The client normally appoints a site manager who is responsible for:

- directing the work
- purchasing
- transport
- stores
- salaries
- accounts.

The project manager is the client's representative on the building site. In addition to technical and economic competence, he/she should have patience and personnel skills to solve any staff problems that might arise. By spending time on the site, the manager can identify potential problems early.

The site manager assists the project manager and acts as foreman, hires staff and pays loans.



There are a great number of actors in the construction process

The storekeeper is responsible for receiving and dispensing materials, and for informing the site manager when to order more. Transport is a high cost. If the project has many vehicles, it could be economical to do ones own maintenance and repairs. Assigning each driver a "personal" vehicle helps create a sense of responsibility, and could reduce the costs for running and maintenance.

Hire local labour when possible, and adopt normal local working hours and rest periods. The project manager should be able to get on with people, but at the same time must be able to make decisions and be just.

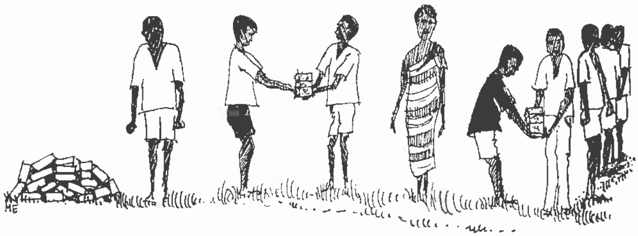
Where there are contractors with their own workers, it might be advantageous to contract for labour, and thus delegate the day to day staff management, salary records, etc. Material must still be purchased and stored, since rural contractors often have no access to transport, warehouses and cash to buy and store materials.

Skilled Labour

All buildings require skilled labourers such as carpenters, masons, plumbers, etc. There is often a shortage of such professionals, especially in rural areas. A period of probation helps assess the knowledge and experience of an individual before hiring.

Any obvious mistakes should be fixed, redone or torn down, or it could be assumed that mistakes are tolerated. If a skilled labourer must be imported from another area, there might be problems related to culture, religion, language, etc.

It is easier to introduce a new building technique at a vocational school or with trainees. Experienced workers prefer to build with tested methods.

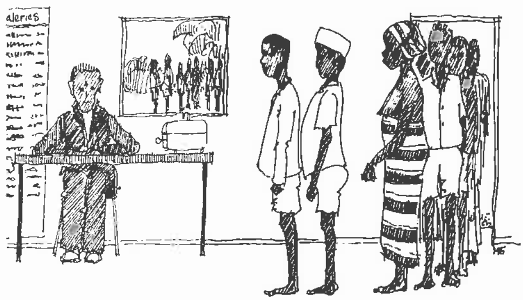


Unskilled Labour

It can be difficult to hire unskilled labourers during planting and harvesting seasons. They might need detailed instructions and regular supervision. Training courses can be useful on larger projects.

Always use as many local labourers as possible to inject money into the local economy. This also makes the local population more positive to the project. In many countries women work with construction, and hiring women helps spread the resources more equally.

Try to organize the work to increase knowledge and competence. Using simple and cheap building materials increases the likelihood that the knowledge will be retained. Take care to inspect all work, and use the occasion to teach. Some buildings can be constructed by apprentices, giving them training for future employment.



Salaries

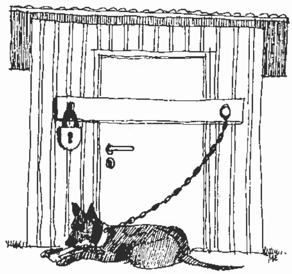
Local salaries are not normally a large part of the project cost. There is no great saving in keeping salaries low, but one should be careful not to push up the salaries levels. It can create problems if workers temporarily earn a higher income than they can maintain when the project is over. A good compromise is to pay just a little more the local salary scale.

Of course, one should observe any official minimum wage laws. Check also if there are any employer's taxes, and if any tax should be withheld from salaries. Sometimes the employer is responsible for health care, and it could be wise to take insurance for this. If there are trade unions, find out how they could affect the project.

The period of employment and period for notice should be stated in the employment contract, even if not required by law. Notice should always be given in writing in good time before the job ends.

Prompt payment of salaries is important for workers whose families depend on their salaries. Incorrect payments or delays reduce workers' confidence in the employer. By producing an official salary list for different categories of workers, one can avoid misunderstanding and discord on the site.

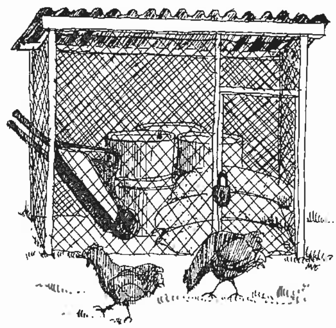
A basic salary with a small performance bonus can be a way to increase motivation and assure that the work is well done.



Stores and Equipment

Every site needs stores: a temporary shed or one of the buildings in the project, to hold stores of building materials, tools and machinery. The stores should be burglar resistant and dry, and it might be necessary to have a permanent guard.

Often the employer provides machinery and equipment, while skilled labourers have their own tools. This means that the tools last much longer, and do not get left around or lost.



Purchasing and Payments

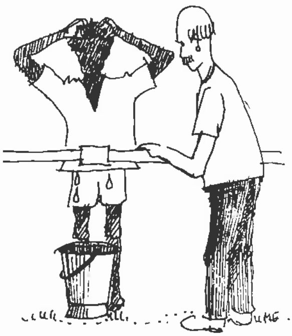
Materials and money must be available as specified in the project time schedule, which requires making a schedule for local and foreign purchases and payments.

It is important to have established routines for purchase, delivery and registration of inventory so that responsibilities are clear. Lack of materials, because of poor planning of purchasing, is a common cause of delays.

A delivery note should be completed whenever material arrive. All materials on a truck are the responsibility of the driver until the head of stores has inspected the unloading and signed the receipt. Registering all the materials makes it easier to allocate costs to different accounts and discover if anything disappears. Continuous inventory makes it also possible to keep control of deliveries and consumption if there is a change in staff.

Accounting

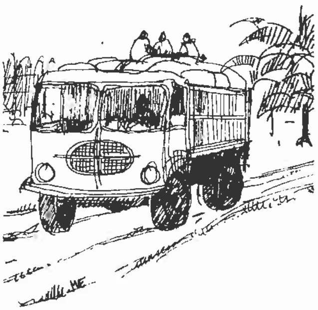
Every building project should have a separate account. A detailed budget and careful bookkeeping are the economic bases for the project, The sub-accounts in the books should follow the headings in the budget, to make it possible to get a quick review of the financial status of the project. The books should be compared to the budget at least once a month. No payments may be made without a receipt.



Inspection

There are two types of building inspection: one by authorities and one by the client. The main purpose of the official inspection is to see that the building was constructed as specified in the building permit and according to applicable regulations. The authorities check that the building is safe: that is structurally stable and safe in case of fire.

The client's inspection checks that the building was constructed as agreed in the contract. This is normally done by an independent inspector. In some countries there are special offices that carry out these inspections, and it could wise to hire on these for larger or unusual projects. Sometimes it could be a requirement that an authorized inspection office is used for the contractor's guarantee to be valid.



Transport

Transport costs in developing countries are relatively high, but good planning can lower costs and make deliveries more reliable. Many sites stand still because of transport delays. It could be worth it for the project to have its own trucks, if one chooses vehicles that are common in the country and there are good local supplies of spares. There might be local transport companies that can be hired.

Roads are often impassable during rain periods. Many roads and bridges will not support heavy trucks. Loads on railways and roads vary greatly over the year, and during the harvest season all vehicles might be full from the countryside into town, and empty on the way back. Ask for local advice on transport.

Tamerza – a Case from Tunisia

A youth centre was built in Tamerza during 1992. It was designed and built by ASDEAR and SADEL. SIDA (Swedish International Development Authority) provided 80% of the financing. ASDEAR (Association pour le Developpement et l'Animation Rurale) is a Tunisian NGO for rural development. SADEL (Swedish Association for Development of Low-cost Housing) is a Swedish NGO that has previously run a self-construction housing project with ASDEAR.

This short description of the building process of the youth centre illustrates what is written in this chapter. Tamerza is a municipality in southern Tunisia, and a village with the same name is a little mountain oasis whose population supports itself by agriculture, trade and tourism.

Preliminary Study

Municipal officials in Tamerza contacted ASDEAR, who worked with an agricultural project in the region, and asked for help in constructing a building for public welfare. If a municipality can put up such a building, the national government guarantees the running costs for staff and maintenance. Since Tamerza is a little municipality with a very limited budget, they investigated different ways to expand services and raise the attractiveness and status of the village.

During a discussion in Tamerza in June, 1989, between municipal officials, ASDEAR and SADEL, it

was decided that the first priority was for a youth centre. It is especially important to provide activities for youth in Tamerza, since the community is isolated and communications with larger cities is so poor. There was already a temporary youth centre in a derelict house adjacent to the village health centre.

It was clear that a new youth centre was needed. Many youth visited the existing youth centre where there was staff and some equipment. But it was dangerous to be in the building since the roof was about to fall in. The location next to the health centre was not suitable, since the youth disturbed the patients and were forced to limit their activities.

It was decided that SADEL/ASDEAR would develop a project in consultation with municipal officials, youth centre staff, and the regional authority in charge of youth centres.

Building Programme

SADEL took responsibility for developing the building programme. The first task was to describe the future activities in the building. The youth centre staff were interviewed and the activities at the centre were observed during four visits. Other youth centres were visited. They were all built according to standard drawings supplied by the Ministry for Youth and Sport. The plot was discussed with the municipality and the architect responsible for regional planning. It was decided that the youth centre should be placed outskirts of Tamerza next to the existing soccar field and a new gymnasium school. A youth hostel is also planned in the area. A simple room programme was developed from this information. See below.

To estimate construction costs, local contractors and the regional authority for construction and inspection of public buildings were contacted. It was also important to assess the experience and technical competence of local contractors. There were also large contractors from other parts of Tunisia building tourist hotels in the region.

Opening hours

Monday	Closed
Tuesday–Saturday	9–12, 14–18
Sunday	9–12

Room	**Area (m²)**	**Activity**
Office	14	Director + 2 assistants
Store	7	Equipment, games, etc.
Library	80	Office space for librarian, shelves, reading places, 2 computers, chess, etc.
Activity hall	145	Entry hall, games, cafeteria, table tennis, video, etc.
Toilets, wash area	17	Men and women
Total area	*270*	

Ball games on existing field
Some activities with the planned youth hostel

Staff

Director	1 person
Librarian	1 person
Assistants	2 persons
Watchman	1 person

The running of the centre was discussed with the responsible regional authority and the county governor. Counties are much more important than the municipalities in Tunisia, so it was important to get approval at that level. The governor issued the official certificate required by development aid agencies providing financial support.

In January 1990, SADEL applied to SIDA's Division for Cooperation with NGOs for a grant to meet 80% of the costs for design and construction. The request was granted in June. In the application, the project was described briefly as follows.

Inventory: A baseline survey of the local climate, availability of building materials, traditional and modern building methods, design and use of existing youth centres in the region.

Programme: Starting with the standard programme for youth centres in Tunisia, adapt it to local conditions in consultation with the municipality.

Design: The design will be based on the inventory, the local programme and Hans Rosenlund's research in Algeria on building in a warm, dry climate. The design stage will include preparing complete contract documents.

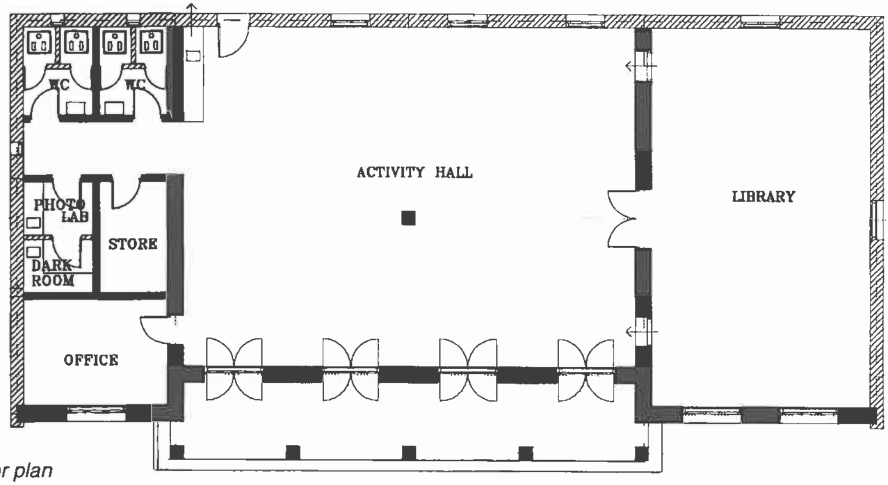
Construction: Local contractors will be used. ASDEAR will be responsible for tendering and supervision of construction. After the final inspection, the building will be transferred to the municipality (Tamerza) for use. Instruments will be installed to record temperature and humidity over one year.

Evaluation: The indoor climate achieved will be evaluated in a comparative study. General recommendations will be made for the design of buildings with reference to orientation, building materials, window areas, thermal insulation, etc.

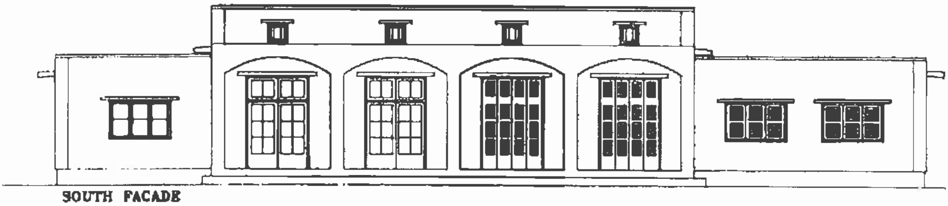
ASDEAR is responsible for construction, and SADEL is responsible for everything else.

Preliminary Design

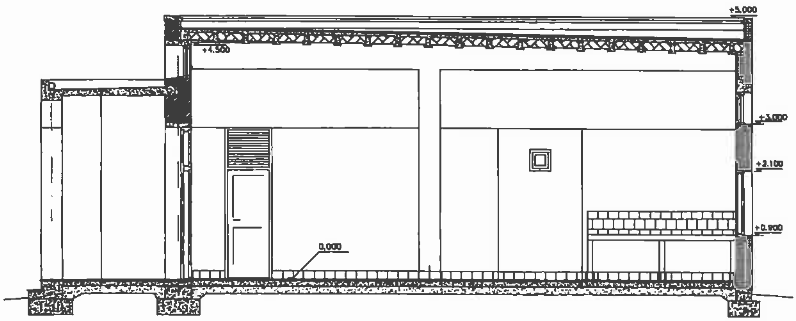
Hans Rosenlund, an architect, designed the building in consultation with other SADEL members. The main aim was "to design and build a youth centre with a



Floor plan



Facade



Section

comfortable year-round indoor climate. It is hoped that the lessons from the youth centre will lead to improve the dwellings in the region, by making them better adapted to the climate."

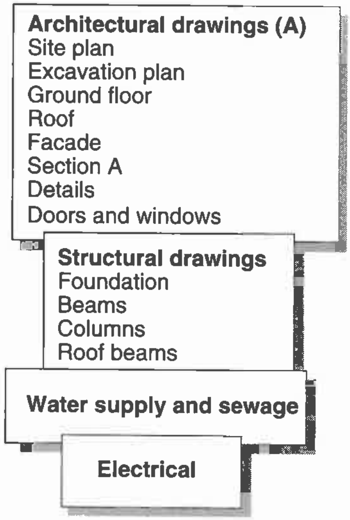
This required detailed climate data from the site and good knowledge of the building materials to be used, in particular their thermal insulation and storage capacities. Different solutions were tested by computer simulations; orientation of the building, room arrangements, ceiling heights, window areas and building materials were some of the parameters considered.

From this comprehensive study emerged a proposal for a building that was optimal in terms of climate: that is, relatively low indoor temperatures during the summer and as warm temperatures as possible during the winter without using any extra energy for cooling or heating. And the building should also be functional, attractive, appropriate for its surroundings and not too extreme. The proposal was discussed during the whole process with different actors in Tunisia, both during visits and by telefax.

The Municipality of Tamerza and other involved approved the proposal in January 1991, and work with contract documents could begin. A simple model was made to visualize the building, and this was a great help during the discussions. Most were very positive to the new design, but some questioned the large glass-paned doors. The computer simulations were a great help in showing the benefits of these windows for the indoor temperature in the winter.

Contract Documents

There were high requirements for these documents. Mainly local building materials would be used, but requiring a technique that was new to local contractors. The roof would contain imported woodwool slabs, probably for the first time in Tunisia. The reason for using woodwool slabs was that there was a joint project by Lund University and the CNERIB (Algerian National Centre for Building Research and Studies) to develop local production of woodwool slabs in North Africa. The local contractors were skilful, but had limited technical training. The contract documents were to be prepared in Sweden, and there was very limited possibility for consultation between the contractor and the designers. It was thus very important that the documents were complete, clear and easy to read.



The documents were drafted by Hans Rosenlund; Erik Johansson, a structural engineer; and Lars-Anders Hermansson, a civil engineer with over 30 years of professional experience in Tunisia. His experience was invaluable in producing the documents in French and in a form that was acceptable to the contractor and the authorities.

The contract documents included 22 drawings in A1 format (594x840 mm) and a description. The description included the rules for the validity and scope of the tenders; administrative regulations for the division of responsibility among client, contractor and authorities; work specifications; unit prices which also served as the basis for the coming work, schedule and cost estimates.

It took about six months to produce the documents. If the work had been done full-time, and not on a voluntary basis, the time could probably have been cut by a half. Note however that the design stage takes time to do well.

When all the contract documents were ready, they were given to a Tunisian inspection bureau for review. Insurance companies in Tunisia require approval of the documents by an authorized inspector, in order to purchase insurance for construction and the guarantee period, which extends five years after the final inspection.

Construction

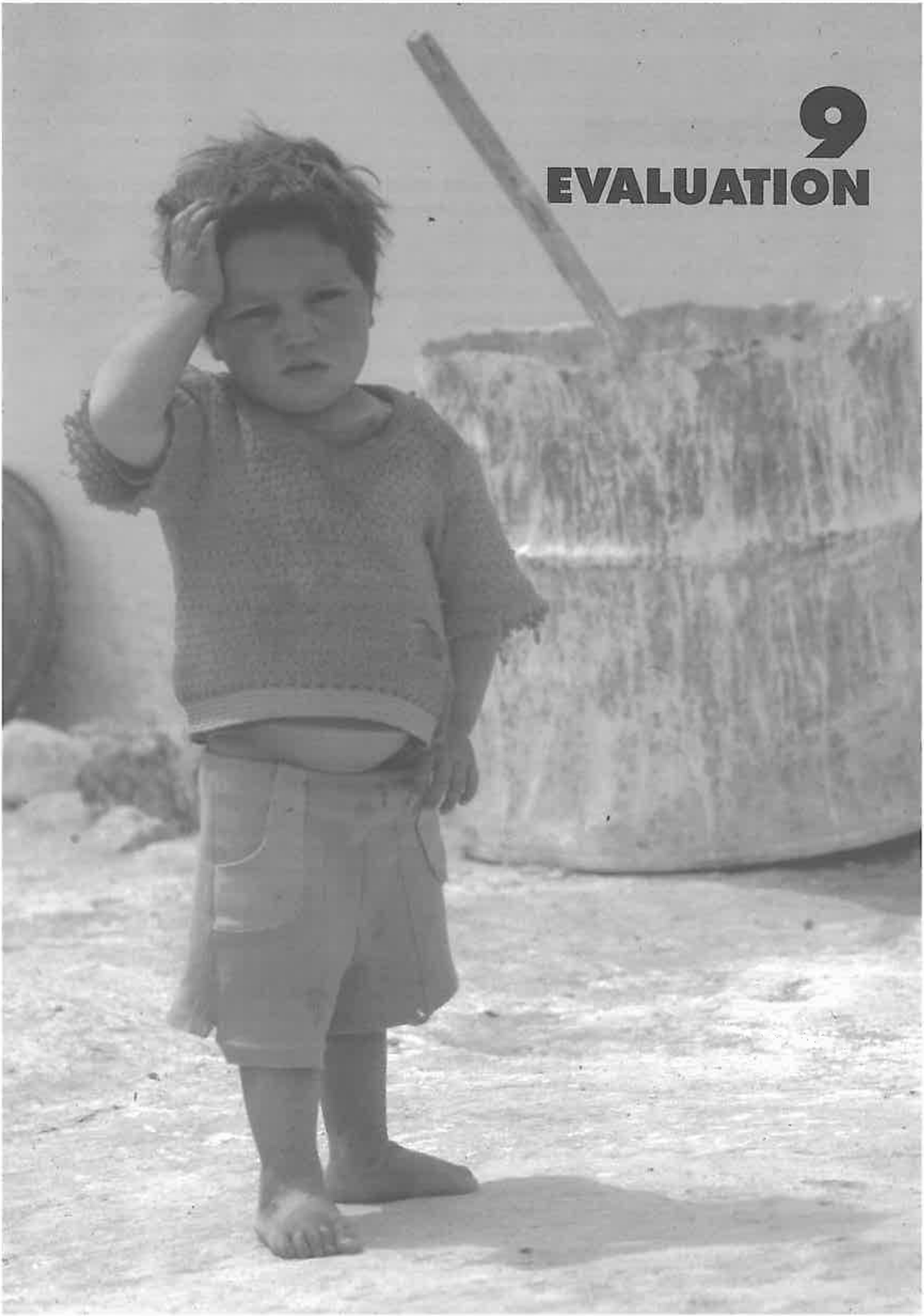
Contract documents were given to five local contractors. The tender period was one month, and the offers were to be valid for two months, which is normal practice in Tunisia. Three contractors submitted offers. The contractor with the lowest price was eliminated because the offer was incomplete and was judged to be uncertain. Instead the next lowest bid was accepted.

The contract was awarded immediately after the tender assessment according to the guidelines in the contract documents and construction began 15 August, 1991. The same inspection bureau that reviewed the contract documents was appointed to inspect the construction on behalf of the client ASDEAR. The inspection is required for the insurance to be valid during the guarantee period, and is the client's way of seeing that the contractor executes the work according to the project documents.

Construction went surprisingly smoothly, considering that some technical solutions were unfamiliar and that woodwool slabs were used, a material new to the contractor. Construction went so well because that the contractor was competent, well organized and very responsible, and that the contract documents were well developed and highly detailed. Other contributing factors were that ASDEAR's representative in Tamerza followed the day to day work, and SADEL members visited the project several times during the period of construction.

The building was ready on 15 May 1992, and there were no significant remarks in the final inspection. Construction time was nine months, a slight overrun of the schedule, but this was caused by delays in deliveries of building materials and waiting for the building inspector, and not the fault of the contractor.

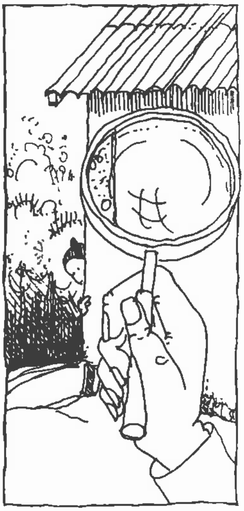
9 EVALUATION



Evaluation

Construction is a significant part of development and external aid in developing countries, so it is important to learn from experience, both to avoid repeating mistakes and to adopt successful solutions in new projects. A basic requirement for this is that everyone working with construction in developing countries tries to evaluate or follow up his or her own building projects, and then shares the findings with the organizations involved, fellow professionals and co-workers.

Evaluation: Feedback of Experience



Evaluation should be something positive, a way to learn from experience and become better prepared for the next job. Unfortunately evaluation has become a loaded term with a negative undertone, creating a feeling of uneasiness and insecurity, perhaps also a degree of anxiety, especially if one's own work is to be evaluated. Evaluation is often misunderstood as only a check of the completed job with the assignment of a grade; all too rarely is it correctly understood as a means to learn, to gain information that can help reach even better results in the future.

Although there is much construction financed by development aid, very rarely are the buildings themselves evaluated. Evaluation is **not only** a matter of objectively measuring and checking the result against the goals stated; it is also a question of valuing and assessing the result. Personal assessment and impressions perhaps play a more important role that previously thought.

The evaluation of a building is, in principle, to see if a building was constructed according to plans, if the budget was followed and resources correctly used, if the technical solutions were good and the correct materials chosen, etc. But evaluation should not be just to measure and check; it should include an analysis of the whole programme, where the building is one component. It can be worthwhile to assess the strengths and weaknesses of the whole project, and to talk to the people involved about what they think about the building from their perspectives, how it functions and how serves its intended purpose.

Common sense and some experience of construction in developing countries go a long way in evaluation. The following list of questions might also help.

Evaluation - For Whom?

Evaluation can be more or less thorough, and it up to each person to decide what should be done and how much time and money it can cost. It is important to begin to think through the following questions well ahead of time:

> "A well frased question is half the answer."

- **Why should the building be evaluated just now?**
- **What is the aim of the evaluation and how will the findings be used?**
- **For whom is the evaluation done?**
- **What questions should be answered? Decide the scope.**
- **How should the evaluation be conducted?**
- **Who should do it? One person or several?**
- **How long may it take? When should it be ready?**
- **How much can it cost?**
- **How should the findings be presented and spread to interested parties?**

A carefully considered plan for the evaluation makes the work easier, and is a requirement for a valid and useful result.

Internal and External Evaluation

Evaluation can be done internally in cooperation with local staff and residents or externally by hiring an independent consultant.

The advantage of internal evaluation is that the evaluators are already familiar with the project: the environment, culture and background. The evaluators normally share the values of the organization and are known in the project area, which helps avoid the unnecessary drama that arises when strange faces appear.

Internal evaluations involve the people in the organization who will have the immediate responsibility to follow up the recommendations and suggestions. What is learned from the evaluation remains within the organization, which can use the experience and new knowledge in the future. Finally, an internal evaluation is usually much cheaper than an external.

The advantage of an external evaluation is that there is usually greater objectivity. The evaluators might have more technical knowledge and/or a broader view of the development issues in the sector and see the activities from another perspective. Recommendations and assessments from outsiders often have greater weight and impact, especially for donors and authorities. Another advantage of external evaluators is that they can be relatively neutral about project staff and other interested parties, which is especially valuable if the project has serious internal problems causing conflicts between parties.

In conclusion one can say that internal and external evaluations are not exclusive; on the contrary, a combination may often be appropriate.

When Should Evaluation be Done?

Evaluation should not be a single event at the end of the project; it should rather be an integral part of it.

Ideally, it should already be clear during planning how evaluation will be conducted, what it should cover and when it should be done.

Construction projects are normally evaluated after the building is finished. Evaluation thus mainly looks back at what was done to collect experiences that could be useful for future construction.

Sometimes it is appropriate to evaluate a building several years after it is built. What does it look like 5, 10, perhaps 20 years later? Is it used as originally intended? What could have been done better? Unfortunately this type of evaluation is extremely rare, although it could certainly give very valuable and interesting information.

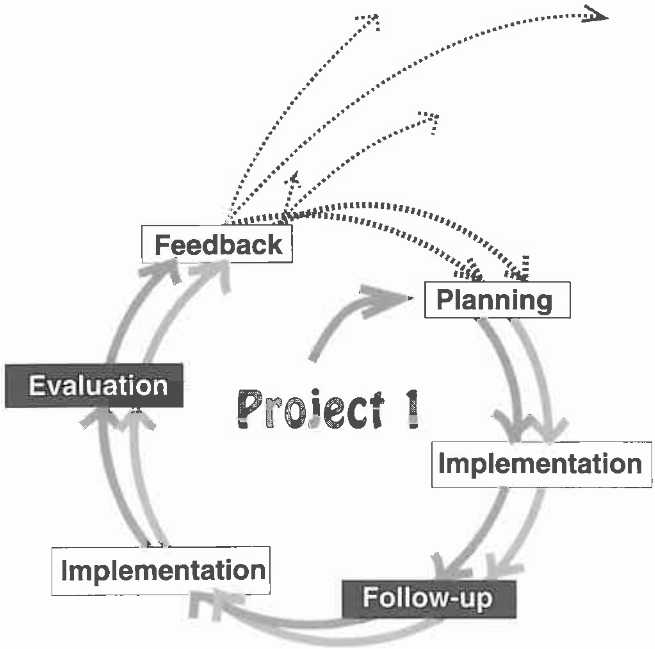
Evaluation provides a different way of learning, from both current construction and finished projects, which gives a good basis for planning future activities. Evaluation is thus something positive and valuable that should be done more often.

The Purpose of Evaluation

The purpose of the evaluation process can be summarized as follows. Some of the points must be adapted to building projects, but they are still relevant if the local community, both professionals and users, are included in the evaluation.

Opportunity to express oneself

Try to create an atmosphere where people can express themselves clearly. Allow participants to reflect on their values as well as on their aims without forgetting to look at results and the means of action.



Evaluation is part of a process wich includes: planning, implementation, follow-up, evaluation and feedback. Evaluation gives new insights, experiences and knowledge wich can be used in other ***similar projects*** *(feedback). It might also leed to changes and improvements in* ***ongoing projects****.*

Information

The evaluation process takes shape when each person discovers what the others have observed, measured and analyzed. Information involves both the recording of facts and their transfer. Different approaches may be to be used when interacting with illiterate persons, people with some schooling, and professionals – all have valuable information.

Measurement of Results

Try to be clear on the objectives that should be considered and what instruments should be used for measuring achievements, quality, etc. Usually the degree of achievement is measured with reference to the aims stated in the project description. What do the users feel about the aims? Measurement of quality is difficult; it depends on how the evaluators conceive the reality they are observing, and is a reflection of their values.

Analysis of Results

The analysis of results is also an opportunity to express judgements. Each team member will probably have slightly different judgements to make. The evaluators, after comparing their different views, will have to agree on a common statement, or leave the responsibility to the team leader.

Looking to the Future

It is hoped that the evaluation process will improve the understanding of the evaluators' situation as well as the situation of all others involved in the exercise. This attempt at clarity among the participants (partners) will also lead to better understanding and improved relations. Evaluation in a sense is full of expectations – it is a tool for planning future undertakings.

10

HOUSING IN DEVELOPING COUNTRIES

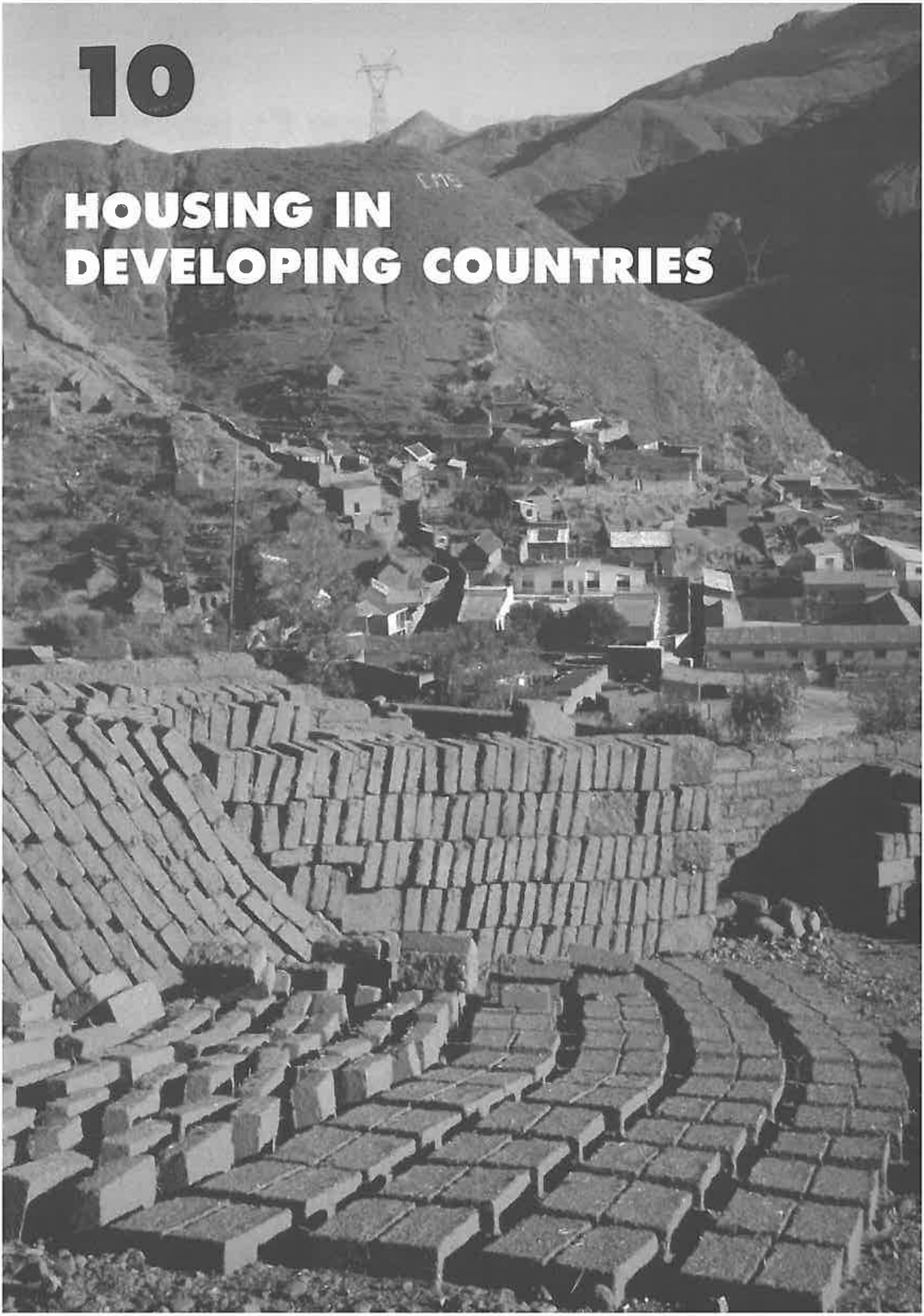


PHOTO PREVIOUS PAGE: KARL-ERIK LUNDGREN

Housing in Developing Countries

Current Status

In 1982 the United Nations General Assembly designated 1987 as *The International Year of Shelter for the Homeless.* The reasons for directing attention to housing included:

- More than one billion people, a quarter of the world's population, either totally lack a dwelling or live in miserable conditions.
- By the year 2010, for the first time in history, there will be more people living in urban than in rural areas.
- Almost 90 percent of the total increase in the urban population is expected in the developing countries.

House in a Nairobi slum

The problems are well known and conjure up images of people living crowded together in collapsing shacks in the slum areas of large cities, without access to drinking water or toilets. The World Health Organization estimates that 18 million people die each year because of inadequate housing. Diarrhea, respiratory infections and other illnesses are easily transmitted where sanitary conditions are poor or there are no special facilities at all. All too common are also refugee camps around the world, where people live long periods in makeshift conditions, facing an uncertain future.

The purpose behind IYSH was not only to provide information about the problems that so many people experience owing to poor housing, but also to show how these problems can be solved. By shedding light on political, economic, social, organizational and technical aspects, it was hoped to create more awareness and commitment to addressing the housing problem among decision makers in governments and state and non-governmental organizations.

In 1988 the UN decided that IYSH 1987 should be followed by a long term programme to support the development of innovative and realistic housing policies, and launched the *Global Strategy for Shelter to the Year 2000* (GSS 2000). The goal is that all people should live in adequate housing by the year 2000, and it can only be reached through cooperation: to use all available resources in the public sector, non-governmental organizations, private companies and individuals. GSS 2000 is based on facilitating and stimulating different initiatives to housing improvement, in contrast to previous policies than often set up barriers through complicated laws and regulations.

The World Bank has also given more attention to housing, especially in urban areas. One reason is that economic development increasingly occurs in cities, so improving urban housing must also be given priority. It seems less and less realistic to stop urban migration, but instead tolerable conditions must be created for living and working in cities.

Since 1988 SIDA has supported a number of programmes for housing improvement in Latin America. The projects are directed to the poorest urban groups, and are based on the principle of making it easier for people to solve their own housing problems through self-help. By providing credits and social, technical and legal advice, it become possible for families to improve their situation.

SIDA's programme for housing improvement in Costa Rica has been very successful: about 2000 dwellings were built or improved and provided with infrastructure at a relatively low cost. This success is to the credit of FUPROVI (Fundacion Promotora de Vivienda), a non-governmental organization in Costa Rica that very professionally took responsibility for implementing the programme. Some SIDA support went to strengthen the organization, especially improving its competence in planning.

SIDA/FUPROVI's housing project in Costa Rica

The Swedish Mission Council (SMC) also feels that it is urgent to call attention to housing in developing countries. The problem is enormous and it can never be solved by aid alone, but one could possibly help to identify and adapt techniques to make it easier for the homeless to help themselves. The member organizations of SMC have a collected experience of development aid in about 40 countries. Their experience is that housing improvement requires longer term, continuous inputs. Thus it is important to build up knowledge of how to improve housing, which methods are suitable, before taking on practical projects.

One way to gain such knowledge is simply to collect information on housing projects and analysing whether to what extent the project was successful. This analysis could be the basis for recommendations on improving housing.

SMC therefore commissioned SADEL to conduct an inventory of housing projects in developing countries. The conclusions from the study are summarized here. The complete report was published as *11 Successful Housing Projects: An inventory of implemented housing improvements in the Third World*, SMC/SADEL 1990. A successful project is primarily one that:

—resulted in a better living standard for the poorest.
—used methods that were accepted by the local people.
—helped to improve health, sanitation, comfort and the living environment.

The purpose of the study was not to collect information from as many projects as possible, but rather to identify the most interesting projects with the help of different organizations. The choice of projects was based more on the personal experience of those asked than any scientific evaluation.

Learning from Successful Projects

In trying to identify the basic requirements for achieving adequate housing in a country, one can start with the following general issues.

- **Democracy**

The government should promote social development and take overall responsibility for the provision of housing in the country. This means that legislation should be designed to simplify the legal formalities surrounding housing improvement, both private and public. The government should also, as far as possible, make resources available for housing improvements.

- **Organization**

There should be an organization at local level that takes responsibility for the planning of new housing and for installation of infrastructure such as streets, drinking water, sewerage, and so on. Also, as a second priority, the organization should be responsible for financing and constructing new housing.

- **Participation**

It is necessary to exploit the inhabitants' own resources of knowledge and labour. Doing this is a guarantee that the improvements that are carried out correspond with the people's real needs. By optimizing their participation, less aid is needed and more people can be reached.

- **Land**

It is of crucial importance that the people be given legal possession of the plots for their dwellings. This minimum security is necessary if the inhabitants are to become motivated to invest their scarce resources in better housing.

- **Materials and Knowledge**

To achieve permanent housing at reasonable cost, knowledge about building and access to suitable building materials are required. It is particularly important that there be readily available knowledge about how

From a successful project in Nicaragua

best to use local building materials in rational, modern construction.

These points are of course a simplification, and might seem obvious, but it comes up over and over in the projects studied that some of these requirements were not met. When the correct conditions were created by the people, NGOs or governments, housing also improved.

Development Aid and Construction

One might think it is obvious that democracy, organization, participation, land, materials and knowledge are necessary prerequisites for the improvement of housing conditions. But it is not obvious for many decision makers in governments or NGOs who are responsible for housing.

The projects studied by SMC and SADEL in 1988 show that these five basic conditions were necessary for success. The aid consisted of meeting those prerequisites that were lacking for housing improvements to be carried out.

Often the form of the aid was more the transfer of knowledge about organizing, planning, construction, etc. than direct economic support to building houses. Continuous development and transfer of knowledge about housing improvement is probably the most effective means to support improved housing in developing countries.

NGOs have an important role to play here, as an independent transmitter of knowledge to authorities, organizations and individuals. The local ties that many NGOs have are invaluable in such a process. It is also valuable to exploit the possibilities that many NGOs have of collating experiences from many different countries.

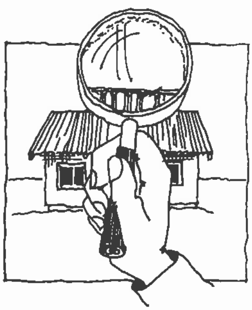
The projects presented here were implemented by the residents themselves, by NGOs or by governments. It might be thought that the ideal form of housing improvement is that which is organized entirely by the residents themselves. This, however, demands a lot of commitment, knowledge, organizational ability and patience. Housing problems in developing countries are so extensive that there is no single solution. One must explore all possibilities through housing cooperatives, NGOs and governments. The projects also show that different organizational forms are appropriate for different countries and circumstances.

Recommendations

One should be careful not to draw detailed conclusions about which technical solutions are most appropriate for house construction in developing countries. The improvements described in these projects vary greatly between different countries, concerning climate and so on. In addition, economic conditions and access to building materials vary over time.

To formulate general rules of thumb for practical construction work would not only be difficult but also hazardous for those in the field. The risk is that if one has too much faith in such recommendations, or if a situation arises where they are inadequate or wrong, this could lead to negative consequences.

On the other hand, one can probably draw quite far reaching conclusions concerning the appropriate method to use when carrying out housing improvements. There is a distinct recurring pattern of how housing problems have been tackled: it recurs from project to project, no matter how different they are. What follows is an attempt to describe this pattern, which should be useful to consider in future housing projects.



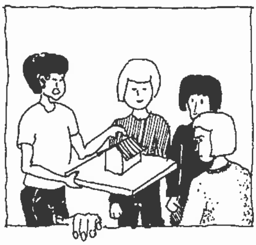
Make Thorough Feasibility Studies

In all projects a thorough feasibility study was carried out to identify the local conditions. The studies emphasized social, economic or technical questions, depending on the aims of the project. In those cases where a long time was spent on feasibility studies, it was possible to achieve effective improvements at low cost and to develop the project quickly.

Self-built house in Tunisia

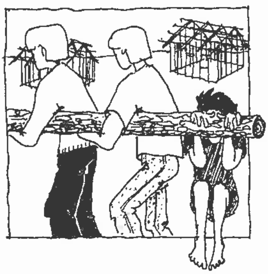
Find Out What the Residents Want

In connection with a feasibility study, the residents should be asked what improvements they want, their order of priorities, and what resources they are prepared to contribute. There are many example of projects where the wishes of the residents were taken for granted, and inappropriate interventions made.



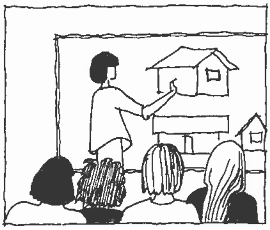
Give Clear Information

It is important to provide continuous information about what will happen so that the residents are not taken by surprise, which leads to feelings of insecurity and scepticism about the project. It can also be important to provide information for an educational purpose. In a project where stabilized earth blocks were introduced as a building material, information was given for a double purpose: to show the material's economic advantage and to overcome suspicions about using earth for construction.



Optimize Participation by the Residents

It is important that costs for improving housing are in reasonable proportion to the householders' incomes. In Papua New Guinea the government realized that the housing programme for construction of standard housing was too expensive. It could not afford to build dwellings for more than a small part of those who needed them. Legislation was therefore changed to give people a larger role in carrying out the improvements. The government made loans available for the purchase of building materials, offered technical advice and provided infrastructure. In this way participation of people in construction could be optimized.

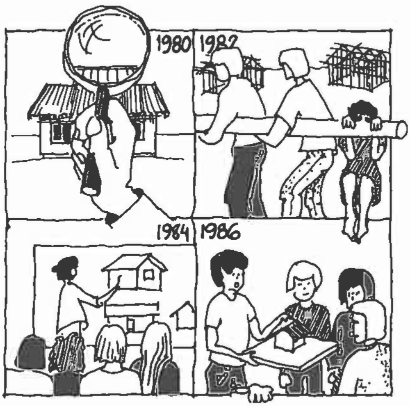


Develop and Disseminate Knowledge

In connection with the introduction of new methods, it is important to train those who will be responsible for the work, so that they can apply the new methods. This was the case in projects implemented in Chile, Colombia, Tanzania and the Mayotte Islands, where there were instructors to advise the self-builders. These instructors were also important sensors who assessed how the building methods were accepted by the people and how they functioned technically. This allowed a continuous improvement of the methods.

Guarantee Security of Tenure

Once the residents receive legal rights to their property, they normally invest in extensive housing improvement. This often happens without loans or subsidies, and even among the poorest. Ownership may not always be the best way to guarantee security of tenure. In some situations it might on the contrary lead to speculation, which favours the rich at the expense of the poor. In such cases it would probably be better to have leasehold contracts that are difficult to transfer.



Assure Continuity

Several of the projects studied were over ten years old and still developing. It shows that housing improvements projects are seldom short-term interventions, but rather need to stretch over a longer period of time. It is important that organizations dealing with housing improvements are able to work continuously over long periods, partly to enable them to further develop different methods and solutions, but also to follow up the maintenance of the new housing. This is particularly important when new methods or materials that were not previously known to the residents are introduced.

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Conversion Factors

1 mile = 1.609 kilometres (km)= 1760 yards (yd)= 5 280 feet (ft)
1 yd = 3 ft = 0.914 metres (m)
1 ft = 12 inches (in) = 30.5 centimetres (cm)
1 in = 2.54 cm
1 km = 0.6214 mile
1 m = 3.28 ft
1 cm = 0.394 in

Areas:

1 square mile (sq mile) = 640 acres = 2.59 square km (km^2)
1 acre = 4 047 m^2
1 sq yd (yd^2) = 9 sq ft = 0.836 m^2
1 sq ft (ft^2) = 144 sq in (in^2) = 929 cm^2 = 0.0929 m^2
1 sq in (in^2) = 6.45 cm^2
1 km^2 = 0.386 sq miles
1 hectare (ha) = 2.47 acres
1 acre = 4 840 yd^2

Volumes:

1 cubic (cu) yd (yd^3) = 27 cu ft = 0.764 m^3
1 cu ft (ft^3) = 1.728 cu in (in^3) = 0.028 m^3
1 in^3 = 16.39 cm^3
1 stere (s) =1 m^3 = 1.308 yd^3 = 35.315 ft^3
1 m^3 = 35.28 cu ft
1 gallon = 4 quarts (qt)= USA 3.785 litres (l), UK 4.545 l
1 qt = 2 pints (pt)= USA 0.946 l, UK 1.136 l
1 pt = 2 gills = USA 0.473 l, UK 0.568 l
1 UK gallon = 1.2 USA gallons
1 litre = USA 2.114 pt = 0.264 gallons
1 liter = UK 1.76 pt = 0.22 gallons

Weight:

1 tonne = 1 000 kilograms (kg) = 2 200 pounds (lb)
1 long ton (UK) = 1 016 kg = 2 240 lb
1 short ton (USA) = 907.2 kg = 2 000 lb
1 lb = 16 ounces (oz) = 0.4536 kg
1 oz = 16 drams = 28.35 grams (g)
1 dram = 1.771 g
1 kg = 2.205 lb
1 g = 0.035 oz

Flow:

1 litre/second = 16 USA gallons/minute
= 13 UK gallons/minute
= 22 800 USA gallons/day
= 19 000 UK gallons/day
= 86.4 m^3/day

The original book was based on the experience of 235 Swedish builders who had worked in developing countries. This English edition has been extensively revised by the Swedish Association for Development of Low-cost Housing (SADEL) and the Swedish Mission Council.

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