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## Measuring Timber Pitched Roofs in Accordance with ARM4

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## Measuring Timber Pitched Roofs in Accordance With ARM4

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### Introduction

Timber pitched roofs are the dominant form of domestic roof construction in the Republic of Ireland. Roofs are usually measured under Element (27) of the National Standard Building Elements (see next slide). Pitched roofs may be constructed with prefabricated trusses and this is a common approach particularly where the roof is built between gable walls, has a constant cross section, and the attic is not designed to provide accommodation. Alternatively, the roof may be constructed in-situ, when it is referred to as a '**cut roof**'. This approach is used when the roof design is more complex and may include features such as hips, valleys, abutments, dormers and other design elements.

There may be occasions on which a building has both pitched and flat timber roofs. In these situations the carcass timbers for the flat roof must be kept separate from those in the pitched roof.

### The Worked Example

This worked example demonstrates the principles and techniques involved in measuring a very simple roof structure design in accordance with the principles of the Agreed Rules of Measurement (ARM4 – 2009). The worked example, nevertheless demonstrates a number of important techniques commonly used in measuring roof structures. The demonstration is addressed to Irish students of quantity surveying related disciplines at foundation level.

# The National Standard Building Elements (NSBE)

BUILDING (Direct Costs)							SITE (Direct Costs)
Substructure	Structure	Structure Completions	Finishes	Services (Mainly Piped and Ducted)	Services (Mainly Electrical)	Fittings and Furniture	
(1 -) Substructure Generally	(2 -) Structure Generally	(3 -) Structure Completions Generally	(4 -) Finishes Generally	(5 -) Services (mainly Piped and Ducted) Generally	(6 -) Services (Mainly Electrical) Generally	(7 -) Fittings and Furniture Generally	(- 0) Site Generally
(11) Ground, Earth Shapes	(21) External Walls	(31) External Walls : Completions within Openings	(41) Wall Finishes Externally	(51) Heating Centre	(61) Electrical Supply and Main Distribution	(71) Display, Circulation Fittings	(10) Prepared Site
(12) Reserved	(22) Internal Walls, Partitions	(32) Internal Walls, Partitions : Completions within Openings	(42) Wall Finishes Internally	(52) Drainage and Refuse Disposal	(62) Power	(72) Work, Rest, Play Fittings	(20) Site Structures
(13) Floors in Substructure	(23) Floors, Galleries	(33) Floors, Galleries : Completions	(43) Floor Finishes	(53) Water Distribution	(63) Lighting	(73) Culinary Fittings	(30) Site Enclosures
(14) Reserved	(24) Stairs, Ramps	(34) Stairs, Ramps : Completions	(44) Stairs, Ramps : Finishes	(54) Gases Distribution	(64) Communications	(74) Sanitary, Hygiene Fittings	(40) Roads, Paths, Pavings
(15) Reserved	(25) Reserved	(35) Suspended Ceilings	(45) Ceiling Finishes	(55) Space Cooling	(65) Security and Protection	(75) Cleaning, Maintenance Fittings	(50) Site Services (Mainly Piped and Ducted)
(16) Foundations and Rising Walls	(26) Reserved	(36) Reserved	(46) Reserved	(56) Space Heating	(66) Transport	(76) Storage, Screening Fittings	(60) Site Services (Mainly Electrical)
(17) Piled Foundations	(27) Roofs	(37) Roof : Completions	(47) Roof Finishes	(57) Ventilation and Air Conditioning	(67) Reserved	(77) Reserved	(70) Site Fittings
(18) Reserved	(28) Frames	(38) Reserved	(48) Reserved	(58) Other Services (Mainly Piped and Ducted)	(68) Other Services (Mainly Electrical)	(78) Reserved	(80) Landscape, Play Areas
(19) Summary : Building Substructure	(29) Summary : Building Structure	(39) Summary : Building Structure Completions	(49) Summary : Building Finishes	(59) Summary : Building Services (Mainly Piped and Ducted)	(69) Summary : Building Services (Mainly Electrical)	(79) Summary : Building Fittings and Furniture	(90) Summary : Site

## The National Standard Building Elements

In Ireland the measurement of new building work is typically organised in accordance with the National Standard Building Elements (NSBE). Elements are defined as *'that part of the building, which always performs the same function irrespective of design or specification'*. The object of the NSBE is to enable design teams to adopt, on a national basis, a common approach to the building process. The Elements stipulate what is included and excluded from each element, which helps design teams coordinate their work and allows the measurement of the work to be divided up among teams while ensuring that all aspects of the building works are fully covered in the Bill of Quantities.

The Table opposite sets out a matrix of elements covering the various building elements. Roofs are measured within the Structure group of elements where it is located at Element (27).

### Element (27) Roofs

The following work is included within the scope of the Roof element:

- Roof Structure, however formed
- The following if integral with roof structure:  
Boarding, insulation, rainwater disposal systems, rooflights, openings and finishes.

It excludes:

- Suspended ceilings
- Sheeting, slating, tiling and associated battens and sarking
- The following if not integral with the roof structure:  
Rooflights and openings  
Insulation  
Rainwater disposal systems  
Finishes

# Element (27) Roofs

## Scope of Works

### Woodwork

- Structural and First Fixings
  - Carcassing timbers (rafters etc)
  - First fixings (wallplates etc)
  - Labours (cleats and sprockets)
- Boarding and Second Fixings
  - Boarding and sheeting (eaves)
- Ironmongery Accessories and Sundries
  - Straps, ventilators, insulation

### Painting and Decorating

- Painting eaves and verges.

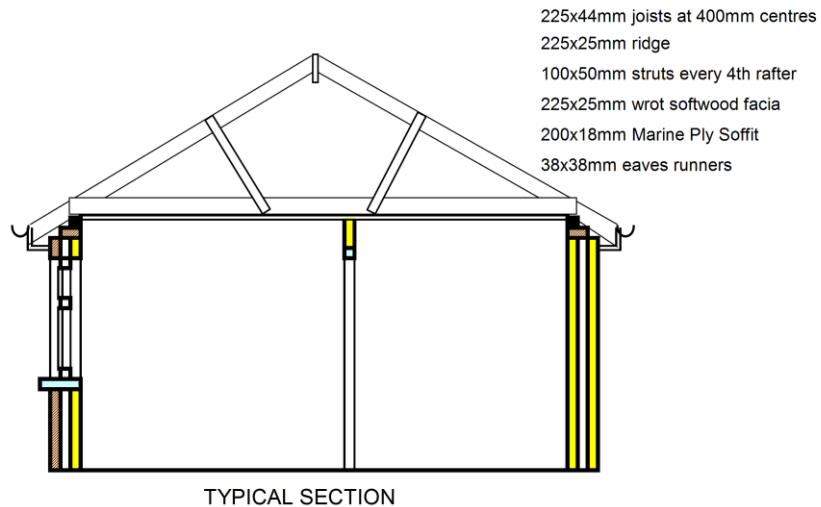
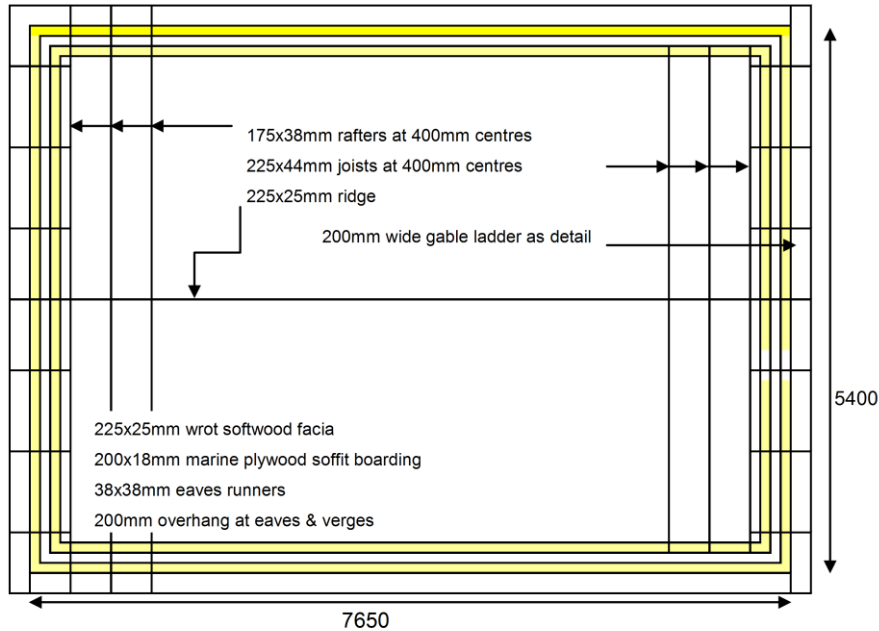
### Scope of the Works

Before commencing taking off quantities for the roof structure, the surveyor should draw up a to-take list to ensure that no work items are overlooked. The order of items on this list should follow a logical sequence and these should then be rearranged into ARM sequence in order to bill the work. It should be noted that when taking off in elemental format, there may be work contained in a number of separate sections of the ARM. In this example the work is predominantly contained within Section J Woodwork, however there is also painting which is governed by Section Q, Painting and Decorating.

### Information Required for Woodwork Structural and First Fixings.

- **Location Drawings** – These are covered by the roof plan and section shown on the following slide.
- **Timber type, quality, preservative treatment, surface finish, fixings and jointing.** – These matters are covered in the specification headings for the works measured below.
- **Colour and/or grain matching.** – There are no requirements for these in this worked example
- **Connectors, cleats, and the like.** – These do not arise in this worked example. Connectors are often associated with pre-fabricated work such as roof trusses. A cleat is a strip fastened to one part to hold it in place or to facilitate the fastening of another part. For example, cleats may be used on the inside of a drawer unit to hold a drawer.

# The Drawings — Not to Scale



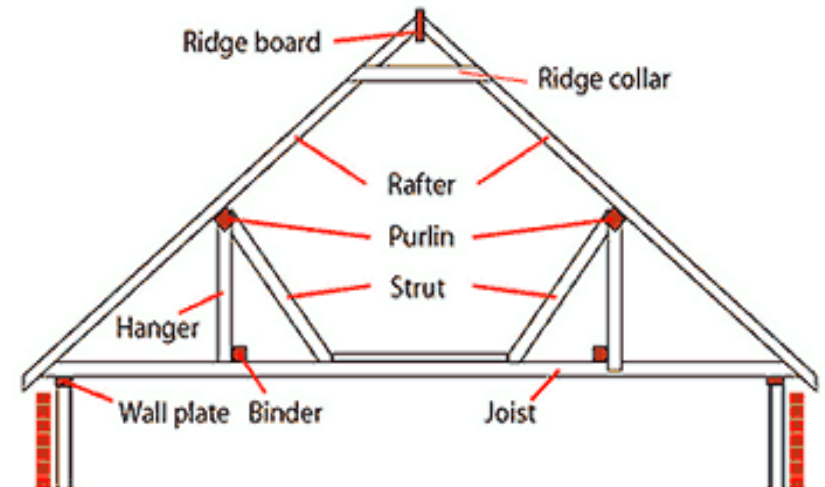
## Pitched Roof Members

ARM defines pitched roof members as “rafters, hip/valley rafters, purlins, ridge boards, ceiling joists, binders, collars, struts bracing and the like.”

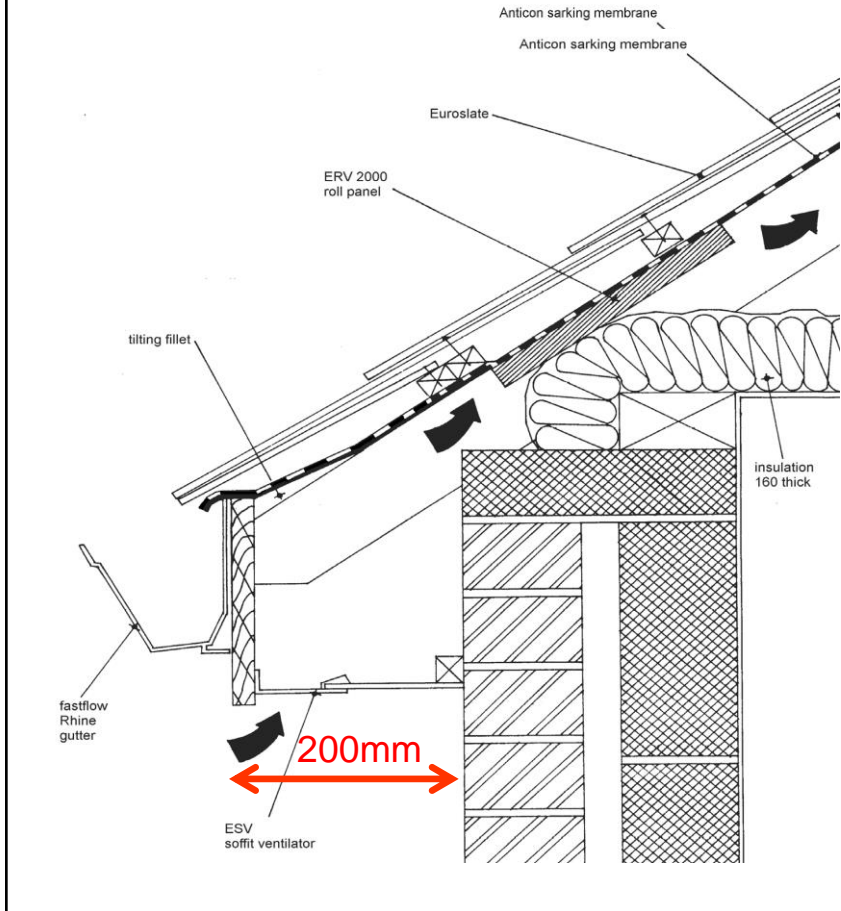
## First Fixings

First fixings are defined as “plates, battens, bearers, grounds, fillets, drips, rolls, upstands, kerbs, firrings and the like.”

The Illustration below identifies various members commonly found in pitched roofs



# Typical Eaves Detail



## Eaves Details

The detail shown on the left is taken from *Seeley and Winfield's Building Quantities Explained Irish Edition* (Hore, O'Kelly and Scully, 2009) and shows a typical eaves detail associated with a slate roof.

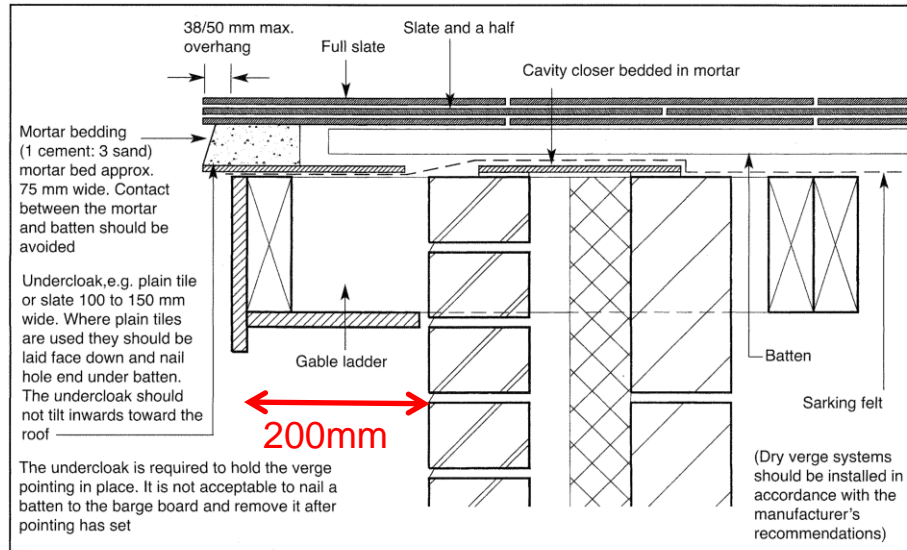
Eaves and other boundary conditions are at the interface of the roofing and carpentry trades and it is easy to leave out items which must be measured. For example, in the detail opposite the tilting fillet, the soffit and fascia boarding at the eaves and their associated decoration are normally measured in Element (27) Roof (structure). It would be logical that the soffit ventilator shown the detail would also be fixed by the carpenters at this stage. However on occasion these are measured in the Roof Finishes element of the Bill.

In the worked example a 200mm projection indicated by the red arrow has been taken from the face of the external wall to the outside face of the fascia board.

Source: Hore, O'Kelly and Scully, (2009) *Seeley and Winfield's Building Quantities Explained Irish Edition*

# Typical Verge Detail

## FIBRE CEMENT AND NATURAL SLATES



Typical bedded verge (double lap fibre cement slates).

Source: *The Homebond Housebuilding Manual* (2012) p 233

## Verges

Verges are located at gable ends of buildings. It is very common, particularly in older buildings to finish the roof almost flush with the outside face of the gable wall – the slating often projects 50mm and is then pointed with cement mortar in order to weatherproof the building.

The worked example is based on the detail shown to the left and shows a projecting verge of 200mm. The soffit and barge boards and their associated decoration will have been included already in Element (27) Roofs.

Rates for verges are deemed to include under cloak courses, bedding, pointing and cutting on boundary. Nevertheless this information is often included in detailed verge descriptions. Slates may also be clipped at this location with slate clips.

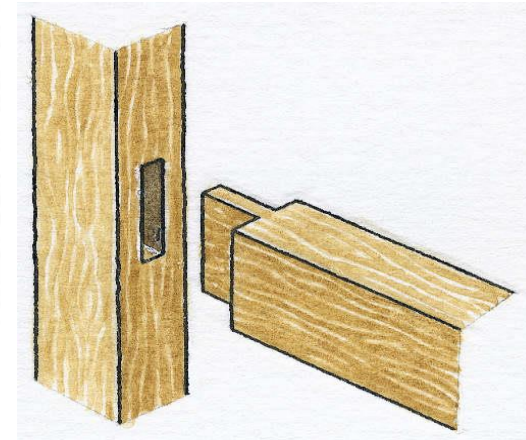
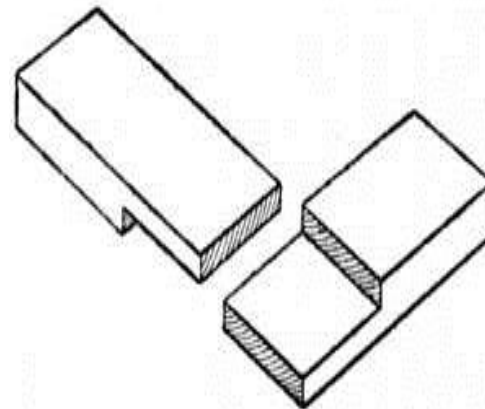
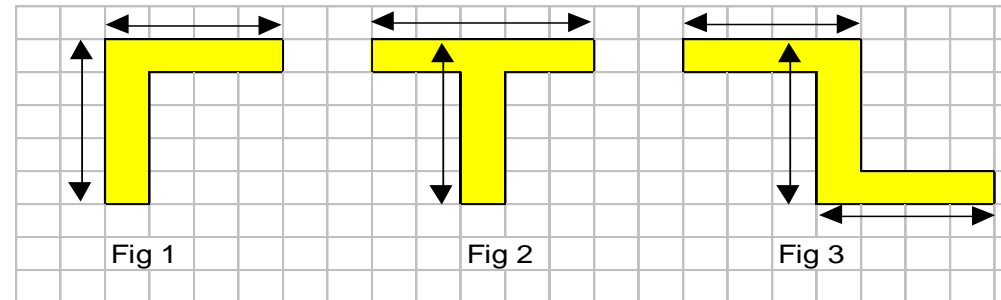
**Note** in this worked example the final 'inside' rafter forming the gable ladder is **not** doubled up as shown in the detail opposite.

# Measurement Principles

- Timber roof members are described and measured in accordance with the Woodwork section of the ARM 4
  - Structural and First Fixings
  - Boarding and Second Fixings (Eaves and Verges)
- Information Required
  - Type and quality of timber
  - Preservative treatment
  - Surface Finish
  - Fixings and jointing (other than nails)
- Generally measured in linear metres stating cross-section dimensions

Timber roof members are described and measured in accordance with the Woodwork section of the ARM 4

The principle of measuring timber is that each individual piece of timber is measured to its extreme length. The purpose of this is to allow for any lap joints or tenons. So if two pieces of timber lap at an angle they are measured as shown in Fig 1. If they intersect they are measured as shown in fig.2. If there is a return on the building they are measured as fig 3. No laps should be added if the timber is butt jointed.





# Woodwork - General Measurement Rules

## Measurement Rules

- Sizes are deemed to be nominal sizes unless stated as finished sizes.
- Fixings other than nails must be stated in the description.
- Fixing to backgrounds other than timber must be stated in the description

## Deemed to be Included

- Labours
- Nail fixings
- Fixing to timber backgrounds.

Measurement Rules	Measurement Scope	Deemed to be Included
<ol style="list-style-type: none"> <li>1 All sizes shall be deemed to be nominal sizes unless stated as finished sizes.</li> <li>2 Limits on planing margins shall be stated.</li> <li>3 Fixings other than nails shall be stated in the descriptions.</li> <li>4 Fixings to backgrounds other than timber shall be stated in the descriptions.</li> <li>5 Work to curve or special shape shall be so described giving a detailed description.</li> <li>6 Pelling where required shall be given in the descriptions.</li> <li>7 Where items do not have constant cross-section, the extreme dimensions shall be stated and described as such.</li> </ol>		<ol style="list-style-type: none"> <li>1 Labours except as otherwise specifically required by these Rules.</li> <li>2 Nail fixings</li> <li>3 Fixing to timber backgrounds</li> <li>4 Cutting associated with differing cross-sectional dimensions</li> </ol>

## Measurement sequence

This worked example has arranged the various timbers in order of increasing thickness and depth. This approach is commonly adopted by Irish quantity surveying practices.

Note it is not necessary to identify the function of the individual members. Therefore if the rafters, joists and collars are the same size they can be measured together. This will help to keep the Bill of Quantities brief, and avoid the possibility of inconsistent pricing among similar items. Individual quantity surveyors, nevertheless, do provide this extra information in their bill descriptions.

# Measuring Rafters

## How many are there?

1. Find the length of the roof between the gables,
2. subtract the distance between the face of the wall to the centre of the first rafter,
3. repeat this at other end,
4. divide the length by the rafter centres,
5. round up this figure if it is not a whole number,
6. add one more to this figure.

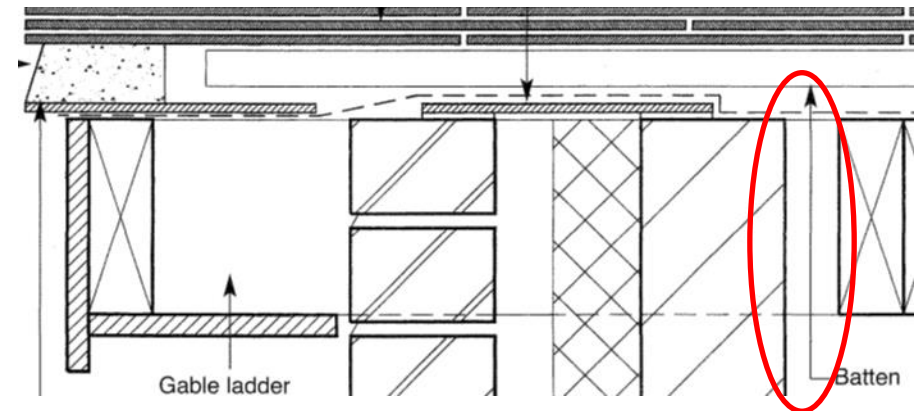
Length of House			10000
Clearance at ends		-2/50	-100
Centers of rafters @ 400 c/c		400)	9900
			24.75
Spaces			25
Add 1 to get Rafters		+1	<b>26</b>

## Calculating the number of rafters

This technique is used where members occur at regular spacings. The technique can be applied to other forms of construction such as stud partitions, floors, and connections such as bolts or straps.

If an intermediate rafter/joist such as a trimmer is in a fixed position then the calculation should be made on either side of the fixed rafter.

The red circle in the illustration below shows the gap or clearance at ends between the final rafter and the gable wall. This allowance is usually taken as 50mm.



# Measuring Rafters

## Length

Many roof timbers are scaled directly off the drawing – This is the simplest way! - But make sure that the scale is correct!

Sawn ends should be taken into account - these will be cut at an angle – it may be appropriate to round the figure up to the next 100mm for good measure.

Alternatively the length may be calculated using pythagoras or trigonometry. The multiplier for the rafter is the inverse of the cosine angle – i.e **divide** the length of the rafter on plan by the cosine of the pitch

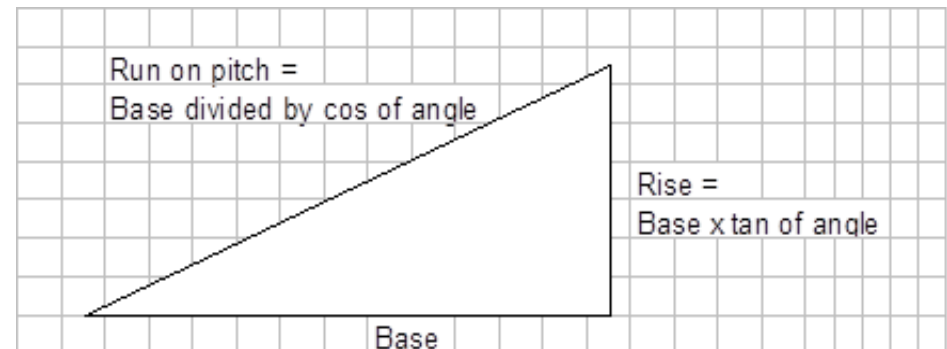
Roof Span	6000	
Wall Thickness	300	
Overhang	200	
Pitch	30 Degrees	
<u>Length of rafter on plan</u>		
Half Span	3000	
Wall Thickness	300	
Overhang	200	
	3500	
de Cos 30 deg (0.866)	4041	
Cut End	50	
	4091	Say 4100

## Measuring the length of rafter

Alternatively a scaled diagram may be constructed on the dimension sheets to work out the length The following example relates to the worked example.

### Constructing a scaled rafter

- Measure the length of the rafters on plan – from the fascia to the point of mid span (below the centre of the ridge). This is the base line opposite [2900mm].
- Draw this to scale along the bottom margin of the page. (1:20 is a good scale to choose but use 1:50 if there is a wide span).
- Raise a perpendicular line at the end the base line (the column rulings are useful for doing this)
- Using a protractor measure the angle of the pitch at the start of the base line and draw this line until it intersects the perpendicular.
- Scale this length an round it off for cut ends and mitres. [3350 say 3400 for good measure]



COTTAGE ROOF. 1

ELEMENT (Z7) ROOF

WOODWORK

38 x 175 mm

Softwood; structural grade  
C 14; pressure treated  
with preservative

143m

Carcassing in pitched roofs

25 x 225 mm; scarf  
joints in the running  
length.

rafters)

7650

- gable  $\frac{2}{300}$  600

- gap  $\frac{2}{50}$  100

6950

centres  $\div 400$

17.38

spaces:  
round up

18

+ 1

19

9 m

Ridge)

7650

$\frac{2}{19} / 3.40$

129.20

length scaled.

verge  $\frac{2}{200}$  400

scarf jt 500

$\frac{2}{2} / 3.40$

13.60

flying rafters at  
eaves).

8.55 8.55

8550

142.80

OR

width  $\frac{1}{2} / 5400$

= 2700

eaves 200

base 2900

$\div \cos 30$  0.866

3348

cut end say 52

3400

SCALED @ 3350  $\approx$  3400mm

30°

BASE 2900 @ 1:20 SCALE.

**Ridge**

The ridge board in the demonstration is long and will need to be jointed in the running length. This is commonly done using a 'scarf' joint as shown below. An allowance of 500mm has been added to the length to cover this joint The verge overhang [200mm] has also been added to the length of the building at both ends.



Source www.nachi.org

**Rafters**

Rafters are usually scaled from the roof section. They are measured to their extremities taking account of any tapered or mitred ends.

If the drawing is not to scale, a scaled diagram representing the pitch can be drawn to find the rafter length. This is done at the bottom of the dimension sheet opposite.

COTTAGE ROOF. 2

44 x 225 mm

95 m

joists

5400

- 2/300 - 600  
walls

+ 2/100 + 200  
plate 5000

19/ 5.00 95.00

50 x 100 mm

12 m

struts

No rafters 19

- 4  
4.75

Spaces = 5

Struts 6

6/2/ 1.00 12.00 scaled/Taken.

### Joists

The number of joists is the same as the rafters [19] calculated on the previous slide

The joist length is found by calculating the overall internal width of the building [5400mm - (2\*300mm for the external walls)] and adding for end bearing onto the wallplate (2\*100mm)

Note that ARM requires carcassing timbers **exceeding 5.00m in one piece** to be measured separately. In this example the joist is 5.00 metres long which locates it just within the 'standard' classification.

### Struts

Struts are specified to every 4<sup>th</sup> pair of rafters

The number of struts has been calculated by the same technique as that used to find the number of rafters.

The length of the struts are usually scaled from the drawings. In this instance the length has been taken as 1000mm long. This figure is somewhat arbitrary, as struts are normally cut on site and offered up to the roof. It is not considered pragmatic, therefore to attempt to accurately calculate their length in this instance.

COTTAGE ROOF 3

First fixings

38 x 38 mm; fixing to blockwork; plugging

15 m

$2 / 7.65 = 15.30$

eaves fixing ground

100 x 75 mm fixing with straps (elsewhere measured) to blockwork

15 m

(Wallplate)

Gables 7650  
- 2/300 - 600  
7050

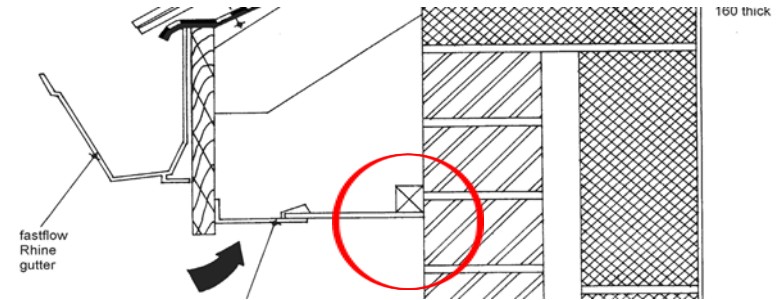
Running laps  
say 2/100 200

7250

$2 / 7.25 = 14.50$

Eaves runner

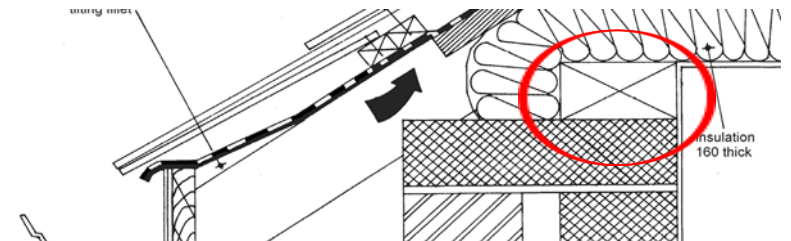
This item is shown on the eaves detail where it forms a ground supporting the soffit boarding. It is fixed to the blockwork along the front and rear elevations.



Wallplates

The wallplates are measured within the gable walls, an allowance has been made for two halved joints in the running length.

Wallplates may be bedded in cement and sand, or may be fixed with galvanised straps or bolts, the method of fixing should be stated in the description.



COTTAGE ROOF 4.

Ex 225 x 38 mm

16 m

tilting fillet at eaves

7650

verge  $2/200$  400

8050

$2/8.05$  16.10

Labours

cleats or sprockets  
550 x 35 x 150 mm

12 Nr

gable ladder

verge 200

wall 300

gap 50

550

Rafter 3400

spacing  $\div 1200$

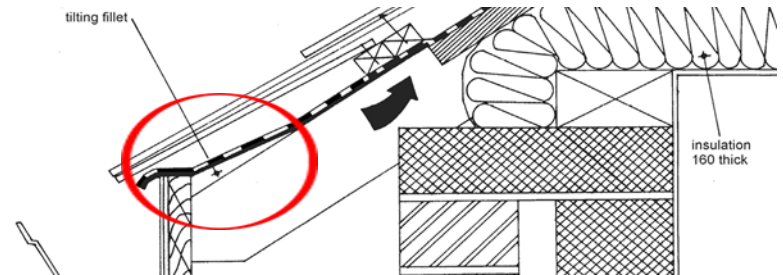
2.83

Roundup 3

$2/2/3$  12

**Tilting Fillet**

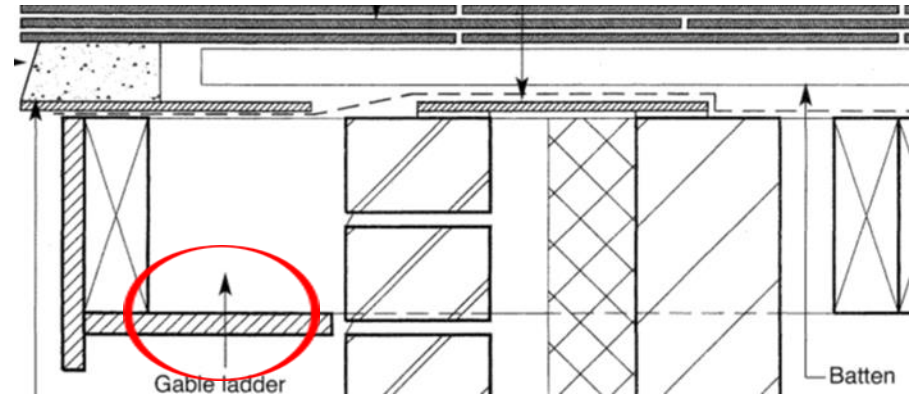
The tilting fillet under the final course of slates is described as ex 225x38 in order to comply with the rule that 'where items do not have constant cross-section, the extreme dimensions shall be stated and described as such.'



**Gable Ladder**

The timber sprockets forming the gable ladder are considered to be labours. They are counted stating the dimensions. Note the use of the waste calculation to figure out the length of the sprockets and its description.

The number of spaces has been used in this instance as the ridge board closes off the final space.



COTTAGE ROOF 5

Softwood; wrought;  
selected

Boarding and sheeting;  
eaves and verges

25 x 225 mm

30 m

2/ 8.05 16.10 (fascia).  
as fillet

2/2/ 3.40 13.60  
as rafter  
29.70

Marine Plywood

Boarding and sheeting  
eaves and verges

200 x 18mm thick

30 m

LAST  
29.70  
as fascia &  
barge.

M 29.70

**Eaves Boarding**

Boarding and second fixings comprise the second section of the Woodwork section of ARM. The specification information required is identical to that provided for structural and first fixing timbers.

Boarding and sheeting is classified in nine separate categories the final one being 'eaves and verges' which is defined as 'boarding includ[ing] fascias, soffits, barges & the like.' This category of work is measured in linear metres.

ARM requires that where work to any one face is  $\leq 300$ mm wide this shall be stated in the description. The descriptions opposite give the actual size and thickness of the boarding.

End cutting, mitres, splays and the like are deemed to be included with the boarding.



COTTAGE ROOF 6.

Ironmongery, Accessories  
and sundries

Accessories

straps; galvanised  
mild steel; 30x5mm  
thick x 800mm long  
fixing to blockwork;  
plugging

38 Nr

wallplate 7050  
÷ 1200  
5.88

spaces 6  
+ 1  
7

2/7 14

2/12 24  
38

stapping at  
gables, joists  
and rafters.  
(as gable ladder)

ventilator strip; E.S.V.  
or equal approved;  
scribing plywood;  
(measured linear -  
not in accordance  
with ARM)

16 m.

2/8.05 16.10

as fascia).

**Carpenters Metalwork**

Woodwork accessories are enumerated providing a detailed description.

Note the approach to measuring the ventilators, the general rule that accessories are counted does not fit this particular item very well and it has been measured in linear metres instead. This departure from the rules must be identified to the tendering contractors.

COTTAGE ROOF 7

Thermal insulation;  
glass fibre quilt

250 mm thick;  
fixing between joists  
at 400 mm centres

38 Sq.m

7.05

5.40 38.07

**Insulation**

The National Standard Building Elements recommends that insulation should be measured in the Roof Finishes element. Nevertheless, in practice, insulation is often taken in the roof structure element.

Insulation is measured in sq.m providing a detailed description and the kind and quality of the materials. Insulation is measured under the rules for Woodwork sundries. The insulation is described as being a) thermal b) acoustic or vapour barriers.

PAINING AND DECORATING  
NEW WORK EXTERNALLY

Knot, prime and stop;  
2 undercoats and one  
finish coat gloss oil  
paint

General surfaces

exceeding 300mm  
girth.

14 m<sup>2</sup>

facia	225
thickness	25
drip.	25
soffit	<u>200</u>
	<u>475</u>

29.70 as eaves)  
0.48 14.26  
14.26

END OF ELEMENT (27)

ROOF.

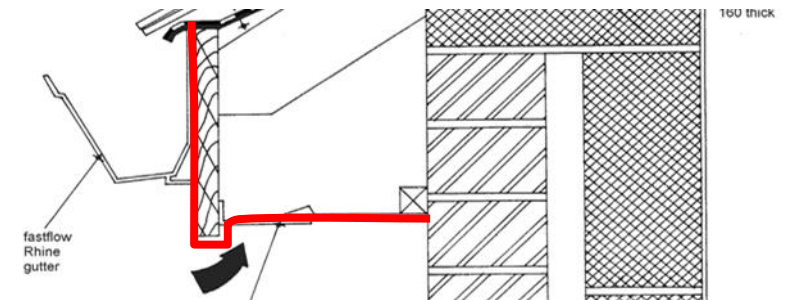
**Painting and Decorating**

The rules for measuring painting are set out in Section Q of ARM; Descriptions shall state:

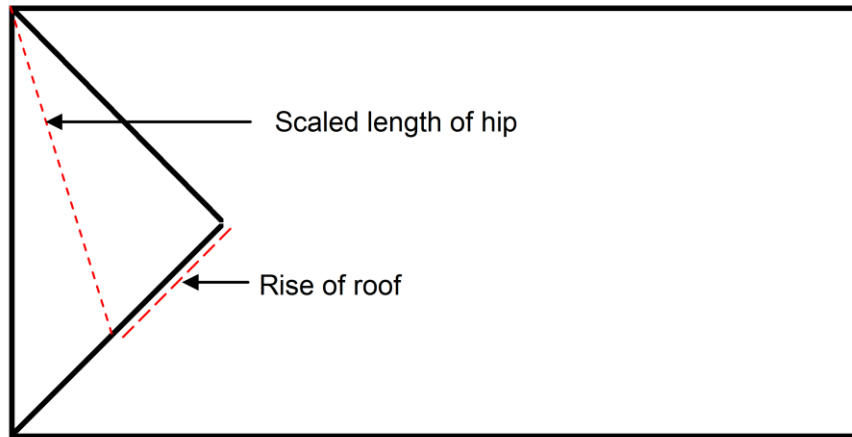
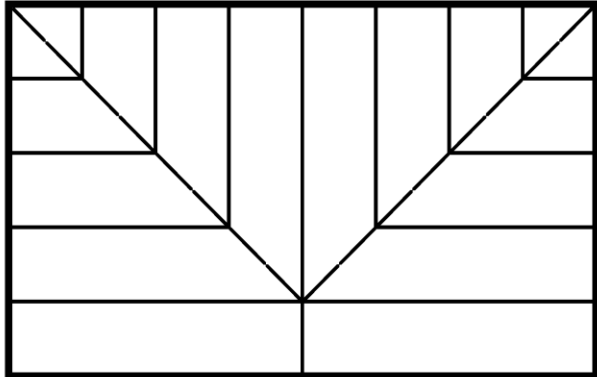
- 1) Preparatory work to base,
- 2) Kind and Quality of materials,
- 3) Number of priming or sealing coats and undercoats,
- 4) Number of finishing coats stating the surface finish,
- 5) Abrasive or other treatment applied between coats,
- 6) Method of application where not at the contractor's discretion.

Painting to the eaves is generally taken in this element of the work.

Painting is measured in square metres identifying the nature of the base and function (walls, floors, ceilings etc and general surfaces).



# Hips



## Hipped Roofs

Hipped roofs contain a number of additional members not encountered in simple pitched roof structures.

### Crown and Jack Rafters

Where a roof has a hipped end, an additional rafter must be added for each hipped end. This member is sometimes called the **crown rafter** and is best thought of as a continuation of the ridge board. Apart from this, the number of rafters will be the same as if the roof were gabled. The shorter rafters at the hipped end are referred to as **jack rafters**. Their individual lengths *do not* have to be individually calculated as the cuts on the return cancel the reduced length as shown opposite.

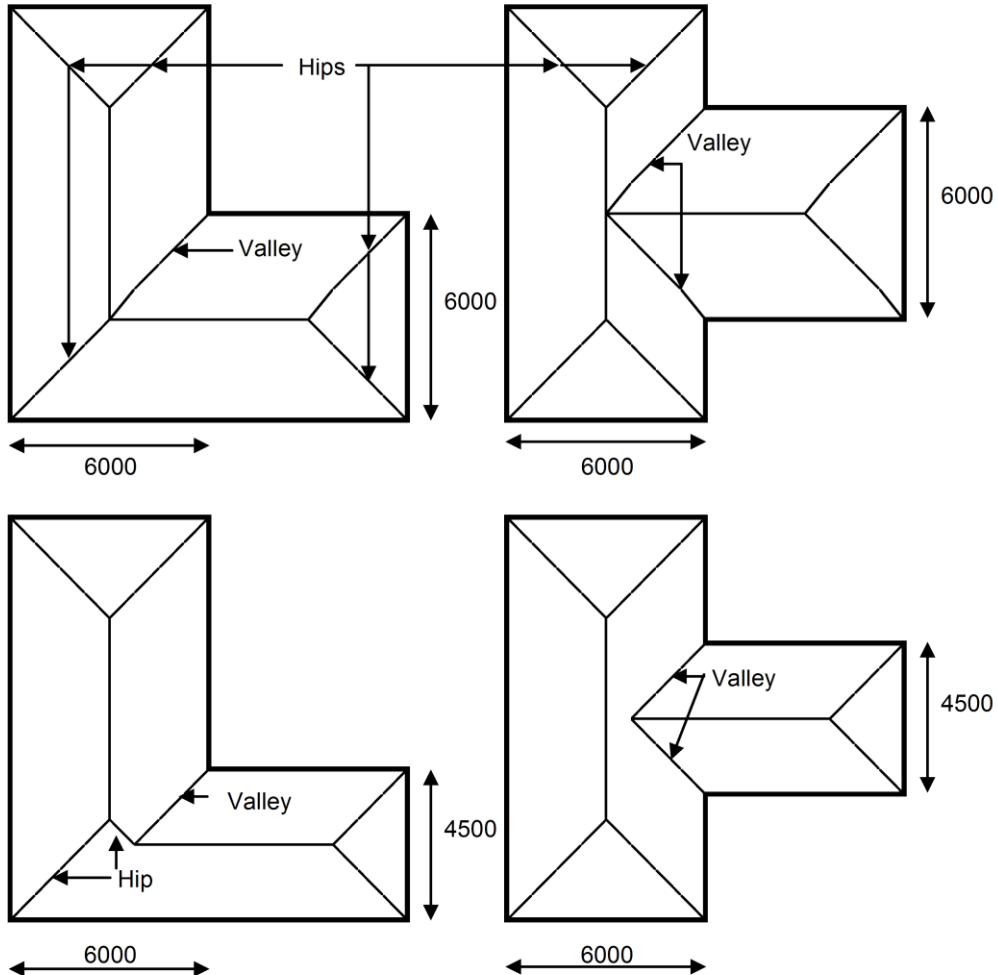
### Hip rafters.

Where the pitch of a hipped end is the same as that in the main roof, then the length of the hip may be found from half the span (length of rafter on plan) and the length of the roof slope (length of rafter) by using pythagoras. The formula is:

$$\sqrt{(\text{rafter on plan})^2 + (\text{rafter})^2}$$

The length of hip rafters can also be found by plotting the height of the roof onto the plan of the hipped end and scaling the result as shown opposite.

# Valleys



## Valleys

Valleys arise on buildings containing projecting roofs. They form a gutter in the roof, typically requiring a valley rafter, gutter boarding and tilting fillets to both sides of the gutter.

The length of valley rafters is calculated the same way as hip rafters. As is the case with hipped roofs, the cutting on the jack rafters on either side of the valley cancels each other out and the roof can be considered as a simple 'A' roof as shown below

The number of joists and pairs of rafters in the projecting roof is normally calculated separately to the main roof run. Where the projecting and the main roofs have the same span and pitch, the various members in the projecting roof will be the same length as those in the main roof. Where the projecting roof span is different from the main roof, the lengths of the various members must be separately measured.

At the junctions of the roofs at ceiling level there is usually an additional thicker beam or a loadbearing wallplate to carry the ends of the joists. In addition joist hangers or framing anchors are often provided to support the ends of joists at this point.

