BASIC ROOF
and CEILING FRAMING

This text introduces subject matter related to ceiling framing and basic roofing. Reference may be made to “Basic Building and Construction Skills”, produced by TAFE and Addison, Wesley, Longman Australia Pty Limited, to re-examine and reinforce these basic skills.

There are two parts to the text, PART 1 – Ceiling Framing and PART 2 – Gable Roofing, which address the following:

Ceiling frames, roof types and terminology are explained, with special reference to gable roofs. Structural members are detailed and their purpose defined.

Methods for determining lengths of members, setting out, cutting and erection processes are covered, including eaves construction for various situations and the various materials used.

The text also covers calculation of members, their lengths, quantities and costs.

Note: Only conventionally pitched roofs are dealt with in this text, as Trussed roofing will be dealt with in a separate text.

A comprehensive ‘Glossary of Terms’ is included at the end of the text, which provides a detailed description of trade terms, technical content and some trade jargon.
INTRODUCTION TO PITCHED ROOF FRAMING

Definitions:

**Roof**: “A roof is the weatherproofed upper covering of a building or structure, which is designed to protect the interior from atmospheric elements such as sun, rain, hail, snow, frost and wind.”

**Flat roof**: Is a roof with a minimum of slope to allow water run-off, usually with a fall of 1 in 40 but a minimum of 1 in 60. These are usually confined to sheet roofs with the sheets being full length, no joins, for a slope less than 1 in 40.

**Pitched roof**: This is a roof with a slope, or pitch, greater than 1 in 12 or 5 degrees. A roof may have a single pitch, like a skillion, a double pitch, like a gable, or an unequal pitch, where both sides of the roof have different angles.

**Coupled roof**: This is where pairs of rafters are attached on opposite sides of a ridge and the feet are fixed to the wall plate. There is no tie between the feet, allowing the rafters to spread under load. It is restricted to small span gable roofs, which may be simply coupled.

**Close-coupled roof**: This is the same as the coupled roof except there is a tie, such as a ceiling joist, placed between the feet of the rafters. This method is used for most roof construction, especially for gables with a wide span.

**Cut roof**: Also known as a conventionally pitched roof, has all of its members cut and assembled individually. These roofs are made up of separate rafters, ridge, purlins, collar ties, struts, etc.

**Free roof**: This refers to any roof, which does not have enclosed walls under it. It is typically used for a freestanding carport, portico, covered walk-way, lichgate, etc.

**Gablets**: These are simply small versions of gables. They may be used on the ends of ridges for ventilation, over a dormer window or as an adornment to the main roof surface.

**Monoslope roof**: Also known as a ‘Monopitch’ roof, it is any roof with a continuous slope, which has no ridge. Skillion and lean-to roofs are monoslope roofs.

**Open roof**: Any roof, which is not enclosed underneath. Verandah, free roofs and garage roofs are typically not lined or framed with a ceiling and therefore classified as open roofs.

**Shell roof**: Made from a thin self-supporting and curved structural membrane used over long spans. Precast, prestressed concrete is commonly used for this construction.

**Southlight roof**: Generally refers to the vertical glass of a sawtooth roof, which faces south to allow glare-free light to enter the building.

**Umbrella roof**: This is a roof placed over a structure, but does not form part of the structure.
THE ROOF

The roof, and roof covering, makes up a large part of the external fabric of the building. It may be designed and constructed to create a picturesque roofscape using a variety of materials or they may be very plain and use only one type of material.

The design of roofs has changed dramatically from the early part of the 20th century where common features included ornate gables, gablets, turrets, spires, crested ridge capping, finials, vents, and complex chimneys decorated with terracotta pots. These steeply pitched and highly decorative roofs have given way to the modern low pitched, plainly coloured roofs of today commonly seen in most new housing developments. Roofing materials such as glazed and unglazed terracotta, slate and ‘fibro’ have been generally superseded by concrete tiles and ‘Colorbond’ roof sheeting.

As with most styles in building, the older types of design eventually become incorporated into contemporary design, or make a comeback, therefore methods of development and construction of roof types should not be forgotten.
**BASIC ROOF and CEILING FRAMING**

Fig. 1 Complex older style roofs

**A-frame:** This is a steeply pitched roof, which forms a shape similar to the letter ‘A’. More commonly used in snow areas to allow the snow to slide off easily, rather than have it add excessive load to the roof frame.

**Bellcast:** This is a roof, which changes its pitch to a lower pitch or angle near the eaves. It is commonly used where the main roof pitch meets the lower pitch of a covered balcony or verandah.

**Clerestory:** This is a roof having two levels separated by a row of windows, which provide light and/or ventilation to the rooms below. It gets its name from the upper part of a church nave, which is the main source of light.

**Deck:** This roof type takes the form of a truncated or cut-off top pyramid with a flat or near flat section in the middle. This may occur where a hip roof has a deck or landing on top, with a handrail around it, used for entertaining or an observation deck.
**Dutch gable:** This is a hip type roof with small gables or gablets at either end of the ridge. It may also be referred to as a ‘half-hipped roof’ or a ‘Gambrel’.

![Dutch gable diagram](image)

**Gable:** This is a roof with a double pitch and vertical ends. It may also be used as an add-on to a main roof in the form of gablets over entries or simply decorating the main roof surface in the form of a dummy gable.

![Gable diagram](image)

**Gambrel roof:** This is similar to the Dutch gable having gablets at either end of the ridge on a hip roof. In recent times the size of the gablet has increased providing a more distinctive style of roof surface.

![Gambrel diagram](image)

**Half-pitch:** This refers to a roof, which has a pitch angle where the rise is equal to the half span of the roof, i.e. forms a 45° angle.

![Half-pitch diagram](image)
**Helm:** This is a pyramidal roof, having a square base, with four gables connected at the bottom horizontal position. The remaining roof surfaces are diamond-shaped. This type of roof was commonly used for spires on square towers.

**Hip or Hipped:** This is a roof with four sloping sides on a rectangular base. The ends are triangular in shape and the sides form a trapezoidal shape.

**Hip & valley:** This is basically a hip roof, which is ‘T’ or ‘L’ shaped on plan. The ridge lines are the same height for the main and extended roof sections.

**(Broken) Hip & valley:** Again it is similar to the hip & valley type except the ridge(s) of the extended sections are not at the same height as the main roof. This creates a shortened or broken hip used to link the minor ridge to the major ridge.
**Hyperbolic paraboloid:** This is a form of shell roof construction, which has raised diagonally opposite corners on a square base. This creates a convex curve between the low corners and a concave between the high ones. They have been used for small architecturally designed airport terminals and swimming centre shade roofs.

![Hyperbolic paraboloid](Image)

**Jerin head:** This is a roof, which is hipped from the end of the ridge half way down to the eaves, and gabled from half way to the eaves. It is also sometimes called a ‘Hipped gable’ or a ‘Clipped gable’.

![Jerin Head](Image)

**Mansard:** This is similar to a hipped roof except all four sides have a double pitch. Each side has a steeply sloping section up from the eaves, then the top section flattens out up to the ridge. It was named after the French architect Francois Mansart, who died in 1666. It has also been referred to as a ‘Curb roof’ or a ‘French roof’.

![Mansard](Image)

**Monitor:** This is a portion of a roof, which has been raised up above the main roof, usually flat, with continuous vertical glazing around the perimeter for natural lighting. Mainly used for industrial buildings.

![Monitor](Image)
Monoslope: Also known as a ‘Monopitch’ roof, it is any roof with a continuous slope, which has no ridge. Skillion and lean-to roofs are monoslope roofs.

Pyramid: This is a roof with square or other regular polygon shaped base, with all hips being equal and converging at a pointed apex.

Sawtooth: This is a made up of a series of connected monoslope roofs, which appear to be sawtooth-shaped when viewed from the end. The shape is a series of right-angled triangles connected at the base or trough with a common box gutter. The vertical face is usually glass to allow natural light to enter. Commonly used for commercial and industrial work.

Station: This type of roof is typically used for train and bus stations where the roof is to cantilever past supports on both sides to provide shelter.
**Troughed:** This is a double-pitched roof with a valley between the two surfaces. This roof is also referred to as a "Valley Roof" or a "Butterfly roof".

**Tudor:** This is a steeply pitched roof, usually a gable style, with dormer windows on one or both sides.
INTRODUCTION TO CEILING FRAMING

The ceiling frame is the horizontal area between the top of walls and the roof, which is designed to enclose the room by providing a dust barrier, insulation and security. The frame consists of ceiling joists, ceiling trimmers, hangers and hanging beams. This system is designed to tie-in with a conventionally pitched skillion, gable or hip roof.

Note: The ceiling frame of a trussed roof is made up of the bottom chords of the individual trusses and does not require additional ceiling joists, hangers or hanging beams.

Ceiling joists

These are the horizontal members with ends that rest on top of the wall plates. They carry the ceiling sheets, and provide a lateral tie between the feet of opposing rafters to form a strong, coupled frame. They may be nailed or bolted to the rafters. They are spaced at maximum centres of 450 mm and 600 mm depending on their stress grade, section size and thickness of ceiling lining being used. They may be joined in length over a wall or under a hanger, where the join can be supported.

Refer to AS 1684 for sizes and stress grades.
CEILING TRIMMERS

These are short lengths of ceiling framing material, fixed at right angles between ceiling joists, placed at the same maximum spacings as the joists.

They are designed to:
- Provide fixing for the ends of ceiling sheets and cornices;
- Provide fixing for the top internal wall plates; and
- Provide continuous lateral stability for the ceiling frame once hangers are fixed.

Fig. 5 Placement and fixing of ceiling trimmers over an internal wall.
Patent type metal connectors may be used to provide a secure load-bearing connection between hangers and ceiling joists, which is particularly useful when work or an inspection is to be carried out inside the roof space in the future. The connectors are fixed on alternate sides, every second joist, to assist in preventing the hanger from overturning.

When very deep, narrow hangers are used it may be necessary to fit a timber brace or hoop iron strap to the ends to prevent the hanger from twisting or rolling over. Alternatively, if the end of the deep hanger runs past the face of a hip end rafter or gable stud it may be bolted to it.
Where hangers run across ceiling joists with the end protruding past the line of the rafters, as would occur at the end of a hip roof, the load is transferred to the wall plate via a ceiling trimmer. The top end of the hanger is bolted to the rafter and then the hanger is strapped to the ceiling trimmer.

*Note*: The end of the hanger is cut to the pitch of the roof before being fixed into place.
Hanging beams

A hanging beam, also known as a counter beam, runs at 90° to the line of hangers and supports them where their length exceeds the allowable span. The hangers are cut onto a bearing cleat on either side of the hanging beam to allow continuous support for the length of the room. The ends of the hanging beam are packed up slightly to allow for deflection. The section size and stress grade will be greater than the hanger. Refer to AS 1684 for stress grades and section sizes.

**Note:** The roof frame must not be supported off hangers or hanging beams unless designed and specified by a structural engineer.

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**Fig. 11** Method of supporting the ends of hangers onto a hanging beam
SET OUT AND ERECTION OF CEILING FRAMES

The set out of the ceiling frame is based on the set out for the roof rafters. Whether the roof type is a gable or a broken hip and valley the set out of the rafter positions is carried out first so the joists may be fixed alongside.

Procedure

STEP 1 Check the top wall plates for straight and that the wall frames are square overall.

Gable:
Mark the positions of the gable end rafters, at each end, then working from one end set out the positions of the common rafters, in-to-over, at the specified maximum spacing, i.e. 450 or 600 mm.
Place a mark on one side, ‘R’ or ‘X’ to represent the position of the rafter and a ‘J’ on the other side to represent the position of the joist.

Note: Ends are trimmed later at 90° to the ceiling joists to provide fixing for the ceiling sheets.

Hip:
Measure in the distance equal to the half span from both ends. This represents the centre line of the centring rafters. Measure half the rafter thickness on either side of this line and place an ‘R’ between the two outside marks. Place a ‘J’ on one side of the rafter position to show the joist position.
Repeat this process for the other end of the roof, and then work from the centring rafter to the end of the walls marking rafters, in-to-over, at the maximum spacings. Mark rafter positions at both ends of the roof working from the centre to the outside. Finally, start from the centring rafter position at one end and mark rafter spacings towards the other centring rafter, until the spacings run out. Mark these with an ‘R’ or ‘X’ and then place a ‘J’ beside them to show joist positions.

Fig. 12 Setting out plates for a gable roof
STEP 2  Cut all ceiling joists to length and fix into position by double skew nailing the ends. Cut and fix ceiling trimmers to ends and above internal walls, which run parallel to the joists.
STEP 3  Fit hangers to the centre of the ceiling joist length over each room as required. Hangers are joined over internal walls and should be blocked off the top wall plate equal to the depth of the ceiling joists. Where ceiling trimmers are close to the required hanger position they may be used as the means of blocking.

**Note:** Hangers may be run continuously over walls, but it may be more economical to treat each room separately and reduce unnecessary cost by using smaller sectioned members where possible.

Note: Where hangers are over their allowable length, hanging beams may be required to support them at mid span.

Refer to AS 1684 - 1999 Part 2, for all member section sizes, spacings, spans and stress grades.
CEILING FRAME CALCULATIONS

The basic procedures are similar to that used for wall framing. Once a system is adopted and formulae are identified it will be necessary to gather the following details for calculation purposes:

**Plan -** This will be required so the dimensions of rooms can be identified to allow a cutting list of material to be formed; and

**Specification or Tables -** The specification or AS 1684 tables will provide section sizes and stress grades of framing members.

**METHOD OF CALCULATING FRAME QUANTITIES**

**Joists -** Where possible the joists should run the short dimension of the room, but should always be placed to tie the feet of the rafters for the length of the roof.

Calculate the ceiling joists for each room separately.

Formula = \( \frac{\text{width of room}} {\text{Max. spacing}} - 1 \) (as there is no 1st joist)

Length of joists = internal room length + (2 x wall plate width)

Ceiling trimmers are calculated separately.

**Ceiling Trimmers -** Allow for ceiling trimmers where ever internal or external walls run parallel to the ceiling joists.

Calculate each wall separately.

Formula = \( \frac{\text{internal room length of wall}} {\text{Max. spacing}} - 1 \) (as there is no 1st trimmer)

Length of trimmers = maximum spacing of joists – (2 x joist thickness)

**Hangers -** Allow one hanger at 2100 mm maximum centres, unless otherwise specified.

Length of hangers = internal room width + (2 x wall plate width)

**Hanging beam -** Placed where the length of the hanger is greater than it’s maximum allowable span. (as per tables or specification)

Length of hanging beam = between supporting walls + (2 x plate width)

**Hanger / joist connectors -** Type as per specification. Allow one per ceiling joist for each row of hangers, per room.
WORKED EXAMPLE FOR CEILING FRAME QUANTITIES and COSTS

The following worked example provides details of how the quantities are arrived at and how the individual materials are presented and costed. Details are as per plan and specification based on AS 1684 - 1999 Part 2.

SPECIFICATION

Joists -

150 x 38 sawn Oregon F8 at 600 mm max. c/c (max. 3.6m continuous span)

Joists are to be joined on a hanger where they exceed 3.6m in length. Where joists are joined on hangers the joins should be staggered, if possible.

Trimmers

100 x 38 sawn Oregon F5 at 600 mm max. c/c

Hangers -

Hangers to be spaced at max. 3600 mm c/c

<table>
<thead>
<tr>
<th>Max. span (mm)</th>
<th>Section size (mm)</th>
<th>Stress grade</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>5400</td>
<td>240 x 45</td>
<td>F27</td>
<td>Seasoned hardwood</td>
</tr>
<tr>
<td>3000</td>
<td>190 x 35</td>
<td>F11</td>
<td>Seasoned hardwood</td>
</tr>
</tbody>
</table>

Hanging beams -

Not required.

Hanger / joist connectors -

Allow one for each joist, per hanger, per room. Fit ceiling dogs on alternate sides for the length of the hangers.

Material costs -

<table>
<thead>
<tr>
<th>Material</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 x 38 F8 sawn Oregon</td>
<td>$4.20/m</td>
</tr>
<tr>
<td>100 x 38 F5 sawn Oregon</td>
<td>$3.10/m</td>
</tr>
<tr>
<td>240 x 45 F27 Hardwood (seasoned)</td>
<td>$19.20/m</td>
</tr>
<tr>
<td>190 x 35 Hardwood (seasoned)</td>
<td>$12.45/m</td>
</tr>
<tr>
<td>Ceiling dogs</td>
<td>$0.55/each</td>
</tr>
</tbody>
</table>

Fig. 16 Typical plan of frame for a brick veneer cottage
Ceiling joists

Length = internal room length + (2 x wall thickness) + (100 mm for laps if required)

Number = width of room – 1

Max. spacing

Room A1 = \[\frac{5250 - 1}{600} = 9 - 1 = 8\]

- Max. span is 3600 mm, therefore join joists on the hanger in the centre of the room;
- Length = \[\frac{6700 + 200 + 100}{2} = 3.5m\]

Order - 16 / 3.6

Room A2 = \[\frac{4200 - 1}{600} = 7 - 1 = 6\]

- Length = 3400 + 200 = 3.6m

Order – 6 / 3.6

Room A3 = \[\frac{2650 - 1}{600} = 5 - 1 = 4\]

- Length = 4200 + 200 = 4.4m

Order – 4 / 4.5

Room A4 = \[\frac{4200 - 1}{600} = 7 - 1 = 6\]

- Length = 3200 + 200 = 3.4m

Order – 6 / 3.6

\[\text{plus} = \frac{2650 - 1}{600} = 5 - 1 = 4\]

- Length = 2400 + 200 = 2.6m

Order – 4 / 2.7

:: Order = 150 x 38 sawn Oregon F8 – 4/ 4.5, 28/ 3.6, 4/ 2.7
Ceiling trimmers

Length = max. spacing – (2 x joist thickness)

Number = \( \frac{\text{length of wall}}{\text{Max. spacing}} - 1 \)

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<th>Room</th>
<th>Formula</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>( \frac{(6700 - 1) \times 2 \text{ walls}}{600} = (12 - 1) \times 2 )</td>
<td>22</td>
</tr>
<tr>
<td>A3</td>
<td>( \frac{(4200 - 1) \times 2 \text{ walls}}{600} = (7 - 1) \times 2 )</td>
<td>12</td>
</tr>
<tr>
<td>A4</td>
<td>( \frac{(2400 - 1)}{600} = (4 - 1) )</td>
<td>3</td>
</tr>
</tbody>
</table>

* Length = 600 – (2 x 38) = 524 mm

\[ \therefore 37 \times 0.524m = 19.4m \]

Order = 100 x 38 sawn Oregon F5 – 1/ 6.0, 3/ 4.5

Hangers

Required as per specification.

Length = span of room + (2 x wall plate width)

<table>
<thead>
<tr>
<th>Room</th>
<th>Formula</th>
<th>Result</th>
</tr>
</thead>
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<tr>
<td>A1</td>
<td>5250 + (2 x 100) = 5450 = 1/ 5.7</td>
<td></td>
</tr>
<tr>
<td>A3</td>
<td>2650 + (2 x 100) = 2850 = 1/ 3.0</td>
<td></td>
</tr>
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</table>

Order = 240 x 45 seasoned hardwood F27 – 1/ 5.7

Order = 190 x 35 seasoned hardwood F11 – 1/ 3.0

Connectors

Allow one per joist, per hanger, per room

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<th>Result</th>
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</thead>
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<tr>
<td>A3</td>
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<td>4</td>
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Order = 20 ceiling dogs
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**TOTAL COST**

$739.52
ALTERNATIVE CEILING TYPES

Flat Roof Construction

Generally, the construction for a flat roof combines the roof frame and ceiling frame to form one structure, which carries the load of the roof and the ceiling linings. A flat roof is one which is pitched at less than 10° or has a slope of less than approximately 1 in 6. To allow for this extra load the rafters/ceiling joists are increased in section size and stress grade. They normally have a single span and are lined on-the-rake, either on top or under the rafters. The roof surface is covered with full-length sheets of corrugated iron, metal tray or decking sheets, clear or coloured fibreglass sheets and/or clear or coloured polycarbonate sheets.

To provide a fall for the roof covering, where the ceiling frame is to be level, different thickness battens may be used. These are referred to as ‘grading battens’. The batten at the guttering end is the thinnest and the other battens gradually increase in thickness to the high end of the roof. This may require some battens to be laid on their flat, some on their edge and some may need to be checked-in slightly to achieve the correct height, at the nominated spacing.

To prevent sideways movement of the ceiling frame members, solid blocking is provided where the joists span more than 2100 mm. Ceiling trimmers are fixed the same as for gable and hip roofs where the internal walls run parallel to the joists.
CONVENTIONALLY LINED CEILING:

- Metal tray decking
- Batten thickness graded to provide fall
- Vapour barrier sarking
- Insulation
- Solid blocking where span exceeds 2100

ALTERNATE FINISH LAY-IN PANEL INFILLS TO CEILING:

- Metal tray decking
- Batten thickness graded to provide fall to roof gutter
- Vapour barrier, sarking, insulation laid loosely over joists

EXPOSED JOISTS CEILING:

- Metal tray decking
- Sarking lapped and taped
- Sheets joined over a joist
- Batten thickness graded to provide fall to roof gutter

Fig. 18 Various methods used to line ceilings
Skillion Roof Construction

This type of freestanding roof/ceiling frame is usually constructed by having the wall frame at one end of the building higher than the other end. Internal walls running parallel to the end walls would be built at different heights, depending on their location in the building. Walls running at 90° to the end walls would taper in height to fit under the sloping rafters/ joists. This type of roofing system may also have its ceiling lined on-the-rake or be fitted as a false ceiling and placed level, as shown below:

The simplest method of marking the skillion rafters/ceiling joists is to scribe them over the supporting plates in position. Once cut they are spaced at the maximum centres, to suit the battens and roof sheets, and then fixed into position by double skew nailing to the plates. They are also connected to the plates with patent metal connectors to prevent wind uplift forces.

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Lean-to Roof Construction

This type of roof system is constructed against an existing wall or other roof structure. It is mainly used for simple extensions, carports, awnings, verandahs, etc. and provides an alternative to re-pitching the existing main roof to cover the extra room or space.

The ceiling finish may be one of the following:

i) The rafters and the covering may be left exposed for a carport, verandah, awning, etc;

ii) The ceiling may be fixed to the underside of the rafters, making it a raking ceiling; or

iii) A separate ceiling frame or false ceiling may be installed to give a level ceiling line.

Fig. 21 Various methods used to line a lean-to roof/ceiling