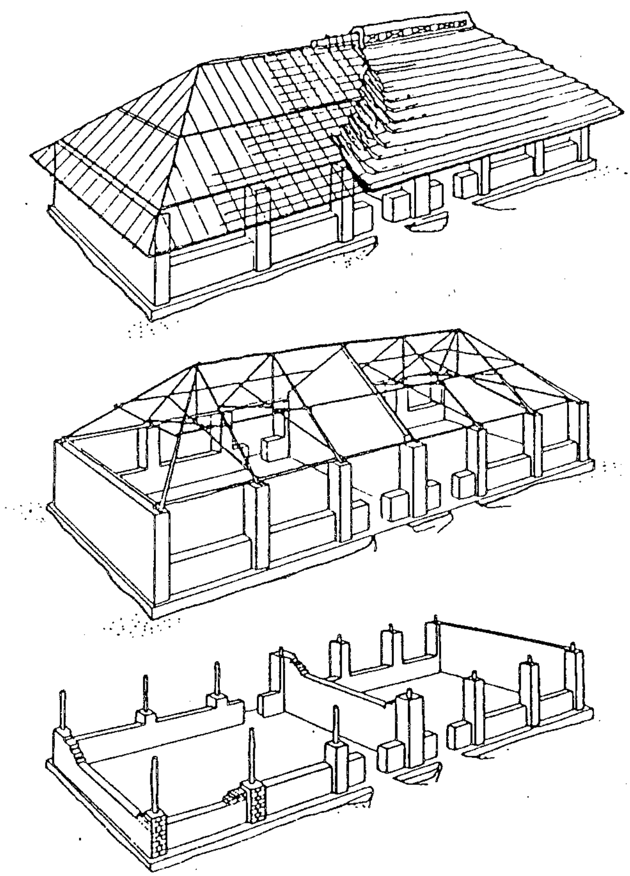
MANUAL FOR CONSTRUCTING A COMMUNITY BUILDING

PREPARED FOR USE
IN SOUTHERN SUDAN



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Development Workshop

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THE MANUAL

PAGE 1.	IDENTIFY A NEED
PAGE 17.	THE SITE
PAGE 31.	SKETCH DESIGN
PAGE 79.	DETAIL DESIGN
PAGE 101.	ORGANISATION
PAGE 113.	CONSTRUCTION

IDENTIFY A NEED

CONTENTS

PAGE 5. INTRODUCTION

PAGE 8. COMMUNITY MEETING

PAGE 12. PLAN OF ACTION

PAGE 15. DESIGN BRIEF

This manual deals with the process of constructing community buildings. Community buildings include all the buildings within a community which are for public use by people living in the community. The most common of these buildings are schools, health clinics, meeting places and market places. Constructing these buildings is part of community development. Community development means improving the standard of living within the community. Importance is placed on the effort of the people in the community to help improve conditions themselves, but there may also be help from the Government and the aid agencies.

Community development begins by finding out about community problems and by working with the people to solve them. The ideas, needs and resources of the people are what make community development happen. Your role, perhaps as a 'community development officer' or as someone working in a government department or for an agency, is to help the people in the community to plan how to solve their problems. Remember that you are not there to solve problems for the community, but to help people learn how to solve their problems themselves.

Community development work begins with discussions. If you are new in a community you should meet with the community leaders, with other government workers and agency people. You should explain to these people that you are there to find out about community problems and to work with the community to solve them. This also means cooperating with the other people working in the community. It is very important that these people understand and agree with what you are doing. Unless you do this there is a danger that different organisations will try to do things in different ways, and the people of the community will get confused and lose interest.

After discussing with community leaders, and the other people working in the community, you must now talk to as many people as possible in the community in order to understand their problems. Keep a note book and write down everything you find out. You are like a doctor, and the community is your patient. You need to understand what problems the people are facing. Talk to people in their homes, under the shade of trees, in tea shops and drinking places, or anywhere they meet.

Always bear in mind that it is the people in the community who must decide what is needed, and tell you. You must not try and tell them what <u>you</u> think they need. This happens very often, and results in many cases in projects being done which do not relate to the needs of the community, and which are therefore a waste of effort and money.

QUESTIONNAIRE

To make the process of finding out what people think are the problems, you can work out a questionnaire, which you can fill in when you talk to someone. For each person you talk to, write down the following information about them:-

Name:
Sex:
Age:
Occupation:

and ask:-

What are the major problems facing the community?

Which problems are the most urgent?

What has the community, or you, done to try and solve each problem.

For each problem, ask:-

How can this problem be solved?

Can you solve this problem yourselves?

If the answer to the above question is 'no', ask why?

Is there any organisation or department already trying to solve this problem?

Don't make assumptions about the answers. If someone tells you that health is a problem, don't simply assume that the answer to the problem is to build a clinic, or vaccinate all the babies.

Ask the person you are talking to what the solution is. In one case, where 'health' was given as a problem, the solution that was suggested was to open up the roads in the area, so that taxis could reach sick people and take them to hospital. Solutions are not always what one might expect.

When you carry out a questionnaire, make sure that you talk to as many women as men. Also make sure that you talk to young people, middle-aged people, and old people. They will have different ideas about what is needed. Young people who do not have children yet may not think education a priority, but they may think that jobs are. Women who carry water may think that a better water supply is important. Remember that each person's opinion is valuable.

To get a good idea of what the problems are, you need to talk to a lot of people: in a large community of several thousand families, you should try to talk to at least ten households in every hundred. The more people you talk to the more accurate the result of your survey will be.

Once you have an idea about some of the problems in the community, you should plan a community meeting. This should be organised with the help of the community leaders and any other community organisations. Plan the meeting with these people, and ask them to set the date for the meeting, and to announce that the meeting will be to discuss community problems and how they can be solved. Do not make the mistake of promising solutions that you cannot give, or of stating anything which you are not sure of.

When you have planned the meeting with the community leaders, you all need to decide on a way of announcing the meeting. This can be done at the regularly used meeting places, such as religious gatherings, and by going round to people's houses.Another possiblity is to use a loudspeaker car to make an announcement. Whatever method you choose, and you may decide to use two or three ways of informing people, make sure that the announcement does not suggest any commitment to solve problems, since this may not in the end be possible.

You also need to make sure that as many people as possible are asked to attend the meeting. For example, it is not enough to ask only the Parents Association to discuss the question of a new primary school: schools affect everyone in the community and everyone should be asked to attend. If you are planning to discuss the problem of water, women must be invited to participate in the discussion, as well as men. In the same way, men should be asked to attend meetings concerned with women's problems, such as maternity and child care. Not doing this can cause problems afterwards about which sort of project should have priority.

To make the discussion with the community more productive, before the meeting find out the following:-

- what official plans already exist for services in the community?
- what action has been taken for establishing services in the community? Who has taken any action?
- what government regulations relating to services are there that you need to consider? For example, if you are planning to discuss a proposed new primary school, does the Area Council Inspector of Education need to give his approval for a new school? Or, if you are planning to discuss water, is the Directorate of Rural Water Development at the Area Council level aware of your plans, and should you invite them to the meeting, since they may be able to give technical advice?
- who needs to give official approvals or permits? You need to know the name of the people who give approvals. Talk to them before meeting the community so that they can help you and guide you. If they know what you are doing from the beginning it can save you problems later.
- what are the aid agencies and non-government organisations, such as religious groups, thinking of doing in this community, and what have they done already?

Knowing the answers to these questions before you meet the community may allow you to answer some of the questions raised by the meeting. For example, it will help if you can tell the meeting that the government are starting to dig wells in the neighbourhood in a few weeks time, or that there is already permission for new markets and that all the community needs to do is apply for individual shop and stall permits.

When people gather for a community meeting it is the custom to introduce the speakers and to explain briefly the purpose of the meeting. This should be done by a community leader. Each person who has been introduced will then be asked to speak. You should be given an opportunity to explain what you have found out so far from the officials, and what you have found in your survey. Do this so that everybody knows what you have been doing.

Now, let the people who have come to the meeting make their own statements and ask questions. Be ready for comments such as:-

> "There have been plenty of promises but never any action."

and expect people to get quite annoyed, even with you, as if it is your fault that nothing has ever been done!

Do not try and change people's opinions, but instead do try and find out why they have strong opinions. Find out what the community has done so far to solve their problems. If you think that you know this already from the survey, don't be suprised if you now hear some different story of what has been done!

Be very careful at this stage not to make any promises about action which you won't be able fulfill later. Do not promise that assistance from either the government or the agencies will be available, and do not encourage the people to make large demands from the government and the agencies, whose resources are also limited. Try to get the people to think in terms of small, practical projects that can be finished without great difficulty.

Find out what the people are able to contribute towards solving their problems. Contributions may include such things as labour, materials, food for workers, tools, skills and money.

Before the meeting finishes, get everyone to choose members for a committee who will be in charge of organising future meetings, taking care of any money that is collected, gathering contributions and organising labour. This committee will represent the community. The newly elected committee members should now summarise the results of the meeting, to pick out which problems have been talked about. The meeting should be closed with a statement that there will be another meeting soon to outline a plan of action for solving some of the problems.

The new committee is responsible for community development. You now need to discuss which of the problems have priority, what can be realistically done to solve these problems, and from this, develop a plan of action.

For each proposed project you need to work out the following:-

- a programme for the coming months which sets out what will be done to solve the problem.

- a clear list of who is responsible for doing each part of the project.

- what government departments and agencies will be approached for assistance. Who is going make the approach or write the necessary letters, and when it should be done.

- what community contributions will have to be made by each household. This includes working out how many men and women will need to work on the project; how much money needs to be contributed; how many women will need to cook food for project workers, and so on.

As soon as possible, the community development committee should call another community meeting and present the ideas and the plan of action to the community. This gives people an opportunity to make comments and changes. The people have to be made aware of what is going to be expected of them, and when. If they agree, you can now begin to work out the scale of projects that are going to be done. There is no point in planning a large project if it is obvious that the community will not make a large contribution. Plan to work within the limits of the resources available.

You will need to encourage and remind people to make contributions. They will do this better if you show that you are very ready to work practically with the people. You must be a leader by demonstrating through your own action.

The plan of action at this stage will deal with as many of the community problems as possible. For example, in the community meetings it has become clear that there are several major problems in the community, such as:-

- not enough water supply
- poor sanitation
- many sick children
- no primary school classrooms
- nowhere to buy food
- no roads going into the community

The plan of action outlines the way that the community can try to overcome these problems. For example, at the second community meeting the community development committee might present the following ideas in response to the problems:-

Problem		Action proposal
water supply	:	request government for training in shallow well digging and maintenance.
sanitation	:	ask agencies for technical assistance and some materials so that ventilated pit latrines can be built on house plots.
sick children	:	arrange with department of health for child vaccination programme in community.
no classrooms	:	build self help primary school.
no shops	:	apply to the Chief Executive Officer of the Area Council for permits to open market stalls.
no roads	:	work with Survey department to mark where roads should go, and then get the community to clear the roadways and fill in major ditches and holes.

Remember that there are many different ways of solving the problems of a community. Some may require bringing in people to the community who have the right skill, such as getting teachers. To solve some problems may require training, so that the community can deal with the problem itself. Other problems require treatment, such as arranging an immunization and oral rehydration programme for babies and small children.

In some cases it will be necessary to construct a building. A community may need a classroom to improve education, or a clinic so that proper health care can be provided.

When it is decided that a new building is needed, do not forget that in most cases you need more than just a building. For example, a school without a teacher is no good, nor is a clinic without health workers and basic medicine going to be of much help. Make sure that the people and equipment you will need are available, in order that the building can function. Remember that a building is a shelter in which an activity or a function can take place.

Once the decision has been made to construct a building, you need to find out from the people who are going to work in the building the following:-

- what all the activities are that will take place in the building.

- how many people will use each space in the building. This includes people who might be waiting for treatment in a clinic, or the number of children who will be in a class room.

- at what times of day the building will be used, and also during which times of the year.

- what furniture and equipment there will be in the building, and how much room each item needs.

This information is your design brief. The more detailed the information is, the easier it will be for you to design a building that will suit the required function.

When you have collected as much information as you can, discuss it with the members of the community development committee. When they have agreed on the brief, you can begin work on designing the building. Start by selecting a site.

THE SITE

CONTENTS

PAGE 21. SITE SELECTION

PAGE 24. SITE SURVEY

SITE MEASUREMENT

LEVELS

Steps in Levelling

SOIL TESTING

It is important that you choose a site which suits the purpose you intend to use it for.

1. WORK OUT HOW MUCH LAND YOU NEED.

- decide how big the building is going to be. Make a rough plan with the number and size of rooms: see 'Sketch Design'.

- decide how much land you need in addition to the size of the building: land around the building. You should allow for such things as:
  - future building (expansion).
  - storage.
  - parking and roadways.
  - latrine.
  - water supply and storage.
  - a watchman's shelter or Tukul.

2. CHOOSE A SUITABLE LOCATION.

Some projects should be sited near to a town or village centre, whilst others, because of their function, should be far away from a crowded centre. A school should not be far away from where the children live; a clinic should be near to the people it is supposed to serve. But a saw mill or a brick kiln needs to be near to the supply of raw material.

3. FIND WHAT LAND IS AVAILABLE.

Check that the land that is available is big enough and in the right place.

4. FIND OUT WHO OWNS THE LAND.

Choose land that does not have an ownership which could conflict with your project. A community facility should be on land that belongs to all the community, and does not belong to one person or one group, who may later claim that the building is for their use only. If necessary you must acquire the land legally so that there is no doubt about ownership.

When you are choosing the land:

5. ASK LOCAL PEOPLE ABOUT THE SITE.

- does the land flood?
- does the soil move? Black cotton soil moves a lot.
- what is the local climate? From which direction do the prevailing winds come?
- why is this piece of land not already built on?

The answers may tell you that the land is not suitable. If this is so, look for another site and start again.

6. MAKE OBSERVATIONS.

- look at the plants, they can tell you about the presence of water. Reeds would suggest the site floods or gets very wet sometimes. Plants may also be useful later, for shade, so note what there is.
- look at the soil type, and for rocks. These may effect how easily you will be able to build.
- check that the land is flat enough to build on.
- check that the site has good drainage. You do not want water to collect on the site.
- check that you will not be building in the path of a seasonal river.
- look at the existing land use; existing buildings can tell you about local building materials and about local building problems. Look for signs of cracking or movement in buildings.
- check whether the site has existing services including a road, water and electricity. You need to know what you will have to provide.

7. DO A SOIL ANALYSIS.

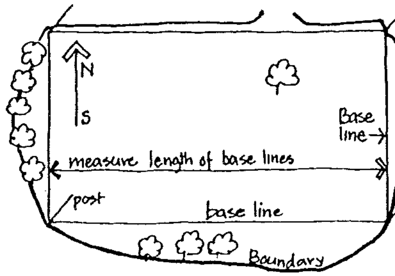
This tells you whether the soil will carry the weight of the building and whether you will be able to build with the soil. Dig a hole (on a large site dig several holes) to see how deep the water table is, and take samples of the soil from these holes for testing, (see Soil Testing) If you reach water just below the surface this will probably make the site unsuitable to build on. Check in the neighbourhood to see if people have wells and what sort they are.

8. CLEAR THE SITE.

If the site is good, clear the land of unwanted plants and objects. Keep trees and bushes which are not in the way of your proposed building. Pace out the site to make sure that it is big enough before you do any clearing.

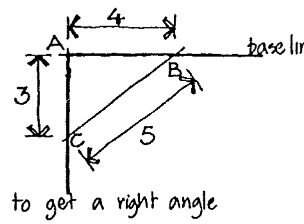
9. DO A MEASURED SURVEY OF THE SITE.

The survey will allow you to place your building accurately on the site, and to avoid any obstacles or features that you may wish to keep, such as large rocks, or trees and existing buildings.



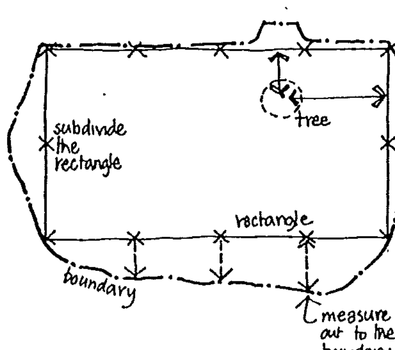
Set out base lines on the site, so that you have the biggest rectangle possible. If you can, make one of the base lines point north and south. Make sure that the base lines are at right angles to each other. At each of the corners, put in a marking post.

To make a right angle, measure 4 metres along one of the base lines: A - B. Measure 3 metres along side A - C. A is the corner between the two base lines. When the distance between B and C measures 5 metres, the sides A - B and A - C will be at a right angle. Move the side A - C in or out until B - C measures 5 metres. This method of getting a right angle is called 'Pythagoras' Theorem'.



Now measure the length of the base lines of the rectangle, and divide them into shorter equal lengths. It will help if you have made the overall length of the base line dividable into smaller equal lengths such as 2 or 5 metres. These divisions mark out a grid on the site. Run a string along each side from corner to corner, and using the grid points, measure out from the base line to the boundary.

As well as measuring where the site boundaries are you need to measure all the objects on the site which you wish to keep, as shown in the diagram here.



Make a plan of what you are measuring and mark down neatly each measurement as you take it. When you have all the measurements you need, draw an accurate plan of the site using a scale which will allow you to get all the drawing on the size of paper that you have.

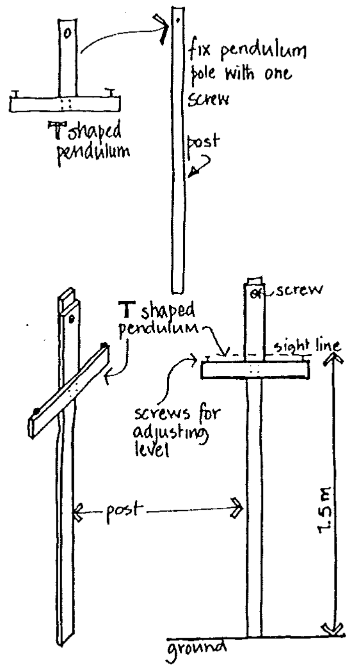
You not only need to know how big the site is, but also if it is level. If it is not level you need to know how much it slopes. Remember too that a site may look level but in fact be sloping enough to justify having steps in the foundations.

The grid you have set up when doing the site survey provides you with a number of fixed points.

You can work out the level for each of these 'points', or, if the site is nearly level, a few selected points will probably be enough.

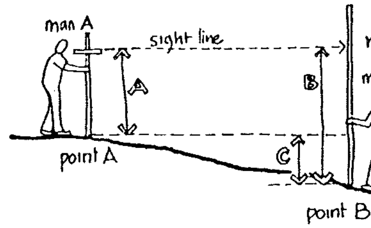
Choose the highest point on your site as the base level or 'datum point'. You can then relate the levels of all the other points marked on the grid to this 'datum point'.

You can use a simple pendulum level for working out site levels. This is a simple piece of equipment that you can make. You need a post 2 metres tall, and, attached to the post, a wooden 'T' shape, about 0.50m long, and hanging up side down. The 'T' shape is the pendulum and must be able to swing from side to side freely. It can be fixed to the post with a screw.



Two screws should be placed in the crossbar of the 'T' so that the level can be adjusted. The tops of these two screws give you the site line of the level. To check that the equipment is level before you begin work, look along the level to a fixed point a short distance away. Turn the level round and look again. If the line of the level does not come to the same fixed point, adjust the site line by raising or lowering one of the screws until the reading is the same whichever way round you use the level.

STEPS IN LEVELLING



1. Check what the distance from the top of the screws to the ground is, and write this measurement down. Call this dimension 'A'.

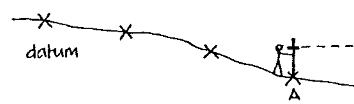
2. Set up the level at the 'datum point', point A. The level is held by Man A who will take the readings and write them down.

3. A second person, Man B, holds a marked rod, vertically, at position B.

4. Man A looks along the site line on the level and writes down the height he reads off the marked rod. Remember that all the points are lower than the datum point. So to get the level of point B you subtract the height of the pendulum level, dimension 'A', from the reading that Man A has just taken, dimension 'B'.

$$B - A = C$$

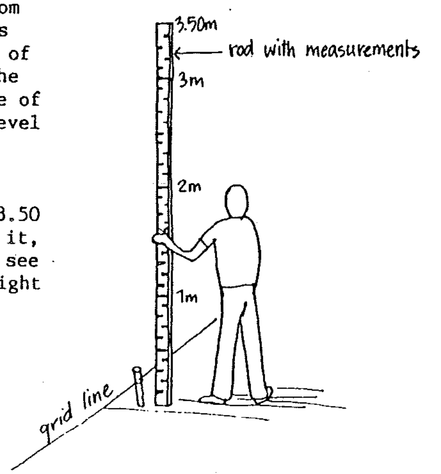
C is the amount that point B is lower than the datum point A. Repeat this process for as many points as you want levels for and that you can see from point A.



As you take each level, mark it onto the survey plan of the site. The levels will appear as a number of centimetres or metres below the datum point, which is marked as zero: 0.00.

To make the building design easier, you can join up the points which are at the same level to make contour lines, and you can also draw a section across the site.

If there are points which you cannot see from point A, either because the ground level has dropped so much that you cannot see the top of the rod, or because there is an object in the way which stops you seeing, then move to one of the other points that has already had its level measured, and from where you can see the remaining points that you need to level.



The rod used in levelling is usually about 3.50 metres tall, and has measurements marked on it, so that you can tell how high the point you see is off the ground (when looking along the sight line of the level.)

The purpose of soil testing is to see what you can use the soil for, and, if necessary, what you need to add to the soil to make it a better building material. For example, you need to add cement to sand in order to build with it; you can make soil blocks with soil that has clay and sand in it, and it is often not necessary to add anything, but if you have too much clay you may need to add sand to get good mud blocks, or add clay if the soil is too sandy.

Soils are divided into types:

NAME	CHARACTERISTIC	SIZE OF GRAINS
Clay	Very fine grain	Smaller than 0.002mm
Loam/silt	Medium grain	Between 0.06 & 0.002mm
Sand	Coarse grain	Between 2mm & 0.06mm
Gravel	Small stones	Up to 60mm

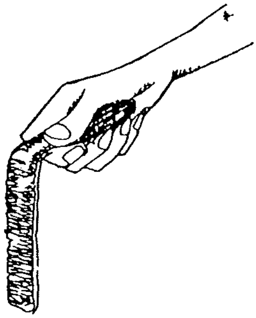
TESTING.

1. Test the soil by observation: you will be able to recognise by sight which soil is sand, gravel or clay, etc. by looking to see how big the grains are.

2. Test the soil by touch: rub the soil between your fingers and grind it in your teeth, and you will be able to tell if the grain is coarse or fine. Clay soils feel fine, and when dry, powdery whilst when wet they are sticky.
Silt will feel slightly gritty in your mouth.
Sand is unpleasant and gritty in your mouth.

3. The Ribbon Test is a good on site test, easy to do. Take enough soil to form a roll about the size of your thumb but about 2 or 3 times longer. Wet it slightly (the drop test will tell you how much water to add) until it is still firm but damp.

Put the roll in your hand and flatten it by squeezing it between your thumb and forefinger to form a ribbon of 3 - 6mm thickness. Push the ribbon that results out in front of your thumb and forefinger. See how long the ribbon gets before it breaks and the end falls off.
A long ribbon, 25 - 30cms means a lot of clay.
A short ribbon means medium to small clay content, which is probably good for block making
No ribbon means no clay - or very little - and too much sand: add clay for block making.



* after CRATERRE

4. The Sedimentation Test is an accurate measure:

The Principle:

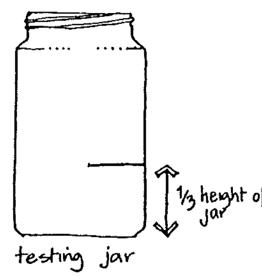
When soil is mixed with a lot of water in a container such as a jar, (after mixing up the soil and the water thoroughly), the larger - and therefore heavier - grains of soil will fall to the bottom of the jar before the smaller grains.

Sand first, then silt, then clay.

These will settle in layers and you can measure the proportion of clay, silt or sand in the soil that you have tested.

The Method:

1) Take a straight sided jar, the taller the better.



2) Mark on the side of the jar where one third of its height is.

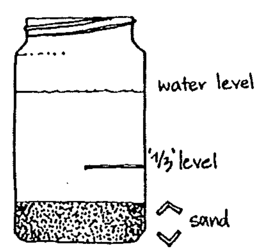
3) Fill the jar with damp soil up to $\frac{1}{3}$ the height of the jar. Push the soil well down and remove any soil above the $\frac{1}{3}$ mark.

4) Add water up to $\frac{3}{4}$ of the height of the jar. (More than this and you risk spilling it.)

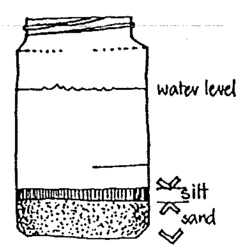
5) Stir the soil and the water well together, and with a lid on the jar or your hand over the top, shake the contents up thoroughly so that everything is mixed up.

6) Put the jar down and count 1 minute. If you don't have a watch count up to 60 at a moderate pace.

At 1 minute, mark on the jar how much soil has fallen to the bottom. Do not shake the jar. The soil that has fallen after 1 minute is sand.* Measure how high this new mark is and write down the figure. This is the amount of sand.

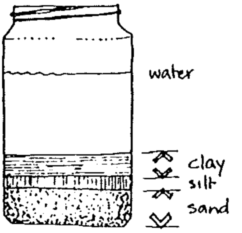


7) Keep timing. After one hour mark again on the side of the jar how much soil has fallen to the bottom of th jar. This new total is the sand and the silt combined. Write down the total height. To find out how much silt there is subtract the 1 minute sand figure from the new 1 hour figure. The result is the silt content.



*Ref. Alfred Bush Jar Test. Unpublished material.

8) Now leave the jar for at least 24 hours, or longer if you can since sometimes clay is very slow to settle. After the 24 hours (or more) measure how much soil has now settled to the bottom. The water should begin to be clear now. The amount of soil that has settled to the bottom is sand, silt, and clay. Subtract the sand and silt measurement, which was the value you got after one hour, from the new measurement to see how much clay there is. Write it down.



You can now work out the proportions of sand, silt and clay.

To get the proportion of each soil type divide the measurement for each soil type by the total height of the soil, which is the sum of the three soil measurements you have written down. This will give you a percentage, or in other words what proportion each soil type is of the total. For example, if the results of a soil test are as follows:-

Sand measured = 12 cms high
Silt measured = 2 cms high
Clay measured = 6 cms high

Total height = 20 cms

Then the proportions are:-

Sand $\frac{12}{20} = 0.6 = 60\%$

Silt $\frac{2}{20} = 0.1 = 10\%$

Clay $\frac{6}{20} = 0.3 = 30\%$

In order to make good mud blocks you need a soil with the following proportions:-

	Minimum		Maximum
Sand	55%	-	75%
Silt	10%	-	28%
Clay	15%	-	18%

(Ref. Craterre)

If you find after doing the sedimentation test that you have too little clay or too little sand, you can add more of one or the other to correct the proportions of the soil. When you do this, do another test to see if you have got the balence right.

Characteristics of soil.

1. Clay swells when it gets wet - the more water you add the more it swells. It shrinks when it dries and will crack.

   Sand does not swell with water, nor does it shrink when it dries. No cracking.

2. Clay is sticky, will stick together and is strong. It can carry high loads; good in compression.

   Sand does not stick together and will not carry loads; poor in compression.

For a good building block you need to balance 1. Shrinking/swelling against 2. Ability to carry a load.

Earth building blocks should always be used in compression. They have no effective tensile strength. Make sure that the load on a mud block is pushing and never pulling. Tensile strength means that a material will resist breaking when pulled.

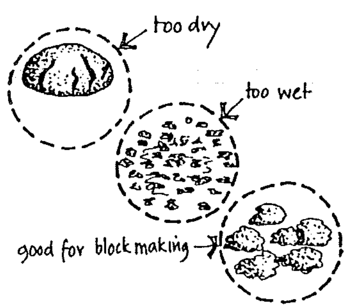
How to work out how much water to add to the soil for blockmaking.

You can use a method called the 'drop test' to find out how damp the soil should be.

Take soil that has had some water added to it. Squeeze the damp soil into a ball in your hand.

Then with your arm out straight at shoulder level, drop the soil ball onto a smooth clean surface at ground level. Look and see what has happened to the ball of soil.

- if the soil stays in one piece it is too dry: add water and try again. If still in one piece the clay content is too high.
- if the soil breaks into many pieces, it is too wet: add more dry soil to reduce water content.
- if the soil breaks into a few pieces it is damp enough for block making.



SKETCH DESIGN

CONTENTS

PAGE 34. INTRODUCTION

PAGE 35. FUNCTION

Activity
Relationship between Spaces

PAGE 37. SHELTER

RAIN

EXTREMES OF HEAT OR COLD

SUNLIGHT

WIND

NOISE

DUST AND DIRT

PRIVACY

SECURITY

PAGE 47. LOCAL PHYSICAL CONDITIONS

PAGE 48. STRUCTURE AND MATERIALS

ROOF COVERING
Thatch
Clay Tiles
Corrugated Iron Sheeting
Asbestos Cement Sheeting
Fibre Cement Roof Tiles

ROOF FRAMEWORK

WALLS

- Timber Pole and Infill
- Masonry Column and Infill Panel
- Fired Brick Wall
- Mud Block Wall
- Bamboo Walls with Posts
- Stone Wall
- Concrete Block Wall
- Soil Cement Block Wall

OPENINGS

FOUNDATIONS

FLOOR

PAGE 74. DRAWING

- Scale
- Symbols

You should do a sketch design of the building to work out the basic dimensions and relationships between spaces, and to work out what sort of roof, walls, openings, floor and foundations you are going to have. From this you can work out what materials the building is going to need and roughly what it will cost. The sketch design should be discussed and agreed upon with representatives of the community and any other people involved in the project. For example, if the project is to provide a health centre, you will discuss the sketch design with the people who are going to run the health centre. After any necessary changes have been made you can then move on to develop the detail design.

The sketch design is based upon four things:

1. The FUNCTION - what activity is going to take place in the building.
2. The type of SHELTER that this activity requires.
3. LOCAL PHYSICAL CONDITIONS which will effect the building.
4. The MATERIALS AND TECHNIQUES that are available.

ACTIVITY

You need to know what activity is going to take place in each room, and how many people (or animals or vehicles, etc.) there will be. This will allow you to decide on the size and form of each space. Include open spaces as well as enclosed spaces. Remember that a court-yard has as many important uses as an enclosed room may have.

If you have difficulty working out how much space an activity needs, think about how much space each piece of furniture needs,how much space each person needs - standing, sitting down or lying down - and from these you can begin to develop an idea of the overall space needs. It will help you to look at people doing different activities and note how much space they need. Try acting out an activity yourself to see how much room you take up. Getting sizes right will become easier with practice and experience.

Buildings designed for the same function will vary in size from one place to another because the materials that are available may also limit how large a room you can build. For example, if there is no long timber available, you will find it harder to build large span roofs, and your design will therefore need to adjust the size and shape of the room in order to make use of the locally available materials.

RELATIONSHIP BETWEEN SPACES

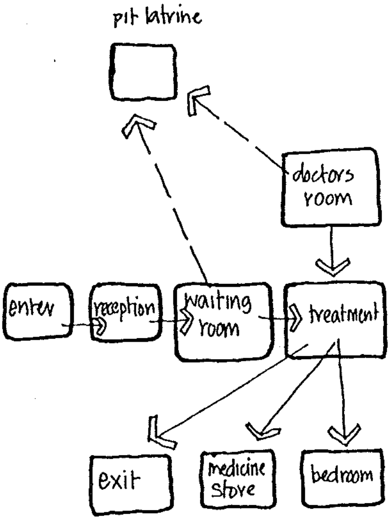
You need to work out what relationship each space,and the activity that goes on in it., has with the other spaces and activities in the building. Take each activity and think about its relationship with all the other activities. Should they be:-

- very close together?
- quite close together?
- quite far apart?
- very far apart?
- maybe it does not matter if they are close together or not.

For example, a pit latrine should be very far a·ay from a well. A waiting area for mothers and babies in an oral rehydration centre should be quite near to the demonstration area, and t ey should certainly not be far apart.

Try and see if activities go in sequence, and if this tells you what relationship rooms have. For example, in a clinic, you have a sequence of activities:-

1. Enter
2. Speak to receptionist
3. Wait in waiting room
4. Enter treatment room
5. Leave clinic



A building should be designed to provide the right sort of SHELTER so that the chosen function can be carried out comfortably and safely. How and when the spaces are to be used will decide what sort of shelter is needed.

In turn, decisions about what type of construction will be suitable and what sort of materials can be used depends upon the sort of shelter needed. They also depend upon the local physical conditions, such as soil types, drainage, ground movement, and what materials are available.

Shelter means providing some or all of the following:

: protection from
- rain
- extremes of heat or of cold
- unwanted sunlight
- excessive wind
- noise
- dust and dirt

: privacy.

: security.

Shelter should also allow for -

: ventilation.

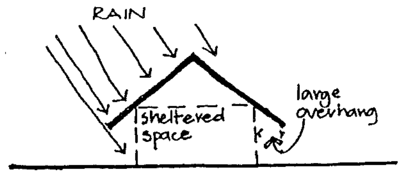
: light.

: coolness or warmth.

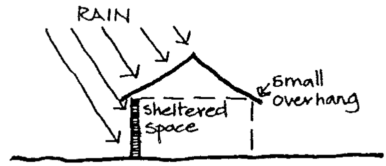
You have to decide which of these shelter needs are important in the proposed building, and then see how the roof, walls and openings can be built in order to provide the chosen shelter needs.

For each item - rain, wind, etc. - you must ask yourself whether shelter from them is important or essential in the new building. Different buildings will have different needs. Different places will have different climatic conditions to which the building will have to respond.

The main protection from rain is provided by the roof. Where the roof has a large overhang you will not normally need tall walls to protect the room from rain.

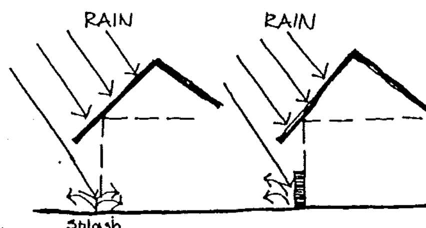


But if the roof only has a small overhang the walls will then need to provide some protection too, to stop the rain being blown into the interior 'sheltered space'.



Remember that rain blown by the wind falls at an angle, not just straight down from the sky.

Rainwater may splash up when it hits the ground. A low wall can prevent this splashing water from entering the room.

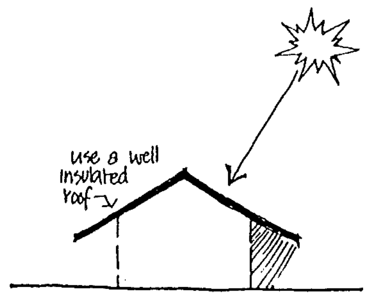


If a wall is exposed to rainwater it too may need protection. This is important with materials which can be easily damaged by rain, such as mud blocks, and quite often fired bricks too when they have been poorly fired. It may be cheaper to provide a large roof overhang to give this protection than to cover the wall with a waterproof material such as cement.

The slope of the roof depends upon what material is being used for the covering, but in all cases the roof must be made steep enough for the rain to run off quickly and be thrown clear of the walls.

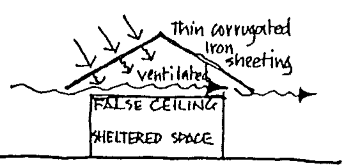
Rooms may need to be protected from excessive heat or cold. In Southern Sudan it is sometimes cold in the very early morning. This will not affect buildings which are only used during the daytime. Think about the times of day at which the building will be used. A classroom is only used during the daytime and will not need protection from cold. What about a bedroom in an hospital?

Heat in Southern Sudan is more of a problem. You need to protect the inside of the building from the sun's heat: the sun will heat up the outside surfaces of the building which face the sun. Use materials which do not allow this heat to pass quickly to the inside of the building.



Thick solid (and therefore well insulated) construction materials will provide better protection than most thin materials do. Materials such as stone, mud, fired brick and thatch are good for keeping heat (or cold) out of buildings. Corrugated iron sheets are poor because the heat or cold can pass quickly through them.

The roof needs to provide protection from the sun's heat especially during the middle of the day when the sun is high in the sky. The roof therefore needs to be well insulated. If corrugated iron sheets are used, then you will need to use a false ceiling as well, to keep the room below cool. Make sure that the space between the sheeting and the false ceiling is well ventilated so that hot air under the sheets will be blown away.

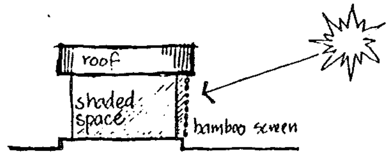


The roof's overhang can provide shade for the north and south facing sides of a building. But when the sun is low in the sky in the early morning and late afternoon, the sun will shine directly onto the east and west facing walls.

Rooms used in the morning facing east should be protected from the heat of this low level sun: use a well insulated wall facing east.

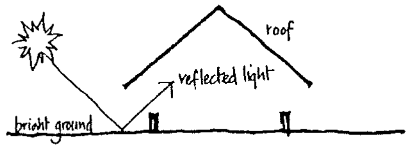
Rooms used in the afternoon should be protected from the heat of the sun when it is low in the sky in the west. If you know when a room is going to be used you can work out which walls in the building need to provide protection against the sun's heat.

In spaces which are very well ventilated you can provide protection against the sun's heat with screens (of bamboo for example) which will provide shade; the heat that does pass through the screen will be blown away. This is a cheap solution and suitable for buildings such as market stalls. It is still important to provide a well insulated roof.



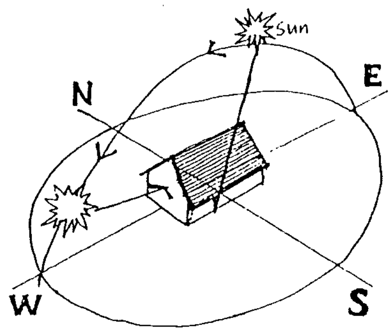
SUNLIGHT

Direct sunshine into a room will not only make it too hot but also too bright. You need to shade interiors from both.



You need enough light to see what you are doing comfortably: this can be provided by reflected light. Sunlight shining on the ground and objects outside the building will provide indirect reflected light to the inside of the building.

On the north and south sides of a building a large roof overhang will provide protection from unwanted direct sunshine, and so these are the sides in which openings should be placed.



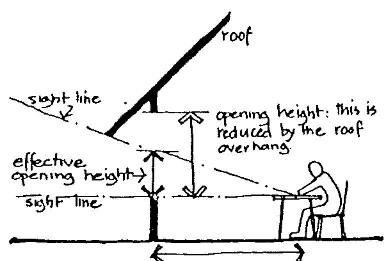
On the east and west sides which face directly towards the sun when it is low in the sky it is better to have no openings for light, as they are more difficult to shade.

Where you do need shade, lightweight thin screens will provide just as much shade as thick solid walls. Trees and neighbouring buildings may also provide shade, and so it is worth noting what is available on the site when you are designing the building.

LIGHTING

To calculate how much opening you need in order that a room will be bright enough you can use the following formula:

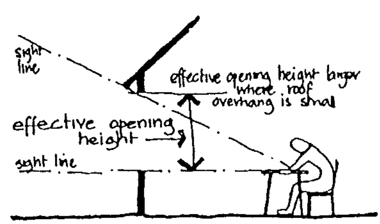
- the area of opening for light should be at least 10% of the room floor area.



so: $\frac{\text{floor area}}{10}$ = area of the openings.

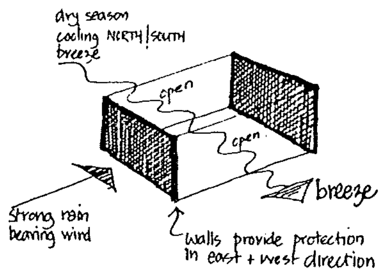
(This is a minimum and you could allow up to 20% of the floor area.)

To work out the total width of the opening you need, divide the area of the opening by the effective opening height. The effective opening height is the distance between the bottom of the opening, (or the level at which you are working, such as a desk top,) and the top of the opening or the line of the roof overhang, whichever is lower.

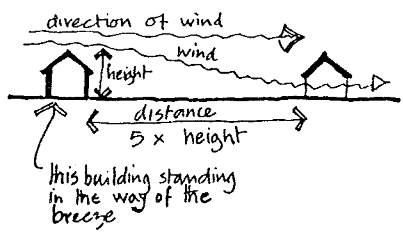


Divide the opening width into equal size openings and position them in the walls: place openings near to where people will be working, so that they can see.

You should provide protection against strong winds, which occur mostly during the rainy season. These winds can damage the building and blow objects away. Try and place the building where there can be some shelter from the rainy season winds. Shelter can be provided by trees and bushes, by neighbouring buildings and sometimes by natural features such as hills. Don't put your building on an exposed site such as on top of a hill.



In Southern Sudan the rainy season winds blow from east to west. so you can provide protecting walls against winds blowing in this direction, which fits well with the heat and sunlight shelter needs. On the other hand, during the dry season slower winds blow from north to south. Openings in the north and south sides of a building would allow these slower winds to blow through the building and cool it down.

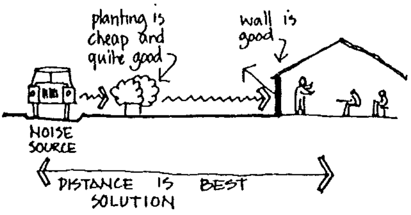


Don't place buildings too close to each other in the direction of cooling breezes that you do want to enter the building. In this case, where dry season winds blow from the north, allow a distance of 5 times the height of the building standing in the way of the breeze, so that there is no obstruction.

Noise is sound that you do not want to hear. Very loud noise can damage your hearing. Noise makes it difficult to concentrate, in school for example.

You can reduce the problem of noise by good planning. Choose a site for your building which is away from the source of the noise.

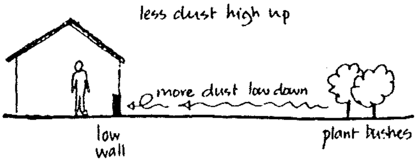
If you cannot build away from noise, then you can put up a barrier to reduce the amount of noise that can reach your building and disturb the people inside it. A barrier can be created by planting trees and bushes; the thicker the planting the better the barrier. The most efficient solution is to have a solid wall between the source of the noise and the building occupants. Try not to place openings facing the source of the noise.



If you decide to build a wall to reduce the noise, a thick wall will reduce noise better than a thin wall.

Common sources of noise are: roads, especially roads with lorries.
: airports.
: workshops and factories.
: public places.
: school playgrounds.

Dust can cause throat and eye diseases, as well as making things dirty. Most dust is blown into rooms by the wind and this happens most of all low down near the ground. The higher you go above ground level the less dust there is in the air.



Use low walls and plant bushes to help reduce low level dust blowing into the building. For most cases except when there are very high winds a low wall will be nearly as effective as a high wall. Inside the room smooth hard surfaces are good: a cement floor is better than a dirt floor as you can clean it more easily.

Thatch roofs are often a source of dust. If this is a problem you may need to use a false ceiling. You can also plaster the underside of tiled or thatched roofs with mud or gypsum, plastering onto the battens..

Dust and dirt will be more of a problem in health buildings than in schools. You may want to provide shutters where it is important that rooms are kept very clean. Shutters can be made out of wood.

PRIVACY

There are two types of privacy: one is sound, meaning that you may not want people to hear what you are saying or doing. To deal with this, apply the same ideas as for the protection from noise, except remember that in this case you are the source of the noise.

The second type of privacy is visual privacy, meaning that you may not want people to see what is happening in a room. Visual privacy can be provided by anything which you cannot see through.

Visual privacy will be more important in clinics, hospitals, latrines and washplaces, than it is in schools and work places such as workshops and markets.

Security needs of different types of buildings will vary a lot. A clinic will need to be more secure than a school because there are often more things that could be removed.

Security can be provided by a watchman; by having a fence; by having a secure store. It may be cheaper to build a small secure store than to make the whole building secure.

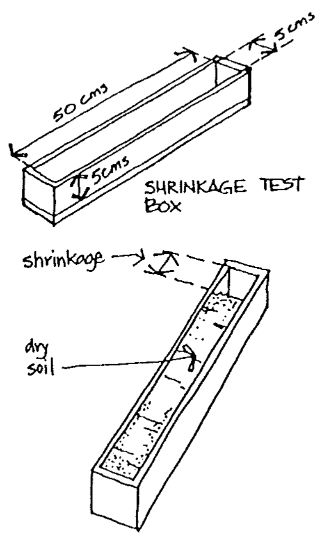
You can also try and build furniture into the building so that it cannot be removed. School benches and desks can be fixed permanently.

LOCAL PHYSICAL CONDITIONS

Climate, which determines most of the shelter needs, is only one of the local conditions. You need to consider other local conditions which can affect the design and location of the building.

Of these, the most important consideration affecting the design of the building will be the stability of the soil and its ability to carry the weight of the building. Stiff sandy or clay soils are usually good for building on, but look out for loose sandy soils, and for swelling clay. North of Juba in the Jonglai district there are large areas of swelling clay known as 'black cotton soil'. This soil expands a lot when it is wet, and then shrinks again when it is dry, with the result that the building also has to be able to move, otherwise it will crack. Brickwork and blockwork, which cannot move without cracking, are not suitable for building on these unstable soils: instead it is better to choose a constuction method which allows movement, such as a timber frame construction.

To help you decide what the soil is like, first you should look at the existing buildings in the area. Check for any signs of cracking or sinking; make a note of the construction method that has been used. Look at several buildings, and if there are different types of construction in the area, look to see how they have all behaved.

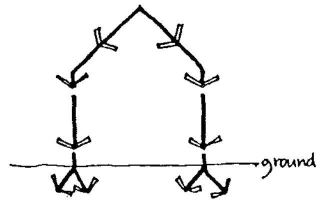


You can also take soil samples and do a shrinkage test. Build a wooden box with the inside dimensions shown here. Fill it with soil that is wet enough for block moulding. (See 'Soil Testing' for the right water content.) Leave the full box in the sun for several days until the soil is completely dry. The soil will shrink and crack as it dries out. Tap the box gently so that the soil moves to one end of the box, leaving a gap at the other end. Measure how long this gap is and divide the measurement by the overall length of the box. The resulting number should be written down with two figures after the decimal point, like this - 0.00 - to give you a percentage (%). For example, if the gap (shrinkage) measures 5 cms, and the overall length of the box is 50 cms, then -

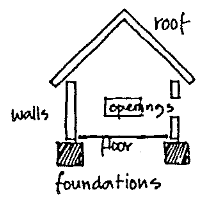
$$\frac{5}{50} = 0.10 = 10\%$$

A soil with more than 10% shrinkage will be very unstable.

Although we build from the ground upwards, when you design a building you must remember that the load of the building is carried down to the ground, and that the choice of roof covering and roof structure will have an effect upon the choice of wall system needed, which in turn will have an effect upon the type of foundation that you need.



Although the purpose of the building is to provide shelter, the individual parts of the building - walls, roof, openings, etc. - not only have to meet the shelter needs but also need to be designed to meet the structural needs of the building.



Take the five main parts of the building:

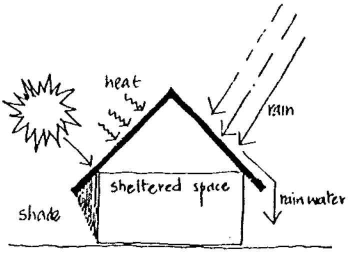
ROOF - COVERING AND FRAMEWORK
WALLS
FOUNDATIONS
OPENINGS
FLOOR

and consider their purpose, what is available commonly in Southern Sudan, and how it serves the required purpose.

The roof divides into two main parts: 1.Covering
2.Framework

What is the purpose of the covering?

- keep rain out of the building and to carry the water clear of the building.
- provide shade from the sun.
- protect the interior from extremes of heat or cold.
- keep dust and dirt out.
- permit water catchment linked to water storage.
- provide security.



What materials are available in Southern Sudan for roof covering?

- grass and reeds for thatching.
- clay tiles.
- corrugated iron sheeting.
- asbestos cement sheeting.
- fibre cement roof tiles.

THATCH

Thatch is the most common roof covering material in Southern Sudan. There are several different ways that the thatching is done, some of which are better than others. The life of the thatch depends very much on how well it is laid on the roof. It depends too on the sort of grass that you use: try and use grass that is tough and fibrous.

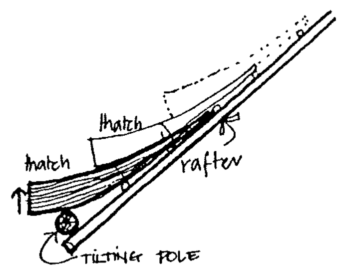
In general thatch is good because it is:-

- locally available.
- cheap.
- keeps heat out.
- provides shade.
- keeps water out, if well done.

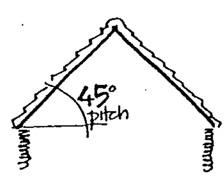
It has some disadvantages:

- the lifespan can be short: 5 years.
- there is a high fire risk.
- it collects dust and dirt.
- insects and small animals can live in it.
- you can only collect the grass after the rains, so it is only seasonally available.

The lifespan of thatch can be increased by using more grass on the roof and by making sure that it is packed very tightly together. Doubling the grass quantity more than doubles the life, so it is worth doing. Pushing the bottom layer of grass up at an angle also helps to close the gaps between each stem and results in a tighter finish. Use a tilting pole to do this. The effect of having the thatch packed more tightly is to reduce the amount of water that can penetrate the grass, and also to reduce the amount of air in the roof. This reduces the fire risk because fire needs air in order to burn: the less air there is the slower the grass will burn.

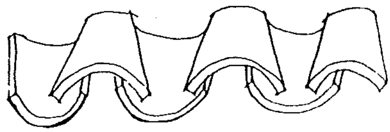


Thatch should be laid at a steep angle: 45° or more, so that water runs off quickly. Thatch weighs about 30 - 50kg/m² and the roof structure must be strong enough to carry this load, as well as the weight of water. Because you need a large and strong structure, very wide rooms may become expensive to cover.

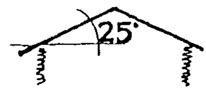


Most people have a basic knowledge of thatching, but it requires skill to do it well. The great advantage of thatch is that it is cheap and locally available, and can therefore be replaced and maintained using only local resources.

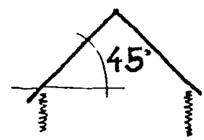
CLAY TILES



Clay tiles have been used quite a lot in the past, although not often on low cost domestic building. Tiles are a local material, produced in kilns where the clay is suitable, and providing local employment. Buying roof tiles therefore helps the local economy. The skill to produce tiles exists in Southern Sudan, but very few tiles are produced and they are not readily available. Half round tiles have been produced and some flat tiles (plain tiles). In both cases they are a heavy roof covering, weighing up to $80kg/m^2$. The roof structure must be strong enough to take this load. Plain tiles require a steeper slope (45°) than the half round tiles(25°). Although skill is needed to produce the tiles, learning to lay them is easy.



HALF ROUND TILES



PLAIN TILES

Tiles make a good quality roof covering: they last a long time, keep rain out and provide quite good protection against the sun's heat. Tiles provide a good run off for water and can therefore be used if you wish to collect rain water. Dust can be blown in between the tiles, but generally a tile roof is quite clean. Roofing can be done at any time of year.

The main disadvantage of tiles for roofing is that they are quite an expensive way of covering a building, and at the moment their availability is poor.

CORRUGATED IRON SHEETING

Corrugated iron roof sheeting is a very popular roofing material, mainly because it is thought to be long lasting and waterproof. The sheets come in different thicknesses, and the thicker the sheet the longer it will last. Unfortunately much of the sheeting that is brought into Southern Sudan is of poor quality and thin. This means that the lifespan is often less than expected. Because the sheets are thin they are more liable to wind damage.

The sheets are imported from Kenya or from northern Sudan, and are therefore not a local material. They are normally very difficult to get.

Sheets last about 10 - 15 years, and weigh about 10 - 15 kg/m^2, which means that the roof structure does not have to be very strong. The roof slope should be between 15° and 25°.

The main advantages of corrugated roof sheeting are that it is waterproof,(and good for water collection). The sheets won't catch fire and do not harbour insects or dust. Not much skill is needed to lay them and it can be done at any time of the year.

The disadvantages are firstly that they are hard to get, and therefore you should not plan a building with a corrugated iron roof unless you are sure that you can get the sheets. Because the sheets are imported they are expensive as well. Corrugated iron sheeting provides very poor protection against the sun's heat, so that rooms roofed with this material will need a false ceiling and a ventilated space between the roof and the ceiling in order to reduce the build up of heat. This adds to the cost of the roof.

Aluminium roof sheeting is more expensive, and very difficult to get in Southern Sudan. It provides much better heat insulation.

Roof sheets will last longer if the outside is painted with a limewash or oil-based water proof paint.

ASBESTOS CEMENT SHEETING

Asbestos cement roof sheets cannot be considered as normally available. However, they are sometimes found in Southern Sudan. They are imported and expensive. The sheets are heavy and fragile, which means that the transport costs are high.

Because they are heavy they need a stronger roof than is neede for corrugated iron sheeting, but the slope is the same. Because the sheets are thick they need more skill in laying than the corrugated iron sheets.

Asbestos cement sheets provide good heat insulation.

Most important is that the asbestos in the sheets is dangerous to health, and their use should therefore be avoided if at all possible.

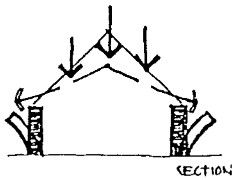
FIBRE CEMENT ROOF TILES

Fibre cement roof tiles can be produced using quite small quantities of cement mixed with sand and natural fibres such as sisal. Moulding forms are needed and a vibrating table. The vibrating table runs on electricity, for which you either need a mains supply or a generator with a storage battery.

There have been some buildings roofed with these tiles in Southern Sudan, but whilst cement is difficult to get even in the small quantities needed (about 5kg/m^2 roof), few communities will be able to produce these tiles. In addition, the need for an electricity supply limits the potential of this system at the moment. The situation might improve in the future.

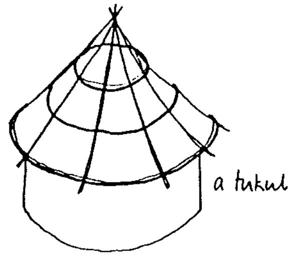
The skill required for laying the tiles is the same as for clay tiles. The roof structure can be the same as for the corrugated iron roof sheeting, but with a greater number of battens. The heat insulation value is quite good. Insects and dust are not a problem, and the tiles are good for rainwater collection.

The roof framework provides the base for the roof covering material. The framework must be strong enough to support its own weight, the weight of the covering material, and the weight of water and the pressure of the wind during a storm.



The roof framework must be rigid and not bend. It must not push outwards where it rests upon the supporting walls or frame. If it pushes out there is a danger that the supporting walls, posts or columns will fall over.

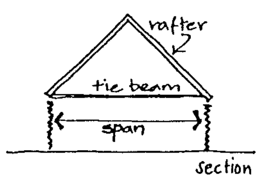
In a round building such as a Tukul the roof is held together by tension rings running right round the roof, which stop the base of the roof being pushed out. Higher up the roof these same rings become compression rings and stop the rafters bending inwards.



In round roofs these tension or compression rings are quite easy to make.

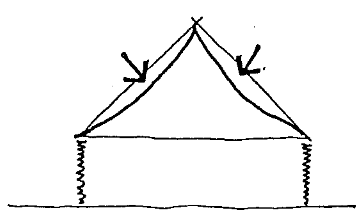
In a rectangular building the roof framework rests on two side walls which it could push outwards.

We use a tie beam to hold the base of the roof together. A simple roof framework with two rafters and a tie beam is strong enough for spans up to about 4 metres wide.

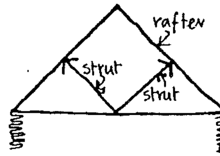


The word span describes the width of the space that is covered by the roof. The slope of the roof is called the pitch.

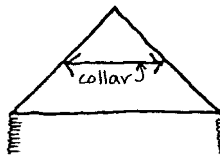
If the roof span is increased, in order to cover a wider room, then the weight of the roof and of the framework will increase too. With this increased weight the rafters in a simple roof will bend inwards.



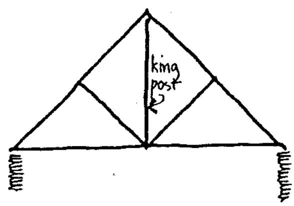
To stop the rafters bending, introduce struts or a collar.



Both these methods push out against the rafters and stop them bending inwards under the weight of the roof. These roof frameworks are called trusses.

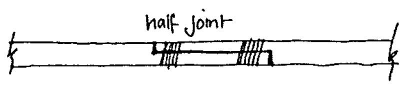


If the span is more than 5.50 - 6.00 metres, the pressure of the struts will push the tie beam down. To overcome this, a king post can be added to reduce the downward pressure on the tie beam The king post is in tension between the ridge and the tie beam.

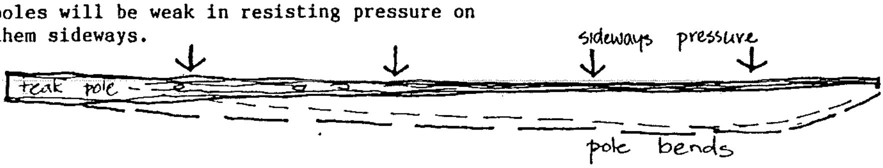


Large spans will create another problem: the wood available may not be long enough. You can join two pieces together but the join is often weak, especially where you are trying to join two thin pieces of wood.

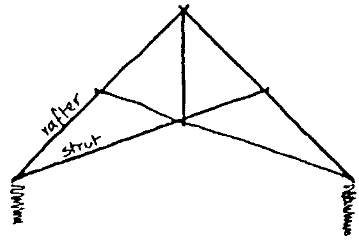
Use a half joint for joining poles.



The teak poles available in Southern Sudan are not always very long, and lengths of more than 4 metres may be very thin. This means that the poles will be weak in resisting pressure on them sideways.

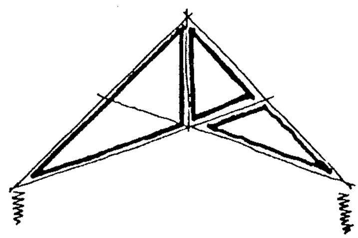


Because the poles are thin it is better to use a truss where you do not need to join two pieces of wood.



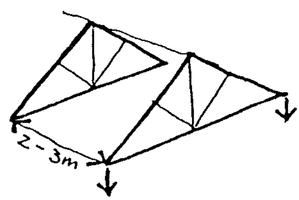
This truss uses shorter poles than would be used if there was a tie beam. The struts cross over from the middle of the rafter to the base of the truss on the opposite wall.

The king post helps to resist any opening out of the truss.



All roof trusses must be made up in the form of triangles. Provided the timber is strong enough, the triangles cannot change shape. For any change to happen one of the sides would have to get either longer or shorter. A triangle is therefore a strong shape. In a roof truss there are several triangles.

Roof trusses should be spaced about 2 - 3 metres apart.



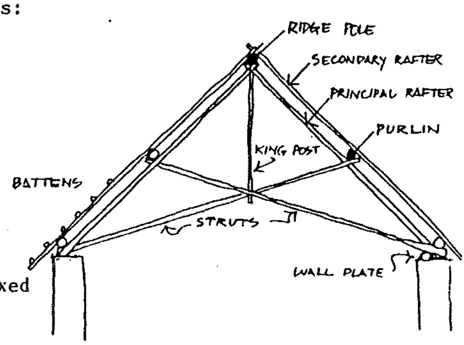
The trusses support a secondary framework, which in turn supports the roof covering: thatch, corrugated sheeting, tiles, etc.

The secondary framework has to transfer the roof weight evenly onto the roof trusses, and through them down to the ground.

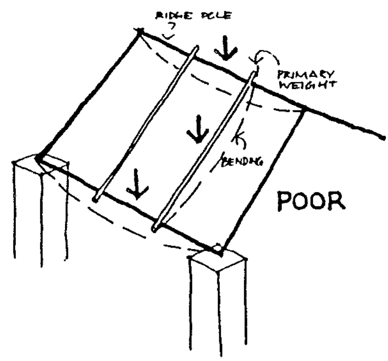
The secondary framework is built up in layers: the purlins and the ridge pole rest upon the main rafters of the trusses,

and secondary rafters rest on the purlins:

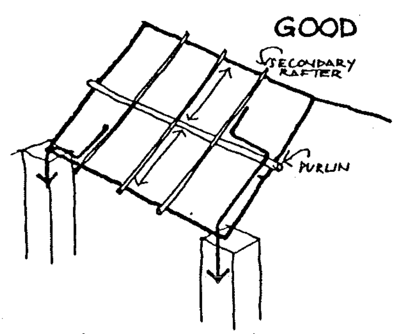
The battens to which the roof covering is fixed rest upon the secondary rafters.



Sometimes roofs are built with the secondary rafters resting directly on the ridge pole and the pole or wall plate at the eaves. This does not make use of the trusses but puts the roof weight onto the ridge pole and the pole at the eaves, which may then bend. Also, the secondary rafters are only supported at each end, so they have to be made with larger pieces of wood, to avoid them bending. This wastes material.



Instead, use a purlin half way up the slope of the roof to transfer some of the weight of the secondary rafters over onto the trusses. The secondary rafters then only have to span a shorter distance between the purlin and the ridge, and the purlin and the eaves. The weight is spread more evenly over the whole roof and you can use smaller poles for the secondary rafters, which will save money.



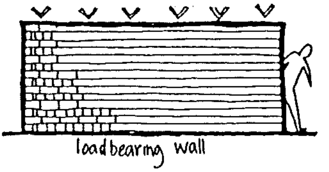
When you work out how to build the roof framework, always think about how the roof weight is going to be transferred evenly to the ground.

The purpose of a wall is: to provide shelter.
: to hold up the roof.

There are two ways of supporting the roof: with loadbearing walls, or with a framework with non loadbearing walls inbetween.

Loadbearing walls carry the weight of the roof and their own weight evenly down to the ground. There is no concentration of weight on any one part of the wall, and you cannot simply remove parts of the wall without risking damaging the roof it supports.

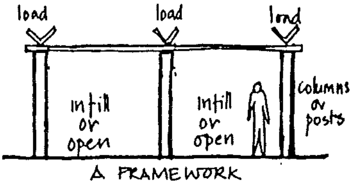
Loadbearing walls are good where suitable materials are locally available and where the shelter needs require having large solid walls, for example where you need to keep heat out.



Loadbearing walls are also good where there is a heavy roof to carry, such as a tile roof, and when it is better to spread the load over as large an area as possible, instead of concentrating it onto columns.

The most common materials used for loadbearing walls are stone, cement blocks, fired bricks and mud blocks.

A framework uses posts or columns to support the roof. The space between the columns can be filled in with whatever material is either suitable or available. The space between the columns can be left open as well, since all the weight of the roof is carried by the columns. This gives one good flexibility to choose the right material for the shelter needs. For sheet roofing and for thatch, a framework supporting structure will be good, but with a heavier tile roof you need to make sure that the concentration of weight on the columns does not make them sink into the ground. This means that the foundation must be large enough and the soil stable enough to carry the load. An answer in situations where the soil is not stable is to avoid heavy roof coverings.



Framed construction can be cheaper to build than loadbearing walls, because less material is needed.

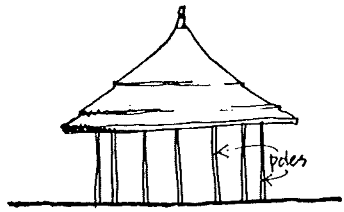
The characteristics of a wall depend not only upon whether it is loadbearing or a framework, but also on the materials that it is built with. The way you can use a fired brick wall is slightly different from the way you can use a mud block wall. There are even greater differences between building with timber columns and building with masonry columns.

In Southern Sudan, there are eight main wall or frame building methods:

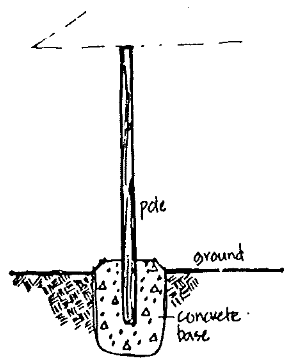
- timber pole and infill panel.
- masonry column and infill panel.
- fired brick wall.
- mud block wall.
- bamboo wall with posts.
- stone wall.
- concrete block wall.
- soil cement block wall.

TIMBER POLE AND INFILL PANEL

Timber poles with infill panels is the most commonly used wall construction method in Southern Sudan, and most Tukuls are built like this: posts, which support the roof, are placed upright in the ground, and the space between the posts is filled in most commonly with branches and smeared mud, but sometimes with more solid materials such as broken fired bricks.



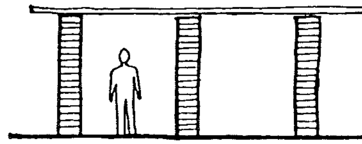
The lifespan of this wall system is short, (5 to 10 years), mainly because termites attack the supporting posts. The lifespan can be increased by bedding the posts in a concrete base, and by using poison when it is available. Both these improvements will increase the cost as well as the lifespan. Normally the cost of materials for this method is low, because the poles are small and cheap, and the infill material is often available very locally, usually at no cost. Labour needs are low, and everybody knows how to build like this, which means that in self-help projects many people can participate in constuction of this type.



The walls are often thin, and so the insulation value against the sun's heat is not very good.

The short lifespan is a major disadvantage, and this type of construction will often not get official recognition. The main advantage of the pole system is that it is cheap and simple.

MASONRY COLUMN AND INFILL PANEL



Masonry column and infill is a frame system like the pole system, but this uses bricks, blocks or stones to build up the columns which support the roof. The material used to fill in between the columns is usually the same as for the columns, but because it is not loadbearing the infill wall can be thin and cheaper to build than the column. The advantages of this system are that the columns are less likely to be attacked by termites, so the lifespan of the building is longer, and the infill panel can be built up according to the shelter needs. For example, the infill panel could be left out if the shelter needs did not require any wall at all.

The disadvantage of this system is that to build up the columns requires more skill than to do the pole construction. The material costs may be higher too, but the longer life would justify this expense if the money is available.

The columns must be large enough to support the weight of the roof. Remember that the weight is concentrated on the columns, so they need to be thicker than a normal loadbearing wall. For example, if a loadbearing wall is 30 cms thick, a column of the same material would need to be at least 45cms thick. As a guide the width of a column should not be less than 1/10th of the column height.

Both the pole and the column system have the advantage of seperating the structural needs, holding up the roof, from the shelter needs, which allows you to build exactly what you need for the shelter requirements, which can save money.

FIRED BRICK WALL

Fired brick is used for most 'official' building because it is regarded as a permanent material, with a lifespan of 35 - 50 years. Well made fired bricks are excellent and will last a very long time, but unfortunately a lot of the brick produced in Southern Sudan is not well made. Clay which is too sandy is often used, which makes the brick weak, and the bricks are often under-fired or fired irregularly. These bricks are easily damaged by rain and in many cases are no stronger than unfired mud blocks. As a result many fired brick walls have to be plastered on the outside to protect them from rain damage, which should not be needed if the bricks were of good quality. If you decide to build with fired bricks, try and make sure that they are of good quality, otherwise you will be wasting money buying a material which is not in fact 'permanent'.

A good fired brick will give a clear ringing sound when struck with a hard object, and should be nearly even in colour.

The most common use of fired bricks is for building loadbearing walls, although they can just as well be used for the column and infill system. Walls are usually built the same width as the length of the brick, and when cement is available the bricks are laid in a cement sand mortar. More commonly a mud mortar is used which is not as strong but quite good enough for most of the single storey building that is usually needed in Southern Sudan.

Tha advantages of fired bricks is that they are locally produced, which helps the local economy and gives employment; good bricks are strong and durable; the skill needed to lay bricks is learnt quite easily. A fired brick loadbearing wall gives good protection against the sun's heat, so it can be used on east and west facing walls where this protection is needed.

The disadvantages of fired brick are that: the quality is very often poor; the cost is quite high and especially for a self-help community building programme, may be too expensive; the exposed surfaces often need a coating, usually of cement, which is hard to get and expensive. A growing problem with fired bricks is the need for large quantities of firewood, which is very scarce.

MUD BLOCK WALL

Mud blocks have not been very common in Southern Sudan but their use is increasing. They are easy to make and cheap. The technique for making them can be learnt without difficulty. Very little special equipment is needed, and all of it can be made locally. To produce mud blocks wet mud is moulded by hand into a wooden form and the resulting block is then left to dry for several days in the shade. Mud blocks require a suitable soil, (see page 27.) and a reasonable water supply. If these are available it is best to set up block production next to the building site. Try and avoid transporting blocks over rough roads, since they will break quite easily. Mud blocks are only strong under compression, which means that they are good at carrying loads but that the walls or columns must be quite thick or large. Because block construction is thick it gives good protection against the sun's heat, and against cold, and mud block walls are particularly good in places where it is hot during the day and cool at night. Protection from noise is also good.

Mud blocks are laid in mud mortar, never in cement mortar, which does not stick to mud. Block laying can be learnt quickly and because blocks can be cut easily slightly less skill is needed than for laying fired bricks.

The main disadvantages of mud blocks are that they are easily damaged by rain, and it is necessary to protect mud walls from contact with water: this can be done either by having large roof overhangs or by coating the outside of the wall. The simplest coating is to smear mud onto the wall, and to repeat this as necessary. Lime and cement based coatings are also possible but cost more money and require some skill in order to get the coating to stick onto the wall.

If mud blocks are kept dry they will last for a very long time.

BAMBOO WALL WITH POSTS

Bamboo is used a lot in Southern Sudan, for fences and simple screens. It should not be used in contact with the ground because termites will reduce its lifespan to as little as one year. If treated with used oil it will last longer. The short lifespan is a major disadvantage. In public buildings where repair and replacements are often not done, bamboo should be used carefully to ensure that it is not damaged quickly. However, it is a good material for making screens and for providing privacy.

STONE WALL

Except where it is available right on the building site, stone is an expensive material to use because of the transport needed. It is heavy and you need a solid cart or a lorry to transport it. It is a good building material with a very long life.

Because stones are different shapes and sizes quite a lot of skill is needed for stone wall building. For a good wall you should use cement for the mortar, which adds to the expense, but mud mortar can be used where the stones are flat enough. Stone can be used for either loadbearing walls or for column and infill. Stone is sometimes used with fired bricks, where the fired bricks are built up to make the straight edges at corners and openings and the stone used as a loadbearing infill.

The main advantages of stone are that it is strong and long lasting. Stone walls provide very good insulation from heat and cold, as well as protection from noise.

The main disadvantages are the cost of transporting the stone, which may make it too expensive for community development projects with little money. If you have some stone available, try to use it in the foundations where its strength makes it a good material.

CONCRETE BLOCK WALL

Concrete blocks are not used very much because of the cost and difficulty of getting cement. This limits their use to very expensive projects.

Concrete blocks are strong, both in compression and tension. This means that they can be used for loadbearing walls and columns without having to be very thick, unlike, for example, mud blocks. Because the walls can be thin they can be built quickly, but the thinness means that the protection against the sun's heat is not very good.

The quality of concrete blocks depends upon how well they have been made: has enough cement been used? Because cement is hard to get blocks are often made with too little cement and are weak. A cement mix which is either too dry or excessively wet will also probably produce weak blocks.

Blocks should be laid with a cement and sand mortar, and although they should be laid neatly it does not require great skill to lay them, since often the walls are thin and the bonding of blocks quite simple.

The advantage of concrete blocks is their potential strength and therefore their long life. The major disadvantage is the need for cement.

For most community development building work alternative cheaper and more readily available wall building materials usually exist, such as mud block or fired brick.

SOIL CEMENT BLOCK WALL

Soil cement blocks are similar to concrete block but the sand and gravel are replaced by a sandy clayey soil. Blocks are usually produced in a press, a machine which compacts the soil into the form of a block. The compaction gives the block much of its strength. Cement or lime can be used to bind the soil, and in particular give an improved water resistance.

The cement content of a block will vary depending upon the type of soil you have, and also what the block is to be used for. Foundations need stronger blocks than walls. You measure cement content by weight in proportion to the weight of the block. Commonly between 5 and 10% cement is used for making blocks. For lime you double these quantities.

The disadvantage of cement or lime stabilised blocks is similar to the concrete block: the cement or lime is difficult to get and expensive. Because the soil varies, working out how much cement to use requires skill and practice. Not all soils are suitable for compression or stabilisation.

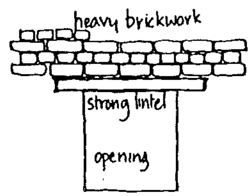
Bitumen and asphalt can also be used to stabilise soil, with the aim of improving the water resistance, and in some cases improving the strength. As with the compressed cement or lime blocks, to get the best results you need to use special equipment, although it is possible to make asphalt stabilised blocks by hand.

Wall building with stabilised blocks is the same as for mud block and fired brick wall building. You can use either a soil cement or a sand cement mortar.

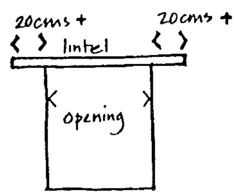
Stabilising blocks can often work out to be as expensive as concrete blocks, becuase most of the stabilisers are imported, such as cement. It may work out more economical to build with unstabilised mud blocks and concentrate upon protecting the outside of the building from the rain.

The purpose of openings is to let light and air into a room, to allow people in the room to see outside, and to allow one to go in and out of a room.

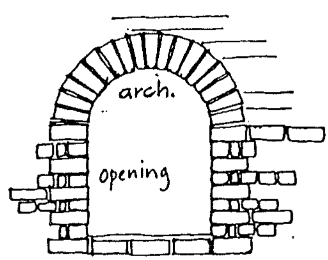
Openings - doors and windows - can be different sizes and shapes. In particular the width of an opening has an effect upon the structure of the building, since the wall or roof above the opening has to be supported. The support over an opening is called a lintel. You need to think about how the lintel will be made. It will need to be stronger if there is the weight of bricks or blocks over the opening, than if there is only the weight of the roof framework.



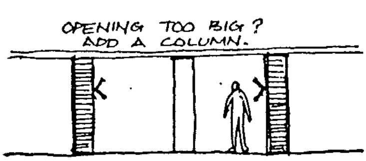
It is easier to make the lintel over a small opening than it is over a very wide opening. When designing your building you need to think about what load you have over the opening, and whether you have materials available which are able to carry this load. As the width of the opening increases, it gets harder to find materials that will be able to carry a heavy load: therefore try and avoid heavy construction over wide openings. A roof framework can be designed to carry its load to columns or posts on either side of a wide opening, whilst a wall over an opening will place a load along the full length of the opening.



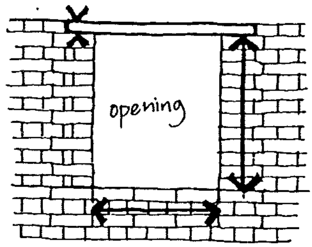
Lintels over small openings can be made with wood. If the load is light the pieces of wood can be quite small, but you need to use a thick (about 15cms in diameter) piece of wood if there are bricks over an opening of 1 metre. Make sure that the wood extends for at least 20cms into the wall on either side of the opening. Small openings can also have arches over them. Arches can be made with blocks or bricks. You will need a trained mason to build an arch, but it is not difficult to learn. Arches over large openings (more than 1 metre) require more skill.



Large openings can have timber lintels. A teak pole about 15cms in diameter would be suitable for an opening up to 3 metres wide if there is no heavy load. However, if you are in doubt, you can reduce the size of the opening by putting in an additional post or column.

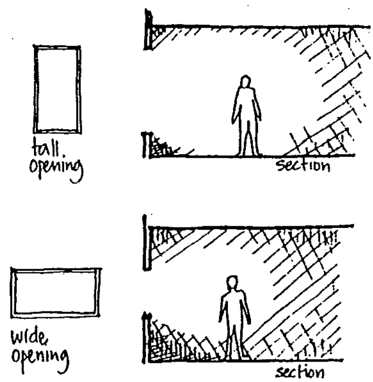


Openings in brick or blockwork should be made the same height as an exact number of brick courses, and the same width as the exact length of a number of bricks. If you don't do this will have to cut a lot of bricks which wastes time and material, and the result will be untidy. You should also try to make the lintel the same depth as one or two courses of brick or block work.

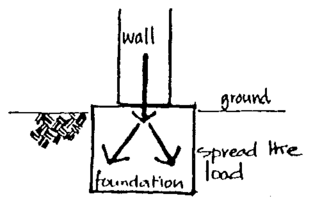


If you have a window or door frame , put it in before building the wall, and then build up the wall around it: this is both quicker and neater than putting window and door frames in after the masonry is finished.

Because it is easier to make small lintels, tall thin openings are better than short wide openings. They also give a better distribution of light to the interior of a room.



The purpose of the foundations is to transfer the weight of the whole building down to the solid ground. The soil at the surface is usually not very solid, and the weight has to be carried on solid ground below the surface.



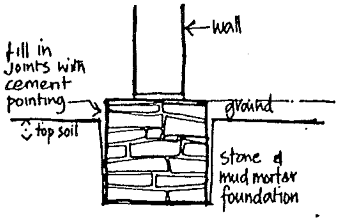
The aim is also to spread the building weight over as large an area as possible, rather than have the weight concentrated on one point: this is to reduce the risk that the building or part of the building will sink into the ground.

There are several types of foundation which can be used.

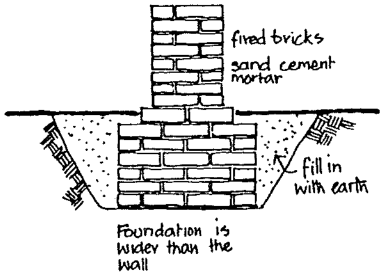
The simplest form, and widely used in the construction of round and rectangular Tukuls, is to place posts in the ground. You need quite a lot of posts to spread the weight of the building, and the posts are likely to be attacked by termites, which means that the lifespan of the building may be short.

An improvement is to put the poles into a base of concrete, and to treat the poles with oil, and poison too if it is available. The concrete base also has the advantage that it helps to spread the load over a larger area of ground.

The post system is only suitable for walls that are also built with posts. For masonry walls you need a more continuous foundation. Whatever materials you have available, always remove the topsoil, which is unstable. If stone is available it can be laid in a mud mortar to provide a basic foundation. This will at least protect the base of the wall from damage by water in the ground and at ground level. The trench that the stone is laid in should be dug down to a firm base. This foundation will carry low weights such as applied by a single storey building. It will be greatly improved by the use of a cement mortar. It is no good if you have an unstable soil, such as in the Jonglei district. Any part of a stone foundation that is exposed above ground level should have the joints filled with a little cement mortar , to protect it from water damage.



Stones can also be laid in a mixture of lime and earth, which will set slowly below ground level but will become very strong after a few weeks. You need to wait several days before you can build on top of a lime based foundation because lime sets very slowly.



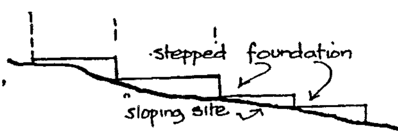
Good fired bricks can also be laid in foundations, but because bricks are small they need to be laid with a cement sand mortar when used for a foundation.

If cement is available, a considerable increase in strength is achieved by putting a 10 - 15 cm deep layer of concrete at the bottom of the foundation.

Whatever the type of foundation, make sure that water will not collect and drain down into the base. Instead water must be able to drain away from the foundation.

Foundation trenches should always be dug down to a hard base, and the bottom of the trench should be level. The foundation should be wider than the wall to be built on top of it, so that the weight of the wall is spread over a larger area.

If the ground is sloping, the foundation must still be based on level trenches, and built up level.



On sloping sites you can use a stepped foundation, going down in level stages. Stepping the foundation will help to save material. Remember that the foundation, especially if it uses stone and cement, can be one of the most expensive parts of the building. Before designing the building you must therefore check the levels to see if steps are needed.

In single storey building the floor will not be structural: it won't affect whether the building stands up or not. However, it should not be ignored, since finishing the floor may use up quite a lot of material, which can cost money.

Where the foundations have been built up above ground level(and this will normally be the case) you will need to fill in between the foundations to raise the floor level. Even if the floor is made only of compacted earth, the amount of earth needed may be more than is available on the site, which means that you will have to find and transport extra material. To avoid this, keep the level of each room close to the ground level (15 - 20 cms above ground level). On sloping sites, as with the stepped foundations, you may need to have each room at a different level. If the levels change a lot, this may make it difficult to cover the building with a single roof: consider building several seperate rooms.

The simplest floor material is compacted earth. If available, you can mix cement in with the earth in a proportion of about 1 part cement to 10 parts earth. Use double this amount if you have lime instead of cement. A more economical floor can be made with a layer of broken bricks and small stones , mixed with dry lime, raked smooth and compacted, and then sprinkled with water.

A cement floor, between 2 and 4 cms thick, gives a very good finish, but it must always be laid on a solid base, made of compacted stones, or bricks if no stones are available.

A good durable floor can be laid with fired clay floor tiles or fired bricks, set in a sand cement mortar.

Drawings represent the real building at a small scale and are your opportunity to check that everything has been thought of before construction work starts. You can check the size and the relationship of rooms; work out where you need walls, columns, openings, and other parts of the building; and look at the detail of how each part of the building will be constructed. This means that you will need to prepare both floor plans, sections and elevations which deal with the whole building, and also draw details to show, for example, a brick bonding pattern in a column.

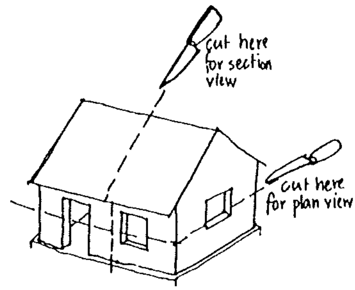
Because the drawings represent the actual building, they provide the basis for calculating the quantities of materials needed and, following this, what everything will cost.

When all the planning is finished, the drawings of the building must contain all the information needed so that builders can construct what has been designed and agreed upon. If the drawings are incomplete or innacurate, the building will be built innacurately as well: the result may not be what the community nor you wanted. You may have wasted money, time and materials. If you think that preparing drawings before you start work is unnecessary, you must remember that it is better to get all the detail right before starting work , and get everyone's approval. As well,it is a good idea to have a signed agreement between the people who have requested the building, the people who are going to build it and yourself; the drawings form the basis of this agreement.

DRAWINGS

There are three main views of a building that we use in order to communicate information clearly and accurately to anyone involved in the project. They are:-

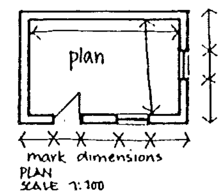
PLANS
ELEVATIONS
SECTIONS.



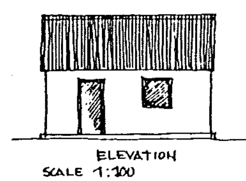
Plans look at the building from above and normally show the layout of the rooms, the position of all the openings and the thicknesses of all the walls.

Plans are normally drawn as if the building has been cut in half just above the window cill level, and the top half removed.

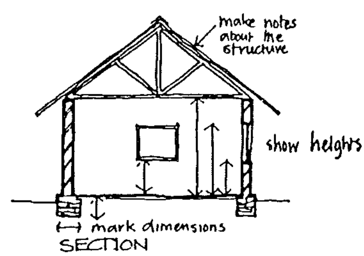
You can also have a roof plan, when you want to show the layout of the roof, and a foundation plan to show the size and shape of the foundations.



Elevations are views of the building from the outside. They are always drawn looking flat at a side of the building, so that you will never see two sides on the same drawing. You have to do a seperate elevation for each side that is different and has something that you need to show: thus you can have a side elevation, and ones for the back, front or other side of the building. If two elevations are the same you can use one drawing and say that it shows both, for example, the east and west sides of the building.

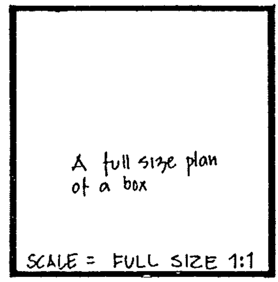


Sections, flat views like the elevations, show the inside of the building. They are cut away views showing the internal structure, such as wall thicknesses, cill heights, roof trusses, and they complement the information provided in the plans and elevations. You may want to have several sections showing different cut away views of the building.

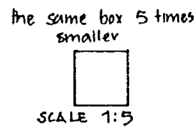


Sections are shown on the floor plan with a symbol like this.............................. which marks where the 'cut' is and which direction you are looking in.

Drawings of the building, and the drawing that you do of the site when it has been surveyed, are all done to scale. This means that the drawing shows an object: the site, the building, a brick etc, at a size smaller than the real object, but in direct proportion to the size of the original object. In other words, you draw something 100 times smaller, or 50 times smaller. A site plan might be drawn, for example, 500 times smaller than the actual site.



This means that a stick measuring 1 metre in real life could be shown on paper, drawn at a scale of 1:100 measuring only 1 centimetre: 100 times smaller than the actual stick, since there are 100 centimetres in a metre.

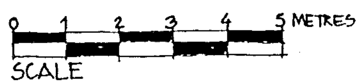


Every drawing should have its scale marked on it like this:

1:10 = ten times smaller
1:50 = fifty times smaller
1:100 = one hundred times smaller

A scale of 1:10 means that 10 centimetres on paper represent 1 metre at full size.
A scale of 1:50 means that 2 centimetres on paper represents 1 metre at full size.

Scales are also drawn like this................



To show different things and materials in the drawing of a building, we use symbols.

In plans you can use the following symbols:

- a window opening in a wall, with no frame nor glass..................................
- a window opening with frame and glass........
- a doorway opening, with no frame nor door....
- a doorway with a frame and a door in it.......
- walls in plan can be drawn like this, with thick lines..................................
  unlike, for example, the wall under a window, which could be drawn with a thin line........

There are symbols for materials as well. These symbols are used mostly in sections.

Concrete...............

Brickwork..............

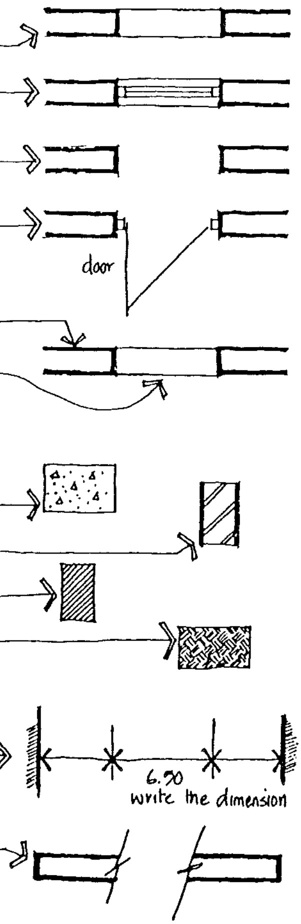
Earth walls............

Earth in the ground.....

But always write down what the material is as well in order to avoid mistakes.

Dimensions on drawings are shown like this......

And this symbol is used to show that the lines continue but have not been drawn because there is not enough room on the paper...............



DETAIL DESIGN

CONTENTS

PAGE 82. INTRODUCTION

When to start Detail Design
What is Detail Design?
Working Drawings
Detail Drawings

PAGE 85. WORKING DRAWINGS

FLOOR PLAN

SECTIONS

ELEVATIONS

FOUNDATION PLAN

SITE PLAN

PAGE 90. DETAIL DRAWINGS

WALLS

ROOF FRAMEWORK

ROOF COVERING

PAGE 93. QUANTITIES

PAGE 97. COSTING

WHEN TO START DETAIL DESIGN ?

The sketch design stage is finished when:

- you are sure that your design for the project meets the needs of function, shelter and structure, and that it will cost no more than the money and resources available. Remember that there is no point in designing a building that you will not be able to finish because either there is not enough money or you cannot get the materials you have chosen.

- the design has been discussed and agreed upon by the community representatives and any other people whose approval is needed, such as an Agency providing help or the people who will work in the building when it is finished.

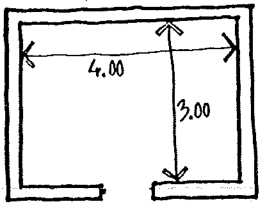
WHAT IS DETAIL DESIGN ?

You can now move on to do the detail design of the building.

In the detail design stage you will work out exactly how the building will be constructed. This includes what materials you need and exactly how big each part and item of the building will be. When the detail design is finished you can work out the exact quantities of materials you need and do a detailed cost estimate.

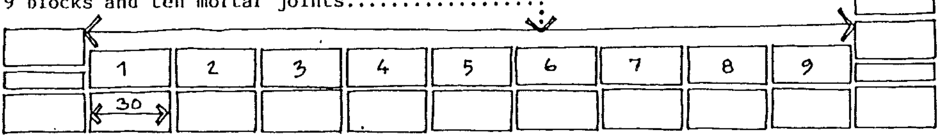
The detail design drawings will have all the information that is needed in order to build the building, and you should be able to hand these drawings to a builder and he will build what you want.

Working out all the exact sizes is important. For example, at the sketch design stage you may have decided that one of the rooms will measure 3 metres wide and 4 metres long, and that it will be built with mud block walls. In the detail design stage you need to make sure that the room size relates to an exact number of block lengths and mortar joints, so that when you build you do not have difficulty in getting the block bonding pattern right, nor have to cut a lot of odd size blocks to get the length right.



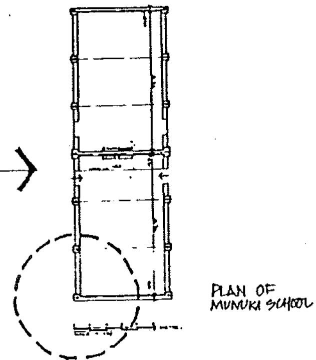
plan
scale 1:100

If the blocks you are going to use are 30 cms long, with 2 cms wide mortar joints, then it will be better to have a room measuring 2.90 x 4.18 metres: a wall 2.90 metres long uses 9 blocks and ten mortar joints.................



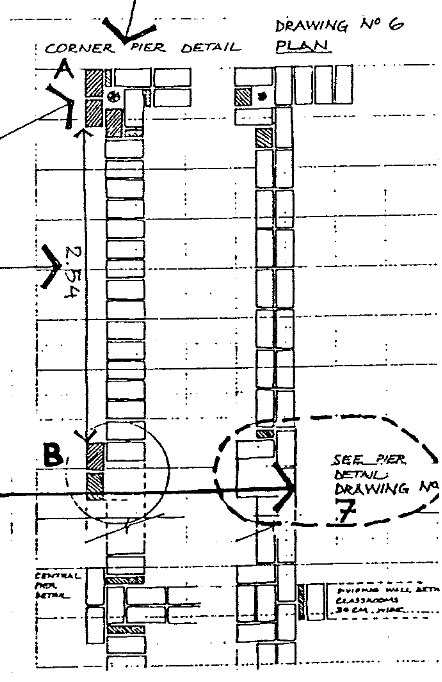
On the following pages are some of the detail design drawings for the Munuki Self Help Primary School, built just outside Juba. They show the type of information you should produce at the detail design stage. In this case the building is quite simple - two classrooms. The more complicated the building gets the more details there are which need to be worked out.

WORKING DRAWINGS



The drawings you do at the detail design stage will show all the notes and dimensions needed in order to build the building. The two most important drawings are the floor plan and the sections. These should contain all the basic information about the building.

However, to develop these drawings you will need to look in detail at how the building is to be put together. This means to work out how the roof framework is made and fixed to the walls, or how the blockwork is bonded in a column.



The drawing shown here is an example of detail design. The drawing shows two courses of blockwork, drawn to scale.

Firstly, the corner pier detail is worked out so that one can see how the blocks need to be cut, and how they fit together.

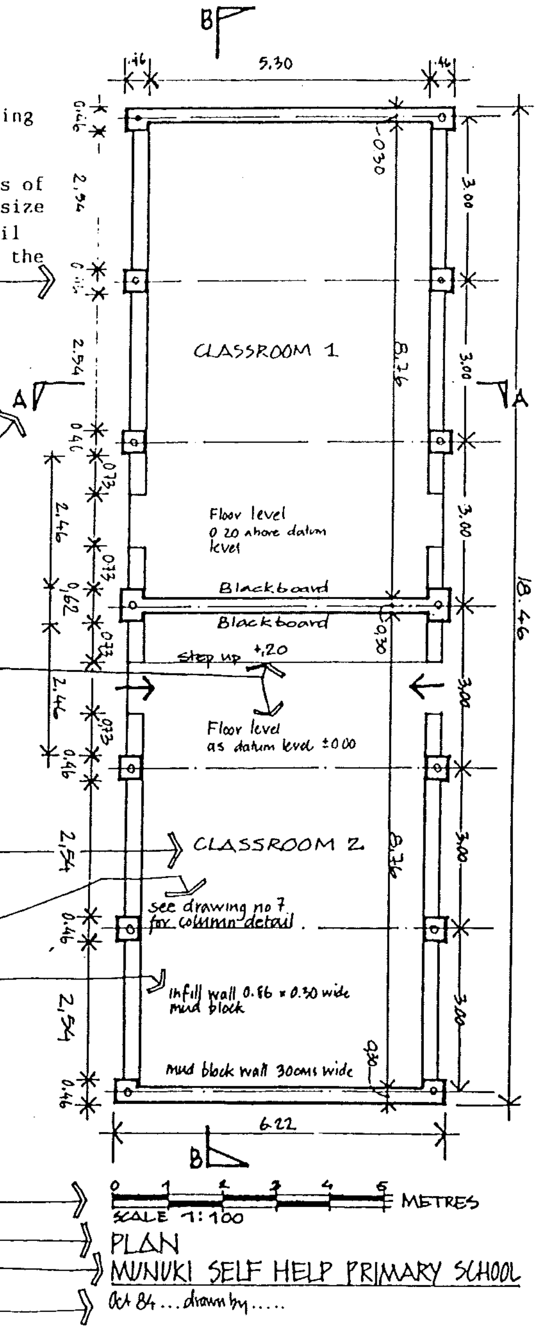
The exact number of blocks on each course are drawn between the corner pier (A) and the column (B). This fixes the dimension between the pier and the column. Using dimensions worked out like this you can now draw the detail plan of the whole building.

DETAIL DRAWINGS

The drawing also refers to another detail drawing which shows how the columns are to be built. You can do as many detail drawings as are needed to work out the design. Number each drawing so that you can refer to it.

The floor plan should show the following information:

- dimensions, including the thickness of walls and columns, as well as the size of rooms and openings. Put in detail dimensions and the overall size of the building.
- section lines, to show where a section cuts through the plan and which way it is looking.
- changes in the level of the floor.
- the name of the room
- which detail drawing to look at
- notes about the construction
- the scale of the drawing.
- the title of the drawing.
- what the project is.
- the date and who drew the plan.



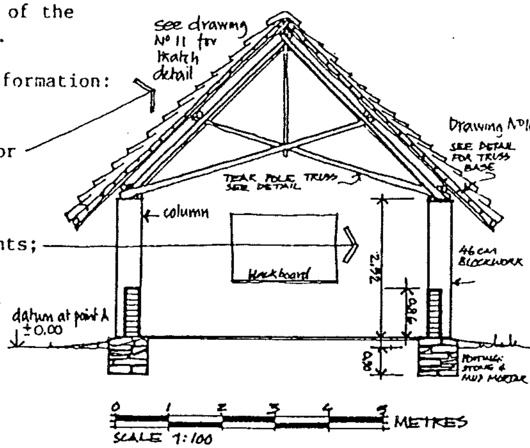
You may need to draw several sections in order to show all the necessary information. On the plan of the building used here as an example, two sections are indicated, with section lines: section A - A; and section B - B. Section B - B is cut along the length of the building. Section A - A is shown here.

A section should show the following information:

- notes about the roof construction.
- which detail drawings to look at for more information.

- all the vertical dimensions of the building:- wall heights; cill heights; position of lintels (if any); foundations.

- the datum point ground level.

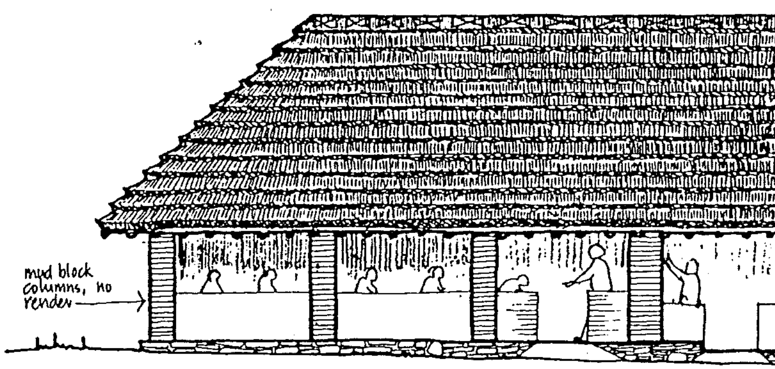


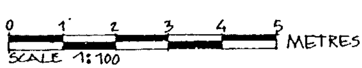
SECTION A-A
MUNUKI SELF HELP PRIMARY SCHOOL
Oct 84... drawn by........

- the scale of the drawing.
- the title of the drawing.
- the name of the project.

The elevations of the building show what the outside of the building is going to look like. You should draw an elevation for each side of the building, unless there are two sides the same, in which case one drawing can be used to show, for example, the 'east and west' elevation.

The elevation can also have notes written on it, especially any information about the outside surface of the building, such as wall coatings, and notes about the roof finish.



Mark the scale of the drawing: 

Mark the title of the drawing, and the name of the project.

SOUTH ELEVATION

MUNUKI SELF HELP PRIMARY SCHOOL

Oct 84 drawn by.....

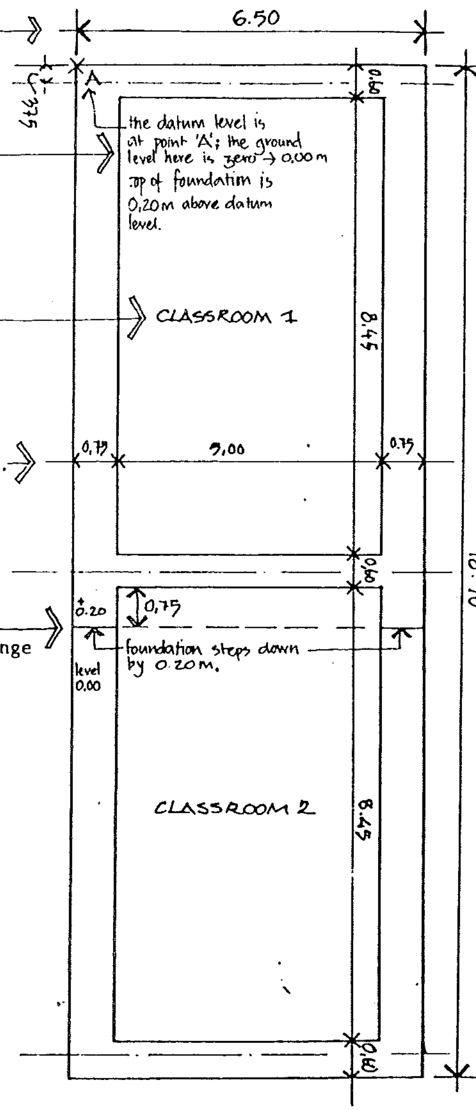
The foundation plan should show the overall dimensions of the building's foundations, which you will need to know when laying out the building on the site.

Mark on the plan where the datum level is, point A. The same point (A) should be marked on the site plan.

Write down the name of each room.

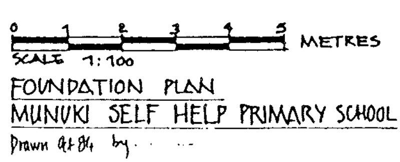
Show the width of the foundation and the measurement between the foundations.

If the foundation changes level, mark where this happens and how much the change in level is.



Mark the scale of the drawing.

Mark the title of the drawing and the name of the project.

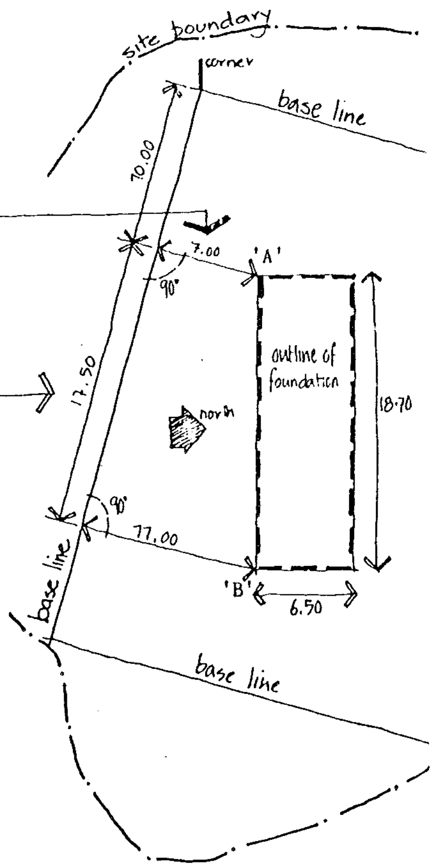


The site plan shows where the building is placed on the site. Draw the site plan carefully using the information from the survey. Mark the base lines onto the site plan, and relate the position of the building to one of the corners made by the base lines.

Measure out from the base line to fix corner 'A'. Make sure that the measurement is at a right angle to the base line.

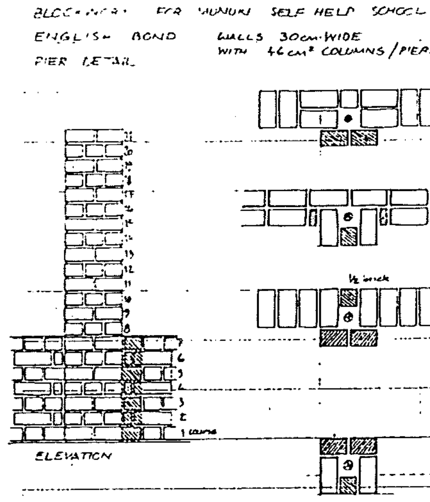
Do the same for corner 'B'.

Mark how far the measuring points out to 'A' and 'B' are from the corner of the base lines.



The drawings on the following three pages are examples of the type of detail that you need to think about and do drawings of.

The detail shown here works out the block bonding pattern on the columns of the Munuki Self Help Primary School. The first seven courses of blockwork have to bond into the low wall on either side of the column, so the bonding will then need to change when the column is above this low wall.

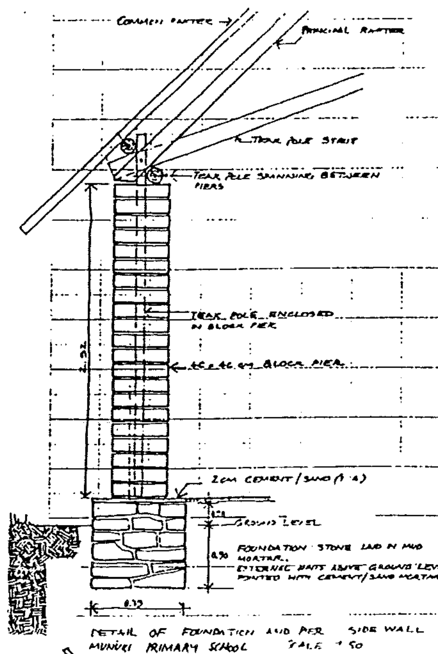


DETAIL DRAWING No 7 PLANS 1:20

This detail section shows the foundations, floor, and basic information about the column and junction with the roof.

This information could be included on a large scale section of the building, but where you do not have large sheets of paper it helps to do smaller detail drawings of parts of the building.

Number each detail drawing in order that it can be referred to on the main plan and sections of the building.



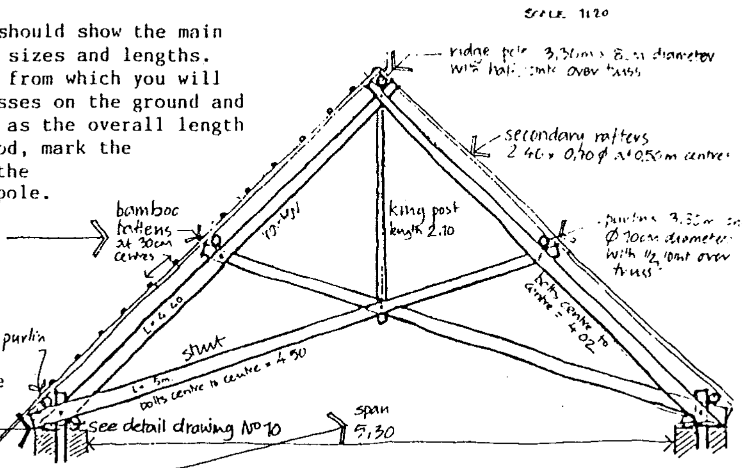
DRAWING No 8

Detail of the roof should show the main timbers, with their sizes and lengths. This is the drawing from which you will lay out the roof trusses on the ground and build them. As well as the overall length of each piece of wood, mark the dimensions between the bolt holes in each pole.

Show the spacing of battens.

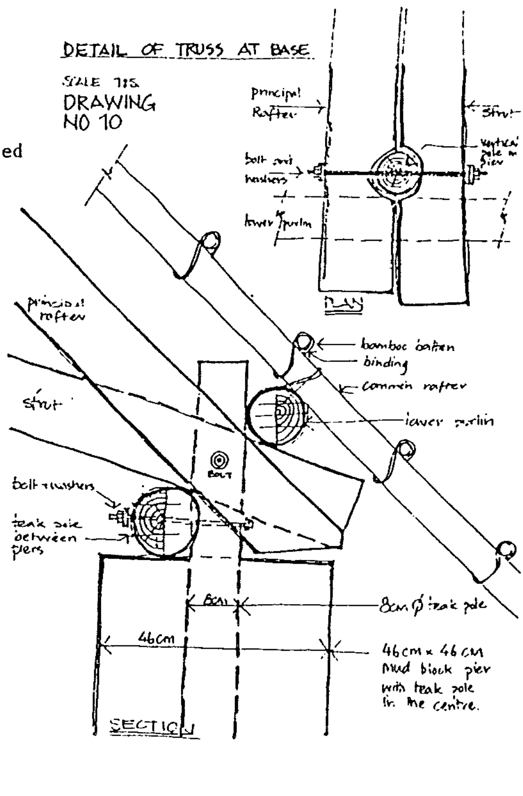
Show where there are more detailed drawings to look at.

Show the span of the roof.



Some parts of the roof framework may need to be worked out in great detail. This drawing shows the base of the truss where it meets the wall.

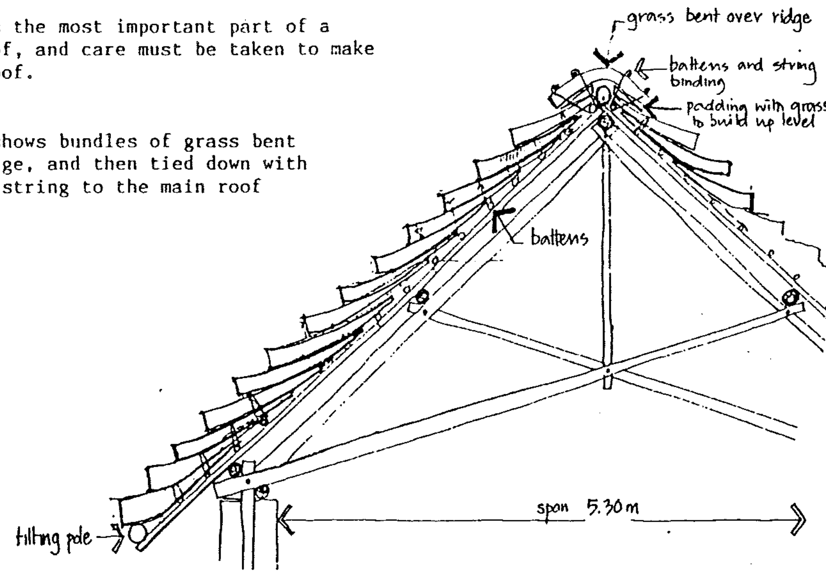
This detail was drawn originally at a scale of 1 : 5, which is a good scale for detailed work.



You can also do details of things which are difficult to draw accurately. The detail below is a section of a thatched roof. It has been drawn as a sketch in order to work out how the grass will be placed on the roof at the eaves and at the ridge. Sketches like this are helpful in working out building problems, or for introducing new ideas.

The ridge is the most important part of a thatched roof, and care must be taken to make it water proof.

The detail shows bundles of grass bent over the ridge, and then tied down with battens and string to the main roof battens.



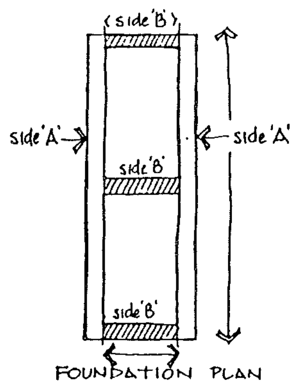
At the eaves a tilting pole is used to force the thatch upwards and into tension, which helps to pack the thatching grass more tightly and make it last longer.

Using the completed detail design drawings, now work out the quantities of materials that you will need for the building.

The quantities tell you how much material to order, and what the building materials will cost: for example, if you need 20 bundles of bamboo, and each bundle of bamboo costs £s 20.000, then the total cost of bamboos will be 20 x £s 20.000 which equals £s 400.000.

The quantities are not difficult to work out, but you must work carefully through the building, from the digging out of the foundation to the covering of the roof, adding up every item you will need.

The following is an example, using the Munuki School plan. With the detail drawings you have all the information that you need, about sizes and amounts.



1. FOUNDATIONS

The foundation is stone with mud mortar, with a cement/sand mortar in the exposed joints above ground level.

The depth of the foundation is 0.70m.

Take the plan of the building and divide it up into equal size parts: in this case you have two equal sides 'A', and three equal sides 'B'.

Foundation 'A' is 0.75m wide and 18.69m long. The depth is 0.70m. The volume of the 'A' foundation is therefore: .... 0.75 x 18.69 x 0.70 = 9.8m³

There are two sides 'A', so multiply 9.8m³ by 2: .... 9.8 x 2 = 19.6m³

Foundation 'B' is 0.60m wide and 5.00m long.
Repeat the process for the sides 'B'..............$0.60 \times 5.00 \times 0.70 = 2.1m^3$

There are three sides 'B', so multiply $2.1m^3$ by 3...$2.1m^3 \times 3 = \underline{6.3m^3}$

Add the sides 'A' and 'B' together: ....$19.6 + 6.3 = \underline{25.9m^3}$

This gives you the volume of stone <u>and</u> mortar needed for the foundation. The mortar occupies about 30% of this volume, so you will need 70% of the volume in stone........................$\frac{25.9m^3}{10} \times 7 = 18.13m^3$

Allow 10% extra, to be sure that you have enough material:.................................. $\frac{18.13}{10} \times 11 = 20\ m^3$.

You need 20 m^3 stone for the foundations. If, for example, you have a lorry which can carry 4 m^3 each time, you will need 5 lorry loads. Knowing this makes it easy to order the material.

You now need to work out what you need for the mud mortar. The volume of mud is 0.3 of the total foundation volume............................$\frac{25.9m^3}{10} \times 3 = 7.77m^3$

If earth is not available on the site you will need to have it delivered. How much earth? You need $1.5m^3$ loose earth to make $1m^3$ mud. So, multiply the volume of mud by 1.5, in order to see how much earth you need..............$\frac{7.77}{10} \times 15 = 11.65m^3$
Allow 10% extra.... = $\underline{12.8\ m^3}$.
Using a lorry which can carry $4m^3$, you need about 3 lorry loads of earth.

You will need water for making the mud: about 0.3 of the volume of the mud itself: ....$\frac{7.77}{3} = 2.6\ m^3$ water.

$1m^3$ equals 1000 litres, so you need 2600 litres. If the water is going to be delivered in barrels, divide the total by the volume of the barrel, 200 litres...................................... $2600 \div 200 =$ <u>13 barrels</u>.

You now need to calculate how much cement mortar you need for pointing the exposed joints.

Firstly, work out how much foundation is exposed. This means the outside edges of the foundation only. The two 'A' sides are 0.20 above ground level, and are 18.69m long....... the exposed area is therefore the height times the length times 2, since there are two sides:........................2 x 18.69 x 0.20 = 7.5m²

(length)

The two short sides 'B' have a total exposed area of...2 x 6.50 x 0.20 = 2.6m²

Total exposed foundation is 10.10m²

1m² of wall needs about 4.5kg cement for the pointing mortar; and using a sand cement mix of 1 part cement to 8 parts sand, you need about 0.28m³ sand for each 1m² of wall.

For the school, multiply these quantities by the amount of foundation that is exposed: 10.1m²..........10.1 x 4.5kg cement = 45.5kg

10.1 x 0.07m³ sand = 0.6m³

Each sack of cement weighs 50kg, so you need..........50 ÷ 45.5kg = 1 sack.

When you have finished the foundations, continue with the rest of the building, for example:-

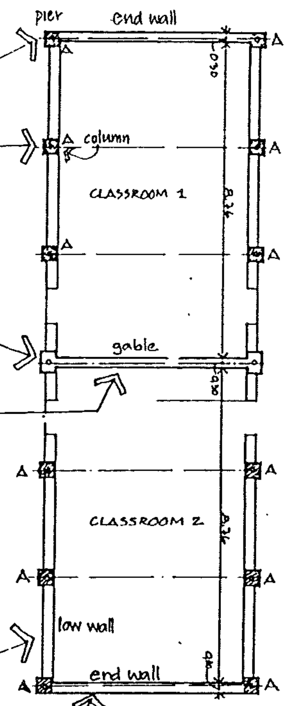
- cement finish on top of foundations
- floor
- walls, including posts in columns
- roof framework
- roof covering
- doors and windows, mosquito netting, and security wire
- paint

For the cement finish on top of the foundations, and the floor, work out the area to be covered and multiply this by the depth of material.

If the walls are made of bricks or blocks, you need to calculate the volume of wall, and then see how many blocks or bricks you need to build this volume of wall (and columns).

To work out the volume, divide the building into smaller parts as you did for the foundations, for example:-

- columns and piers.
- low walls between columns.
- end walls.
- gable wall.



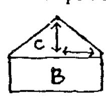
1. Take all columns and piers measuring 'A' 0.46 x 0.46: there are 12 of them, 2.5m high:-

   $$12 \times .46 \times .46 \times 2.5 = 6.35\text{m}^3$$

2. Work out the same for the two piers at the end of the gable wall:-

   $$2 \times .46 \times .62 \times 2.5 = 1.43\text{m}^3$$

3. Work out the volume of the gable wall. To do this divide the wall in to a lower part, which is a rectangle... 'B'

   and an upper part, 'C' which is a triangle. To work out the surface area of this triangle, multiply half the width by the height:-

   $$3.0 \times 2.65 = 7.95\text{m}^2$$

   Multiply this by the thickness of the wall to get the volume.

4. Work out the volume of the low walls.... and of the end walls....................

Add the volumes up to find the total volume of wall. For the plan used here, the total volume is <u>29.70 m³</u>

When you have worked out the total volume of the wall, divide it by the volume of each brick or block. But subtract about $\frac{1}{3}$ of the volume for the mortar. Therfore, you need $\frac{1}{3}$ of 29.7m³ for mortar:- 10m³ mortar.

.... and take the remaining $\frac{2}{3}$ of the volume, 19.7m³, and divide it by the volume of the block or brick; for example, a mud block can measure .30 x .14 x .10. divided into 19.7m³ gives you 4700 blocks. Allow 10% extra for breakage............. 4700 x 1.10 = 5170 blocks

You can then work out how much earth and water you need for the mortar in the same way that it was done for the foundations.

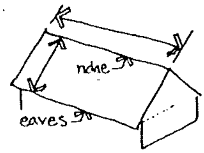
To work out the roof framework you have to list every item:-

- wall plates
- principal rafters
- struts and tie beams
- king posts
- ridge poles
- secondary rafters
- purlins
- battens

and all the bolts; washers; nails; string and binding twine.

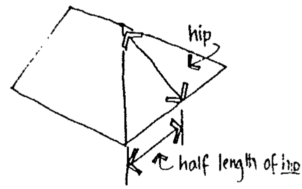
For each item, count how many there are, and the dimensions of the item. For example:-

Ridge pole: 4 poles, 3.23 metres long, 0.15 metres diametre.



For the roof covering, work out the roof area. For each slope of the roof, multiply the length of the slope by the measurement from the eaves to the ridge.

For the hipped end of a roof, multiply half the length of the hip by the measurement from the eaves to the ridge.



When working out how many roof sheets you will need to cover a roof, do not forget the overlap on each sheet. The overlap will vary, but you should allow at least 15 cms vertical lap, and between 5 and 15 cms horizontal lap.

To work out how much grass you need for thatching will come from experience, but it may help to look at a well thatched roof and count how many bundles of grass have been used in one M^2.

For thatch and for tiles always allow more material than you have worked out, because there will be a certain amount wasted or broken. Add 10% on to the quantities.

COSTING

When you have worked out all the quantities, you can now work out what the materials will cost.

For each part of the building: foundation; floor; walls..... , draw up a chart showing the following:-

1. Each material used, with a description when necessary, and dimensions. For example, in foundations you would list stone, mud, water, sand and cement. In the roof framework section you would need to describe each item, for example; - struts, 5m x .15m diameter teak pole.

2. Next to each item, mark the unit it is measured in: litres; metre^2; metre^3; metres; sacks; etc.

3. Next write down how many units needed, for example if you need 5 sacks of cement you write down '5'; in the roof you would list , for example, the number of battens needed as: metres - 150

4. Now write down the price per unit: this price you will have to get from the local markets and suppliers.

5. Multiply the number of units by the price in order to get the total cost for this item.

At the end of each section add up the prices to get the total cost.

Below is an example of this chart:-

ITEM	Unit	Quantity	Unit Price	Cost	Total Cost
B. FOUNDATIONS					
Stone (from quarry)	m^3	20	39,000	780,000	
Earth labour cost only	m^3	13	—		
Water in 200 litre barrels	barrel	13	0.500	6.500	
Sand labour cost only	m^3	0·30	—		
cement	sack	1	30,000	30.000	816.500
C. CEMENT FINISH ON FOUNDATION					
Sand					
Cement					

ORGANISATION

CONTENTS

PAGE 104. SIGNED AGREEMENTS

PAGE 105. ACCOUNTS

PAGE 107. SITE BOOK

PAGE 109. SITE ORGANISATION

PAGE 110. TOOLS AND EQUIPMENT

Before starting any work make all the people who will be involved in the building programme sign agreements. These take the form of contracts between the following groups or people:-

- the community representatives,
- the people who will run the facility (e.g. school or hospital),
- and yourself.

If the community are going to work on the building programme, you also need to clearly explain what you expect the community to provide -

- labour or skills
- materials
- equipment and tools
- food and water -

and once their contribution is worked out, make a signed agreement showing what they are going to do.

These agreements are important. You will be responsible for organising the building programme; for seeing that the building is constucted according to the plan; and for working to a programme. You do not want people to try and change the design of the building after it has been started, nor change the contribution they are going to make. Remember that it is much easier to say you will do something than it is to do it!

Keeping to a programme is also important. If the work goes too slowly you may find that, for example, you have not finished the building before the rains start which can cause damage.

Finally, the agreements are your protection, so that other people involved in the programme will not argue about what you have done, nor complain about the way you have done it!

From start to finish of the project you must keep accounts: a record of how much money you have available for the project, and, as the project develops, how much of this money you have spent. It is important that you do not spend at any one stage of the building, more money than has been allowed for it.

For example, after working out the quantities and doing the costing for all the building, you know that the foundations should cost £s 816.500. When you have built the foundations you find, by doing the accounts, that you have spent more money than estimated, £s 1500.000. You have overspent. The rest of the building will have to be done with less money than estimated, or you will run out of money before you finish.

There are many examples of buildings which did not get finished because the money ran out. Make sure that the cost estimates agree with the amount of money available, and then use the accounts to be sure that you are not spending too much of the money.

The accounts will also show you exactly how the money was spent: item by item you will be able to see what everything cost. From this you can see which item, if any, is costing too much, and therefore where you must try and save money, perhaps by finding a cheaper material.

Accounting is quite simple. Basically, you need three columns. The first column shows how much money is available: MONEY IN. This is the money given for the project, perhaps by the government, or by an agency, or by the community.

The second column shows item by item how the money was spent: MONEY OUT. You write down here the cost of everything you spend money on.

The third column shows, week by week or day by day, how much money you have left: BALANCE, which means: 'money in' minus 'money out'.

The accounts should include, in the 'money out' column, any labour costs as well as material and transport costs.

You can divide up the first two columns to show more detail:-

- the Money In column should show, for each entry, the date, who gave the money, and how much.

- the Money Out column should show, for each entry, the date, the receipt number (always get a receipt for everything you spend money on), the item, and what it cost. If you are paying for labour, make a column for this as well. At the right hand side of the Money Out column, leave a space for adding up the total.

Below you will see an example of accounting. Keep a note book or an excercise book for the accounts, and keep all your receipts.

Column 1			column 2							Column 3
MONEY IN			MONEY OUT							
DATE	RECIEVED FROM	AMOUNT Rs	DATE	RECEIPT NO.	ITEM	QUANTITY BOUGHT	COST	LABOUR COST	TOTAL COST	BALANCE
17/11	community fund	1000.000								1000.000
			18/11	1	Stone	4m³	156.000	34.000	190.000	810.000
				2	Water	5 barrels	2.500	—	2.500	807.500
				3	Earth	3m³	—	50.000	50.000	757.500
				4	Used engine Oil	1 barrel	25.000	5.000	30.000	727.500
			20/11	5	Bamboos	180 bundles	200.000	10.000	210.000	517.500
				6	Teak Poles	80 poles	304.000	20.000	324.000	193.500
			22/11	7	Debarking Poles	30	—	15.000	15000	178.500
25/11	donation from agency	2000.000								+ 2178.500

add new amount of money in see column 1.

On the site, keep a site book. At the end of each day, or after every morning and afternoon work period, write down the following information:-

1. Date.
2. What the weather was like.
3. Activity on the building site.
   Write down each activity; for example:
   i. Block-making.
   ii. Laying stone in foundation.
   iii. ....

   For each activity, write down-

   (1) How many skilled workers; example: .... 2 block-makers.
   or: .... 1 mason.

   (2) How long they worked; example:..........2 hours.

   (3) How many unskilled workers; example:...'5'

   (4) How long they worked; example:......... 3 hours.

   (5) How much work was done; example:....... 3 courses brickwork.
   or:....... 200 blocks made.

   (6) How much material was used; example:... 2 sacks cement.
   100 litres water

   (7) Any comments, reasons for delays or stoppages; example:.................... ran out of water.

DATE	WEATHER	ACTIVITY	NUMBER OF SKILLED WORKERS	HOURS WORKED	NUMBER OF UNSKILLED WORKERS	HOURS WORKED	WORK DONE	MATERIALS USED	COMMENTS
2/5	FAIR	Dig foundation	1 builder	3	4	8	Trench complete classroom 1	none	good progress
3/5	Rain in morning	blockmaking	1 block maker	7	4	7	200 blocks	6 barrells water	
		dig foundation	1 builder	8	4	8	Trench complete classroom 2	none	
4/5									

<u>Keep a record of materials</u>; fill it in each day.

In the site book, draw four colums. Write the following information in each column:-

	Column 1	Column 2	Column 3	Column 4
	Material delivered on site.	Material used	Material remaining at end of day	Number of deliveries by truck, cart, etc.
May 2.	example: 20 sacks cement	14 sacks cement	6 sacks cement	2 donkey cart loads

Keep a record for all materials. Column 3 will tell you how much material you have left at the end of each day. <u>Re-order before you run out.</u>

At the end of each week, add up how much material has been used, and how much work has been done.

Check with the estimates for materials to see if you are using too much material. This is one way of seeing if people are stealing materials from the site.

Check and see if work is going slower than you expected; you will be able to do this by comparing this project with earlier projects you have done.

If you wish, you can add general comments in the site book, at the end of each day. The site book is important because:

- it allows you to control the work, the materials used, and to order more before you run out.

- it is a record of what has happenned on site which you can show to anybody who wants to know how you are getting on.

- it is a record of your experience and will help you in future jobs.

To make the building programme easier, you need to organise the building site. You should allow space for materials to be delivered, and have earth, sand, gravel and stones put not far away from the building but also where a lorry can get to from the site entrance.

You should leave an area for the workers to wash, and you may need to provide a temporary latrine.

Some basic things to plan for are as follow:-

- latrine
- washing and changing area
- store
- water supply and storage area
- access for deliveries
- blockmaking, setting up roof truss
- sand, gravel, earth and stone dumps
- guard's shelter

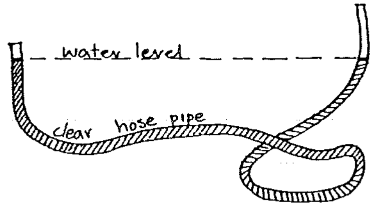
Most of these will be cleared away when the job is finished. The latrine and the guardian's shelter could be put in the place where they will need to be after the building is completed.

You will need to get tools and equipment for the building site.

The following are some of the things you may need. Not all of them will be available, and different types of construction need different tools:-

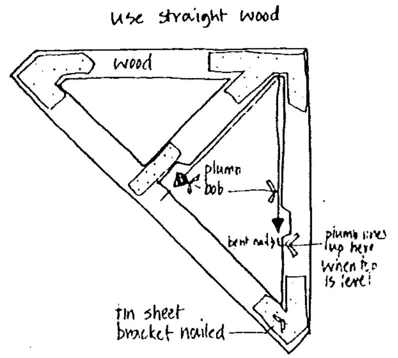
- shovels
- pickaxes
- digging hoes
- digging iron
- wheelbarrow
- tape measure - short and long
- plumb bobs
- hammer
- saw
- spirit level*
- string
- mason's trowel
- buckets
- mortar bowls
- straight board for levelling
- straight board for smoothing cement and concrete
- wood for pegs and site boards
- grass cutting sickles
- block-making frame
- paint brush for putting oil on wood
- hand drill and bit
- hose
- nails
- sieve (6mm)
- First Aid kit
- water containers
- drinking water containers

* If a spirit level is not available you can make a level by using a short length of hose-pipe, 1 - 1.50m long, and putting water in it.........



.... the water will be at the same level at each end of the hose-pipe.

You can also make a builder's handlevel and square with the use of a plumb bob and a wooden square. Use 'Pythagoras theorem' (see page 24) to make sure the angles are at 90° (a right angle).



On the building site you need to arrange a water supply and transport, as well as a way of storing equipment and materials. The community may help you with this, but it will be easier to keep small tools in a metal box with a padlock on it. Have a watchman to guard large pieces of equipment.

CONSTRUCTION

CONTENTS

LAYING OUT
PAGE 116.

FOUNDATIONS
PAGE 118.

Mark Trench Lines
Mark Levels
Foundation Digging
Levelling off Foundation

WALLS
PAGE 121.

LAYING OUT

BUILDING

BRICK AND BLOCK LAYING

GABLE WALLS / LINTELS

ROOF
PAGE 126.

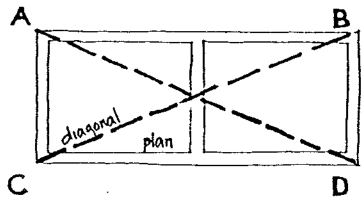
WALL PLATE / TRUSS

TRUSS

PURLINS

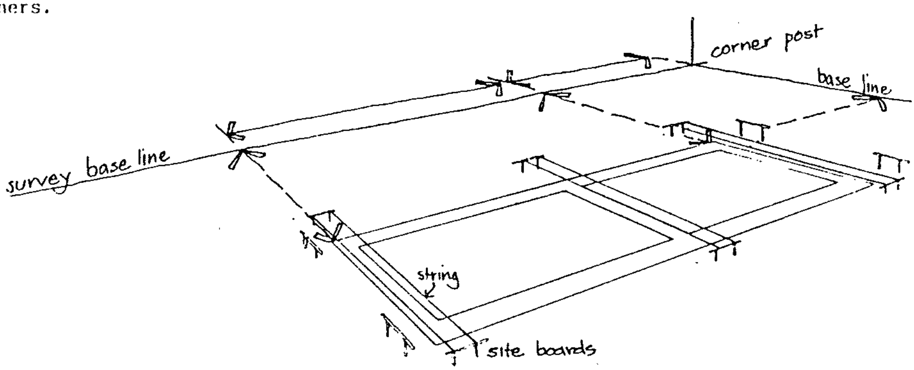
SECONDARY RAFTERS / BATTENS

THATCHING

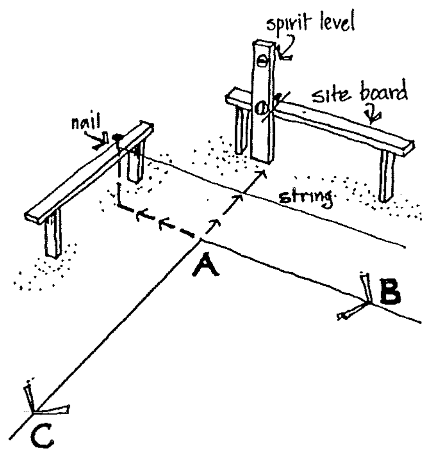


Lay out on the ground where the foundations will be. To begin, measure out from the survey base line in order to locate the corners of the foundations - A, B, C, D.

To check that the corners are right angles, measure the two diagonal lines A - D and B - C. These diagonals must be the same length if the rectangle has right angle corners.



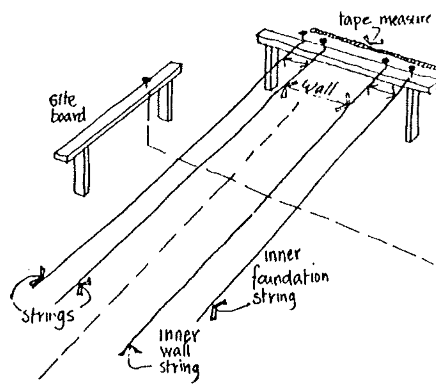
At each corner, you put two site boards. You should also put site boards opposite the point where an internal wall meets an external wall. The site boards are placed just outside the limits of the foundations. The site boards will have nails put in them to mark the inner and outer edges of the foundations.



To find the position of these nails, follow this example:-

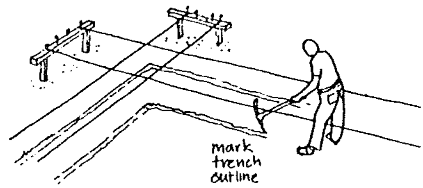
- Continue the line A - B along until it is under the site board. This line is the outer edge of the foundation on side A - B.
- Use a spirit level or a plumb bob to mark the position of this line on the site board.
- Put a nail in at this spot on the board.
- A string running from this nail on site board A to a similar nail on site board B will follow the outer edge of the foundation.

To mark the position of the inner edge of the foundation, and also of the inner and outer sides of the wall, use the measurements marked on the foundation plan and the floor plan: measure across the site board, putting in a nail to mark each point. You can then run strings along the lines of the walls and foundations. The strings will later help you to check if you are digging in the right place.



MARK TRENCH LINES

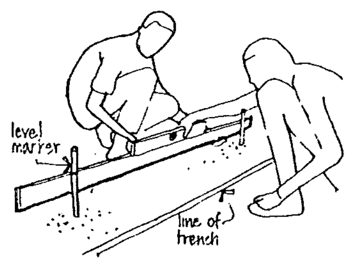
Use a spade, hoe or pick-axe to mark the line of the foundation on the ground, exactly below the strings attached to the foundation nails.



MARK LEVELS

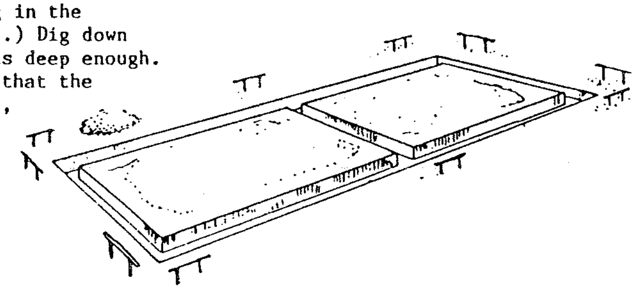
Mark on the site board at the highest corner of the site the level of the top of the foundation. Remember that the foundation levels have been marked on the foundation plan.

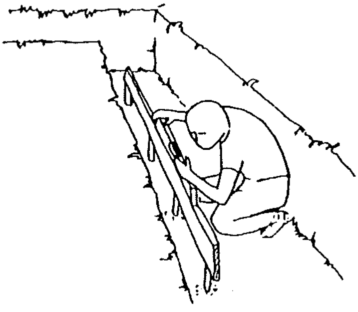
Using a straight piece of wood and a spirit level, put in more level markers every 2 or 3 metres along the side of the foundation. This means that you can check the depth you need to build to, and - later on - how high to build up the foundation.



FOUNDATION DIGGING

When this has been completed, you can dig out the foundation trench. (You can place some of the earth you dig out in the middle of the building, so that it can be used later for filling in the floor up to the correct level.) Dig down until the foundation trench is deep enough. Don't go too deep. Make sure that the bottom of the trench is level, and using the strings, check the the sides of the foundation trench are wide enough.



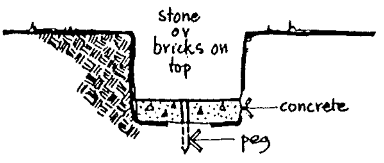


If you are using concrete at the bottom of the foundation, hammer pegs into the bottom of the trench, at 1.5 metre gaps. Hammer the pegs in until the top of each peg is at the level of the top of the concrete. Check this with the straight board and spirit level, measuring down from the levels marked at the side of the foundation trench.

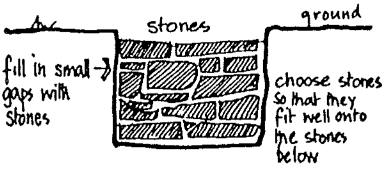
When this has been done, pour the concrete in until it comes up to the top of the pegs. Leave it to dry for about two days. If the weather is hot and sunny, cover the concrete with grass or old cement sacks so that it is shaded and does not dry too fast and crack.

A concrete base can be laid to a depth of 20 to 30 cms. A concrete mix should have roughly the following mixture:

- 1 part cement
- 3 parts clean sand
- 4 parts clean gravel

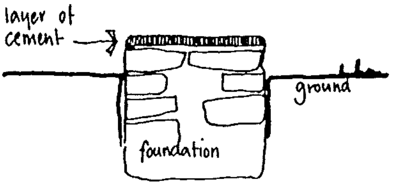


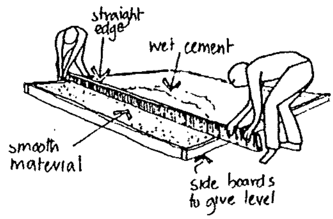
If you are laying stones in the foundation, make sure that each stone is well-bedded in, which means that it must be placed on the mud or cement mortar so that there is mortar in contact with all parts of the bottom of the stone, and so that the stone will not rock if you press down or stand on it. If you are using large stones, you can fill in small gaps with small stones, to bring each layer of stone up to a level finish, ready for the next layer of stone to go on top.



LEVELLING OFF FOUNDATION

The top of the foundation can be levelled off with a thin layer of cement, if available. This provides a smooth surface for the wall to be built on, and also makes it more difficult for termites to pass into the walls. The cement can be between 2 and 4 cms thick. Allow the cement to dry slowly in the shade.



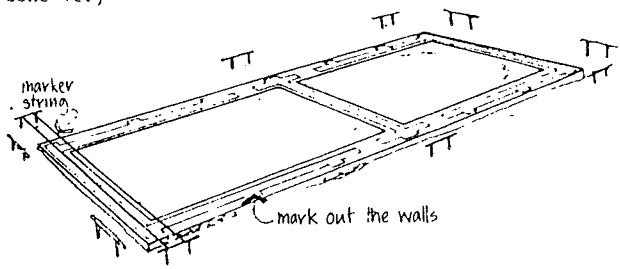


Level wet cement or concrete by pulling a straight edged board along the surface of the wet material. The two ends of the board should rest upon pieces of wood which have been placed so that their top edge is level with the desired surface of the cement or concrete. Any material above the desired level will be scraped away by the board. Pull it over the wet material using a side to side motion which you will find easier than just pulling pulling the board straight across.

After smoothing out the cement with the board, use a trowel to give a good finish to the surface.

When the foundations have been completed, remove the foundation strings and replace them with the strings that mark out the walls.

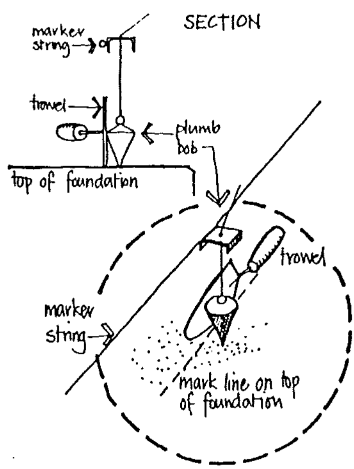
Marking out the walls must be done very carefully.



Use a plumb bob to mark the line of the string down onto the finished foundation underneath. Mark this point with a line drawn with your trowel.

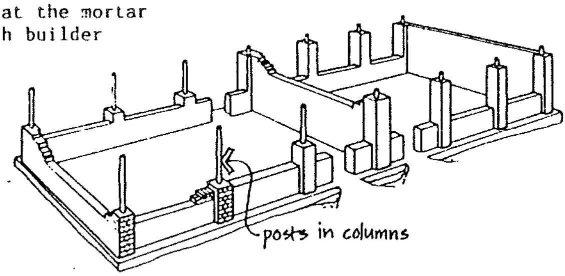
You can mark a corner by repeating the same process for the two lines which are at right angles to each other.

Using the information marked on the floor plan of the building, you can now draw out all the walls and columns, as well as door openings, on the foundation. In fact what you are doing here is drawing out the building at full scale.



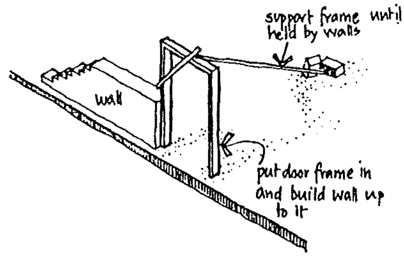
Laying out is particularly important when you are going to build walls with bricks or blocks, which need to be laid accurately so that the bonding of the masonry is correct.

Start wall-building at the corners. If you have a large building, and several builders, you can begin the walls in more than one part of the building at the same time, but be careful to make sure that the mortar joints and courses done by each builder keep the same levels.



If there are door frames in the openings, you should put them in place before starting to build the walls, so that the wall can be built up to the frame.

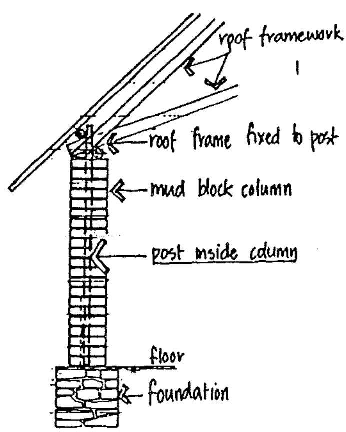
The same should be done with window frames when you have reached the level of the window cills.



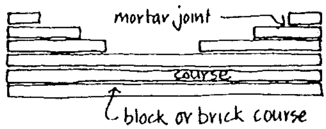
As you get higher up the building you will need to build up a platform for the builder to stand on. If you have old oil drums you can stand these on end and place a plank between the two of them. You can also build a simple wooden frame with timber, nails, and rope.

In the detail section shown here, the mud block column has a wooden post inside it. The post can be thin. Its purpose is to provide a good fixing point between the column and the roof framework.

Another way of making a fixing point is to put a piece of wire or metal into the column. This can than be tied or nailed to the wood of the roof framework.



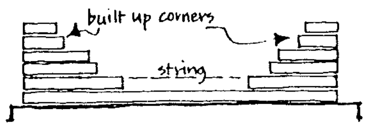
Walls of bricks or blocks should be built up with the bricks or blocks laid in neat level courses, and with the sides of the wall vertical.



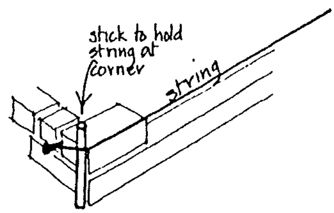
Each layer of bricks or blocks is called a course.

In between each course there is a mortar joint.

To keep the courses level it helps to build up the corners of the building, and if the wall is long, part of the wall in the middle as well, to a height of 5 or 6 courses. You can use a measuring stick or a level to check that each part is built up to the same height. When this has been done, stretch a string between the built up parts, so that the string is level with the top of the course that you are about to build, and then fill in the remaining wall.

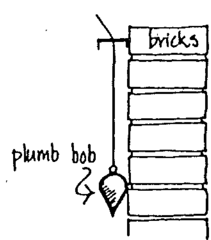


You can check that you are building level by using a level and a piece of straight wood.



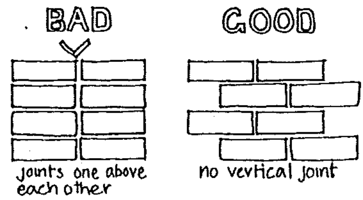
Use a plumb line to get the sides of the wall vertical. If the plumb bob either touches the wall or hangs away from the wall the bricks are not being laid exactly one above each other.

Mortar joints, both vertical and horizontal, should not be too thick, or too thin. With mud blocks try and make the joints about 2 cms thick.
With fired bricks try and make the joints about 1 cm thick.
Brick and block dimensions are chosen to allow for these joint thicknesses: the width of the block is just less than ½ the length of the block, so that two widths + a mortar joint are the same as the whole length.



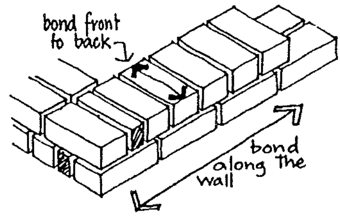
When laying bricks or blocks, in all cases, and no matter what mortar you are using, you should ensure that the brick or block is wet before laying it on the mortar: this helps it stick. With mud blocks the damp surface of the block will mix with the mud mortar.

Bricks and blocks must always be laid so that there is no vertical joint in one layer or course which is directly over the joints of the course below it or under the joints of the course above it. This is called bonding and is important in order to have a strong wall. If there is one joint above another a natural line will exist up which cracking can occur, which means that the wall would be weak.



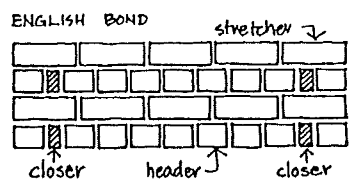
Walls which are only one brick width thick only need to be bonded in one direction: along the length of the wall. This is not difficult.

Walls which are one brick length thick or more need to be bonded both along the wall.......... and from the front to the back, which means that you do not want to have the front half of the wall seperated from the back half.



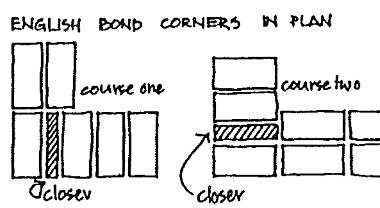
There are two common bonds which you can use to get a strong wall. One is called the English Bond, the other the Flemish Bond.

The English Bond looks like this in elevation. One course is laid with <u>headers</u>, which are bricks laid with their length going accross the wall. The next course is laid with <u>stretchers</u>, which run along the wall so that you can see the full length of each brick.

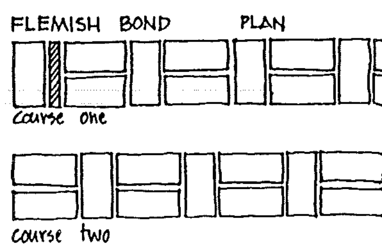


At corners and openings, a ½ brick called a <u>closer</u> is always laid next to the first header This is in order to make the position of the joints correct.

The corner of an English bond wall looks like this in plan. You will see here that one course has been drawn with headers, and then the next course, above, with stretchers.



Flemish bonding alternates headers and stretchers on each course, but there is still a closer beside the first header. It is not quite as strong a bond as the English Bond. It is shown here in plan.



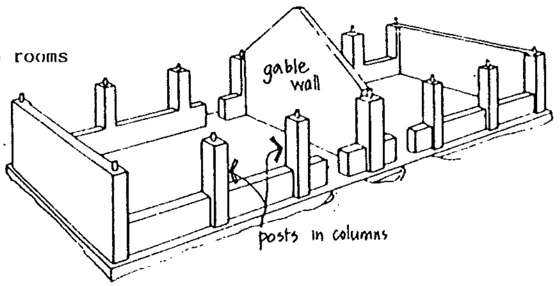
Special situations such as the meeting of a wall with a column will create new bonding paterns. You will have to work out the patterns. Do drawings for this each time.

GABLE WALLS / LINTELS

Finish all the wall-building before you start work on the roof. Make sure that all the walls and columns are up to the right level.

GABLE WALLS

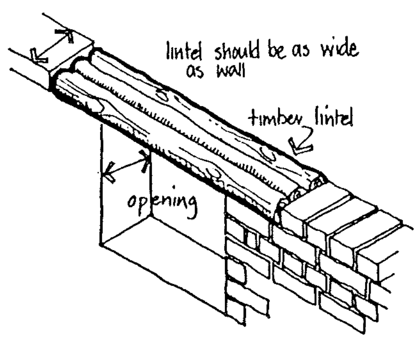
In the building shown here the two rooms are seperated by a gable. This wall is built up to have the same slope as the roof, and it helps to support the roof and make it stable.

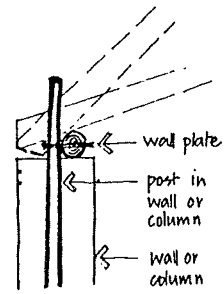


LINTELS

Buildings which have openings in the walls will need to have lintels over the openings. Different types of lintel have been looked at in the Sketch Design stage (see Openings).

In all cases the lintel must be made as wide as the wall that it has to support. This will mean that you may have to use two or three pieces of wood side by side to make up the thickness of the wall.



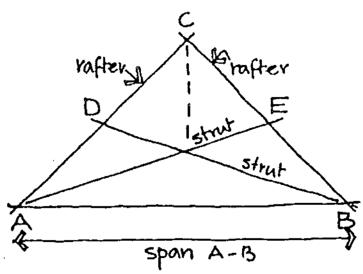


On top of the finished walls and between the columns you place a wooden pole. Over a wall this is called a wall plate. The pole is fixed to the posts which stick up above the top of the columns and at the corners of the walls. You can tie the pole and the post together with wire or string, but the best fixing is with a bolt.

The building is now ready to have the roof trusses put on it.

The roof trusses should be made on the ground and then lifted into place.

To make the roof trusses, work with the detail drawing of the truss.



ROOF TRUSS

Measure out the span of the truss A - B, and mark these two points on the ground at full scale.

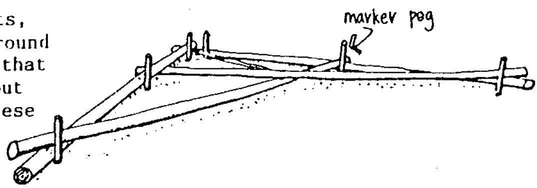
Measure the length of the two rafters, and mark the point where they meet on the ground at C.

Measure half way along each of the rafters to find the point where the strut begins, D and E. Mark these two points on the ground.

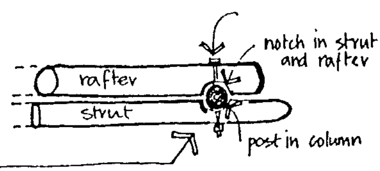
Now choose the poles that you are going to use for making the truss. They should be as straight as possible, and if you have a choice between thick and thin poles, choose the thick ones.

Strip all the bark off the poles. This will help to reduce termite attack. If you can get some used engine oil, paint it onto the poles as this will make them last longer. If poison is available, mix it with the oil.

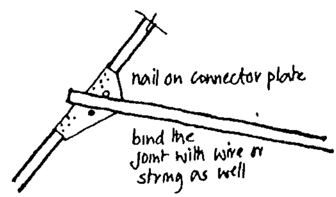
When the poles are dry, lay one along the line of each of the rafters, A - C and B - C, and along the line of the struts, A - E, and B - D. Put pegs into the ground beside each pole at A,B,C,D and E, so that the next truss you build can be laid out simply by placing the poles against these pegs.



If you are going to use bolts for fixing the truss together, drill holes through each of the points where two poles cross, and then bolt them together. At the base of the truss, drill the hole but don't put the bolt in yet. Cut out a notch between the rafter and the strut so that the post that sticks up out of the columns can fit between the strut and the rafter.



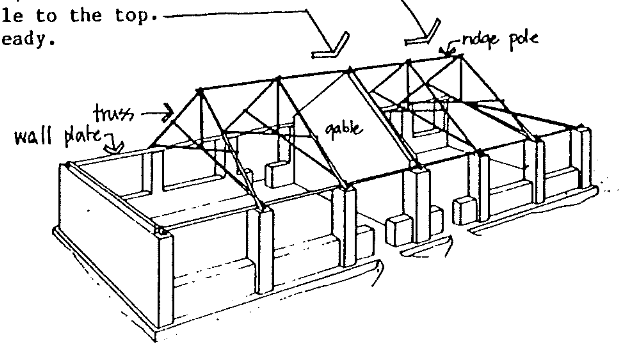
If you do not have bolts, you can tie the poles together with wire. This is not very strong. Try and find a flat piece of wood which you can put between the two poles and which you can nail to each pole, to act as a connector plate.



Make as many trusses as you need. You can now lift them into place. Make sure that you have enough people to help. You will need ropes for holding each truss steady until they can be joined together by the ridge pole.

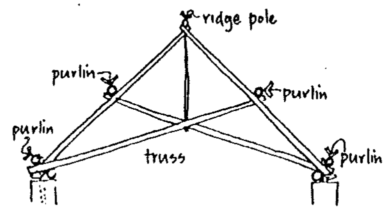
To hold the trusses steady you can put in a diagonal brace.

If the building has a gable wall, place a pole up each slope of the wall, like two rafters, and fix the ridge pole to the top. This will hold the trusses steady.

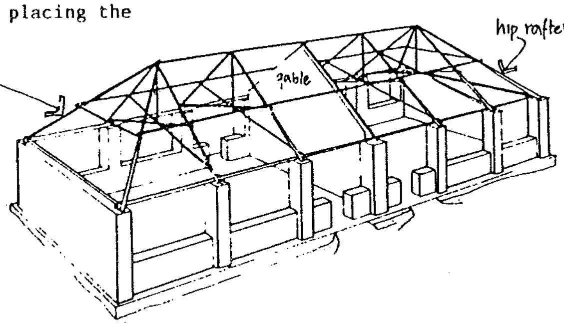


When the trusses are all in position and bolted or tied to the posts in the columns, you can then put on the purlins.

All the poles for purlins must be stripped and treated with oil, as was done for the poles used for the trusses.

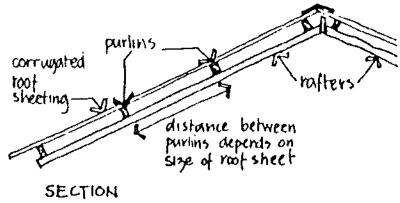


If the building has a hipped roof, you need to put on the hip rafters before placing the purlins.



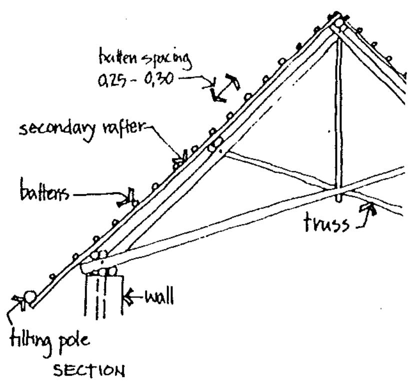
The purlins can be held in place with bolts. If bolts are not available, nail a block of wood to the rafter just below the position of the purlin, so that the purlin can rest on it. Tie the purlin down with wire or string.

If you have a choice between string or wire for binding the roof framework together, use wire which will resist termite attack.

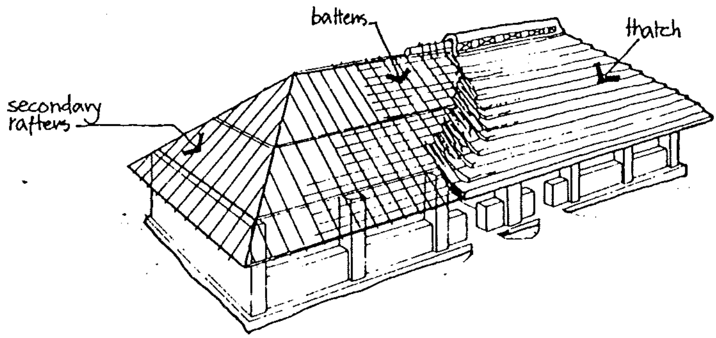


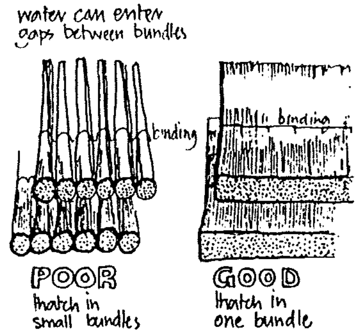
The number of secondary rafters and battens which you need depends upon the type of roof covering you will use. Corrugated roof sheets can be laid directly onto the purlins if the purlins are placed close enough together.

Tiles and thatch need a system of secondary rafters and battens. The secondary rafters rest on the purlins. They can be placed 0.50 to 0.60 metres apart. For tiled roofs the spacing of battens depends upon the size of the tile. There will be a batten for each layer of tiles.



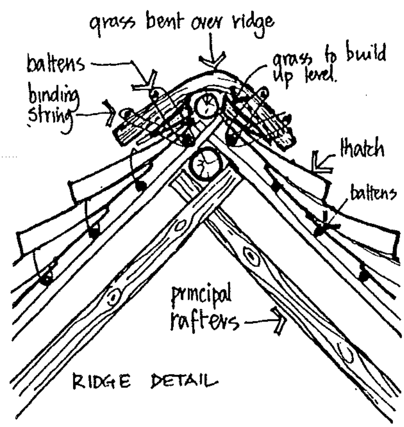
The battens on a thatched roof should be 0.25 to 0.30 metres apart. At the eaves a tilting pole should be placed, at least 7 cms thicker than the battens. The tilting pole pushes the thatch up and into tension, which improves the life of the thatch. The battens can be tied to the secondary rafters with wire or string, or binding strips from strong fibrous plants or bark. String or wire is better because of termite resistance.





Thatch the roof starting, on each side, at the right hand bottom corner. If you use bundles of grass or reeds, make sure that the bundles of grass are pushed very tight together. It is better to undo the bundles once you have them in place, so that all the grass gets pushed together in each layer, to form one continuous bundle.

Tie the grass tightly down to the roof battens. Use strong string to bind the grass, and preferably use a termite resistant string such as nylon. Each layer of grass should be about 15cms thick at its bottom end when it has been tightly bound. Thick thatch will last longer than thin thatch.



At the ridge, build up the level on the last layer of grass so that the ridge grass will lie at the same slope as the rest of the roof. Take grass that you can bend, and bend it over the ridge, and then tie it down with battens string, tied through to the main roof battens.

If the ridge is poor, the roof will rot more quickly.

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