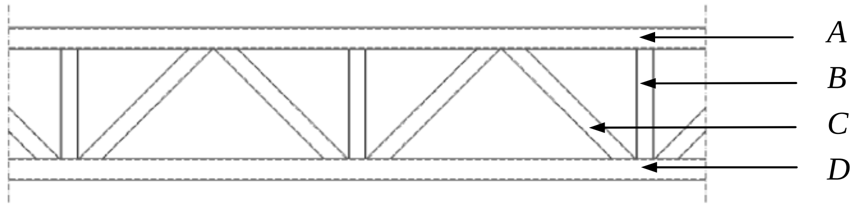
Scheme Development: Conceptual design of truss and column solutions

This document presents different applications of trusses and examples of conceptual designs of trusses and columns for single storey buildings.

Contents

1. Introduction

A truss can be defined as a beam with an open web, formed by a triangulated arrangement of linear elements. A typical arrangement of a truss is shown in Figure 1.1. This arrangement has parallel 'chords' (equivalent to flanges) and the 'web' is provided by a mixture of 'diagonals' and 'posts' or 'verticals' (at right angles to the chords). There are many alternative arrangements of trusses: there are different arrangements of diagonals; sometimes there are only diagonal web members (no posts); sometimes the chords are not parallel to one another.



Key A – Upper chord, B – Vertical or post, C – Diagonal, D – Lower chord

Figure 1.1 Different parts of a truss

2. Trusses

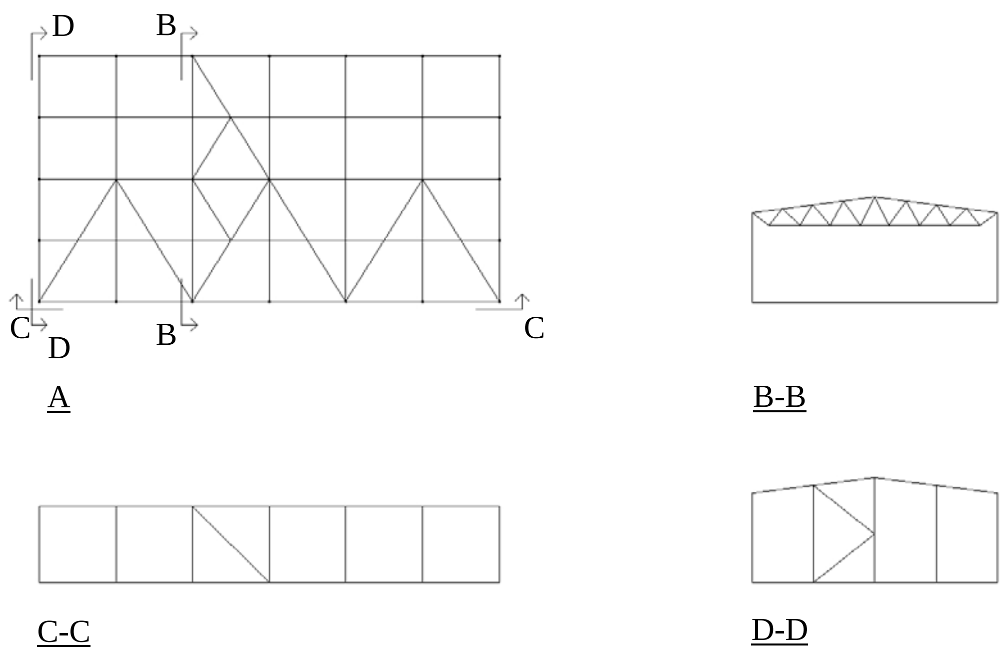
The truss' primary advantage towards other solutions is that with a proper design a strong, stiff and weight-efficient member is achieved. Often, economical aspects determine whether a truss or a steel beam is chosen for the roof structure and here the span and the magnitude of load is of importance. The savings in steel weight for a truss compared to a steel beam gets bigger with larger spans and when the material savings makes up for the higher fabrication costs the truss is chosen. When choosing between a hinged truss and a hinged hot rolled beam the truss is normally the best choice for spans exceeding about 15 m.

A roof truss together with pinned columns and a roof sheeting used as both lateral bracing for the rafters and as a stressed skin diaphragm to transfer the wind forces to the wind bracings is often the most economical way to stabilise a open plan building. When it is important to keep the building height to a minimum or difficulties in making room for the vertical wind-bracing, portal frames can be taken into consideration since they have a lower section height due to a different bending moment distribution.

Sometimes the great possibility for installing ventilation and service pipes through the web in a truss is an advantage worth consideration.

2.1 Applications

The main use of trusses is for roof trusses and wind bracings, which here is considered as a truss, see Figure 2.1. Occasionally it is also advantageous to use trusses for trimmer joists and columns, i.e. very large columns with dominating bending.



Key:

A – Horizontal wind bracing for use with pinned columns
B-B – Roof truss
C-C and D-D – Vertical wind bracings

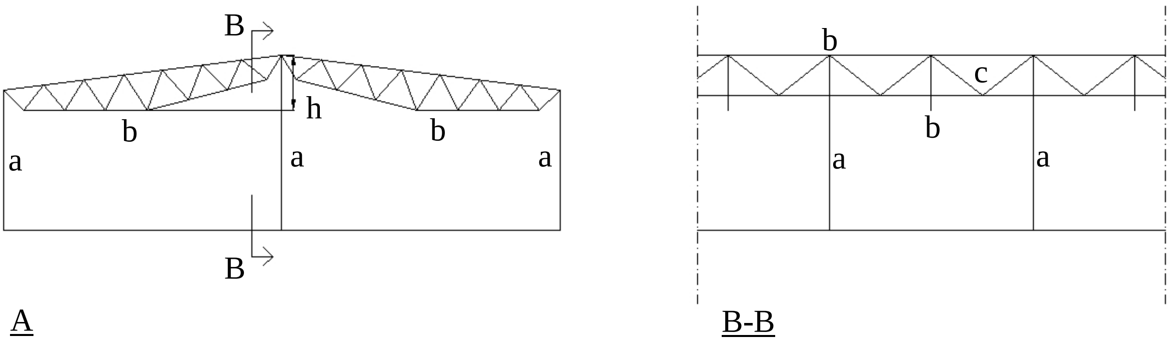
Figure 2.1 Trusses

2.2 Design

The truss should preferably be designed such that loads are applied at the joints to keep the magnitude of the chord moment to a minimum. This means that purlins are positioned over the joints in the upper chord and that girders for hoists are hung in the joints in the lower chord member. In large chord-members minor loads may be applied between the joints.

2.2.1 Roof trusses

The normal span lengths for industrial buildings are 12 – 35 m. The roof trusses are produced in a workshop and transported to the construction site, if possible in its full length. Longer components can be divided into two or more parts and jointed together at the site. For wide buildings and if inner columns are accepted it is favourable to divide the building into two sections. To avoid an inside gutter, that always comes with a risk for leakage, it is possible to keep one crest and use two trusses, see Figure 2.2. Since the required free height normally is at the lowest part of the rafters the available height in the middle of the building is large, this can be used for a primary truss and every second of the inner columns can be avoided.



Key

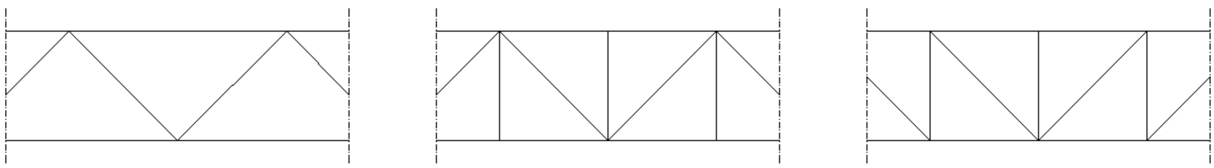
A – Roof truss
B-B – Primary truss
h – Height available for primary truss

a – column
b – roof truss
c – primary truss

Figure 2.2 Roof truss and primary truss

The roof slope is normally chosen to 1:16 or 1:10, depending on type of roofing. A slope less than 1:16 should be used with caution since the deflection decreases the inclination and if the actual roof slope becomes too small trouble with water run-off can give problems with water accumulation (ponding). The smallest possible slope depends on the size of the snow load. A rough estimate of the section height for a gabled truss is that for roof slope 1:16 $H = L/25$ – $L/30$ and for slope 1:10 $H = L/35$ to $L/40$ where H is the depth at the support. For parallel trusses the relation is approximately, $H = L/20$.

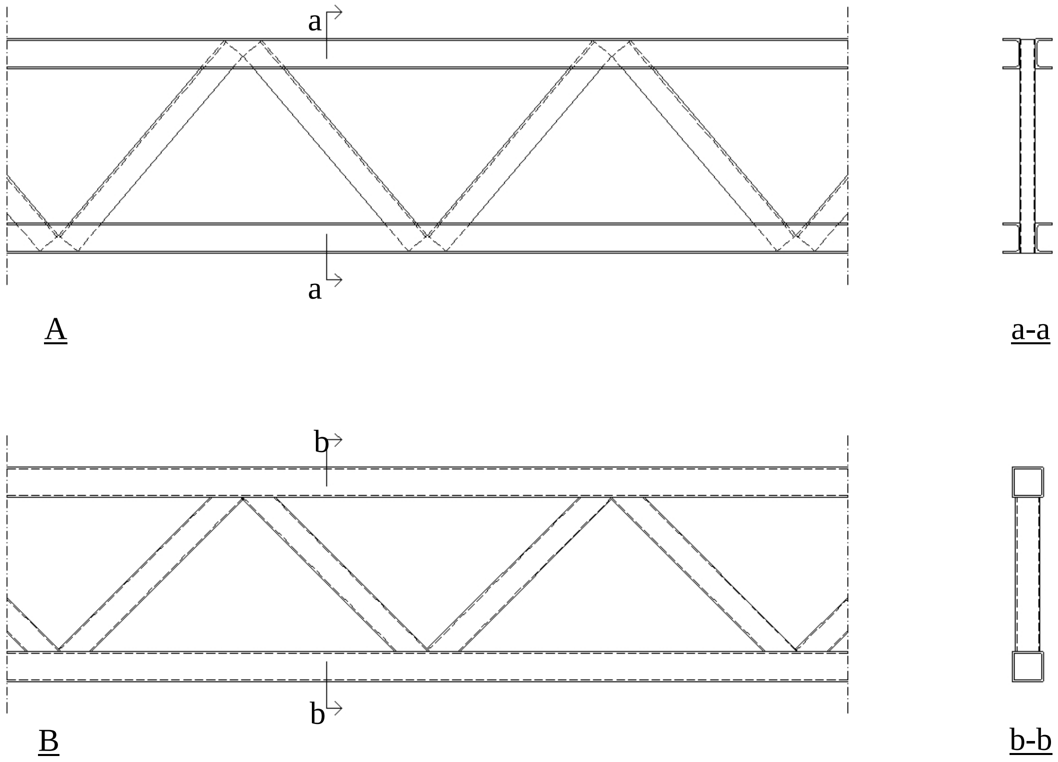
The truss patterns usually used are shown in Figure 2.3, where (a) is perhaps the most common truss due to its simple detailing. Figure 2.3(b) is of the same kind but strengthened with verticals for longer spans. Figure 2.3(c) shows a truss with all the diagonals subjected to tension and the shorter verticals handling the compressive forces; this makes it possible to use diagonals with small cross-sections, resulting in an economic design.



(a) (b) ©

Figure 2.3 Typical truss patterns

Because of rational fabrication the most cost effective sections for trusses usually are channel or angle sections, see Figure 2.4. There are several companies specialised in producing rafters of this type. An alternative section often used is a rectangular hollow section (RHS). When the chords are subjected to loads between the truss nodes that give bending moments, an I-section can be the most favourable section.



Key: A – Truss with U-sections, B – Truss with RHS sections

Figure 2.4 Rafters with different cross-sections

Deflections are usually a minor problem in this type of buildings. Therefore it is often economical to choose a minimum steel grade of S355. The most common is to use hot rolled sections, but it is also possible to use cold-formed sections.

2.2.2 Erection

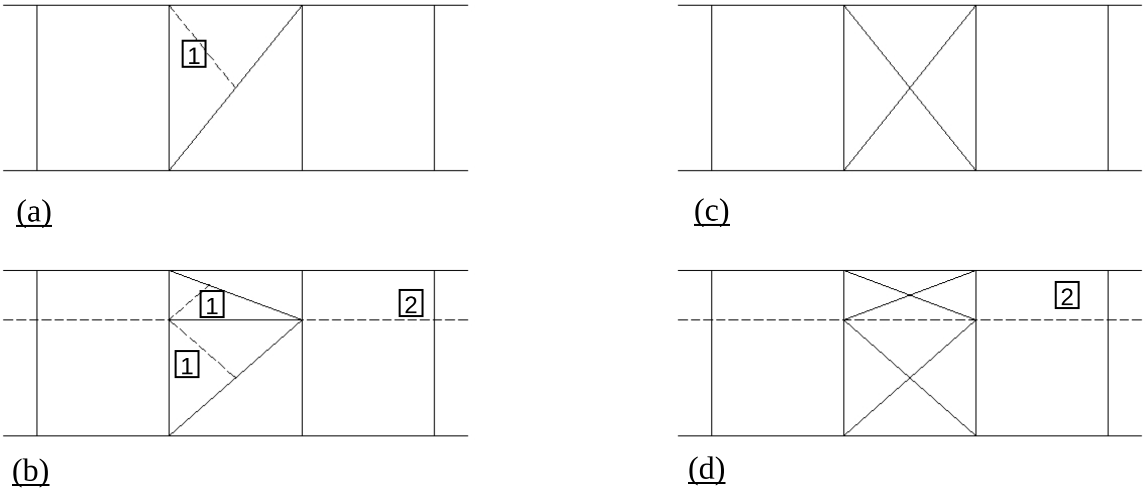
Roof trusses are usually welded at the workshop and transported full size. Where the truss is larger than can conveniently be transported in one piece, it is fabricated in several parts and the parts joined together at site. Trusses up to about 20 m long and up to about 3,5 m deep can be readily transported in most European countries. .

For long span trusses it is important to include a design for the erection stage. For example, if the truss is lifted in its whole length the truss needs to be designed to carry its self-weight, unrestrained. The building may also need temporary restraints – see SS048.

2.2.3 Wind-bracings

The horizontal wind bracing in a roof works as a beam with the vertical wind-bracings as support. In general, purlins are used as chords and the truss is made complete by adding diagonals.

Vertical wind-bracings are positioned in the column lines and use the columns as chord-members. To minimise the effects of temperature changes in long buildings the trusses should be placed as close as possible to the middle of the building. Depending on the design the diagonals can be subjected to just tension or both tension and compression, see Figure 2.5. If deformations do not govern, “the tension only” design is more economical. The choice of cross-section is made from an economical point of view and for members subjected to tension only, round bars, L-sections or channels should be used. For members subjected to compression a rectangular hollow section (RHS) is a good choice. However, sometimes the choice of an H-section is more economic, because of more easily executed connections or because of substantial bending moments from cranes. The bracing is usually placed with an offset from a crane runway girder and the horizontal force from the crane girder causes this bending moment. Such diagonals are usually braced for buckling in the weak direction, as shown in Figure 2.5(b).



Key:

(a) Wind-bracing subjected to compression and tension without crane girder

(b) Wind-bracing subjected to compression and tension with crane girder

(c) Wind-bracing subjected to tension without crane girder

(d) Wind-bracing subjected to tension with crane girder

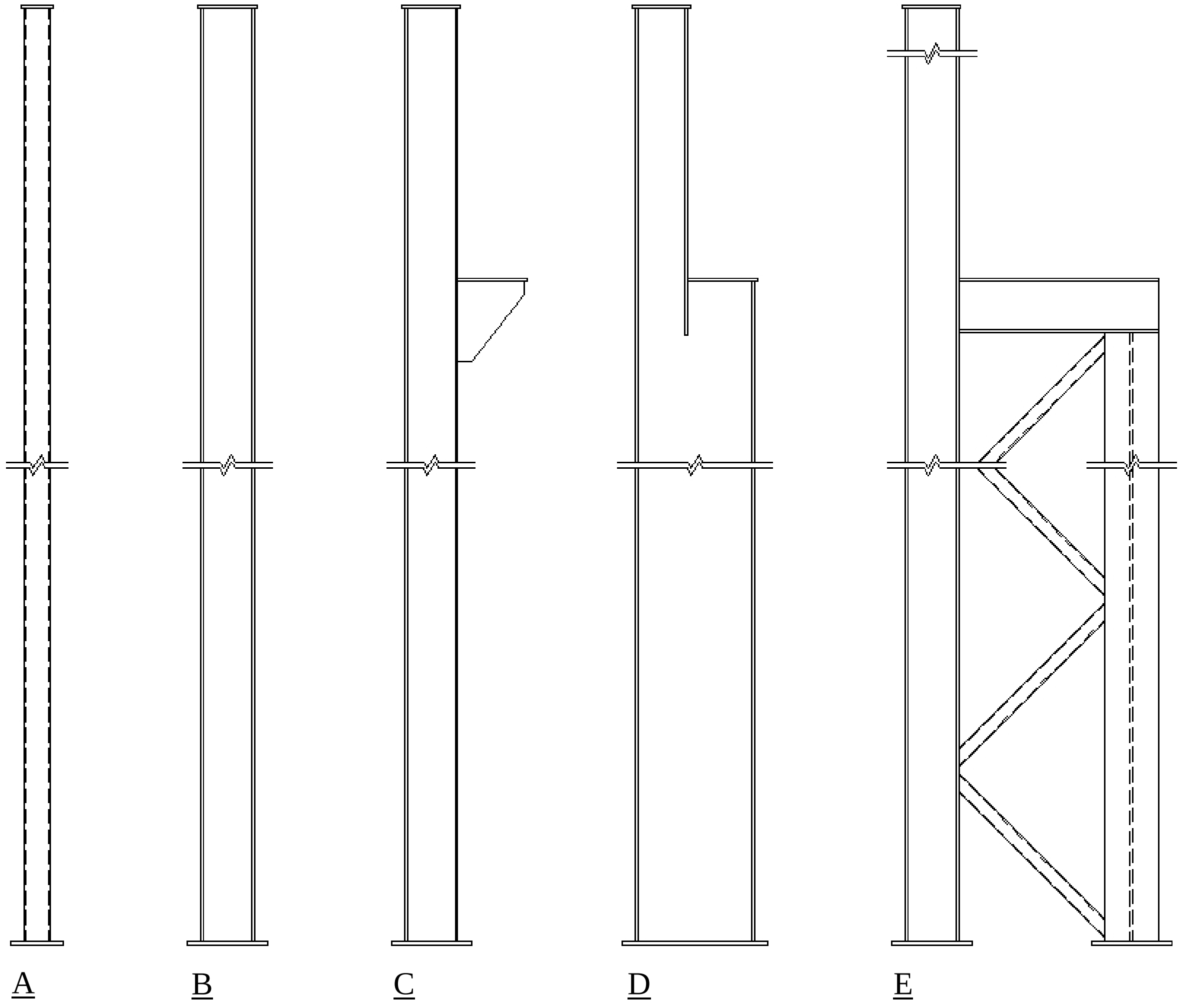
1 Optional bracing

2 Crane girder

Figure 2.5 Typical wind-bracing arrangements in walls

3. Columns

In addition to the function to carry vertical loads from snow, cranes etcetera, columns in industrial buildings must be designed to carry the bending caused by wind loads at the exterior wall structure and horizontal loads from cranes. Since the horizontal loads results in bending moments in the columns the most common cross-section is the rolled HEA-sections. Also HEB-, IPE- and RHS-sections are used and, for larger buildings, welded H- or box-sections and sometimes trusses are selected. Different column types are shown in Figure 3.1.



Key:

A RHS

B HEA, HEB, IPE

C HEA, HEB with support for a crane girder

D Welded section with support for a crane girder

E Truss with support for a crane girder.

Figure 3.1 Different column-types

3.1 Design

RHS-columns have a large capacity to carry vertical loads but they are less economic to carry horizontal load. This makes them well suited for inner columns in buildings without cranes. For outer columns in high buildings with large wind-loads and for inner columns carrying cranes, a better option would be an H-section for its better bending resistance in relation to the steel weight. IPE may be used in some applications but they are slender in the weak direction and require closely spaced lateral bracings.

In larger industrial-buildings with heavy cranes welded profiles of H-section or RHS-section are used. An unsymmetrical profile can be considered due to eccentric loading. The change of section can be used to achieve a natural shelf for the crane girder. The truss column shown in Figure 3.1E is only used in very large buildings with very heavy cranes, for example a steel mill.

4. Background material

1 L. Cederfeldt, Hallbyggnader, SBI Publ. 53, Stålbyggnadsinstitutet, Stockholm 1977

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