BRANZ

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BULLETIN

LOAD PATHS

August 2017

- Buildings must be designed to withstand a variety of loads that are imposed both vertically and horizontally.
- This bulletin defines a load path, describes the loads imposed on framed buildings and explains how loads are transferred through the building via load paths.
- It describes the design requirements to ensure effective load paths are created.

1. INTRODUCTION

1.0.1 Buildings must be designed to withstand a variety of loads (Figure 1) from:
- the weight of the building elements, materials, fixtures and permanently attached equipment
- people, furniture and movable equipment stored in the building
- external forces acting on the building such as wind, earthquake and snow.

1.0.2 The loads are transferred down through the building structure and its fixings to the foundations and into the ground. The routes by which the loads are transferred are called load paths.

1.0.3 This bulletin describes:
- the loads imposed on buildings
- the load paths through buildings
- design requirements for load paths.

2. LOADS ON BUILDINGS

2.0.1 Loads acting on buildings are:
- vertical loads (gravity or uplift), and
- lateral loads.

2.1 VERTICAL LOADS

2.1.1 Loads acting in a vertical direction are:
- Dead loads are from the weight of the building components and materials such as the roof, walls, columns, beams, floors and so on (Figure 1a).
- Live loads are from building occupants, furniture, storage, movable equipment and machinery and may also include the loads imposed from rain or snow (Figure 1b).
- Uplift loads from wind action.

2.1.2 Dead loads are permanent and static – that is, they are constant throughout the life of the building. Live loads are temporary and will change during a building's lifetime.

2.1.3 A vertical load may be a downward or upward acting force. Upward movement can occur from uplift or a suction effect from wind or vertical shaking from an earthquake (as occurred in the Canterbury earthquakes).

2.2 LATERAL LOADS

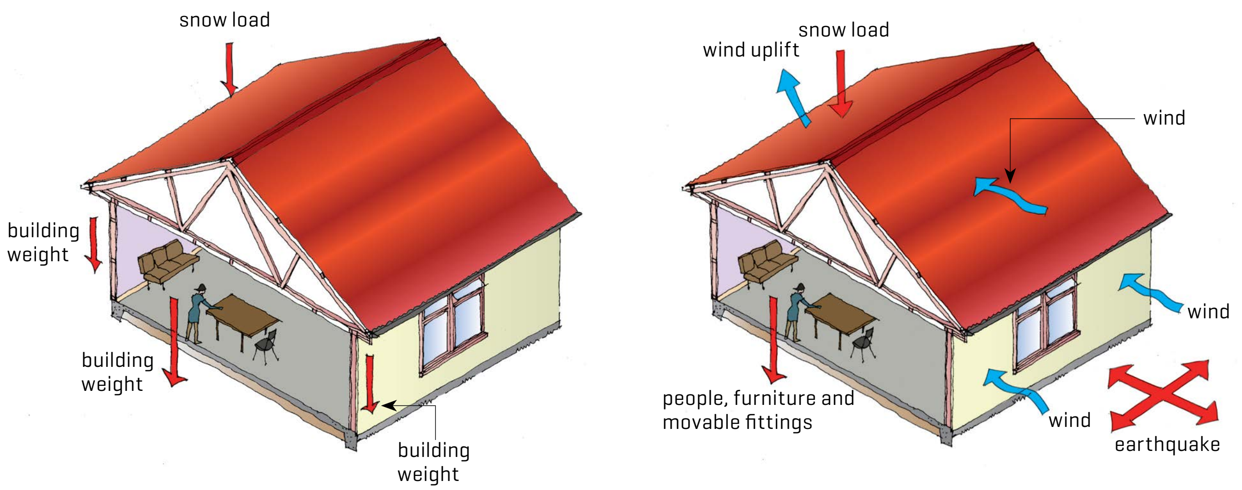
2.2.1 Lateral loads are from wind and earthquakes. They are externally imposed, intermittent, dynamic (changing) forces that may act either vertically or horizontally on a building.

2.2.2 A horizontal load is a sideways force from wind striking the side of a building or a side-to-side movement from an earthquake.

2.3 RESISTANCE TO LOADS

2.3.1 Buildings must be able to withstand or resist the imposed loads. They may be resisted in different ways:
- Vertical gravity loads are resisted by the floor structure and wall framing and ground bearing.
- Vertical uplift loads are resisted by the connections, floor structure and wall framing transferring the load to the ground.
- Lateral loads must be resisted and transferred to ground through the framing and connections by incorporating stiffness (bracing).

2.3.2 As loads are transmitted down through the structure, the structural members and their fixings must be able to withstand them.



(a) Dead loads on buildings

(b) Live loads on buildings

Figure 1. Loads on buildings (insulation omitted for clarity).

3. LOAD PATHS

3.0.1 Load paths describe the way loads are transferred through structural elements such as columns, beams, loadbearing walls, diaphragms, braced walls and rigid frames. They run down from the roof to the foundations and into the ground in a continuous route.

3.1 VERTICAL LOAD PATHS

3.1.1 Vertical load paths transfer gravity and uplift (suction) loads through the building to the ground. For gravity loads, each structural element must be able to support itself under compression, the weight of the structural elements above that it is supporting and the imposed loads. For uplift loads, the load is resisted by the ability of the members in tension and their connections.

3.1.2 A typical load path runs from the roof to purlins, rafters or trusses, down through loadbearing walls or frames to a concrete floor slab and foundations or to flooring, joists and bearers and foundation walls (Figure 2).

3.1.3 Where there is a break in the vertical path such as a window or door in a loadbearing wall, the load must be transferred horizontally through a beam or lintel to its supporting framing. The load path splits the load in two directions to be evenly distributed along the member in each direction (Figure 2).

3.1.4 Where an internal loadbearing wall is to be removed, an alternative load path must be provided, such as a beam across the opening formed where the wall was removed.

3.2 HORIZONTAL LOAD PATHS

3.2.1 Horizontal load paths resist lateral loads from wind and earthquake through connections, framing, wall bracing, ceiling and floor diaphragms, and solid blocking or herringbone strutting between floor joists. The lateral loads are then transferred from the horizontal load path to vertical elements and ultimately to ground (Figure 3).

4. WIND LOADS

4.0.1 Wind loads from a moving mass of air act horizontally from one direction but create pressure variations around and over the building according to the direction of the wind and the shape of the building.

4.0.2 Wind acting on a building creates positive and negative pressure:

- Positive pressure on the windward vertical faces of the building and the roof surfaces that have a slope more than 30° and are facing the direction of the wind.
- Negative pressure (suction) on all leeward faces and windward roof surfaces that are sloped less than 15° and all leeward roof surfaces (Figure 4). Windward roof surfaces between 15° and up to 35° may experience uplift or a downward pressure depending on wind strength and direction.

4.0.3 Wind forces on a building can create the risk of different actions:

- Overturning from a positive pressure on the windward side and negative pressure on the leeward side. The effect of overturning must be resisted by the building weight and the framing connections and connection to the foundations (Figure 5).

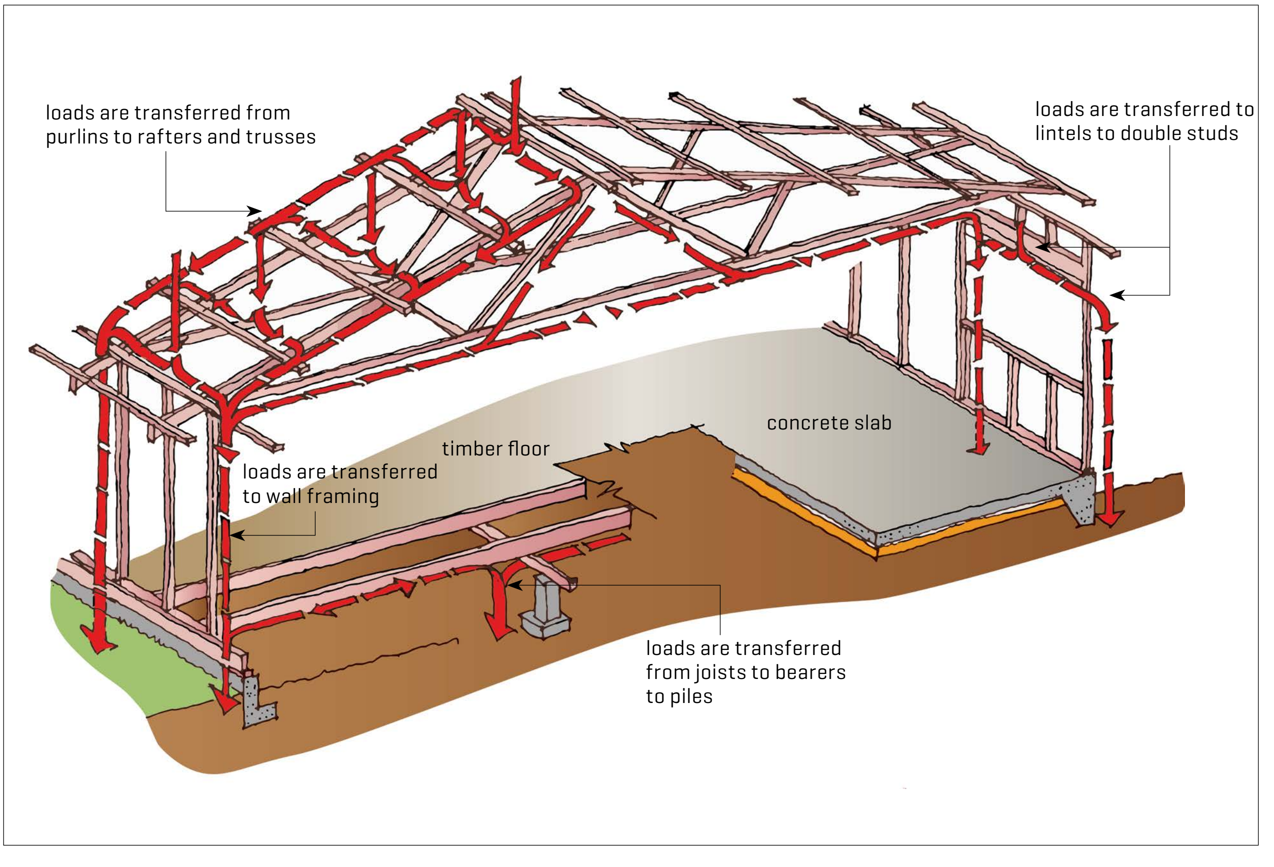
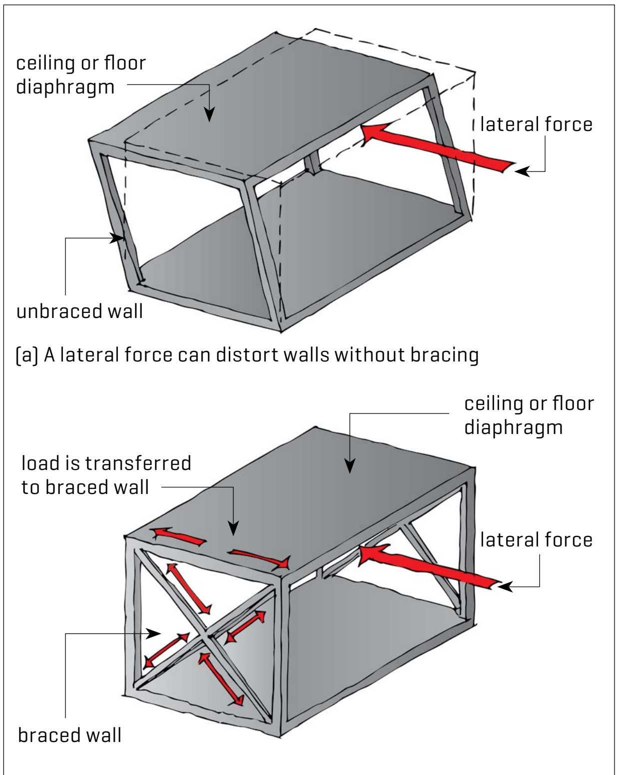


Figure 2. Load paths through a building.



[a] A lateral force can distort walls without bracing

[b] A lateral force is transferred through the diaphragm to the braced walls

Figure 3. Load transfer through ceiling diaphragm to braced wall.

- Racking (twisting) resulting in deformation of all or part of the structure. Racking is resisted by bracing, ceiling diaphragms and rigid joints and connections.
- Uplift from a negative pressure on the roof surfaces and a positive pressure on the ceiling (especially if an opening such as a broken window occurs). The differential pressure can create suction or uplift.
- Suction when wind exerts a negative pressure on the framing and cladding on side and leeward walls. The suction is resisted by framing depth and cladding fixings.

5. LOAD TRANSFERENCE

5.0.1 While load paths are the routes from applied loads to the ground, load transference between elements on the load path occurs at the connections (bolts, straps, brackets and fastenings). Connections are critical to the transfer of loads between different structural elements in the load path in both horizontal and vertical directions (Figure 6).

5.0.2 Both load paths and connections are equally important in providing structural support to a building. If there is a failure of either the load path or the connection, the building or part of the building may fail.

6. DESIGNING LOAD PATHS

6.0.1 Load paths and connections for timber-framed buildings should be designed in accordance with NZS 3604:2011 *Timber-framed buildings* (apply a similar approach for lightweight steel-framed buildings). For lightweight steel, use the NASH standard *Residential and low-rise steel framing – Part 1: Design criteria*.
NZS 3604:2011 covers:

- timber sizes and spacings to resist vertical and horizontal loads
- calculating bracing
- using diaphragms to resist lateral loads
- connections to prevent uplift
- sizings, fixings and jointing requirements for top plates
- lateral support of top plates
- anchors for bottom plates
- sizing/spacing of foundation systems for suspended floors.

6.1 WALL BRACING

6.1.1 Bracing is provided to external and internal walls in both directions along allocated bracing lines to resist the horizontal wind and earthquake loads. Bracing lines must be no more than 6 metres apart in both directions.

6.1.2 Wind loads are from one direction – the direction from which the wind is blowing. Earthquake loads, which typically produce a back-and-forth shaking movement, can come from both directions. Bracing requirements for a building are different for wind and earthquake loads so must be calculated separately.

6.1.3 Wind load calculations are based on the area of the roof and walls facing the wind and are calculated separately for directions perpendicular to one another. Earthquake load calculations are based on the same load in two perpendicular directions. The greater bracing

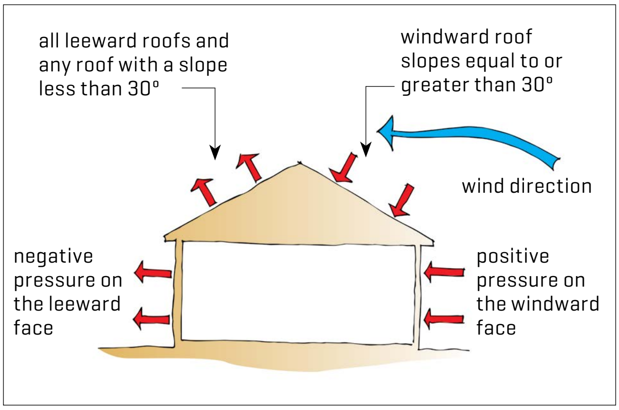


Figure 4. Effects of wind pressure on a building.

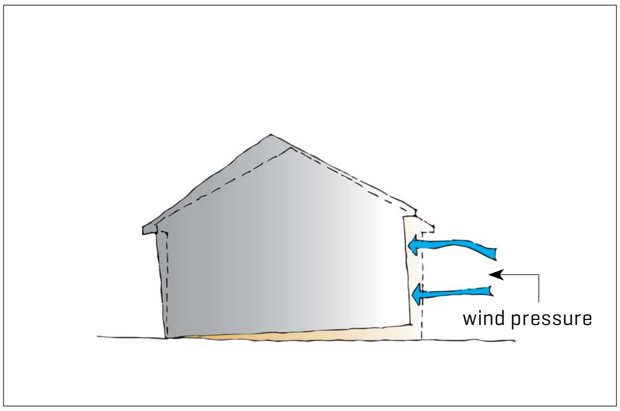


Figure 5. Overturning tendency.

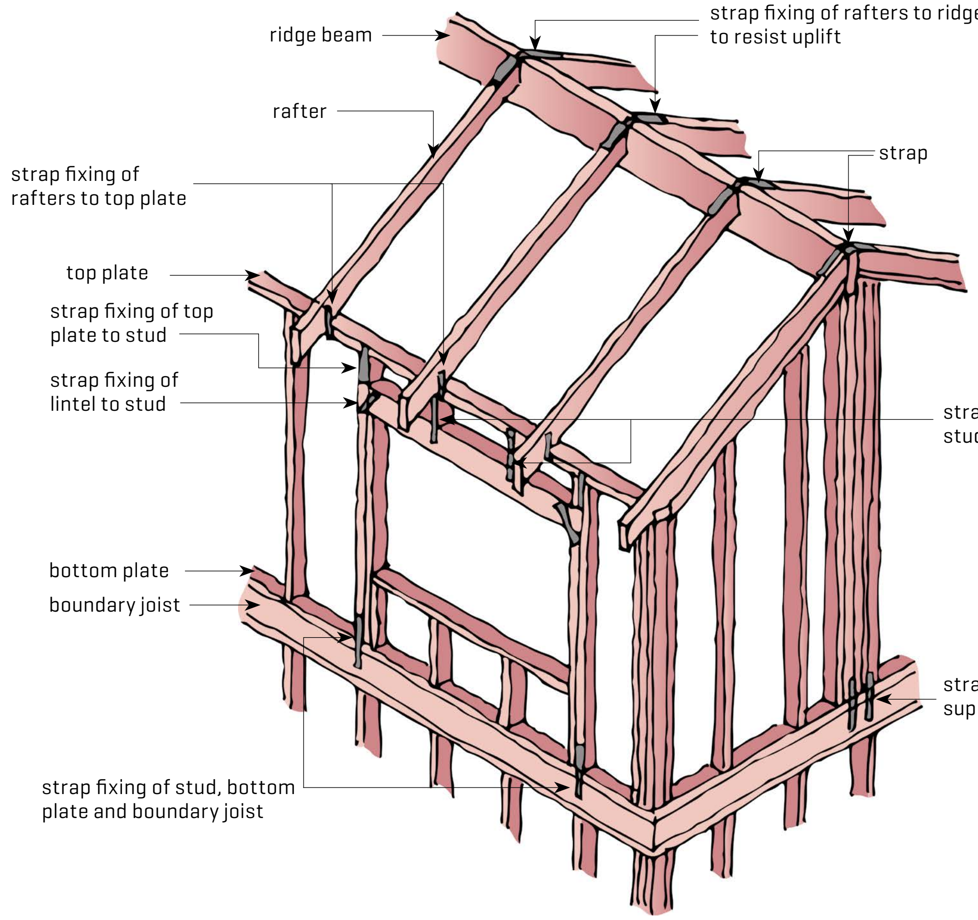


Figure 6. Strapping to resist uplift.

demand (wind or earthquake) becomes the bracing requirement for the building.

6.1.4 Bracing should be:
- distributed around a building as evenly as possible
- located as close as possible to the corners of external walls
- allocated along bracing lines through the building as evenly as possible.

6.1.5 There are many proprietary bracing systems using sheet materials (plasterboard, fibreboard, particleboard and plywood). Systems have been tested to give specific bracing ratings for the material, sheet size and thickness, fixings and framing specifications. For proprietary bracing systems:
- use only the manufacturer's components – do not mix components between systems
- follow the specific system installation instructions.

6.2 FLOOR AND CEILING DIAPHRAGMS

6.2.1 A floor or ceiling diaphragm (Figure 3) is a horizontal load distributor that effectively acts as a flat beam. It transfers laterally imposed loads in both directions to braced walls or rigid frames via a sheet material. For timber-framed buildings, NZS 3604:2011 requires structural diaphragms in situations where the distance between brace lines exceeds 6 metres.

7. SPECIFIC DESIGN REQUIRED

7.0.1 Construction requiring specific design includes:
- lightweight steel framing
- steel portals within lightweight framing used to transfer gravity, wind and earthquake loads
- construction outside the scope of NZS 3604:2011 including:
  - the lintel over an opening in a gable end wall where a ridge beam supports the rafters (Figure 7) and the beam support creates a point load on the lintel
  - a girder truss supporting jack trusses supported by a lintel (Figure 8) – this is a concentrated or point load not covered in NZS 3604:2011 lintel tables
  - when loadbearing walls of an upper floor (parallel to or perpendicular to the floor joists) are more than 200 mm offset from a lower floor loadbearing wall or support (Figure 9).

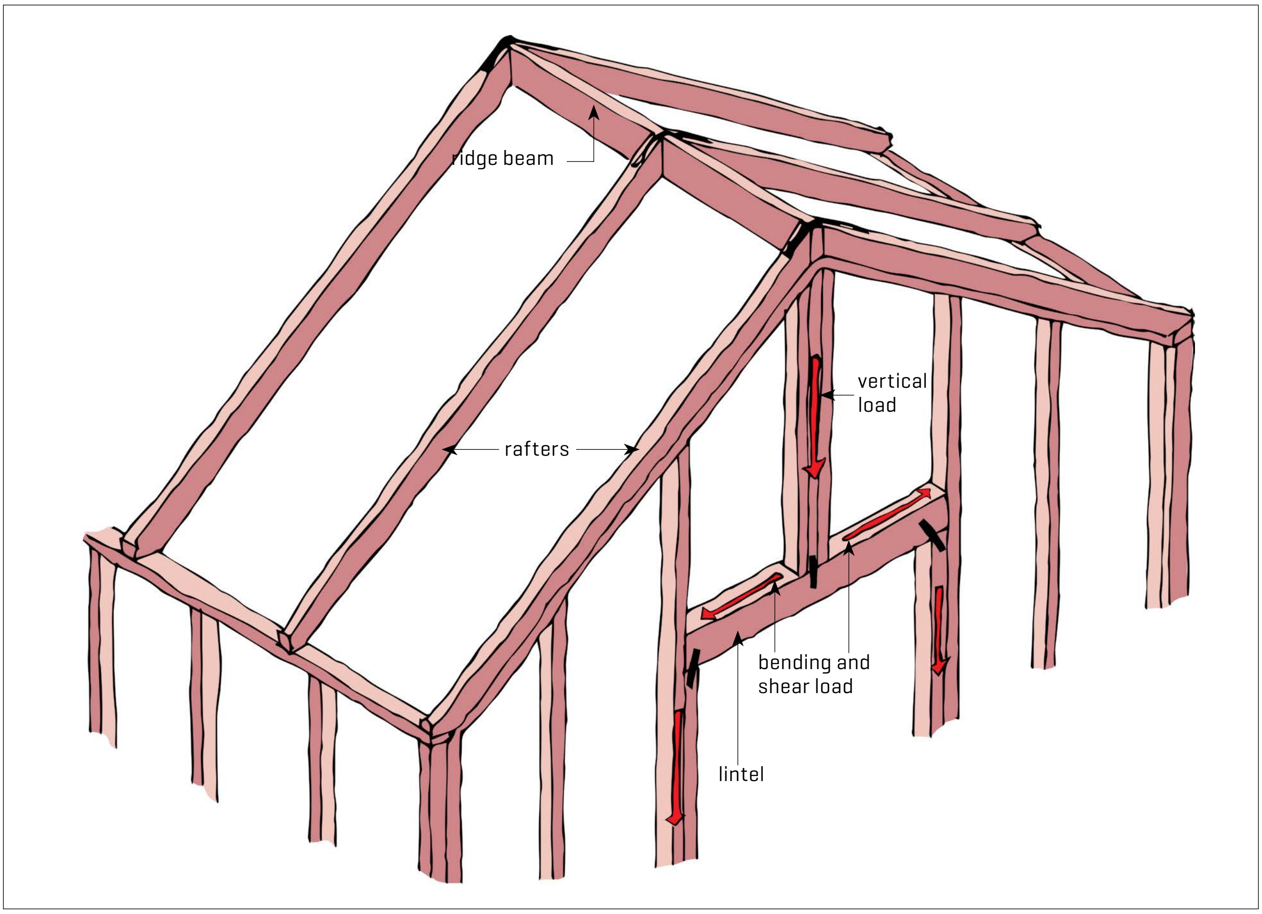


Figure 7. Ridge beam support of gravity loads (uplift loads work in reverse).

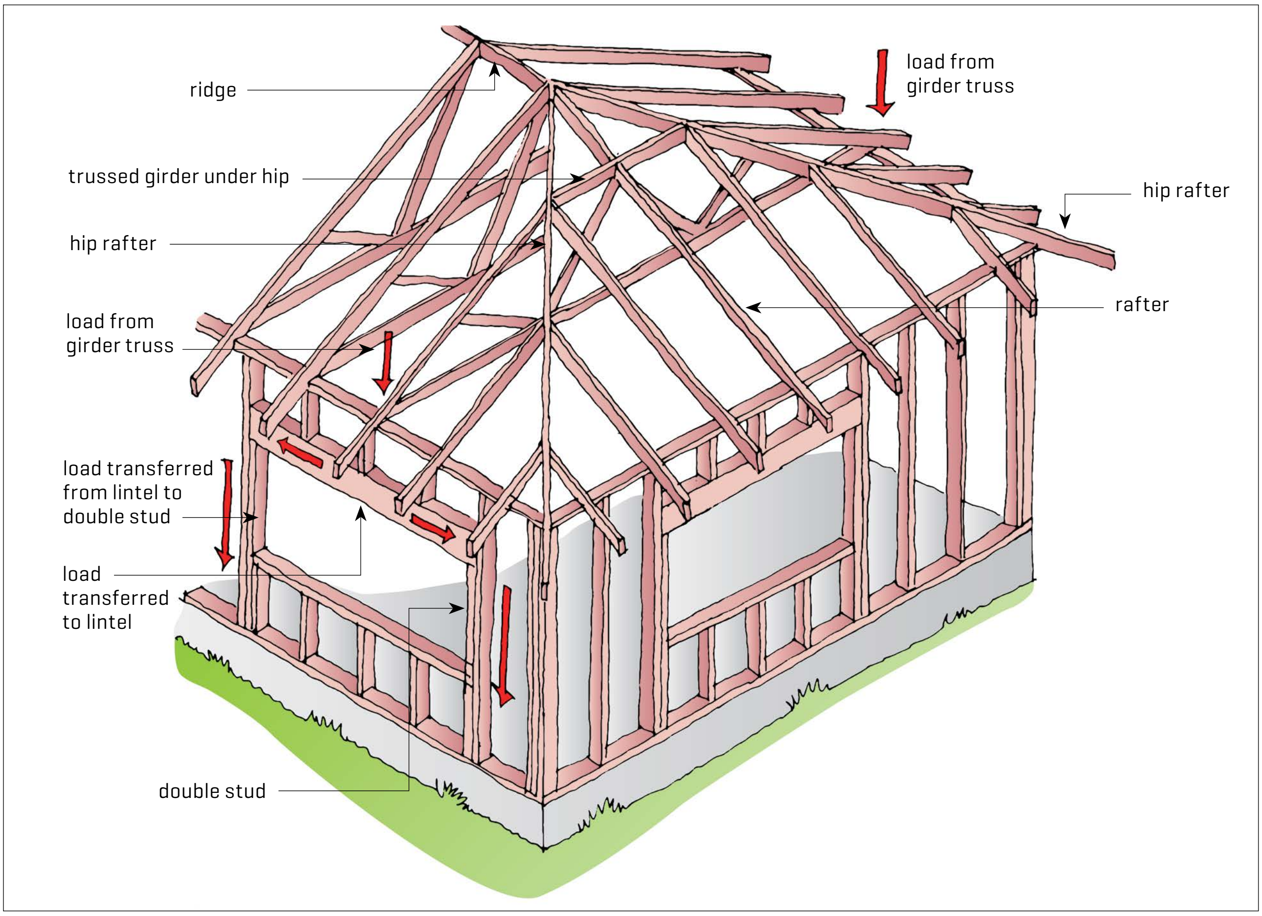


Figure 8. Loads transferred by a lintel supporting a girder truss.

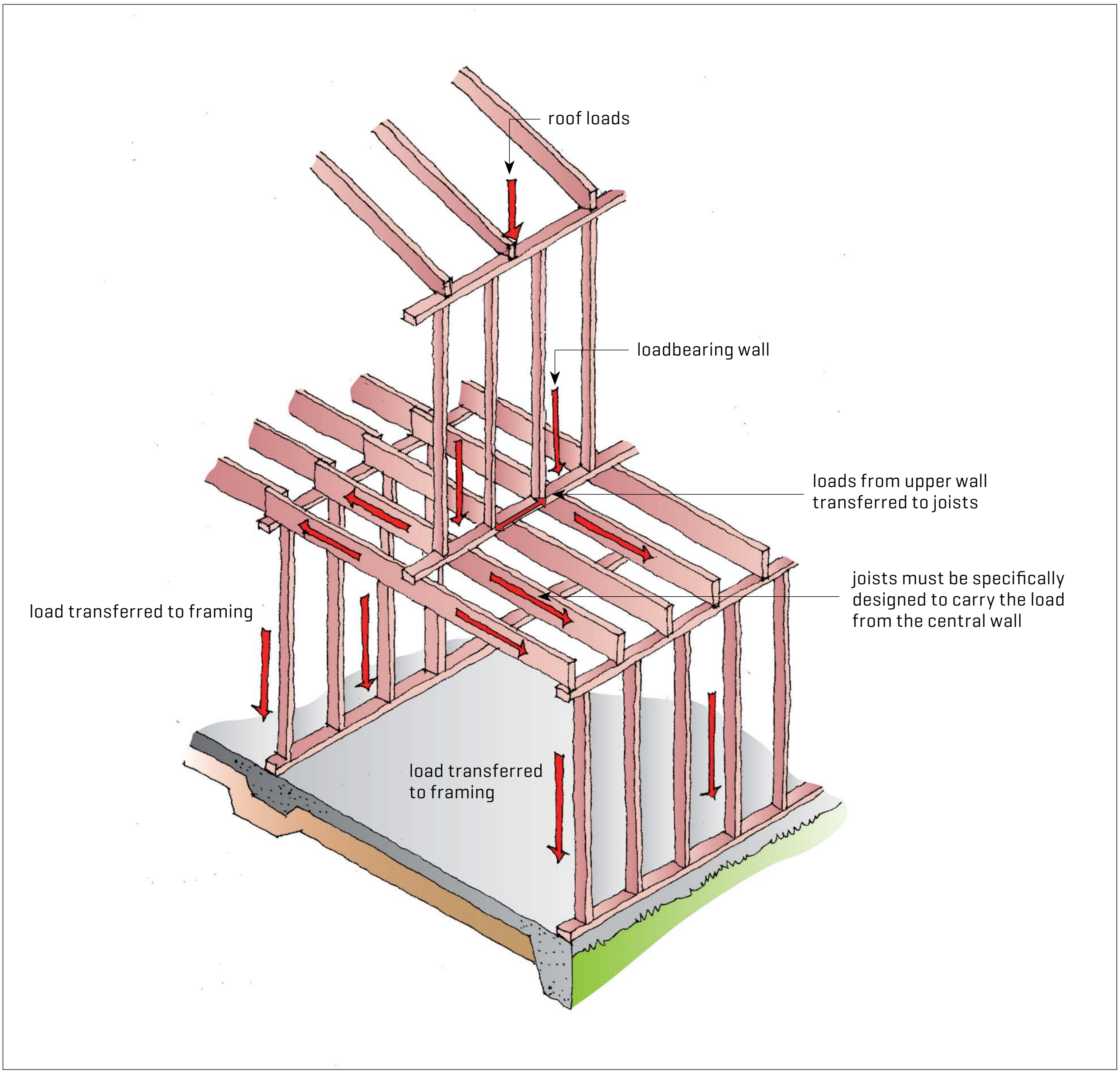


Figure 9. Specific design is required to transfer loads for loadbearing walls supported on joists.

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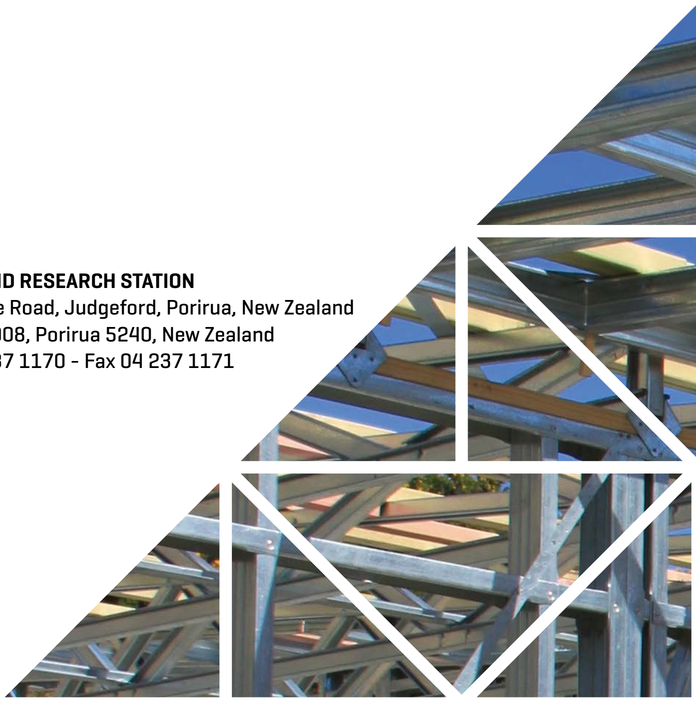

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