Column to beam and beam to beam connections

STEP lecture D5
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Objective

To describe the main types of connection used, to point out the design problems to note and to present examples of the design of various types of connection.

Summary

The main types of column to beam connections, hinged or fixed, as well as beam to beam connections are described. The principles of design of these connections to resist shear, axial force and bending moment are described. The design principles concerning problems specific to wood such as compressive or tensile strength perpendicular to the grain or dimensional changes are also covered. Actual examples are presented.

Introduction

The design of a connection must allow the function selected to be carried out (i.e. hinged or fixed in one or more directions). The connection should be designed to resist all the internal forces and moments about all three principal axes:

- shear forces in *y*- and *z*-direction,
- axial loads in *x*-direction,
- torsional moments about the *x*-axis,
- bending moments about the *y*- and *z*-axis.

The internal forces or moments in the connection are either balanced by mechanical fasteners such as nails, dowels or bolts or by direct wood to wood contact. Glued connections are not dealt with in this lecture.

In general the main internal forces and moments are those which occur in the plane of the frame made up of a column and a beam. The other internal forces and moments essentially arise from the additional forces applied out of the plane of the frame, especially the bracing forces. In any case, in a column to beam connection, the torsional moment must be counterbalanced by some means to prevent the rotation of the beam around the *x*-axis.

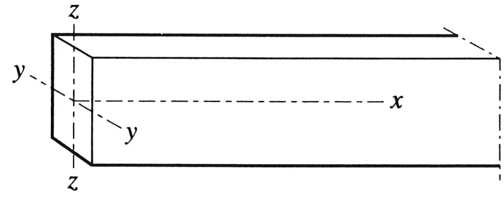

Figure 1 Beam axes.

Figure 2 shows the main types of connection. Connection type 4 in Figure 2 is either free to rotate about the *y*- and *z*-axis or continuously fixed in three axes. In connection type 5 the secondary beam is usually simply supported by the main beam. allowing rotation about the *y*- and *z*-axis of the secondary beam.

Because of the eccentricity of the secondary beam support the main beam is often subject to a torsional moment (see Figure 3).

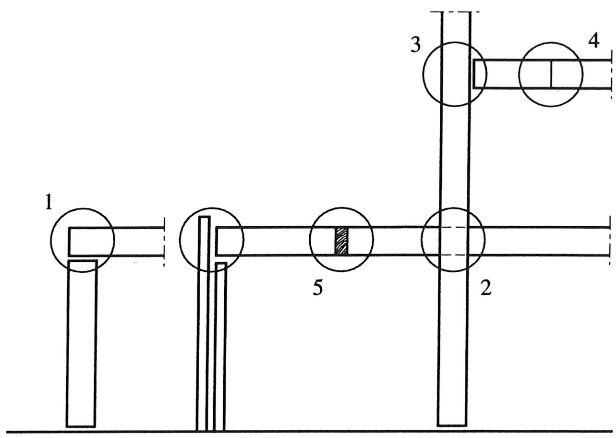

Figure 2 *Main types of connection. (1) Corner connection, column to beam or frame corner, (2) connection between continuous beam and column, (3) column to beam connection in a multi-storey structure, (4) beam to beam connection: two beams in line, (5) beam to beam connection between a secondary beam and a main beam.*

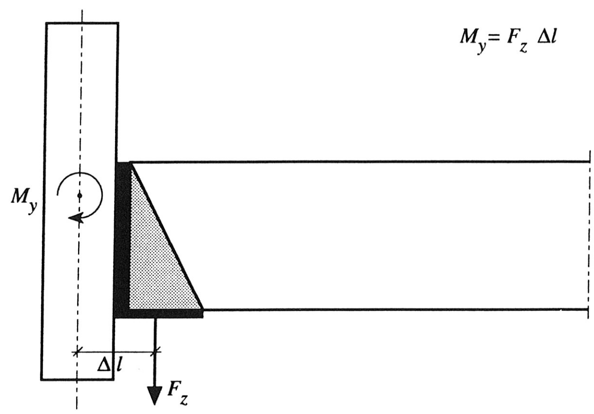

Figure 3 *Eccentricity of secondary beam support.*

Connection examples

Column to beam connection type 1

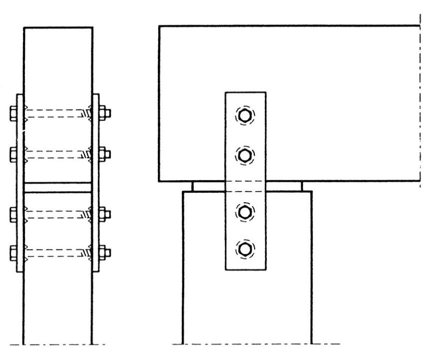

Figure 4 *Joint with steel bars with bolts or screws and with or without connectors. The bearing plate (e.g. of plywood) between the column and the beam centres the load and prevents overloading of the corner of the column.*

Generally these connections allow free rotation about the y-axis. The support reaction of the beam is transmitted either by direct contact or by mechanical fasteners. If the column is wide, neoprene sheets may be provided in order to keep the load centred on the column. Both the beam and the column must be torsionally restrained.

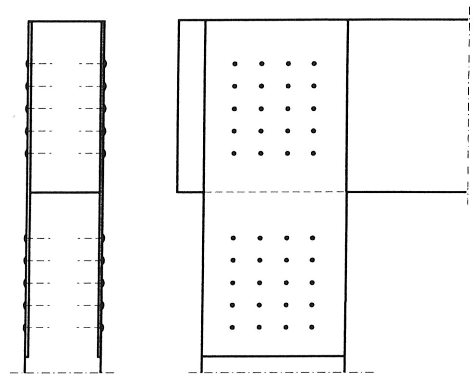

Figure 5 *Joint with nailed gusset plates of steel or plywood. The joint can take up some moment and thereby contribute to the lateral stability of the structure.*

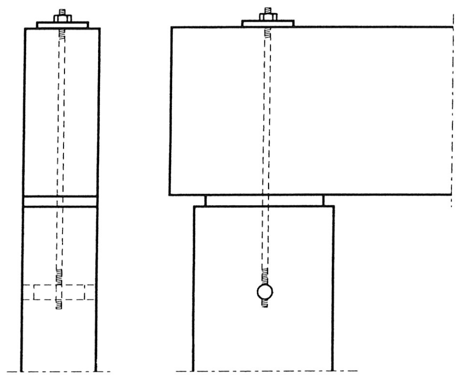

Figure 6 *Joint with a vertical bolt screwed into a round steel bar with a threaded hole. The hole in the column is plugged after assembly. The bolt should be retightened, especially for deep beams.*

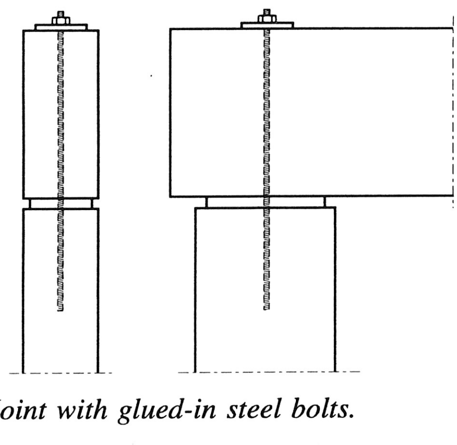

Figure 7 *Joint with glued-in steel bolts.*

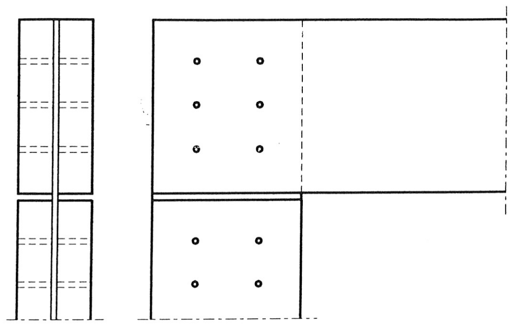

Figure 8 Dowelled steel plate in slots in beam and column.

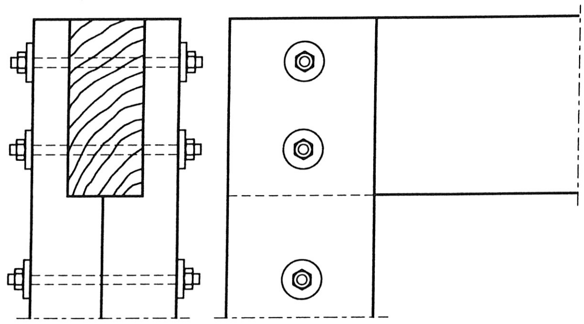

Figure 9 Forked beam bearing on twin column.

Column to beam connection type 2

This type of connection is often used in column to beam structures at right angles between continuous columns and continuous beams supporting floors.

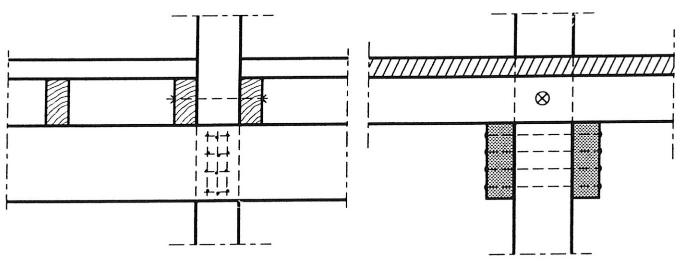

Figure 10 Spaced double beam connected by dowels or bolts to the column.

The connection in Figure 10 needs a large connection area to allow the necessary number of fasteners to be placed.

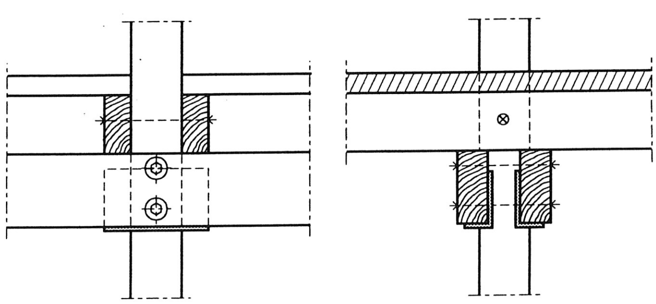

Figure 11 Double beam connected to indented columns using steel angles to increase bearing surface.

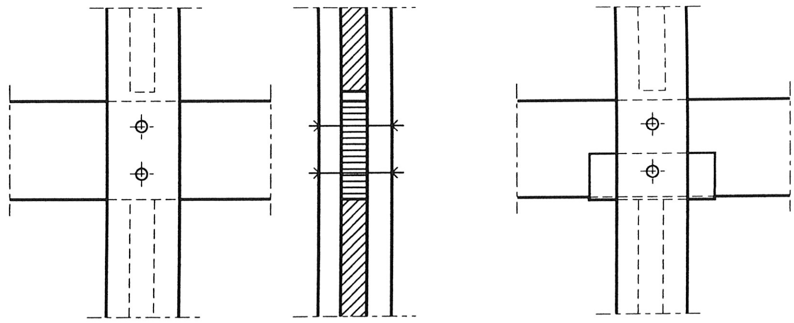

Figure 12 Central beam resting on spacing blocks of double column. Right: the bearing surface is increased by using a U-shaped steel support.

In Figure 11 and 12, the bolts are placed in oval holes to allow for dimensional changes in the timber and are only used to position the beams. To avoid large compressive stresses on top of the beams in Figure 12, a clearance is provided between the upper face of the beam and the spacing block of the double column.

Column to beam connection type 3

This type of joint essentially concerns the connection of a cross member to a continuous column. Except for traditional jointing by means of mortise and tenon, these connections are made using metal fittings.

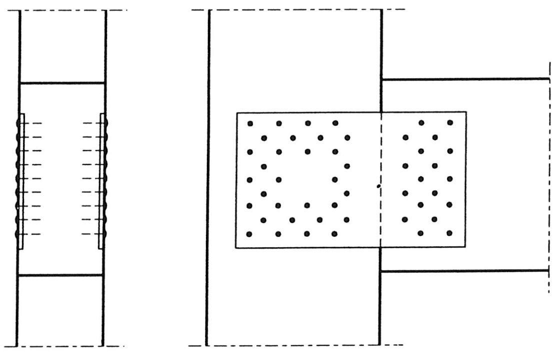

Figure 13 Nailed plywood or steel gusset plates. The joint is effective and easy to make. It may be necessary to protect the gusset plate against fire.

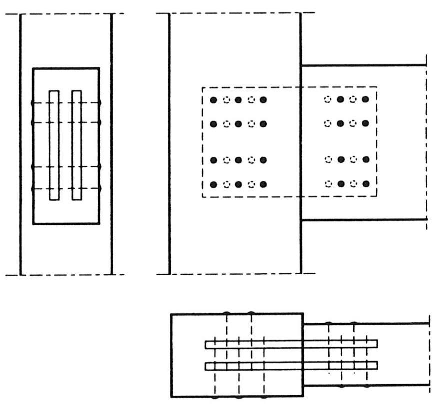

Figure 14 Gusset plates in slots with nails (plywood gussets) or dowels (plywood or steel gussets). The fire properties are very good.

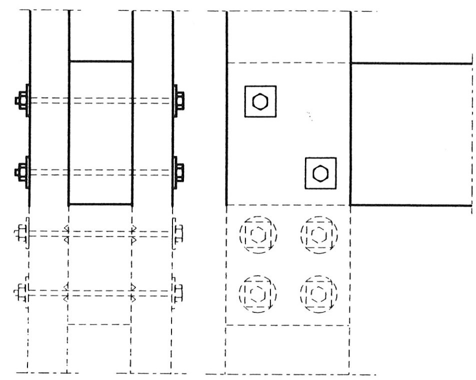

Figure 15 *Beam between two columns. Part of the load can be taken by a support block.*

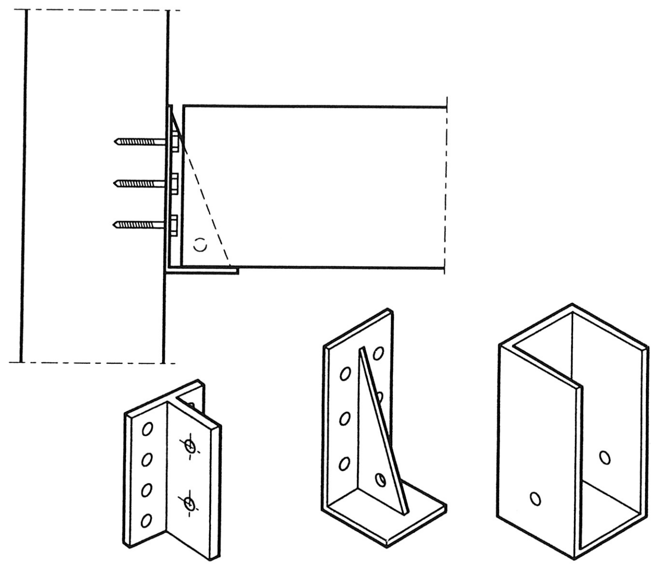

Figure 16 *Beam shoe or bracket. The column will be loaded eccentrically.*

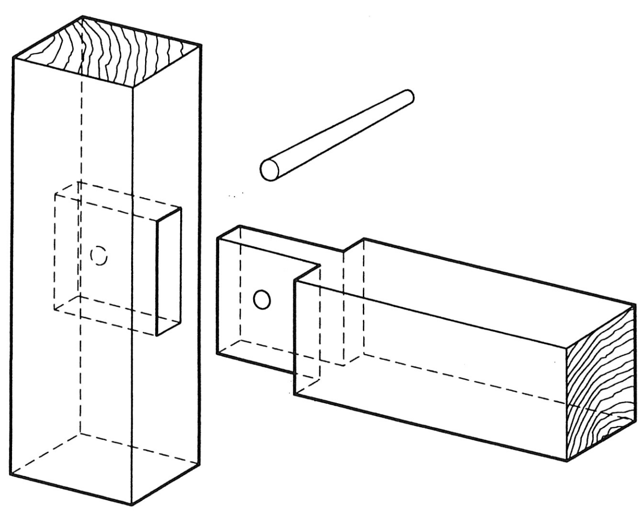

Figure 17 *Traditional connection by mortise and tenon with hardwood dowel. The support reaction is transmitted by direct contact; the hardwood dowel only keeps the beam in place. This connection is attractive but needs to be carried out by specialised craftsmen and is only suitable for low loads.*

Beam to beam connection type 4

Purlins are often designed with cantilever connections or with continuity over the supports. Both solutions are advantageous compared with simple beams on two supports. The necessary timber volume is decreased and the stiffness of the structure increased. Cantilever connections (Figure 18 to 21) are very economic in labour and time.

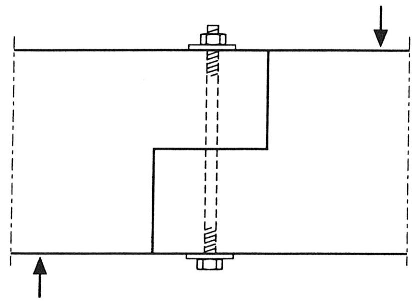

Figure 18 *The simplest joint: the short beam is hanging in the cantilever. Where the forces are not too large, the beam can be supported directly on the cantilever.*

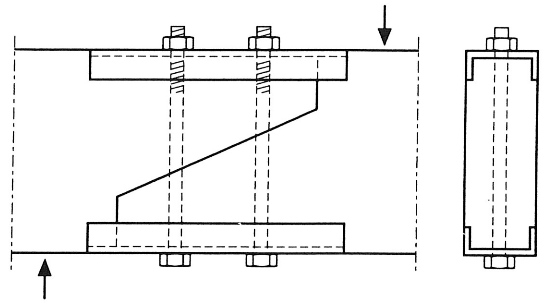

Figure 19 *For large forces it may be necessary to reinforce the joint with steel channels.*

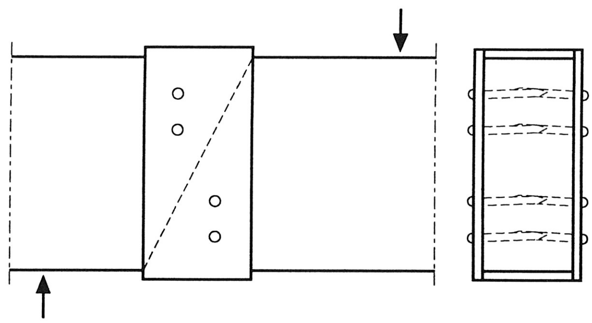

Figure 20 *Joint with a special steel shoe. In the version shown, only shear forces can be transferred.*

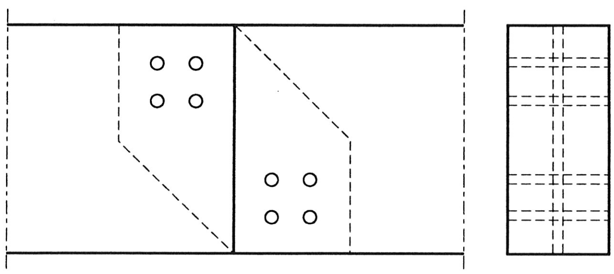

Figure 21 *Joint with doweled steel plate in slots. The dowels are placed close to the unloaded edges to prevent splitting.*

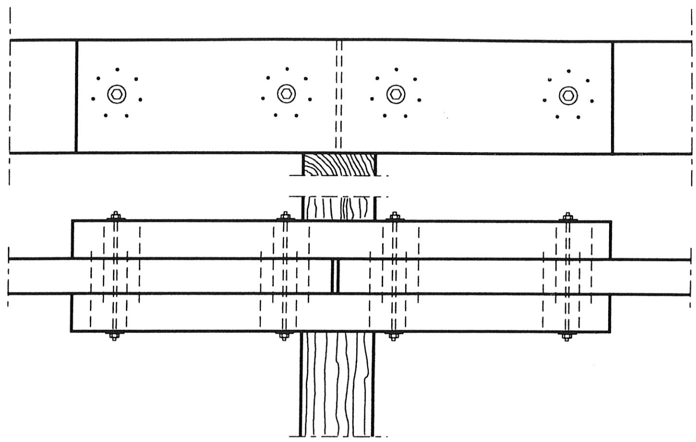

Figure 22 Continuous connection with wooden battens on a support.

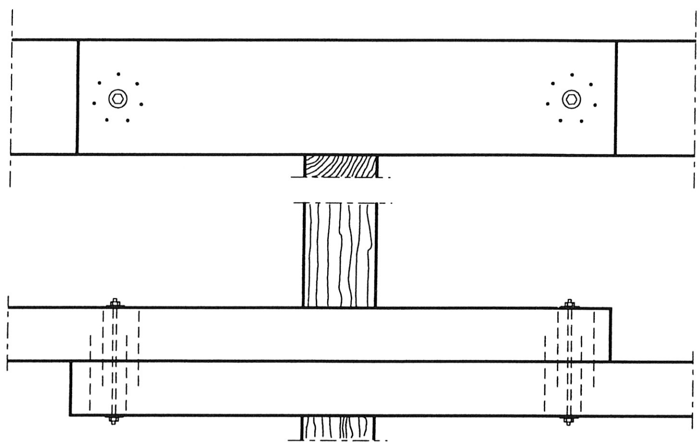

Figure 23 Continuous connection with crossed purlins on a support.

Beam to beam connection type 5

This type of joint essentially concerns the connection of a cross member to a continuous main beam. Except for traditional jointing by means of mortise and tenon, these connections are made using metal fittings.

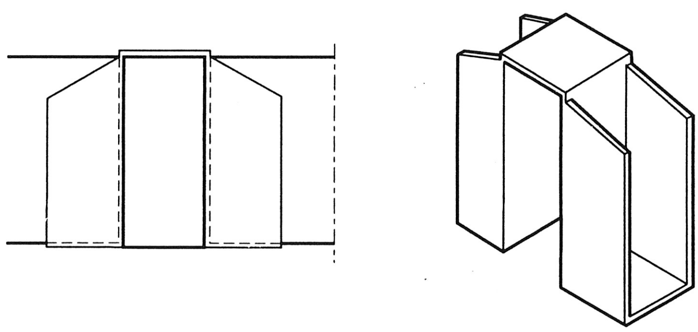

Figure 24 Beam shoe.

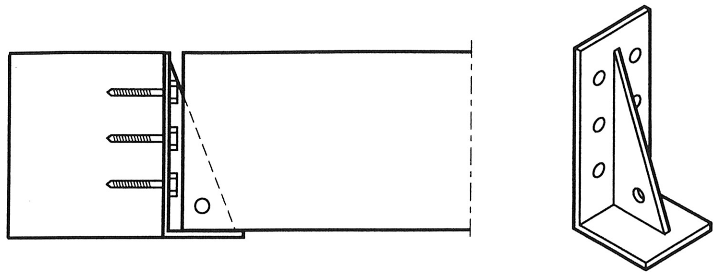

Figure 25 *Beam from one side only supported on a steel bracket. In this case it is necessary to design the main beam for the torsional moment.*

Common problems to be avoided

Due to slipping and rotation of the connection, the forces which must be counterbalanced by the fasteners act in the tangential direction of the rotation circles through the bolt lines and may not be parallel to the grain (see Figure 26). The fastener force components perpendicular to the grain, which are resisted by the stiff metal side plates or channels, cause tensile and compressive stresses parallel to the grain. The side plates or channels are very rigid and tend to split the wood. In order to avoid this problem, the stiffness of the metal fittings should be decreased at the joint.

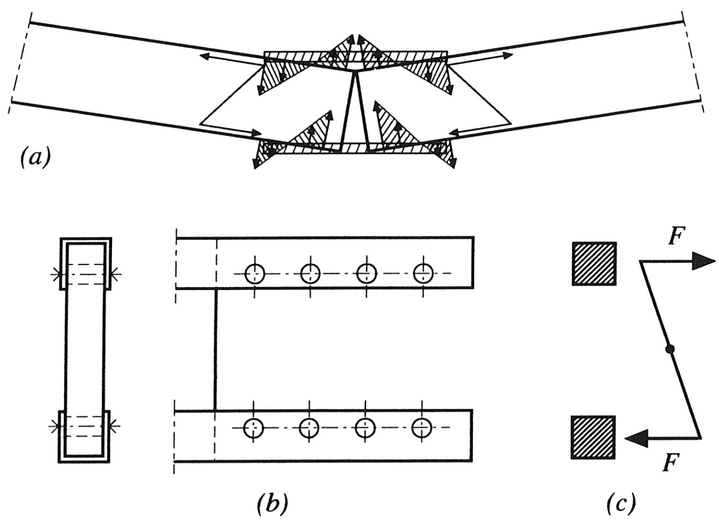

Figure 26 *Splitting failure due to stiff steel channels used to connect the beam ends.*

The net area indicated in Figure 26c has to be large enough to resist the force *F* in order to avoid a local tensile failure parallel to the grain.

For very deep glulam beams the dimensional changes in the wood due to moisture content changes may cause splitting of the timber, if free shrinkage is prevented (see Figure 27). The column in Figure 27, less thick than the beam and better ventilated, dries out more quickly and its shrinkage is hindered by the circle of bolts which attach it to the beam. Since the beam hardly shrinks in grain direction, a split occurs in the centre area of the circle of bolts.

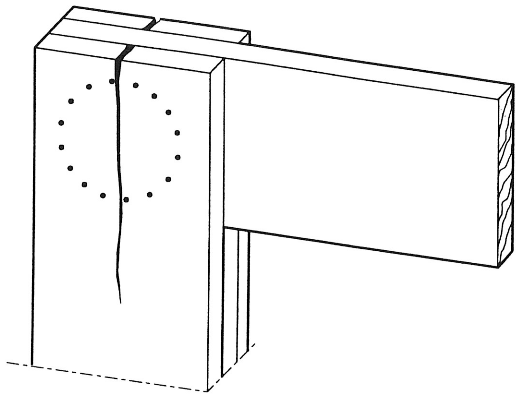

Figure 27 *Splitting failure due to differential shrinkage and different moisture variation in beam and column.*

For secondary beam to main beam connections it is necessary to place the steel connector of the secondary beam as high as possible to limit the tensile stresses perpendicular to the grain. In practice, if the fitting covers 70% to 80% of the main beam depth, the tensile stresses perpendicular to the grain are not governing the design. However, it will be necessary to check that the fitting does not prevent dimensional changes of the main beam which would cause cracks due to resisting the shrinkage effects.

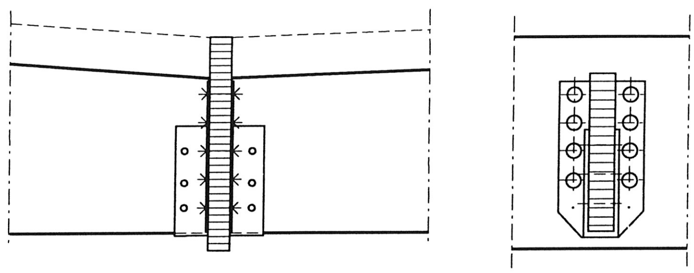

Figure 28 *Connection of secondary beams to a main beam by mechanically connected hangers.*