Scheme development: Details for portal frames using rolled sections

This document provides typical details and guidance for the basic components in portal frames using rolled sections.

Contents

1. Introduction

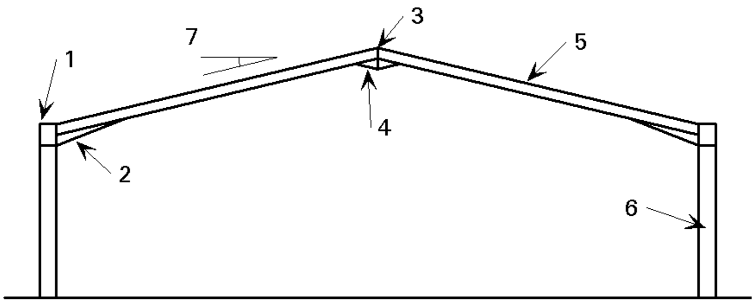
Steel portal frame are a common and an economic form of construction for single storey buildings. Portal frames are used in many aspects of modern life, such as retail stores, distribution warehouses, manufacturing facilities and leisure centres.

1.1 Pitched roof portal frame (using I sections)

A single-span symmetrical pitched roof portal frame (Figure 1.1) will typically have:

- ❑ A span between 15 m and 50 m
- ❑ An eaves height between 5 m and 10 m
- ❑ A roof pitch between 5° and 10° degrees (6° is commonly adopted)
- ❑ A frame spacing between 5 m and 8 m (the greater spacing being associated with the longer span portal frames)
- ❑ Haunches in the rafters at the eaves and apex.

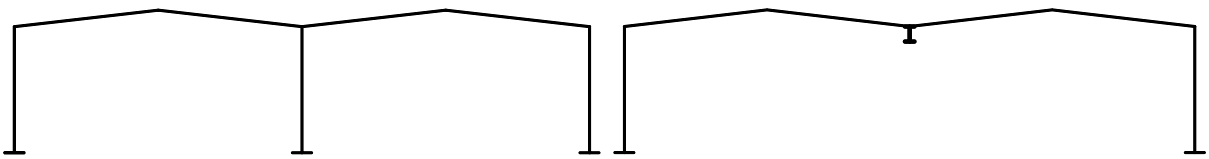
Most of these characteristics are dictated by the economics of portal frames relative to other forms of construction. The use of haunches at the eaves and apex both reduces the required depth of rafter and achieves an efficient moment connection at these points.



Key:		3	Apex	6	Column
1	Eaves	4	Apex haunch	7	Roof pitch
2	Eaves haunch	5	Rafter		

Figure 1.1 Single-span symmetric portal frame

In multi-span portal framed buildings, it is common practice to use valley beams to eliminate some columns (see Figure 1.2)



(a) With internal column ***(b) With valley beam***

Figure 1.2 Multi-span frame

1.2 Types of bolt

Opinions vary about the type of bolts to be used.

For non preloaded bolts (generally 20 mm or 24 mm diameter bolts in normal clearance holes) the bolt class used usually depends on the country of construction: class 10.9 bolts are used in most of Europe, but class 8.8 bolts are used in UK and 6.8 bolts are used in France.

Preloaded bolts may also be used, especially for cases involving heavy dynamic loading, such as where the frame is designed to support crane girders. Such bolts may be used in those connections directly supporting the crane to prevent fretting of the connections and loosening of the bolts. Other connections that may be affected by vibration can be fitted with lock nuts or spring washers to prevent loosening of the bolts.

For secondary steelwork, 12 mm diameter class 4.6 bolts are commonly used.

1.3 Types of Weld

Fillet welds are generally preferred to butt welds.

The welds to the rafter web and around stiffeners can almost always be fillet welds. A minimum throat size of 4 mm (i.e. leg size of 6 mm) is recommended.

If the size of the fillet welds to the tension flange of the rafter is large (say greater than 8 mm throat size i.e. leg size of 12 mm), in some countries, the fabricator may prefer to use a partial or full penetration butt weld.

The shear along the haunch length is usually low enough to permit suitably designed intermittent fillet welds to connect the haunch web to rafter flange, although continuous fillet welds may be specified for aesthetic or corrosion reasons.

The weld between the haunch flange and rafter flange is normally made a fillet weld with a leg size equal to the haunch flange thickness.

1.4 Connection details

There should be a sensible relationship between the bolt spacing, bolt size and plate thickness. An efficient solution is to make the plate thickness approximately equal to bolt diameter.

For initial sizing and details, it may be necessary to refer to information available in a particular country.

In UK, preliminary estimates of connection sizes and details can be obtained from Joints in steel construction: Moment connections (P207/95)[1], which presents a number of standard connections in a tabular and easily used form. In principle, the approach is generally in agreement with EN 1993-1-8.

In Germany the relevant publication is DStV/DASt: Typisierte Verbindungen im Stahlhochbau, Stahlbau-Verlags [2], also known as DASt – Ringbuch, that is fully consistent with EN 1993-1-8.

2. Eaves haunch

2.1 General

The eaves haunch is required to perform the following functions:

- Supplement the bending resistance of the rafter in the area of highest moment, permitting a smaller rafter to be used.
- Provide adequate depth at the rafter/column interface to achieve an efficient connection. The haunch depth is often determined by the lever arm to the bolts required to achieve the necessary moment resistance.

The eaves haunch can be cut from a hot rolled section or fabricated from plate. Cuttings from rolled sections are generally preferred, and it is convenient to use a similar section to the column or rafter, although the actual size could be dictated by stability and connection considerations. If the chosen rolled section is not deep enough to provide sufficient haunch depth, an infill plate can be used.

It should be recognised that if the haunch is made from the same section size and weight as the rafter, it may not always be possible for the connection to achieve its required bending resistance. In terms of connection design, a deeper and heavier haunch may be more suitable. This will reduce the tensile force in the bolts and the force in the compression zone at the bottom of the haunch, and will therefore reduce the bolt sizes and stiffening requirements. It will also reduce the shear force (caused by the tension in the bolts) in the top of the column. Increasing the section from which the haunch is cut also increases the stability of the haunch.

The haunch may affect the overall height of the structure because clients may require a clear depth to the underside of the haunch. From this point of view it is important to minimise the haunch depth. It is generally agreed that the haunch will usually be most efficient in terms of the overall frame design if:

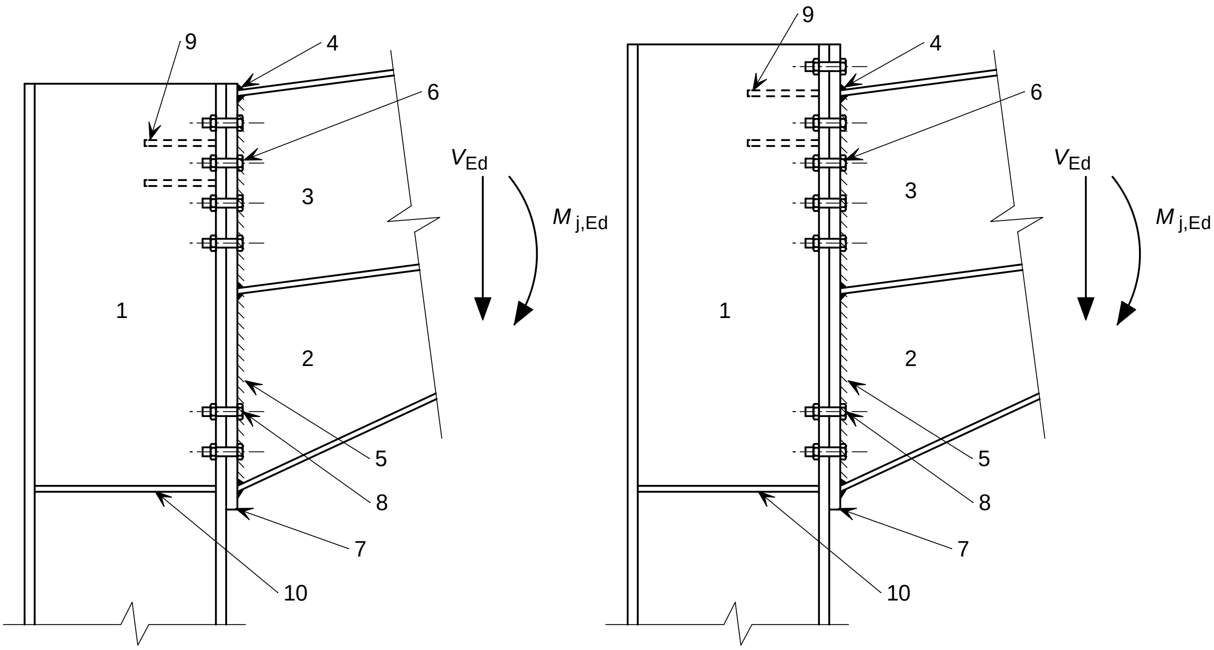
- The depth of haunch below the rafter is approximately equal to that of the rafter.
- The length of the haunch from the centre-line of the column is approximately 10% of the span of the portal frame.

2.2 End plate, eaves connection

Figure 2.1 shows a typical flush and extended end-plate, eaves connection for a haunched portal frame. Figure 2.2 shows alternative eaves connection details.

The connection at the eaves is required to be moment-resisting connection and to provide both adequate stiffness and bending resistance. The design of the connections need not be carried out in detail at the preliminary design stages, although it will be necessary to provide a connection of adequate depth to resist the applied moment. Also, the column must resist the shear induced by tensile loads in the bolts at the top of the haunch. In some cases, strengthening of the web may be needed. The design procedure for an eaves connection is given in SN041 and a worked example in SX031.

Because of the greater depth available, it is possible to be more flexible with load paths through the connection. The main tension bolts are moved down the connection as shown in Figure 2.1, transferring the tension force from the line of the rafter flange into upper region of the rafter and column webs. This usually means that all tension stiffening to the web can be avoided because of the greater vertical spread of tension in both the column and rafter webs. However, small stiffeners may be necessary to increase the flexural resistance of the column flange under the local bolt forces, particularly if the column is a light rolled section.

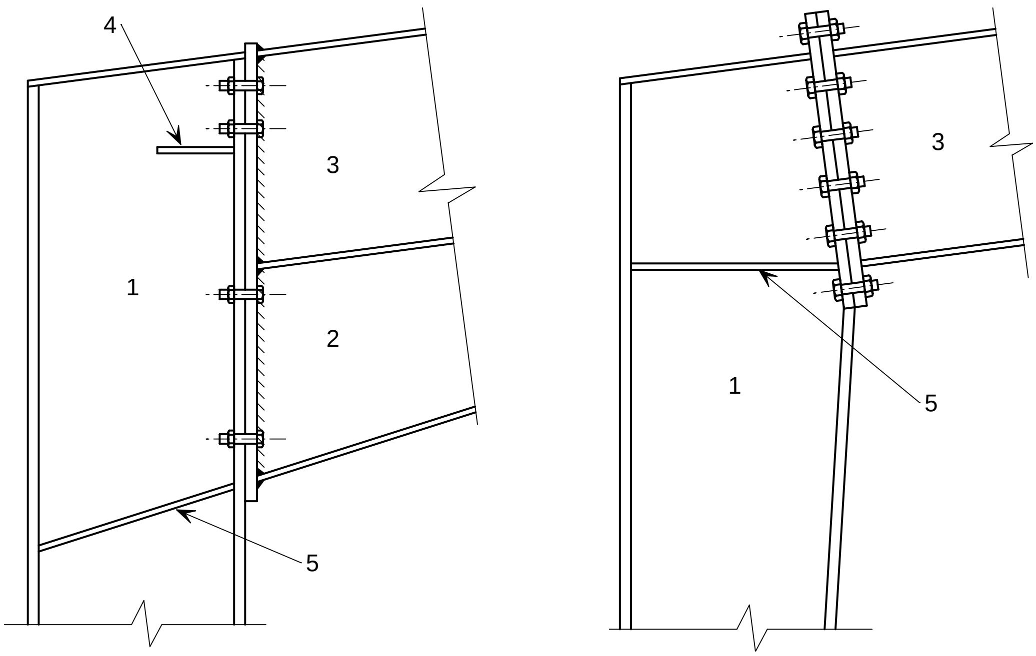


(a) Flush end plate eaves connection ***(b) Extended end plate eaves connection***

Key:

1	Column	6	Tension bolts
2	Eaves haunch	7	End plate
3	Rafter	8	Shear bolts
4	Flange weld	9	Optional tension stiffeners
5	Web weld	10	Compression stiffener

Figure 2.1 Typical end plate eaves connection in a portal frame



Key:

1 Column
2 Eaves haunch
3 Rafter
4 Tension stiffener
5 Compression stiffener

Figure 2.2 Alternative eaves connection in a portal frame

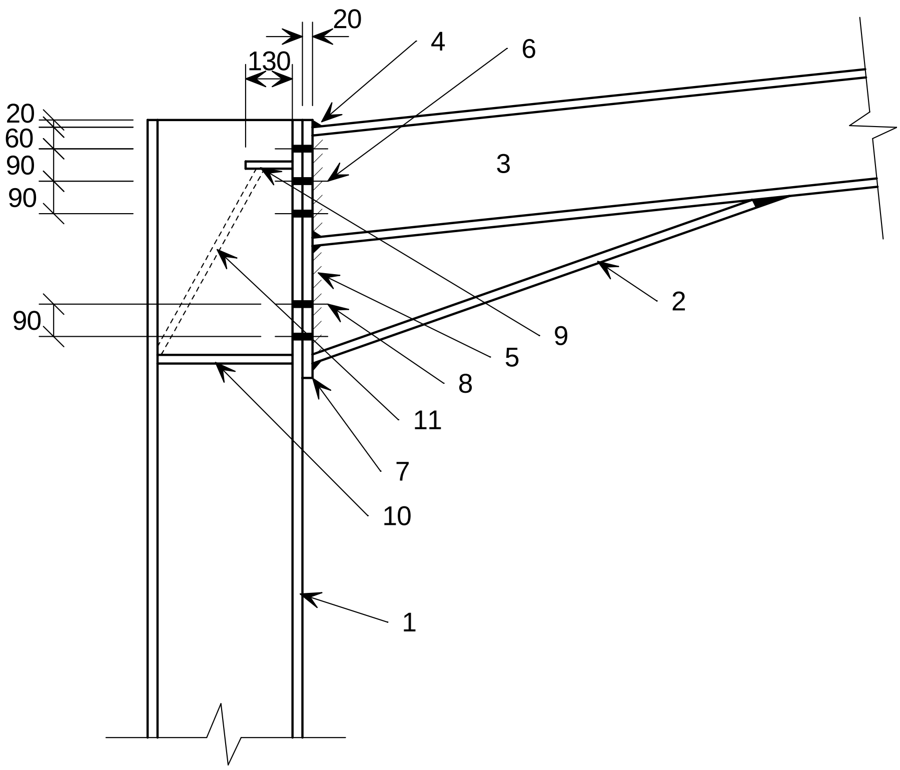
2.3 Details

Typical details of an eaves connection are shown in Figure 2.3.

An alternative detail at the sharp end of eaves haunch is shown in Figure 2.4

A series of typical design tables for haunched connections are given in P207/95[1]. These tables do not cover all design cases, but are a useful start point.

Final design may be carried out in accordance with the simplified, conservative approach given in SN041 or by using readily available appropriate software package.



Key:

1	Column	6	Tension bolts
2	Eaves haunch	7	End plate
3	Rafter	8	Shear bolts
4	Flange weld	9	Tension stiffeners
5	Web weld	10	Compression stiffener
		11	Optional stiffener

Figure 2.3 Details of a typical eaves connection in a portal frame

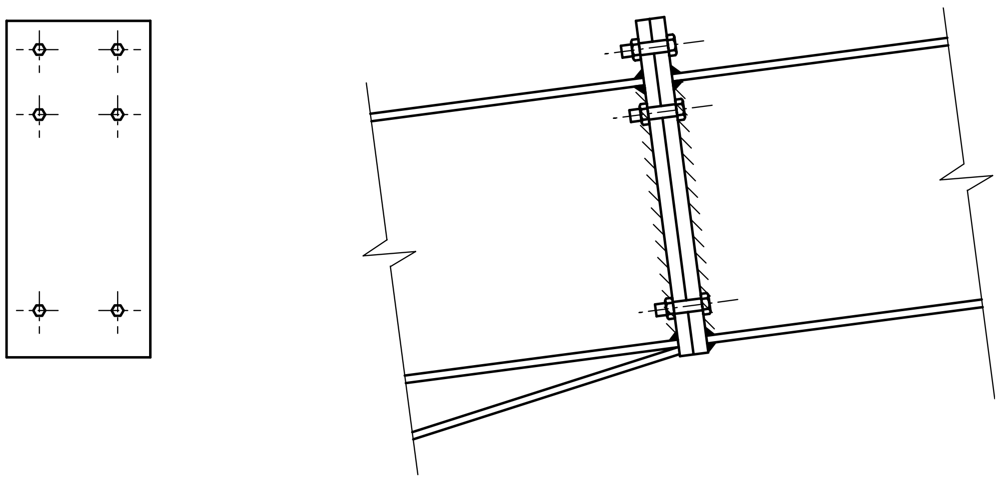


Figure 2.4 Alternative detail at the sharp end of eaves haunch

3. Apex haunch

3.1 General

The purpose of the apex haunch is to achieve an efficient connection between the rafter members. It will usually be fabricated from plates and its detailed design will be part of connection design. The size and details need not usually be considered at the preliminary design stage.

3.2 End plate, Apex connection

The connections at the apex are required to be moment-resisting connections and to provide both adequate stiffness and bending resistance. The design of the connections need not be carried out in detail at the preliminary design stages, although it will be necessary to provide a connection of adequate depth to resist the applied moment.

Figure 3.1shows the basic types of extended end-plate connection. In Figure 3.1(a) the end plate is simply extended downwards. In Figure 3.1(b) there is simple gusset reinforcement to the extension and in Figure 3.1 (c) full haunches are provided.

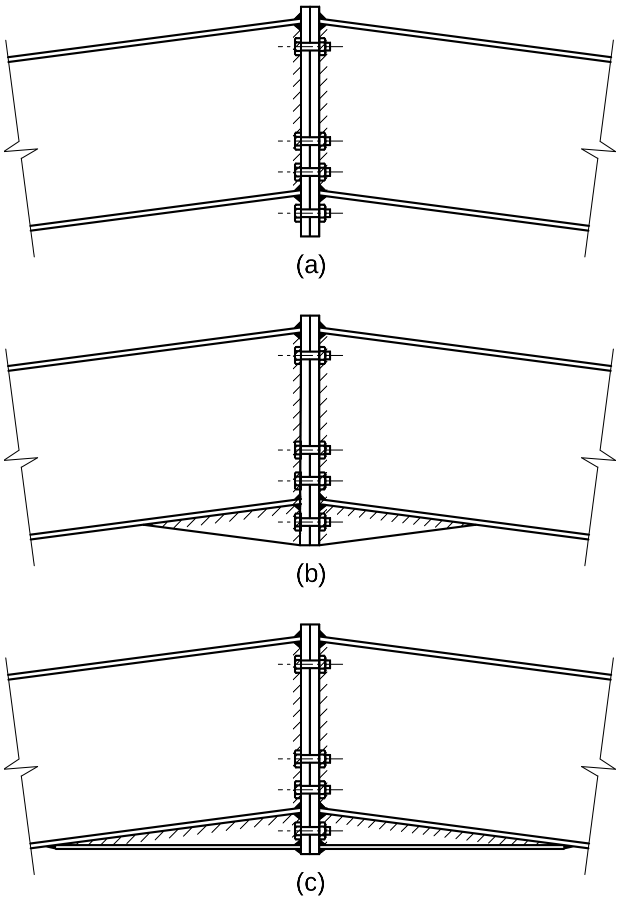


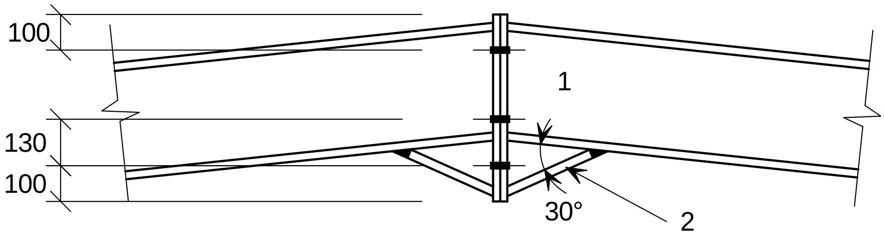
Figure 3.1 Typical end plate apex connection in a portal frame

3.3 Details

Typical details of an apex connection are shown in Figure 3.2

A series of typical design tables for haunched connections are given in P207/95[1]. These tables do not cover all design cases, but are a useful start point.

Final design may be carried out in accordance with the simplified, conservative approach given in SN042 or by using readily available appropriate software package.



Key:
1 Rafter
2 Apex haunch

Figure 3.2 Details of a typical apex connection in a portal frame

4. Restraints

4.1 General

For plastically designed frames, a torsional restraint should always be provided at the top of the column i.e. at the bottom of the eaves haunch. Additionally, a further torsional restraint may be required within the length of the column because the side rails are attached to the (outer) tension flange rather than to the compression flange.

Similar restraints may be provided for elastically designed frames or alternatively the position of the top restraint can be moved further up on the column.

4.2 Torsional restraints at the top of the column

At plastic hinge positions

A number of methods are available to provide the torsional restraint; some of these are as follows:

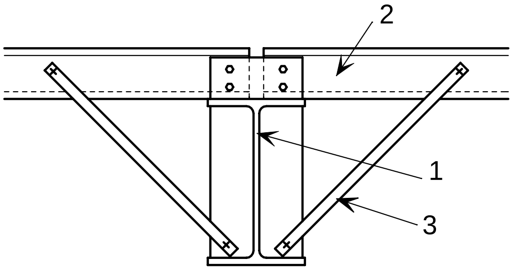
- For columns of depths less than 600 mm, a column stay as shown in Figure 4.1 may be used. In order to ensure adequate stiffness, it is recommended that the depth of the side rail is at least 25% of the depth of the column.
- For all spans, a possible method is to provide a longitudinal member close to the compression flange at the bottom of the haunch, which is tied into the vertical bracing (Figure 4.2). The torsional resistance can then be provided by the circular hollow section

acting with the side rails on the outer face of the column. It is important that plan bracing is provided between these components at some point in the length of the structure.

For elastically designed frames

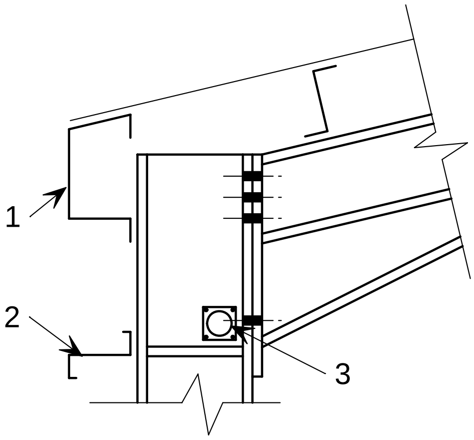
If a frame is designed elastically, the torsional restraint at the top of the column may be designed in the same way as given above or alternatively the position of the top restraint can be moved further up on the column.

(courtesy of Caunton Engineering Ltd)



Key:
1 Column 2 Side rail 3 Column stay

Figure 4.1 Typical eaves detail using a column stay



Key:

1 Cold rolled Eaves beam
2 Side rail
3 Circular hollow section

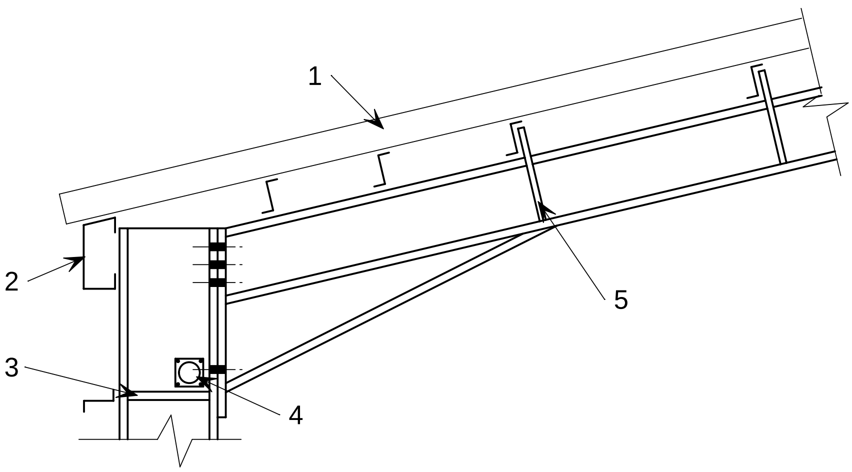
Figure 4.2 ***Typical eaves detail using a circular hollow section as a longitudinal bracing members***

5. Secondary structural components

5.1 Eaves beam

The eaves beam connects the individual frames at eaves level (Figure 5.1)

Its primary function is to support the roof cladding, side walls, and guttering along the eaves, but it may also be used to provide lateral restraint at the top of the outer flange of the column.



Key:

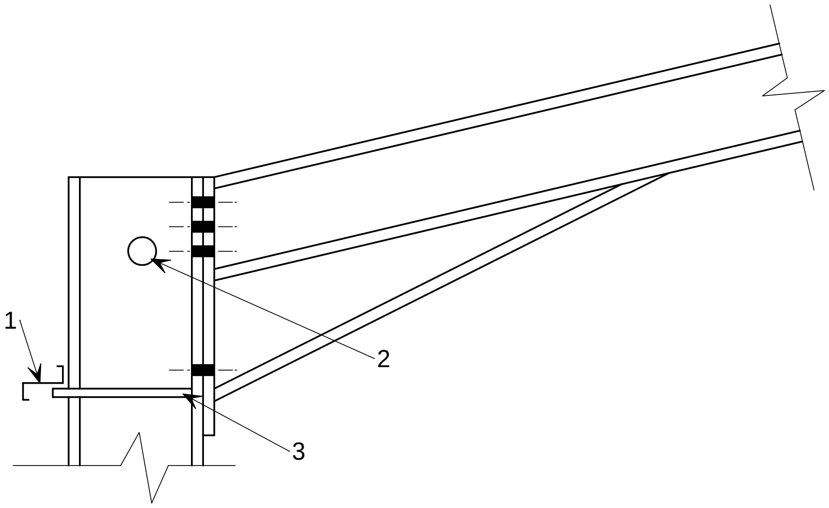
1 Built up or composite cladding
2 Cold rolled Eaves beam
3 Stiffener
4 Circular hollow section acting as eaves strut/tie
5 Rafter stay

Figure 5.1 ***Haunch detail with eaves beam***

5.2 Eaves strut/tie

If vertical side wall bracing capable of resisting tension and compression is provided at both ends of the structure, an eaves strut is not required other than in the end bays. However, it is good practice to provide a member between the columns to act as a tie during erection and provide additional robustness to the structure.

If a circular hollow section is used to restrain the plastic hinge at the bottom of the eaves haunch (Figure 5.1), this can fulfil the role of a longitudinal strut/tie as well as restraining the plastic hinge. If a member is provided as an eaves strut/tie above this level (Figure 5.2), it is ineffective in restraining the plastic hinge at the bottom of the haunch.



Key:
1 Side rail 2 Eaves strut/tie 3 Column stay

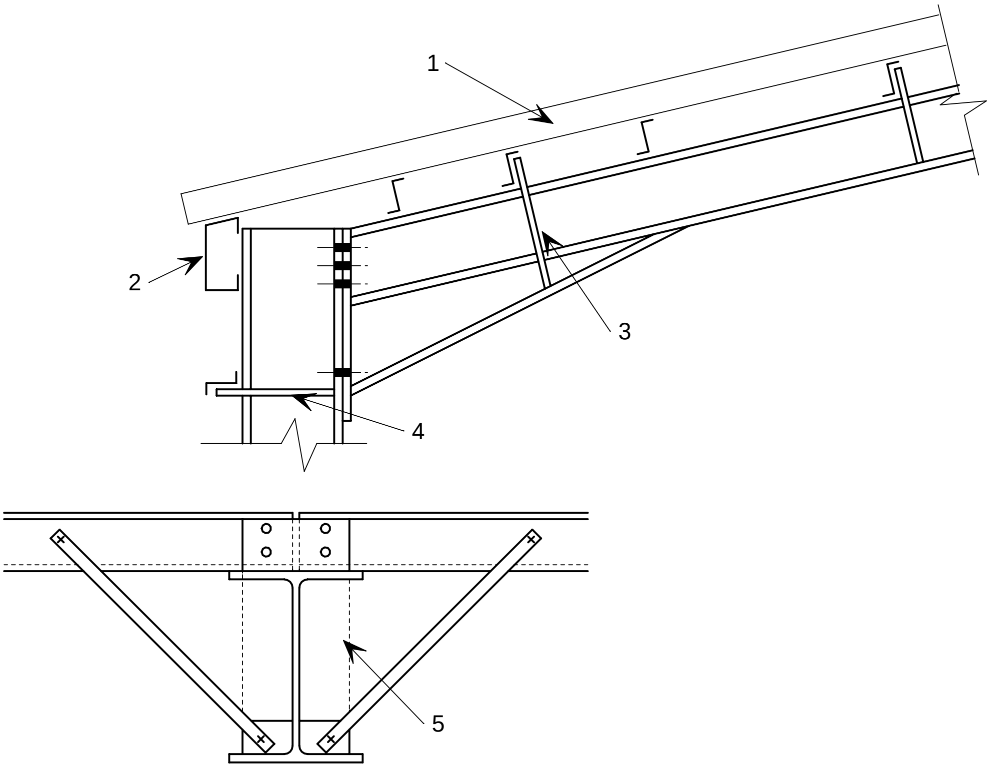
Figure 5.2 Eaves detail where the eaves strut/tie does not provide restraint at the bottom of the haunch

5.3 Column and rafter stay

A column or a rafter stay is a convenient method of providing bracing to a compression flange that is remote from the flange to which the purlins or side rails are connected. It provides torsional restraint at the location when connected to a suitable purlin or side rail (see Figure 5.3 and Figure 5.4).

Flats or angles may be used as stays. If flats are used as stays, it should be assumed that they will act in tension only. They are therefore required at each side of the rafter or column. If, for detailing reasons, only one stay can be provided, an angle section of minimum size 40 × 40 mm should be used. The stay and its connections should be designed to resist a force equal to 2.5% of the maximum force in the column or rafter compression flange between the adjacent restraints.

It is important that the purlins or side rails are large enough to provide the required stiffness to act as restraints to the rafter/column. As a rule of thumb, it will be adequate to provide a purlin or side rail of at least 25% of the depth of the member being restrained.



Key:

1	Built up or composite cladding	3	Rafter stay
2	Cold rolled Eaves beam	4	Column stay
		5	Stiffener

Figure 5.3 Details of column and rafter stay and connection

Figure 5.4 Details of rafter stay
(courtesy of Caunton Engineering Ltd)

5.4 Bracing

Bracing is required both in the plane of the rafters and vertically in the side walls (see Figure 5.5) in order to provide:

- Stability, both during erection and in the completed building.
- Resistance against wind loading in the longitudinal direction.
- An adequate anchorage for the purlins and side rails in their function of restraining the rafters and columns.

Figure 5.5 ***Bracing details***
(courtesy of Caunton Engineering Ltd)

6. References

(1) Joints in Steel Construction – Moment Connections (P207/95). The Steel Construction Institute and The British Constructional Steelwork Association Ltd., 1995.

(2) DStV/DASt: Typisierte Verbindungen im Stahlhochbau, Stahlbau-Verlags. GmbH, Köln, 1984 (neu bearbeitete Auflage 2001).

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