

BC CARPENTER APPRENTICESHIP PROGRAM

LEVEL 2

2018 (Harmonized)

Line H: Wood Frame Construction

Competency H-6: Build Roof Systems

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Symbol Legend



Electric shock: This icon is a reminder for potential electric shock.



Explosive: This icon is a reminder for a possibly explosive situation.



Flammable: This icon is a reminder for a potentially flammable situation.



Important: This icon highlights important information.



Poisonous: This icon is a reminder for a potentially toxic/poisonous situation.



Resources: The resource icon highlights any required or optional resources.



Safety gear: The safety gear icon is an important reminder to use protective equipment.



Self-Test: This icon reminds you to complete a self-test.

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Program Outline

Line B – Documentation and Organizational Skills

B-1 Use Construction Drawings and Specifications

B-2 Interpret Building Codes and Bylaws

Line C – Tools and Equipment

C-2 Use Portable Power Tools

C-3 Use Stationary Power Tools

C-4 Use Oxy-Fuel Equipment

Line D – Survey Instruments and Equipment

D-2 Use Site-Layout Equipment

Line F – Site Layout

F-1 Lay Out Building Locations

Line G – Concrete Formwork

G-4 Build Slab-On-Grade Forms and Suspended Slab Forms

G-7 Place and Finish Concrete

Line H – Wood Frame Construction

H-2 Select Framing Materials

H-4 Build Wall Systems

H-5 Build Stair Systems

H-6 Build Roof Systems

Line I – Finishing Materials

I-1 Describe Roofing Materials

I-2 Install Doors and Hardware

I-3 Install Windows and Hardware

I-4 Install Exterior Finishes

Line J – Building Science

J-1 Control the Forces Acting on a Building

J-2 Control Heat and Sound Transmission

J-3 Control Air and Moisture Movement in Buildings

Competency H-6: Build Roof Systems

Roof construction is a major part of wood frame construction. Whether the roof is a truss roof or a rafter-framed roof, knowledge of roof framing is vital for carpenters.

Learning Objectives

When you have completed the Learning Tasks in this Competency, you will be able to:

- design gable roof members
- frame ceilings
- describe gable roof components
- calculate rafter lengths
- lay out rafters for a gable roof
- construct a gable roof
- install roof sheathing
- erect and install prefabricated roof trusses

Competencies

Written: “Build Roof Systems”

- You will be tested on your ability to determine the size, spacing and nailing requirements for roofing members. You will also be tested on your ability to calculate and lay out roof members using a framing square, and on your knowledge of installation procedures for roof trusses.

Practical:

- You will be required to calculate, lay out, cut and assemble all members of a gable roof, including ceiling joists.

LEARNING TASK 1

Describe Gable Roof Systems

Roof construction is a major part of wood frame construction. Whether the roof is a truss roof or a rafter-framed roof, knowledge of ceiling and roof framing is vital for carpenters.

Ceiling Framing

Ceiling joists have several purposes. They tie the bottoms of the rafters together, creating a stable triangle shape. They also tie the supporting walls together, preventing them from spreading out. Ceiling joists also support the interior ceiling finish, insulation and vapour barriers, and services such as electrical fixtures, HVAC ducts, sprinklers, etc.

Some hand-framed roofs have a vaulted ceiling with a ridge beam supported by columns or walls. Also called *cathedral ceilings*, this type of roof does not require ceiling joists to tie the supporting walls together. The Ladysmith Vacation Cabin is designed with a ridge beam over the living/dining room and floor joists acting as the ties for the roof joists in the loft sleeping area. The “rafters” are actually “roof joists” in a vaulted ceiling. They carry an additional load of the ceiling finish and insulation. There is a separate span table for roof joists in the *BCBC*.

Tension in Ceiling Joists

Dead loads (the framing and roofing materials) and live loads (primarily built-up snow, but also the uplift and lateral forces of wind) are transferred to the supporting walls through the rafters. This creates a tension force at the bottom of the rafters, potentially spreading the walls apart and changing the structure. The ceiling joist must be continuous across the span of the building, from rafter end to rafter end, and must be fastened securely to both the wall plate and rafter. If the span is too large for a single length of lumber, the ceiling joists must be joined on an interior support, such as a bearing wall or beam. This connection is under tension and must also be fastened securely.

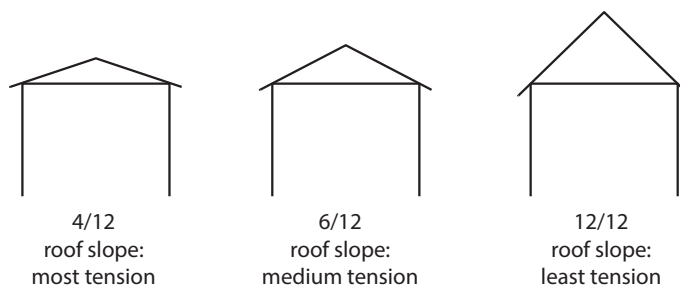


Figure 1 — Tension in ceiling joists

The design of a building has a great effect on its structure. With a steeper roof, the load is transferred more directly onto the supporting walls and the tension across the ceiling joists is lower. A flatter roof produces greater tension on the ceiling joists (Figure 1).

Roof Framing

Specific terms are used to describe the components used in a gable roof (Figure 2).

The **span** is the width of the building. The common rafters run parallel to the span.

Rafter span is the horizontal distance between the points of support. For a common rafter, these supports are the ridge and the outside of the plate. The rafter span is used for designing the rafter, not for calculating the rafter's length. Although the *BCBC* uses the term *span*, it's more commonly referred to as the *run* of the rafter.

Unit rise is the amount that a rafter rises for each unit it runs.

The **unit run** is the base unit for calculating the rafter's length and laying out the adjustments. One unit of run is equal to 12" or 1' in the imperial system and 250 mm when using a metric-based Fredrickson framing square.

The angle of the roof is specified by the roof slope triangle. The **roof slope** triangle uses 12" as the base in the imperial system or 250 mm when using a Fredrickson framing square. Examples of roof slope are 8 in 12 or 150 in 250. The *BCBC* uses a roof slope where 1 is the rise and the second number is the run (e.g., 1 in 1.5 is the same as 8 in 12 and 1 in 1.667 is the same as 150 in 250).

Pitch is another way to describe roof slope and is often used interchangeably with *slope*. Pitch can also describe the total rise of the building over the span of the building. A 6 in 12 roof slope is referred to as a ½ pitch roof.

Run is the total horizontal distance that a rafter covers. On an equal slope roof with the ridge centred in the width of the building, the run of a common rafter is half the width of the building. The run of a rafter is used to calculate its length. The *BCBC* uses the term *span* instead of *run*.

The **total theory rise** is the vertical distance that the rafter rises above the plate at the working line. The actual total rise is the vertical distance from the top of the wall plates to the top of the ridge and includes the wood above the plate at the bird's mouth.

Rafters are sloping roof framing members that transfer loads to the exterior walls and support the roofing material.

Roof joists are sloping roof framing members that carry both the roof loads and the ceiling finish and insulation. They are similar to rafters except for the extra dead load, and are usually larger.

The **common rafter** slopes up from the wall plate to the ridge. In plan view, the common rafter runs at 90° to the wall plate and ridge. The roof slope triangle on blueprints refers to the common rafter.

The **ridge** is a horizontal board used to align the tops of the common rafters. The ridge does not structurally support the rafters.

A **ridge beam** is used to support and align rafters at the ridge. Bearing walls or posts support the ridge beam. These supports are continuous to the foundation. A ridge beam is a type of supported ridge found in a vaulted ceiling.

Projection is the horizontal distance that the rafter projects beyond the exterior wall.

Overhang is the slope distance the rafter extends beyond the building. The overhang is measured along the length of the rafter.

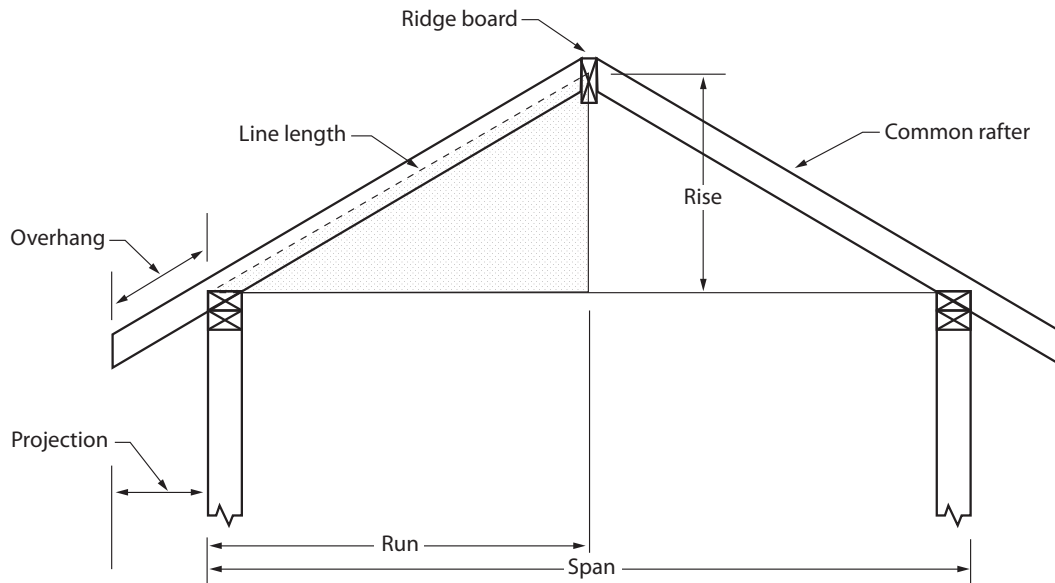


Figure 2 — Common roofing terms

The **bird's mouth** is a triangular section cut from the bottom edge of the rafter at the point where it sits on the top wall plate. This notch ensures that the rafter sits securely on the wall plate (Figure 3).

The **seat cut** is the horizontal or level cut that forms the top of the bird's mouth.

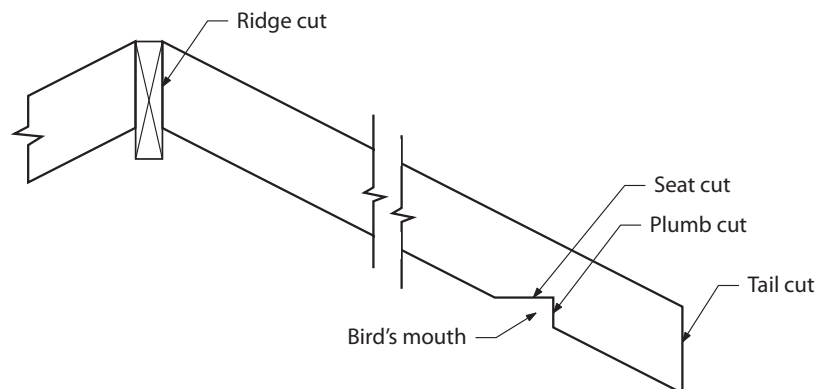


Figure 3 — Rafter cuts

A **plumb cut** is any cut on a rafter that is plumb when the rafter is installed. The vertical cuts that form part of the bird's mouth, ridge cut and tail cut are plumb cuts (Figure 3).

The **line length** of a rafter is the calculated sloped length from the centre of the ridge to the outside of the wall plate, or working point to working point. The line length is also referred to as the *theory length*.

Working points are the marks on the rafters where measurements are made and cuts laid out. Working points are created by the intersections of the theory lines of the rafters. Often the working point for one rafter is the working point for other rafters. The working point is always located at the centreline of the rafter.

Line lengths are measured from the working points. Various rafters need to be cut shorter than the line length to fit into other rafters or framing members. The adjustments made to allow for the other members are measured from the working point.

The **rafter tail** is the portion of the rafter that extends beyond the wall plate. The rafter tail forms the eaves.

Ceiling joists are horizontal framing members that act as ties to resist outward pressure from the common rafters and support the finished ceiling (Figure 4).

Collar ties are horizontal framing members that are installed between opposing common rafters. They reduce the span of the rafters.

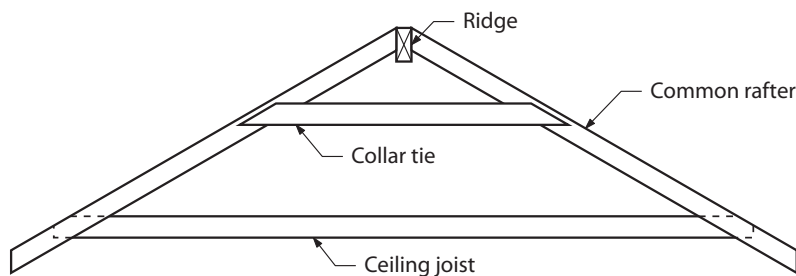


Figure 4 — Ceiling joists and collar ties

Purlins are structural members at right angles to rafters. They can be installed on top of rafters (where they will support the roof decking), between rafters or below rafters (Figure 5).

Strapping on top of the rafters, commonly used to support metal roofing, shakes or shingles, or to create a ventilation space on vaulted ceilings, is sometimes referred to as *purlins* or *cross purlins*. The Ladysmith Vacation Cabin specifies purlins under the plywood sheathing to create this type of ventilation space.

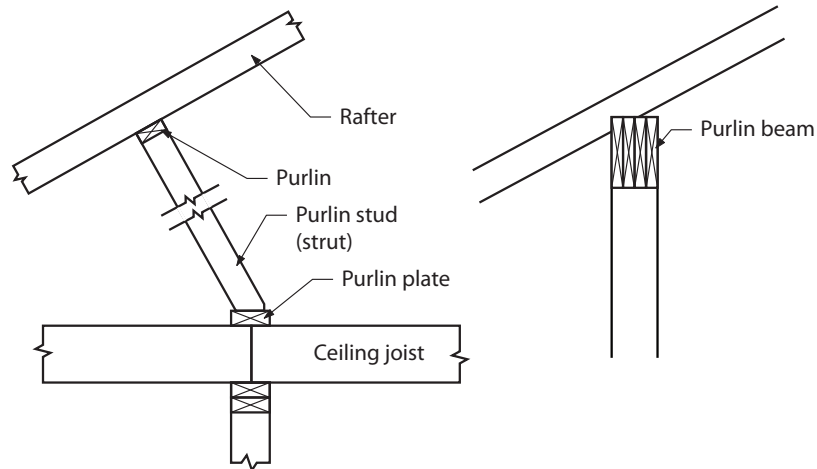


Figure 5 — Rafters supported on a purlin

The BCBC uses the term *dwarf wall* for the vertical wall supporting the mid span of rafters. This wall is commonly referred to as a *pony wall* or a *knee wall* (Figure 6).

The supports that typically slant at 45°s from the ceiling joists to the rafters are referred to as *struts*.

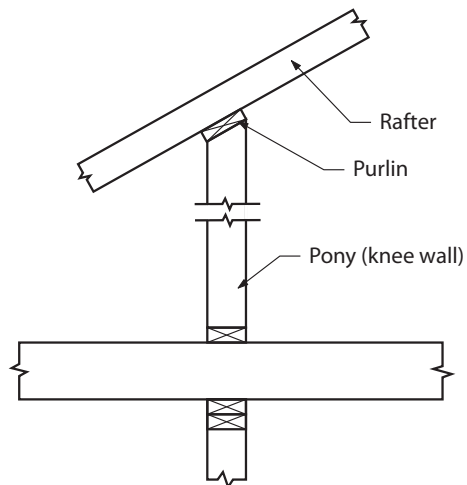


Figure 6 — Pony or knee wall supporting a purlin

Gable studs are used to frame the triangular ends of the gable roof. They support the exterior wall finish. Gable studs may be notched at the top and cut to fit the slope of the roof (as in Figure 7) or butted under a top plate that supports the outriggers. Gable studs typically have the same spacing as the wall studs below.

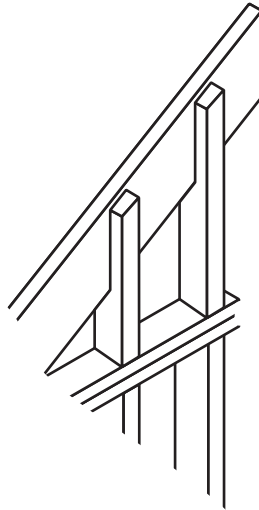


Figure 7 — Gable studs

Outriggers are used to frame the overhang of a gable roof. They support the cantilevered portion of the roof assembly (Figures 8 and 9). The terms *outrigger* and *lookout* are interchangeable in this content.

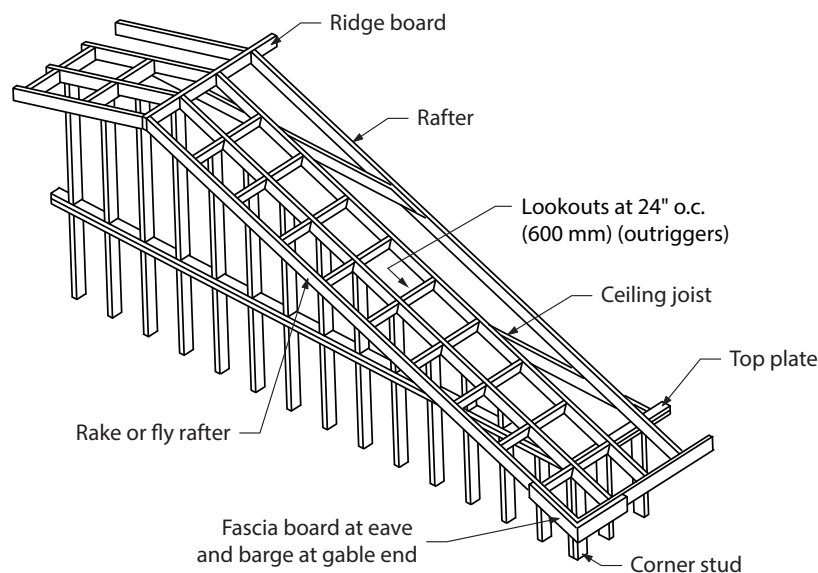


Figure 8 — Roof framing for overhang at gable end



Figure 9 — Outriggers notched into gable rafter

Also known as a *barge rafter*, the ***rake*** or ***fly rafter*** is the outside rafter at the gable end of the roof. The finish bargeboard is attached to the rake or fly rafter (Figure 8).

Lookouts are horizontal members installed under the overhang of the roof and support the soffit. They are nailed to the sides of the rafter tails, to the rough fascia and to the ledger (Figure 10).

Eaves are the bottom portion of the roof that extends beyond the exterior wall and includes the rafter tail, the fascia and the soffit.

Wood above plate (WAP) is the plumb line measurement of the wood above the bird's mouth. It's important to be aware of this when matching existing rafters or trusses.

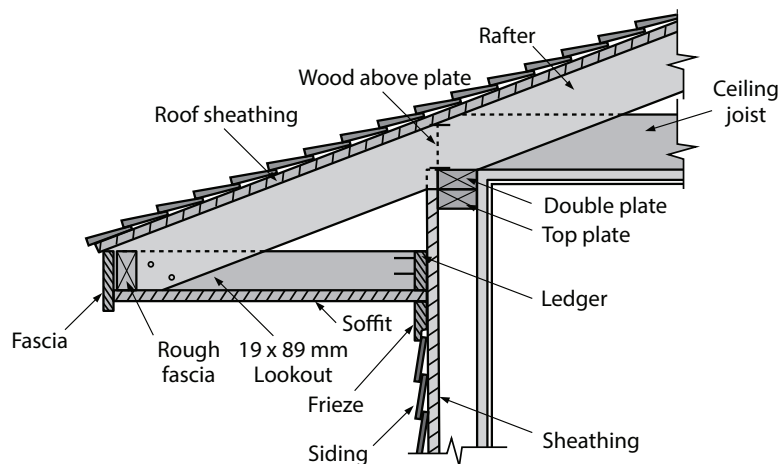


Figure 10 — Eave details

Ledgers in the eaves are horizontal members installed near the top of the wall that support the lookouts (Figure 10).

Rough fascia is installed at the ends of the rafter tails to align the rafters, support the ends of the lookouts, support the bottom edge of the roof sheathing and provide backing for the finish fascia and gutter.



Now complete Self-Test 1 and check your answers.

Self-Test 1

1. What are the functions of a ceiling joist?

2. Which type of roof creates the most tension in ceiling joists: low-slope roofs or high-slope roofs?

3. What is the difference between “overhang” and “projection”?

4. What is a “fly rafter”?

5. What is the unit of run when using the imperial system?

6. What is the unit of run when using the Fredrickson square?

7. What is a “working point”?

8. What is the difference between the “line length” and the “run” of a rafter?

9. What is the difference between a “ridge board” and a “ridge beam”?

LEARNING TASK 2

Plan Gable Roof Systems

Planning a gable roof system will include safety considerations, construction drawings, *Building Code* requirements and a logical construction sequence. Gable roof systems can be either hand framed (stick framed) or framed with manufactured trusses. Hand-framed roofs may have separate ceiling framing or have the ceiling attached to the underside of the rafters. When this is the case, the rafters are called roof joists. In some cases the roof joists are left exposed as an architectural feature and the roof decking becomes the finished ceiling with the air barrier and insulation placed on top of the roof decking.

Safety

Ceiling and roof framing normally involves working at heights. Although all the work can usually be performed working from ladders, this isn't as safe or productive as working from scaffolding. At no time should a worker stand on or walk along a top plate without proper fall protection.

Site-made single-pole scaffolding is constructed along each load-bearing wall so that the working deck is low enough to allow the walls to act as fall protection guards. This also enables the workers to duck under the ceiling and roof framing to facilitate fastening framing members, bracing and the first course of sheathing.

If a ceiling is framed before rafters are installed, it can be temporarily decked and used as a work platform under the ridgeline. If not, either double-pole site-constructed scaffolding or manufactured scaffolding is placed under the ridgeline. This row of scaffolding must be installed so as not to interfere with the ceiling framing. When building this row of scaffolding, it often works well to have the height of the working deck just low enough to slide under the partition wall top plates.

All scaffolding for roof framing must meet WorkSafeBC regulations, including being two 2x10 planks wide.

Temporary bracing is critical because the design of a gable roof allows for a hinged domino action. Without enough bracing, partway through assembly the roof can pivot at the wall connections and fold down, trapping and injuring or killing workers.

Fall protection is normally required when sheathing and sometimes when framing roofs. A fall protection and rescue plan is also required if falls of over 25 feet are possible.

Construction Drawings

Construction drawings will provide enough information to determine ceiling and roof framing member size and spacing. In many cases there will be a roof framing plan as part of the construction drawings or roof truss package.

Truss packages will include bearing, fastening, permanent bracing and other information. The carpenter should contact the truss manufacturer whenever in doubt as to how to read and interpret information in the truss package.

Construction Sequence

The assembly of a gable roof system starts with laying out and marking of the top plates for the location of ceiling joists and rafters, or trusses.

Hand-framed Roof Assembly

The next step after layout is to install the ceiling joists. Although ceiling joists can be installed after rafters, there are several advantages to framing the ceiling first.

Before rafters or roof joists can be installed, the first length of ridge board is supported in place and braced. A rafter is then marked and cut. It is used as a pattern to cut a second rafter. The two rafters are then temporarily fitted to check lengths and cut angles. Once the fit is determined to be acceptable, the first rafter is used as a pattern for cutting the remaining rafters.

Rafters should be installed in pairs from opposite sides so as not to push the ridge board out of alignment. Once three or four pairs of rafters have been installed, additional diagonal bracing is nailed or screwed to the underside of the rafters. This bracing can be temporary or permanent.



To keep the ridge board level, the first two pairs of rafters are installed near each end of the ridge board.

As more pairs of rafters are installed, the ridge board is lengthened and additional diagonal bracing is added. When rafter framing is complete, the gable end framing is done, including the lookouts (outriggers) and fly rafters (Figure 1).

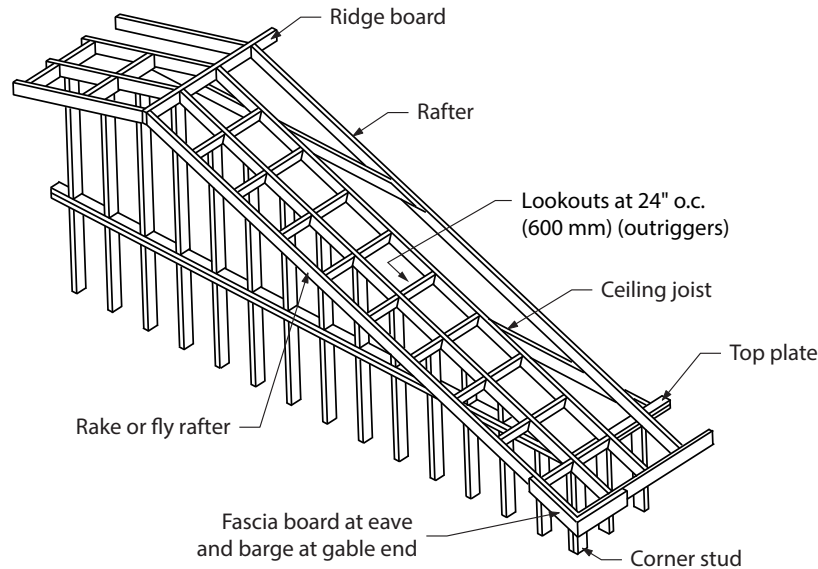


Figure 1 — Lookouts and fly rafter

The last step is roof sheathing or strapping. This is normally done starting at the bottom and working up to the ridge. Orientation of panel-type roof sheathing face grain is 90 degrees to the framing.

Truss Framed Roof Assembly

Once the truss locations are laid out on the wall top plates, both gable end trusses are erected and braced. Some carpenters prefer to sheath the gable end trusses before standing them up. This increases the possible wind load and requires additional bracing.

A string and block line is used to align the common trusses as they are installed. Girder trusses may need to be installed before some of the common trusses. Jack trusses (mono trusses) are often installed last.

Similar to hand-framed rafters, trusses are braced as they are installed. Temporary ridge strapping is also placed to hold the trusses plumb.

Lastly, lockouts and fly rafters are framed, all permanent bracing is fastened, and then the roof is sheathed or strapped.

Building Code Requirements

Requirements for ceiling and roof framing are found in *Subsection 9.23.14* of the *BC Building Code*. Roof sheathing requirements are found in *Subsection 9.23.16*.

Ceiling Framing Code Requirements

The design of a building has a great effect on its structure. With a steeper roof, the load is transferred more directly onto the supporting walls and the tension across the ceiling joists is lower. A flatter roof produces greater tension on the ceiling joists. The *Building Code* reflects these structural requirements. The fastening requirement for rafter-to-ceiling-joist connections is as few as four nails for steep roofs and up to 11 nails for low-slope roofs. The connection where the ceiling joists join on a bearing wall requires one nail more than the rafter-to-ceiling-joist connection.

BC *Building Code* Table 9.23.14.8 is used to determine the rafter-to-joist nailing requirements for buildings with an unsupported ridge. The information needed to use this table includes:

- roof slope
- rafter and joist spacing
- building width
- snow load

Roof slope in the *Building Code* is given as a basic ratio of “rise in run.” The rise is always 1, and the run is the variable (e.g., “1:2” or “1:2.4”). A 1 in 2.4 slope in the Code is equivalent to a 5" in 12" imperial roof slope or a 104 mm in 250 mm metric roof.

Spacings for rafters and joists are specified on the plans.

Building width is the dimension of the building in the direction the rafters and joists are running.

Snow Load

Snow load is the weight of accumulated snow on the roof. Given the varied snow conditions in BC—deep and continuous in the mountains to wet and rain-soaked on the coast—the calculation for snow load takes into account several factors. The *Building Code* provides the formula for specified snow load in *Section 9.4.2.1*. This formula makes use of the climatic data found in *Division B Appendix C*. This is where climatic data for locations in BC and explanations of the various data are provided. Local municipalities will often have more detailed and current climatic data. Contact your local building inspector to determine the criteria for your area.

The notes for the Ladysmith Vacation Cabin show the use of this formula. The specified snow load takes into account:

- The width of the building. The cabin is 22' (6.706 m) wide, therefore $C_b = 0.55$ for buildings greater than 4.3 m wide.
- S_s is the ground snow load, found on Table C-2 in Div 2 Appendix C. Ladysmith has an S_s of 2.4.
- S_r is the rain load, found in the same table. For Ladysmith, it's 0.4.

$$\text{Snow load} = (2.4 \times 0.55) + 0.4 = 1.72 \text{ kPa}$$

To convert kilopascals to pounds per square foot (psf), multiply by 20.8854:

$$1.72 \times 20.8854 = 36 \text{ psf}$$

Nailing Requirements

Table 9.23.14.8 (Figure 2) applies to the floor joists in the sleeping loft of the Ladysmith Vacation Cabin.

The roof slope is 1 in 1 with rafter spacing at 16" o.c. (400 mm). The ceiling joist spacing is also 16" o.c. The rafters are therefore tied at every joist (so use the section of the table labelled "Rafter Tied to Every Joist"). Since the snow load of 1.72 kPa is greater than 1.5, use the "2.0 or more" column of the table.

The rafter-to-joist connection requires 4 nails. Where the joists lap at the mid span, 5 nails are required.

Table 9.23.14.8. Rafter-to-Joist Nailing (Unsupported Ridge) Forming part of Sentences 9.23.14.8.(5) and (6)													
Roof Slope	Rafter Spacing, mm	Minimum Number of Nails not less than 76 mm Long											
		Rafter Tied to every Joist						Rafter Tied to Joist every 1.2 m					
		Building Width up to 8 m			Building Width up to 9.8 m			Building Width up to 8 m			Building Width up to 9.8 m		
		Roof Snow Load, kPa			Roof Snow Load, kPa			Roof Snow Load, kPa			Roof Snow Load, kPa		
		1.0 or less	1.5	2.0 or more	1.0 or less	1.5	2.0 or more	1.0 or less	1.5	2.0 or more	1.0 or less	1.5	2.0 or more
1 in 3	400	4	5	6	5	7	8	11	—	—	—	—	—
	600	6	8	9	8	—	—	11	—	—	—	—	—
1 in 2.4	400	4	4	5	5	6	7	7	10	—	9	—	—
	600	5	7	8	7	9	11	7	10	—	—	—	—
1 in 2	400	4	4	4	4	4	5	6	8	9	8	—	—
	600	4	5	6	5	7	8	6	8	9	8	—	—
1 in 1.71	400	4	4	4	4	4	4	5	7	8	7	9	11
	600	4	4	5	5	6	7	5	7	8	7	9	11
1 in 1.33	400	4	4	4	4	4	4	4	5	6	5	6	7
	600	4	4	4	4	4	5	4	5	6	5	6	7
1 in 1	400	4	4	4	4	4	4	4	4	4	4	4	5
	600	4	4	4	4	4	4	4	4	4	4	4	5

Figure 2 — BC Building Code Table 9.23.14.8

Size and Spacing of Ceiling Joists

The size and spacing of ceiling joists are designed using Part 9 Table A-3 of the *Building Code* (Figure 3). The design process is almost exactly the same as the design for floor joists. The table is for ceiling joists where the attic is not accessible by a stairway. If the attic is accessible by a stairway, then the table for floor joists is used instead.

Table A-3
Maximum Spans for Ceiling Joists – Attic not Accessible by a Stairway
 Forming part of Sentence 9.23.4.2.(1)

Commercial Designation	Grade	Joist Size, mm	Maximum Span, m		
			Joist Spacing, mm		
			300	400	600
Spruce – Pine – Fir (includes Spruce (all species except Coast Sitka Spruce), Jack Pine, Lodgepole Pine, Balsam Fir and Alpine Fir)	Select Structural	38 × 89	3.22	2.92	2.55
		38 × 140	5.06	4.60	4.02
		38 × 184	6.65	6.05	5.28
		38 × 235	8.50	7.72	6.74
		38 × 286	10.34	9.40	8.21
	No. 1 and No. 2	38 × 89	3.11	2.83	2.47
		38 × 140	4.90	4.45	3.89
		38 × 184	6.44	5.85	5.11
		38 × 235	8.22	7.47	6.52
		38 × 286	10.00	9.09	7.94
	No. 3	38 × 89	3.06	2.78	2.43
		38 × 140	4.81	4.37	3.82
		38 × 184	6.32	5.74	5.02
		38 × 235	8.07	7.33	6.34
		38 × 286	9.82	8.93	7.36
	Construction	38 × 89	3.06	2.78	2.43
	Standard	38 × 89	2.94	2.67	2.33
		38 × 89	2.88	2.61	2.28

Figure 3 — Part of BCBC Table A-3

Because the ceiling joists only support insulation and a interior cladding such as drywall, members can have long unsupported spans. For example, using *Table A-3* we see that #2 spruce 2x6 (38 x 140) at 16" (400 mm) on-centre can span up to 14'7" (4.45 m).

Roof Framing Code Requirements

Roof framing member size and spacing are based on the horizontal run (span) of the rafter or roof joist, not the length of the member. For example, a common rafter for a 20-ft. wide building would have a 10-ft. span but would be more than 14-ft. long if at a 1 in 1 slope.

The calculation for Ladysmith, BC, gives a factored snow load of 1.72 kPa. Although interpolation is allowed within the span tables, it is simpler and safer to go up to the next value listed, which is 2.0 kPa. It is wise to consult the authority having jurisdiction (building inspector) when in doubt as to the local snow load.

The building is 22 feet wide, giving a span of 11 feet (3.35 m). Because the rafter supports the ceiling finish, *Table A-4* (Figure 4) for roof joists must be used instead of the rafter table.

Table A-4
Maximum Spans for Roof Joists – Specified Roof Snow Loads 1.0 to 2.0 kPa
 Forming part of Sentence 9.23.4.2.(1)

Commercial Designation	Grade	Joist Size, mm	Maximum Span, m								
			Specified Snow Load, kPa								
			1.0			1.5			2.0		
			Joist Spacing, mm			Joist Spacing, mm			Joist Spacing, mm		
			300	400	600	300	400	600	300	400	600
Spruce – Pine – Fir (includes Spruce (all species except Coast Sitka Spruce), Jack Pine, Lodgepole Pine, Balsam Fir and Alpine Fir)	Select Structural	38 × 89	2.55	2.32	2.03	2.23	2.03	1.77	2.03	1.84	1.61
		38 × 140	4.02	3.65	3.19	3.51	3.19	2.79	3.19	2.90	2.53
		38 × 184	5.28	4.80	4.19	4.61	4.19	3.66	4.19	3.81	3.33
		38 × 235	6.74	6.13	5.35	5.89	5.35	4.68	5.35	4.86	4.25
		38 × 286	8.21	7.46	6.52	7.17	6.52	5.69	6.52	5.92	5.17
	No. 1 and No. 2	38 × 89	2.47	2.24	1.96	2.16	1.96	1.71	1.96	1.78	1.56
		38 × 140	3.89	3.53	3.08	3.40	3.08	2.69	3.08	2.80	2.45
		38 × 184	5.11	4.64	4.05	4.46	4.05	3.54	4.05	3.68	3.22
		38 × 235	6.52	5.93	5.18	5.70	5.18	4.52	5.18	4.70	4.11
		38 × 286	7.94	7.21	6.30	6.94	6.30	5.50	6.30	5.73	5.00
	No. 3	38 × 89	2.43	2.20	1.93	2.12	1.93	1.68	1.93	1.75	1.53
		38 × 140	3.82	3.47	3.03	3.33	3.03	2.65	3.03	2.75	2.37
		38 × 184	5.02	4.56	3.77	4.38	3.97	3.24	3.98	3.54	2.89
		38 × 235	6.41	5.65	4.61	5.60	4.86	3.97	5.00	4.33	3.53
		38 × 286	7.57	6.56	5.35	6.51	5.64	4.60	5.80	5.02	4.10
	Construction	38 × 89	2.43	2.20	1.93	2.12	1.93	1.68	1.93	1.75	1.53
	Standard	38 × 89	2.33	2.12	1.85	2.04	1.85	1.59	1.85	1.68	1.41
		38 × 89	2.28	2.07	1.81	1.99	1.81	1.58	1.81	1.65	1.44

Figure 4 — Part of BCBC Table A-4

Using #2 spruce at 16" (400 mm) o.c. and a snow load of 2.0 kPa, according to *Table A-4* the smallest joist size we could use to span 3.35 m is 38 x 184 (2x8).

The *Building Code* allows 2x4 or larger collar ties to be used to reduce spans as long as the roof is sloped at 4 in 12 or steeper. Loads should be similar on both sides of a gable roof, and the collar keeps the spans from deflecting. The Ladysmith Cabin has collar joists at 7 feet above the floor, reducing the single span from 3.35 m to two spans at approximately 4 feet and 7 feet (Figure 5).

Using the greater span of 7 feet (2.13 m) and *BCBC Table A-4*, the smallest allowable joist size for #2 spruce at 400 mm o.c. and a snow load of 2.0 kPa is 38 x 140 (2x6).

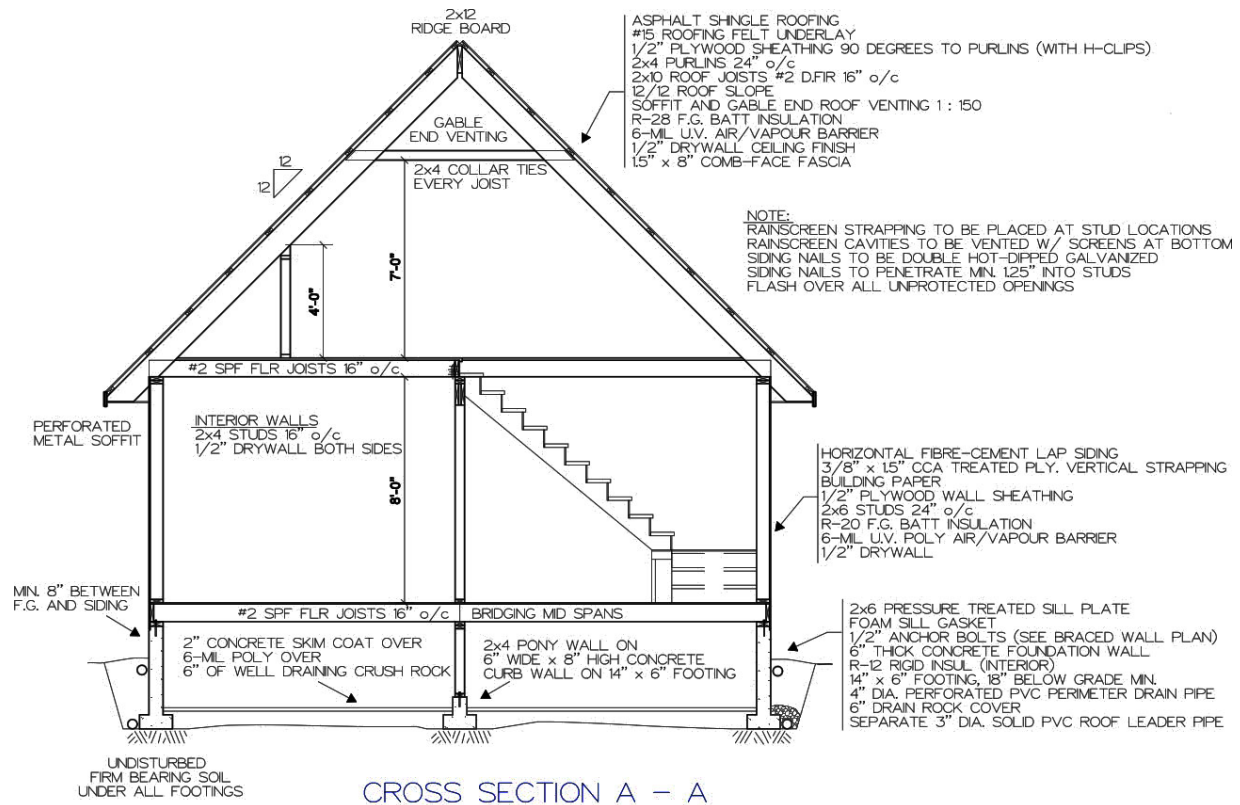


Figure 5 — Ladysmith Cabin cross section

Although 2x6 is allowable by the *BC Building Code* for the Ladysmith Cabin, the plans call for 2x10. This allows for R-28 fibreglass batt insulation and a 1" required air space for ventilation above the insulation.



Now complete Self-Test 2 and check your answers.

Self-Test 2

1. What determines the position of the ceiling joists?

2. Using *BC Building Code Table 9.23.14.8* and the following specifications, what are the rafter-to-ceiling-joist nailing requirements?

- location: Surrey
- width: 6.3 m
- unsupported ridge
- roof slope: 1 in 1.33
- rafter and ceiling joist spacing: 400 mm o.c.

3. For the roof specified in question 2, how many nails are needed to connect the ceiling joists over a beam?

4. Use *Table 9.23.14.8* with the following specifications to determine the nailing requirements.

- location: Fort St. John
- width: 9 m
- unsupported ridge
- roof slope: 1 in 2 (6 in 12)
- rafter and ceiling joist spacing: 600 mm o.c.

5. How wide must the working deck be for a single-pole scaffold built along a wall?

6. Why is temporary bracing so important when constructing a gable-type roof?

7. Why are rafters installed opposite each other in pairs?

8. What is the maximum span in feet and inches for #1 spruce 2x10 ceiling joists at 16" o.c.?

9. Using a snow load of 2.0 kPa and a spacing of 400 mm o.c., how far can a #2 spruce 38 x 89 mm (2x4) roof joist span? Give the answer in feet and inches.

LEARNING TASK 3

Calculate Gable Roof Systems

Calculating the quantities of materials is referred to as a *material take-off* or an *estimate*. An estimate usually includes prices of materials.

Accuracy, Waste Factors and Rounding

The intent of a material take-off is to make an accurate cost estimate and to ensure there's sufficient material on-site for the project to proceed efficiently. The actual dimension of each piece of lumber will be determined by on-site measurements. The calculations made in the take-off need to be accurate. It's common to round up to simplify the calculations, since it's not always necessary to carry three decimal places of accuracy. Rounding up is a reliable way to include a waste factor. Furthermore, since dimensional lumber is only available in increments of two feet, rounding will be necessary.

The accuracy of waste factors in calculating materials is dependent on the methods used by the builders, the experience of the carpenters and the design of the building. Some builders are careful and efficient in material use, while others consider wasting some material to be less expensive than the labour required to be more careful. Experienced carpenters are accurate and efficient in layout, and they make fewer mistakes and therefore waste less material.

Buildings with dimensions not divisible by 4' or 8', or with intersecting roof shapes require higher waste factors than those with few or no intersections. Hips and valleys will always have off-cuts, only some of which can be used elsewhere.

A waste factor of 5% is common for many jobs. Because the roof is the final part of the framing, it's the place to use up material that is left over from other parts of the job, such as unused wall sheathing and framing lumber.

It's helpful to use a simple spreadsheet to organize the estimate for material take-off for the roof. The calculations for the table in Figure 1 are explained below.

	Number	Length	Total	Lumber order
Ceiling/Floor Joists	10 per side = 20	12'	240 linear	20 pcs of 2×10 @ 12'
Bridging	9 per side × 2 × 2 = 36	Approx. 18"	54 linear 2×2	36 pcs per cut for 2×10 @ 16" o.c.
Rafters/Roof Joists	44	18'	792 linear	44 pcs 2×6 @ 18'
Ridge Beam	1 × 3-ply beam	14'	42 linear	3 pcs 14'
Collar Ties	22	10'	220 linear	22 pcs of 2×4 @ 10'
Purlins	22	31.166'	686 linear	44 pcs of 2×4 @ 16'
Sheathing	(1110 ft. ² /32) × 1.05 = 37 sheets	4×8		37 sheets ½" plywood
Fascia	2	32	64 linear	4 pcs 2×8 comb face @ 16'
Bargeboards	4	18	72 linear	4 pcs 2×8 comb face @ 18' or 20'
Fasteners	33 per sheet	33 × 37 = 1221 nails 2"	1221/245 per pound = 5 lb.	1 lb. 3" galvy casing nails for fascia/barge
H clips	5 per sheet	5 × 37	185 H clips	4 bags of 50 H clips
Gable End Sheathing	8 sheets			
Gable End Studs	17 per end = 34	Avg length 5.5'	187 linear	16 @ 12'

Figure 1 — Material take-off for Ladysmith Vacation Cabin roof

Ceiling Joists

The ceiling joists span the width of the building. For calculation purposes, their length is the width of the building. If the building is wider than one length of lumber, the ceiling joists need to be lapped on a midspan bearing wall. The length will depend on the location of the bearing wall, and the connection method on the bearing wall needs to be considered. When lapping the joists, include the lap in the length estimate.

In the Ladysmith Vacation Cabin, the loft floor joists act as ceiling joists because they tie the walls together. The joists span the 22' width. The plans don't show a connection detail at the bearing wall, so assume a lap of 1'. Efficient use of 12' joists can be made without having to cut them. The spacing of the joists is 16" o.c. = 1.333' o.c. along the 12' length.

$$12' \div 1.333' = 9 \text{ joists plus one to start} = 10 \text{ joists per side} = 20 \text{ joists}$$

A joist in the stairwell opening isn't needed, so 19 joists could be ordered or the 20th joist can be used as blocking or lintels or somewhere else in the house.

Bridging

Cross-bridging is required in this take-off because a floor is being framed. (Ceiling joists typically have a strap of 1×4 on top to keep them aligned to the on-centre spacing and prevent twisting.)

Each half of the floor system requires a row of bridging at the midspan. There are 9 spaces per side with two pieces of bridging per space:

$$9 \times 2 \times 2 = 36 \text{ pcs.}$$

The length of the pieces of bridging is approximately the hypotenuse of the space between the joists (14½") and the depth of the joist (9¼"). This is just over 17".

Rafters/Roof Joists

The cabin has a vaulted ceiling. The roof framing members support the normal live and dead loads of the roof and also the dead load of the ceiling finish. They are roof joists. The 2×10 roof joists are spaced at 16" o.c.:

$$28' \div 1.333' = 21 + 1 \text{ to start} = 22 \text{ roof joists per side} = 44 \text{ pcs.}$$

Previously, the overall length of the roof joists (including the overhang) was calculated as:

$$186.67" + 26.864" = 213.534" = 17.795' = 18' \text{ pieces}$$

Ridge Beam

The ridge beam in the Ladysmith Vacation Cabin is a 3-ply built-up beam. From the plans, the ridge beam length is 14' + 1'10" = 15'10" – 3'6" (jog) = 12'4". The actual length will include the end bearing and will be determined on-site. Three 14' pieces are required.

Bargeboards and Fascia

Gable roofs have both fascia and bargeboards.

The length of each bargeboard is the length of the common rafter that it parallels, including the overhang length. Additional length is needed for the plumb cut angles at the top and bottom. The bargeboard covers the end of the ridge and has no adjustment for length at the top. The bargeboard often projects past the fascia and sometimes past the ends of the eavestrough for a decorative look. Typically, the length required is the length of the common rafter including overhang, plus 2'.

The fascia lengths are measured for the length of the roof for each side. The Ladysmith Vacation Cabin plans specify 2×8 combed face finished fascia. $31.167 \times 2 = 62.334'$. These need to be joined on a rafter tail. 16-foot pieces will work efficiently as long as they are free of checks at the ends.

Collar Ties

Collar ties are installed on each pair of roof joists. Typically, collar ties are one-third the span of the building plus the nailing surface to the roof joists or rafters. For the Ladysmith Vacation Cabin, the collar ties are $22 \div 3 = 7.333'$ clear plus approximately 12" at each end = 9'4". Order 22 pieces of 2x4 @ 10' long.

Purlins

Purlins are specified as 2x4 @ 24" = 2' o.c. along the length of the roof joist.

$$(18' \div 2') + 1 = 10 \text{ pcs. per side} \times 2 \text{ sides} = 22 \text{ lengths.}$$

The purlins extend to the bargeboard. The length of the building plus gable projection = $28' + (2 \times 1.583') = 31.166'$.

The total linear feet of purlins required will be $22 \times 31.166 = 686'$. Because purlins are not visible, it's common to use accumulated leftover pieces of 2x4. For example, there may be 2x4s left over from the formwork.

Two pieces of 2x4 @ 16' long for each purlin will work efficiently.

The joins in the purlins are made on top of a roof joist and must be staggered.

Panel Roof Sheathing

The total area of the roof is the length of the rafters to the fascia multiplied by the length of the roof, including the gable projection, for each side.

$$17.795' \times 31.167' \times 2 = 1109.233 \text{ square feet is an exact roof area.}$$

(Round up to 1110 square feet.)

$$1110 \div 32 \text{ (area of sheet of plywood)} = 34.6875 \text{ sheets.}$$

There will be some waste, but on a rectangular roof, not much so use a waste factor of 5%:

$$34.6875 \times 1.05 = 36.397 \text{ (Round up to 37 sheets.)}$$

As is specified for the Ladysmith Vacation Cabin, it's common to use the same sheathing for the walls as for the roof. Leftover sheets from the walls can be used on the roof.

Slope Gain Ratio

Slope gain ratio is how much larger the roof is on the slope than on the flat. Slope gain ratio is another way to calculate roofs. It's simply the ratio of LCPUR to run. For a 12 in 12 sloped roof, the slope gain ratio is $16.97 \div 12 = 1.414$.

The area of the cabin roof on the flat is the width of the roof multiplied by the length (both dimensions include the projection):

$$28' + (2 \times 1'7") \times 22' + (2 \times 1'7")$$

Flat area of the roof is $31.167' \times 25.167' = 784.38$ square feet.
(Round up to 785 square feet.)

$785 \times 1.414 = 1110$ square feet is the total roof area.

You can also use the slope gain ratio to calculate rafter lengths. For example, the line length of the common rafter (roof joist in the case of the Ladysmith Vacation Cabin) can be calculated as:

$11 \times 1.414 = 15.554' = 186.648"$, which is within $\frac{1}{16}$ th of an inch of the unit method of calculation.

Gable Ends

Although the gable ends are walls, they need to be included in the material take-off. The area of the gable end is based on the triangle formed by the roof. The area of a triangle is (base $\times$ height) $\div 2$, or $\frac{1}{2}$ base times height.

$22'$ wide (base) $\times 11'$ high $\div 2 = 121$ square feet at each end = 242 square feet.

$242 \div 32 = 7.563$ sheets of plywood. (Round up to 8 sheets.)

The average length of the gable end studs will be half of the height = 5.5 feet.

$22' \div 1.333$ o.c. stud spacing = 16.54 on each end (round up to 17).

34 pcs. at 5.5 feet or 16 studs at 12 feet.

Fasteners

The number of nails or screws required is usually estimated for bidding purposes. In reality, most carpenters stock large quantities of nails and screws. Leftover fasteners go to the next job.

Tables 9.23.3.4 and 9.23.3.5 of the BC Building Code stipulate the minimum numbers of nails needed for each type of application. For example, a 4 $\times$ 8 sheet of roof sheathing requires nails every 6" on the edge supports and every 12" along the intermediate supports. Using these numbers, a minimum of 33 nails per sheet are required, but it's not unusual to use more.

Typically, it takes about 250 pounds (lb.) of nails to frame a 1200 to 1500 sq. ft. house.

A more accurate method is to use the total board feet of material to estimate the number of nails needed. For sheathing, subflooring and 1 $\times$ material, the number of pounds of nails needed is found by multiplying the nail length by the board feet and then dividing by 400 (treat each sheet of plywood or OSB as 40 board feet). For framing with typical dimension lumber, the number of pounds of nails needed is found by multiplying the nail length by the board feet and dividing by 600.

For specialty nailing, such as fastening fascia and bargeboards, an unusual length of galvanized casing nails might be needed that won't be used for the next job. For these situations, a rough count can be done and then the total number can be converted to pounds.

There are many types of nails, and the number per pound varies by length, type, gauge and finish. This information is available online. Figure 2 lists some examples.

Type	Nail length (inches)	Number of nails per lb.
Hot dipped galvanized casing	2	245
	2 ½	146
	3 ½	77
Joist hanger nails (9 gauge)	1 ¼	149
	1 ½	123
Common bright	2	170
	2 ¼	140
	2 ½	105
	3	63
	3 ¼	60

Figure 2 — Number of nails per pound

Similar tables are available for the number of screws per pound.

H Clips

H clips are a common roof framing hardware. They support the edge of the plywood in the spaces between the rafters. The Ladysmith Vacation Cabin does not need H clips because the plywood is supported by the purlins. On a roof that requires H clips, there are five rafter spaces for every 8' length of plywood. The H clips are installed on the top edge of each sheet.

5×37 sheets = 185 H clips.



Now complete Self-Test 3 and check your answers.

Self-Test 3

1. On what does the accuracy of waste factors depend?

2. What are two ways to calculate amount of panel roof sheathing?

3. What is the slope gain ratio for a roof with a slope of 8 in 12?

LEARNING TASK 4

Build Gable Roof Systems

The first step when building a hand-framed gable roof (after the walls have been straightened and braced) is to frame the ceiling with ceiling joists.

Lay Out and Cut Ceiling Joists

The end of the ceiling joist that rests on the exterior wall and where it is joined to the rafter is cut to fit the rafter (Figure 1).

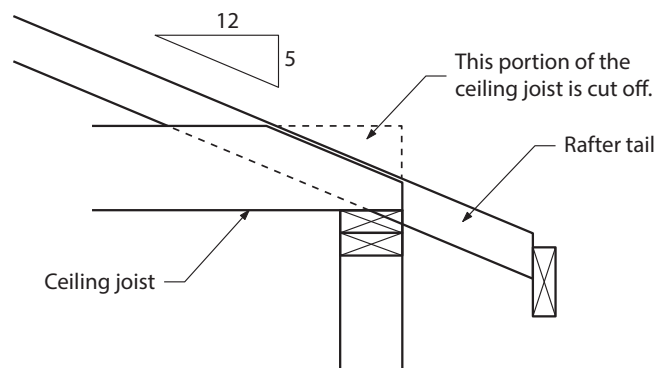


Figure 1 — Ceiling joist cut at the exterior wall plate and rafter end

The angle of the cut is laid out using a framing square. The slope of the roof determines the angle of the cut. The rise and run are used to position the framing square on the top edge of the ceiling joist. The cut line is made on the 12 side of the framing square (Figure 2).

The height at the end of the joist is $\frac{3}{8}$ " less than the "wood above plate" of the common rafter. We cut this lower so the ceiling joist does not interfere with the roof sheathing, even after some shrinkage of the rafter.

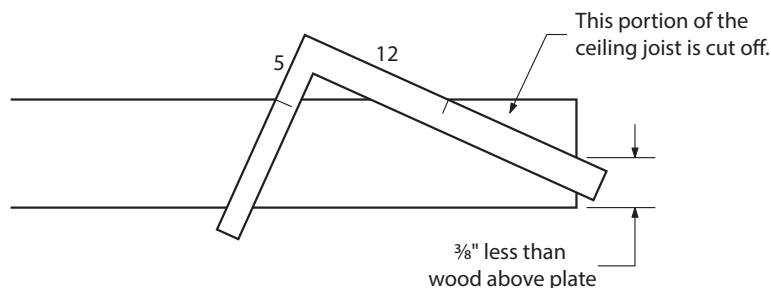


Figure 2 — Laying out the angle and wood above plate on ceiling joist

Plate Layout

Typically, all framing members are laid out to align vertically—rafters directly above studs directly above joists, etc. In advanced, high-performance framing (where use of single top plates is common), structural alignment of framing members is required. In traditional platform-framing, the use of a double top plate does not have this requirement. However, although not required by the Code, alignment of framing members is always good practice.

Where ceiling joists are required to tie the rafters together (unsupported ridge), ceiling joist layout corresponds to the rafter layout. The structure is best supported when the spacing for rafters and joists are the same and each ceiling joist is joined to a rafter (Figure 3).

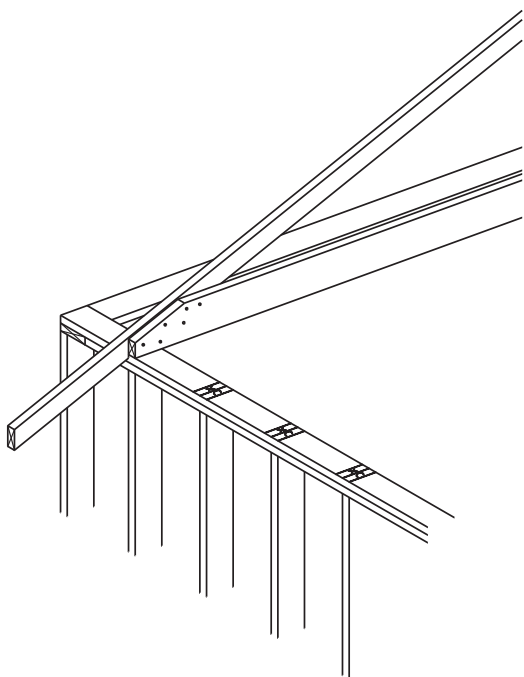


Figure 3 — Ceiling joist and rafter layout

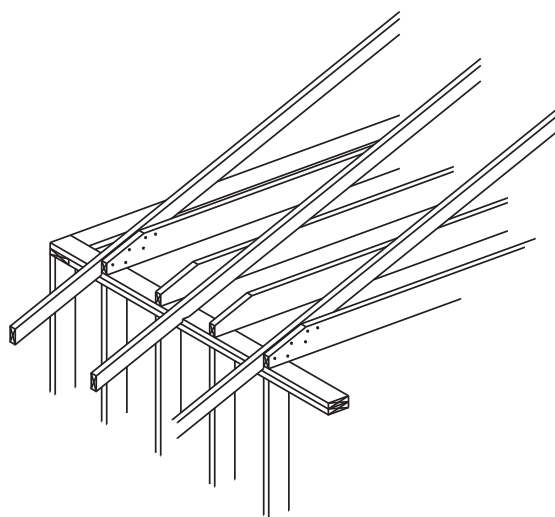


Figure 4 — Rafters tied to every third ceiling joist

It's common for rafters to be spaced at 24" on centre and ceiling joists at 16" on centre, in which case only every third rafter and joist are tied together (Figure 4). This requires more nails at each connection, as per *Table 9.23.14.8*.

Openings in Ceilings

Openings in ceiling framing accommodate attic access hatches and chimneys. The framing for these openings is similar to framing floor openings.

For openings that do not require more than one ceiling joist to be cut, the construction shown in Figure 5 is adequate. Larger openings must be designed by a registered engineer due to the complicated tension loads.

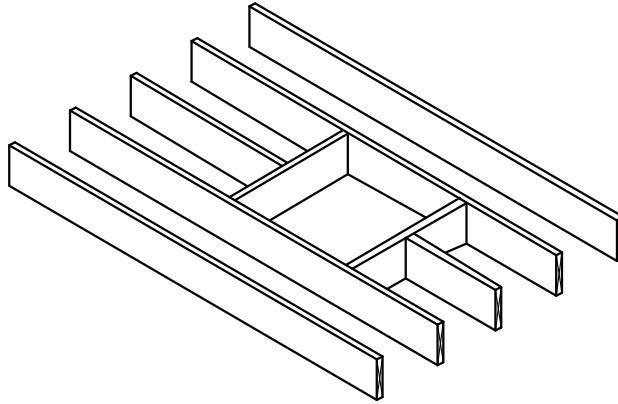


Figure 5 — Opening requiring only one ceiling joist to be cut

If rafters are supported at the ridge by a beam or bearing wall, large openings in the ceiling can be designed and built following the *Building Code* for floor openings.

Installing Ceiling Joists

Most buildings are wide enough to require the ceiling joists to be joined at a load-bearing interior wall or beam. The tension in the ceiling joist is transferred through this important connection.

When ceiling joists are lapped and joined over a bearing wall or a dropped beam (a beam under the joists), the *Building Code* requires that they be nailed to each other with one more nail than required for the ceiling-joist-to-rafter connection for an unsupported ridge (Figure 6).

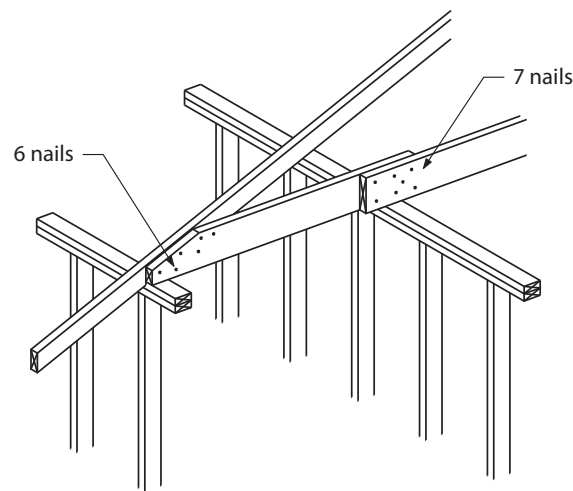


Figure 6 — Joining ceiling joists over a bearing wall

In buildings with large, open spaces, it's common for ceiling joists to be supported by a flush beam. The bottom of the beam is flush with the bottom of the joists, creating a flat ceiling. In this case, the ceiling joists are attached to the beam with joist hangers and connected across the top of the beam with a metal strap (Figure 7).

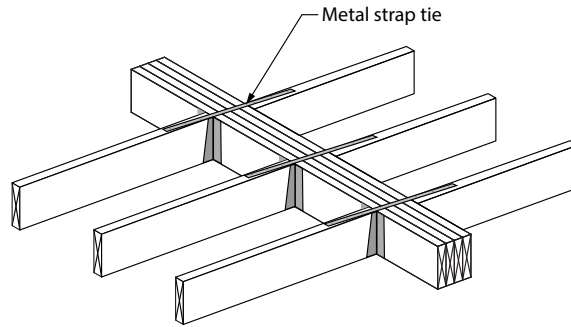


Figure 7 — Ceiling joist connection at flush beam

Lay Out Roof Members

For a simple gable roof, rafter calculations and layout of the common rafters and ridge are done at the job site using a calculator, a pencil and a framing square.

Framing Square

The framing square is the main tool used to calculate and lay out roof framing members. The *face* side of the square is the surface that has the rafter tables stamped on it (Figure 8). The opposite side is the *back*. The wide leg of the square is the *blade* or *body* and the narrow leg is the *tongue*. (The terms used to describe a framing square are the same for both imperial and metric squares.)

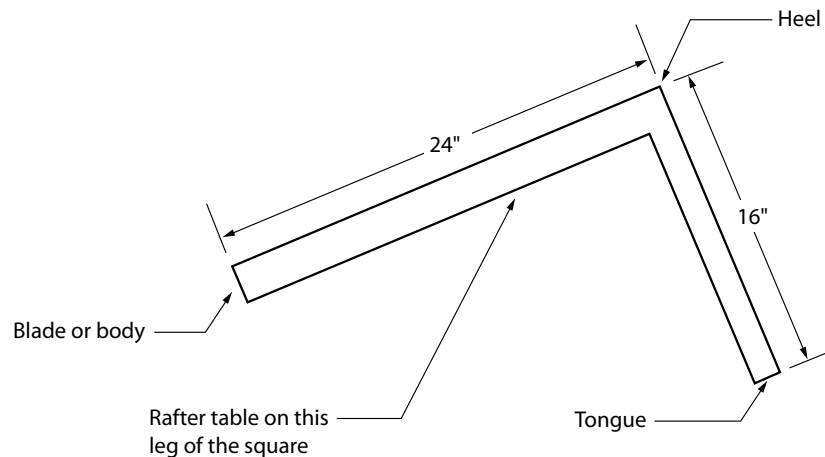


Figure 8 — Face of a standard imperial framing square

The angle formed by the body and tongue of the square is a “right angle” or 90°.

Rafter Table

A framing square has a rafter table on its face. This table includes all of the information needed to calculate and lay out all of the rafters for even the most complicated roof.

The rafter table has columns of information under the inch marks on the framing square (Figure 9).

COMMON RAFTER LENGTH PER FOOT OF RUN	23	22	21	20	19	18	2	1
COMMON RAFTER LENGTH PER FOOT OF RUN	21 63	24 74	28 7/8	43 1/4	6 11/16	8 1/8	12 17	17 09
HIP OR VALLEY RAFTER LENGTH	24 74	28 7/8	43 1/4	6 11/16	8 1/8	12 17	17 09	24 5/16
DIFF IN LENGTH OF JACKS 16 INCH CENTRES	28 7/8	43 1/4	6 11/16	8 1/8	12 17	17 09	24 5/16	11 3/16
DIFF IN LENGTH OF JACKS 24 INCH CENTRES	43 1/4	6 11/16	8 1/8	12 17	17 09	24 5/16	11 3/16	11 15/16
SIDE CUT OF JACKS	6 11/16	8 1/8	12 17	17 09	24 5/16	11 3/16	11 15/16	
SIDE CUT OF HIP OR VALLEY	8 1/8	12 17	17 09	24 5/16	11 3/16	11 15/16		

Figure 9 — Rafter table

The first row of the table gives the common rafter length per foot (unit) of run. The inch marker above each column gives the unit of rise for that column of information.

For a roof with a 2 in 12 slope (Figure 10), the length of common rafter per foot of run is 12.17" (note that the table does not show the decimal point). For a very steep roof with a slope of 18 in 12, the length per unit of run is 21.63".

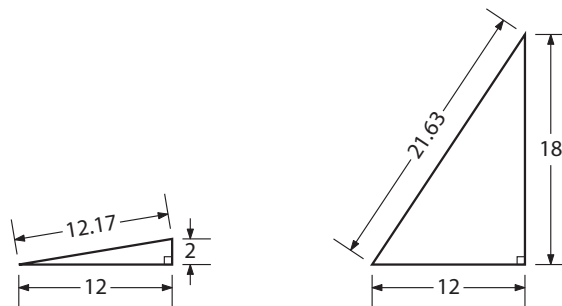


Figure 10 — Slope triangles

This first row is simply the hypotenuse of this rise/run triangle and is referred to as the Length of the Common Per Unit of Run (LCPUR). By using the Pythagorean theorem ($a^2 + b^2 = c^2$) with "a" as the rise and "b" as the run, "c" is the hypotenuse or the LCPUR.

For example, the LCPUR for a roof with a slope of 8 in 12 can be calculated as follows:

$$a^2 + b^2 = c^2$$

$$\sqrt{a^2 + b^2} = c$$

$$\sqrt{8^2 + 12^2} = c$$

$$c = 14.42 \text{ inches}$$

Similarly, for a metric roof with a slope of 150 in 250:

$$\sqrt{150^2 + 250^2} = 291.5 \text{ mm}$$

Other Rows

The other rows of information on the rafter table are used for calculating and laying out hip, valley and jack rafters. Only the first row of information is used with the common rafter.

Common Rafter Calculations

The common rafter is the basis for much of the roof. The correct calculation and layout of this rafter are important because they are used in the following ways:

- The roof slope given on the plans refers to the slope of the common rafter.
- The amount of the rafter that's left above the plate once the bird's mouth is cut is the same for all rafters on the roof. This is often referred to as the *wood above plate* (WAP).

Common rafters are used with all types of rafter-framed roofs. A gable roof consists of pairs of common rafters meeting at the ridge. Two separate calculations are needed for a common rafter: the line length and the overhang length (Figure 11).

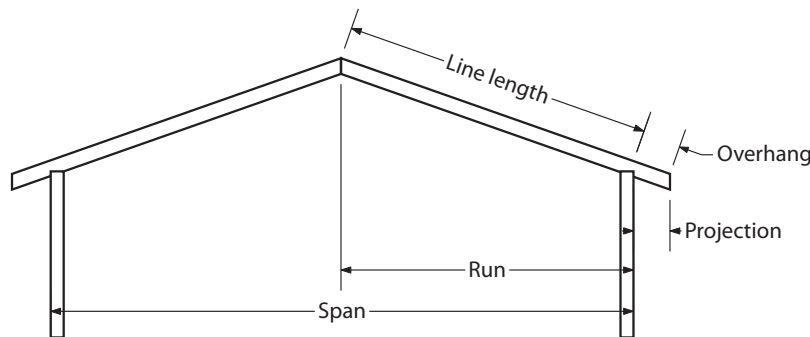


Figure 11 — Common rafter lengths

Line Length

The line length of a common rafter is found in three steps:

1. Divide the span of the roof in half to find the run.
2. Convert the run into number of units of run. (This is expressed as feet and decimals of a foot for imperial measurements, or $\text{run} \div 250 \text{ mm}$ for metric measurements.)
3. Multiply the number of units of run by the LCPUR to find the line length of the rafter.

These three steps are used for both imperial and metric measurement systems.

Example

The Ladysmith Vacation Cabin has a roof span of 22'0" and a roof slope of 12 in 12.

1. $22' \div 2 = 11$ feet
2. 11 feet = 11 units of run

The LCPUR for a 12 in 12 roof is 16.97". (This can be determined from the rafter table or using the Pythagorean theorem: $\sqrt{12^2 + 12^2} = 16.97$.)

3. $11 \text{ units} \times 16.97" = 186.67" = 186\frac{11}{16}"$

The line length of the rafter is $186\frac{11}{16}"$.

The LCPUR is also used to calculate the overhang. The roof has a projection of 1'7" (19").

$$\frac{19"}{12"} = 1.583 \text{ units of run}$$

$$1.583 \text{ units} \times 16.97" = 26.864" = 26\frac{7}{8}"$$

The overhang of the rafter $26\frac{7}{8}"$.

It's important to physically measure the span of the roof. If everything is accurate, this dimension will match the blueprints. The earlier decision regarding the position of the wall sheathing now comes into play: whether the framing is to the overall building dimensions and the wall sheathing is outside of this, or whether the outside of the wall sheathing is included in the overall dimension.

Common Rafter Layout

All rafters are laid out in a similar manner. The common rafter is the simplest and is usually laid out first.

Hold the piece of lumber being used for the common rafter in front of you. Decide which end of the board will be the ridge (the other end will be the tail). If the board has a crown, it should be up when the rafter is nailed in place (indicate the direction of the crown with an arrow).

With the rafter laid flat in the work area for layout and cutting, it's easiest to visualize the rafter by keeping the top surface of the rafter away from you and the underside of the rafter closest to you.

Working Points

The first step in laying out any rafter is to locate the working points (Figure 12). Make a pencil mark at the top (ridge end) of the board. This is the working point at the ridge. Measure the line length from this point toward the tail and mark the working point at the bird's mouth. Measure from the bird's mouth and mark the working point at the overhang.

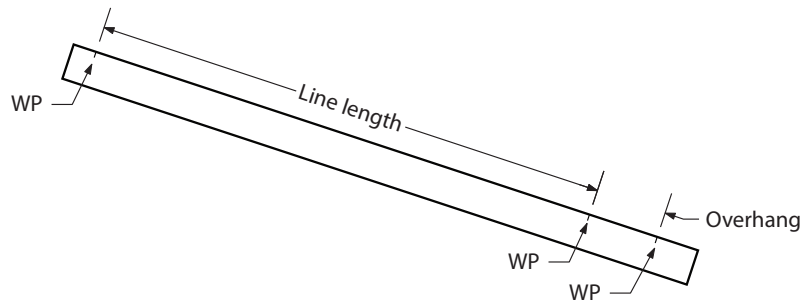


Figure 12 — Working points on a common rafter

Write the symbol “WP” on the side of the rafter to indicate that the mark is a working point. During the layout of hip, valley and jack rafters, there are several marks at each layout location. It’s easy to lose track of which one of these marks is the working point.

It’s convenient to make the working point the corner of the rafter at the end of the board. This way you can hook your measuring tape on the end to measure to the working point at the bird’s mouth. Ensure the board is sound and free of checking at the end.

Plumb Lines

Mark plumb lines at each working point (Figure 13). Hold the framing square with the unit of rise on the tongue and the unit of run on the blade.

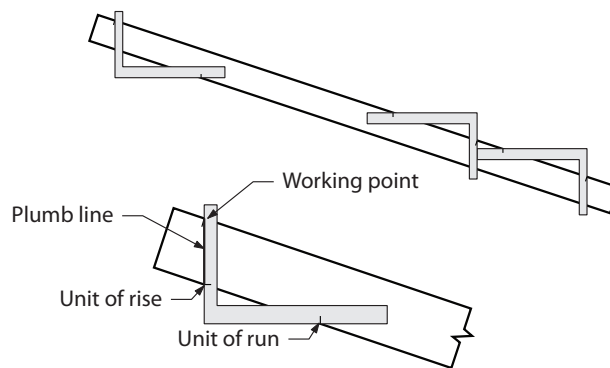


Figure 13 — Mark the plumb lines

The square may have to be rotated 180° when marking the plumb lines at the bird’s mouth and the tail.

All plumb lines must be parallel—hold the rafter up and visualize how it will look.



After the first common rafter is laid out, it’s used as a template for all other common rafters. Check the layout of the first rafter very carefully.

Adjustment at the Ridge

The line length is calculated to the centre of the ridge. If a ridge is used, the rafter must be shortened by half of the ridge thickness (Figure 14).



Adjustments for all rafters are always measured square to the plumb line.

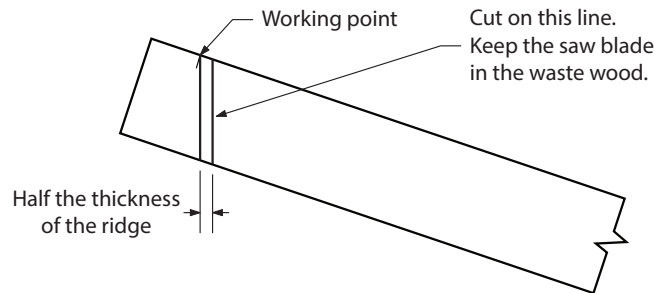


Figure 14 — Adjustment at the ridge

If no ridge is used, cut at the working point line. This is how the vaulted ceiling section of the Ladysmith Vacation Cabin is built, with the common rafters on each side butting into each other above the ridge beam.

Bird's Mouth

The depth of the bird's mouth for the common rafter is very important for two reasons. It sets the amount of wood that is sitting above the plate (WAP) for all rafters on the roof, including the hips and valley rafters in an intersecting roof. It also determines how much space is available for insulating at the wall plate.

The only *Building Code* requirement is that the rafter be supported on the wall plate by a minimum of 38 mm (1½") (Figure 15).

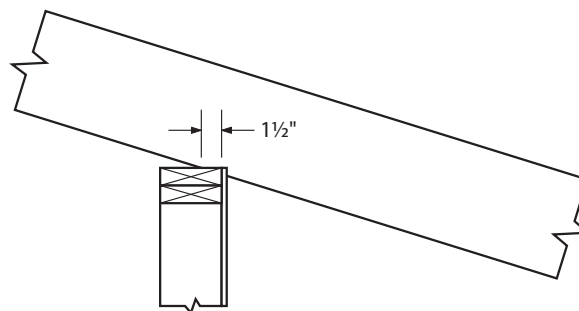


Figure 15 — Minimum bearing for rafters

The bearing must be fully supported by the wall framing, not including the wall sheathing. (This 38-mm minimum is rarely used because it's difficult not to split the wood when toenailing the rafter to the plate.)

An important factor that can influence the size of the bird's mouth is insulation and ventilation requirements. Even in the warmer climate zone of southern BC, the required roof insulation for a vaulted roof system is $R28 = RSI\ 4.9$. $R28$ is about 9" thick and the required ventilation space is 63 mm ($2\frac{1}{2}$ "). This is wider than a 2x12 without the seat cut. There are several ways to accommodate these insulation requirements: high heel trusses, rigid insulation on the outside of the roof sheathing or a rafter plate on top of ceiling joist (Figure 16).

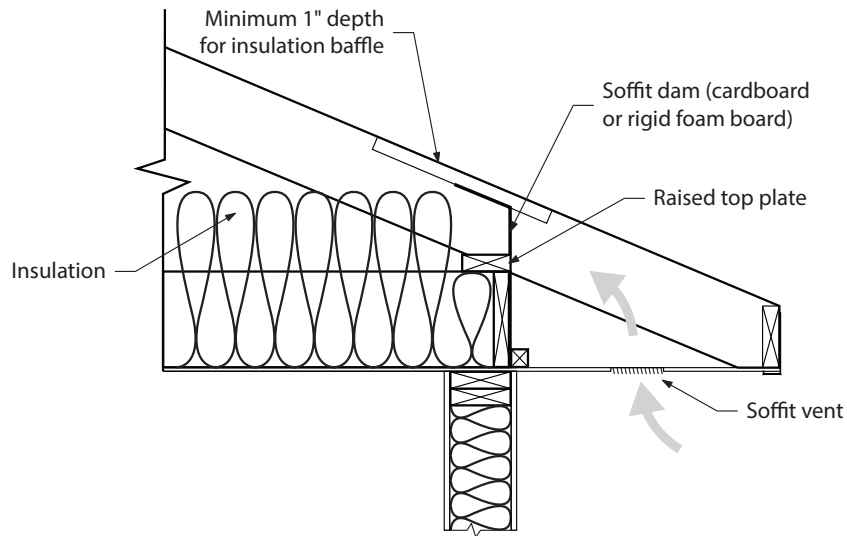


Figure 16 — Rafter on raised top plate

A common way to set the size of the bird's mouth is to measure the actual length of the plumb line and draw the horizontal seat cut $\frac{2}{3}$ of the measurement from the top of the rafter. For example, if the plumb line is $4\frac{1}{2}$ ", the seat cut will be 3" from the top (this is the WAP). $1\frac{1}{2}$ " will be below the plate.

Seat Cut Layout

On the plumb line at the bird's mouth, measure the depth of the WAP from the top of the rafter down. Hold the framing square along the bottom edge of the rafter and slide it until the unit of run lines up with the seat cut mark (Figure 17).

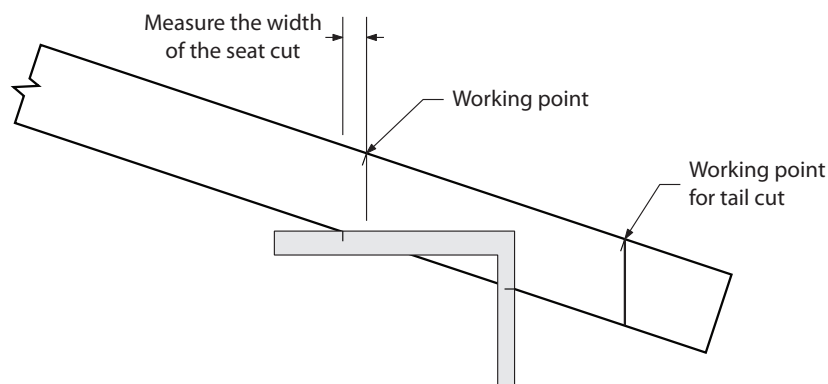


Figure 17 — Seat cut layout

The finished bird's mouth cut should always have a right angle at its inside corner (Figure 18). Place the heel of the square into the bird's mouth cut to check it for square.

It's common to lay out and cut one rafter and use it as a template for the rest of the rafters. The template needs to be very accurate.

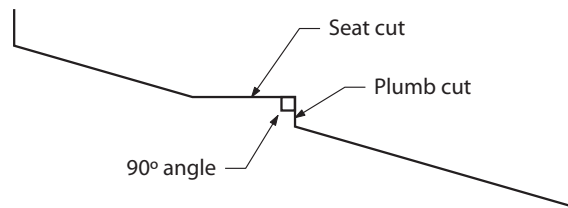


Figure 18 — Plumb cut and seat cut

Tail Cut

The final cut on the common rafter is the plumb cut at the fascia. If there is no rough fascia, the plumb cut laid out at the overhang working point is the final cut. If a rough fascia is used, mark the cut line toward the ridge by the thickness of the rough fascia (Figure 19). Once again, all adjustments are made at a right angle to the plumb line.

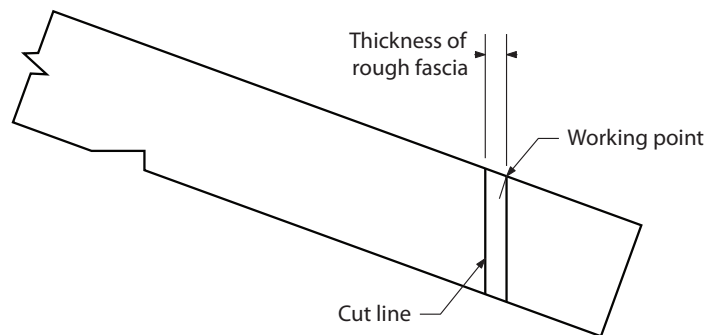


Figure 19 — Allow for the rough fascia

Some carpenters will make this adjustment for the fascia in their calculations and not during the layout. The advantage to doing this is that once the calculation is made, you no longer have to consider adjustments at the tail on any other rafters. The Ladysmith Vacation Cabin has a 1'7" projection with a 1½" fascia. Rather than using the "theory" overhang calculation from above (26⅞"), calculate the "actual" overhang using a projection of 1'5½" (1'7" – 1½").

$$17.5" \div 12 = 1.458 \text{ units} \times 16.97" = 24.742" = 24\frac{3}{4}"$$

This is the measurement from the bird's mouth working point to the fascia working point and does not need to be adjusted for the fascia.

Note that the bottom of the rafter tail on the Ladysmith Vacation Cabin is level. This level cut is laid out square to the plumb cut at a distance down from the top of the rafter. This is a design decision often based on the height at the top of the windows.

Ridge Length

The length of the ridge is based on the construction of the fly rafter and/or bargeboard. Best practice is to support these rafters with outriggers. Outriggers can be supported by a gable wall (Figure 20) or be notched into a common rafter at the gable end (Figure 21).

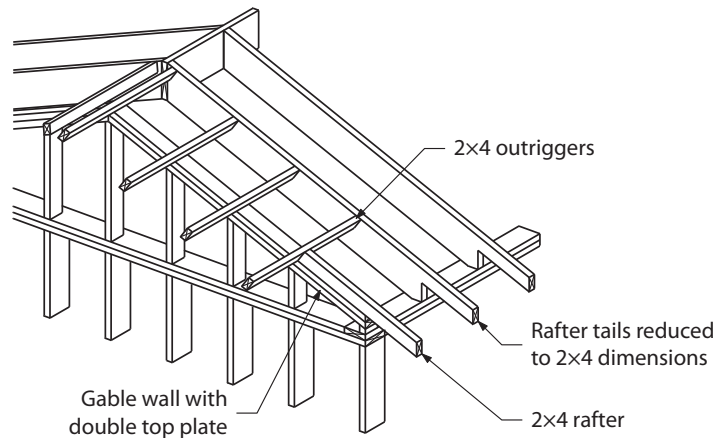


Figure 20 — Gable wall with outriggers (ceiling joists omitted for clarity)



Figure 21 — Notched rafter supporting outriggers

If the roof is framed without outriggers, the ridge will stop at the outside face of the last rafter at the gable end. In this case, the bargeboard is supported by the roof sheathing. If the roof is framed with outriggers, the ridge board will stop at the last rafter before the gable end.

In either case, the length of the ridge is the length of the building plus two times the projection. The end of the ridge should not be exposed. That is, it should be held back by the thickness of the bargeboard. Often the ridge outside of the building on the gable end is ripped to 3½" and covered by the soffit.

The overhanging rafter can be supported by the roof sheathing, but this will sag over time. If this projection is over 6", it should be supported by framing lumber.

Plate Layout

Plate layout typically follows the stud layout of the supporting wall. This may mean an unusual length for the first sheet of plywood, depending on the gable end projection. It's not uncommon to base the layout on a full sheet of plywood starting at the bargeboard, but this is only possible when using a double top plate and the rafters don't have to align with the studs, or if the stud layout has been planned for this system.

Collar Ties

Collar ties are horizontal members used to reduce the span of rafters. The ends of the collar ties are cut on a long taper to match the slope of the roof (Figure 22).

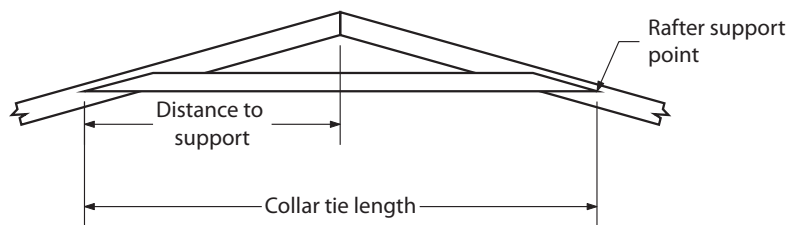


Figure 22 — Collar tie length

Collar Tie End Cut

The cut at the end of the collar tie is similar to the sloped cut at the ends of ceiling joists. The unit of run and unit of rise are used to lay out the cut (Figure 23). The slope is marked on the unit of run.

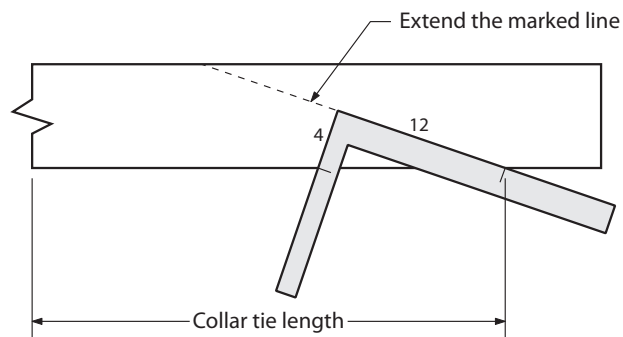


Figure 23 — Collar tie end cut layout

Normally, the tapered cut of the collar tie is $\frac{3}{8}$ " below the top of the rafter (similar to a ceiling joist). However, if the collar tie also acts as a ceiling, such as in the Ladysmith Vacation Cabin, it must be installed level and flat and at the specified height.

Design of Collar Ties

Flat roof slopes create large tension forces in the ceiling joists and collar ties. The roof slope must be 4 in 12 or steeper if collar ties are used to reduce the span of the rafters.

The *Building Code* requires that the collar ties be made from 2×4 or larger material. If the collar ties are longer than 8', the midpoint of the collar ties must be braced with a 1×4 at right angles to the collar ties.

Collar ties are nailed to opposing rafters with three 3" nails at each end.

Gable End Studs

Gable studs that are spaced evenly will have a common difference in length. The difference in length is equal to the o.c. spacing in inches divided by the unit of run and multiplied by the unit rise.

If the o.c. spacing is 16" and the roof slope is 4 in 12, the difference in the lengths of gable studs is:

$$(16 / 12) \times 4 = 1.333 \times 4 = 5.33" = 5\frac{5}{16}"$$

The First Gable Stud

The gable studs are laid out from the outside corner of the building. Whether the studs are notched around the last common rafter or fitted into a gable wall, the first stud will be a special length.

Calculating the length of the first stud is possible but not practical in most cases. Irregularities in the cut of the bird's mouth, uneven thickness of plates and other variances make the calculated length inaccurate.

Lay out the first gable stud's position on the wall plate and use a framing square to mark the location of the first stud on the last common rafter. Measure the length of the first stud from the plate to the long point of the gable stud (Figure 24).

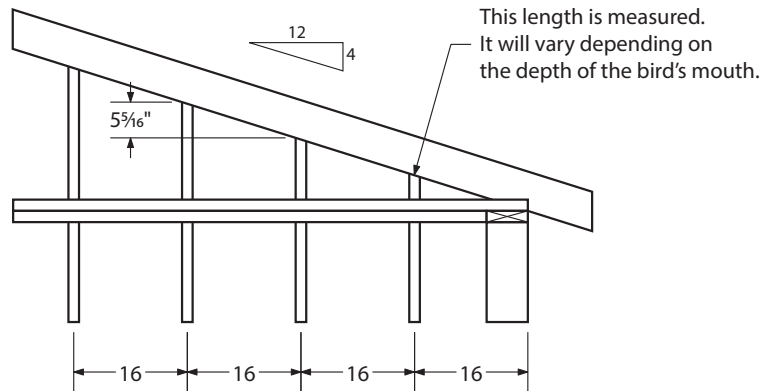


Figure 24 — Measuring the first gable stud length

Cutting Gable Studs

The gable studs are cut at an angle to fit to the underside of the rafter or the underside of the double top plate. This angle is laid out using the framing square. The unit of rise and the unit of run are held on the edge of the gable stud and the cut is marked on the unit of rise side of the square (Figure 25).

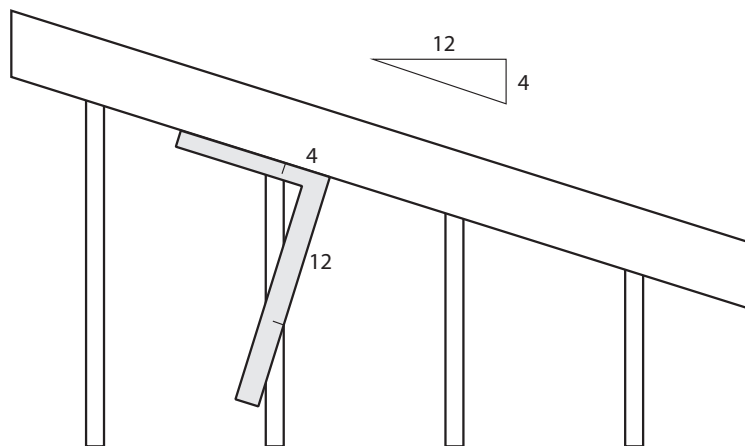


Figure 25 — Marking the angle on gable studs

The angle is easily cut with a mitre saw or portable circular saw. Set the angle on the saw by marking a board and test cutting to the mark. The angle can be calculated but it is easier and faster to make a test cut.

Length of Outriggers

The purpose of outriggers is to support the gable end projection. The *Building Code* does not specify when outriggers are required or what size and spacing of member is needed.

Outriggers are usually 2×4 members on edge, that are supported on a gable wall or 2×4 notched into the gable end rafter. They should project into the building at least one full rafter spacing and ideally more than they project. There is a cantilever effect such that downward deflection of the projection will raise or bulge the roof inside the gable end wall.

An important aspect of roof construction is to have the fascia lines straight. It's common to extend both the rafters tails and the outriggers long, chalk a line and cut them in place. In the case of the tails, a plumb line will be drawn on each rafter. If the tails are covered by a soffit, shims can be used to straighten the fascia. For an open soffit, cutting the rafter tails needs to be finishing-quality work.

Rafter Design

Rafters are designed in the same way as floor joists or ceiling joists. The size of the rafter is dependent on the species of wood, the span, the spacing of the rafter and the snow load. Refer to the *BCBC* to determine the size of the rafter.

Example

Determine the size of the rafters required for the following house:

- location: Surrey
- framing material: SPF#1 & 2 lumber
- width: 6.3 m
- unsupported ridge
- roof slope: 1 in 1.33
- rafter spacing: 400 mm o.c.

First, determine the Specified Roof Snow Load using the formula from *BCBC* 9.4.2.2:

$$S = (C_b \times S_s) + S_r$$

Because the house has a span greater than 4.3 m, use C_b of 0.55.

The Specified Snow Load for Surrey = $(0.55 \times 2.4) + 0.3 = 1.62$ kPa.

Now go to *Table A-6* for Roof Rafter - Snow Loads 1–2 kPa. (Use the 2 kPa columns on the table.)

Notice you go to the species, spacing and span to determine the size.

The (span) run of the common is 3.15 m. 38 × 140 rafters will span up to 3.53 m.

Assemble a Gable Roof

After the ceiling joists have been installed and all of the common rafters have been cut, the roof is assembled. It's common to place a row of sheathing on the top of the ceiling joists as a walkway for working at the ridge. At the plate, fall protection is usually required (scaffolding with guardrails or safety harnesses attached to lifelines).

Setting the Ridge

Cut the ridge to length. If the ridge is joined, make the joins at a rafter location. Lay the ridge across the ceiling joists. Position it next to the 1×4 strap used to hold the ceiling joists in place. Use the ceiling joist location to mark the rafter locations on the ridge.

Nail opposite pairs of common rafters to the ends of the ceiling joists (Figure 26). Let the tops of the rafters rest against each other. Install a pair at each end of the ridge board or at the ends of the pieces of ridge.

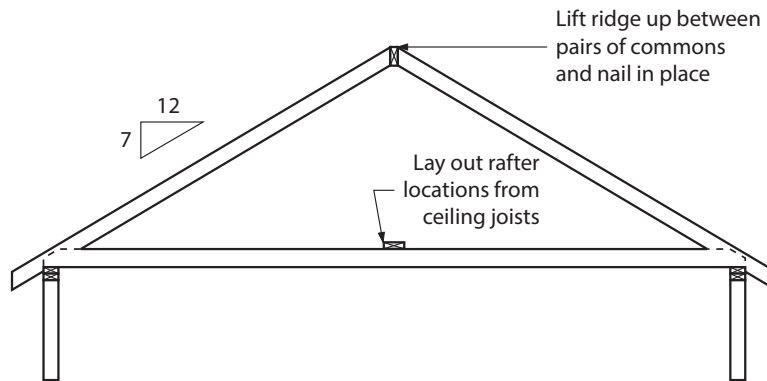


Figure 26 — Installing ridge

Lift the ridge and place it between the pair of rafters. The weight of the rafters will clamp the ridge in place. Position the top of the ridge board flush with the top of the rafters and nail through the ridge into the end of the rafter.

Brace the ridge with a sway brace to either a gable end stud or a temporary board on the gable end (Figure 27). Install the common rafters one side at a time, ensuring the ridge stays straight. With three workers, the rafters can be installed in pairs with a worker at the bottom on each side of the building and one at the ridge.

Nail the rafter to the ceiling joists with the required number of nails. With the rafters in place, check the flatness of the roof by sighting along the tops of the rafters.

Temporarily brace the rafters to keep them on spacing and straight.

Gable Ends

Install the gable studs. Make sure they're plumb in both directions. If the correct difference in gable stud length is used, the studs will automatically be plumb. The gable end studs should be directly in line with the wall studs below (this aids the installation of sheathing and exterior finishes).

Bracing

Brace the gable ends plumb using a 2×4 brace nailed to the gable wall and to a bearing wall inside the building (Figure 27). This is commonly called a *sway brace*.

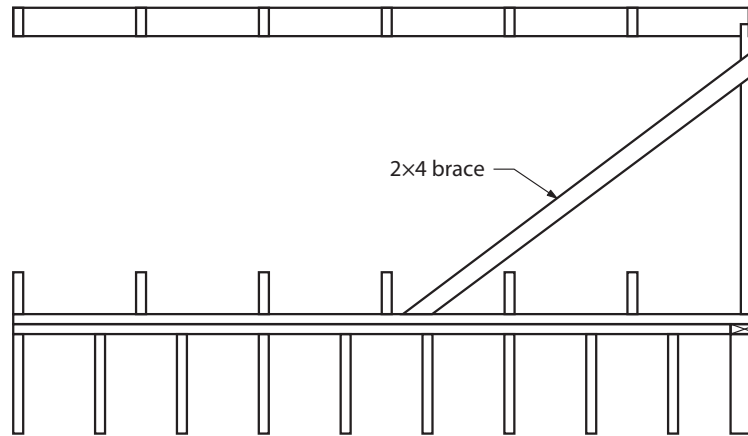


Figure 27 — Sway brace at the gable end

After one end is braced, the other will automatically be plumb. If it's not plumb, check the ridge length and look for gaps in the joins of the ridge. Brace both gable ends.

Collar Ties

Install collar ties level. Keep the top of the sloped edge of the collar tie down from the top of the rafter by about $\frac{3}{8}$ ".

Roof Sheathing

After the rafters have been installed and braced, the roof sheathing is applied. The type of roofing materials will determine the type and installation of sheathing.



Fall protection is required when working at heights greater than 10 feet from the ground or floor.

Panel-type Roof Sheathing

Panel-type sheathing is either plywood or oriented strand board (OSB). $\frac{1}{2}$ " panels are the most commonly used thickness for roof sheathing.

Panel sheathing is installed in the same manner as floor sheathing. Snap a chalk line 4 feet from where the edge of the sheathing hangs over the finished fascia. Install the sheets flush to this line. OSB should be installed with the rough side up.

The position of the roof sheathing at the eave should be carefully considered. The bottom edge of the roof sheathing may be exposed to moisture from drips wicking up the underside of the shingles or splashback from the eavestrough. Some builders will install the sheathing flush with the rough fascia and cap the edge of the sheathing with the finished fascia. Metal edge flashing can also be used to cap the join between the sheathing and the fascia (Figure 28).

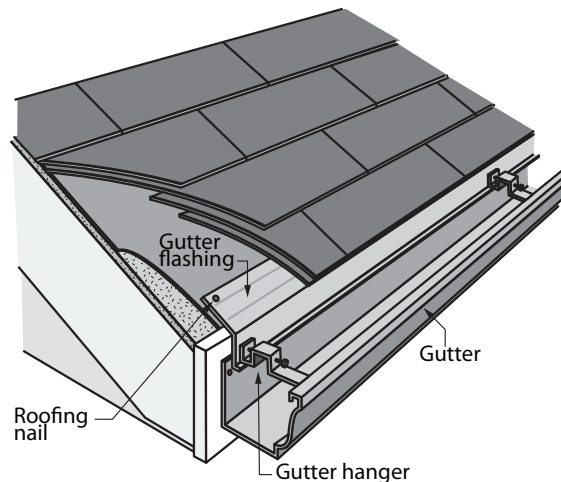


Figure 28 — Eaves flashing at the intersection of the roof sheathing and flashing

Leave a $\frac{1}{8}$ " gap between the ends and edges of the panels. Install H clips if the sheathing thickness requires them (Figure 29). The clip supports the edges of the sheathing and is positioned at the middle of the space between the rafters.

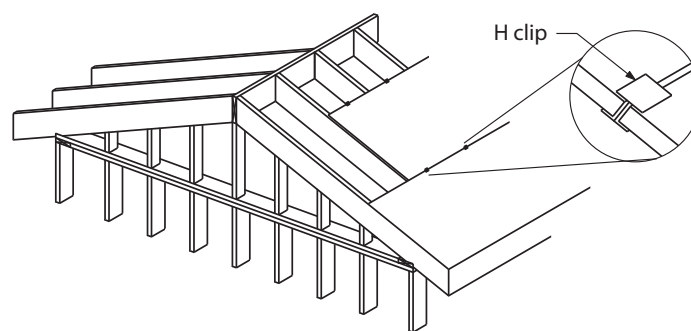


Figure 29 — Supporting sheathing with H clips

Panel sheathing requires fastening at a maximum spacing of 6" along the perimeter and 8" o.c. along supports in the middle of the sheet. The ends of sheets are staggered between rows of sheathing.



Sawdust on a sloped roof surface is very dangerous. Sweep sawdust away after each cut.

Special Roof Sheathing Systems

There are some brands of roof sheathing that have tongue-and-groove edges and don't need H clips.

There are brands of roof sheathing that are waterproof for several months. This system allows interior work, such as electrical and plumbing rough-ins, to be performed as soon as the roof sheathing is installed. This relieves some of the scheduling concerns with more typical roof sheathing (in which shingles must be installed immediately after sheathing).

Lumber Sheathing

Lumber sheathing is installed in a similar manner to panel-type sheathing (Figure 30). Tongue-and-groove boards are commonly used when the eaves or underside of the roof is exposed, such as with an uninsulated outdoor gazebo. If this is done, the roof may need to be strapped to avoid nail penetration to the underside. Stagger the end joints of the boards.

Lumber roof sheathing should be avoided when asphalt roofing materials are used. The expansion and shrinkage of the boards can cause damage to the shingles.

Purlins or Strapping

Spaced roof strapping or purlins were the traditional methods used when installing cedar shakes or shingles. (Some modern installations of shakes and shingles are done over panel-type sheathing, although this can reduce the lifespan of the shakes due to the lack of airflow.) The strapping is spaced according to the required spacing of the shingles.

When the roofing material needs support perpendicular to the rafters, such as clay or concrete tiles, the roof must be strapped with 1×4s or 2×4s spaced for the exposure of the tiles.

Roof strapping is used when installing metal and concrete tile or slate roofs where supports must be perpendicular to the rafters. Lay out the strapping at a spacing that will adequately support the gauge of metal roofing used or the exposure of the roofing material (usually 1×4 or 2×4 strapping is used). Whereas panel-type sheathing effectively braces the roof, purlins don't provide the same bracing effect. The BCBC requires 4" nails to install purlins when used in this manner.

Strapping is also used to achieve cross-ventilation under the sheathing and shingles. Strapping is installed directly onto the rafters and panel sheathing over the strapping, as in the Ladysmith Vacation Cabin.

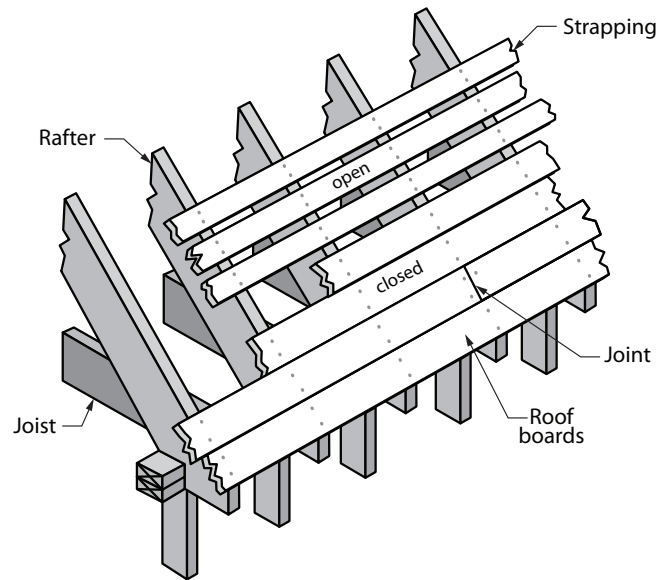


Figure 30—Lumber sheathing



Now complete Self-Test 4 and check your answers.

Self-Test 4

1. Why is the ceiling joist cut $\frac{3}{8}$ " lower than the height of the rafters?

2. Why must a registered engineer design ceiling openings that require more than one ceiling joist to be cut?

3. How are ceiling joists attached when supported by a flush beam?

4. Why are insulation requirements a concern when designing the size of a rafter?

5. What figures on the framing square are used to lay out the angle cut on a gable stud?

6. What figures on the framing square are used to lay out the plumb cut on a common rafter?

7. What figures on the framing square are used to lay out the seat cut at the bird's mouth for a common rafter?

8. What is the minimum size of seat cut allowed by the *Building Code*?

9. What figures on the framing square are used to lay out the sloped cut on a collar tie?

10. What are two ways of framing in the gable end of a building?

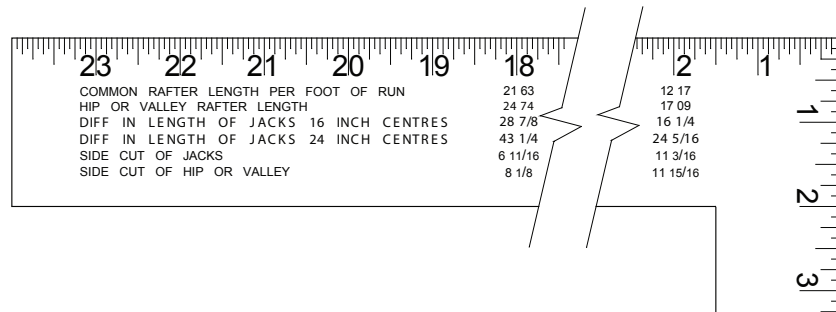


Figure 1 — Portion of rafter table

11. Calculate the line length of a common rafter for a building that is 28' wide with a 5 in 12 slope.

12. Calculate the overhang length for a common rafter if the projection is 18" and the roof slope is 3 in 12.

13. What is the size of the roof framing members required for the Ladysmith Vacation Cabin?

14. How is the ridge installed?

15. What is a sway brace?

16. What are two important points to remember when installing collar ties?

17. How is the ridge laid out?

18. What are H clips used for?

19. What types of roofing require strapping?

LEARNING TASK 5

Describe Truss Roofs

When a package of trusses and hardware arrives at a job site, it can be overwhelming determining what goes where. Trusses are typically bundled in sets by size, by type or the location they're to be placed. These sets are usually numbered for identification.

Accompanying the trusses is a documentation package consisting of a truss layout (Figure 1) and an engineering drawing of each truss (Figures 2 and 3). Detailed information is also included for handling, installation of trusses and hardware, and bracing (Figure 4). The drawings of each truss are often referred to as *truss certificates*.



As the truss package is an engineered product, it must be installed exactly as designed. Trusses cannot be cut nor have holes drilled in them. In many cases, air nailing of hardware is not allowed.

Layout Plan

The layout plan shows where to place each truss as well as any associated hardware.

Example

Figure 1 shows trusses labelled J6. Working up from the bottom, there's a single J6G truss (the G denotes a gable-end truss), seven J6 trusses, five J6A trusses (each of which spans a little farther than the J6 trusses), a single J6 and finally another J6G.

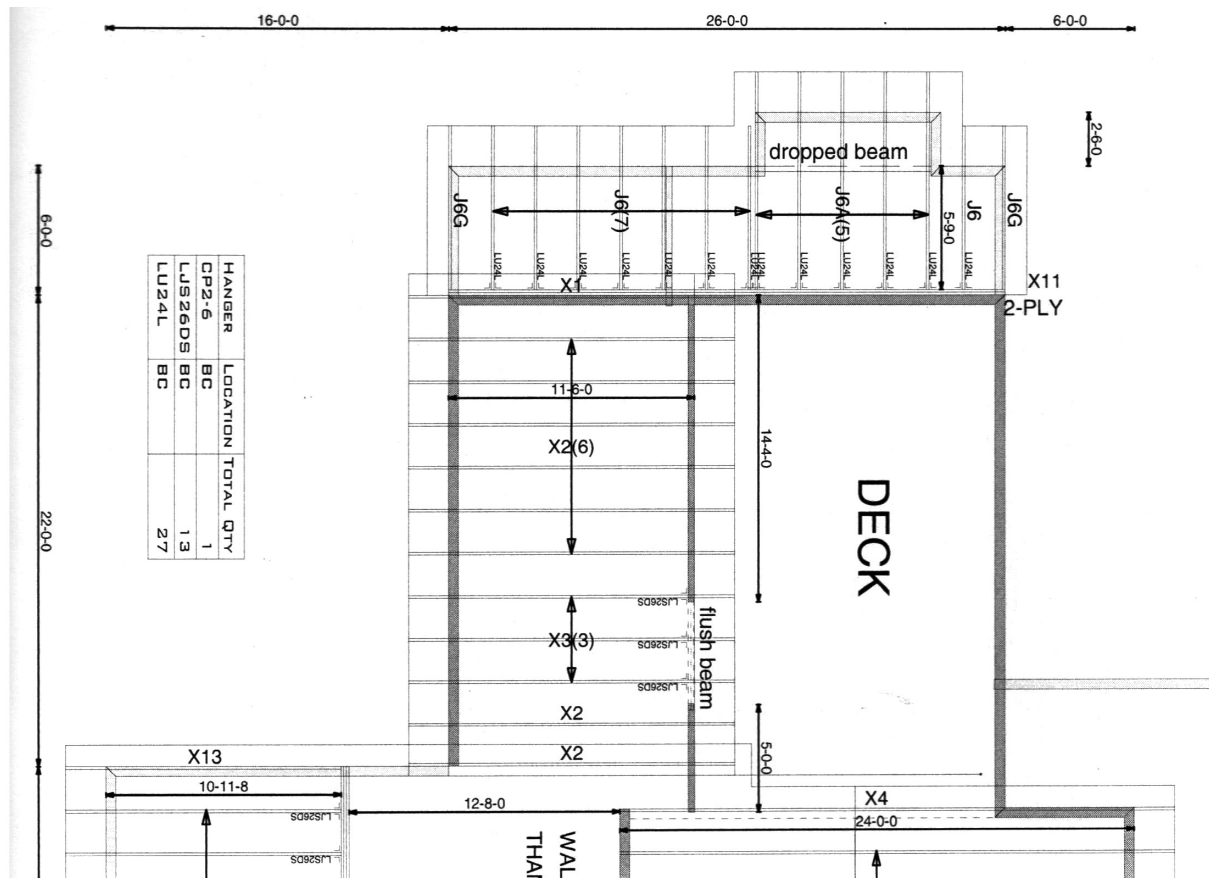


Figure 1 — A portion of a truss layout plan

Truss layouts are sometimes confusing without knowledge of the construction drawings. In Figure 1, J6 trusses are over the main floor level and are hung off a flat top 2-ply girder truss labelled X11. The trusses labelled X1, X2 and X3 are over the 2nd storey. X1 is a gable-end truss. The main floor level walls are shown with light shading and the 2nd level walls are shaded dark.

Hardware is shown in Figure 1 where trusses are hung off the girder and the flush beam. As the X3 trusses are spanning farther than the J6 trusses, the hangers for them are required to be stronger.

Measurements shown on the plan are given in feet, inches and $\frac{1}{16}$ ths of an inch. "5'-9-6" represents 5'9 $\frac{3}{8}$ ".

Truss Certificates

Figures 2 and 3 are not true truss certificates as they don't show all the loads and engineering, and they do not have an engineer's seal. What is shown are the drawings used by the carpenter. A copy of the truss certificates goes to the building inspection department prior to the approval of framing.

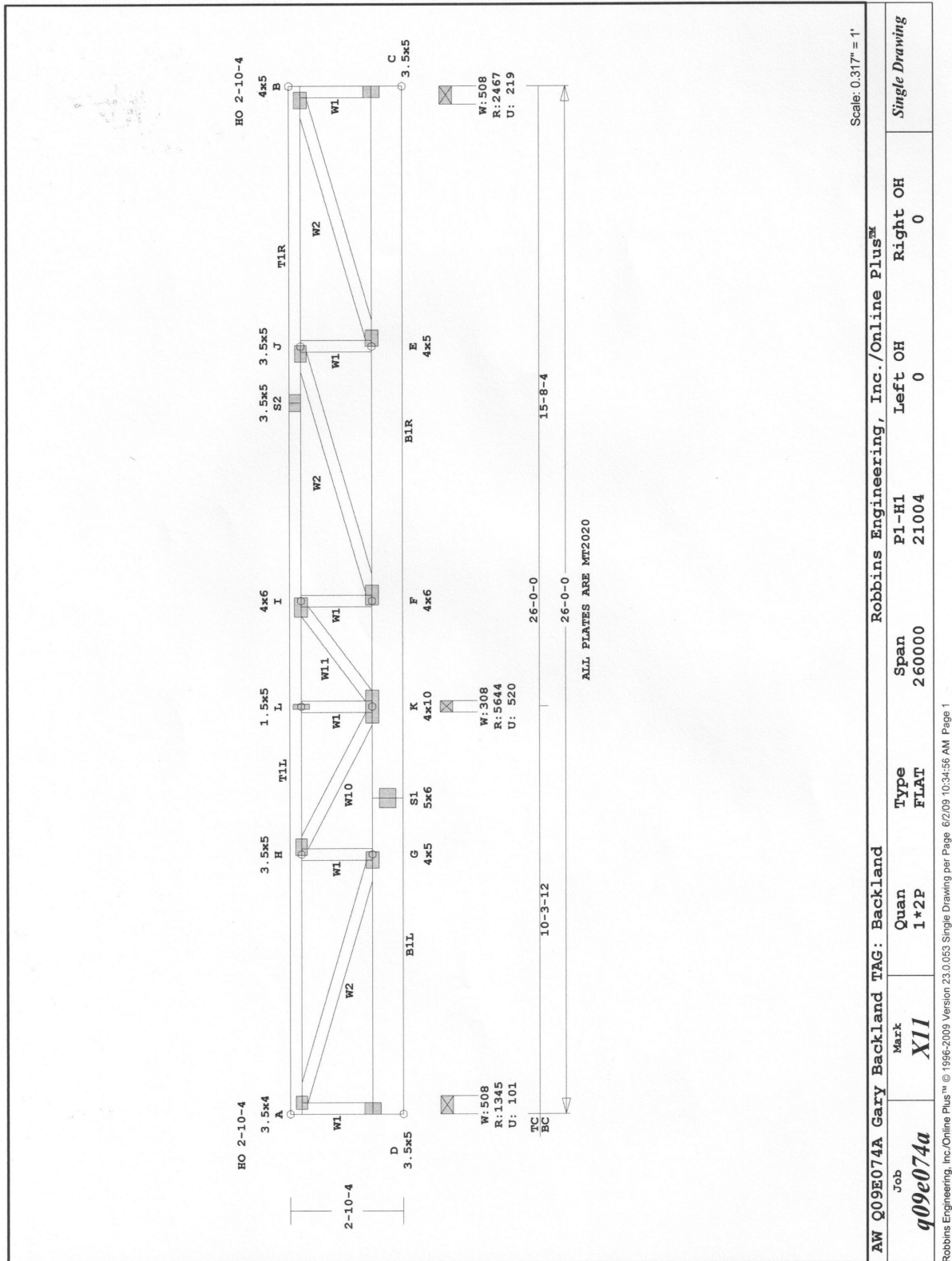


Figure 2—Girder truss drawing X11

Girder truss X11 shown in Figure 2 is a three point bearing truss. The drawing shows this by the three walls shown below the truss. Since this truss is not symmetrical, if it's installed reversed or upside down, it won't be able to carry the loads it was designed for.

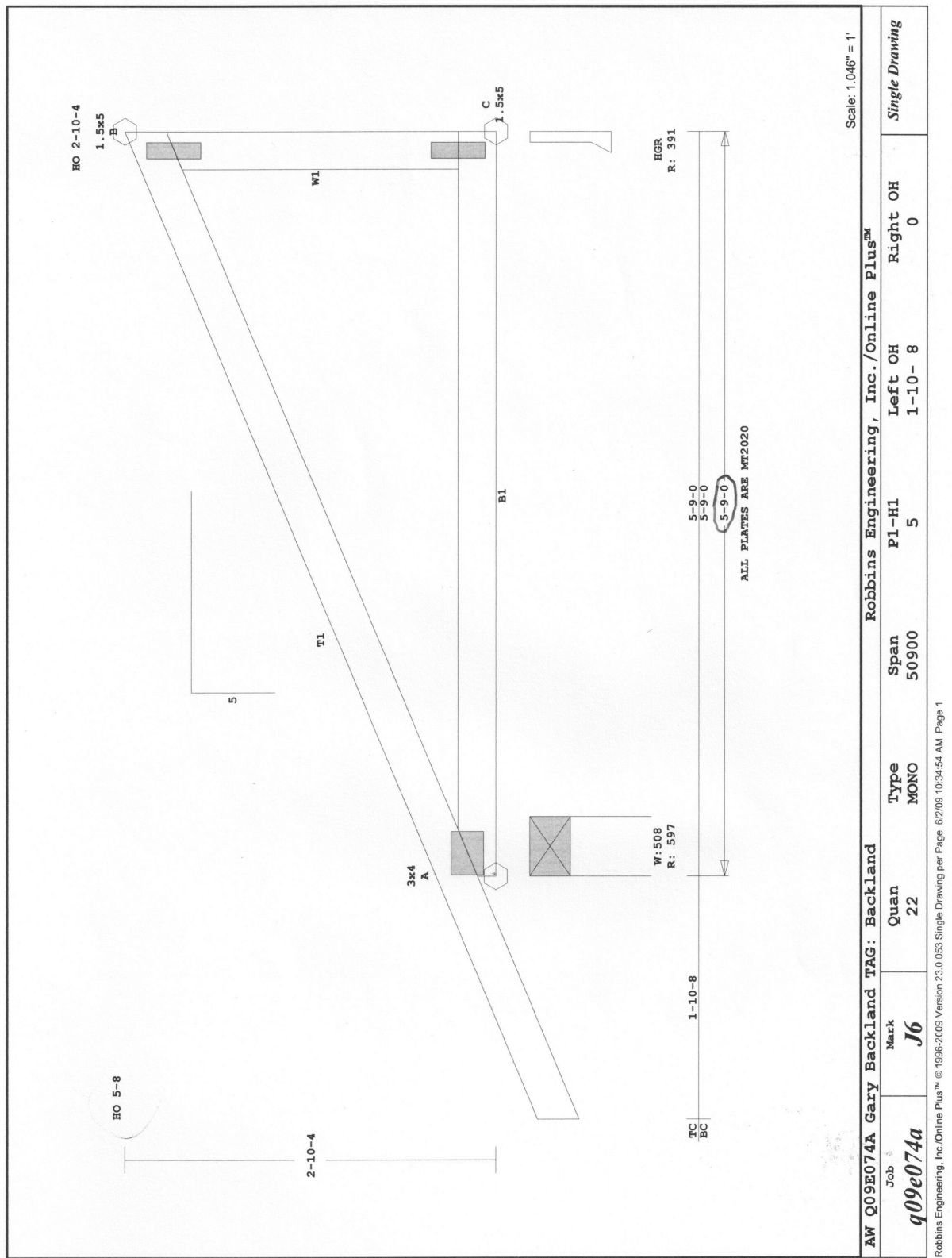


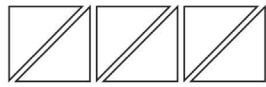
Figure 3 — Truss drawing J6

Figure 3 is a mono truss (only one slope) that's supported by a wall on the left, and on the right with a hanger supported by the girder truss X11. It has a total span of 5'9" and projects 1'10½" past the wall framing (not past the wall sheathing). The thickness of the wall is shown as W:508 for 2×6. In Figure 2, the interior 2×4 wall is shown as W:308.

Handling Installation and Bracing Documentation

Along with the layout and truss drawings are instructions for truss handling, installation and bracing. It's typically several pages long and covers:

- checking trusses
- handling recommendations
- alignment (vertical and lateral)
- permanent bracing
- erection procedure
- mechanical handling
- temporary gable end and top cord bracing
- top cord sheathing plane



**WESTERN WOOD
TRUSS ASSOCIATION
OF BRITISH COLUMBIA**

HANDLING, INSTALLATION AND BRACING OF WOOD TRUSSES

IMPORTANT!

GUIDELINES

Trusses should not be installed until the installer understands these guidelines and has all other installation details including design drawings, truss layout and any other information supplied in the truss site package.

While the guidelines for handling, erection and bracing contained herein are technically sound, it is not intended that they be considered the only method for erecting and bracing of a roof system. Neither should these guidelines be interpreted as superior to or a standard.

These guidelines originate from the collective experience of leading technical personnel in the wood truss industry, but must, due to the nature of responsibilities involved, be presented only as a guide for the use of a qualified building designer, builder or erection contractor. Thus, the Western Wood Truss Association expressly disclaims any responsibility for damages arising from the use, application, or reliance on the guidelines and information contained herein by building designers or by erection contractors.

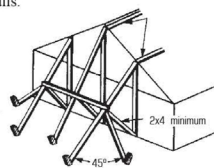
FOR A COMPLETE PROFESSIONAL JOB READ ALL INSTRUCTIONS.

1. Check Trusses

- Count trusses to ensure that you have received the correct number for the job.
- Measure trusses for the correct pitch, span and any special details.
- Check for damage, broken members, loose plates, etc.

2. Erection Procedure

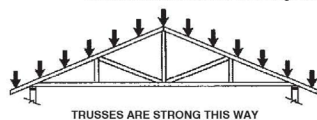
- Mark the bearing plates on both walls to the required spacing of trusses, (Normally 24").
- Hoist the trusses to the roof level, taking care not to bend or twist the trusses.
- If interior walls are available, trusses may be laid flat.
- If no interior walls, trusses shorter than 32' may be inverted and hung from the bearing plates.
Caution: Adequate wall bracing is required to prevent lateral splay of walls.
- Erect Gable or End trusses and install braces to prevent lateral movement, (See Figure). Pre-sheathed gables should not be installed unless adequate bracing is attached to withstand the effects of wind.
- Run a string from heel to heel of the end trusses to be used as a guide line.
- Erect trusses using string to locate heels. Brace each truss as it is erected.
- Trusses may be marked at one end. Place trusses so that all marked ends are on the same side of the building.
- When flat trusses are used, ensure that they are installed with the proper side up.
- Install temporary bracing with sufficient X-bracing to prevent trusses from buckling or toppling over. Install permanent bracing.
- Complete roof by installing roof decking, gable end ladders, etc.



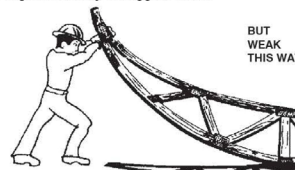
Always provide horizontal restraint for the Top Chords

3. Handling Recommendations

Trusses must be in the vertical plane to take advantage of their superior ability to support loads.



The truss erector or the builder shall take the necessary precautions to ensure that erection procedures and handling methods do not damage the trusses and thus reduce their load carrying capacity.



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Figure 4 — Page 1 of a handling installation and bracing document

Terms

It's important to understand the terminology used in the documentation:

Term	Definition
Bearing	is where the truss is supported
Cantilever	when the bottom cord projects past the exterior wall
Chords	are the top and bottom members
Compression	is a force pushing on a member
Flat top truss	has all or part of the top chord level
Girder truss	is a truss that works like a beam to support other trusses
Heel height	the height of the truss at the exterior wall (for insulation purposes)
Mono truss	has a single top chord sloping in one direction
Piggyback truss	is a truss directly on top of another truss (for transportation purposes)
Point load	is a concentrated localized load
Scissor truss	has a sloping bottom chord
Tension	is a force pulling on a member
Webs	are the short intermediate members and vertical end members

The long webs shown in Figure 5 are tension webs (or ties) and the short webs are compression webs (or struts). Bracing requirements will often be different for the two types of webs.

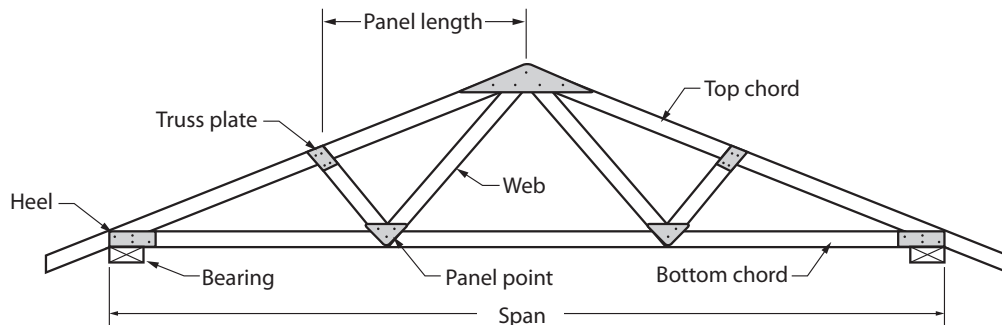


Figure 5 — Common truss terms

Erect Truss Roofs

Trusses are the ultimate example of the use of triangles. Roof trusses use special gang-nail connectors to transfer the tension and compression forces. This makes the whole truss act as one member. Figure 6 shows the forces acting on the members of a typical "W" or Fink truss.

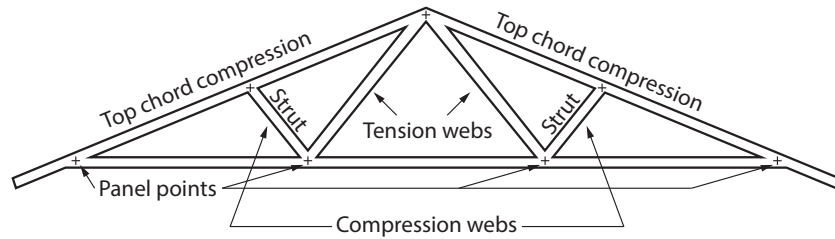


Figure 6 — “W” or Fink truss

The intersection of the web members creates a stable point called a *panel point*. The tension webs are connected to the panel point at the ridge. They keep the bottom chord from sagging.

The panel point formed by the tension web and the bottom chord provides support for the bottom of the compression web (strut). The strut holds up the midpoint of the rafter (top chord).

Truss Shapes

Many truss names derive from the engineers who invented them. The designers Fink, Pratt and Howe patented their truss designs.

The two most common truss shapes used for pitched (sloped) roofs are the “W” (or Fink) truss and the king post (or Pratt) truss (Figure 7).

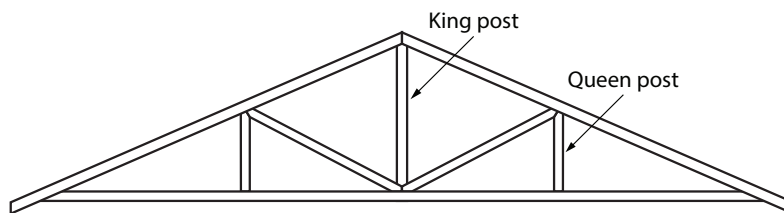


Figure 7 — King post truss

Girder Trusses

When intersecting roofs are built using girder trusses, the girder truss supports the tails of the trusses on the main roof (Figure 8).

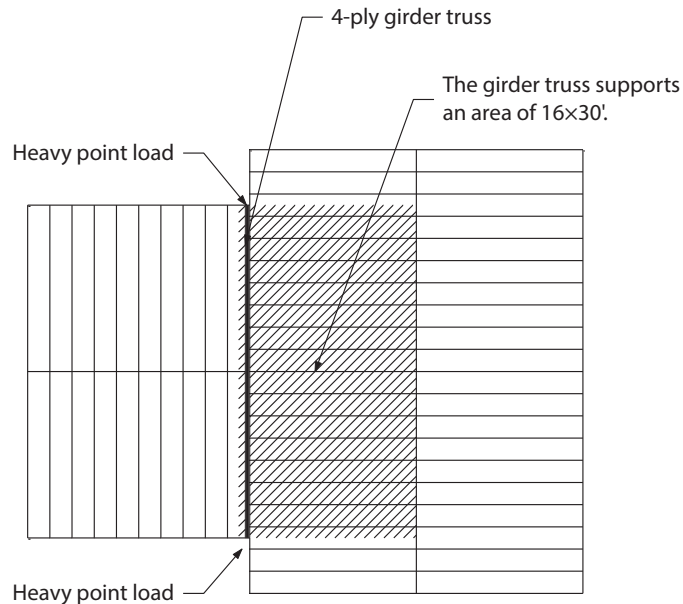


Figure 8 — Plan view of an intersecting roof

The amount of snow load varies, but even with a light snow load the girder is supporting over 20 000 pounds. This means that the supports at each end of the girder are supporting 10 000 pounds each. These heavy loads must be carefully supported.

An engineer will often require that the top plate of the wall supporting the girder be made from Douglas fir. Douglas fir has greater compressive strength than spruce and will not crush under the heavy load. Metal bearing plates are specified for very heavy loads.

Valley Trusses

The valley of an intersecting roof is built using valley trusses. Valley trusses are a simple triangle shape. They're supported on top of the trusses of the main roof (Figure 9). Often the main roof is partially sheathed and the valley trusses are installed onto the sheathing.

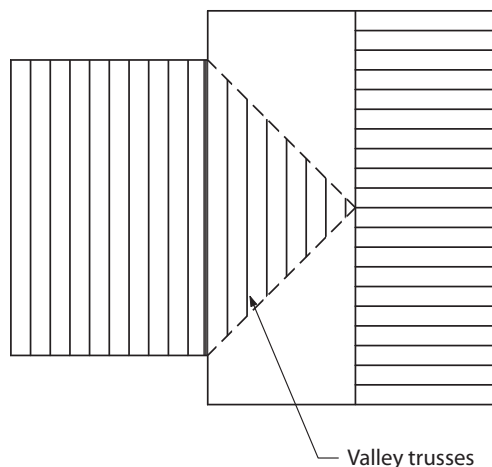


Figure 9 — Plan view of valley trusses

Flat Top Trusses

Flat top trusses are regular pitched trusses that have their top flattened off.

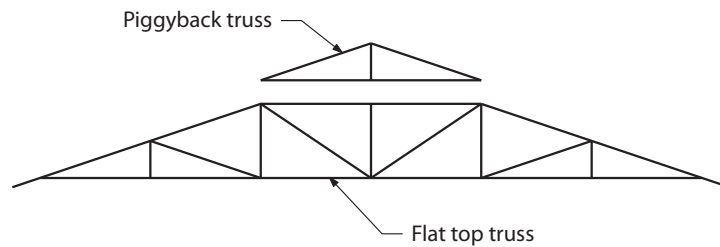


Figure 10 — Flat top truss with piggyback truss

There are several reasons for flattening the top of a truss: for design purposes, to create a hip end or to allow for the transport of larger trusses. For the latter case, a piggyback truss is set on top of the flat top truss (Figure 10).

Installation of Trusses

Most roofs are built using prefabricated trusses. Trusses are built in a plant using jigs and clamps to keep them exactly the same shape and size. They're delivered to the site by flatbed trucks and lifted onto the walls with a crane.

There are several methods of installing the trusses for a gable roof. All of the methods position the trusses by aligning them to a string line or a straight wall. A crew of three or four workers is best for installing trusses. Three are needed on the roof and one on the ground.

Truss Layout

The layout of trusses is no different than the layout of rafters. Trusses are generally laid out at 24" o.c. Make sure the layout of the trusses is done before the trusses are lifted onto the walls. The truss manufacturer will provide a detailed layout map for the trusses. This layout must be followed precisely for correct installation. As trusses are an engineered component, the installation will be inspected by an engineer.



As with rafter installation, safety harnesses attached to lifelines are required when working over 10 feet above the ground or the floor level.

Lifting Trusses

Roof trusses span the full width of the building. If the rafter tails are included, the width of the trusses can be over 30 feet. Trusses are usually built from small-dimension lumber, such as 2×4 and 2×6. The large size and the lightweight structure make trusses awkward to handle.

Trusses are usually lifted with a crane. The trusses are lifted either in packaged groups of 10 to 20 trusses, or individually. It's not uncommon for some trusses to be lifted by hand. They're awkward, often heavy and require two or more people to lift safely.

Lifting Packages of Trusses

If packages of trusses are lifted onto the walls, make sure the walls are sheathed or adequately braced to support the trusses. The installation usually begins with a gable truss or a girder truss. Ensure the trusses within the package are oriented in the correct order.

Lifting Single Trusses

When lifting a single truss with a crane, a single sling is used at the peak (Figure 11).

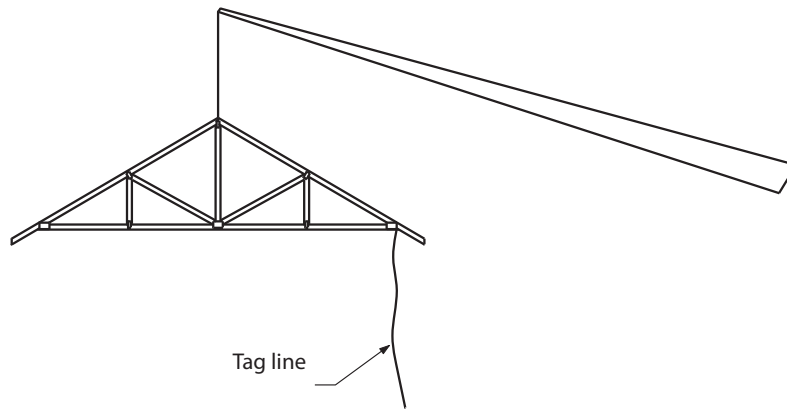


Figure 11 — Lifting a single truss

If the roof slope is very flat, a spreader bar may be needed to keep the truss from bending out of shape.

Use a *tag line* when lifting with a crane. The tag line should be long enough to control the load until on the roof.

Gable Trusses

The gable trusses are installed first. Most gable trusses are “dropped.” The top chord is lowered to allow space for 2×4 outriggers to be installed. Tail rafters are extended from the dropped truss to support the eave.

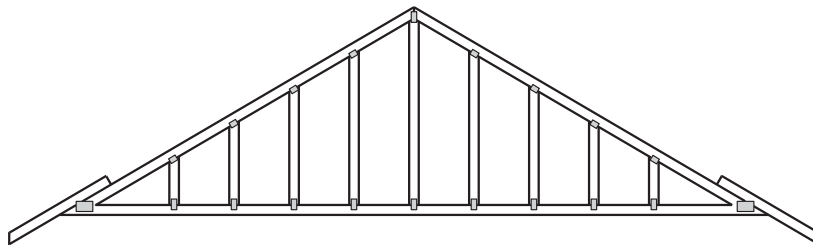


Figure 12 — Dropped gable truss (non-structural)

The gable truss shown in Figure 12 is non-structural. It cannot span over open space—a bearing wall must support it. If a gable truss is used over the end of a carport or open space, a structural gable truss must be used.

The 2×4 verticals in Figure 12 are positioned on the flat. They're used to support the wall sheathing and exterior finish.

Install and brace the gable trusses at each end of the building. Use the “three block” method described in Competency H-4 Build Walls Systems to align the intermediate trusses. As each truss is positioned, brace it to the previously placed truss.

Nailing

Trusses are toenailed to the supporting walls with two 3¼" nails. Drive these nails through the metal gang-nail plate at the walls. The bottom chord of the trusses should not be fastened down to the interior walls in the building. Avoid splitting the truss member when nailing.

Anchors

An engineer may specify that framing anchors be used to secure the trusses at the walls (Figure 13). These anchors must be installed as shown on the drawings.

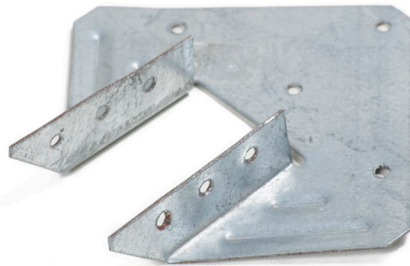


Figure 13 — Hurricane clip

Bracing

Temporary and permanent braces are used with trusses. When installing trusses with a crane, install bracing to keep the bundle upright before releasing the truss from the crane.

Temporary Bracing

Temporary bracing is used to hold the trusses plumb and align them while installing the roof sheathing. The braces consist of 1×4 boards at the ridge and midway along the top chord. Temporary 1×4 angle braces installed on the inner webs are used to plumb the trusses. Install temporary bracing so that the first row of sheathing can be installed without having to remove the bracing.

Permanent Bracing

Permanent braces are used to make the truss frame rigid and to support compression webs. Bracing requirements are included in the engineering specifications for the roof. Typically, diagonal or perpendicular lateral 2×4 braces are nailed to each truss with two 3¼" nails at 10-foot intervals. T or L braces are sometimes specified.



Never leave trusses overnight without installing the permanent bracing required by the engineer's design.



Now complete Self-Test 5 and check your answers.

Self-Test 5

1. Can trusses be notched or drilled?

2. How does the builder know where to place each truss?

Refer to Learning Task 5 Figures 1–3 when answering questions 3–6.

3. How many X3 trusses are there in Figure 1?

4. What is the distance of the span on the left side of the interior bearing wall shown in Figure 2?

5. How tall is the girder truss shown in Figure 2?

6. From the bottom of the bottom cord to the top of the top cord, how tall is the mono truss J6 in Figure 3?

Refer to Learning Task 5 Figure 4 when answering questions 7–9.

7. Which trusses are installed first?

8. What is used to align trusses?

9. What is the concern with pre-sheathing gable end trusses?

10. Give an example of a point load.

11. Why is a piggyback truss used?

12. List two reasons that flat top trusses are used.

13. Sketch a “W” truss. Show the compression and tension webs. Label all of the parts with their names and the stresses they resist.

14. Why would an engineer specify Douglas fir for the top plates?

15. For what situations is a structural gable truss used?

16. What o.c. spacing is usually used for trusses?

17. How are trusses aligned when setting them?

18. Which trusses are set first?

19. Describe three safety precautions used when setting trusses.

Answer Key

Self-Test 1

1.
 - i. tie the bottoms of the rafters together
 - ii. tie the supporting walls together
 - iii. support the interior ceiling finish
2. low-slope
3. Overhang is measured along the length of the rafter; projection is measured horizontally.
4. Also known as a *barge rafter*, the rake or fly rafter is the outside rafter at the gable end of the roof.
5. 12"
6. 250 mm
7. Working points are the marks on the rafters where measurements are made and cuts laid out.
8. Line length is measured along the rafter's length. The run is the rafter's horizontal span.
9. A ridge board is used to align the tops of the common rafters. A ridge beam is used to support and align rafters at the ridge.

Self-Test 2

1. rafter layout
2. 4 nails per connection
3. 5
4. 8 nails (the joist-to-joist connection requires 9 nails)
5. minimum of two 2x10s wide
6. Without enough bracing, partway through assembly the roof can pivot at the wall connections and fold down, trapping and injuring or killing workers.
7. to keep the ridge board straight (aligned)
8. Max. span is 24'6" (7.47 m).
9. Max. span is 5'10" (1.78 m).

Self-Test 3

1.
 - i. the methods used by the builders
 - ii. the experience of the carpenters
 - iii. the design of the building
2.
 - i. Line length plus overhang of the common rafter times length of the building plus gable end projections is the area on each side. Multiply by 2.
 - ii. Area of the roof on the flat times the slope gain ratio.
3. $14.42 \div 12 = 1.201$

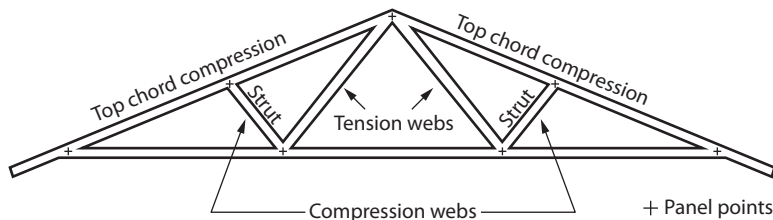
Self-Test 4

1. so the ceiling joist does not interfere with the roof sheathing
2. due to the complicated tension loads
3. with joist hangers and metal connectors across the top of the beam
4. The minimum rafter size may not provide enough depth for the insulation and ventilation required in the ceiling.
5. rise and run—cut on the rise
6. rise and run—cut on the rise
7. rise and run—cut on the run
8. 38 mm
9. rise and run—cut on the run
10.
 - i. supported by a gable wall
 - ii. notched into a common rafter at the gable end
11. 182"
12. $18\frac{9}{16}"$
13. 38×184 (2×8) can span 3.87 m
Table A-4 Roof Joists-Specified Roof Snow Load 1–2 kPa
Snow load = 1.72, use 2
Fir #2 at 16" o.c.; required span in loft area = 3.35 m
14. Nail opposite pairs of common rafters to the ends of the ceiling joists. Let the tops of the rafters rest against each other. Install a pair at each end of the ridge board or at the ends of the pieces of ridge. Lift the ridge and place it between the pair of rafters. The weight of the rafters will clamp the ridge in place. Position the top of the ridge board flush with the top of the rafters and nail through the ridge into the end of the rafter.
15. brace used to plumb the gable end and brace the ridge in the correct position

16. i. install level
 - ii. keep the top of the sloped edge of the collar tie down from the top of the rafter by about $\frac{3}{8}$ "
17. using ceiling joist layout
18. support the edges of the sheathing
19. metal, tile or slate

Self-Test 5

1. no
2. by matching the trusses against the truss drawings and using the layout plan
3. three
4. $10-3-12 = 10'3\frac{3}{4}"$
5. $2-10-4 = 2'10\frac{1}{4}"$
6. $2-10-4 = 2'10\frac{1}{4}"$
7. gable end trusses
8. a string line from heel to heel of the gable end trusses
9. bracing for wind loads
10. Where a beam or second girder truss is hung off a girder truss. Where a girder truss sits on a wall.
11. for trusses that are too tall to transport
12. i. design purposes
 - ii. to create a hip end
 - iii. to allow transport of larger trusses
- 13.



14. Douglas fir has greater compressive strength than spruce and will not crush under the heavy load.
15. situations where the gable truss spans an open space
16. 24" o.c.

- 17. to a string line or a straight wall
- 18. gable truss or girder truss
- 19.
 - i. fall protection when working at height
 - ii. several workers when lifting
 - iii. adequate bracing to keep trusses from falling

