

# CONSTRUCTION HANDBOOK

## How to rebuild and reinforce your wooden house?

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EUROPEAN COMMISSION



Humanitarian Aid

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## Introduction

Following the passage of hurricane Dean in Jamaica in August 2008, the Jamaica Red Cross in partnership with the French Red Cross and supported by ECHO implemented a reconstruction program to assist with the repair of 70 roofs and the construction of 40 wooden houses.

The French Red Cross created this handbook to train some builders and carpenters men and women all over 5 parishes in new construction techniques, especially a new design of roof according to the Jamaica Building Code. This handbook also explains how to make reinforced concrete, build foundations and reinforce wooden houses including the use of hurricane straps. It also gives some tips on how to prepare the house before a disaster occurs.

The objective of the French Red Cross together with the Jamaica Red Cross is to build back better, stronger and safer wooden houses according to hurricane standards and thereby to make life better.

## Making concrete

To make CONCRETE, you need:

- Gravel
- Sand
- Cement
- Water

The cement must be Portland Cement 32,5 MPa. It must be fresh and contained in unopened sacks which have been protected from moisture.

The sand and gravel must be clean (no earth, no plant, no paper...)

Only clean and potable water should be used for the mixing of concrete.



Composition of CONCRETE and MORTAR:

Concrete 1:2:4 <i>For foundations, columns, beams, ...</i>	Mortar 1:3 <i>For blocks</i>
<ul style="list-style-type: none"> <li>• 1 bag of CEMENT</li> <li>• 12 buckets of GRAVEL</li> <li>• 6 buckets of SAND</li> <li>• 3 buckets of WATER</li> </ul>	<ul style="list-style-type: none"> <li>• 1 bag of CEMENT</li> <li>• 12 buckets of SAND</li> <li>• 3 buckets of WATER</li> </ul>

### 1. Different steps to make CONCRETE:

1. find a clear area to mix the concrete, prepare your site
2. lay down the sand
3. pour the cement on top of the sand
4. mix up dry sand and cement until you obtain only one colour
5. spread the gravel on top of the mixture
6. add some of the water, mix up again until the mix is consistent



### 2. Different steps to make MORTAR:

1. find a clear area to mix the concrete, prepare your site
2. lay down the sand
3. pour the cement on top of the sand
4. mix up dry sand and cement until the mix is consistent
5. add some of the water, mix up again until the mix is consistent

Note: For the finishing coat, the sand should be sifted.

## Making reinforced concrete

To make REINFORCED CONCRETE, you need:

- STEEL      →    use steel bars ½ inch diameter for longitudinal bars  
                 →    use steel bars 3/8 inch diameter for stir up  
                 →    binding wire
- CONCRETE →    see How to make concrete?



### 1. Different steps to make REINFORCED CONCRETE:

*For example for continuous foundations:*

1. at first, blind the foundation trenches with 2 inches thickness of concrete in the hole
2. put the steel cage on the top of the concrete, leave 2 inches free all around the steel cage as cover
3. pour the concrete, the thickness required
4. level the concrete with the level line
5. vibrate the concrete to make the concrete compact and more resistant
6. wet the concrete or cover it with a wet cloth for curing, it will avoid cracks
7. let it become hard and resistant

#### Notes:

The steel has to be covered all around by the concrete.

The concrete cover is:

- 2 inches when the concrete is in contact with earth (foundations)
- 1 ½ inch for beams and columns

Transporting the concrete over long distances should be avoided.  
Prepare the concrete close to the spot where you cast the concrete.  
Use a rubber wheel wheelbarrow.

## Building foundations

### Hypothesis:

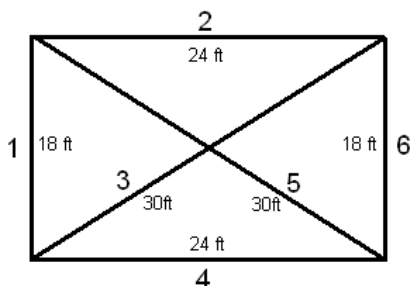
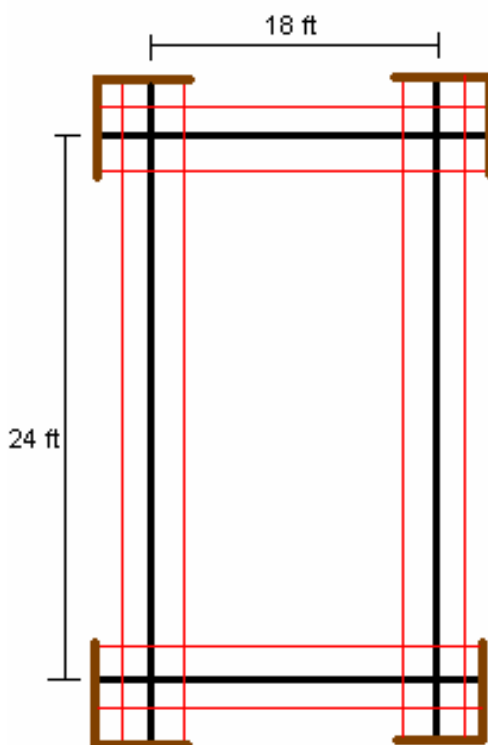
- wooden structure
- house 18 ft by 24 ft

Which kind of foundations?

- Pillars (columns)
- Continuous strip foundations

What do you need to build the substructure?

- Steel bars  $\frac{1}{2}$  inch and Stir up  $\frac{3}{8}$  inch
- Concrete 1:2:4
- 6 inch blocks and mortar



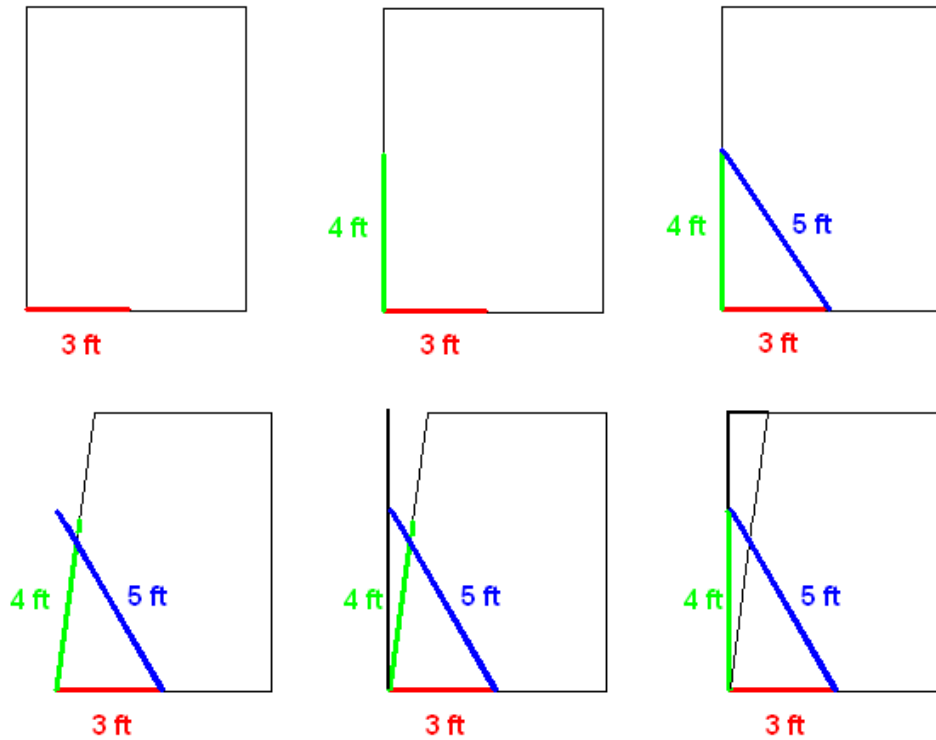
### 1. Different steps to build continuous strip foundations:

1. layout the foundations using profile boards, line cords and measuring tape,

**Note:** be sure the foundations are squared

- start with one of the small side 1 (18 ft)
- put 2 pegs
- take the measurement for one of the long side 2 (24 ft)
- put a peg
- check the diagonal 3, the measurement must be 30 ft, if not the sides 1 & 2 are not squared.
- square up the 2 sides by moving only the last peg
- take the measurement for the next long side 4 (24 ft)
- put a peg
- check the diagonal 5, the measurement must be 30 ft, if not the sides 1 & 4 are not squared.
- square up the 2 sides by moving only the last peg
- take the measurement of the side 6, you should get 18 ft

*Each time you want to check if 2 sides are squared, you can use the method below: 3-4-5 triangular method.*



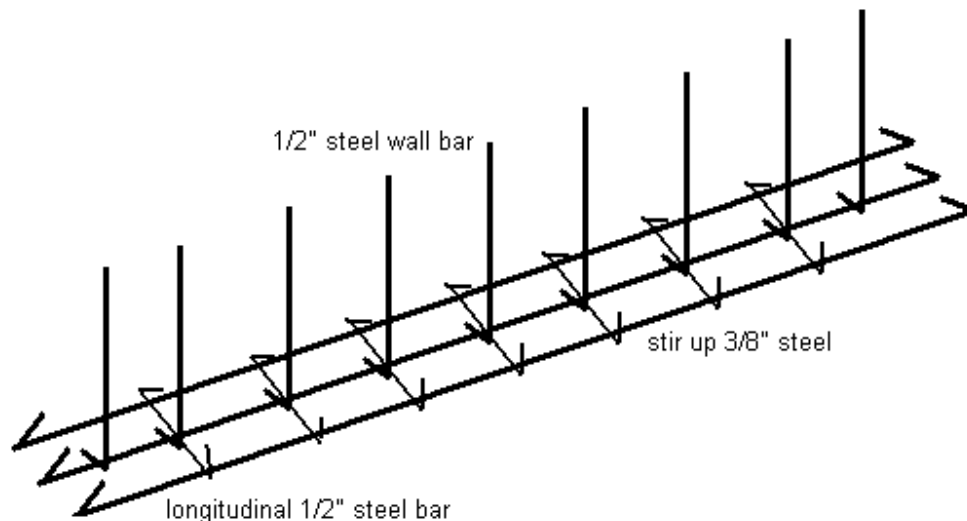
2. dig the ground 2 feet wide and 2 feet depth to give a good anchoring to the foundations in the ground.

**Note:**

- if good soil as marlin → the foundations depth will be 2 ft
- if the soil is clay → the foundations depth will be 2 ½ ft and you will fill up 6" with compact marl



3. prepare the steel cage of the foundation: 3 length of 1/2" steel with 3/8" stir up every 16 inches, and attach 1/2" steel vertical wall bar every 16".



**Note:**

The length of the vertical bars is the height of the foundations plus the extra piece on the top to bolt a nut with a washer in the plate.

For a 3 row of block, the vertical bars will be 39 inches long.  
 $12 + 24 + 3 = 39$  inches

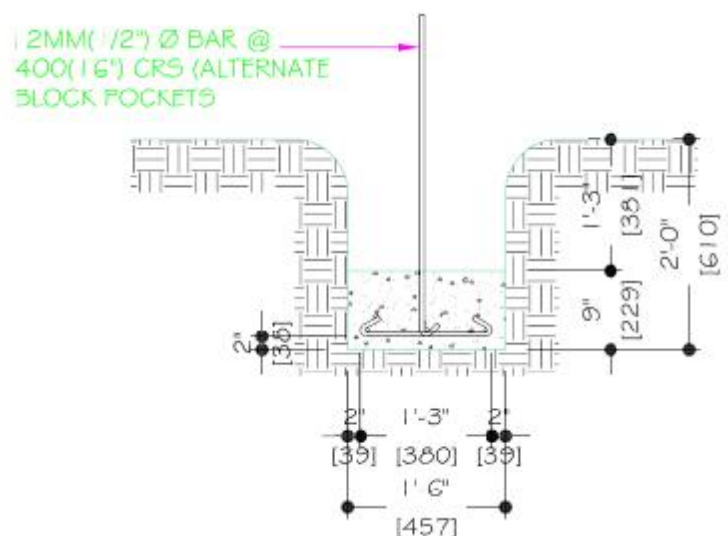
4. make concrete 1:2:4 (according to how to make concrete?)

5. blind the foundations trenches with 2 inches thickness concrete

6. put the steel cage on top of the 2 inch concrete,

Make sure there are some 2" spacers (stone) between the steel cage and the soil (ground)

7. pour the rest of the concrete, 7 inches thickness



8. level the concrete using the level line and a measuring tape
9. vibrate the concrete to make it compact and resistant.
10. wait over the night to put on the blocks
11. layout the foundation before putting the blocks
12. make some mortar 1:3
13. place 1 block over the reinforcement in the corner
14. check the location, level and plumb the block



15. place a second block in the next corner
16. level and plumb
17. put on a line between the 2 blocks
18. fill intermediate with blocks
19. level and plumb each block you place
20. repeat those operations until you reach the height you need: 2 or 3 rows of blocks
21. make some concrete 1:2:4
22. fill blocks alternative pockets containing wall bars with the concrete
23. ram the concrete to make it compact and resistant

## Building the flooring slab

### Hypothesis:

- wooden structure
- house 18 ft by 24 ft
- reinforced concrete foundations

Which kind of flooring?

- Flooring slab

What do you need to build the flooring slab?

- Steel BRC fabric mesh
- Concrete 1:2:4



### 2. Different steps to build flooring slab:

1. fill with compact marl until you reach the good level, which is 2 inches under the top of the last block
2. compact the marl
3. lay down the steel BRC fabric mesh, overlap 1 square in each direction



4. prepare the concrete 1:2:4

5. wet the marl with water

**Note:**

The base plate has to be fixed on the top of the blocks before you cast the slab

6. pour some concrete in the corner and middle to fix the BRC fabric mesh

7. cast the flooring slab 4" high

8. vibrate the concrete

9. level the slab on the top of the base plate, using a flat edge board straight

10. pour some cement on the top to get a better finish



**Notes:**

- cover it with wet cloth for a better curing and to avoid cracks
- wet the slab sometimes the following day for better curing

## Building the wooden frame

### Hypothesis:

- wooden structure
- house 18 ft by 24 ft

### 3. build the frame

1. thread the vertical steel bars, spaced every 32 inches
2. bolt the base plate to the foundations, using washers and nuts



3. Prepare the corners with 4 x 4 and 2 x 4 nailed on the sides; nail a J bolt at the bottom.



4. prepare the side:
  - starting from the middle,
  - the studs should be 2 feet on centre
5. fix one squared strap on each stud and base plate

6. lift up the side
7. level and plumb it before fixing it
8. prepare the others sides, the same way, level them, plumb them and fix them
9. brace the corners with 2 x 4, as explained in [bracing a wooden house](#)

**Note:**

The J bolts will be fix in concrete only when the house will be completely finished.

10. nail on the 1 x 8 Clinker



## Bracing a wooden house

### Hypothesis:

- wooden structure
- house in construction or already built

### **4. brace the wooden floor**

Wind or water forces can lift the wooden floor from the foundation if the connection between the two is not adequate. The drawings below show ideal details for the connection of floor framing members to ensure adequate resistance against separation during high winds.



*The beam is secured to the foundation by a steel plate fastened with nuts, washers and bolts. This method securely anchors this beam to the foundation.*

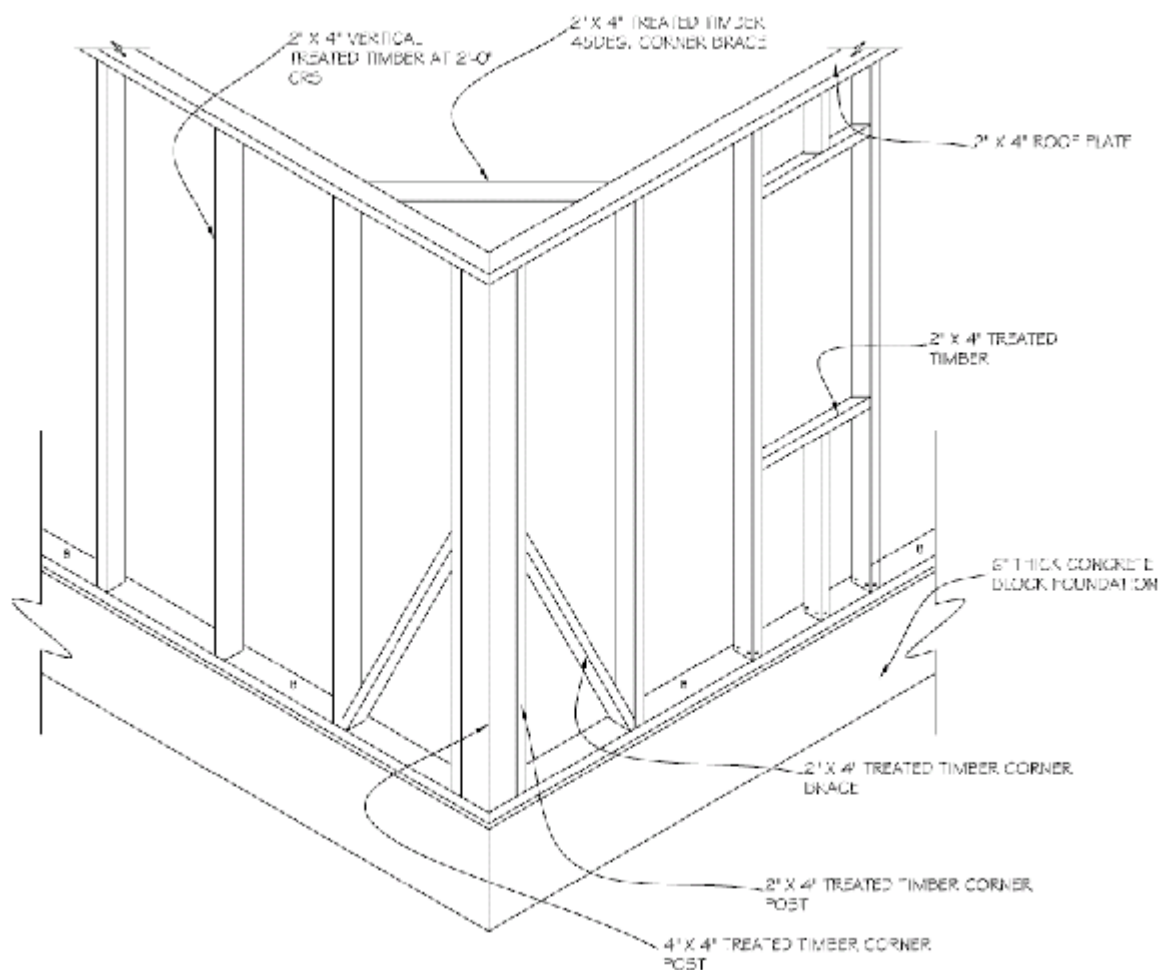
*The joists are also secured to the beam with a hurricane strap.*

## 5. brace the frame

The walls of the house should withstand the lateral forces produced by hurricane winds. The external walls should also sustain the load of the roof. In timber wall framing, rigidity is critical. Rigidity can be achieved by closer spacing of studs, by bracing studs with diagonal bracing as well as by horizontal noggins and cladding the stud wall frame with rigid board materials (clinker board).

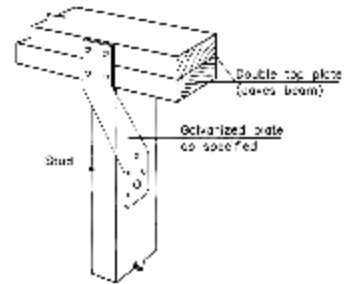
To reinforce the frame:

- ✓ The stud spacing should be kept to a maximum of 2 feet.
- ✓ You should put cross bracing 2"x4" and diagonal bracing, as in drawing.
- ✓ You should double the top plate with 2"x4" (depending on the existing frame).



Metal straps (T or twisted) plus corner braces must be added to secure studs at top and base plates and at corners of the structure.

Metal connectors allow nails/screws to work in shear, which is the most efficient way for them to perform.



*'T' strap used to connect the stud to the bottom plate.*

*Twisted strap used to connect the stud to the top plate.*

### **Recommendations—Framing and Cladding:**

- Ensure that cladding material used provides sufficient strength and that adequate bracing has been provided to withstand high winds.
- Studs spacing should be 2'-0" on centre.
- Studs are doubled around openings.
- Diagonal bracing is provided at corners.
- Metal straps are used to connect components.
- Use lath and plaster on external walls on weather side to protect plywood siding from the elements.

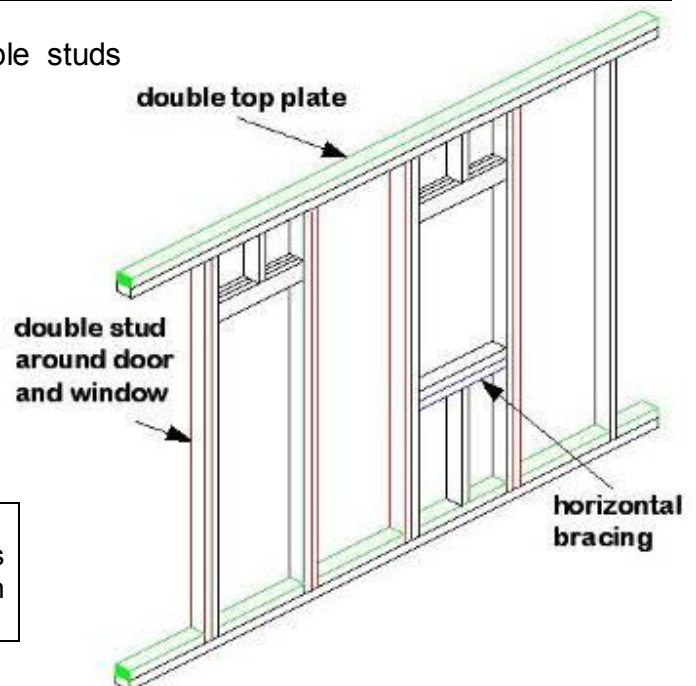
Metal straps are also useful to connect the components of the roof, as rafters to the top plates and rafters to the ridge beams



*Hurricane straps connect rafter to ridge beam. This helps to resist the uplift effect during high winds.*

## 6. brace the windows and the doors

To reinforce the frame, we should double studs around windows and doors as in drawing



**Note:**

If permanent shutters are not installed, it's necessary to create temporary shutters with plywood sheeting and timber battens.

## Constructing a gable roof

### Hypothesis:

- wooden structure
- house 18 ft by 24 ft

### 7. Gable roof or hip roof?

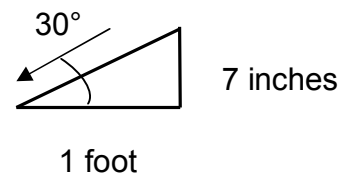
You have to decide if you build  
a gable roof or a hip roof



### 8. carrying out a gable roof

#### Note:

- roof should NOT be flat (or with a single slope)
- roof should be with a slope of at least 30 degrees (7 inches high for 1 foot long)

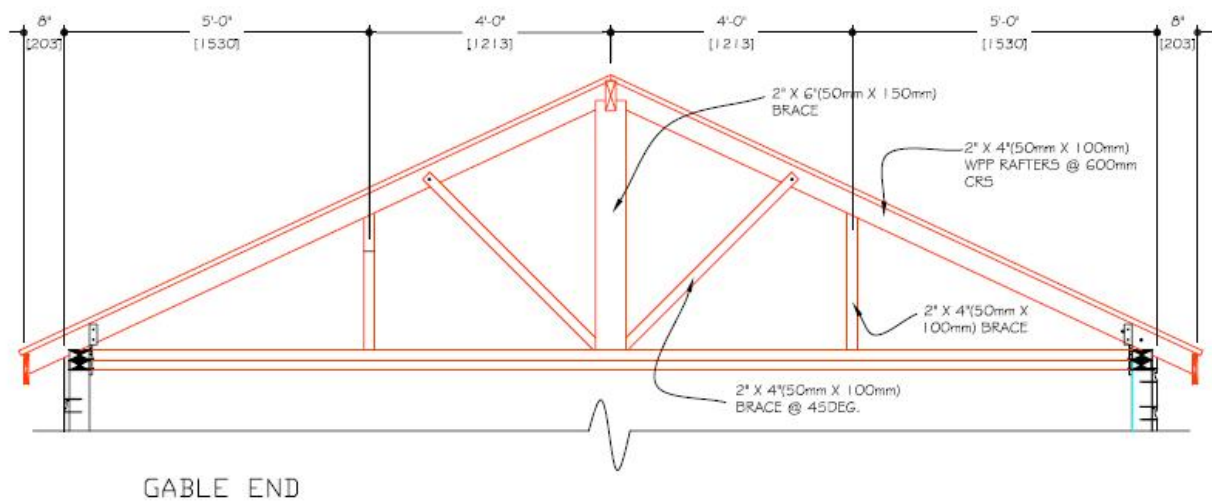


- 1) choose the slope of the roof, no less than 30° (7 inches high for 1 foot long)

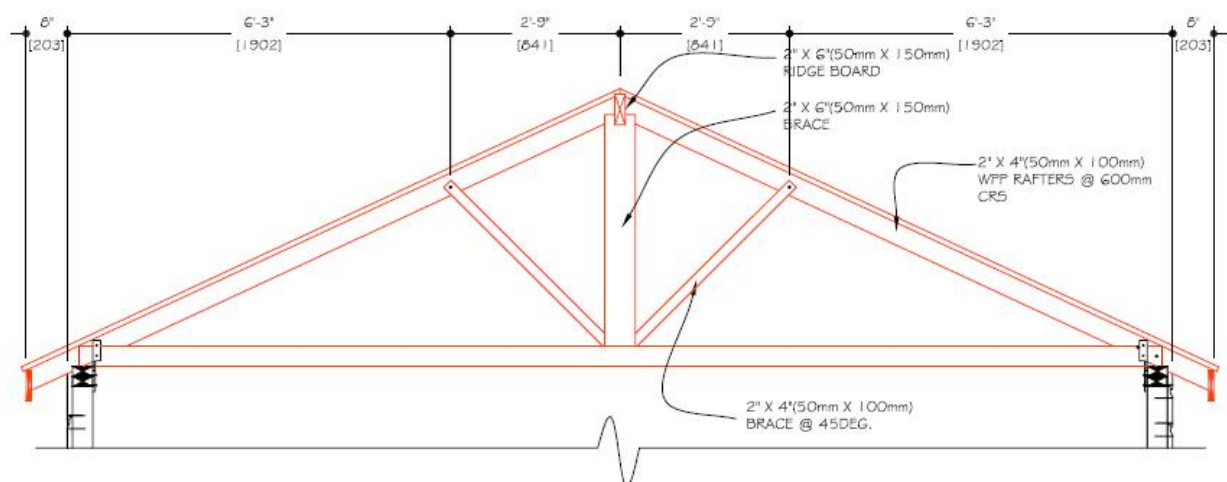
Example: house 18 ft x 24 ft

height of the ridge beam = (wide of the house / 2) x 7 inches  
height of the ridge beam = (18 / 2) x 7  
height of the ridge beam = 9 x 7  
height of the ridge beam = 63 inches (5 feet and 3 inches)

- 2) Double the top plate (2"x4") all around to strengthen the house. On the longer side, the top plates will go out 8" on both sides.
- 3) Make a platform to work safely.
- 4) Calculate the height of the ridge poles (2"x6"). Cut them and nail them on top of the top plate.
- 5) Nail 2 rafters onto the ridge pole. And brace them with 2"x4" as in the drawing below.



- 6) Prepare an intermediate frame with 2"x4" and 2"x6" to receive the ridge beam jointed. It will be placed exactly in the middle of the long side.

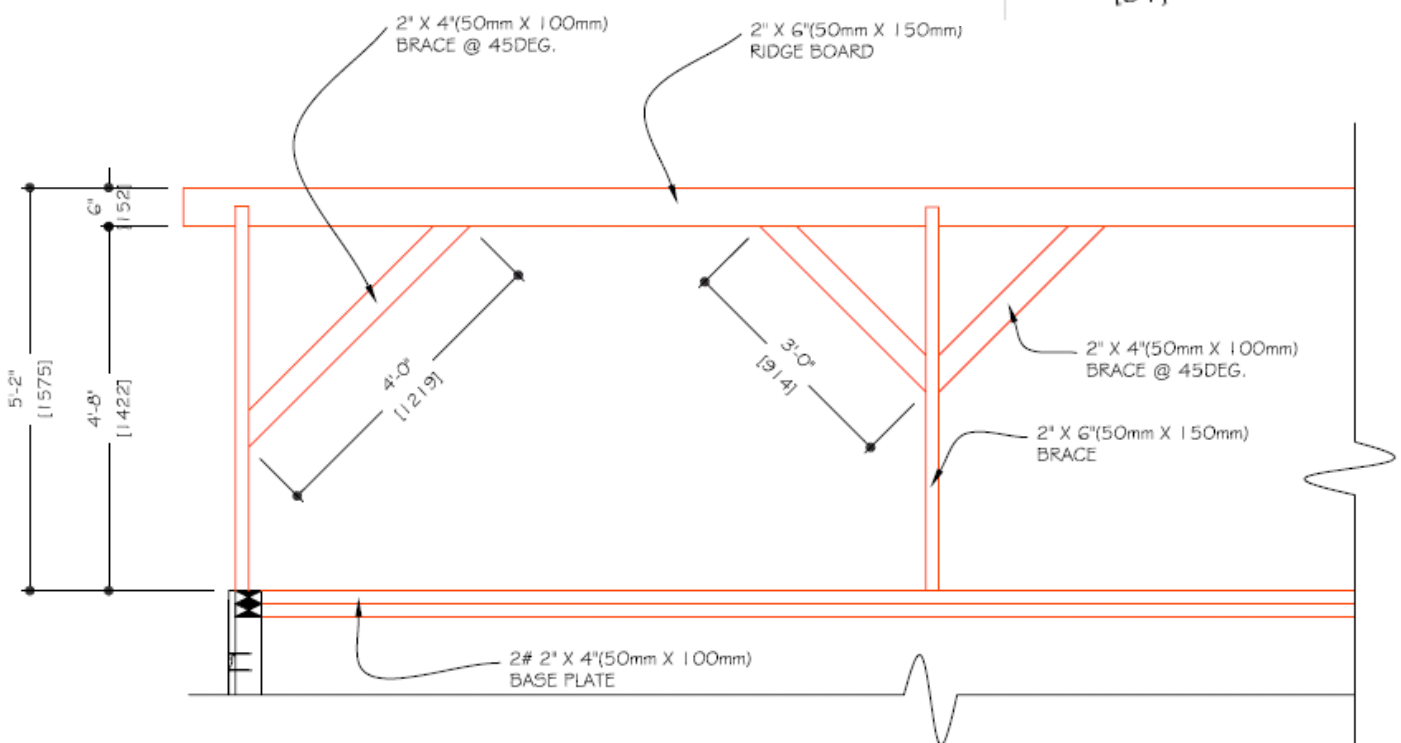


- 7) Nail 2 rafters onto the intermediate frame

- 8) Join the ridge beam with a scald joint as in the drawing.

And nail onto the ridge poles.  
The ridge beam will go out 8" on both sides.

- 9) Brace the ridge poles with 2"x4", as in the drawing below



- 10) Nails the rafters 2"x4" onto the ridge beam and the top plates. And trim the ends.

The rafters are located 2 feet on centre starting from the middle

- 11) Fix one twisted straps on each rafter to connect them with the top plates and the studs
- 12) Fix one squared straps on each rafter to connect them with the ridge beam



- 13) Nail on a verge board (1"x6") between the rafters.

Leave 2 opened spaces on both sides to allow ventilation.

- 14) Nail on the fascia board (1"x 6")

The eaves are no more than 8 inches long.

- 15) lay and nail the plywood on the rafters, it consists on making a ceiling above the rafters, as in the drawing

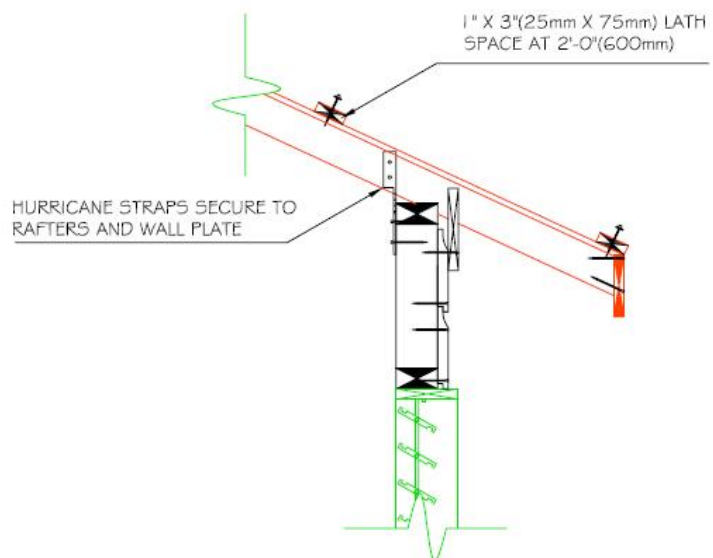
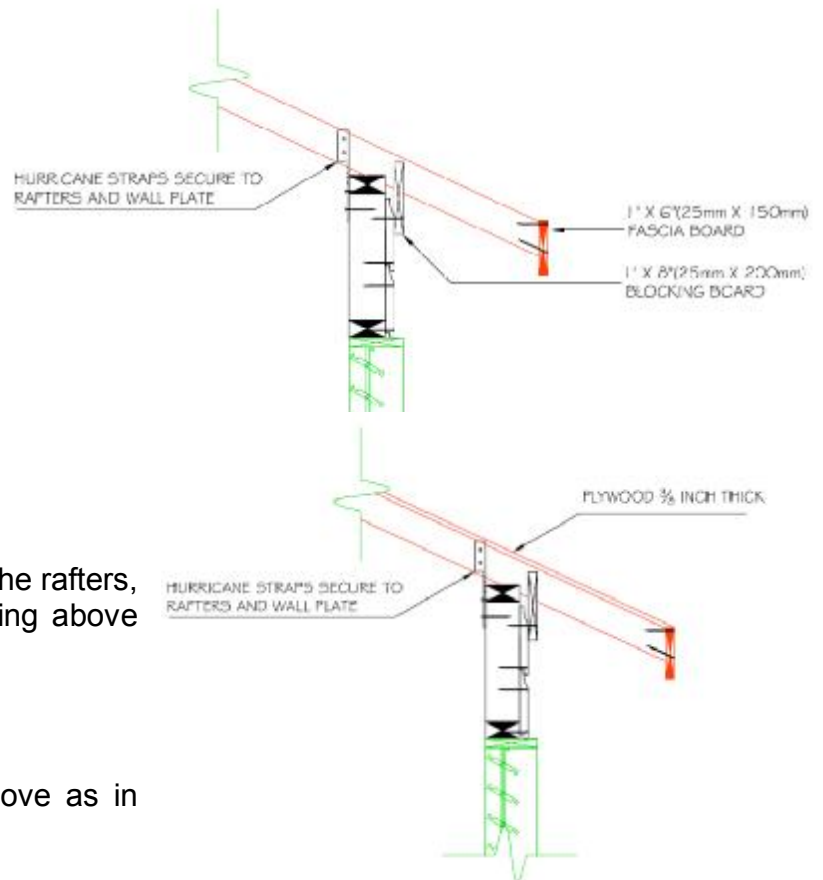
- 16) add the purlins (1" x 3") above as in the drawing:

At the eaves, you should put a purlin 1" x 3" nailed on each rafter.

The second purlin is located 1 ft next to the first one.

The last purlin at the top of rafters is located 5 inches from the centre of the ridge beam.

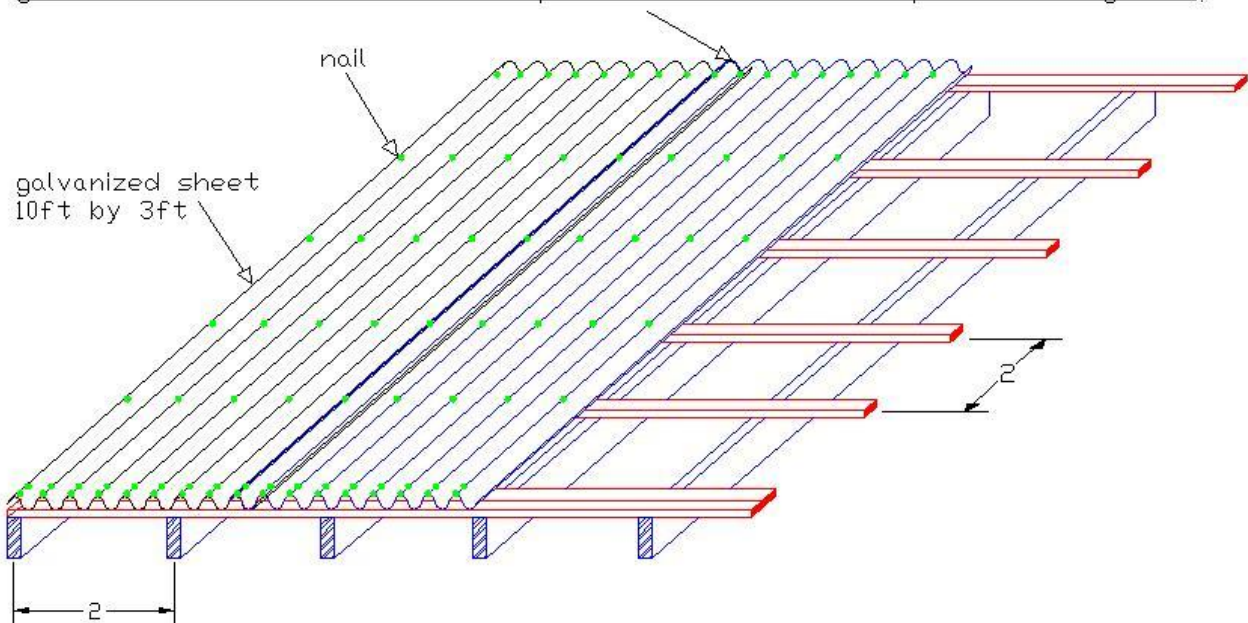
The others purlins (1" x 3") are located no more than 2 feet on centre



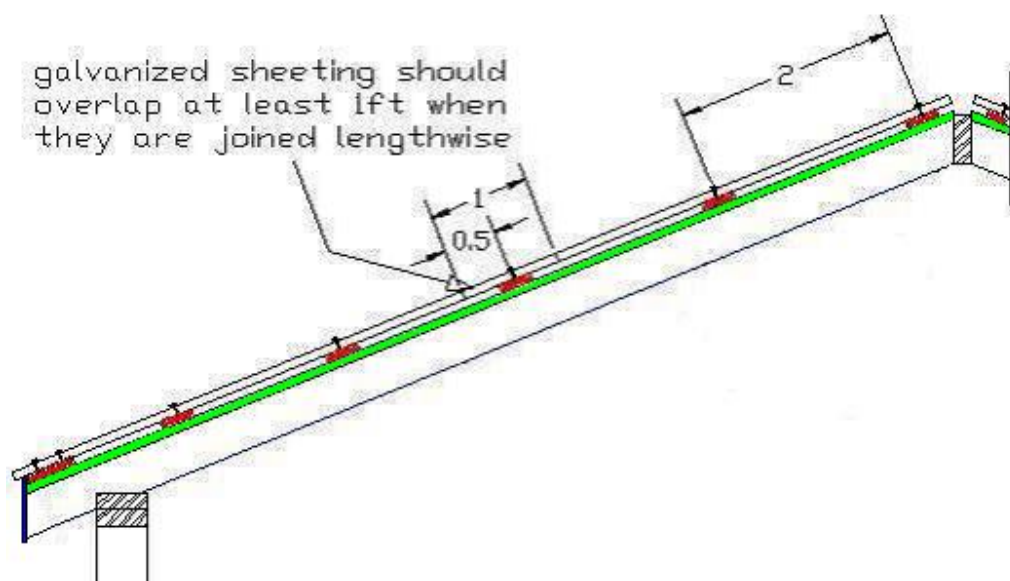
- 17) Fix on the galvanized sheets with screws or large cap nails.

The galvanized sheets should overhang 2 inches from the fascia boards.  
The galvanized sheets should overlap to two complete corrugations as in the drawing.

galvanized sheets should overlap to at least one complete corrugation.

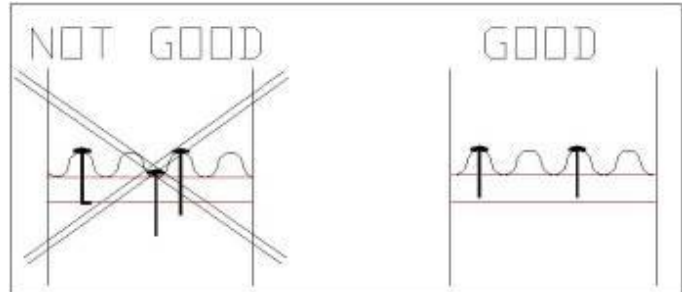


If one galvanized sheet is not enough to cover the entire roof slope, you should overlap by at least 1 foot, as in the drawing below:



**Nailing tips:**

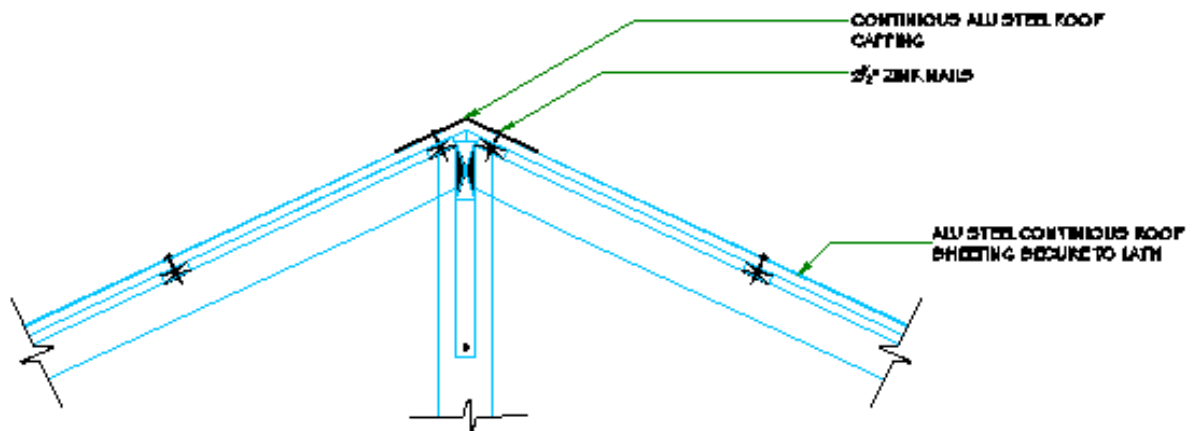
- On the ridge and the eaves, galvanized sheets are nailed at the top of every single corrugation,
- On the purlins, every other corrugation is nailed,
- Nails should not go through the beams (as in the drawing):



18) nail on the fascia capping on each purlins and on the fascia board, starting from the lower point if the fascia capping have to overlap in the length.

19) put on the ridge cap

The ridge cap is nailed at the top of every simple corrugation.



**Recommendations—Roof:**

- If galvanized sheets are used, ensure that they are of appropriate gauge (26 gauge) and are properly secured to the purlins so as to ensure adequate resistance in high winds.
- Nail down fascia capping to prevent lift in high winds
- Roofing nails should be galvanized, with large steel washers at their heads.

## Constructing a hip roof

### Hypothesis:

- wooden structure
- house 18 ft by 24 ft

This time, the choice is to carry out a hip roof.



### 9. carrying out a hip roof

1) level the top plates all around the house and double it (2" x 4")

2) calculate the length of the ridge beam (dressed wood 2" x 6")

Example: house 18 ft x 24 ft

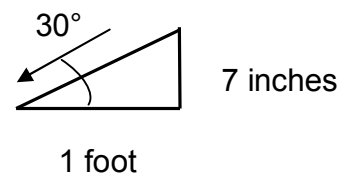
length of the ridge beam = length of the house – wide of the house

length of the ridge beam = 24 – 18

length of the ridge beam = 6 feet

3) fix the ridge beam at the good height

(slope = 30°, 7 inches high for 1 foot long)"



Example: house 18 ft x 24 ft

height of the ridge beam = (wide of the house / 2) x 7 inches

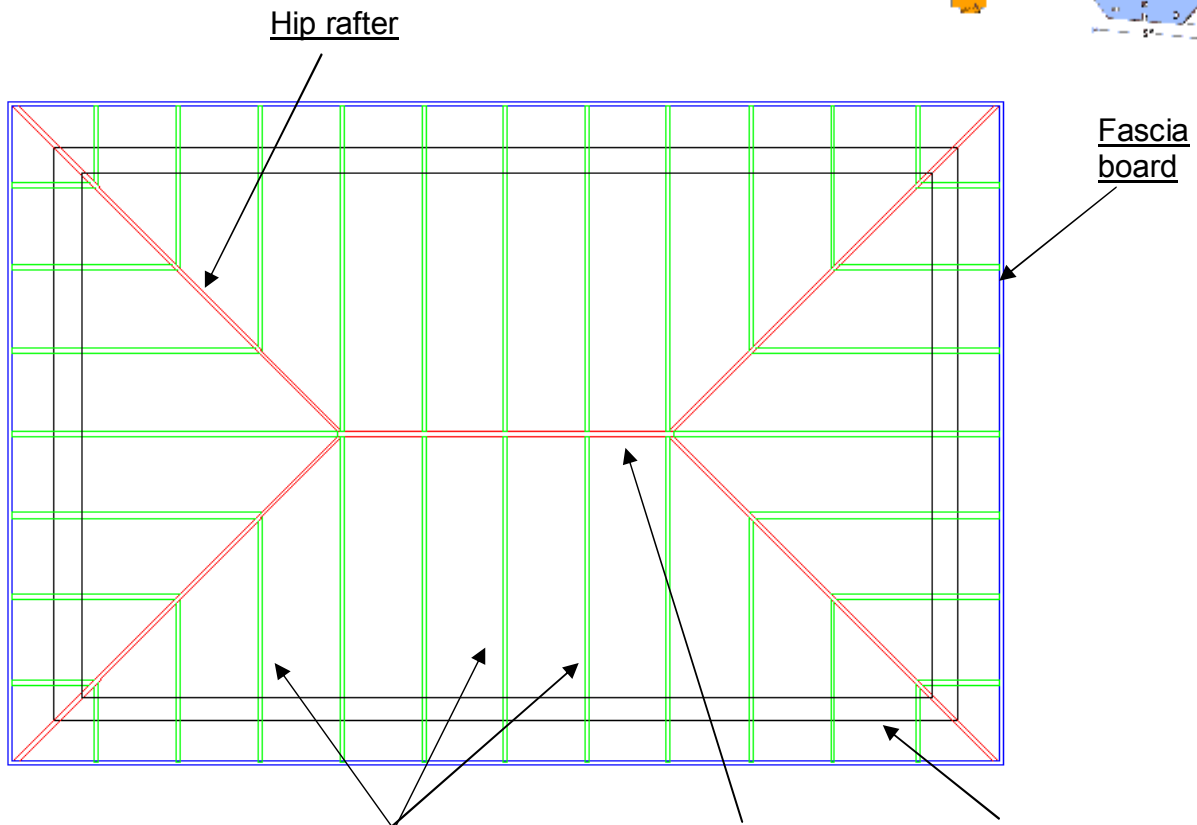
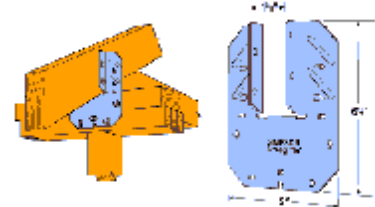
height of the ridge beam = (18 / 2) x 7

height of the ridge beam = 9 x 7

height of the ridge beam = 63 inches (5 feet and 3 inches)

- 4) nail the 4 hip rafters in each corners (2" x 6") to the ridge beam and the top plate as drawing below,

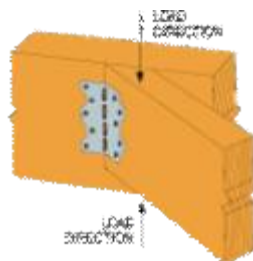
Use a hurricane strap to fix the rafters on the top plate in the corner



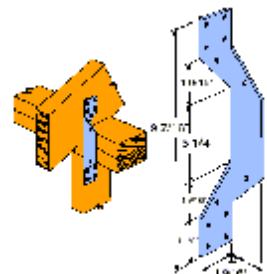
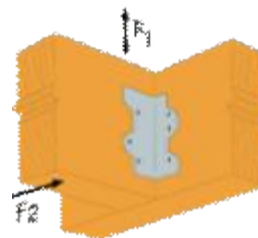
- 5) nail the rafters and jack rafters (2" x 4") to the ridge beam and the top plate as drawing beyond,

The rafters are located 2 feet on centre

Use 2 hurricane straps to fix the rafters on the top plate

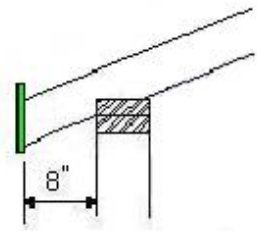


Use 2 hurricane straps to fix the rafters to the ridge beam and the hip rafters



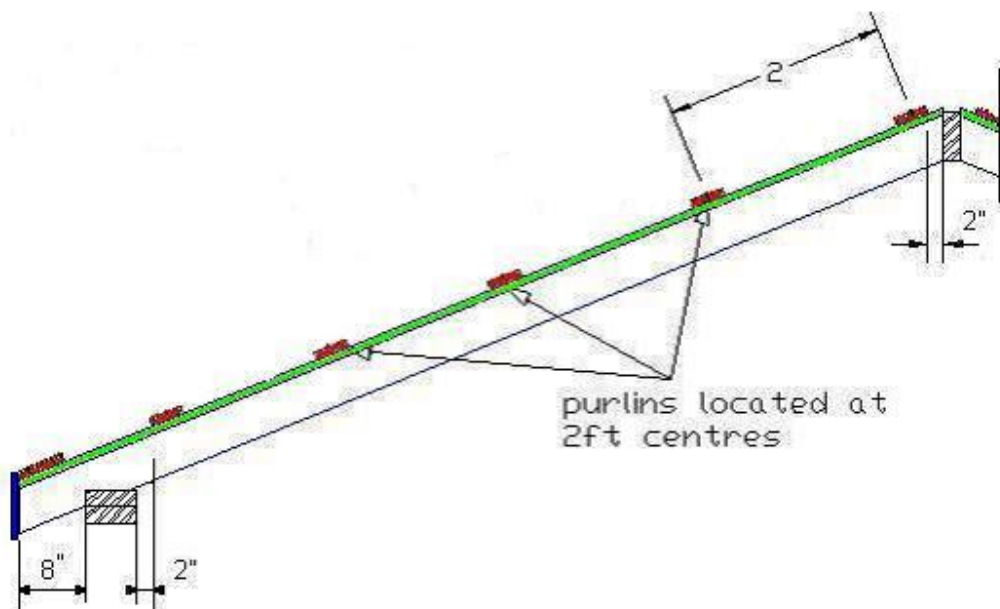
- 6) Nail on the fascia board (1" x 6")

The eaves are no more than 8 inches long.  
It is better to cut the rafters vertically and to put the fascia board vertically as well.



- 7) lay and nail the plywood on the rafters, it consists on making a ceiling above the rafters, as in the drawing below:

- 8) add the purlins (1 x 3") above as in the drawing



On both sides of the hip rafter, we should nail a purlin (1" x 3").

At the eaves, we should put a purlin of 1" x 3" nailed on each rafter.

The second purlin is located no more than 1 foot from the first one to reduce the risk of lift up

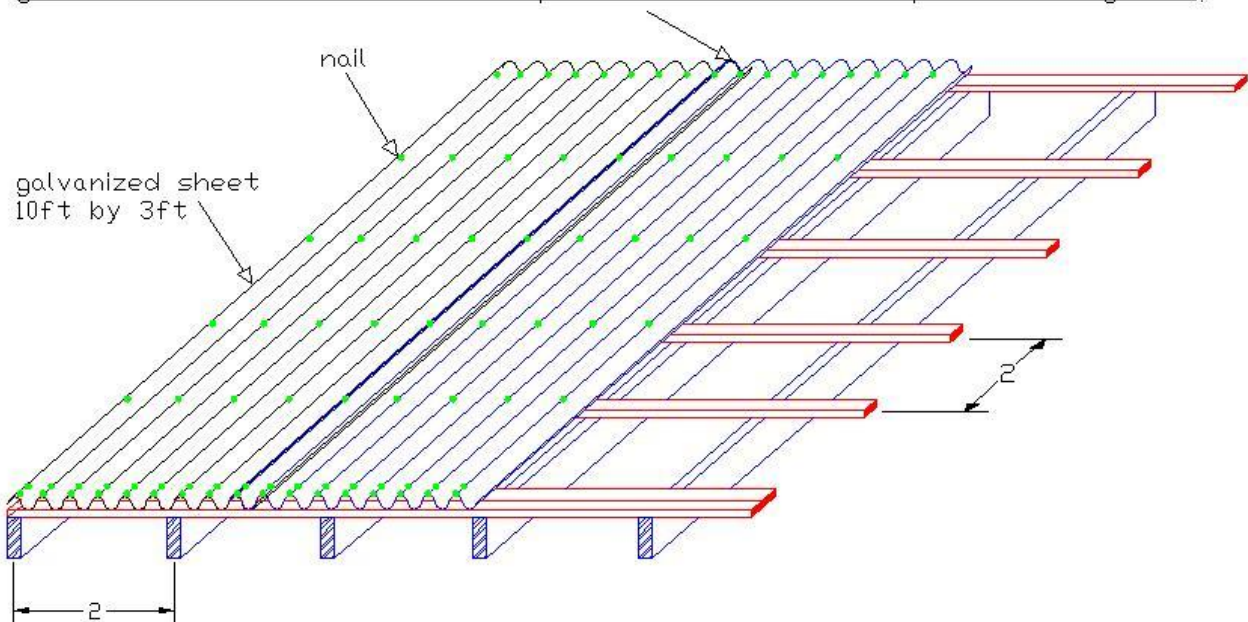
The last purlin at the top of rafters is located at 5 inches from the ridge beam.

The purlins (1" x 3") are located no more than 2 feet on centre.

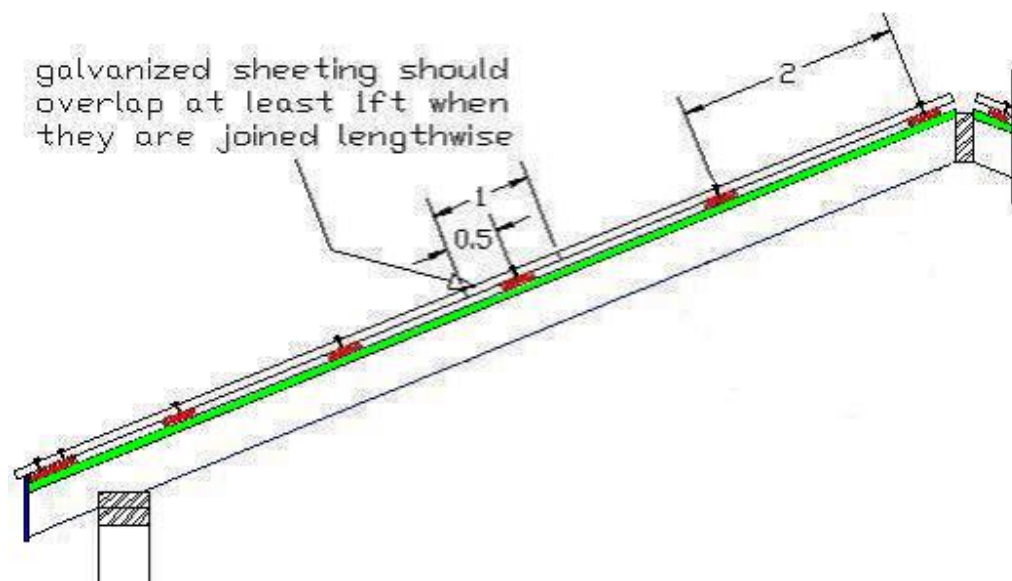
9) put on the galvanized sheeting

The galvanized sheets should jut out 2 inches from the fascia boards.  
The galvanized sheets should overlap to two complete corrugation as in the drawing:

galvanized sheets should overlap to at least one complete corrugation

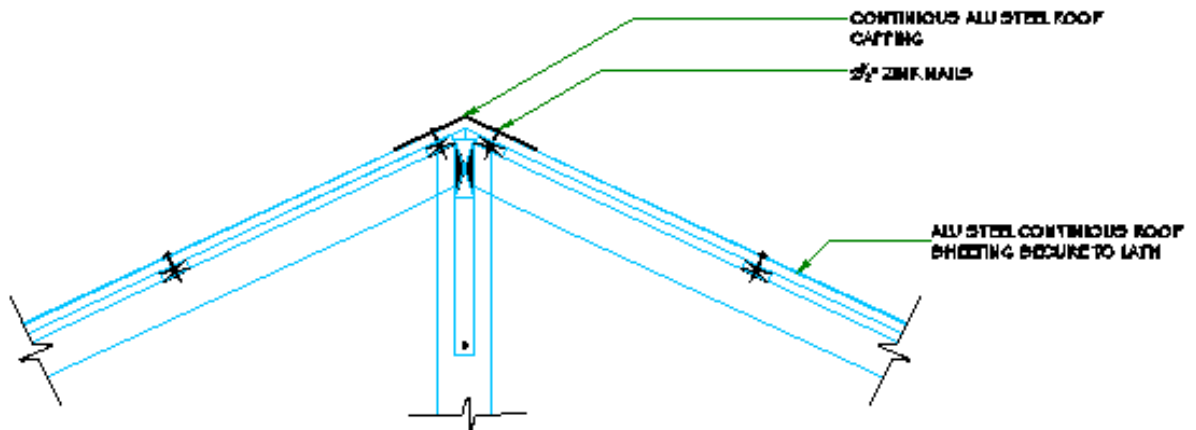


If one galvanized sheeting is not enough to cover the entire roof slope, we should overlap by at least 1 foot, as in drawing below:



10) put on the ridge capping

The ridge capping are nailed at the top of every simple corrugation, on the purlins located close to the ridges (top of the roof and hip rafters).



If one ridge cap is not enough to cover the entire ridge, we should overlap by at least 1 foot.

**Note:**

- Start to fix the ridge cap from the lower part of the roof to the higher part.
- Always finish with the ridge cap on the top of the roof

## Health and Safety

Source: Safer Housing and Retrofit Program St. Lucia National Research and Development Foundation

Building sites can be very dangerous, both to the workmen and passers-by, especially when the following activities are being undertaken:

- *Demolition works*
- *Working at heights*
- *Lifting or carrying heavy objects*
- *Operating electrical powered tools*

Accidents on a building site can be reduced by workers' awareness of the root causes and adoption of safer working habits that can avoid endangering themselves and others. It must be noted that two of the most common factors which cause accidents on a work site (or elsewhere) are the attitude of individuals and the ignorance of the correct way machinery/ equipment work or are operated.

The following are examples of dangerous attitudes:

- *An inclination to take risk and behave recklessly.*
- *Believing that safety precautions are a waste of time.*
- *Thinking that if accidents are going occur, there is little anyone can do to stop them.*

If workers change their attitudes and develop safer working habits, this would go a long way towards reducing accidents.

The second factor, the ignorance of persons as to the correct way machinery/equipment works or are operated, can be corrected by persons ensuring that they are knowledgeable and skilled in the safe use of machinery/equipment before attempting to use them. In the same manner, persons must be skilled in Carpentry or general building works before attempting to erect structures, because when the structure fails lives may be lost.

The following safety tips, if observed, can help reduce accident and save the lives of workers and other people as well.

## **1. Safety on the Building Site**

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1. Keep work area clean. Clean up as you go, especially during demolition work.
2. Pull nails from boards at once. It is the odd piece of material with protruding nails that can cause serious injuries.
3. Wear thick-soled shoes with toe protection to protect your feet from protruding nails and heavy objects that may fall on your toes.
4. Use hard hats whenever you are working with persons above you or when you are below ground level (e.g. if you are digging a pit for a septic tank.)
5. Wear a respirator with changeable filters whenever you are working in a dusty environment
6. Do not operate machinery or sharp edged tools or climb ladders or scaffolds when under the influence of alcohol or other drugs that may impair your judgment.
7. When carrying out demolition/renovation work, make sure there are no children or other persons in the way before knocking out damage cladding.
8. Wear safety goggles whenever there is a chance that your eye would be endangered.

## **2. Electrical Safety**

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9. Always cut the power and check electrical outlets with a voltage tester.
10. When working in areas that you may cut into or otherwise disturb, keep in mind that there may be electric wires and pipes behind finished surfaces.
11. Power tools are commonly used; make sure, you know how to operate them. If it is raining, work should be stopped immediately as there is a chance that you will suffer an electric shock that could be fatal.
12. Check the electric cord of power tools to make sure that there are no cuts.

## **3. Scaffolding Safety**

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13. All supports for scaffolding must be solidly footed. Make sure they are checked every morning before you start work.
14. Platforms for scaffolding should be without twist or major cracks and they should be cleated (nailed) together.
15. Platform ends must not overhang more than 1'-0" beyond their supports.

#### **4. Safety while Working at Heights**

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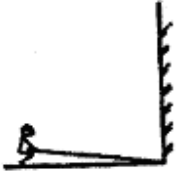
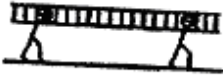
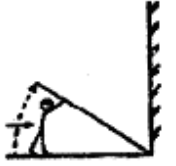
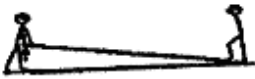
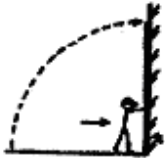




16. Scaffolds that are higher than 3'-0" should have guard rails to protect workers from falling, and toe boards to stop objects from being accidentally kicked off the scaffold.
17. Working with ladders and scaffolds are dangerous as workers can fall from a height and injure themselves and persons below. They must be strongly built and well braced, as they have to carry heavy loads of persons and materials.
18. When working on a roof, erect scaffold up to the lower level of the roof to save anyone who slips down a roof slope.
19. Use roof ladders or crawl board to spread the load of the worker's weight when moving up and down the roof slope.
20. Roofs with zinc-corrugated sheets are not meant to support a person's weight between the timber frames. Walking on this type of roof covering requires extreme care because you need to move along the line of the nails or screws fixed to the battens/purling.
21. Do not use tools or do jobs requiring two hands while standing on a ladder.
22. Do not drop materials from a ladder.
23. Do not straddle from the ladder to a nearby foothold.
24. Do not allow more than one person up a ladder at a time.
25. Do not carry sheets of material, especially if it is windy.
26. Do not overreach.

#### **5. Safety while Lifting or Moving Heavy or Awkward Objects**

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27. Protect your back muscles when lifting heavy objects. Get someone to help you. Lift with your arm and leg muscles, not your back.
28. Get help when carrying long boards or ladders, even if they are not heavy.

## 6. Manipulating and Maneuvering Ladders

Short Ladders	Long Ladders
<p>Stage 1: Lift, bend knees and keep back straight</p> 	<p>Stage 1: Shoulder carrying</p> 
<p>Stage 2: Move forward and raise ladder</p> 	<p>Stage 2: Lifting – Assistant footing base of ladder</p> 
<p>Stage 3: Stand ladder up against a wall</p> 	<p>Stage 3: Move forward to raise ladder, assistant stationary</p> 
<p>Stage 4: Move out from wall</p> 	<p>Stage 4: Lean ladder against wall</p> 
<p>Stage 5: Carrying ladder</p> 	

Note: When erecting and moving ladders over short distances, be aware of overhead cables and other obstacles. Metal ladders must not be used in areas where electric cables are present.

## **7. Ladder Safety**

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Ladders must be used correctly, if not, serious injury can result. The tips below should be a useful guide.

1. Do not erect on sloping ground.
2. Do not erect on movable objects.
3. Do not erect in front of a door that may be opened.
4. Do not erect against a slippery surface.
5. Do not erect at a shallow angle.
6. Do not erect horizontally as a plank or bridge.
7. Do not erect at too steep an angle.
8. Do not use a ladder that is too short.
9. Do not use a defective ladder.
10. Do not use a makeshift or 'home-made' ladder.
11. Do not overload a ladder or support it with a rung bearing on a board.
12. Do not slide down a ladder.
13. Do not carry a ladder while riding a bicycle.
14. Do not use an alloy or wet ladder near electrical conductors.
15. Always place a ladder on a firm level base.
16. Always set at an angle near to 75° from the horizontal (i.e. 4 in 1).
17. Always tie the ladder in position, if possible at both the top and the bottom. (See pictures above.) If that is not possible, a worker should stand with one foot on the bottom rung holding the stiles to steady the ladder.
18. Always make sure the ladder projects above the climbing off level.

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- 3 steps to reinforcing the frame of your house
- 10 steps to rebuilding your roof
- 5 steps to fixing hurricane straps

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