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**Technical guide: shelter and livelihood improvement
project for the indigenous communities of Libacao,
Aklan, Panay Island, Philippines**

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Shelter and livelihood improvement project for the indigenous communities of Libacao, Aklan, Panay Island, Philippines.

DSAC of Kalibo in partnership with
SC/Caritas France and Caritas Belgium

2014-2017

Technical guide



DSAC		ACKNOWLEDGMENT	Technical Guide

Special thanks for their contributions to the technical guide :

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- CRAterre: Annalisa Caimi, Elsa Cauderay, Florie Dejeant and Olivier Moles.
- Caritas Belgium, Secours Catholique - Caritas France and Caritas Luxembourg for their financial support.

Credits photo and drawing: unless otherwise specified all photographs and drawings illustrating this guide are credited to CRAterre and particularly to Annalisa Caimi, Elsa Cauderay, Florie Dejeant and Olivier Moles.

Picture first page : DSAC project: pilote house in Oyang, Libacao.



DSAC			Technical Guide
	ABOUT THE GUIDE		

This guide consists of technical sheets (front pages) and technical comments (back pages). It is important to note that it was designed along with a disaster risk reduction (DDR) training guide. Both documents are complementary and should be taken as a whole.

This guide aims at being a tool in the field of the building sector. It can be used for rural housing improvement, repairs and new construction, or for public building. It was elaborated during two reconstruction projects in the aftermath of the super typhoon Haiyan. Both projects were set up in Panay Island:

1. *Shelter and livelihood improvement project for the indigenous communities of Aklan. Project in partnership with the DSAC of Kalibo, Secours catholique - Caritas France and Caritas Belgium, 2014-2017.*
2. *Technical assistance to the Caritas Luxembourg / PCDR (Panay Centre for Disaster Response) rehabilitation project in Panay and construction of a student dormitory in Tapaz, 2015-2017.*

This guide deals with the specific technical concepts and details that have been identified and developed during the projects to preserve existing knowledge and improve habitat in the targeted areas, making best use of local resources and respecting environmental, cultural, social, technical and economic realities of the targeted communities.

The architectural typology treated corresponds to light-weight construction, including wood and/or bamboo frame, CGI or vegetal roof.

- If you are tempted to replicate this type of construction in another context, make sure it meets the specific needs of the site and that the materials available are of sufficient quality. Moreover, the presence of other local resources (know-how, materials) and a different building culture may necessitate the adaptation of the proposed solutions, or even the development of other models.
- If you have participated as an artisan or trainer in training on this type of construction, this guide will allow you to accompany the setting up of future trainings or activities in the field.
- If you are a stranger to this type of construction and are interested in it, this guide may not provide you with all the necessary information. In this case, get closer to the people and organizations that fully master the concepts proposed, so that they can advise you usefully.

DSAC			Technical Guide
	ABOUT THE GUIDE		

Technical guide

The document is composed of two sided sheets and can be read or printed in two different ways:

- **One side printing: the technical sheet kit on the front pages.**

The technical sheets use many illustrations and drawings to introduce and elaborate the key principles, problems and practices. They aim to be understandable, also for basic level technical reader. They mainly target engineers, foremen, and high-level carpenters.

- **Tow-side printing: the technical sheet and their comments on the back pages.**

The technical comments aim to give further technical explanations with regard to the technical sheets. The technical comments together with the technical sheets mainly target engineers and high-level foremen.



DSAC			Technical Guide
	ROLE OF TECHNICAL WORKERS		

Role of Technical leads, foremen and carpenters

Construction of new houses and improvements of the stability of existing houses are two important activities. As the houses in rural area of Panay island are mainly made out of lumber or bamboo, the role of the local carpenter is very important. Their services and advice are required by almost all families.

Especially in the Philippines, which is prone to rainy season, storms, typhoons and floods, the carpenter has an important role to play: to improve the existing houses and to construct new houses in such a way that they can better behave to the elements. While resistance to typhoon of the magnitude of Haiyan is beyond the scope of the rural carpenter, he should be in a position to advise households if their house can withstand the usual rains, high winds and typhoon and floods - or how the house can be improved to better protect the families during rainy season and eventually, if required, build a new, more resistant house.

Carpenters who participated in the technical trainings and who read the content of this technical guide will also be in a position to act as advisors to householders and PO (people organization) engaged in reconstruction. These carpenters will contribute in an essential manner to the community efforts to be well-prepared for the rainy season and against disasters.

Trained carpenters are invited to share skills and knowledge, together with this technical guide, with their colleagues.

The role of a carpenter is to:

1. Advise households on how they can make their house safer.
2. Improve houses resistance before rainy season and after a warning of typhoon.
3. Upgrade the safety and quality of existing houses.
4. Build safe new houses.



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FOR FURTHER INFORMATIONS AND DETAILS

DSAC	S0	SITE	Technical Guide

Durability

The durability of a building depends on the context in which it is constructed. Proper selection of the building site before construction is of major importance, it will participate in the durability of a house or a building especially during calamities :

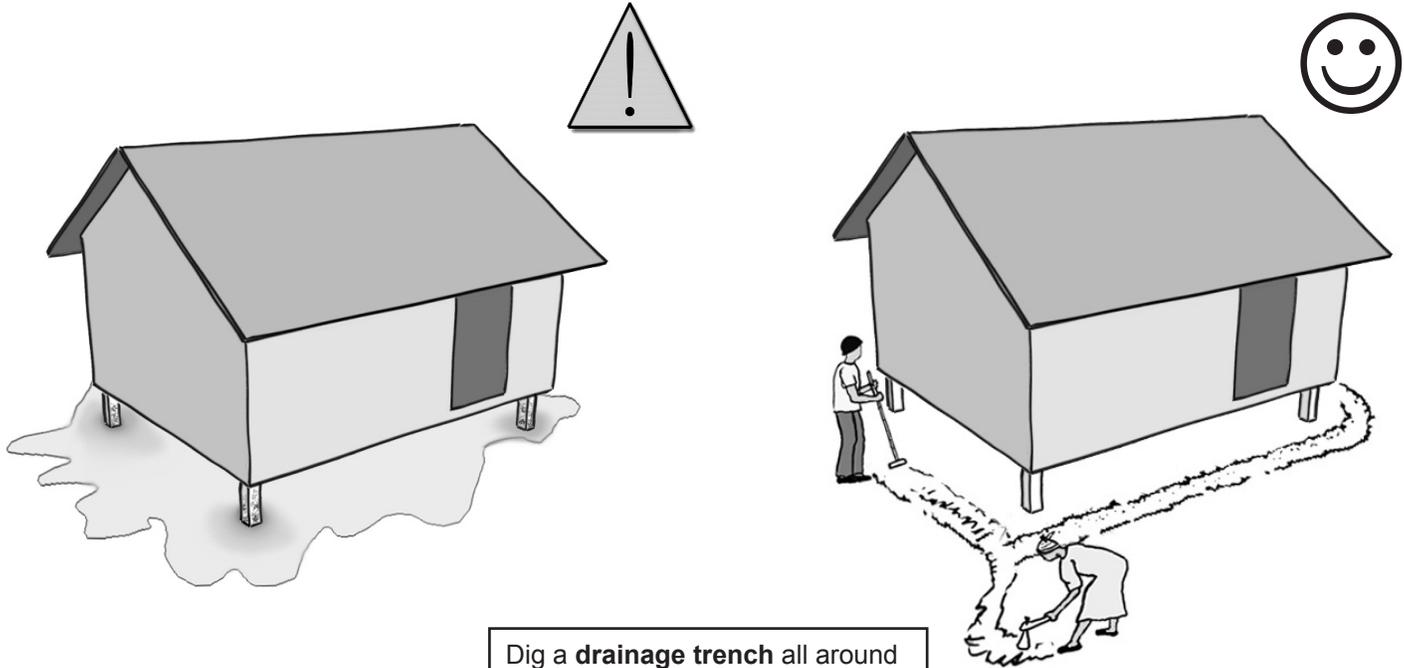
- Before constructing, think about topography of site, orientation, rain, wind, sun.
- Take special care on the site, avoid hollowed grounds, termites, roots, steep slope.
- After the construction, maintain the site as well as your house regularly.
- Before the rainy season, check the tree condition on your site and re-tighten and repair your house.

If regular maintenance is respected, houses and buildings may last longer and give better protection to its inhabitants.

DSAC	S0	SITE	Technical Guide

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PLOT DRAINAGE SYSTEM



Dig a **drainage trench** all around the house, where the rain water falls from the roof and under the sink of the kitchen.



Connect the drainage to a trench to drain the water away from the house.

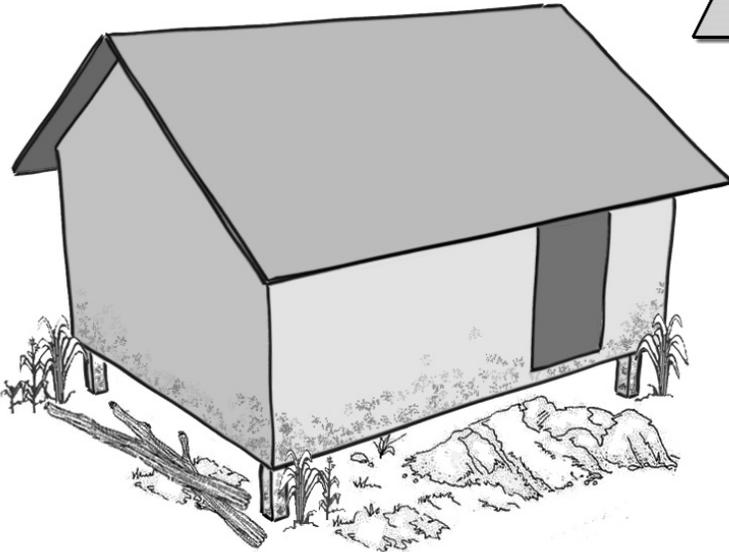
Don't forget to give a slope to the trench.

Fill the trench with small stones. This will protect from the erosion of the trench.

DSAC	S0.1.1	SITE	Technical Guide
	PLOT DRAINAGE SYSTEM		

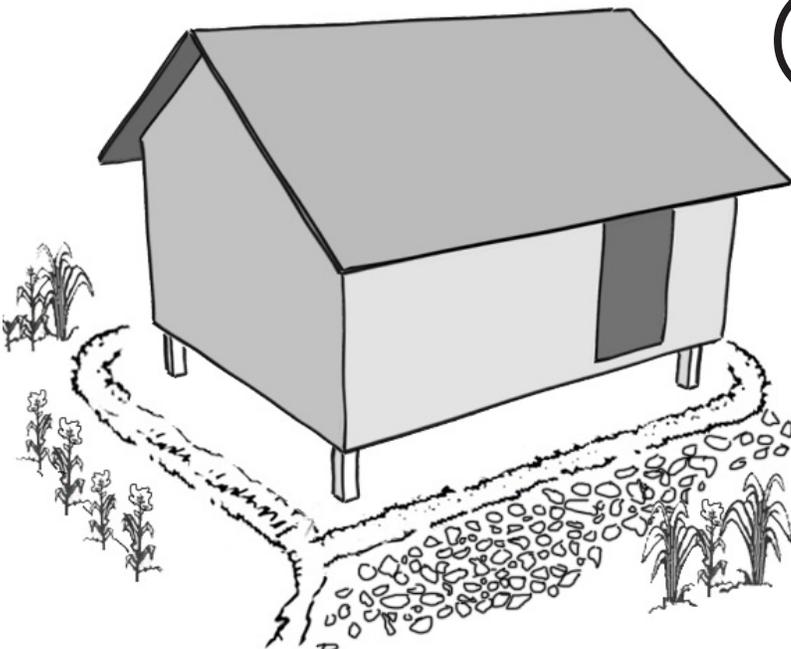
- Backfilled, swampy or flood-prone land areas are unsuitable for buildings. Greater care must be taken when dealing with such grounds or soils.
- A high rainfall area and sloppy plot requires a drainage plan for roof water to be collected and led to a common drain. Levels of the drainage system need to be included on plans so that rain water flows away and does not form puddles that breed insects around houses.

CLEAN-UP OF SURROUNDINGS & LANDSCAPING



Properly maintain the surroundings of the house.
Clean, organise, remove, landscape:

- vegetation
- wood and other stocked materials
- mound of earth / dug in the ground



Level the soil &
Stabilize the ground to reduce erosion using:
gravels, rocks and/or appropriate plants

DSAC	S0.1.2	SITE	Technical Guide
	CLEAN-UP OF SURROUNDINGS & LANDSCAPING		

Clean-up of surroundings

The maintenance and a proper landscaping of the surrounding of the buildings will greatly participate in the durability of the house. Regular cleaning under and around the building will prevent from its early degradation (in particular the posts and the base of the walls).

Check if there are no pools that can accumulate water, especially under and close to the buildings and pillars. In case of uneven soil, level the soil by filling the pools and compact it and by excavating higher soil.

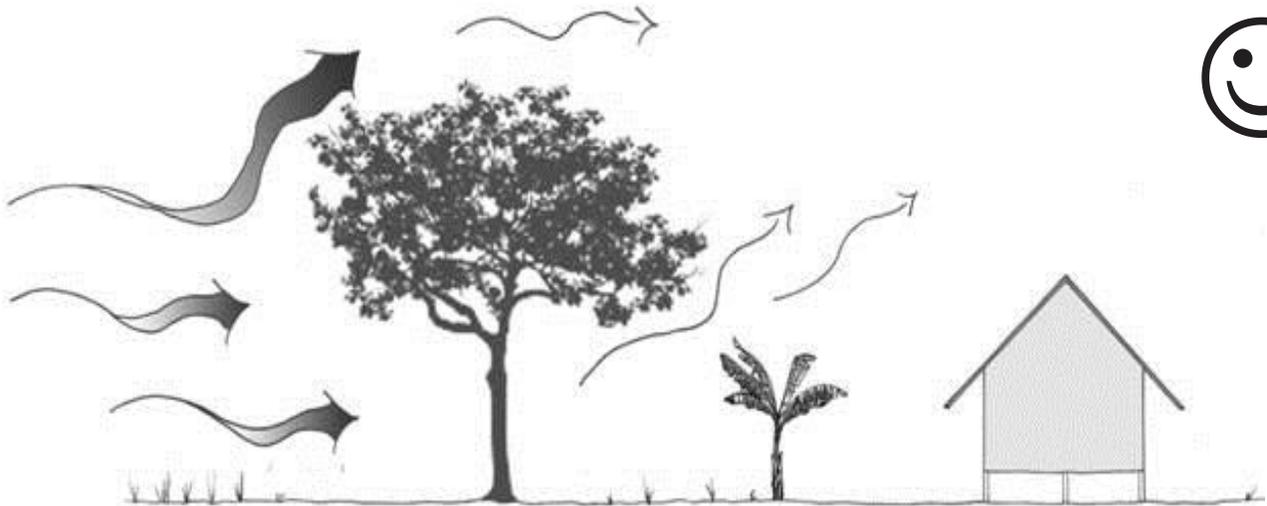
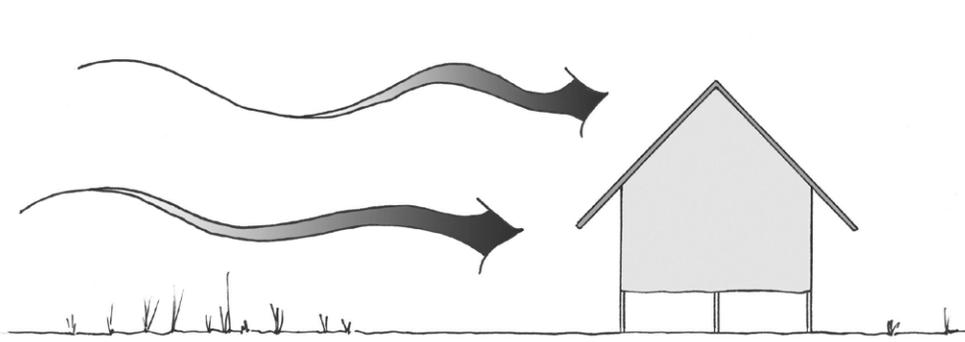
Avoid storing material under your shelter which may obstruct water drainage.

The presence of vegetation and organic materials under or directly close to the building will retain moisture will encourage the presence of termites and rodents around the building.

Landscaping and soil stabilization

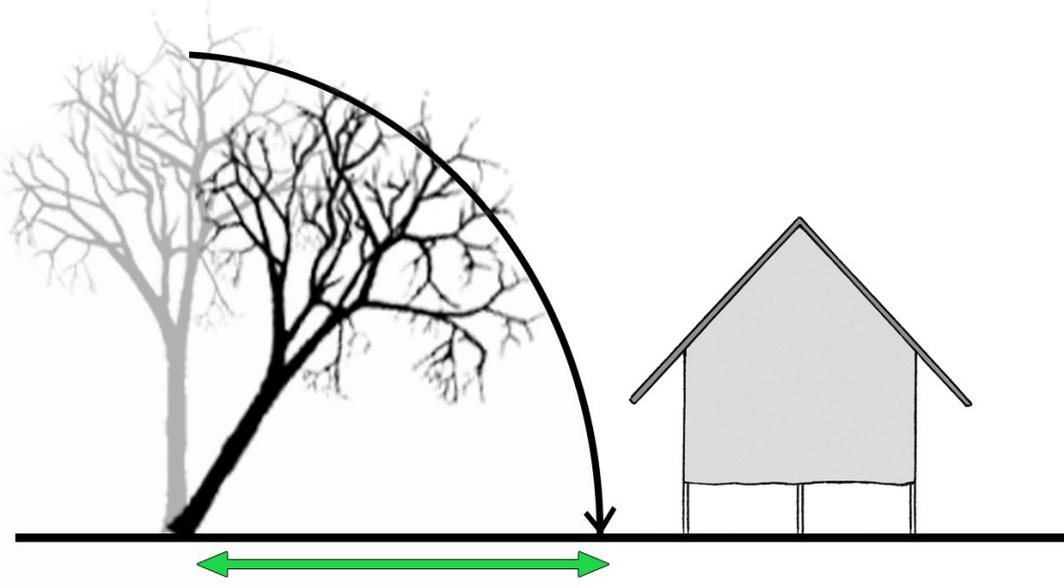
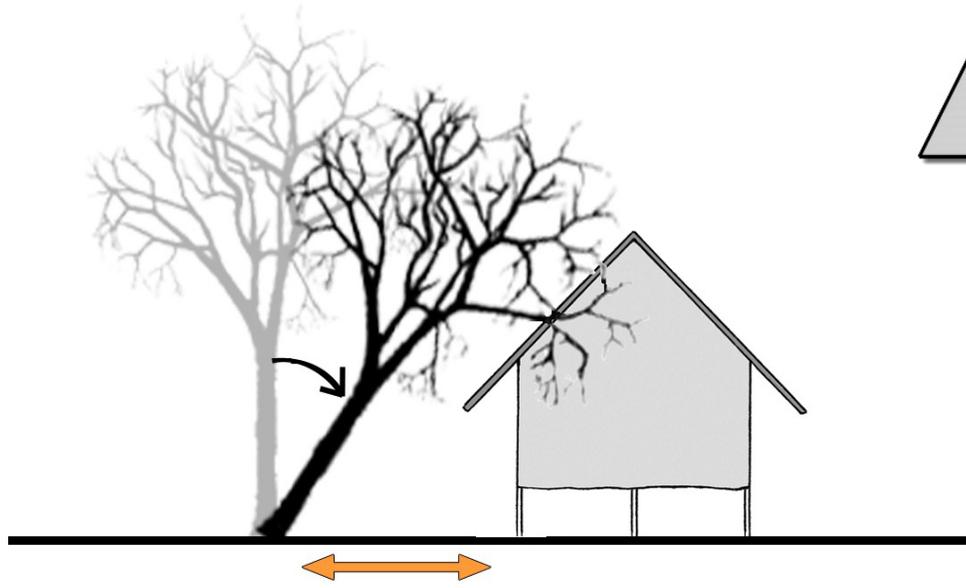
Vegetation should be maintained around the house (away from the posts) in order to stabilize the soil, in particular for slopes. The ground can be stabilized to prevent soil erosion, by reducing the water flow velocity. For example, using gravels, rocks and/or appropriate plants. This will serve also to embellish the site and eventually to delineate some spaces or limits.

BUILDING SITE : TREE BARRIER 01



DSAC	S0.2.1	SITE	Technical Guide
	BUILDING SITE : TREE BARRIER 01		

- For a new construction, it is important to ensure the site where the house will be located have enough vegetation cover to protect it from direct wind. A tree barrier can make a big difference in the protection of a house in case of high winds.
- If the vegetation cover is too little or for an existing building not enough protected, households can plant some small and bigger trees at safe distance around the house. High trees (such as palm trees) can break under wind forces so flexible trees (such as bamboo, banana trees) should be preferred near the house.



DSAC	S0.2.2	SITE	Technical Guide
	BUILDING SITE : TREE BARRIER 02		

- Trees are a threat if too close, but can offer protection if located at a safe distance from your shelter.
- A row of trees planted upwind will act as a shield. The influence of such a shield will be over a limited distance, only for 8 – 10 times the height of the trees. On the other side, trees planted too close to the house may fall and damage the house, hence a safe distance of 1.5 times the height of the tree should be kept in between.
- Cut tree branches that are too close to the house and may damage the roof.

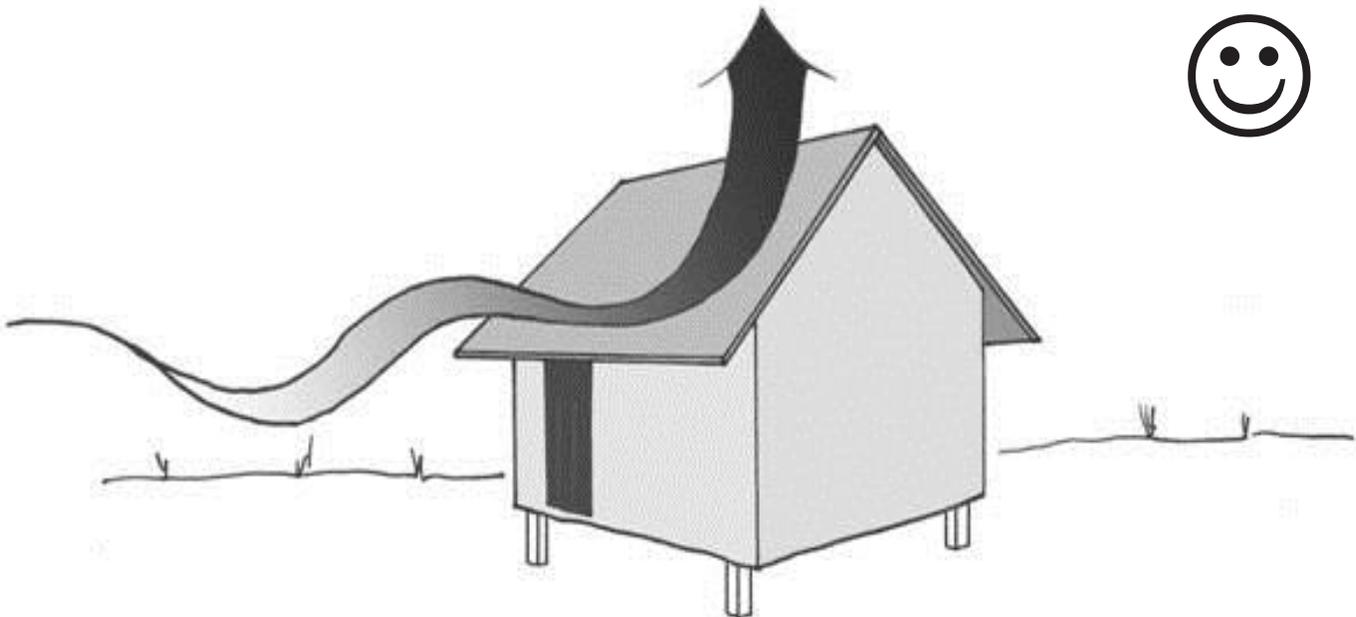
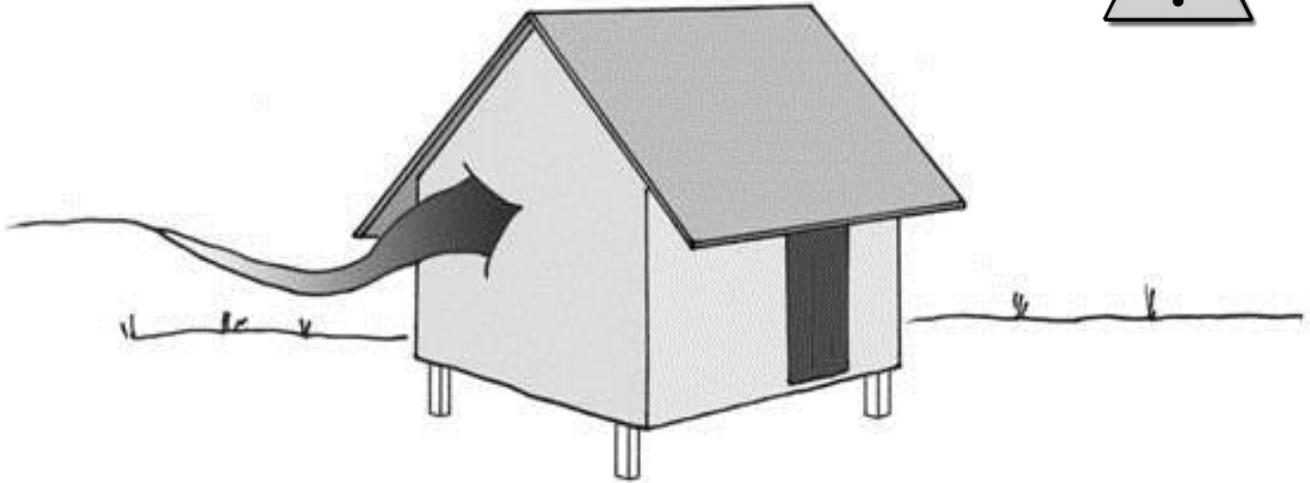
DSAC

S0.2.3

SITE

Technical sheet

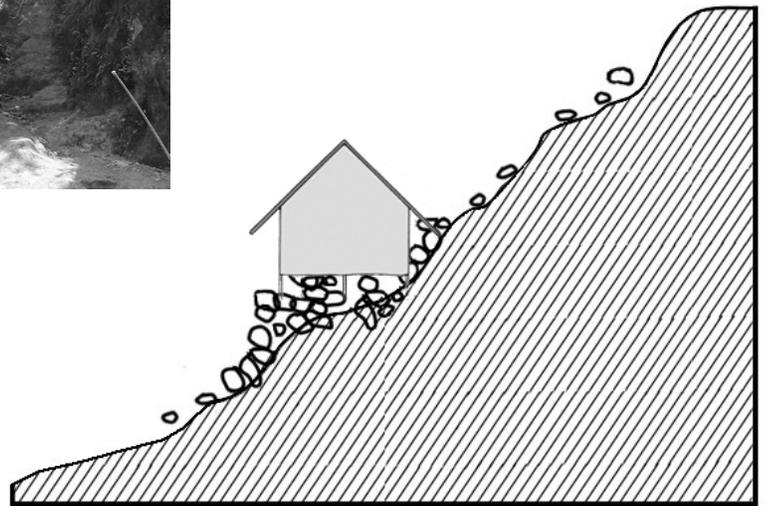
BUILDING ORIENTATION



DSAC	S0.2.3	SITE	Technical Guide
	BUILDING ORIENTATION		

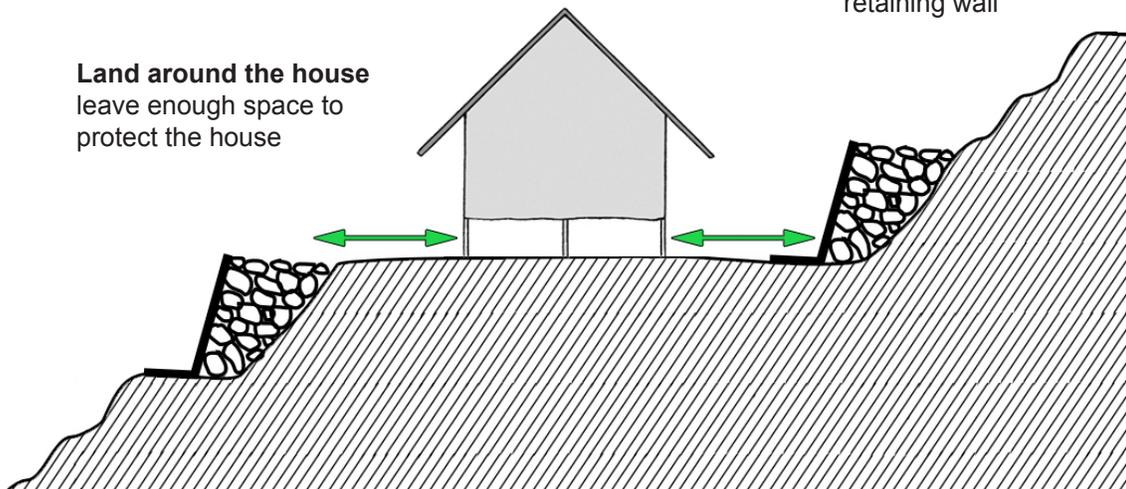
- The durability of a building also depends on its orientation. The orientation of the building must guarantee good protection against rains, winds, direct solar exposition.
- If the roof has 2 slopes, it should be oriented perpendicularly to the main direction of the wind so the wind will easily pass over the house. In case of 4 slopes roof, orientate the small sides of the building toward the dominant wind and the strongest rain. It will reduce the exposition to the dominant rains and reduce the risks of being blown off.

BUILDING SITE : SLOPE AND RETAINING WALL



Land slope
max 30° or build a retaining wall

Land around the house
leave enough space to protect the house



DSAC	S0.3.1	SITE	Technical Guide
	BUILDING SITE : SLOPE AND RETAINING WALL		

- The land should be preferably elevated and slightly sloppy in order to avoid the risks of stagnant water and the over-flow of the rain waters. It is necessary that the site is made flat and well drained.
- Houses must be located away from places subject to landslides where soil may move down a steep slope, debris flows where soil gravel and rocks may be washed rapidly down by heavy rainfall, and flashfloods.
- Keep enough distance on each side of the house, if necessary built retaining wall but don't build against it.
- Don't build on embankments.



DSAC	S1	PRODUCTION	Technical Guide

As timber, bamboo or palm leaves (nipa, ambulang) come from trees and plants their properties of density, weight, strength, flexibility, hardness and durability vary depending on both the species and which part of the plant/tree they are cut from.

Identifying the right species and respecting local knowledge of processing them is an important part of ensuring durability.

Lumber

- Advantages : easy and fast to joint and to build with, availability, can be reused.
- Using timber correctly can reduce risk of attack by fungus and insects. Fell logs preferably during winter (dry season) and store it away from the ground and pull apart with cleats to dry it. Hardwood should be sawn after drying it to prevent cracking and bending afterwards. After the construction, lumber should be ventilated and not exposed permanently to moisture (except a few specific species for posts).
- Each part of the house has his proper species of wood. Usually, local carpenters and farmers know it well : rot-resistant and large section wood for posts, smaller section and softwood for roof structure, etc. Unfortunately some of the local species are depleted (like Toog lumber), mainly the strongest one which need more time to get mature.
- If a structure is correctly designed and built, and the moisture content of its timber does not exceed 20 percent, then a preservative treatment is generally unnecessary for protection against fungal attack.

Bamboo

- Advantages : wide availability, rapid growth, easy handling and desirable properties.
- Bamboo has been well used in the daily life of many local communities for a wide range of purposes: from handicrafts and furniture to scaffolding and even main structure of houses and public buildings.

DSAC	S1	PRODUCTION	Technical Guide

- The lifespan of bamboo is very short if it is not well-managed. Untreated bamboo will last only 1-3 years if it is exposed to rain and in contact with soil and 4-6 years if under cover. But one may expect bamboo lifetime at least 25 years if bamboo is treated and protected from rain and ground contact.
- Bamboo can be treated with or without the use of chemicals. In both options there are many different techniques in order to prevent splitting, insect infection and fungal growth. Priority should be given to non-chemical preservation methods such as correct harvesting and correct structural application :
 1. Non-chemical treatments: (for more details ask local carpenters and farmers) : it is simple and cost-effective without the use of supporting equipment. For example soaking for 4 weeks up to 2-3 months in water, salty or not (river or sea). The sap will be leached.
 2. Chemical treatments: as for lumber, non-poisonous preservatives should be promoted (boron salt, engine oil, beeswax, local mixture based on natural leaves) and poisonous banned (like DDT).

Palm leaves covering (nipa and ambulang)

- Advantages: large availability, 3-4 harvest/year, easy and cost-effective to replace, less risk than CGI sheet in case of strong wind, good insulation against hot climate.
- Palm leaves covering has a good wind resistance: as it is permeable, nipa doesn't attract suction forces as high as CGI sheet roofing. And it is lightweight therefore presents minimum risks to occupants during earthquake.
- Palm leaves for roof covering can be long-lasting if properly harvested, treated, stored and maintained (up to 10 years reported).
- It is possible to treat with non-chemical preservative techniques by treating nipa with salt water (soaking in sea water) similar for coco lumber, for half a day. In some areas the shingles are smoked before installation.

LIST OF MATERIALS AND TOOLS

- Gloves and eye protection
- Borax and boric acid
- Water
- Drums for storage of solution
- Plastic containers for measuring and mixing
- Pointed iron rod (length depend on the bamboo to be treated)
- Stick for mixing
- Tarpaulin (30ft x 40ft)

SITE

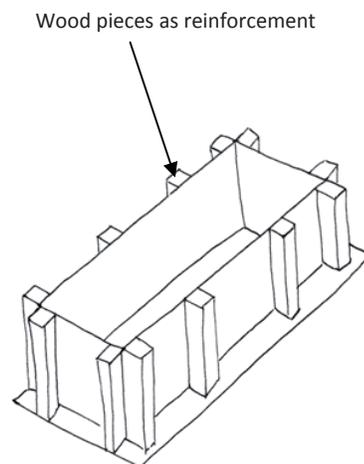
Covered and ventilated place

PREPARATION

1. clean and level the ground
2. treatment tank

OPTION 1: built a wooden tank

dimensions: length: 20 ft 8 inches
width: 2 ft
depth: 29.5 inches

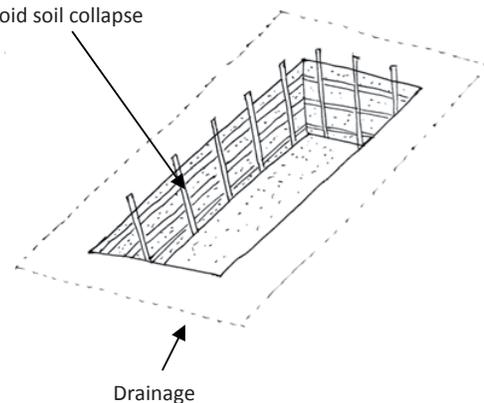


OPTION 2: dug an hole into the ground:

dimensions: length: 20 ft 8 inches
width: 2 ft
depth: 29.5 inches

- put some wooden vertical and horizontal wooden sticks to stabilize the soil
- dig drains around the excavated trench to avoid rainy water to go inside

Wood or bamboo slices as reinforcement to avoid soil collapse



DSAC	S1.1.1	BAMBOO	Technical Guide
	TREATMENT : CHEMICAL (BORON SALT) 01		

- The easiest way of extending the bamboo lifespan is to process it according to local knowledge:
 1. Follow good harvesting practice to ensure minimal sugars within the bamboo: harvesting during winter (dry season) at 10-15 cm (half feet) from the ground and just above the node. Do cut only mature bamboo (3-4 years old).
 2. Store it away from the ground, under a stone for a few days. If treated by soaking in water, best do it green.
 3. Before soaking, place the bamboo against a wall. Insert the iron rod and punch holes through the nodes. The holes will not diminish the strength of the culm.
 4. After treatment, dry the bamboo for 4-6 weeks depending on humidity conditions in a well ventilated, covered area. It must be in the shade (hot sun splits the culms). Make sure that they are not exposed to rain which could wash out the preservative.
- An other way of extending bamboo lifespan and probably the most important defence for any bamboo structure, whether treated or not, is how well it is designed for protection from the elements. Untreated bamboo in direct contact with moist ground or rain may completely breakdown in less than a year, treated bamboo may last no better.

TREATMENT : CHEMICAL (BORON SALT) 02

STEPS

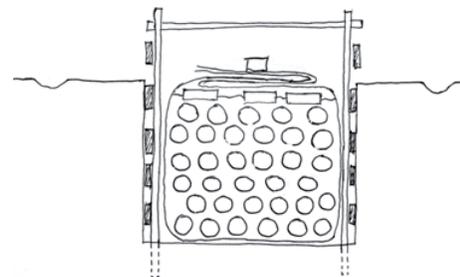
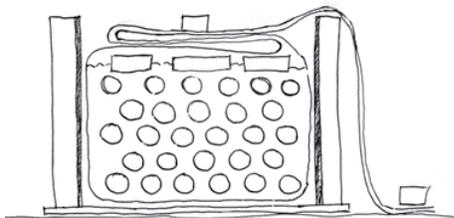
1. mix the borax and boric acid (wear eye protection and gloves!) and add water

borax and boric acid	proportion 3:2	for example: 3 kg borax + 2 kg boric acid
mixture and water	proportion 1:9	for example: 45 litres

for example: 75 kg borax + 50 kg boric acid + 700 l of waters

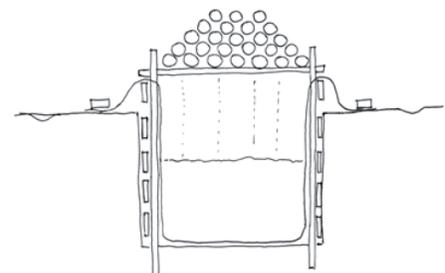


2. fit the tarpaulin into the hole keeping some parts outside
3. put the solution into the tank or the hole
4. cut the bamboo culms into the required length (no more than the tank length) and slice those required in order to not treat bamboo which will not be used
5. dip the bamboos into the solution, they should be completely covered by water
6. put stones or bricks on the bamboos to keep them under the water
7. fold up the tarpaulin to keep rain out and put some stones to keep it in place



8. time: whole bamboo must soak for 5 days
sliced bamboo must soak for 3 days

9. after soaking, lift bamboo (wear gloves!) onto sticks across the tank or the hole to let the preservative solution drains back for few hours



10. after that, let the bamboo dry for 1 week in a rack in a place protected from the rain and direct sun

DSAC	S1.1.2	BAMBOO	Technical Guide
	TREATMENT : CHEMICAL (BORON SALT) 01		

Treatment with boron salt

- Boron salt is more environmentally friendly than other wood and bamboo preservatives currently used. It is a white, odourless, powdered substance that is not flammable, combustible, or explosive and has acute low and dermal toxicity. The product is itself fire retardant and shows no hazardous decomposition.
- Boron salt is non-toxic to the environment, but is highly saline. When a moderate amount of it is absorbed into the ground, the ground filters out the salt to the point where it does not pollute the ground water. However, it is advisable to dispose of it safely and out of reach of children.
- When diluted with more water the discarded solution could be used as a herbicide on terraces and walkways.
- The boron salt solution can be used more than once for treating bamboo. Keep in mind that, as the bamboo is soaked the starch/sugar from the sap will move into the treatment solution. After the 3rd or 4th use add more boron salt. At the point when the drained solution foams significantly and/or mold is forming on the surface of the solution it is time for the solution to be disposed of.



DSAC	S2	CONSTRUCTION	Technical Guide

Repair

Many of the construction details for new housing can also be applied in the successive upgrading of houses. For lumber or bamboo houses, improvements can be easily implemented over time (concrete block houses are more difficult to upgrade, since this often requires higher investments).

Here is a list of various possible improvements:

- Tying-down from bottom up.
- Adequate spacing and type of roof nails.
- Diagonal bracing of walls, posts and roof frame.
- Well-embedded foundation posts (against uplift forces).
- Correct connections (beam extensions, bracings, corners, etc).

The improvement programme depends on the available capacities and resources of the household. In almost all cases, significant improvements can be made at low cost.

Construction preliminary

To ensure a safe and efficient construction site, before starting it is important to think about the site set-up and the work organisation:

- Construction site access: choose and prepare the access.
- Construction site safe perimeter: check for enough space around the layout that will be dedicated for the construction site. If necessary mark a safe perimeter with fences to avoid accident with children.
- Materials storage place: lumber, bamboo and nipa should be kept off the ground on cleats and in case of extended time of construction better to cover it with tarpaulin to keep it dry.
- Working place: check for a flat place to handle, saw and carve the lumber and bamboo.
- Tools storage place: check for a safe place around to store the tools (neighbours house, etc).
- Waste disposal place.



DSAC	S2	CONSTRUCTION	Technical Guide

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DSAC	S2.1	FOUNDATIONS	Technical Guide

Layout

- The layout of a building is the marking of the position of posts on the site. This step is very important and requires a lot of precision in order to avoid further problems when connecting the posts and floor or setting the roofing.
- Determine the slope and the levels of the site through locally known techniques, for example with the use of water level (hosepipe), straight bamboo log or spirit level.

Excavation for posts

- After marking the location of the posts, from the centre, mark width of the pit. Excavate using crow bar and shovel. Stack excavated material away from opening, excavate to required depth. Bottoms of all pits should be at the same level. Use water level for leveling depth of excavation.
- With solid footings your shelter will not sway and will better resist storms and floods. Compaction of the base of the post may not be done after erection, but postponed until the main structure is assembled. This provides room for any adjustments during construction.
 1. Compact the soil under the entire construction.
 2. Ensure the footings are deep enough (abt. 50 cm or 1ft-4in).
 3. Lay gravel, sand or brick pieces on the base of the footings.
 4. Compact the holes around the footings with sand or clay.

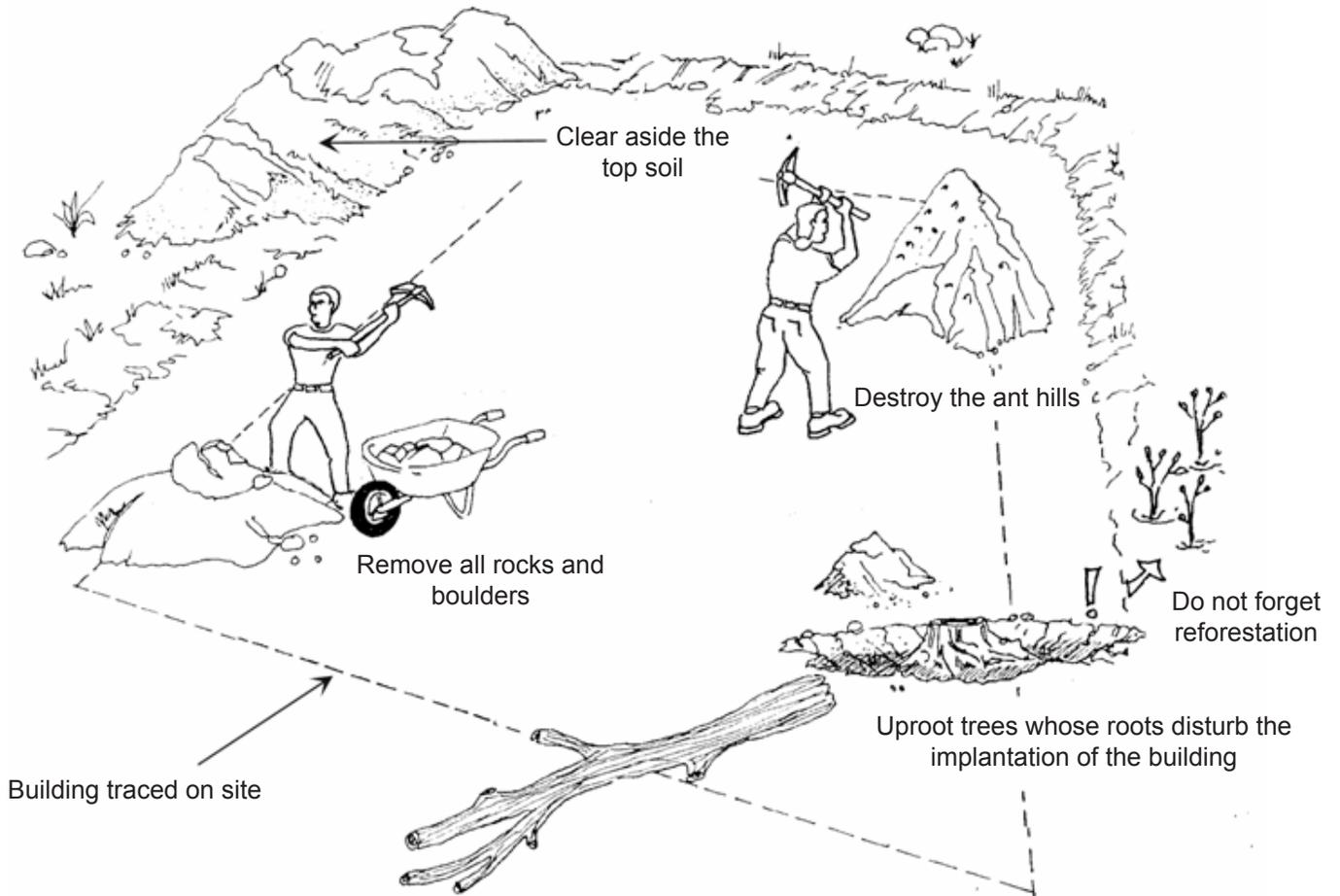
DSAC	S2.1	FOUNDATIONS	Technical Guide

Repair foundations

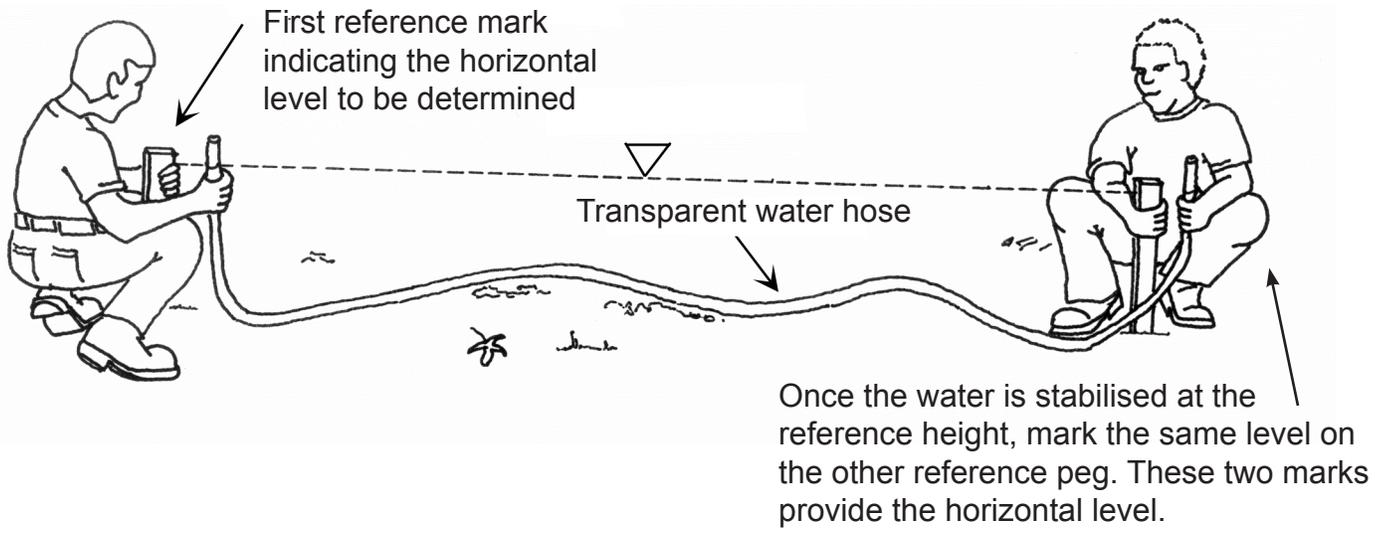
To improve the strength of foundations, the following can be considered:

- **Replace deteriorated posts:** when posts are decayed, they should be replaced by new ones. It is also possible to replace only a part of the post with a good connection. The whole house should be checked for rotten and decayed lumber, which should then be replaced.
- **Concrete foundations:** in some cases the base of the post can be replaced by concrete prefabricated foundation. The concrete posts should be larger at the bottom than at the top.
- **Bracings:** when the gap between the floor and the ground is more than 1 m (3 ft), bracing should be added for strength. With wood posts, the bracings can be connected to the posts and the floor beams.

LAYOUT: WATER LEVEL



It is very easy to transfer the reference height from the first peg to the others by using a transparent hose filled with water.



DSAC	S2.1.1	FOUNDATIONS	Technical Guide
	LAYOUT: WATER LEVEL		

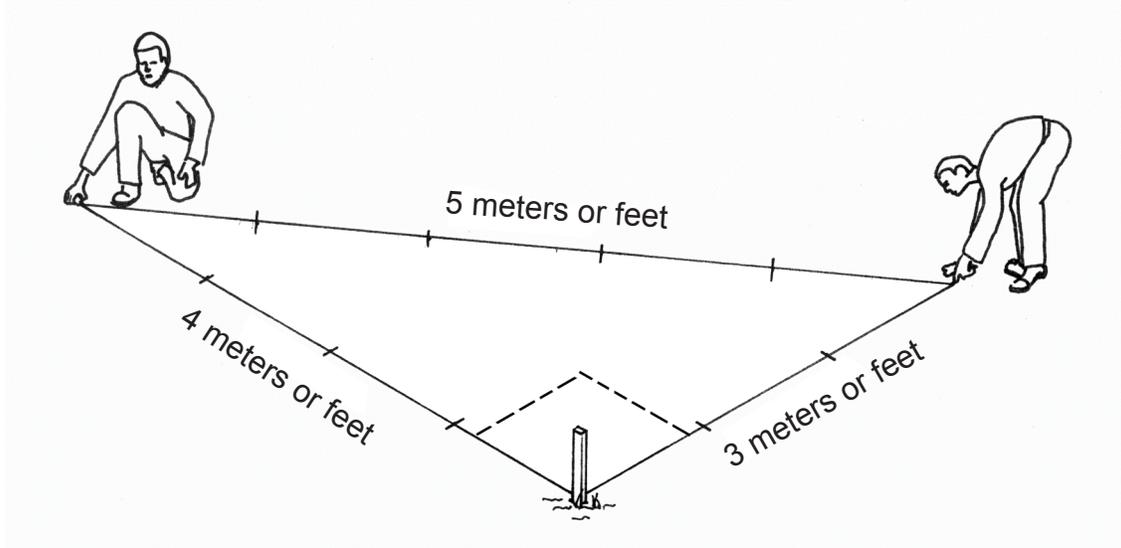
It is necessary to clear the site before any construction:

- Organic soil should be removed up on the whole surface of the building. It allows to set the building on a good and firm soil. Extra allowance of about 2 meters (6 feet) should be given all over the perimeter of the proposed building.
- Remember to remove stones, stumps and roots. The presence of organic materials in the site of the building would encourage the presence of termites and rodents around the construction works. Clear the site of any ant hill.

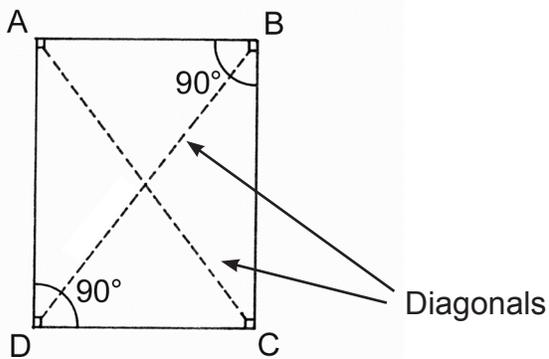
Transfer of the reference height

- Take the 2 ends of a transparent hosepipe of sufficient length, and put them at 2 points of the site. Fill the hosepipe with water while raising up in the air each end. When the water stabilizes, it will indicate the lower and higher points of the site. Measure height between water level and ground. Be careful, where the water rises up higher from the ground is the lower point of the site!
- Check for any air bubble and make sure to remove them before measuring.

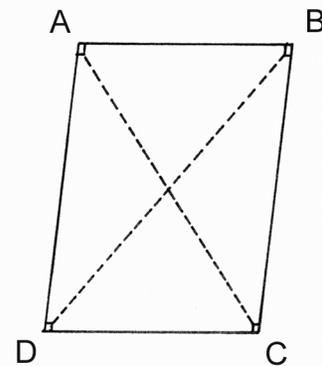
SQUARING: 3-4-5 PRINCIPLE



After defining the four corners, check the diagonals.
Their lengths must be equal



Correct
 $AC = BD$



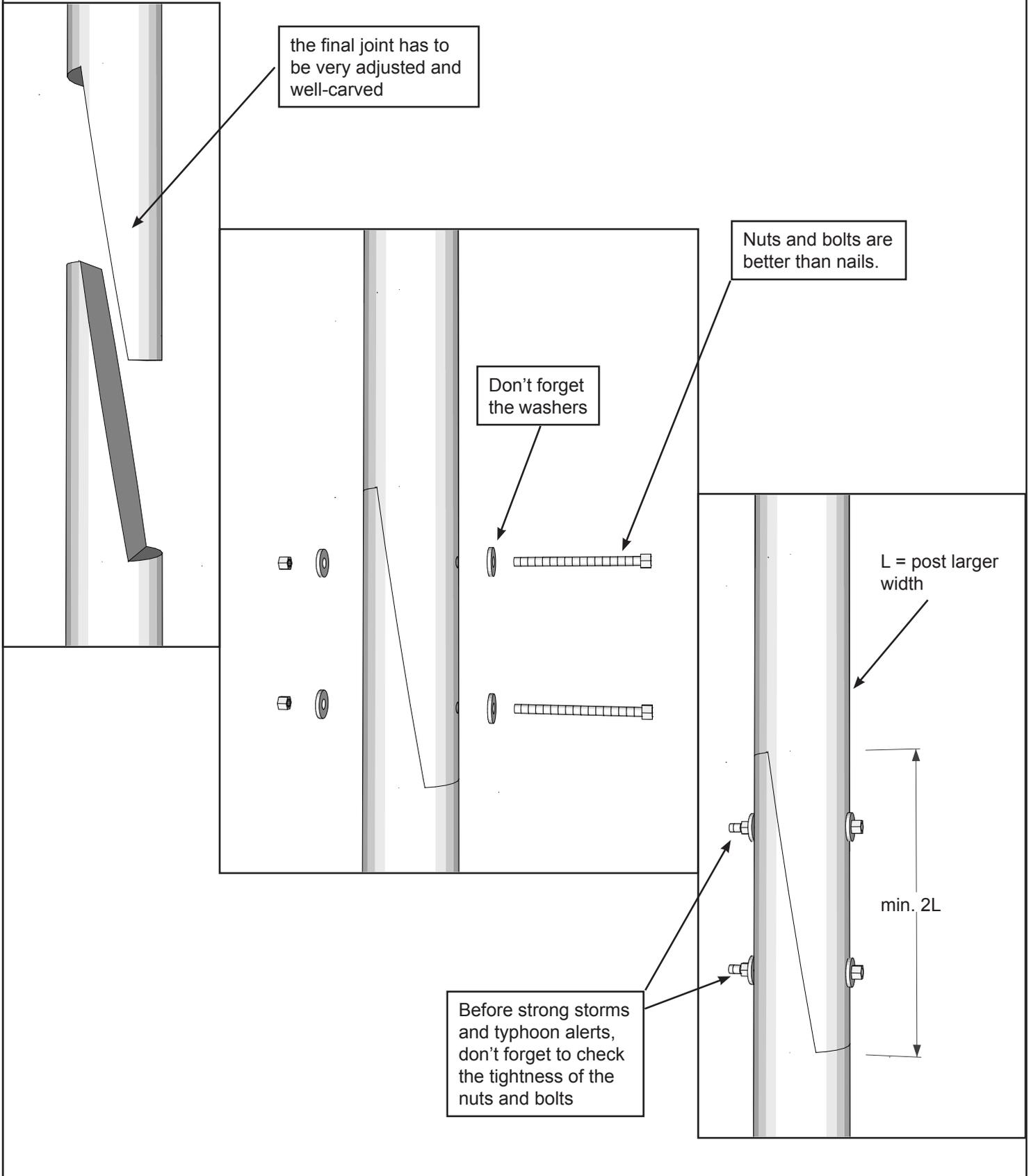
Incorrect
 $AC < BD$



DSAC	S2.1.2	FOUNDATIONS	Technical Guide
	SQUARING: 3-4-5 PRINCIPLE		

- Use the rule of the 3-4-5 for the right angles. Put the 0 of the type measure on the 1st corner (future post), and make a triangle, which length of the sides are the numbers 3, 4 and 5 (for example, 3 m - 4 m - 5 m or 3 ft - 4 ft - 5ft. But it can be 1,5 m - 2 m - 2,5 m).
 1. When the 1st angle of the building is correct, do the same with the 3 other corners.
 2. After defining the angles, check the lengths of the diagonals to be sure they have the same measurements.
 3. When the angles are correct (90°), extend the lines and fix the pegs (pointed pole for the layout) far from the actual corner of the building.
 4. Around the 4 lines representing axes of posts, draw on the ground the limits of the posts excavations with a pick-axe or similar tool.

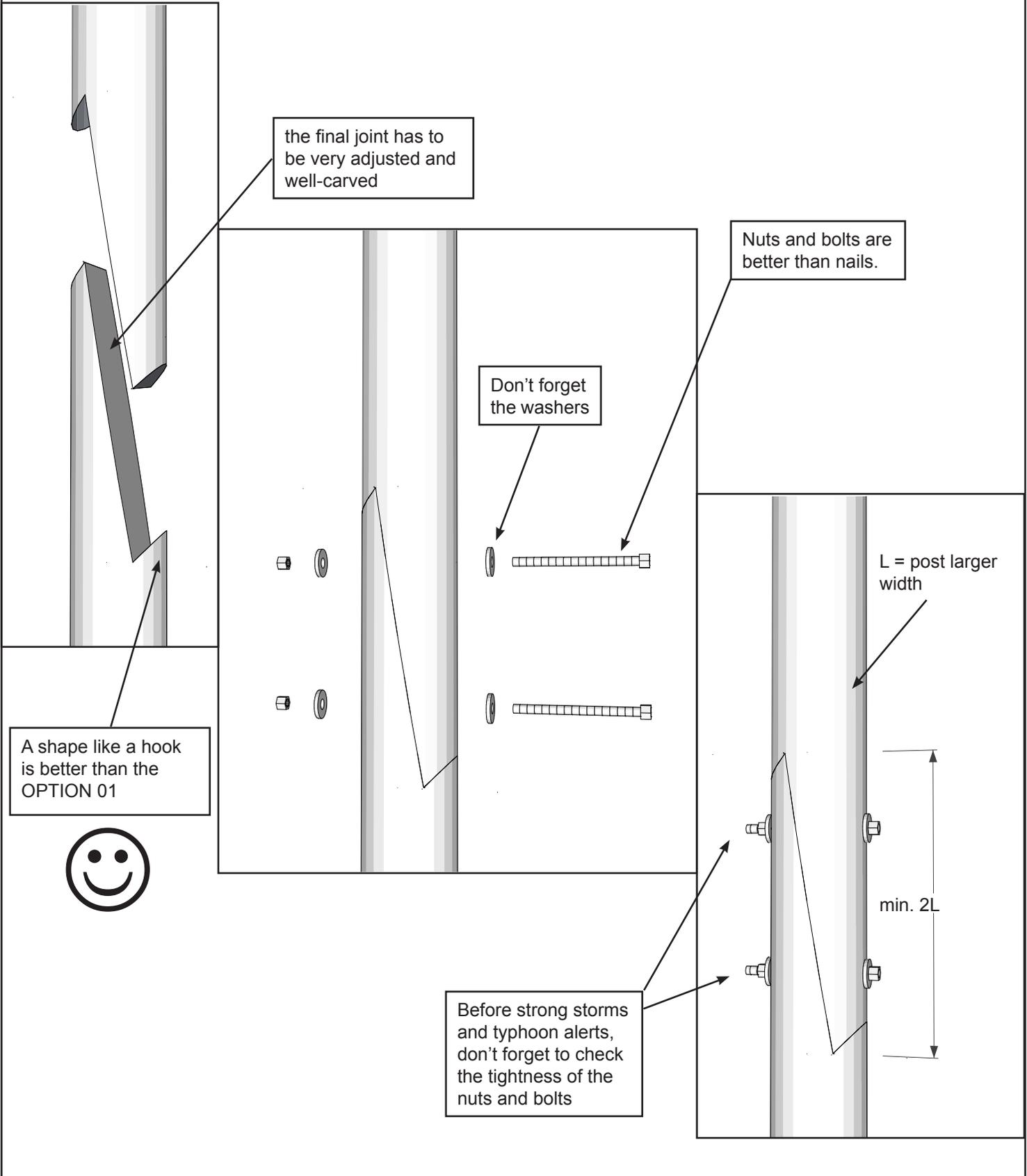
POST JOINT (EXTENSION) OPTION 01



DSAC	S2.1.3	FOUNDATIONS	Technical Guide
	POST JOINT (EXTENSION) OPTION 01		

- In the Philippines, several local species are used and appropriate for posts such as *toog*, *kakawate* (madre di cacao), *tugas*. Appropriate species are dense, durable and resist to insect attacks and doesn't rot easily. Check which are the species used locally.
- The simplest type of foundation is to embed a wood post straight into the ground. Since post foundations are the most pest and rot prone and may provide termites with access to the rest of the building from the ground a particular care should be taken to choose the best solution.
- Where they are to be used, lumber post type foundations can be protected using naturally durable species of timber or in some cases treatments. Treatments for foundation posts should always be completed before use.
- Post type foundations should be embedded in the ground a minimum of 50 cm deep (1,5 feet).

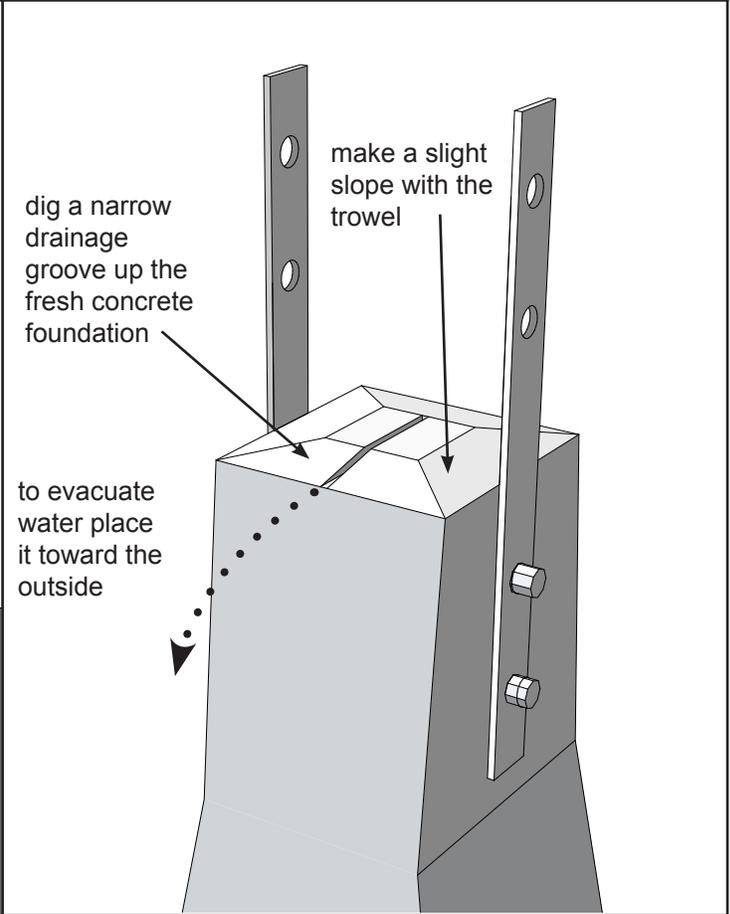
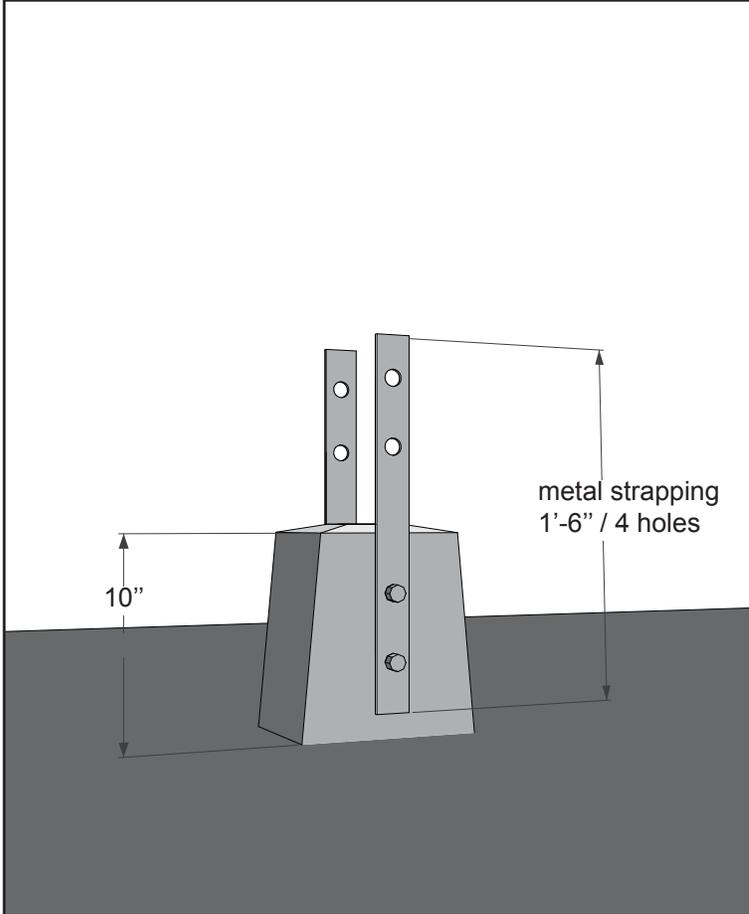
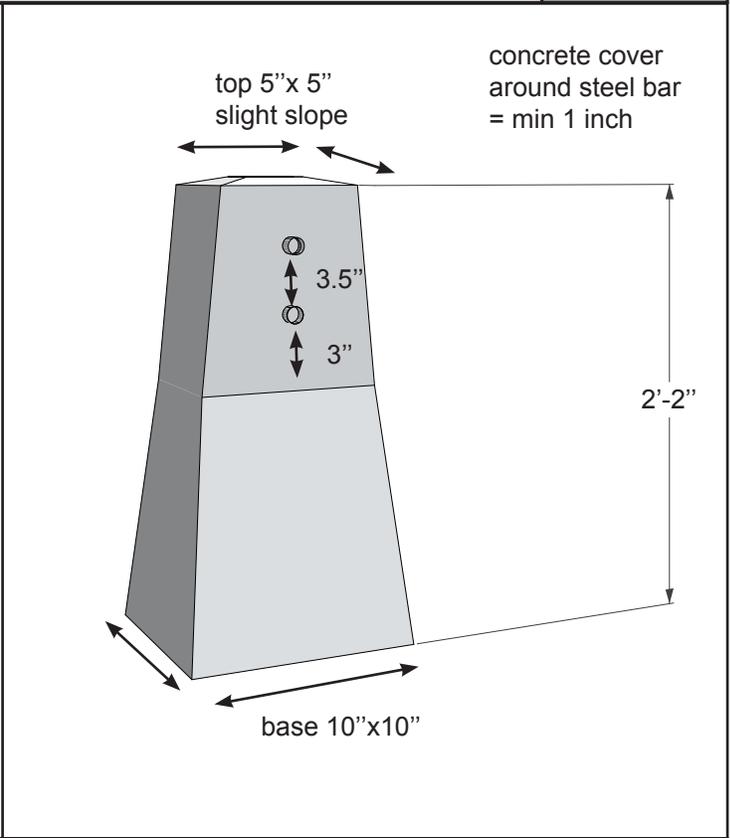
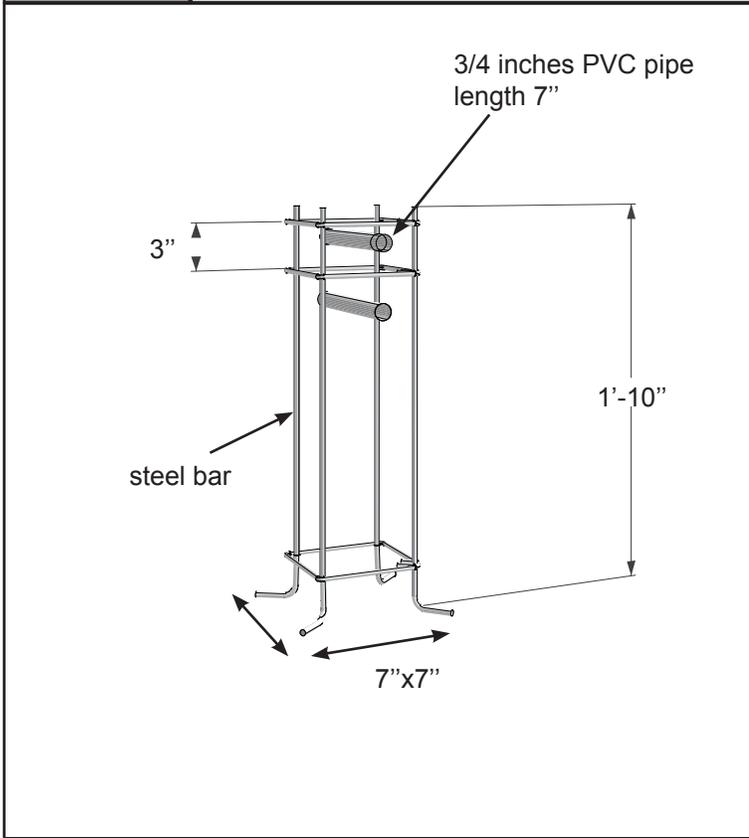
POST JOINT (EXTENSION) OPTION 02



DSAC	S2.1.4	FOUNDATIONS	Technical Guide
	POST JOINT (EXTENSION) OPTION 02		

- To improve the connection tying can be done with rattan, tie wire, rope or metal strap.

DSAC	S2.1.5	FOUNDATIONS	Technical sheet
	PREFABRICATED FOUNDATION		



DSAC	S2.1.5	FOUNDATIONS	Technical Guide
	PREFABRICATED FOUNDATION		

- Hardwood availability is constantly decreasing and appropriate wood for posts are not always available. When appropriated lumber for posts is not available an option to extend the wood lifespan is to build concrete foundation in order to prevent lumber being exposed to moisture. This type of foundation can be prefabricated in advance and the frameworks can be reused. The concrete foundation can be poured in site as well.

DSAC	S2.2	MAIN FRAME	Technical Guide

Structure as a whole

The main problem in withstanding the strong winds of a typhoon is that the connections between the different elements of the building get damaged. Because of that, the structural integrity or coherence of the building diminishes and the house or parts of it are destroyed. The key word in typhoon mitigation is 'connections'; most of the problems are caused by poor connections between different elements of the building.

So, the principle method in building typhoon-resistant houses is to tie down the roof to the walls, the walls to the floor, the floor to the posts and the posts to the foundations. Also, the walls must be strong enough to prevent the wind blowing them in, and the joints must be strong enough so that the wind cannot lift off part or all of the roof or knock the house over.

- Tie the structure to the ground with appropriate foundations.
- Make proper joints between structural components. Special care must be taken with the detail of connection (embedded or notched joint) as well as the material used to fix the joint (nails, pegs, screw, bolts) and to tie it (metal strapping, vegetal or metallic ties, fish plates). A connection should not rely only on nails. Using only nails doesn't make strong connections.
- Support wall-panels where possible: build internal walls to brace the outside wall-panels and prevent them from caving in.
- Brace all walls and roof.
- Nail properly the wall panels.

DSAC	S2.2	MAIN FRAME	Technical Guide

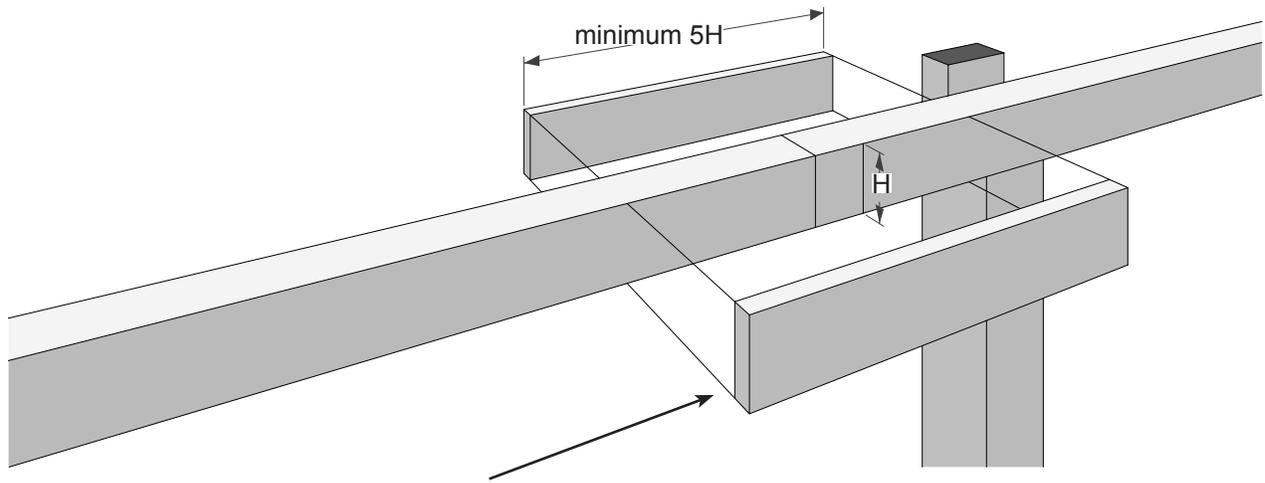
Wood connections

- For simple construction, lumber is most commonly jointed with nails, pegs, screws or bolts. If available, joints can be strengthened with metal strapping, gang plates (metal plates nailed either side of a joint to provide strength).
- Check that timber joints are built so that the building forces push them together rather than pull them apart.
- Nails: it is important to select the right type and size of nail for any particular situation. Nails are specified by their type, length and gauge (the higher the gauge number, the smaller the shank diameter). As they have a tendency to split thin piece of lumber like battens, the following rule is often used: the diameter of the nail should not exceed 1/7 of the thickness of the lumber.

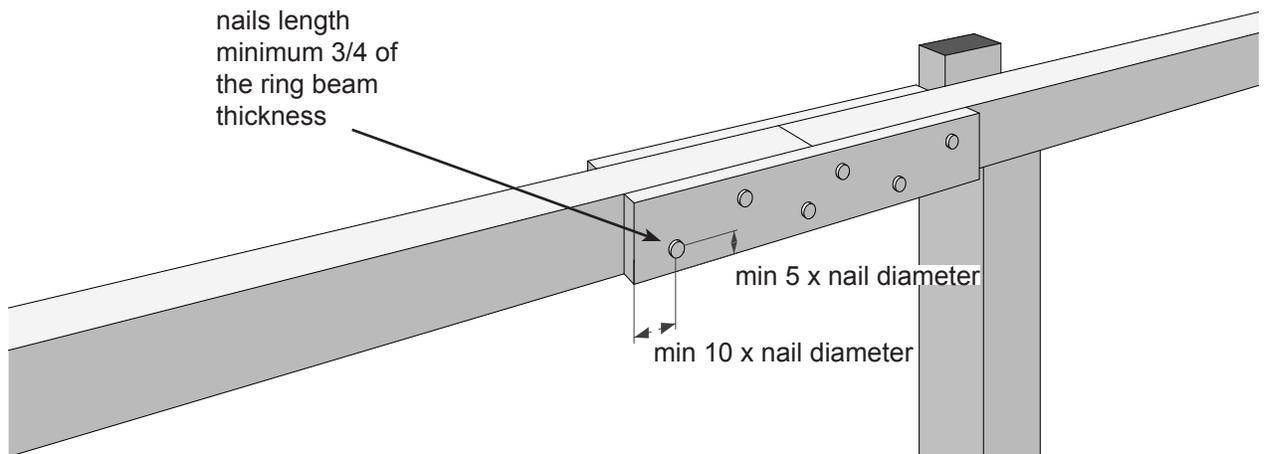
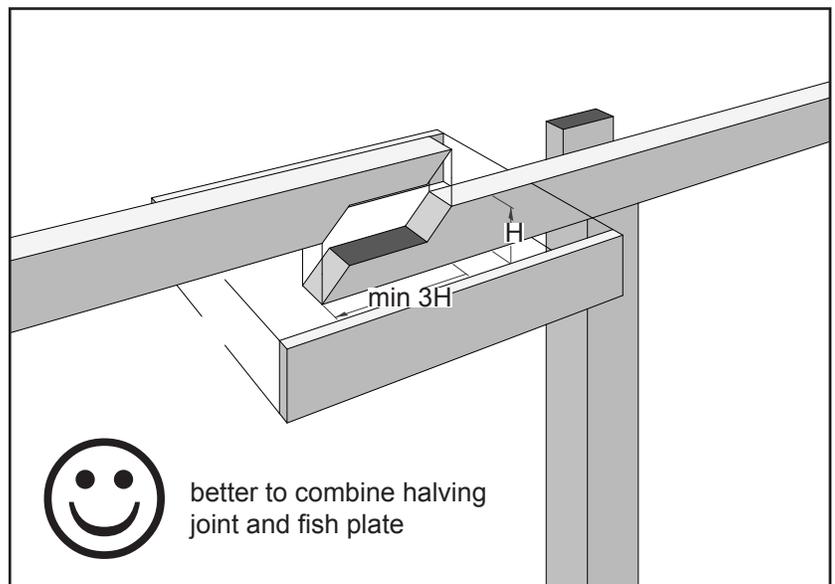
Bamboo connections

- Unlike lumber, bamboo has hollow sections. When joining bamboo, the challenge is to avoid crushing these hollow sections. Bamboo can be bolted, pegged, tied, wired, and screwed. Sometimes they can be nailed but great care must be taken not to split the bamboo.

FISH JOINTS / TWO-NAILED FISH PLATE



minimum 1"x4"
HARDWOOD



DSAC	S2.2.1.1	MAIN FRAME	Technical Guide
	FISH JOINTS / TWO-NAILED FISH PLATE		

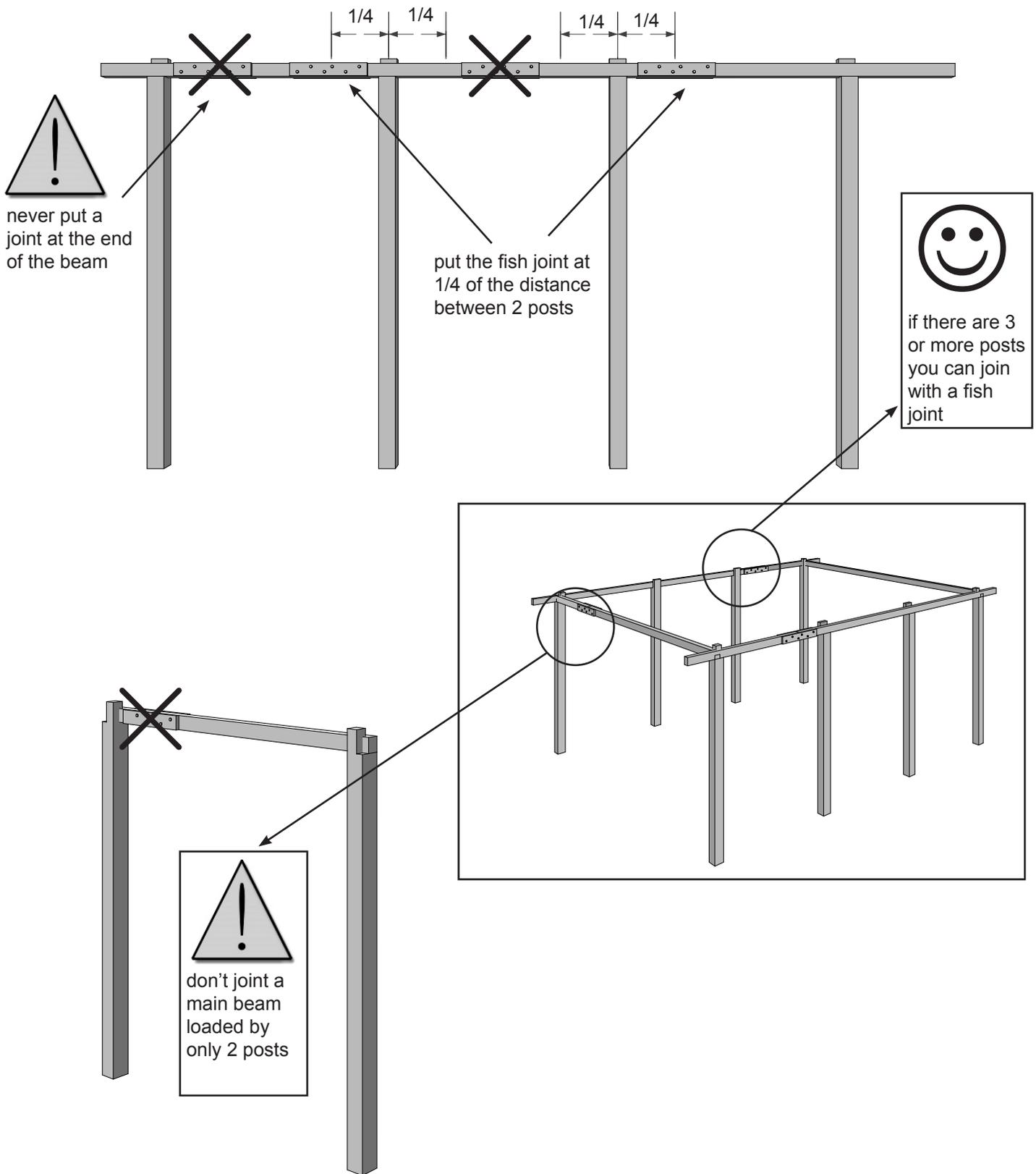
Fish joints

Joints are often strengthened by “fish plates” - lumber (or metal plates) nailed across the joint. They are commonly made with off-cuts of lumber, but care must be taken to ensure that the off-cuts lumber are long enough and do not split. Following rules should be respected:

1. The length of the fish plates should be at least 5 times the height of the joint member.
2. The nails should be as long as to enter 3/4 of the thickness of the joint member and 12 times the diameter of the nail.
3. Nails should be evenly distributed over the entire fish plate, normally in a staggered manner.
4. The spacing between the nails, and between the nails and the edge of the fish plate depends on the diameter of the nails:
5. Along the grain of the timber, the distance between the nails should be 10 times the diameter of the nail.
6. The distance between the nail and the edge of the fish plate should be: along the grain 10 times the diameter of the nail, across the grain 5 times the diameter of the nail.



FISH JOINTS / TWO-NAILED FISH PLATE



DSAC	S2.2.1.2	MAIN FRAME	Technical Guide
	FISH JOINTS / TWO-NAILED FISH PLATE		

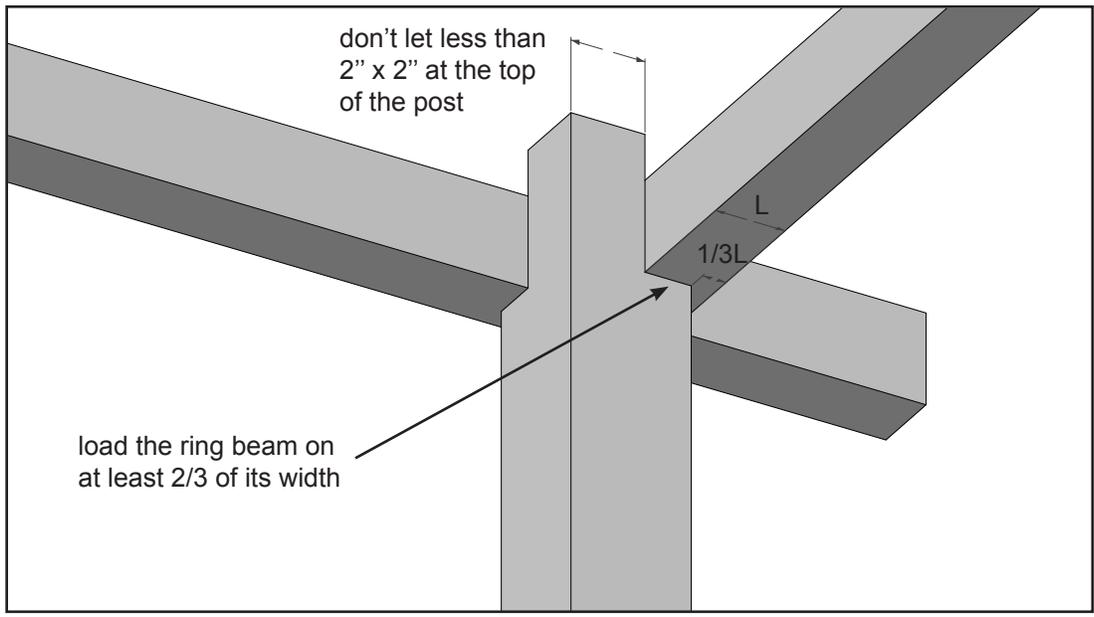
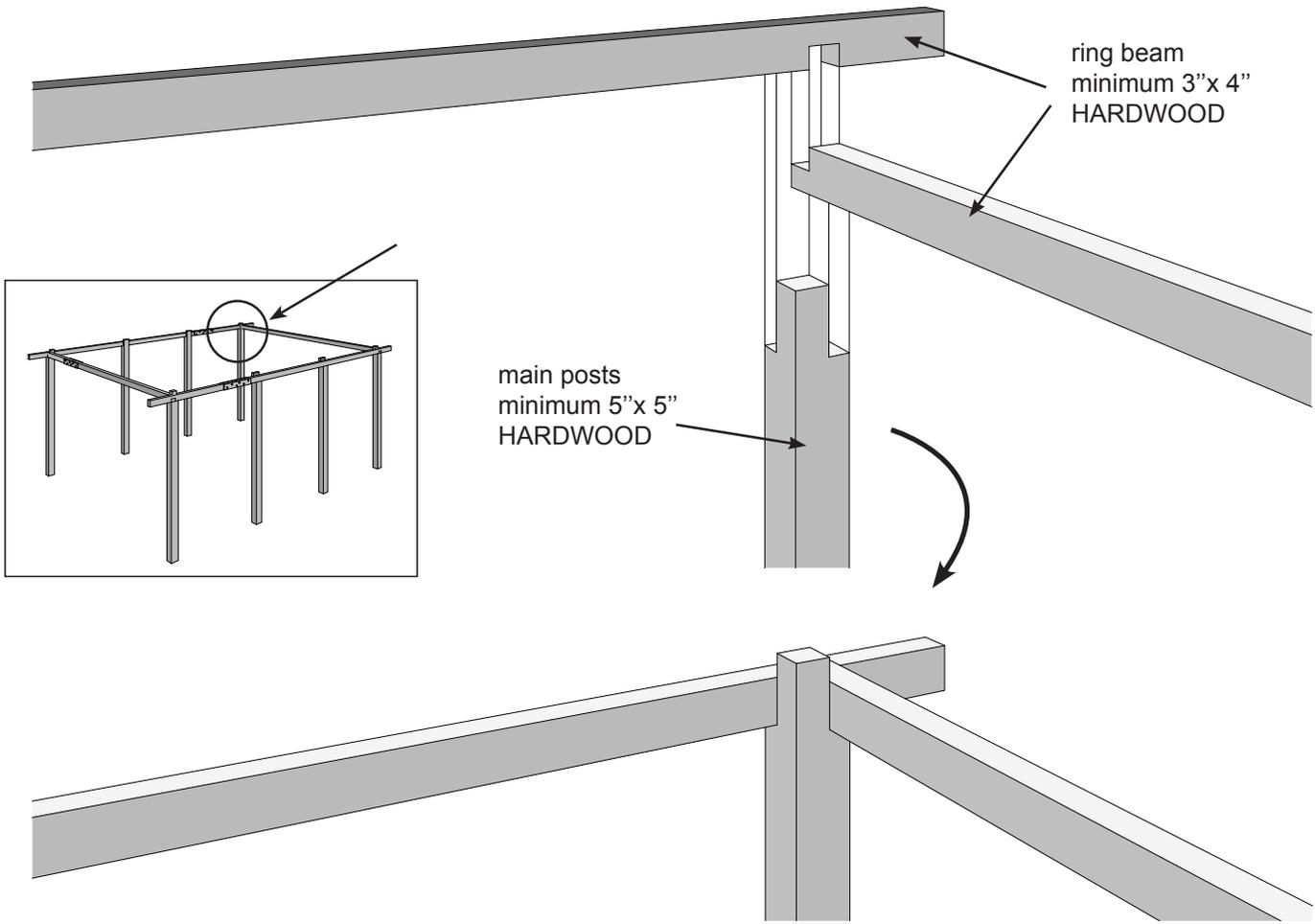
Joints

- A joint is always a weak point in the beam. Therefore, when placing beams, purlins or ridge beams, jointing should be avoided wherever possible.
- Joints should not be used when the beam has bending forces upon it. If a joint is unavoidable, its position should be carefully chosen. It should be placed in a position where the bending moment is small.

Rules for joints

1. Never use joints in beams with only 2 bearing supports.
2. Beams with 3 or more supports can be jointed at the bearing points.
3. Beams with 3 or more supports can also be jointed near the point where there is no bending moment. This method takes advantage of the static system of a continuous spanned beam which has a reduced maximum bending moment compared to a single spanned beam.

RING BEAM / CORNER JOINT



DSAC	S2.2.1.3	MAIN FRAME	Technical Guide
	RING BEAM / CORNER JOINT		

- A ring beam (tie beam) is a continuous beam which performs the role of a tight belt at the floor level and at the top of the wall.
- It provides a solid base on which joists, rafters or trusses can be anchored. It makes the floor react like one element and makes it easier to make strong connections between walls and floor and walls and roof.

RATTAN TYING

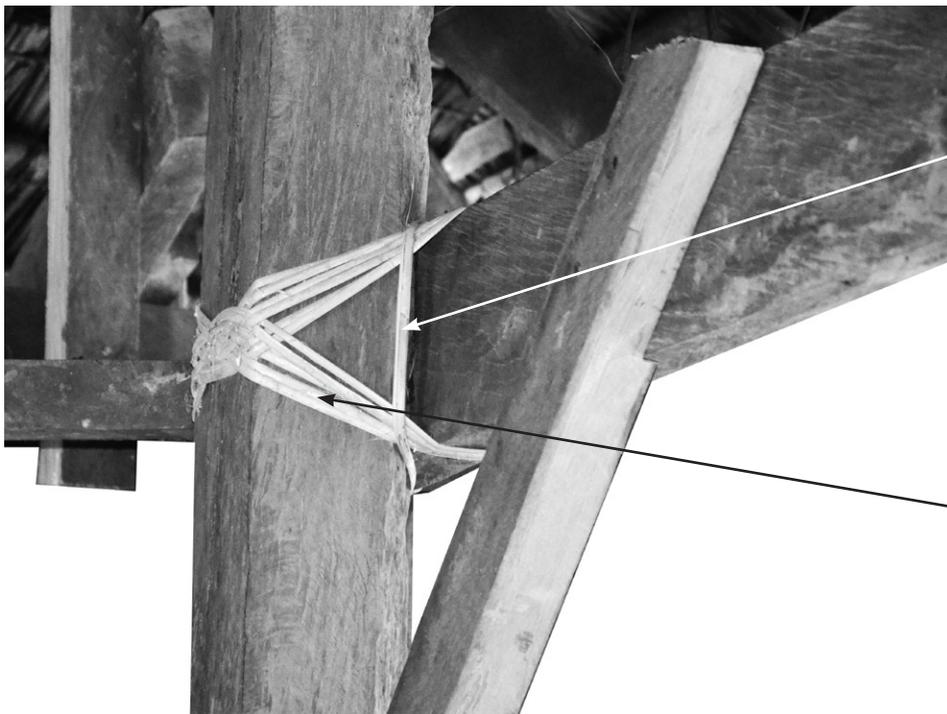


Truss / post and beam tying

tying a least with 8 rattan wisps

Corner post / beam tying

at least 8 rattan wisps on each side (6 for middle post)



Post / beam tying

at least 6 rattan wisps on each side



Middle post / beam tying

at least 6 rattan wisps on each side



DSAC	S2.2.2.1	MAIN FRAME	Technical Guide
	RATTAN TYING		

All components of the wood frame must be tied down:

- Foundations with posts.
- Posts with upper ring beam.
- Ring beam with roof structure (trusses or rafters).
- Fix well the roofing material on the roof frame and the trusses tied to the structure.



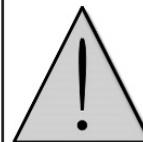
GALVANIZED WIRE / CLEATS TYING

If rattan is not available, gavanized tie wire can be use (may be used together with cleats). Use good quality galvanized tie wire, minimum 16 gauge. Replace when the tie wire is rusty.



Truss / post and beam tying

Don't forget to tie the truss with the post and/or with the beam



Corner post / beam tying

at least 5 tie wire wisps on each side (4 for middle post)



**Option 1
Truss and beam tying**

tie the truss together with the beam with a cleat ("block")

**Option 2
Truss / post and beam tying**

tie the truss together with the beam and the post with tie wire (at least 4 wisps) same way as with rattan

DSAC	S2.2.2.2	MAIN FRAME	Technical Guide
	GALVANIZED WIRE / CLEATS TYING		

Several materials can be used for tying lumber (especially posts) :

- Galvanised tie wire (check the quality of the galvanized, 2-5 mm, at least 13 gauge).
- String or rope (nylon).
- Cleats (off-cuts of lumber).
- Metal strapping (if available or affordable).
- Check that the result is very tight.

DSAC	S2.2.3	MAIN FRAME	Technical Guide
		BRACING	

Reinforce the main frame

Failure of walls occurs when there is insufficient strength to resist horizontal forces caused by winds and earthquake or when the different elements of the walls are not tied together properly. To reinforce an existing structure against lateral forces, the bracing system provides strength so that the building does not collapse sideways but is held together.

Corner bracing can be added easily and at low cost at different places of the structure.

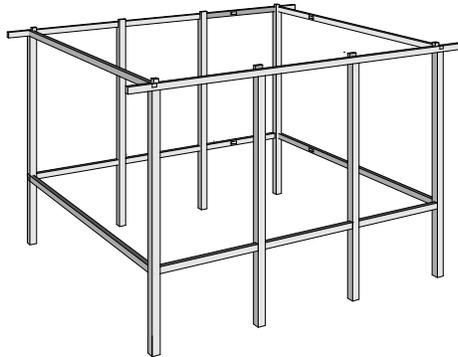
Bracing should be put vertically as well as horizontally to ensure strengths in all directions. As much as possible, posts, walls, floor and ceiling should be braced.

Give a proper care when connecting the braces to the frame using halving joint or embedded joint and appropriate nailing.

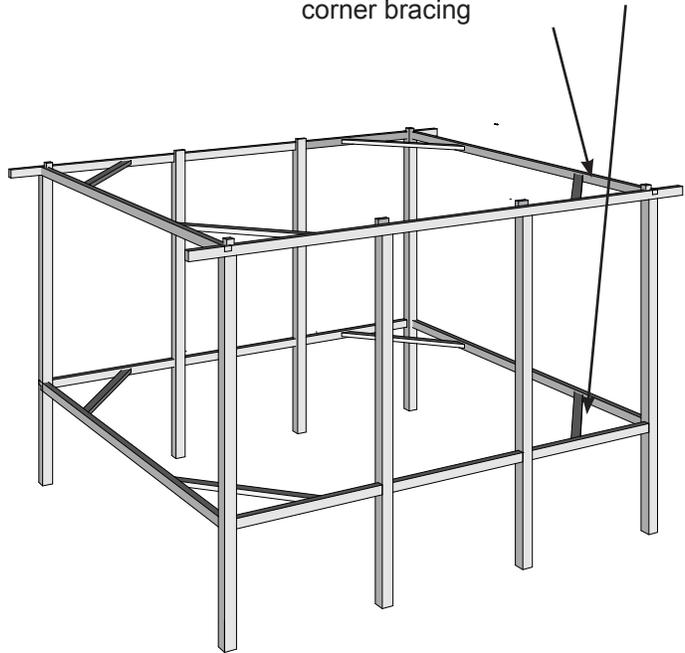
DSAC	S2.2.3	MAIN FRAME	Technical Guide
		BRACING	

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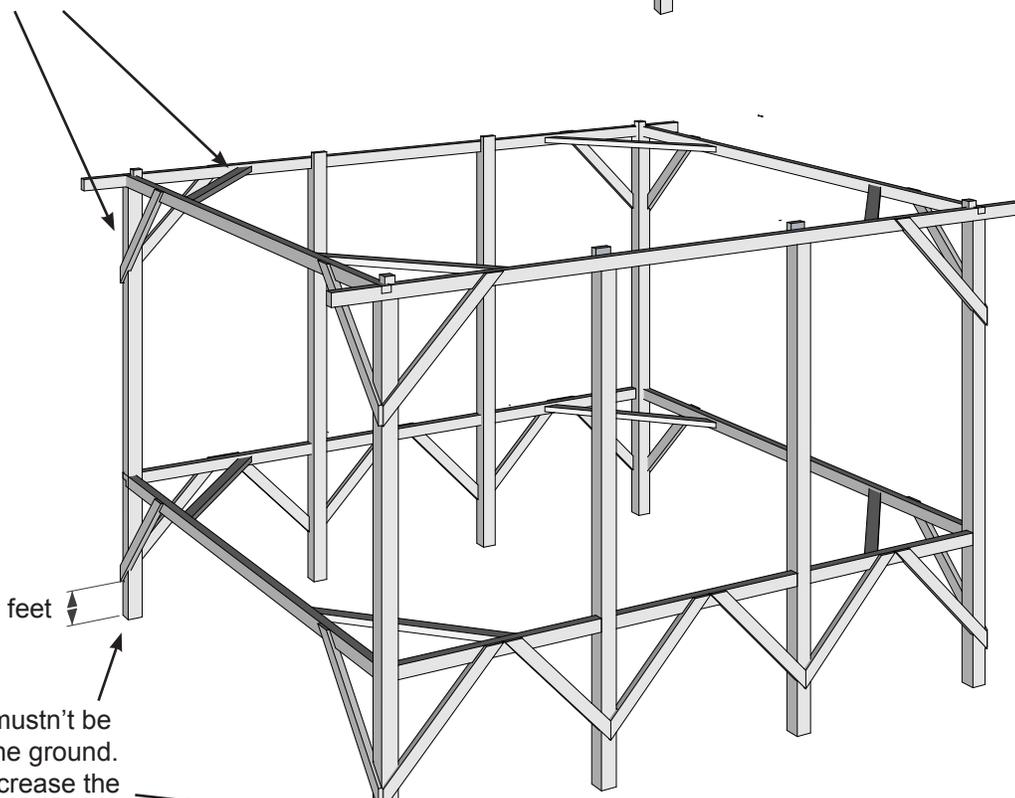
BRACING OPTIONS 1



Don't forget the horizontal corner bracing



The angle of the corner bracing (vertical and horizontal) has to be around 45°



min. 1 feet

The bracing mustn't be too close to the ground. This would increase the wood rotting.



DSAC	S2.2.3.1	MAIN FRAME	Technical Guide
	BRACING OPTIONS 1		

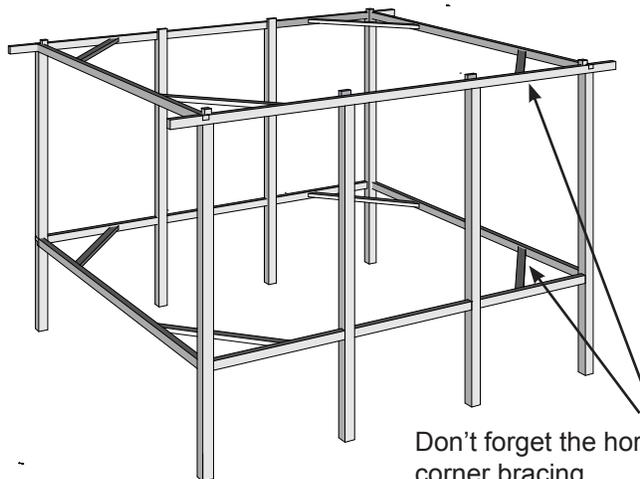
Bracing of posts

- When the floor is higher than 1m (3ft) above the ground, the posts should be braced. Bracing should always be done in two directions, and generally on all four corners of the house.
- This will provide stability to the complete building under lateral loads. Corner bracings will be preferable to full diagonal bracing so as not to obstruct the passage of floating debris during storm surge.

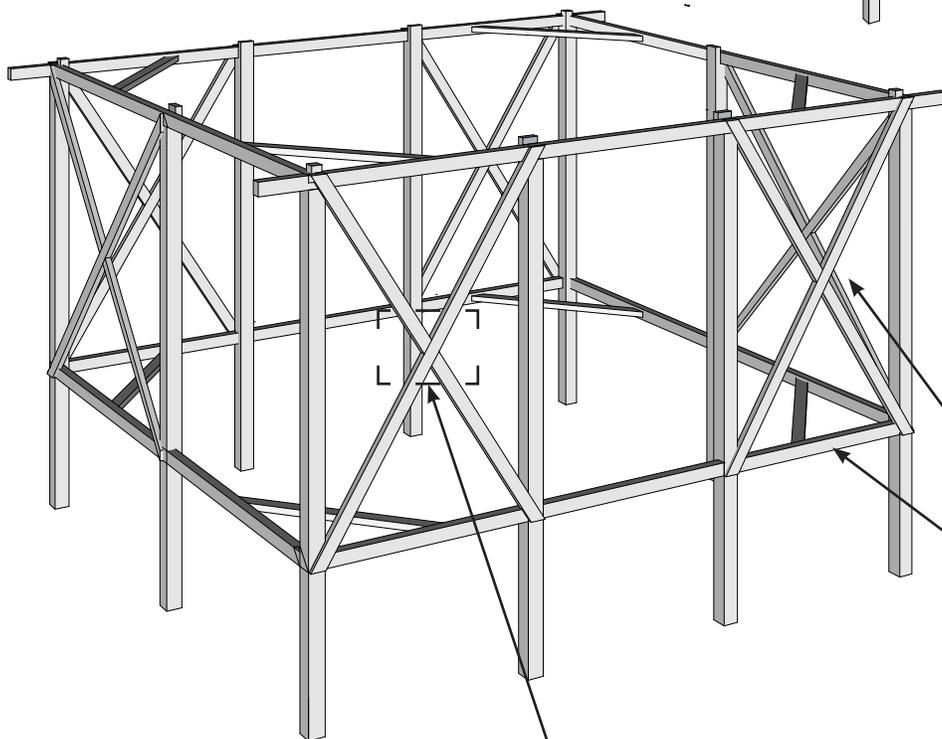
BRACING OPTIONS 2

BRACING : CROSS OR CORNER

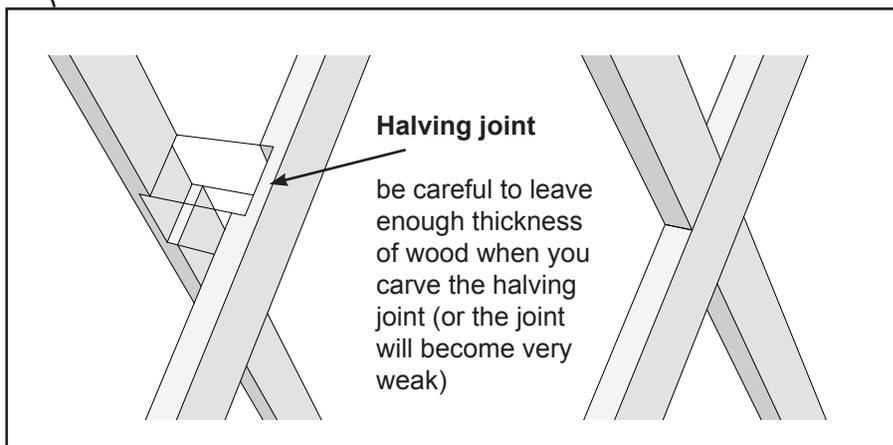
Cross bracing are stronger than corner bracing. But since the length of the bracing is longer the section should be bigger and more wood will be necessary. Wood defects (like knots) have to be avoided !



Don't forget the horizontal corner bracing



The angle of the corner bracing and cross bracing has to be around 45°

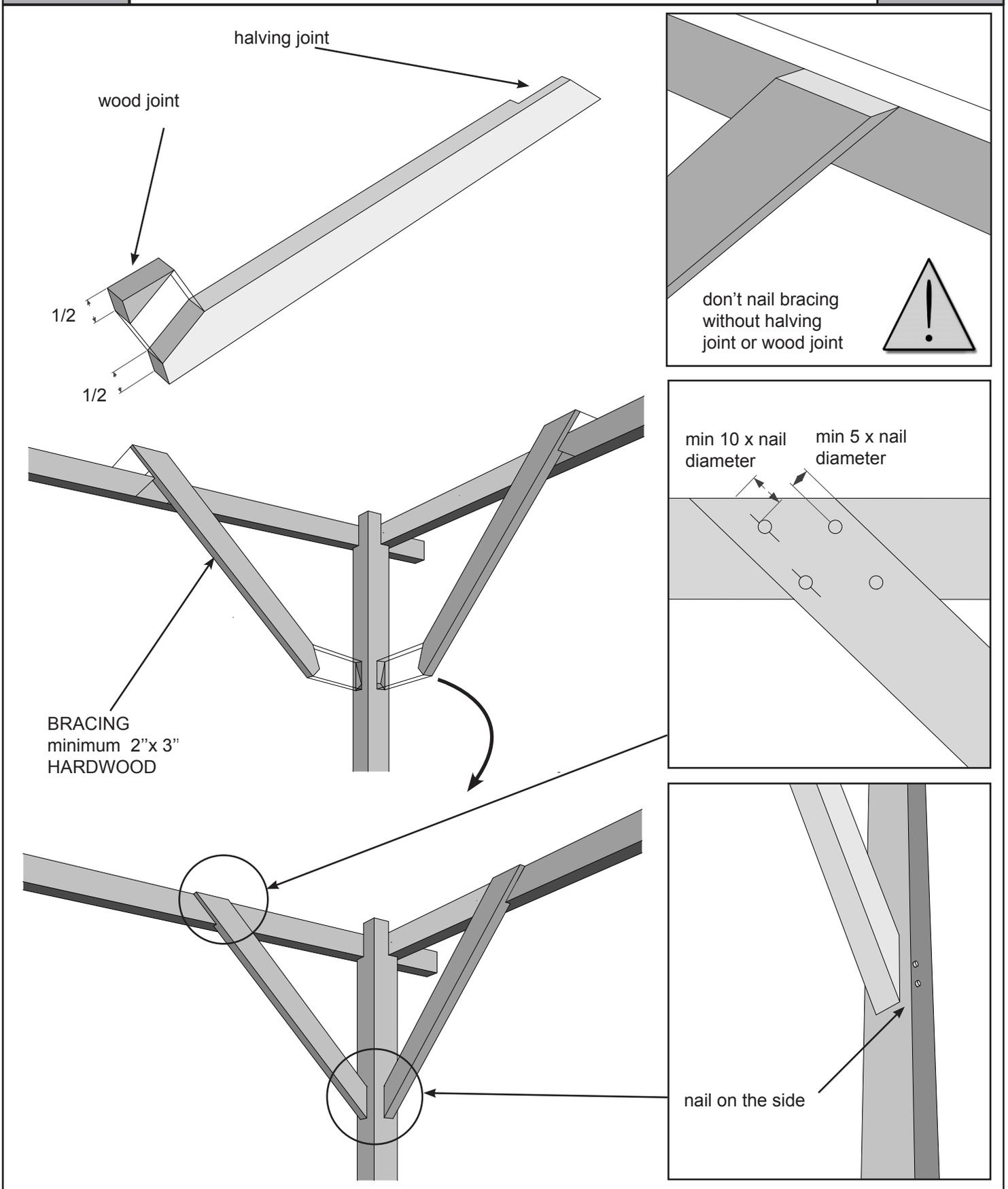


DSAC	S2.2.3.2	MAIN FRAME	Technical Guide
	BRACING OPTIONS 2		

Cross bracing vs corner bracing

Although cross bracings easily give good stability to the whole frame, they require wider section and longer lumber pieces. Households and carpenters tend to reduce the section in order to save money and lumber with consequences in the house stability. To avoid such consequences, corner bracing would be more adapted and affordable in many cases without impact on the house resistance.

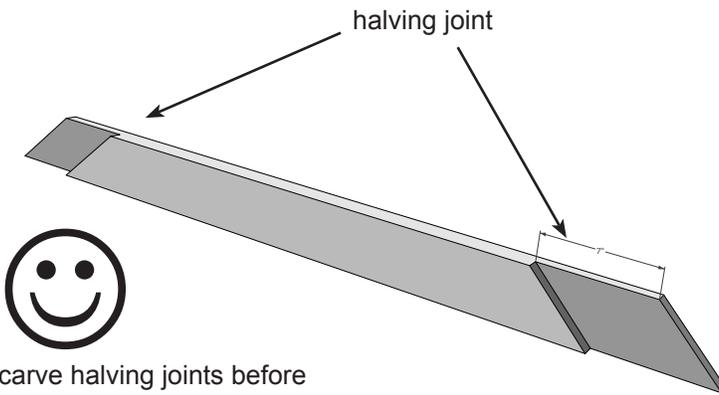
VERTICAL BRACING POST/BEAMS OPTION 01



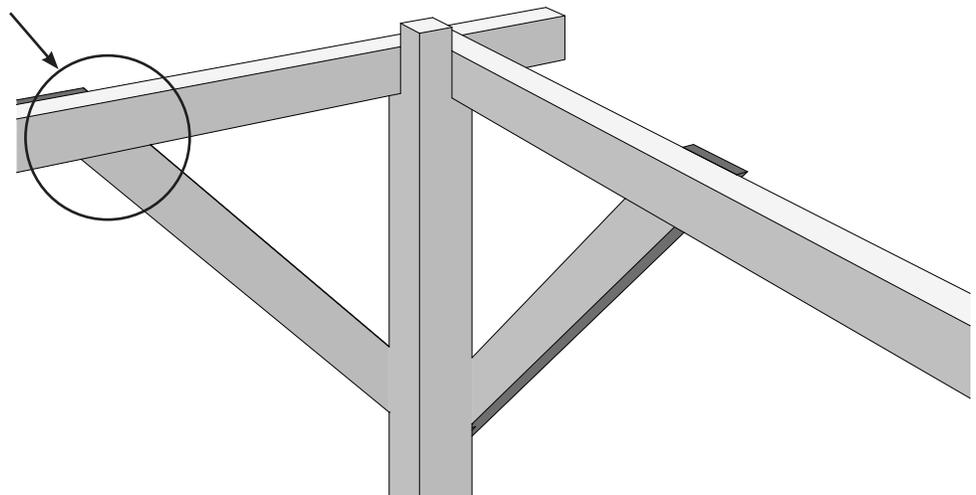
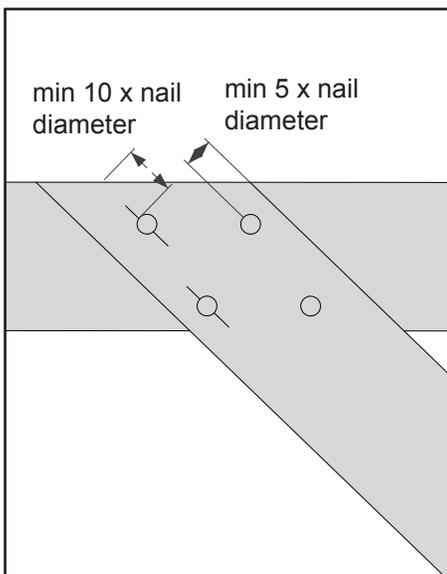
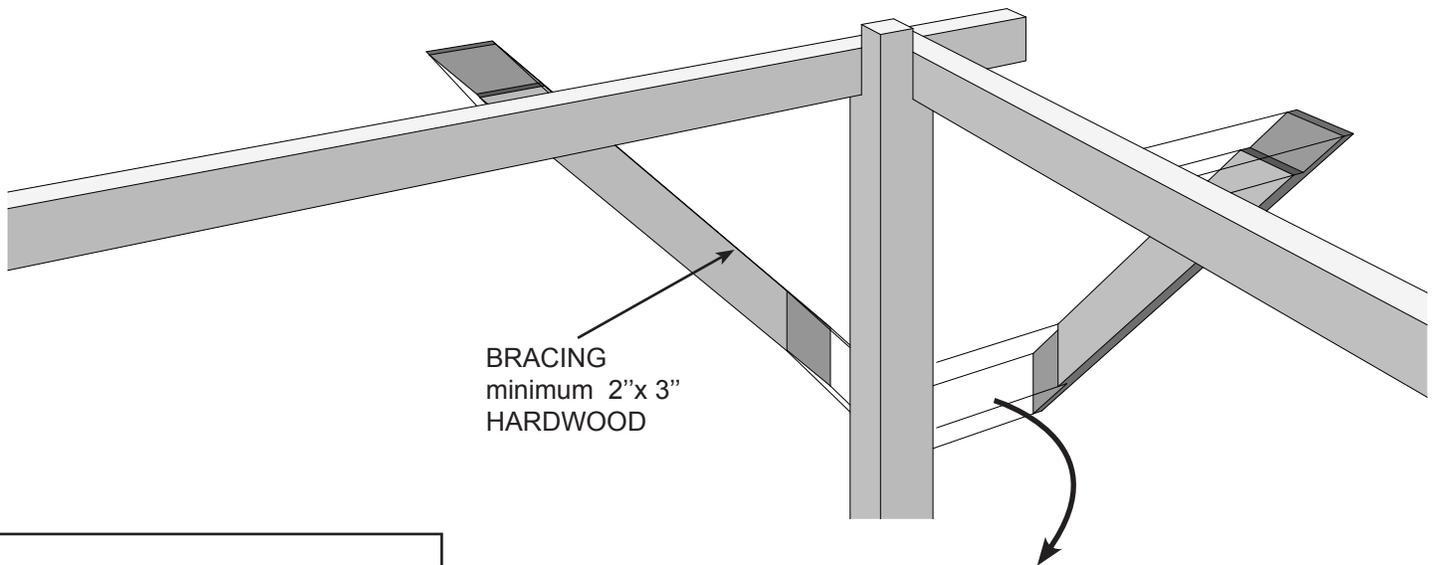
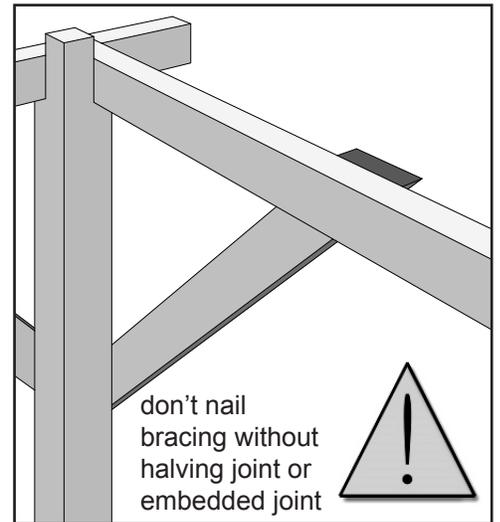
DSAC	S2.2.3.3	MAIN FRAME	Technical Guide
	VERTICAL BRACING POST/BEAMS OPTION 01		

- Bracing in all directions needs to be connected with halving joints or embedded joints. A connection only made with nails won't be able to resist strong wind.
- Proper number as well as the size and length of the nails has to be respected carefully.

VERTICAL BRACING POST/BEAM OPTION 02



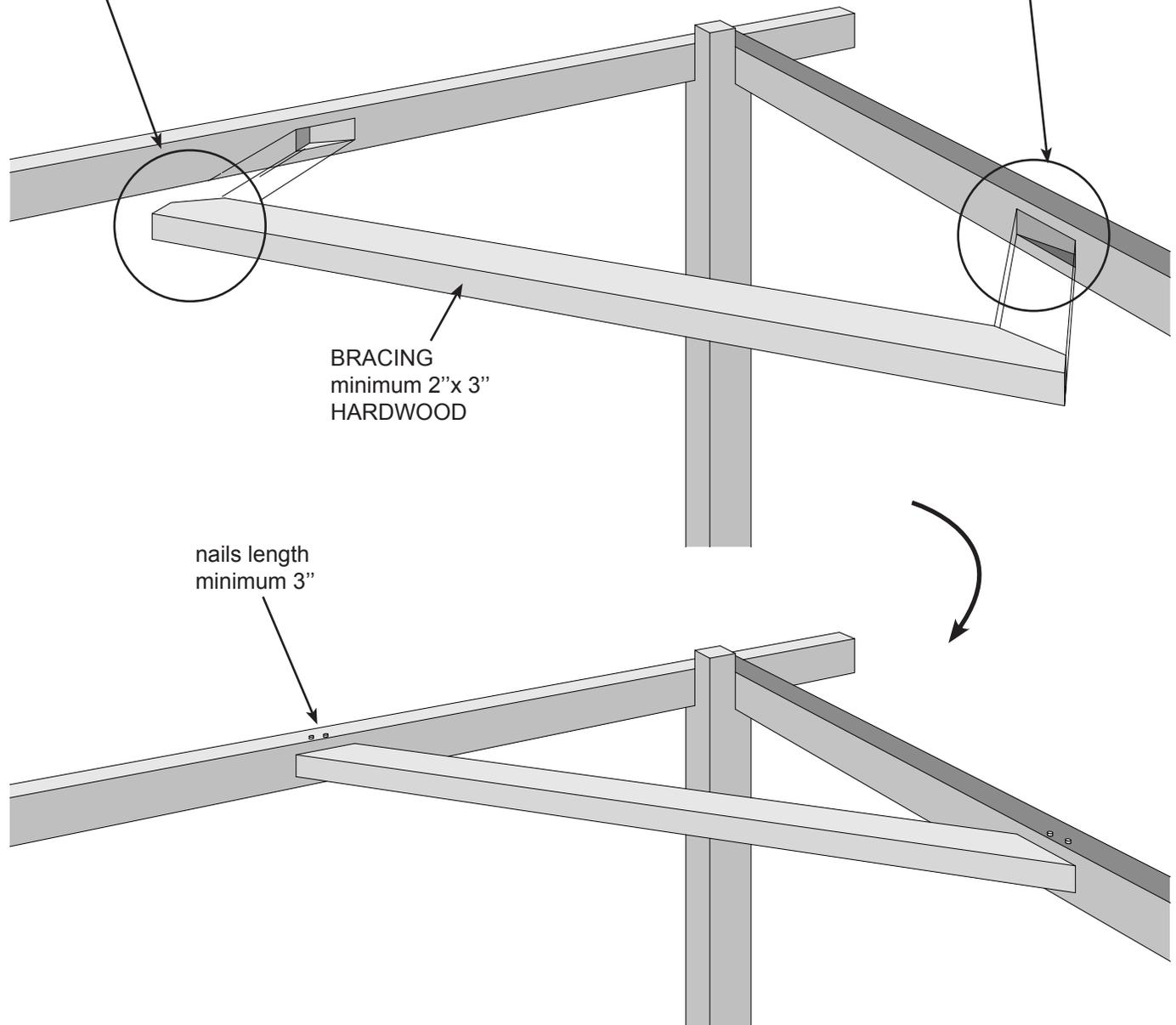
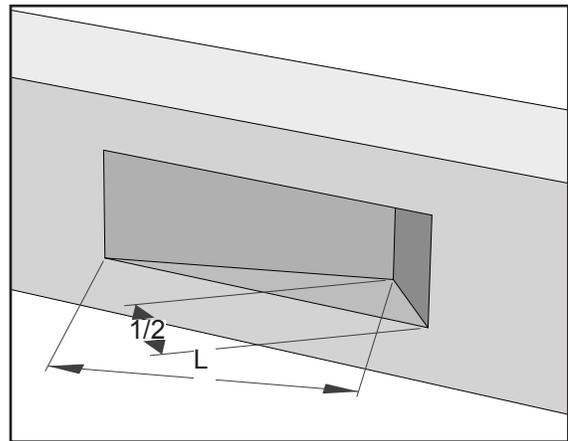
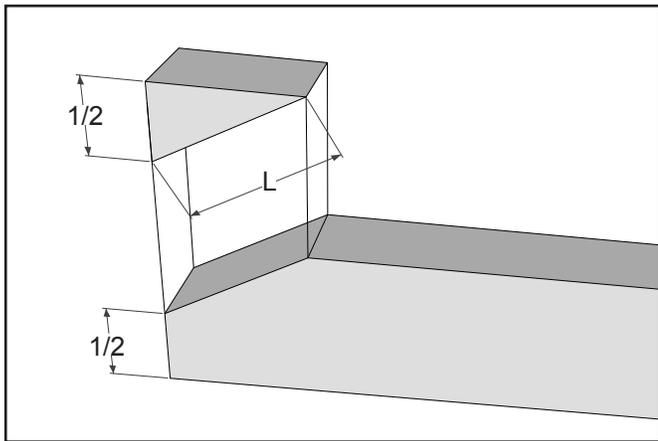
carve halving joints before nailing the bracing



DSAC	S2.2.3.4	MAIN FRAME	Technical Guide
	VERTICAL BRACING POST/BEAM OPTION 02		

- Bracing can be connected from any side of the structure (inside or outside). It will depend on the wall panel structure which is planned.

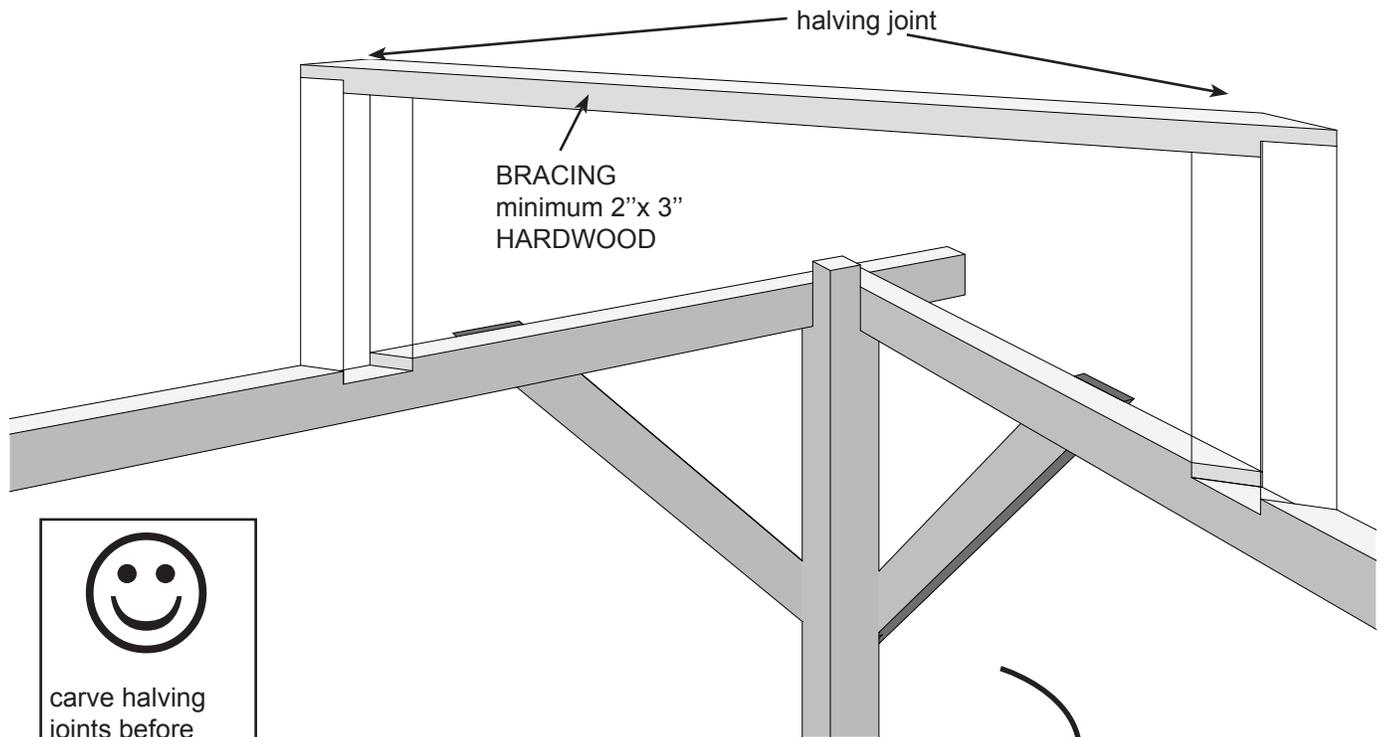
HORIZONTAL BRACING POST/BEAMS OPTION 01



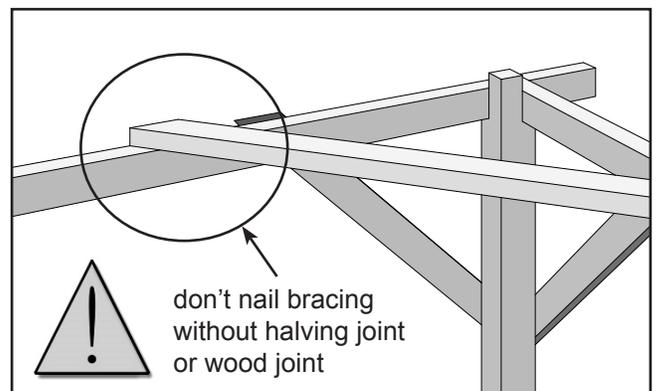
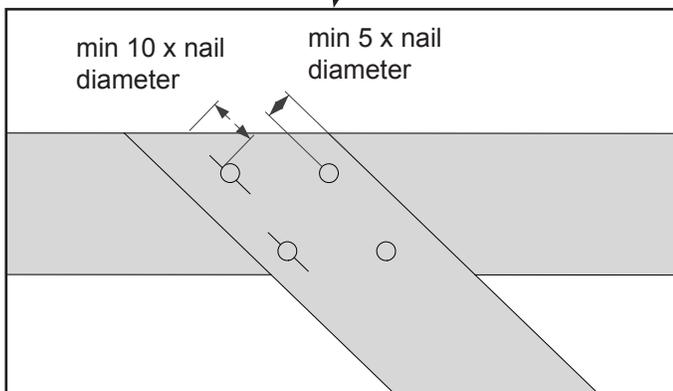
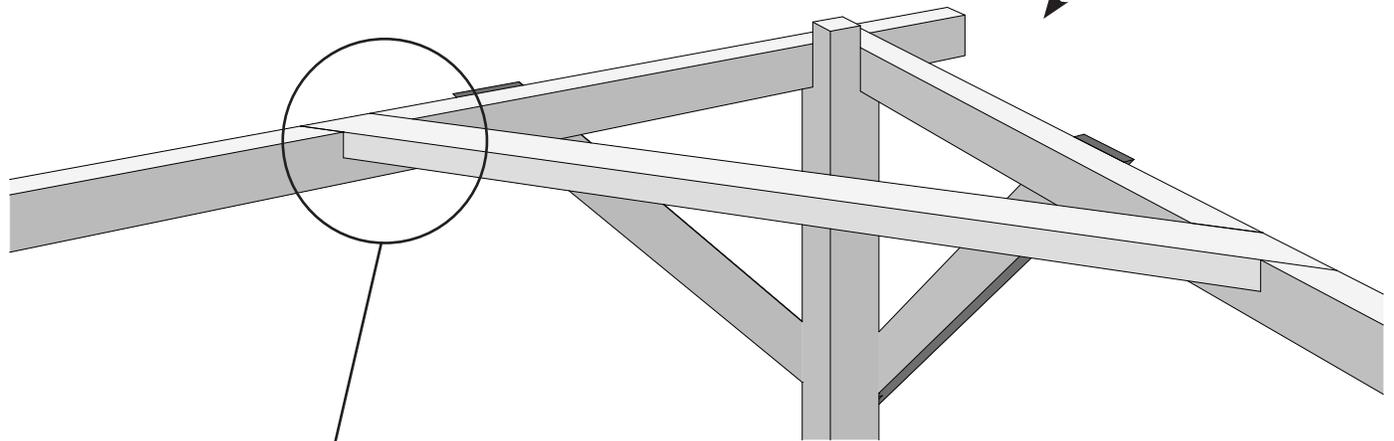
DSAC	S2.2.3.5	MAIN FRAME	Technical Guide
	HORIZONTAL BRACING POST/BEAMS OPTION 01		

- Horizontal corner bracing can be embedded in the ring beam or jointed with a halving joint. Different joints at each end of the bracing are also possible. It depends on the roof structure which is planned, for example, In case of repair, most of the time the beams of the ring beam aren't at the same level so same joint wouldn't be possible at each side.

HORIZONTAL BRACING POST/BEAMS OPTION 02



carve halving joints before nailing the bracing



DSAC	S2.2.3.6	MAIN FRAME	Technical Guide
	HORIZONTAL BRACING POST/BEAMS OPTION 02		

- In some cases horizontal corner bracing at roof level can make difficult trusses to lay on. In such cases, embedded joint would be more suitable.

DSAC	S2.3	ROOF	Technical Guide

Roof disaster resistant

- Winds naturally have a strong horizontal load and suction effect on roofs. To reduce this effect and in addition to proper anchorage, the roof slope should be 30° or 3: 1 (width to height or rise to span).
- The edges (ridge, eaves and verge) of the roof are more exposed to wind than the covering. The most critical parts are the verges (gable roof) and the ridge of a single slope roof. Therefore for wind safety the better shape is the hipped roof (4 slopes roof). Gable roof and single slope roof are more exposed to wind.
- Large overhangs should not face the main wind direction. This would result in very high suction forces.
- Overhangs of more than half a meter (18in) should be avoided. It is better to make a separate veranda construction, so that wind trapped under the veranda will not tear off the whole roof.
- Use fascia boards on the eaves and overhangs to reduce lift up by the wind.
- If the roof is properly anchored and braced for storms then it is also safe for earthquakes.

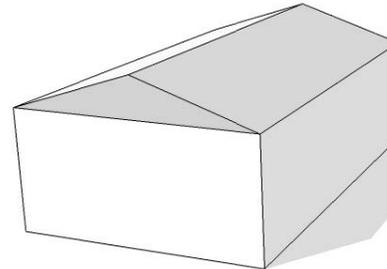
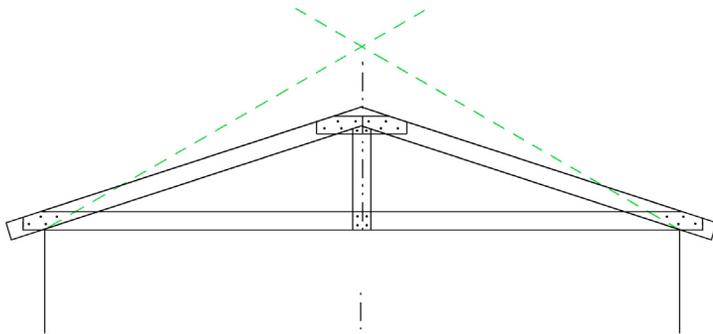
Repair & Reinforcement

Roof failure is a major cause of damage. Improvement of roofs can form a significant contribution in improving the overall strength of the house. In a low cost approach, the following measures can be implemented:

- Roofing nails: increase the number of nails and/or use typhoon resistant nails; focus attention on the eaves of the roof, where the forces highest.
- Eaves and overhangs: reduce the size of eaves and overhangs to 40-60 cm (1-2ft) and install sideboards to fix the sides of the roof. Seal the eaves of the roof in order to reduce uplift forces of a cyclone.
- Tying of roof elements: all elements of the roof structure should be tied. Metal straps, rattan, galvanized tie wire or rope can be used. The wire should be looped around a nail for sufficient strength.

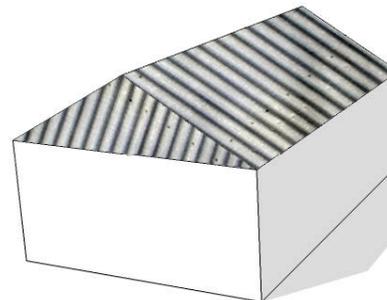
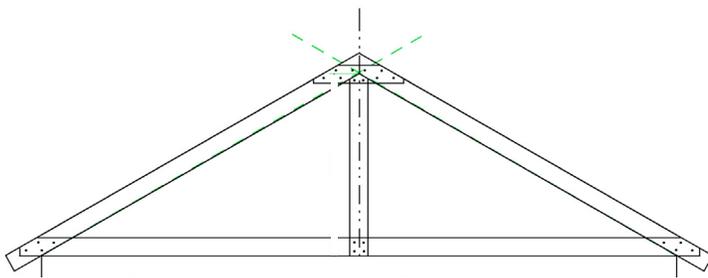
DSAC	S2.3	ROOF	Technical Guide

- Tying to the walls or ring beam: this is one of the most important connections in the building and sufficient tying is indispensable. Preferably use ready made metal straps here or very tight rattan binding.
- Bracing: bracing of the roof construction itself will add strength to horizontal forces. When no braces are incorporated, adding braces should be a priority for gable roofs.
- Roof slope: when the shape of the roof is very vulnerable to high winds (because it is not steep enough or too steep) it may be advisable to replace the whole roof. The preferable new roof construction would be a hipped roof.



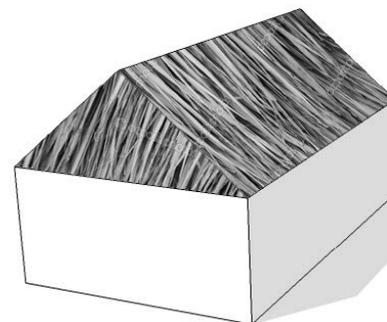
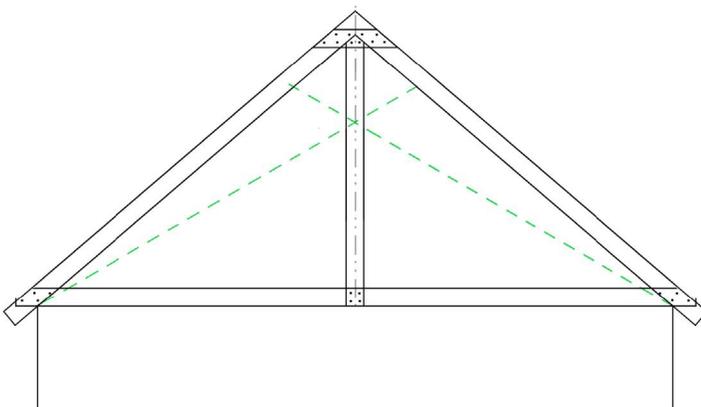
Roof slope

Roof slope mustn't be less than 30°



CGI sheet

Roof slope must be around 30° to reduce wind effect



Nipa or ambulang

Roof slope must be between 40° and 45° to reduce wind effect and water leaking

DSAC	S2.3.1.1	ROOF	Technical Guide
	SLOPE SHAPE		

Influence of roof slope

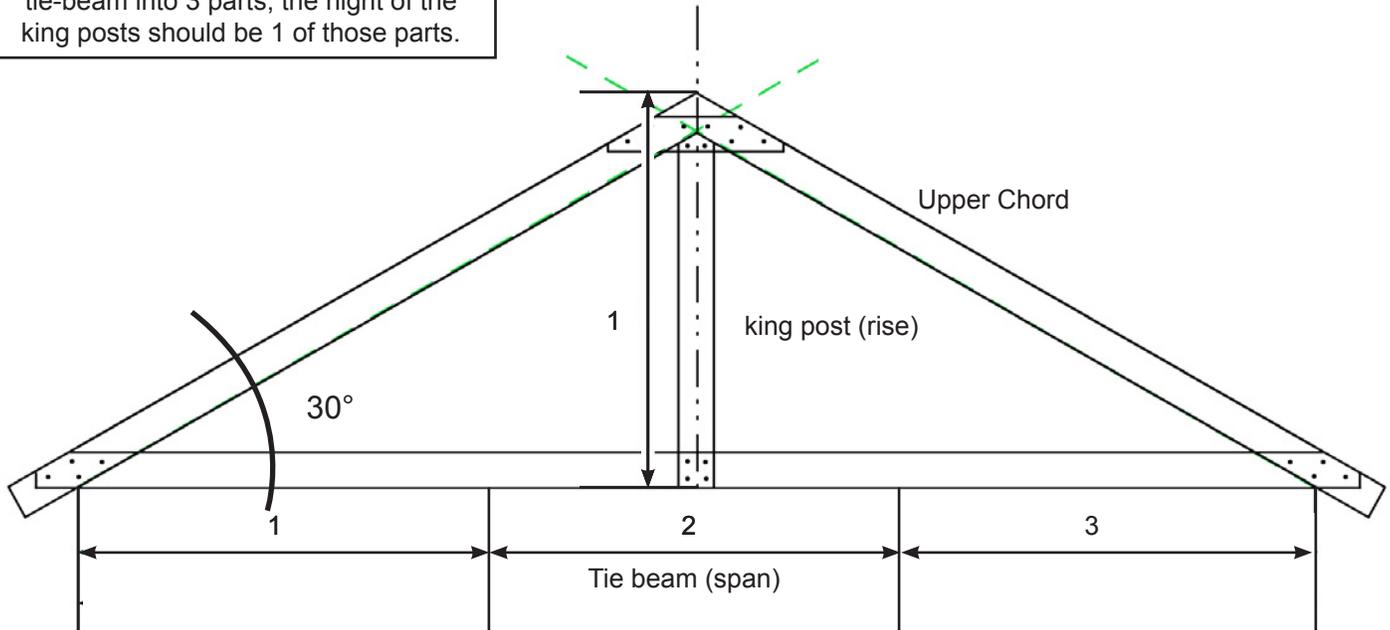
- Wind causes suction on the lee-side of the roof (the side not facing the wind) with a danger of the roof lifting off. In addition to proper anchorage, an increased roof slope can reduce this danger of damage. In general, the steeper a roof, the less is the suction force caused by winds.
- Construct a roof with a steep slope (minimum 30°), to reduce risk of being blown off. An appropriate roof slope depends on the cover material used and on the climatic conditions. The slope of a typhoon resistant roof should be around 30° for CGI sheet and between 30° and 45° for thatched roof (nipa or ambulang covering).

Nipa covering

- In case of thatched roof, the steepest slope would prevent water from leaking inside the house. In order for the water to effectively run off the roof (instead of soaking through the shingles and into the house), a roof slope of 45° is recommended. It is important to note that this steep slope may pose a typhoon risk if the nipa shingles are later changed for CGI or other non-permeable materials which attract high suction forces during strong winds.

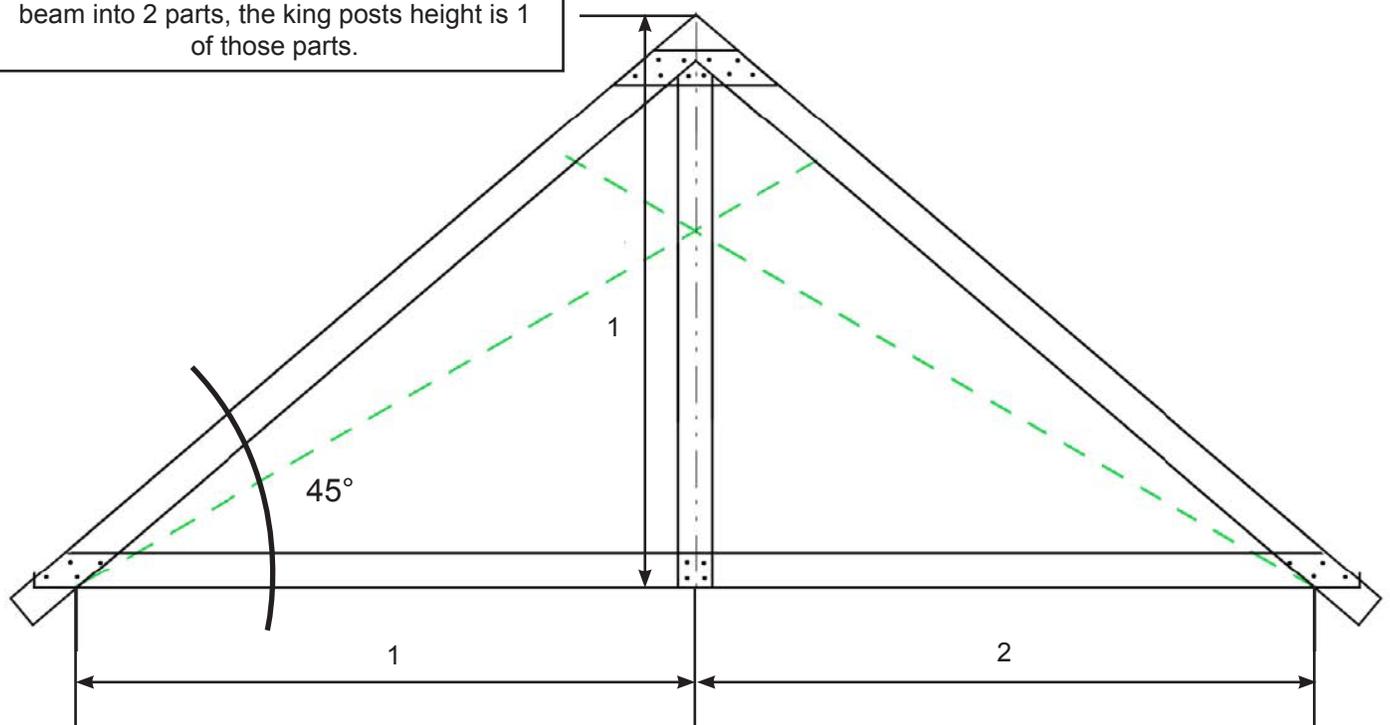
CGI sheet covering (roof slope 30°)

To draw a 30° slope roof divide the tie-beam into 3 parts, the height of the king posts should be 1 of those parts.



Nipa/ambulang covering (roof slope 45°)

To draw a 45° slope roof divide the tie-beam into 2 parts, the king posts height is 1 of those parts.



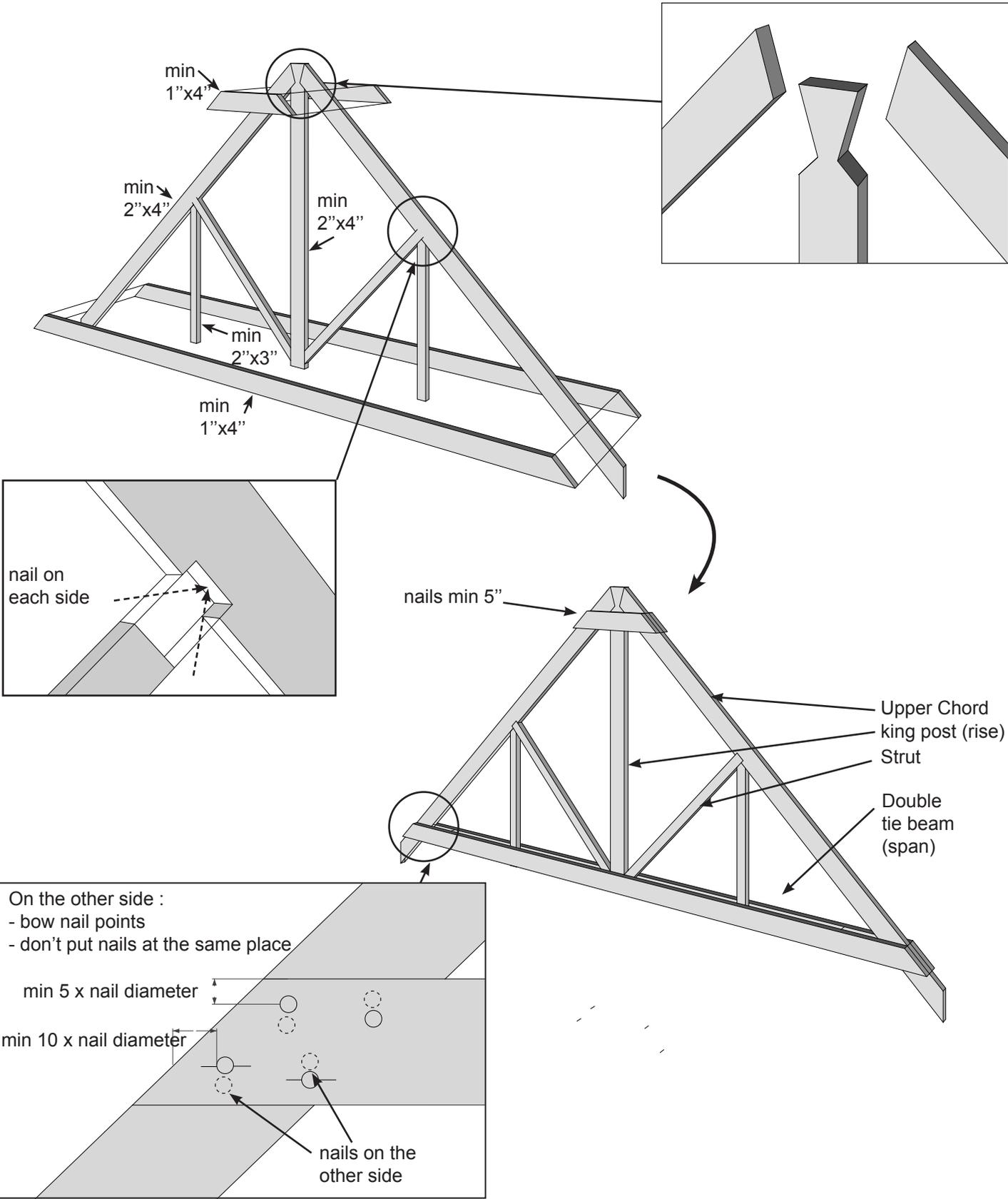
DSAC	S2.3.1.2	ROOF	Technical Guide
	30° AND 45° ANGLE DRAWING		

CGI sheet

- The roof slope for CGI sheet should ideally be approximately 30°, or about 1 meter rise for 3 meters span.

Nipa covering

- The roof slope for thatch roof like nipa or ambulang should ideally be around 45°, or about 1 meter rise for 2 meters span.



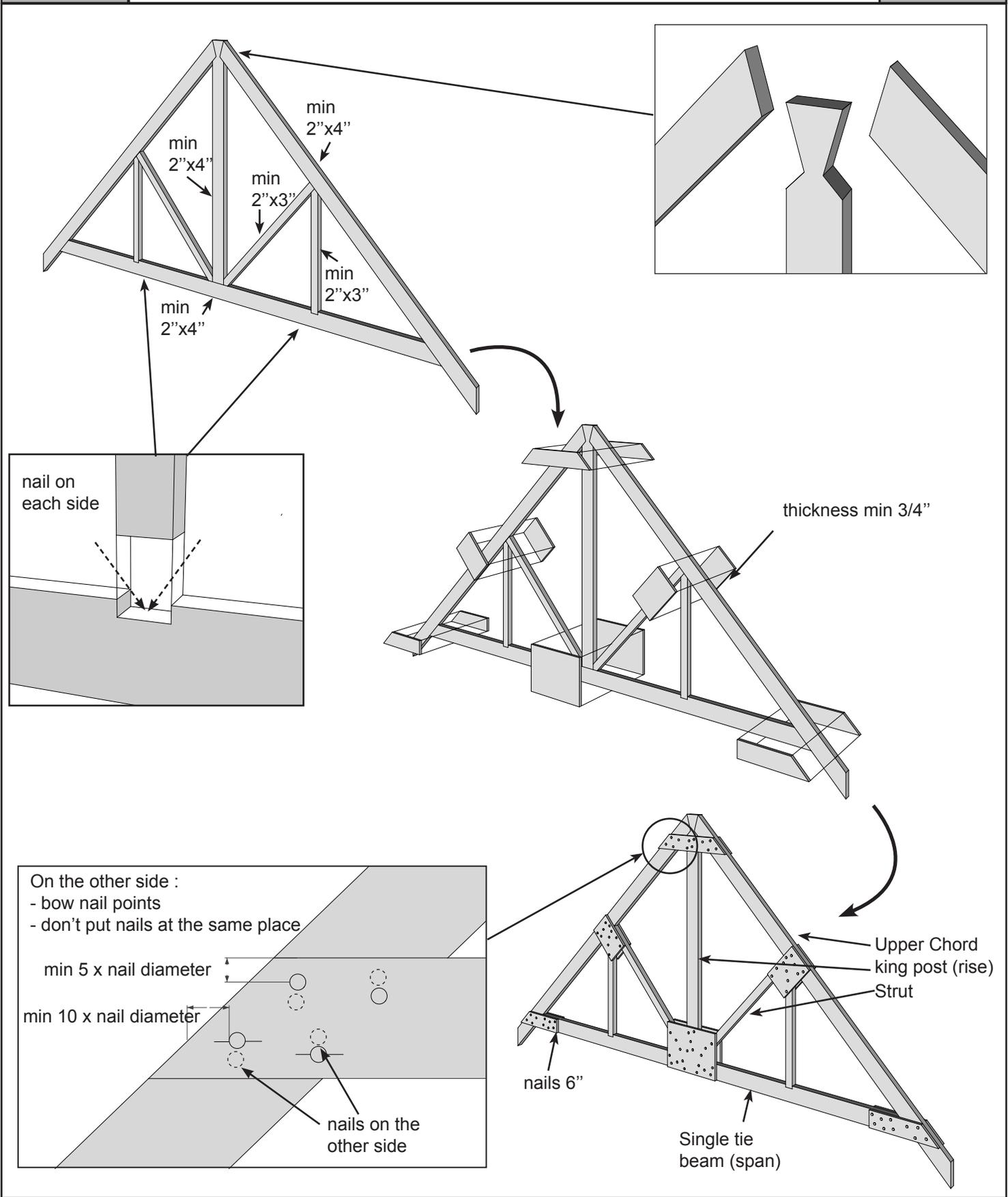
DSAC	S2.3.1.3	ROOF	Technical Guide
	TRUSS OPTION 01		

Roof frame

- The choice of the roof type depends on what is common practice locally. As a general rule, it should be noted that the less 'ideal' the roof shape is, the more additional measures are needed for sufficient strength.
- A few categories of roof frame does exist such as the truss system the rafter system or the purlin system. Each of them has pro and cons : when the truss roof allows to build wider span (up to 12m/36ft), it is easier to have an attic with a rafter or purlin system. When the rafter or purlin system can be built by any local carpenter, the truss roof requires more labour input.

Truss system

- A truss is a structure with straight pieces forming triangles to support a load.
- Roof trusses are characterised by an economic use of construction materials. Composed of individual lightweight pieces. A truss can also provide considerable advantage in transport and assembly as compared to other roof structures.
- Struts are necessary when the span of the truss is above 6 m. Below 6 m, struts are not necessary.
- The vertical struts are not necessary.



DSAC	S2.3.1.4	ROOF	Technical Guide
	TRUSS OPTION 02		

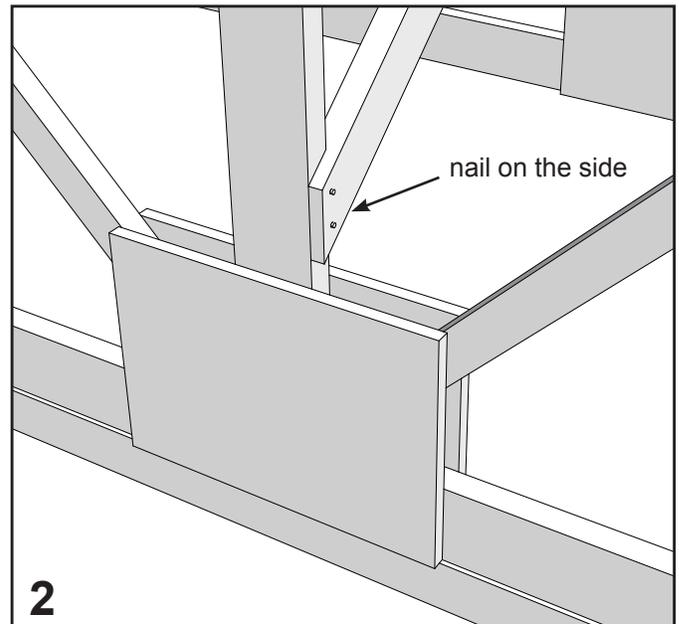
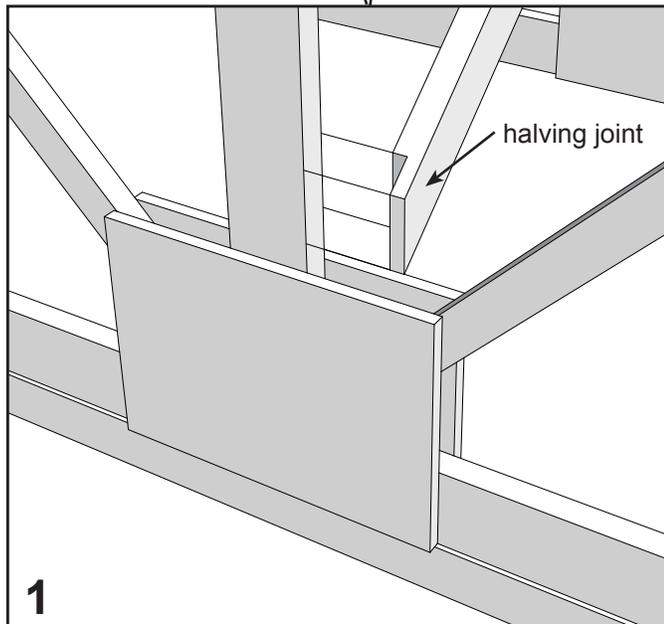
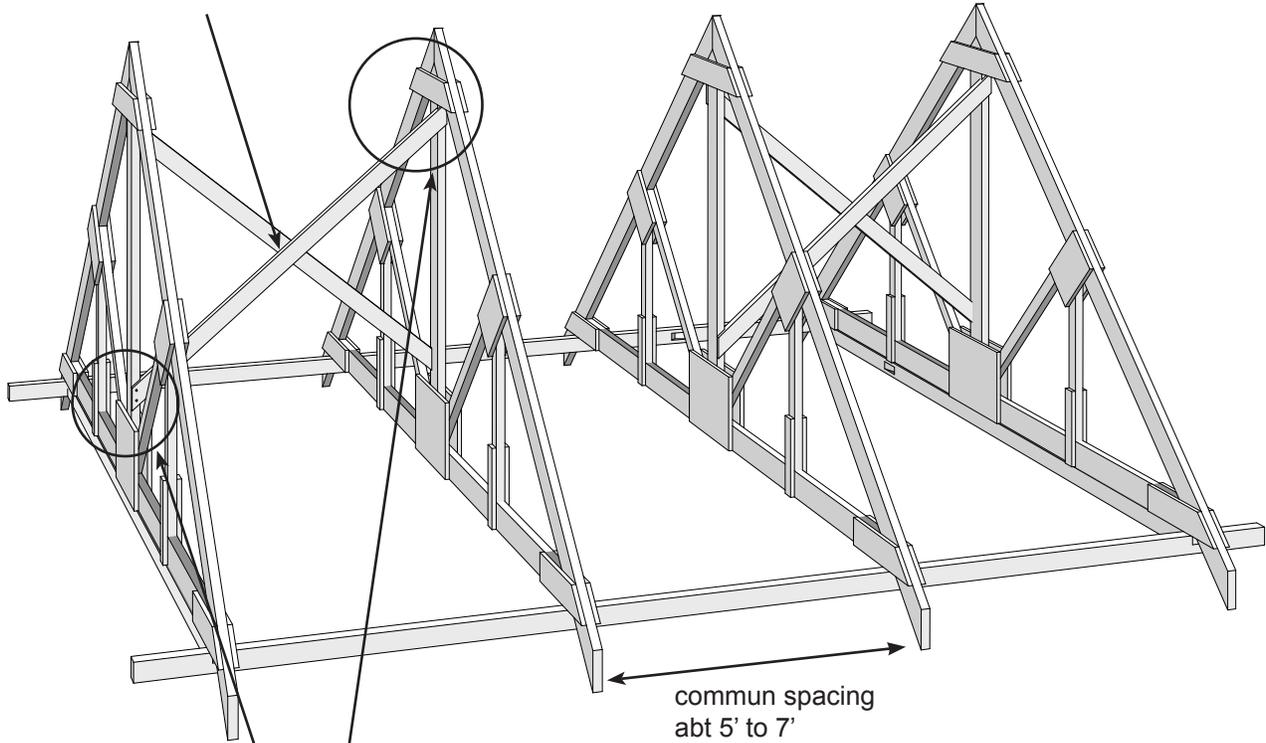
Alternative for truss making

- As an alternative to save lumber (only if plywood is available), plywood plates can be used with nails.
- The advantage is that only single-piece members are used. These members are thicker than those of the simple nail truss so for example ceilings can better be fixed to the tie-beam.
- Be careful, structural plywood should be favoured as plates for wood trusses. The grain direction of the face ply is important for the load bearing capacity of the plywood plate. The plywood thickness should be around 18 mm (3/4 in).



BRACING OPTION 01

bracing
minimum 2"x3"
with halving joints
HARDWOOD



DSAC	S2.3.1.5	ROOF	Technical Guide
	BRACING OPTION 01		

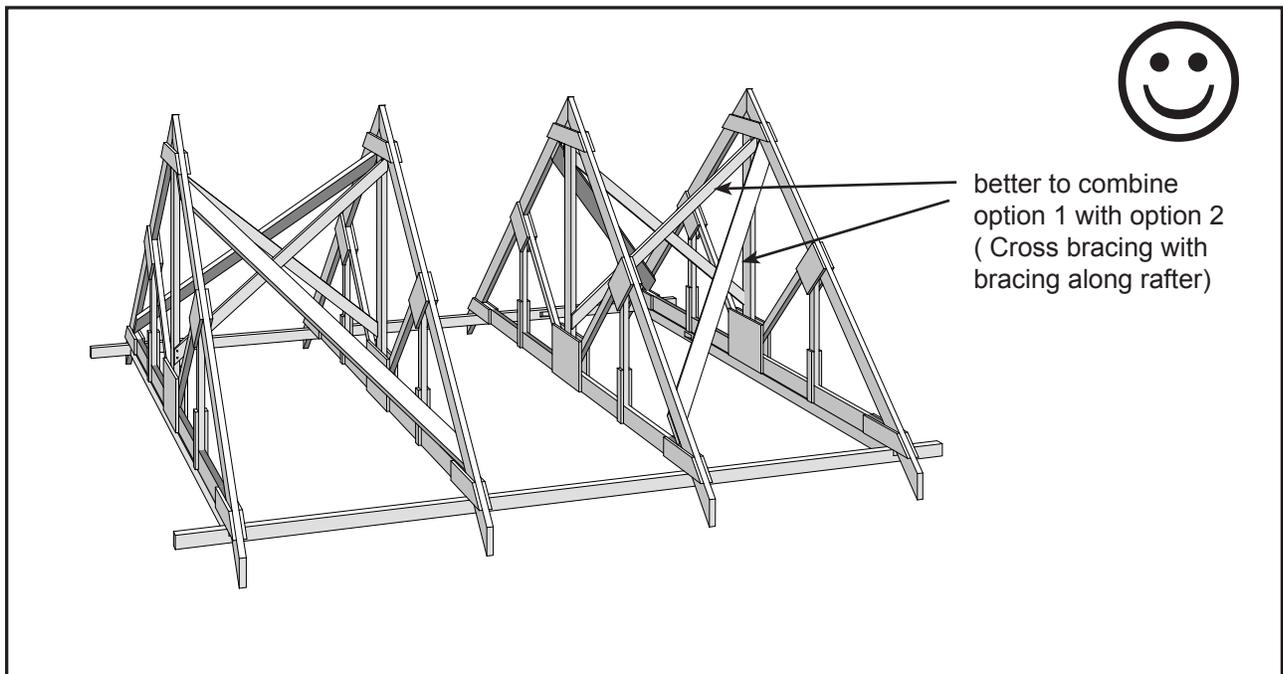
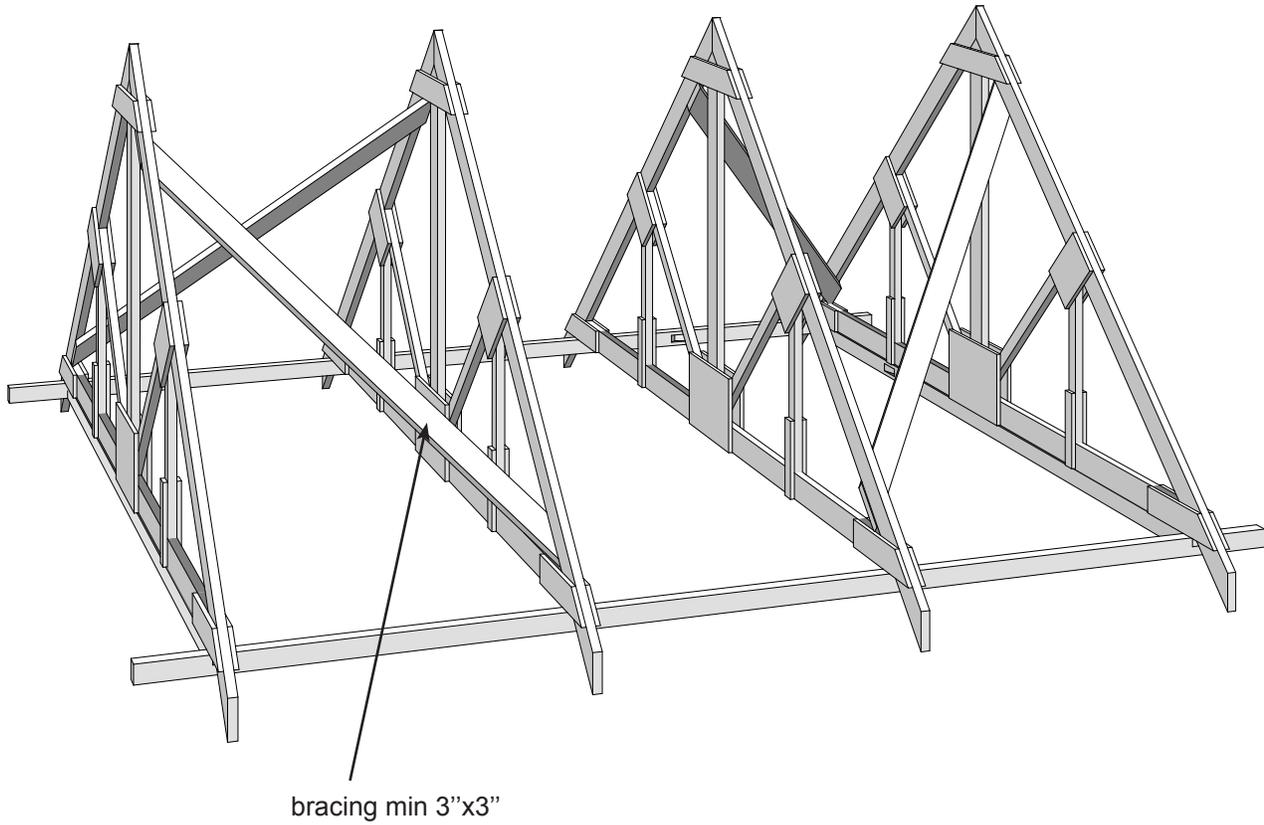
Truss roof structure

- The main structure of the roof consists of two or more roof trusses, bracing and purlins. The lay-out of the roof truss depends on its span and on the number of trusses applied. Generally, up to a 6 m (18 ft) span can be connected with a simple roof truss. The most economical spacing of wood trusses is around 1,5 to 2 m (5 to 7 ft)
- It is important that all trusses are properly aligned so that the final roof line will be level and free from waves. This can be done with a mason string fastened from one side trusses to the opposite.

Roof bracing

- The function of the roof bracing is to prevent horizontal movements in the roof structure caused by winds, earthquake or other horizontal forces. Bracing can be laid either in a vertical position between trusses (S2.3.1.3 option 1) or in an inclined position along the rafters (S2.3.1.3 option 2).

BRACING OPTION 02



DSAC	S2.3.1.6	ROOF	Technical Guide
	BRACING OPTION 02		

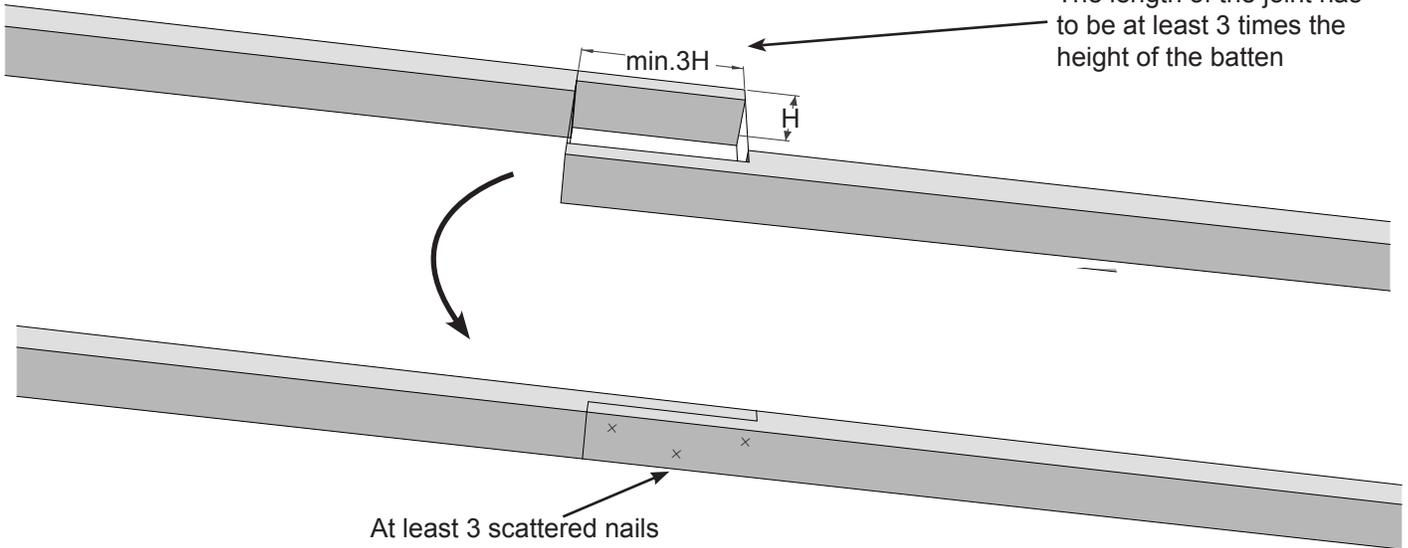
- It is even better to combine bracing between trusses and bracing along rafters.

DSAC	S2.3.1.7	ROOF	Technical sheet
	JOINT : BATTEN (EXTENSION)		

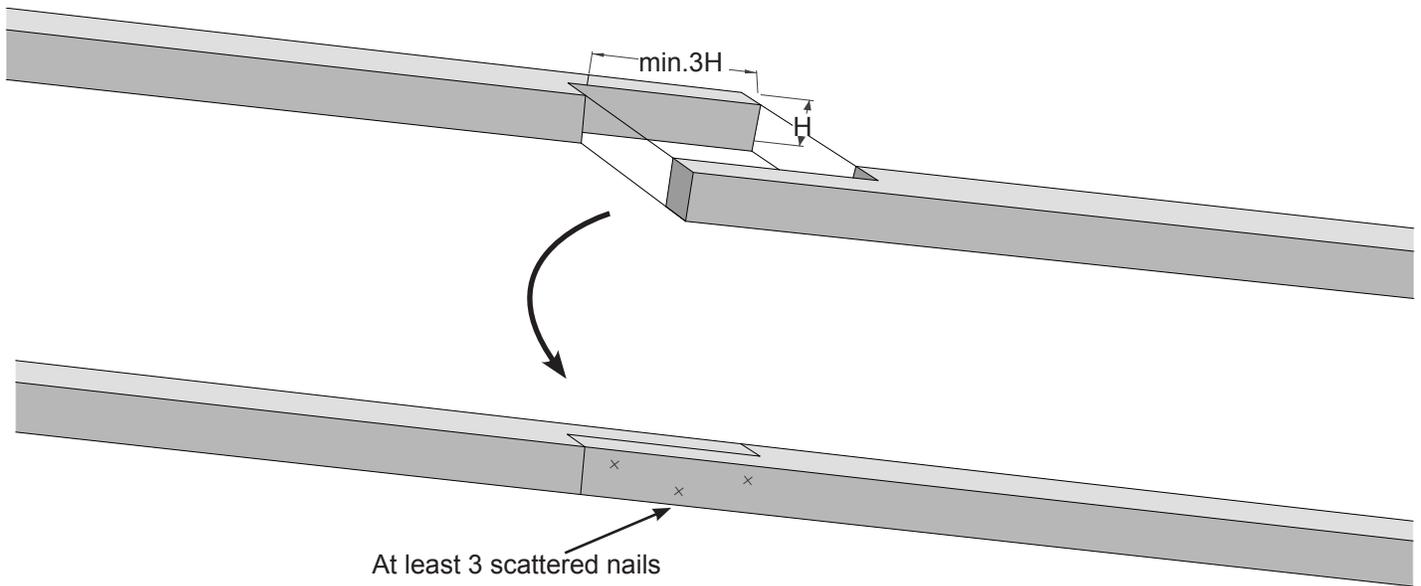


Be careful !
For joist and rafters extension, fish plate joint should be favoured as it is stronger

OPTION 01



OPTION 02

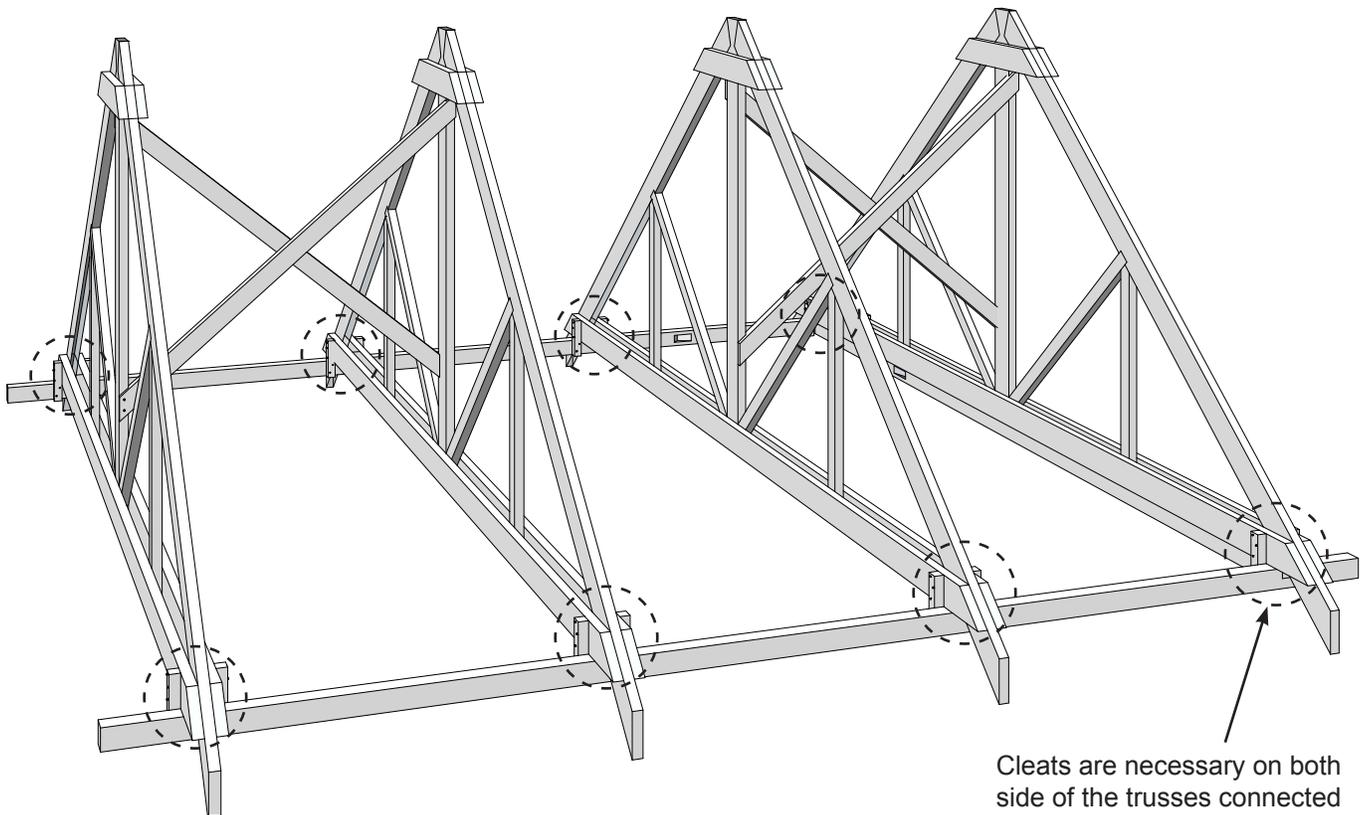
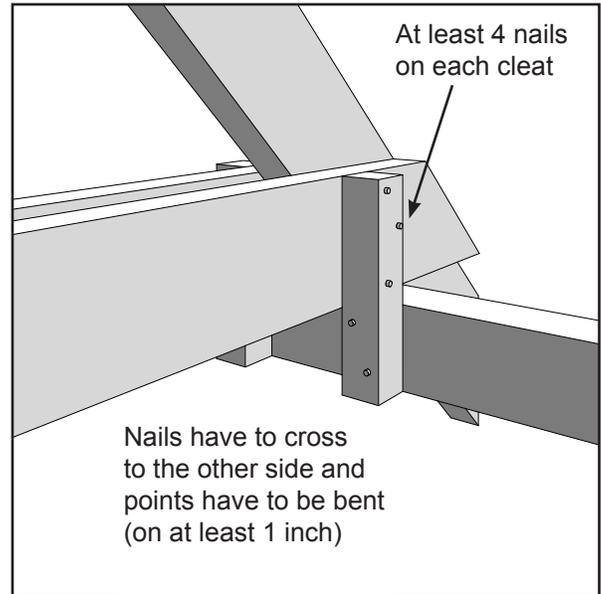
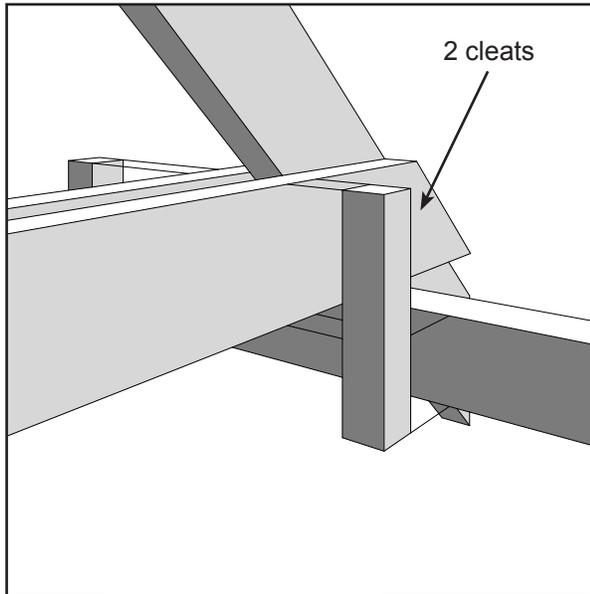


DSAC	S2.3.1.7	ROOF	Technical Guide
	JOINT : BATTEN (EXTENSION)		

Batten joint

If the joint is at the place of the support, vertical halving joints can be used. Horizontal halving joints must be avoided. Fish plate joints are possible if the supporting wall is thick enough.

CLEATS (TRUSS TYING DETAIL)

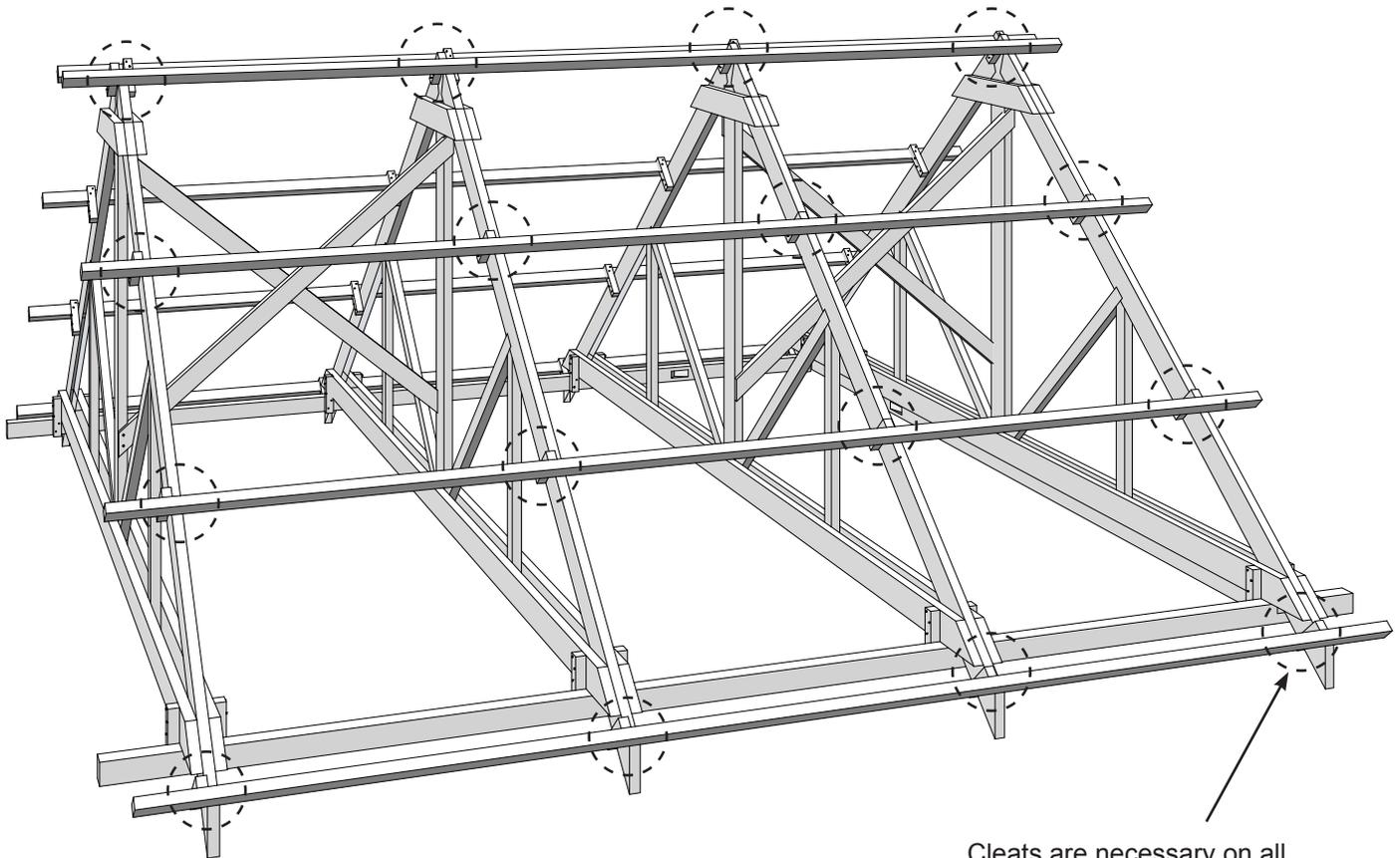
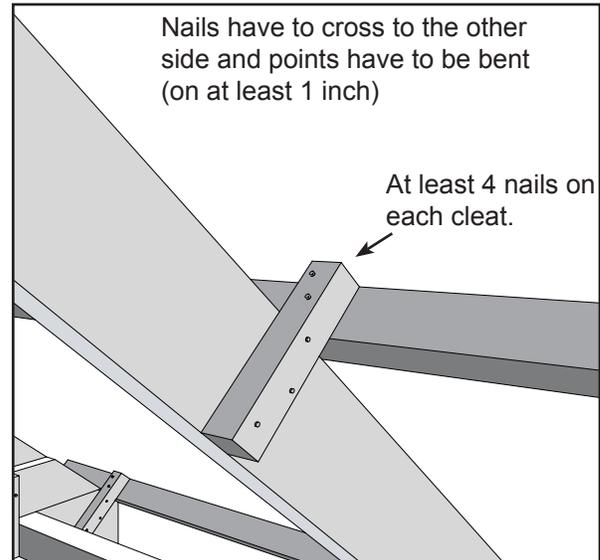
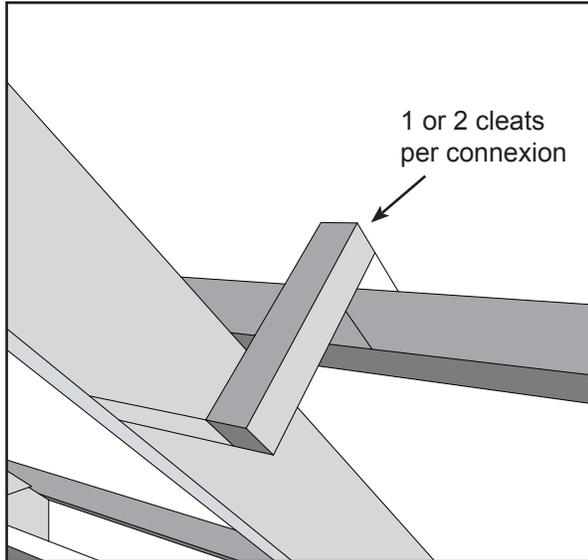


DSAC	S2.3.1.8	ROOF	Technical Guide
	CLEATS (TRUSS TYING DETAIL)		

Cleats or blocks

- Wood cleats or block are necessary for securing the roof frame. Do not use a single nail, which is a weak support, and may corrode and cease its function quickly in the Philippines climate. Nails through the wood structure itself also are a weak support.
- The cleats can be made of any leftover or off-cut of lumber. Each cleats can have a different section since the minimum of 2 in x 2 in is respected.
- Cleats should connect all parts of the roof frame:
 1. Trusses with ring beam or upper wall beam
 2. Purlins/batten with trusses

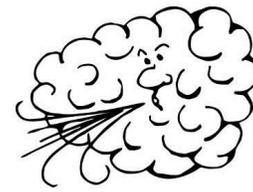
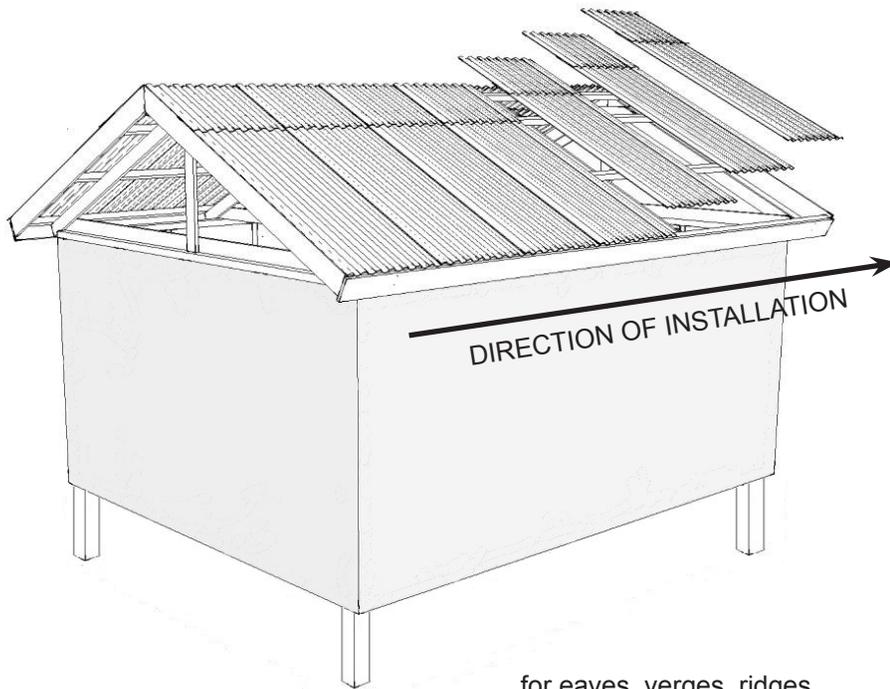
CLEATS (PURLIN TYING DETAIL)



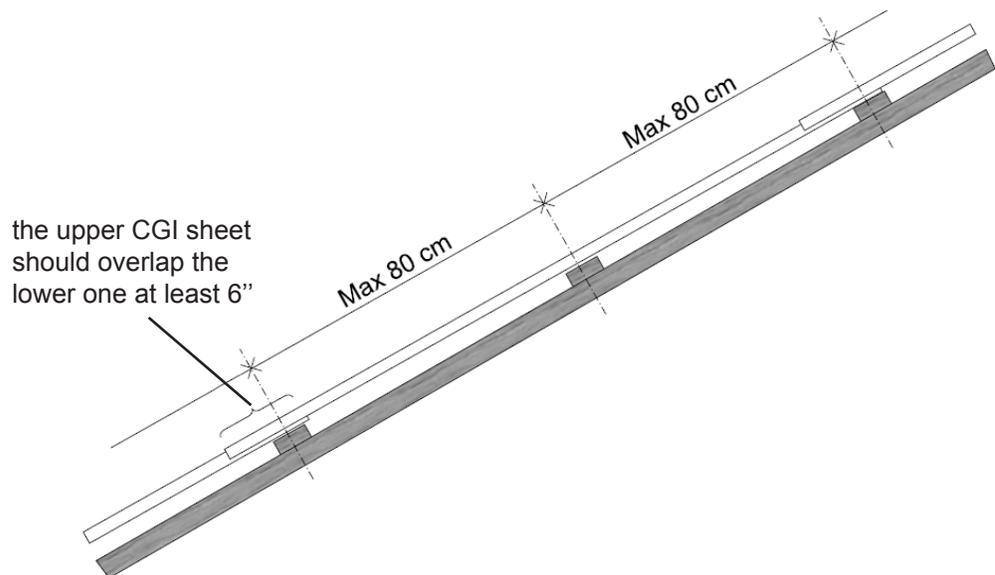
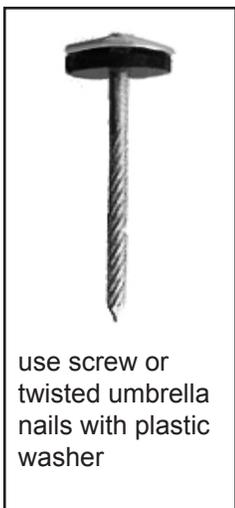
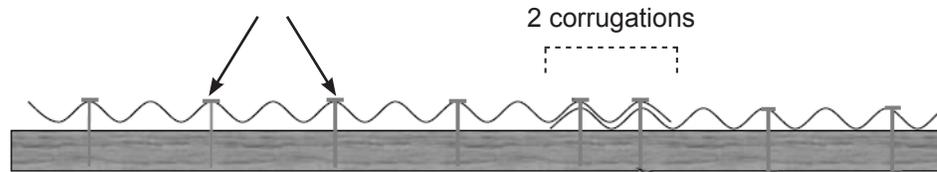
Cleats are necessary on all connexions between purlins/batten and trusses

DSAC	S2.3.1.9	ROOF	Technical Guide
	CLEATS (PURLIN TYING DETAIL)		

- Cleats can be replaced by rattan ties, galvanised tie wire or rope tied strongly.



for eaves, verges, ridges and overhangs nail every 2 corrugations and 3 corrugations for other places



DSAC	S2.3.2.1	ROOF	Technical Guide
	COVERING : CGI SHEET		

CGI sheet covering

- Limit the overhang of the roof on all sides to maximum 18 inches.
- Use fascia boards on the eaves and overhangs to reduce lift up by the wind.
- Fix the cover of the roof firmly to the frame of the roof
- CGI sheet of min 24 gauge is recommended (0,4 mm)
- CGI sheets should be overlapped at least 2 corrugations on lateral direction and 6 inches on vertical direction.
- At eaves, verges, ridges, and overhangs provide fixing nails at every 2 corrugations. At all other location, provide nails every 3 corrugations.
- Use proper screw or twisted umbrella nails with plastic washer. Embed to purlin at least 50 mm.
- Purlins should be placed closer together for thin sheets to provide space for extra fixings: for 24 gauge, spacing for purlins is 60 cm (2 ft). For 26 gauge, 45 cm (18 in).

Nails

- Nails do not hold as well as screws.
- Galvanized coated nails are better than ordinary wire nails and have a square, twisted shank and a washer attached to the head. They are used for fixing corrugated-sheet materials and must be long enough to penetrate at least 20 mm into the wood. If they are not twisted the nails should be long enough to bend over below the lath.
- Alternatively, wire nails with used bottle caps for washers can be used.

DSAC		RESOURCE	Technical Guide
	FOR FURTHER INFORMATIONS AND DETAILS		

Lumber

- CRAterre (2017), *Wood treatment guideline using DOT dip diffusion, draft version* CRAterre-ENSAG & LABEX AE/CC, Grenoble, France.
- FAO (2011), *Rural structure in the tropics, design and development*, Rome <http://www.fao.org/docrep/015/i2433e/i2433e00.htm>.
- IFRC, UN/OCHA, CARE int. (2010), *Timber as a construction material in humanitarian operations*, www.humanitarian timber.org.
- Luc Vrolijk (1998), *Disaster Resistant Housing in Pacific Island Countries. A compendium of safe low cost housing practices in Pacific Island Countries*, the South Pacific Disaster Reduction Programme (RAS/92/360).
- Skat (1993), *Roof structure guide*, St-Gallen, Switzerland.
- Skat (1999), *Roof truss guide*, St-Gallen, Switzerland and ILO, Geneva, Switzerland.
- UNHABITAT (2009), *a guide for village carpenters on how to build a safer shelter*, Myanmar.

Bamboo

- Environmental Bamboo Foundation (2003). *Vertical Soak Diffusion for Bamboo Preservation*, Third Edition. <http://www.bamboocentral.org/>.
- Humanitarian Bamboo (2009), *A manual on the humanitarian use of bamboo in Indonesia*, www.humanitarianbamboo.org.
- National mission on bamboo applications (2006), *Preservation of Bamboo, training manual*, Technology Information, Forecasting, and Assessment Council (TIFAC), Department of Science and Technology, Government of India, New Dehli, www.bambootech.org.

DSAC		RESOURCE	Technical Guide
	FOR FURTHER INFORMATIONS AND DETAILS		

Thatched roof

- GTZ-ITDG-SKAT-CRATERRE (1997), *The basic of biomass roofing, St-Gallen, Switzerland.*
- Humanitarian shelter working group Philippines (2014), *Key messages for commonly used shelter materials, nipa thatching, Sheltercluster.org*

Local building culture

- CRAterre, FICR (2015), *Assessing local building cultures for resilience and development, Craterre editions, Grenoble, France.*