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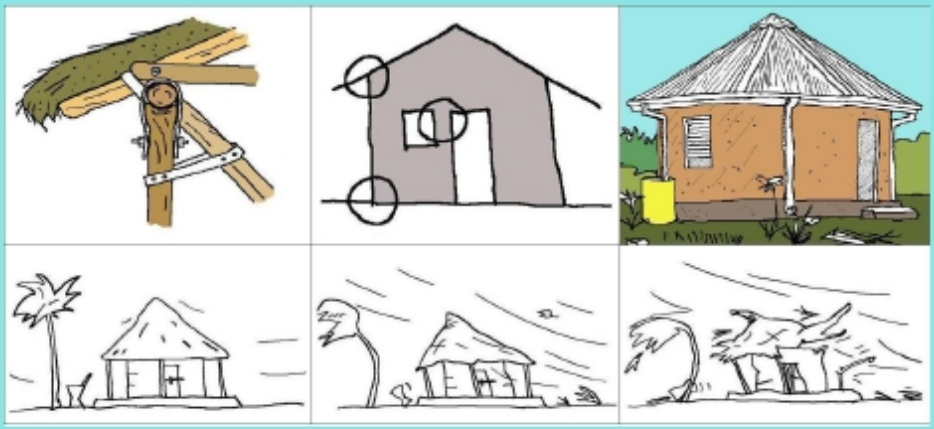
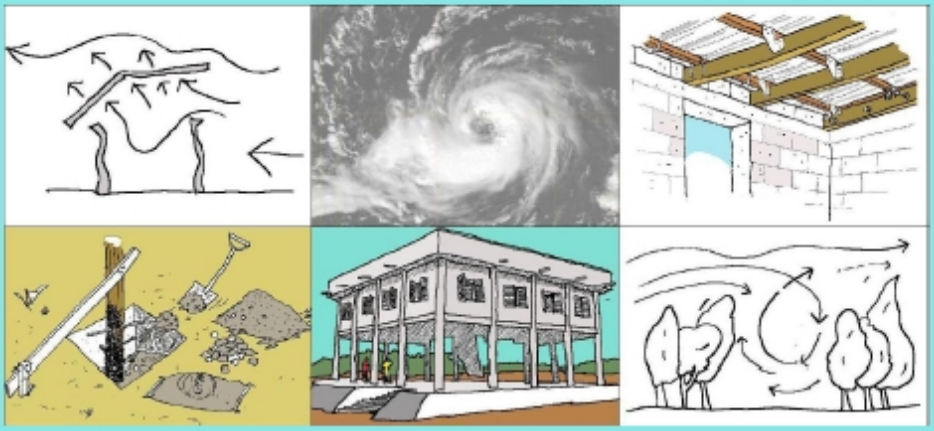


BUILDING WITH WINDS



CONSTRUCTION GUIDE FOR CYCLONE AND WINDSTORM PRONE AREAS

UNDP

UN HABITAT
FOR A BETTER URBAN FUTURE

CRUZ VERMELHA DE MOÇAMBIQUE
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1. INTRODUCTION

The main aim of this guide is to re-think about constructions located in cyclone prone areas, a natural phenomenon by which we should adapt our way of living, planting and building. The Guide contains some suggestions and offers supporting tools for the design of architecture and construction projects with conventional or traditional materials that allow us to effectively reduce the vulnerability of a house in the event of winds and windstorms.

"The pessimist complains about the wind, the optimist waits for it to change and the realist adjusts the sails"

(William G. Ward)

"…there is no tree that the wind has not shaken…"

(Hindu proverb)

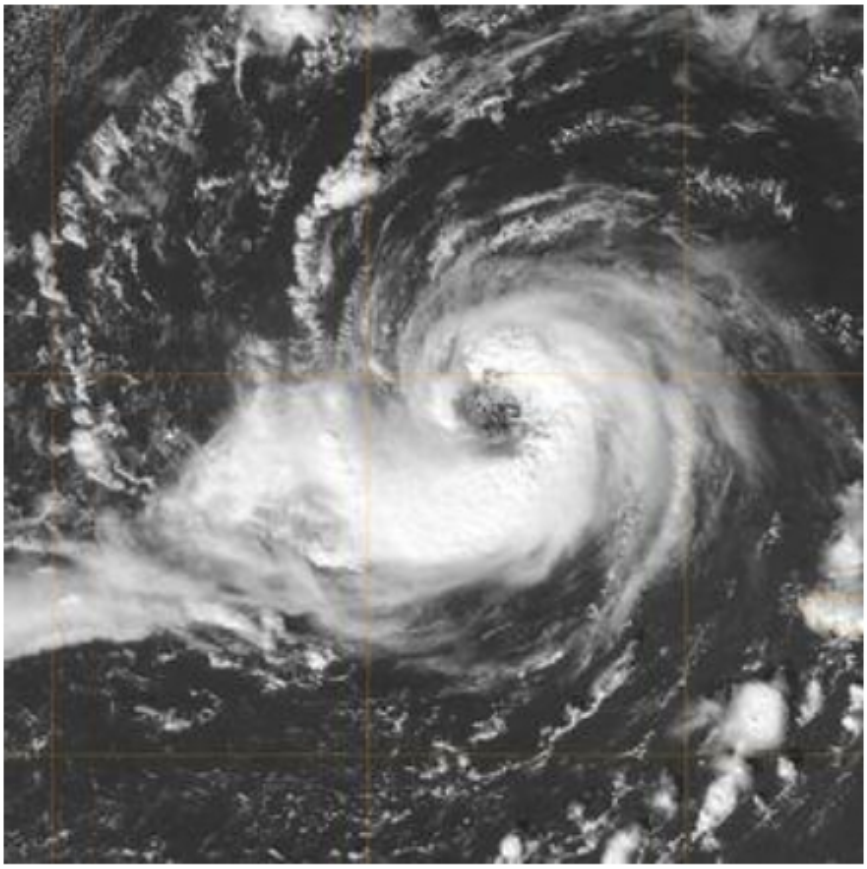
2. WHAT IS A CYCLONE?

2.1. Description

A CYCLONE is an atmospheric phenomenon which causes extremely strong winds and torrential rains. This phenomenon occurs at the end of summer when the waters from the tropical oceans are hotter.

Large hot air masses which absorb vapour becoming lighter are created on the oceanic waters. So, an accelerated spiral ascension of these large vapour masses is produced, reaching high speeds and forming enormous clouds that may reach up to 16 km of height!

This phenomenon is called Tropical Cyclone, Hurricane, Typhoon and other denominations, depending on the different locations where it occurs. Every year about 80 cyclones are formed in the world. Their radius of action may have between 100 and 1000 Km.



Observed via satellite, the cyclones show a sensational aspect: a large spiral of clouds that circulates around its centre. It forms a round hole which has between 20 and 60 km of diameter, known as EYE which moves in a speed that may reach 40-50 km/h.

The strong winds around the Eye cause the movement in the sea of enormous quantities of water which elevates themselves in giant waves. Usually these will collide with all their force in the coastal region that constitutes the biggest danger of deaths in the event of a cyclone. This atmospheric phenomenon may last for various days and even weeks.

2.2. Speed

Breeze 1-20 km/h	Windstorm 20-70 km/h	Cyclone more than 120 km/h

A cyclone reaches a maximum speed over the ocean and loses part of its strength when it enters into the continent, where it is stopped by the morphology of the terrain. When this occurs, large quantities of water fall down in the form of heavy rains, which usually fill the rivers causing FLOODS in the lower areas.

Situation of flooding as a consequence of cyclone

2.3. Atmospheric Importance

Despite their devastating effects, cyclones are very important since they cause large air masses and clouds to circulate, contributing for an atmospheric equilibrium that allows us to live in this planet...

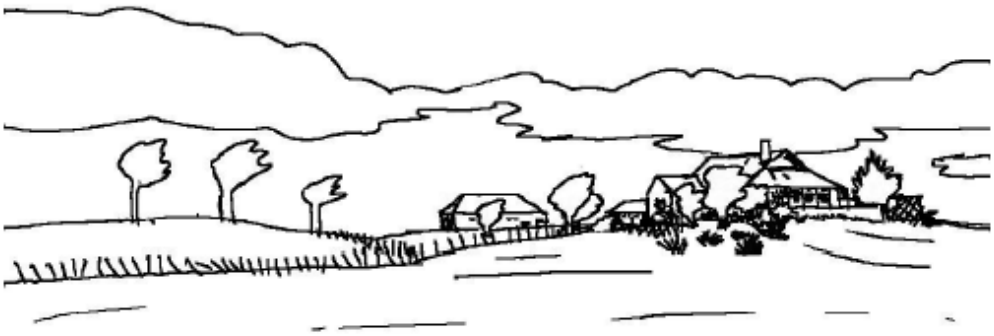
3. 3. THE ACTION OF THE WIND ON CONSTRUCTIONS

3.1. Some basic recommendations

The most important recommendations to reduce the impact of the wind on constructions are as follows:

"...Do not oppose resistance..." and

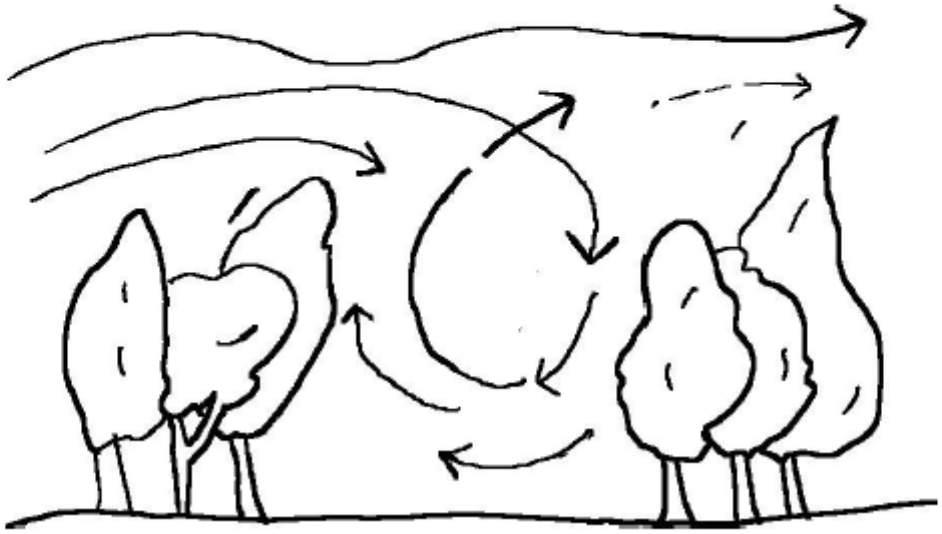
"...Do not let it enter into the house..."



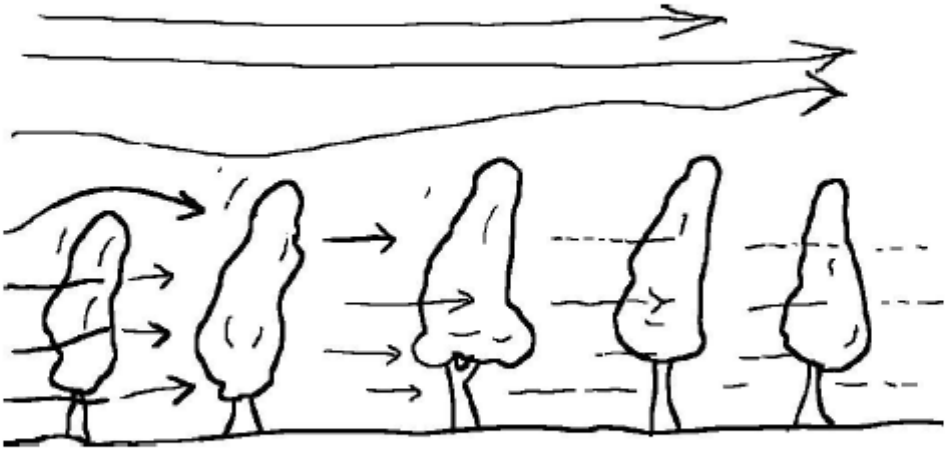
3.2. The action of wind-breaks and of vegetation

Planting low height vegetation and applying wind-breaks serves to deviate the wind upwards and filter it in such a way that enables you to protect your own house. Therefore, the function of wind-breaks is to reduce the strength of the wind and not to face it.

Vegetation considerably reduces the strength of the wind.

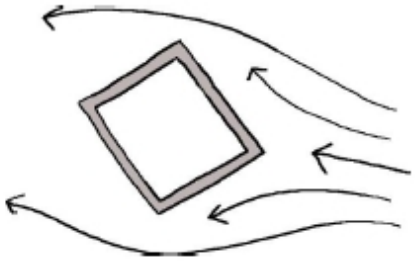


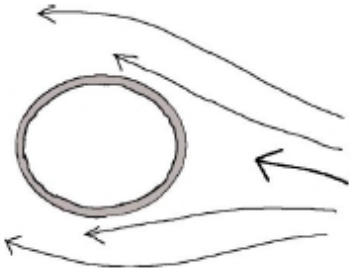
In addition, the trees release the wind from the majority of dust and sand that it transports.



3.3. The form of constructions

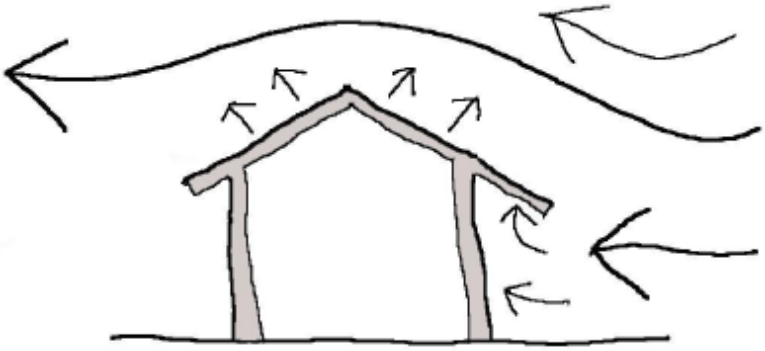
The form of constructions that better faces the wind is compact and symmetrical.



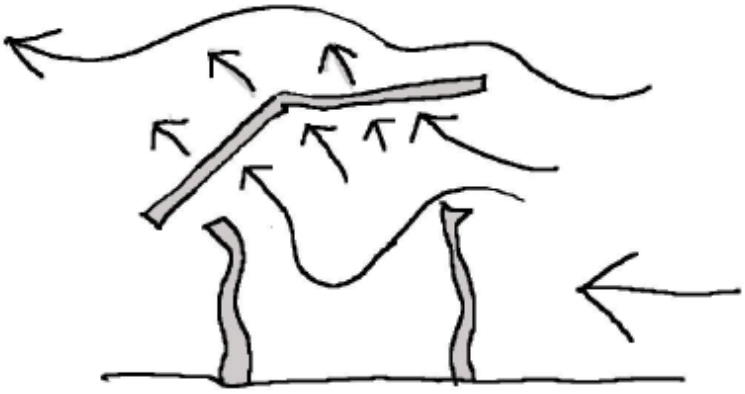


When constructions are open the wind passes through them!

When constructions are closed,



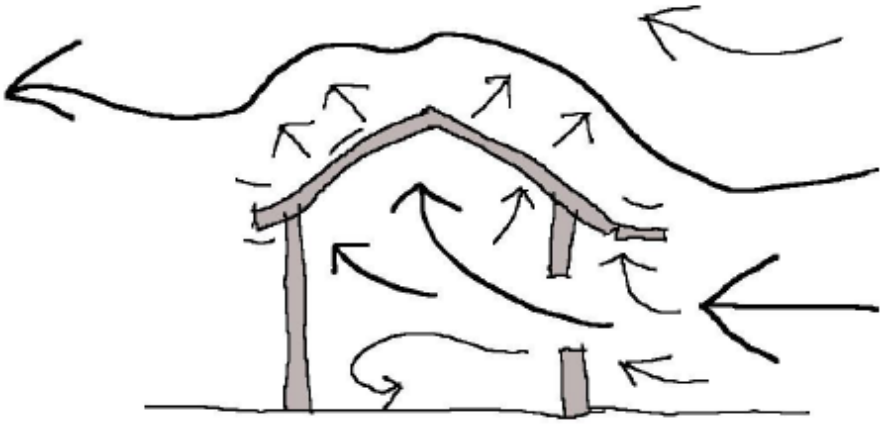
the wind produces an effect of sucking upwards on the roof



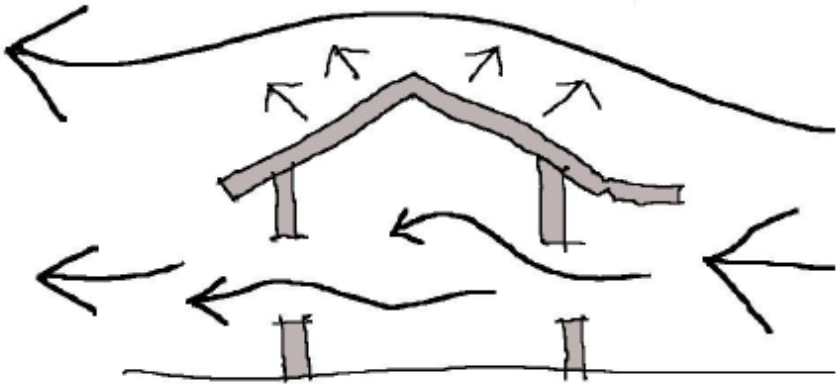
which may lift up the roof completely.....

It is important to create ventilations on the top parts!

When the wind enters into the house through a door or a window, it increases the pressure on the roof.



In this case it is very important to open the other window or the door from the other side of the house in order to allow the wind to pass through.



4. THE MOST VULNERABLE PARTS OF CONSTRUCTIONS

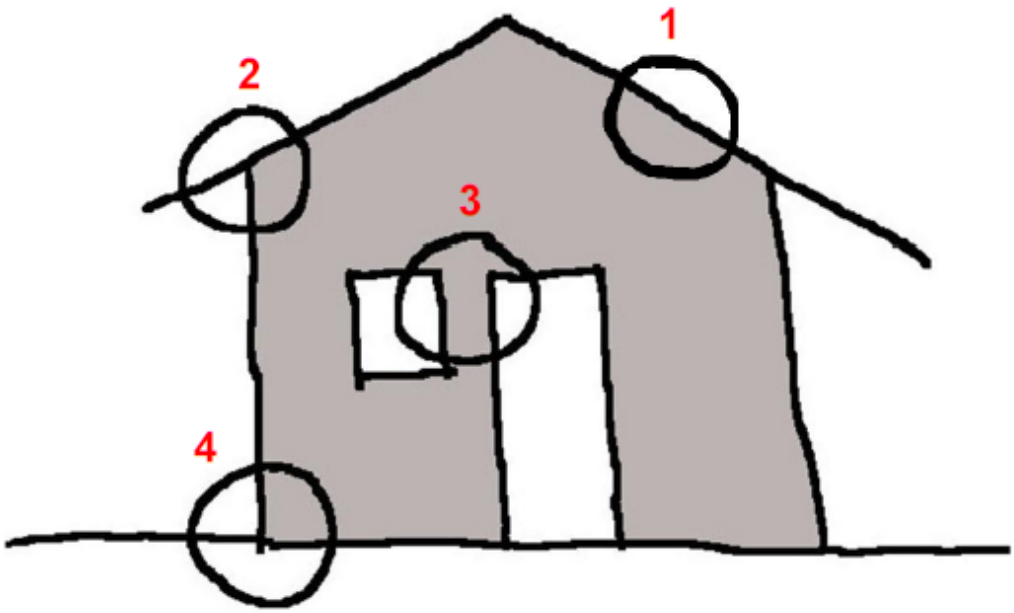
The wind attacks constructions mainly in the following points:

1. roofing,

2. junction of roofing with walls,

3. doors and windows,

4. foundations or junction of walls with the soil.

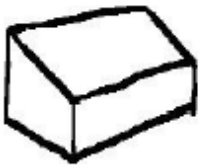


4.1. The roofing

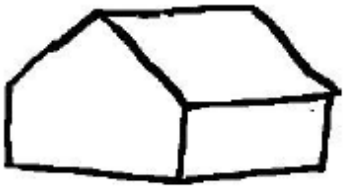
THE ROOFING is the most vulnerable part of a construction in relation to the action of the wind.

4.1.1. The form of roofing

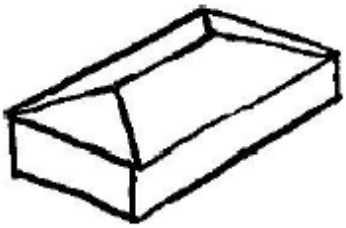
The characteristic forms of roofing that are traditionally used are “pitched” (one slope), “gable” (two slopes), “hipped” (four slopes) or “conical”. The first two ones are more exposed to the wind. Therefore, for these forms it is recommendable to use concrete building systems.



Pitched roof



Gable roof



Hipped roof

Conical roof

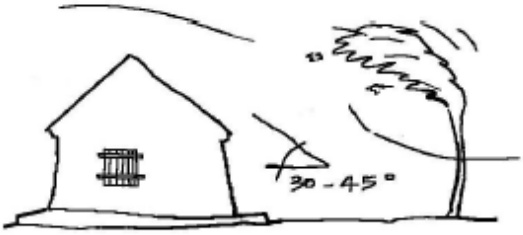
The “hipped” and the “conical” roofings are the most adequate forms to build in cyclone prone areas because they are tied directly to the beams that structure the walls of the building.

Apart from that, the hipped roofing adapts well to the use of conventional building materials (zinc roof sheets, etc.) and facilitates the establishment of rain water harvesting systems.

The bigger is the sucking strength, the more plain is the roofing!

The most secure roofing shows a sloping between 30 and 45 degrees.

The roof of this house was just a bit inclined and not properly fixed. The wind entered through the window which was open and the external sucking strength completely lifted up the roof!



This roof had the recommended sloping and the windows were properly closed. Even with strong wind, the house did not sustain damage!

To build a flat roof in areas where the winds are strong, it is recommendable to use solid slabs or pre-fabricated ones made of concrete so as to ensure that there is more weight on it and that it is resistant to the supporting structure.

The use of zinc roof sheets to build conical roofing is possible but very complicated.

4.1.2. The use of zinc roof sheets

The zinc roof sheet is increasingly being used in Mozambique to cover houses. It is a construction material that is considered more durable than the traditional materials such as grass or macuti, at a relatively affordable price.

Its use has influenced the traditional architecture because it implies an adaptation of the structure of the house in a more rectangular way, which facilitates the placement of zinc roof sheets.

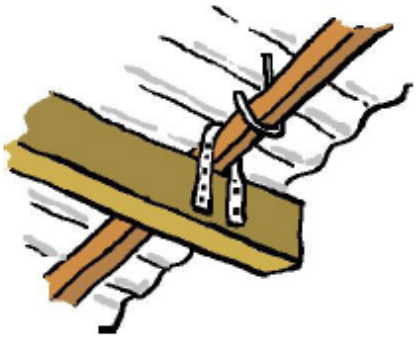



Considering that a zinc roof sheet is light, the roofing that uses this material is fragile and very vulnerable to the action of the wind.

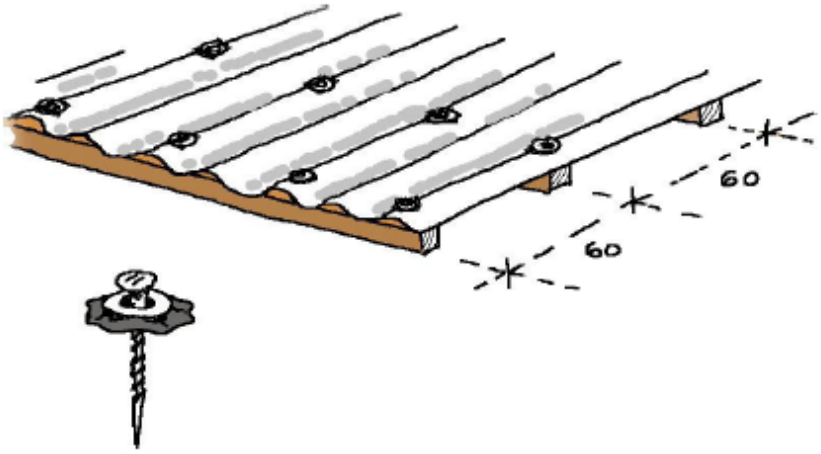
In order to reinforce the roofing of zinc roof sheets there is a need to use sheets with a minimum of 0.5 mm of thickness. Also, it is important to try to make the roofing according to the length of the sheets in order to avoid joinings between the various sheets so as to get “one water”. This union represents a weak point of the roofing that the wind may attack.

4.1.3. The junction of the roofing with its structure

In order to reduce the risk of seeing the roofing of the house removed by the cyclone, it is fundamental to properly fix the roofing with its structure.



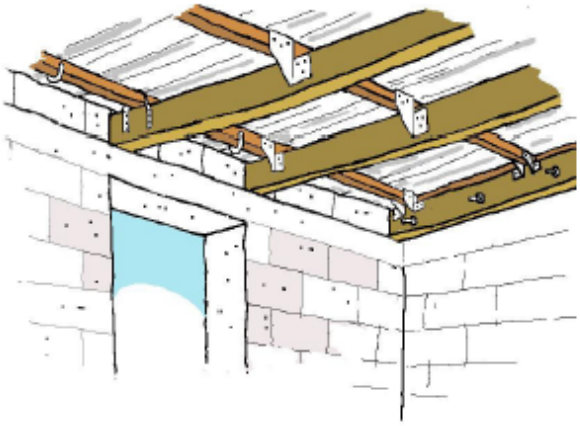
Therefore, the correct spacing between the wooden joists to fix the zinc sheet roofing is 60 cm. Nails are fixed according to this spacing and in every 2 waves towards the joists. Should the nails go beyond the thickness of the joist, these should be bended in the lower part. Nails to fix zinc roof sheets are striated, with washer heads and a rubber joint.

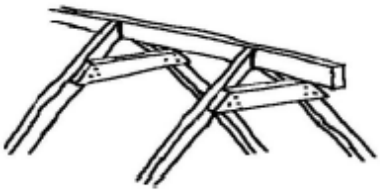


Nails should always be applied on the upper part of the wave so as to avoid rainwater leakage, as the water flows along the lower part of the wave.

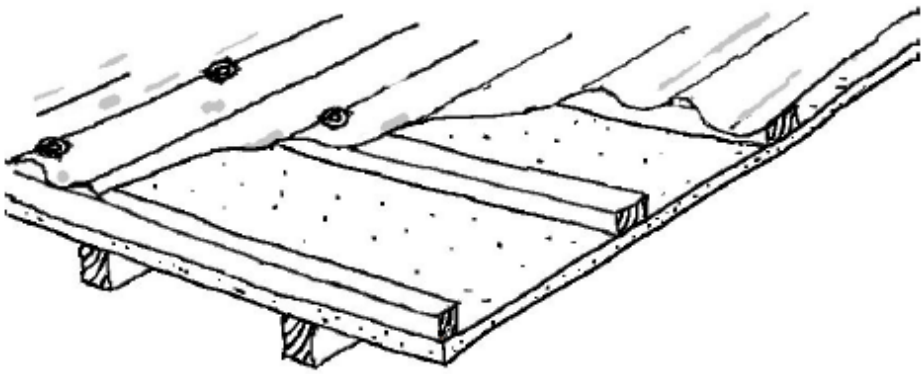
4.1.4. Reinforce the roofing structure

Usually the roofing structure is made of triangular roof truss and wooden joists placed on the upper part of the walls. This structure may be reinforced in various forms. The figures below only show some options.



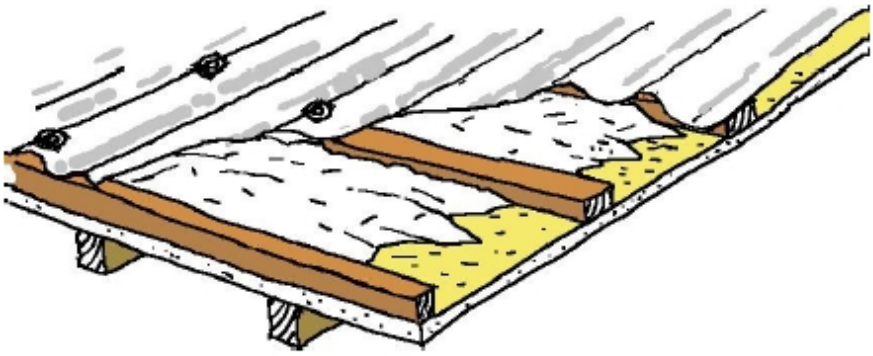


The use of wood slabs or other material on the roofing structure gives more weight to the roofing and serves as defence against the wind and the rain if zinc roof sheets are lifted up.

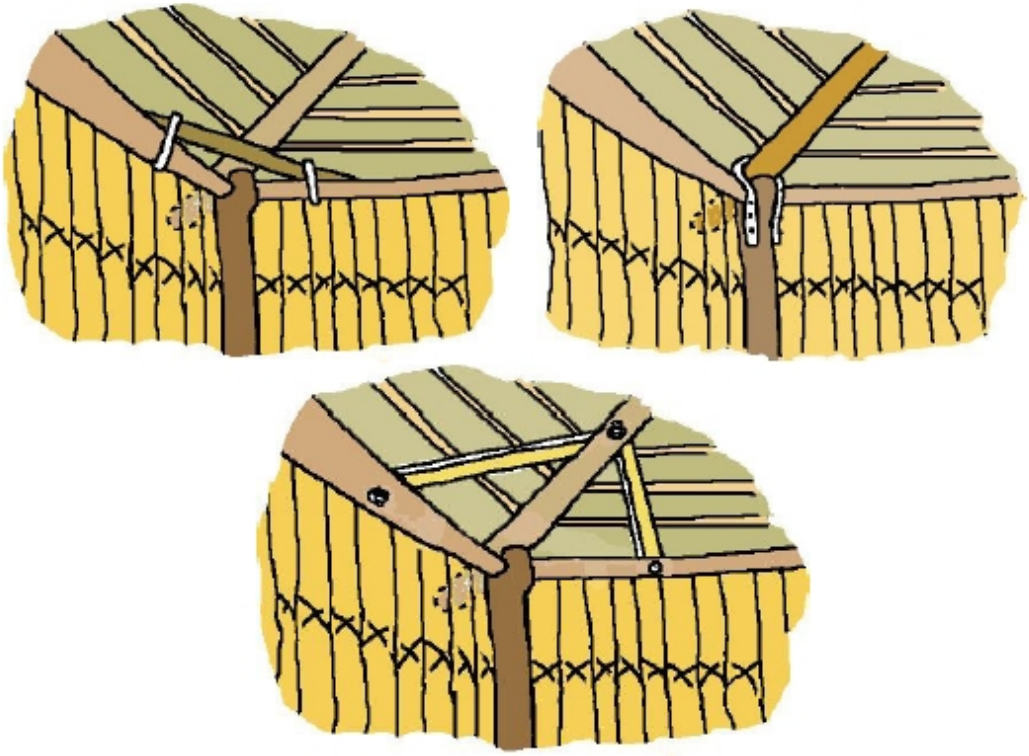


In this perspective, a thermal isolation of the roofing may be obtained by installing vegetal material such as mats or reeds under the roofing (false roofing).

By placing a mixture of sand and straw between the joists on a wood slab covered by a plastic sheet, there is an increase of weight on the roofing and the inner part of the house is isolated even further from the external temperature and the water.



The traditional roofing structures may be reinforced by applying metal straps or pieces of wood. Taking into account that the buildings are light, the idea is to stabilize the structure without losing the elasticity.



4.1.5. Other aspects related to the roofing

Dragging of objects by a cyclone may damage the house, creating gaps that cause the lifting up of the roofing.

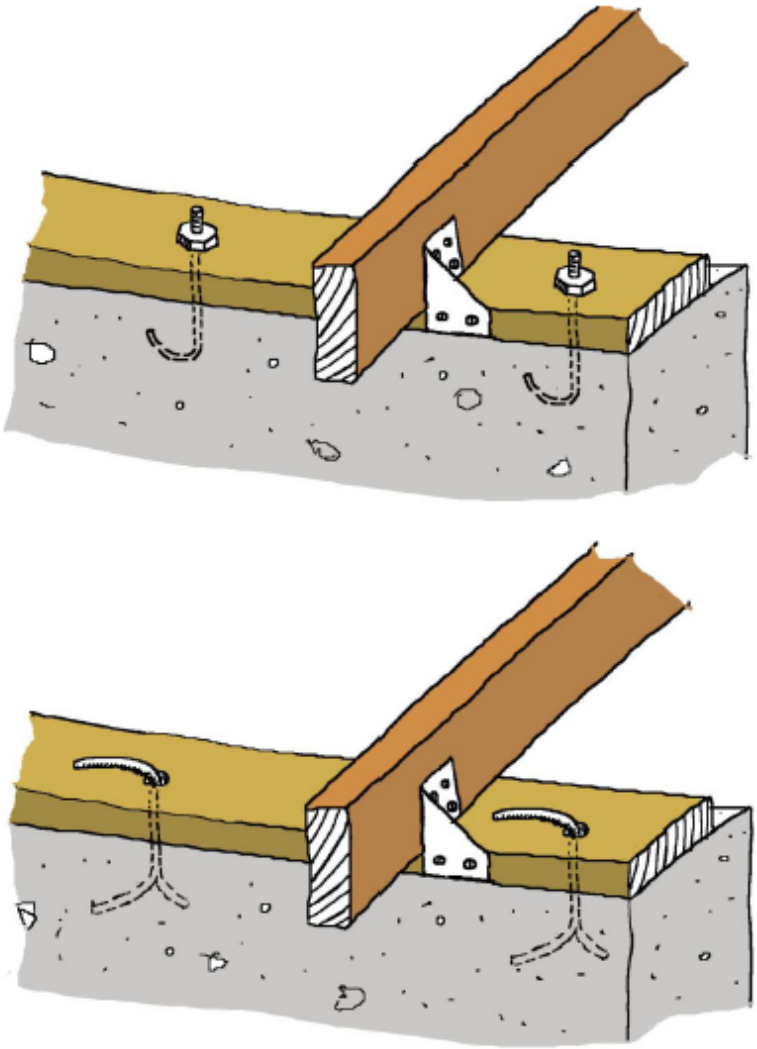
The use of fibro-cement or lusalite in cyclone prone areas is not recommendable. It has to be very well installed, because it is a rigid material which may easily break by the impact of objects dragged by the wind.

4.2. The junction of roofing with walls

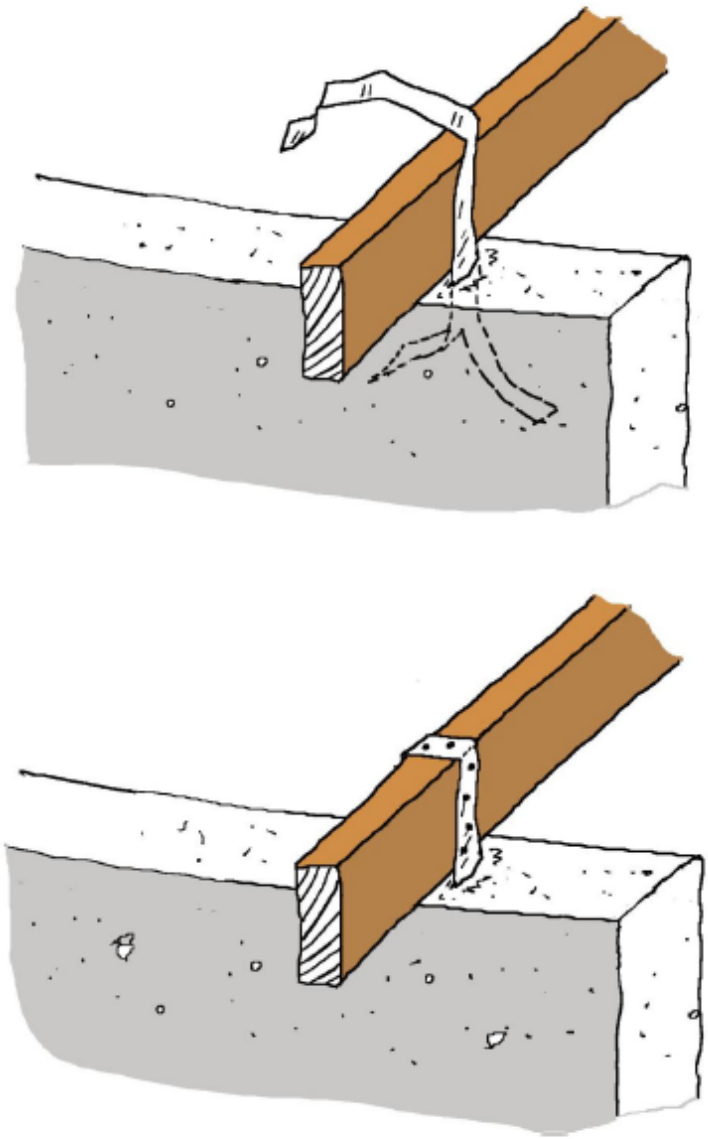
This junction is the most important of the whole house.

4.2.1. Masonry houses

In brick or cement blocks houses, a wooden piece fixed with spindles in the form of J or irons leaded in the upper part of the wall allows using metallic joints to strongly secure the roofing structure with the stone-walling wall.

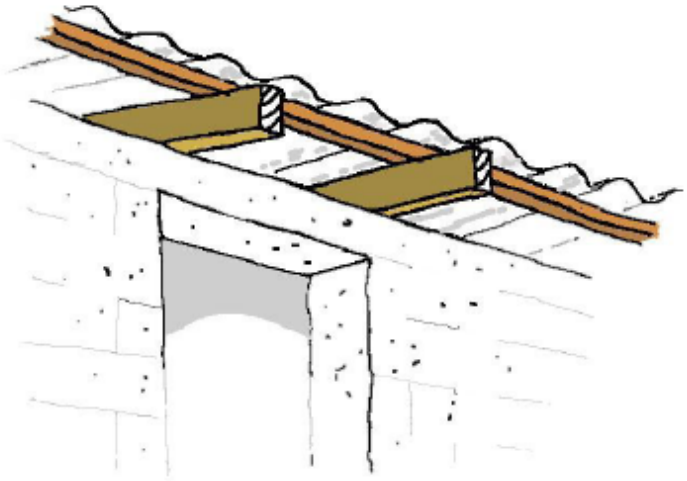


When the roofing structure adjusts directly on the upper beam of the slab, metal straps that are bended on the structural element of the roofing can be placed and are nailed on both sides.

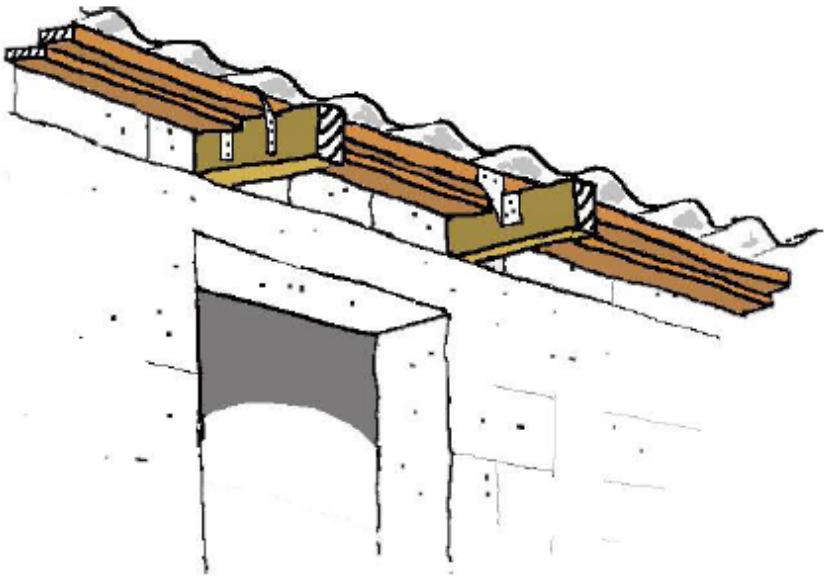


Therefore spindles, pieces of iron or other metallic elements with similar functions may also be used.

It is not recommendable that on the edges of the roof and the upper part of the walls, zinc roof sheets are exposed to the wind.

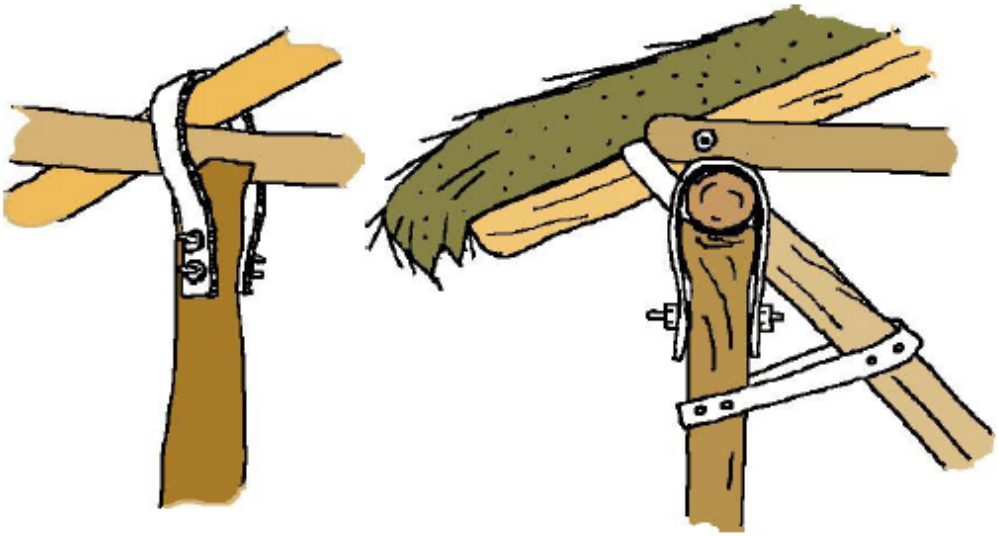


The figure below shows that a form of mitigating this situation is to firmly fix the zinc roof sheets to the roofing structure using metallic elements, and close the space between the wall and the roofing with blocks and pieces of wood.



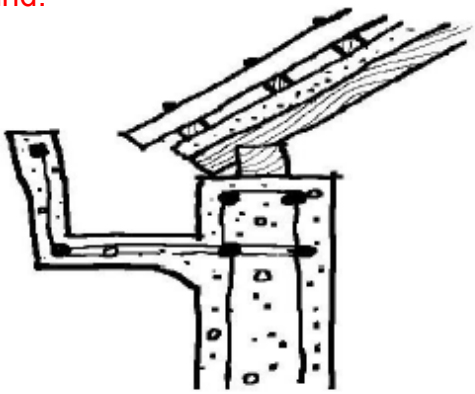
4.2.2. In houses built with local materials

In this case the junction between the roofing and the walls may be reinforced by using wire, ropes of metal straps.

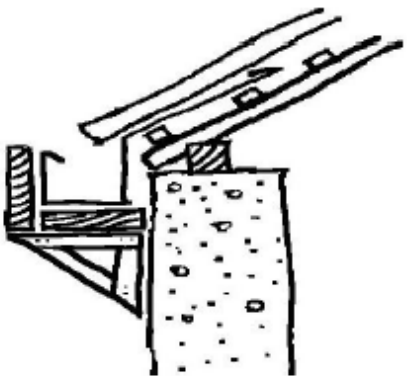


4.2.3. An interesting function of gutter pipes

Apart from collecting rain water, it was observed that gutter pipes effectively protect the extremes of the roofing from the action of the wind.



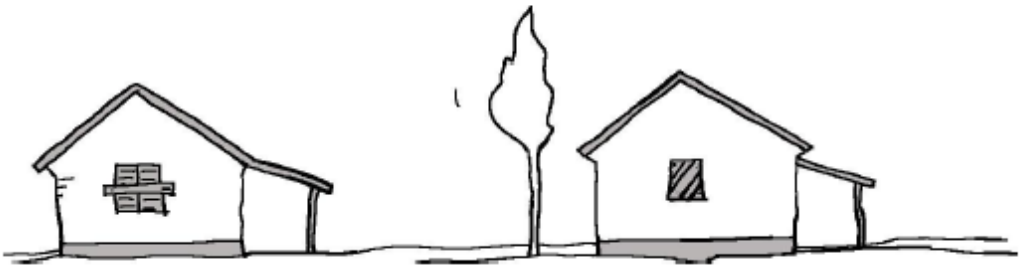
Gutter pipe made of concrete



Gutter pipe made of chain belting protected by pieces of wood

4.2.4. Attached Roofing

In traditional and modern constructions, additional roofing to the main structure of the house is often attached.



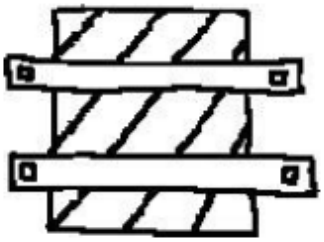
Attached roofing together with the structure of the main roofing	Attached roofing separated from the main roofing

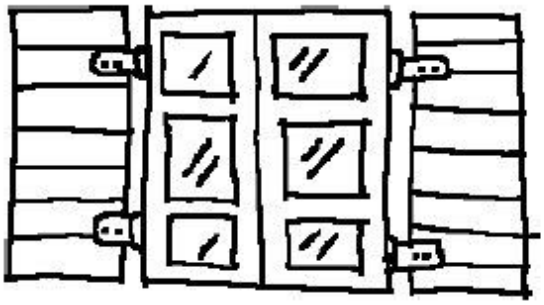
When the additional roofing is lifted up by the wind it affects the main roofing!	When the attached roofing is lifted up by the wind, the main roofing is not affected.

4.3. Doors and windows

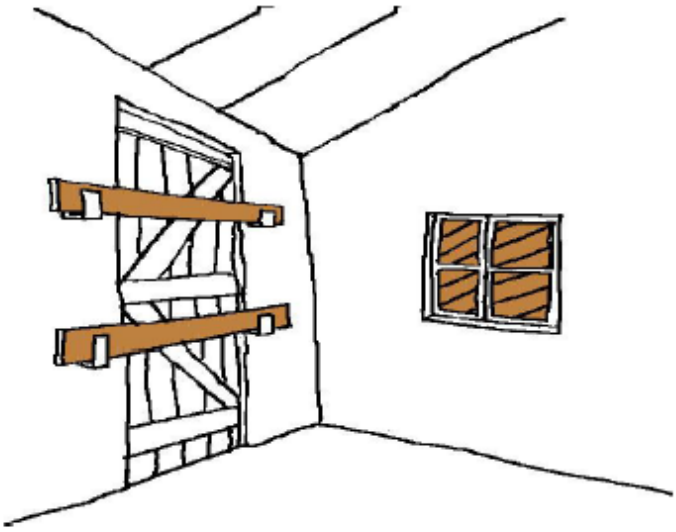
Doors and windows represent the most probable entry points of the wind inside the house.

It is suggested that windows are properly protected with wooden lids. These may be fixed to the wall in such a way that they are always available if needed.



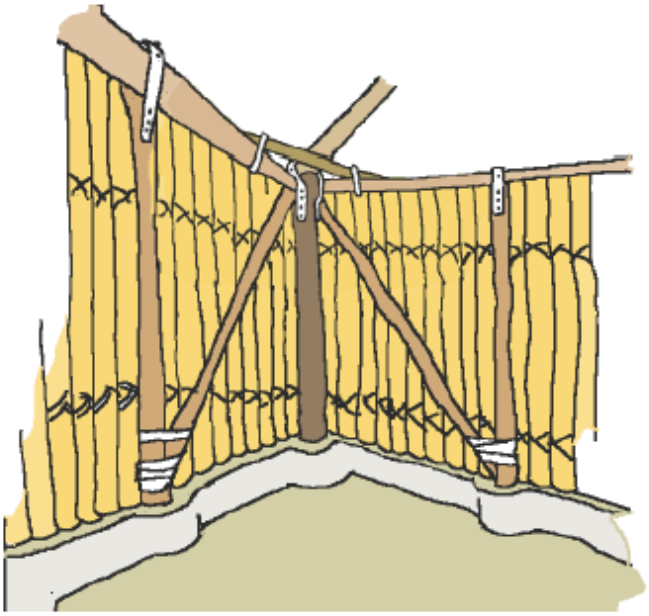


Also, the doors apart from being strong and hard, they should be closed with reinforced systems using pieces of wood or made of metal in order to resist to the pressure and the effect of suction generated by the cyclone.

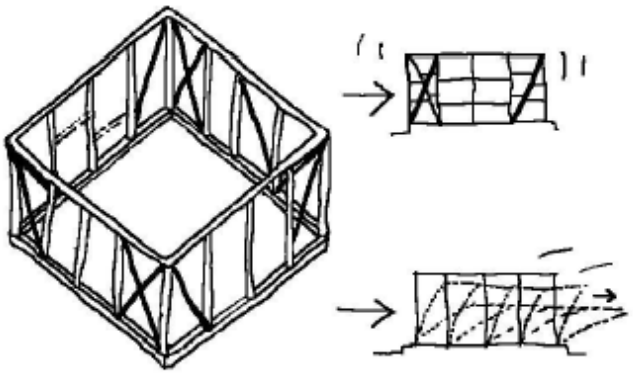


4.4. The foundations

Being lighter, a proper junction of different elements of traditional houses is very important. In particular, the foundations or linkage of walls with the soil should be strong so as to avoid that the building is completely lifted up by the wind.

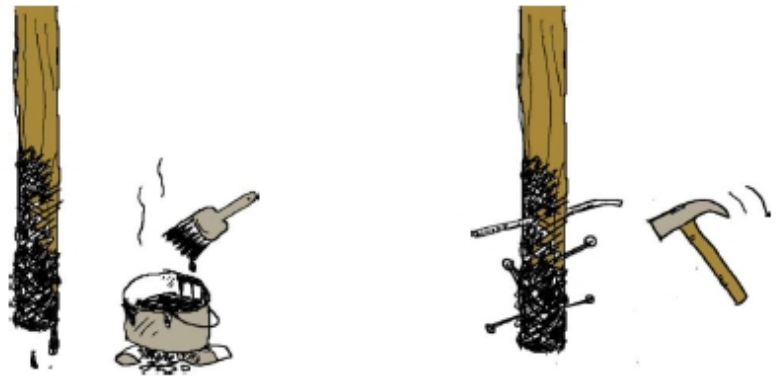


The walls of this type of houses should be reinforced with diagonal elements and anchored on the soil with leaded iron material on the concrete of the foundation.



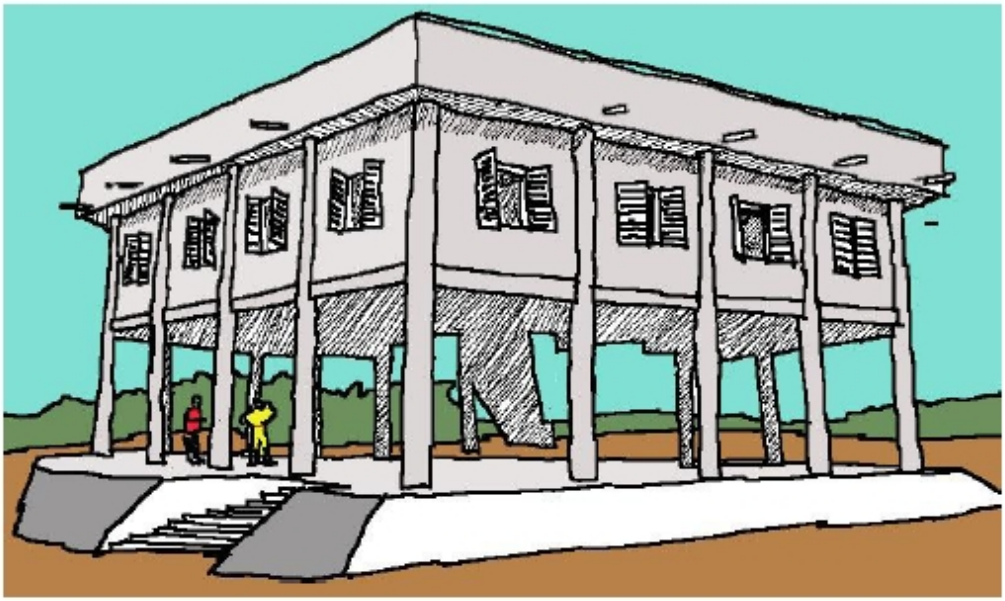
The lighter the construction is, the bigger (or heavy) the foundation should be.

A way of firmly securing the wooden piers in the soil is to impregnate them with tar or burnt oil (so as to avoid that they are attacked by insects) and anchor them on the concrete with the help of irons and nails.



5. SHELTER

The unique shelter that may truly protect us from the cyclone is a building made of concrete with slab roofing.

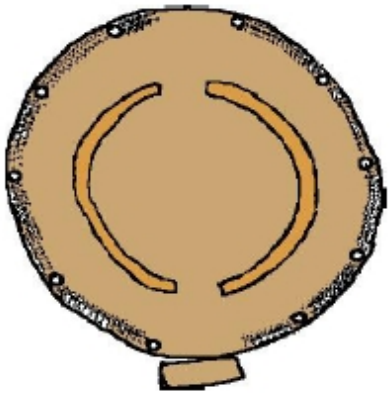


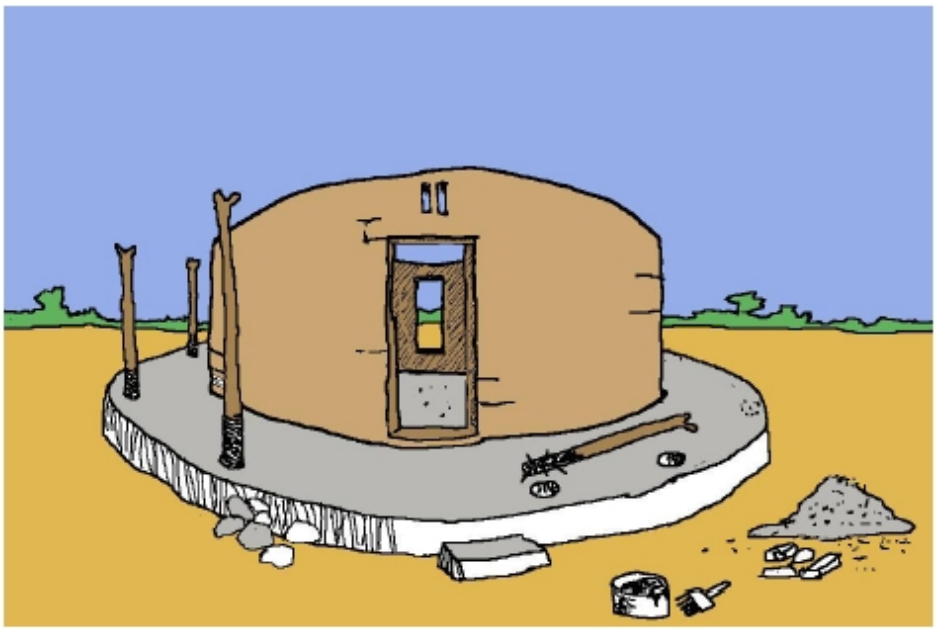
A private shelter to store goods, animals or people may be invented!

6. THE INTELLIGENT HOUSE

This house in a circular form was built in an intelligent manner.

A window is positioned symmetrically on the other side in relation to the door. The house has a centre with brick walls and is built on a platform of 40 cm of elevation. The veranda is semi-closed with reeds that protect the inner structure from the rain and from the sun, and reduces the strength of the wind.





CYCLONE EARLY WARNING SYSTEM

The Cyclone Early Warning System in Mozambique is based on three colours. It refers to early warning messages for the communities that indicate the time available for them to prepare themselves for the beginning of windstorms:

BLUE ALERT – Precaution

A tropical cyclone may affect the area within 24 to 48 hours.

YELLOW ALERT – Action

A tropical cyclone is approaching the area and will most probably affect the communities within the 24 hours

RED ALERT – Shelter

Windstorms are eminent (within 6 hours) or are already blowing.