
Roof Truss Guide

Design and Construction of Standard Timber
and Steel Trusses



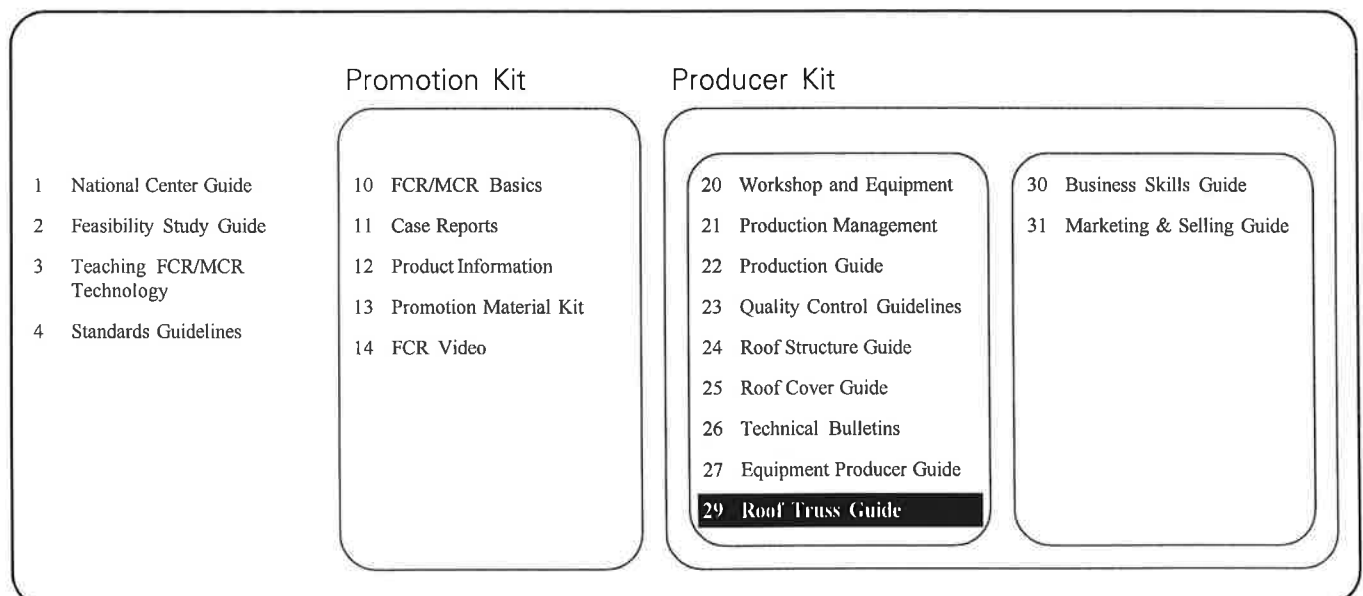
Swiss Centre for Development Cooperation
in Technology and Management

Roof Truss Guide

**Design and Construction of Standard Timber
and Steel Trusses**

FCR/MCR Toolkit Overview

National Center Kit



Author: Peter Eichenberger, SKAT / ENTEC AG, Switzerland
Walter Bieler, Holzbauingenieur, Switzerland
Daniel Mostrales, MSFI, Philippines
Development Alternatives, India

Editor: Daniel Schwitter, SKAT, Switzerland

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Fax: +41 71 228 54 55
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Annex 1: Sample Structural Analysis

Annex 2: Dimensions and Design Information of Angle Bars and Tubes Used in this Manual

1 Introduction

1.1 Objectives of this guide

The roof truss guide is intended to:

- facilitate the design and construction of roof trusses
- improve the quality of trusses
- reduce design and fabrication costs
- achieve more cost- and material-effective roof trusses

The guide is primarily addressed to contractors, builders, practising engineers and architects constructing roof structures with particular emphasis on MCR covered buildings.

1.2 Contents of this guide

The roof truss guide provides:

- hands-on advice on design and construction of roof trusses
- layout drawings and construction details for the most common timber and steel trusses
- design aids in the form of standard detailing tables
- references on more elaborate roof truss designs and construction aspects

The manual is not:

- a text book for the structural analysis of roof trusses
- a guideline for the production of roof tiles and associated issues (production management, quality control and testing, marketing)

For information on these subjects, please consult the respective Toolkit Elements (see overview inside front cover).

Note:

The Roof Truss Guide should be used in consultation with the FCR / MCR Toolkit No. 24: Roof Structure Guide.

The manual does not:

- follow a particular standard of a country or region
- give information on particular problems of specific countries (high-altitude snow or cyclone loading)
- include design aids and sample trusses for large hangars and halls with spans in excess of 15 to 20 m.

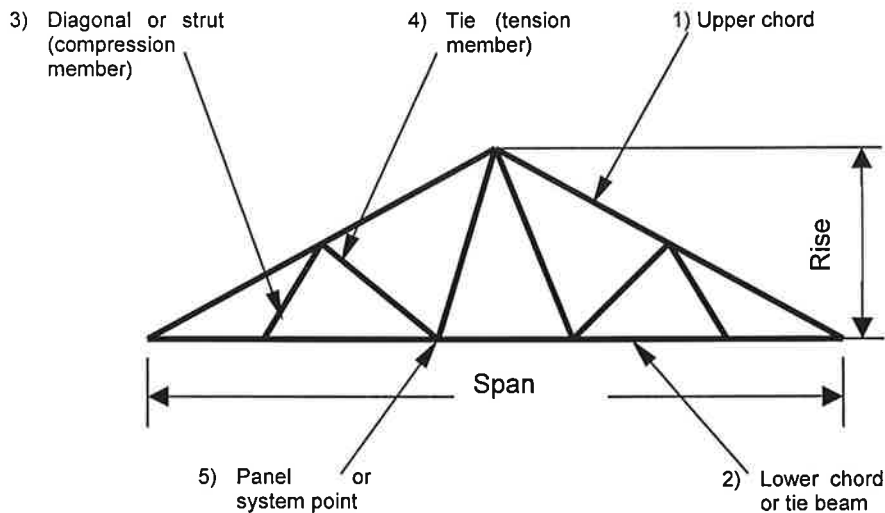
1.3 Validity of data

The material presented in this guide is based on general engineering practice. It is up to the readers to examine the validity of the proposed design for their application. The authors of this guide do not bear any responsibility for damage or failure of roof trusses constructed in consultation of this manual.

2 Principles of roof truss design

2.1 What is a roof truss?

A truss is a structure with straight pieces forming triangles to support a load. The members of the triangles are placed under tension and compression but do not bend.



$$\text{pitch} = \frac{\text{rise}}{0.5 \cdot \text{span}}$$

2.2 When to use a roof truss

Roof trusses are characterised by an economic use of construction materials (timber, steel). Composed of individual lightweight pieces, a truss can also provide considerable advantage in transport and assembly as compared to conventional roof structures. On the other hand, trusses are more labour-intensive and require connection devices. However, if a greater number of *identical* trusses can be manufactured, then considerable economies of scale can be achieved.

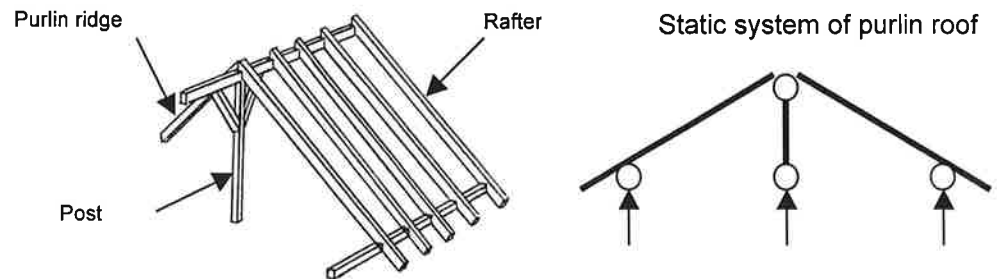
The structural height of a truss is usually larger than the height of similar structures using solid beams. For roofs, however, this is usually no disadvantage as roofs must often - depending on roof cover material used - be higher at the ridge and lower at the eaves to facilitate roof drainage and ensure water tightness.

Competitors of the Truss

While the use of steel for roof structures almost invariably calls for a truss, it is with timber structures where the truss has strong competitors. These are the purlin and the rafter roofs.

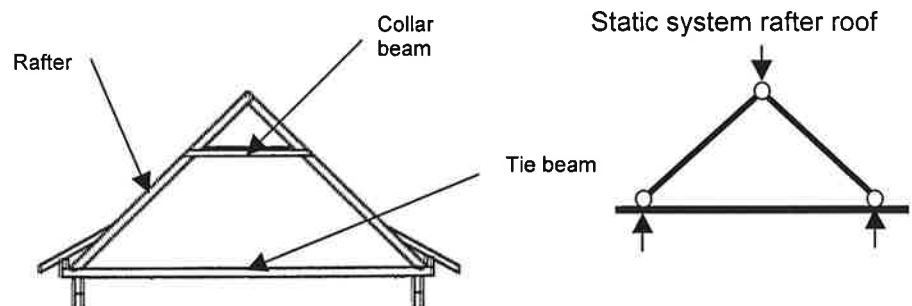
The purlin roof

The purlin roof consists of both rafters and purlins. The ridge purlin is supported by posts. The rafters act as simple supported beams between the purlins, either with or without cantilever.



The rafter roof

The rafter roof originates from tent construction. It consists of two rafters and a tie beam, which form a triangle. The simplest form of the rafter roof is thus identical with the basic element of the truss. Stiffness of the rafters can be increased with a collar beam near the ridge. A bevel shoulder traditionally made the connection between the rafters and the tie beam. This had the disadvantage that the slope of the roof was not uniform but became flatter at the rafter foot to accommodate the bevel shoulder. Today, steel connectors are often used and roof slopes remain uniform. The rafters can also rest on a concrete slab, which then replaces the tie beam.



The following table presents the main features, and the pros and cons of the three basic design options for roof structures. It can assist designers in selecting the most appropriate roof structure for a specific application.

Note, large hangars and halls are not considered.

Selection criteria

Table 1: Selection criteria for roof structures

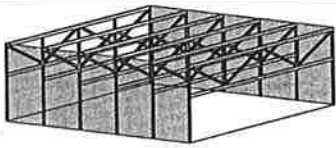
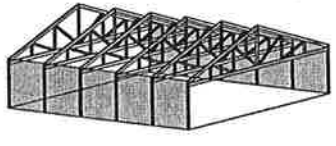
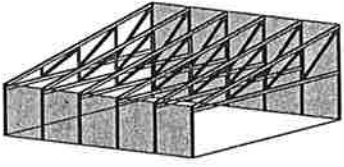
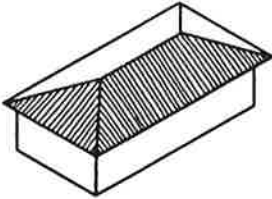
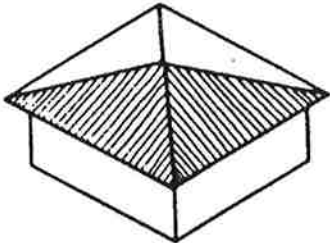
<i>Selection criteria</i>	<i>Truss</i>	<i>Purlin roof</i>	<i>Rafter roof</i>
Span	6 - 30 m	up to 4 m between purlins, but needs intermediate support (concrete slab, girder for posts)	up to 9 m
Distance between trusses / rafters	0.75 - 1.25 m (with battens only) up to 4 m with timber and steel purlins	0.75 - 1.25 m (with battens only)	0.75 - 1.25 m
Slope	any slope (but most economically up to 35°)	25° - 35°	35° - 60°
Use of loft	restricted by diagonals and braces of truss	slightly restricted by posts and struts	free
Roof cover material	any	any	mainly for heavy tiles
Material input	low, but requires connectors, fasteners	high (requires rafters, posts, struts, purlins and battens)	less material input than for purlin roof
Labour input	high (considerable reduction potential if properly planned ahead)	medium	low
Complexity / engineering input	low for standard truss and regular roof shapes; high for non-standard trusses	low	medium

Disadvantage of truss

One of the main disadvantage of the truss is that the strength and stability of its elements is to be designed by an engineer while the other roof structures, especially the purlin roof, can be built by carpenters and steel workshops themselves. It is one of the aims of this guide to eliminate this drawback by providing a number of fully detailed trusses ready for fabrication.

2.3 *Roof shapes suitable for the truss*

Trusses are suitable for a number of roof shapes

	Roof type	Suitability
	Flat	high
	Gable or saddle	high
	Single pitch	high
	Hipped	medium
	Pyramid	low

2.4 Loads on trusses

Dead load (G)

Two categories of loads on trusses can be distinguished: dead load and life load.

Dead loads for roof structures are basically the own weight of the materials used. These forces act vertically.

own weight of truss:

- for timber typically (per area covered) 0.25 kN/m²
- for steel: use the following formula:

$$g = 0.0040(4.42\sqrt{L} + L) \text{ in kN/m}^2$$

where L = span in metre

typical weight of steel truss: 0.10 kN/m²

weight of purlins / battens

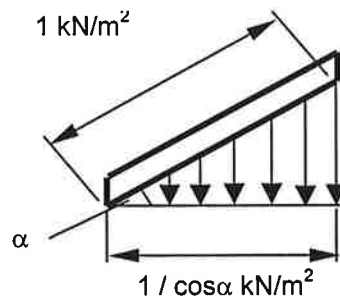
- for timber trusses with battens: negligible (since truss spacing is small, battens are mere laths)
- for steel trusses with steel purlins: 0.09 kN/m²

weight of roof cover 0.27 kN/m² for MCR tiles

0.12 kN/m² for steel roofing

0.47 kN/m² for clay tiles (double depression, interlocking tiles)

weight of under-roof, timber 24 mm thick, 0.14 kN/m²



Note: Dead load per horizontal surface area of roof cover materials increases with the slope of the roof: multiply with $1/\cos\alpha$ where α is the roof pitch or slope. For a typical slope of 30°, the increase in load per horizontal surface area is 15%; hence, an MCR roof would weigh 0.31 kN/m² of area covered.

Life load (Q)

Wind load: the magnitude of the wind load depends on the roof shape, wind direction and location of the building (see figures below). For lightweight roof structures and cover materials, the wind load is the most important load. Wind can also create suction forces and whole roof sections can be blown off. Appropriate fasteners and holding down bolts or anchors must be used (see manuals of roof cover manufacturer).

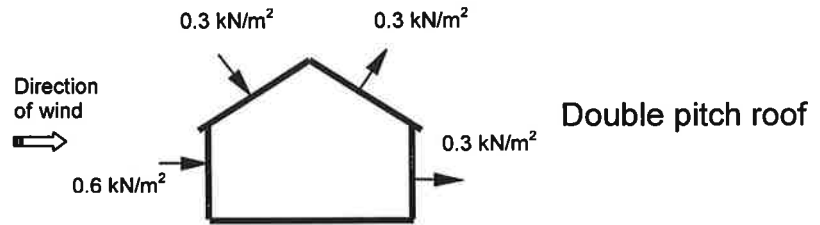
Snow load (according to climatic zones, typically 0.03 kN/m² for each 10 mm of snow)

Concentrated load ("man load") due to foot traffic for fixing and maintenance, typically 0.8 kN. The man load is usually disregarded when analysing the truss as a whole. However, for sizing battens, the man load is the most important life load (see Annex 3.1 of the FCR/MCR Toolkit No. 24).

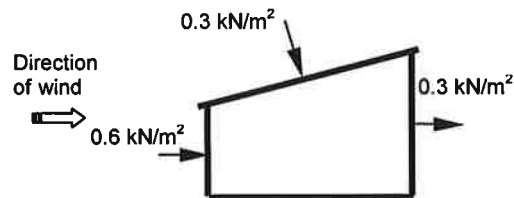
Wind loads increase with the elevation above ground level and the degree of exposure (open fields, coastal strips, mountain tops). The following assumptions have been used:

- max. wind speed: 100 km/h
- max. elevation above ground level: 8 m

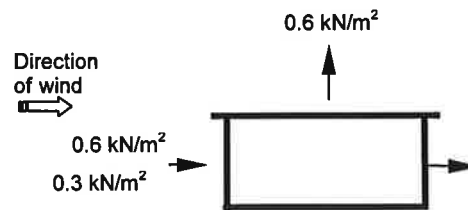
The wind loads indicated below act perpendicular to the roof or wall surface.



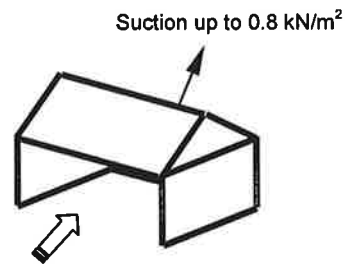
Double pitch roof



Single pitch roof



Flat roof



Open building

2.5 Load combinations

Life loads need not be assumed as acting simultaneously in full magnitude. Maximum wind loads do not occur together with snow. It is also unlikely that somebody would step onto the roof at highest snow depth or during gale winds. In areas where snow occurs, a combination of wind, snow and dead load is taken as the design condition. Two cases need to be examined, one with the snow as the leading impact and one with the wind as the decisive life load.

Case (1): Total load $S'_1 = 1.0 G + 0.9 Q_{\text{snow}} + 0.7 Q_{\text{wind}}$

Case (2): Total load $S'_2 = 1.0 G + 0.9 Q_{\text{wind}} + 0.7 Q_{\text{snow}}$

It must also be checked whether dead load and either of the life loads (at 100 %, without reduction) exceeds any of the total loads of the above two cases.

Total vertical load of a typical truss for a 22° roof slope covered with MCR tiles in a tropical area (no snow) is:

$S' = 1.00 \text{ kN/m}^2$.

2.6 Truss spacing

The factors governing the spacing of individual roof trusses are different for steel and timber structures:

Timber: The sizes of sawn timber boards and beams are limited to widths / heights of 150 to 200 mm. With the given loading capacity of timber, the most economical spacing of timber trusses is around 1.5 to 2.0 m.

Steel: Small roof trusses are usually put in place without the use of cranes. The limiting factor for the spacing of steel trusses is therefore the weight of the individual truss (or portions of it, if it is assembled on site). The steel truss samples presented in this manual are not heavier than 3 kN (300 kg) per individual truss. The other factor to be considered is the size of the purlins. Purlins used for small roofs covered with MCR or steel roofing consist of equal angle bars or C-sections (where available). Spacing of purlins for MCR roofing system is 400 mm. Even for small buildings (8 x 15 m) the total length of purlins required is often several hundred meters of steel sections. Purlins should preferably be light sections to make an economic roof structure.

Considering the above, typical steel truss spacing is 2.5 m to 3.0 m for spans below 15 m.

2.7 Structural analysis

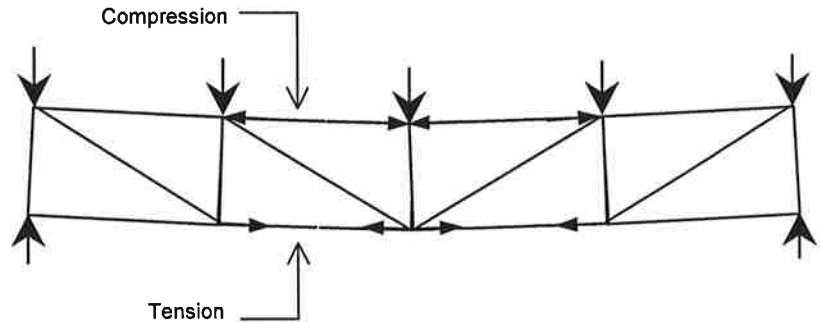
For an introduction into structural analysis please refer to the FCR / MCR Toolkit No. 25, Chapter 2.

With the structural analysis it must be shown that the truss is safe from:

- failure of any of its members (strength and stability) including the connections
- failure of the truss as a whole (stability)
- developing excessive deflection.

Working principle

A roof truss will slightly deflect under a vertical load. The upper chord will be under compression while the lower chord is under tension. Diagonals can either be compression or tension members depending on their inclination.



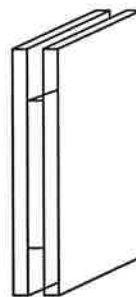
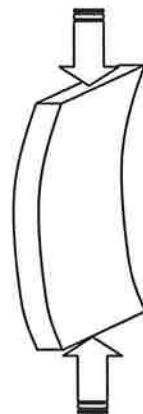
The convention for the presentation of tension and compression members in drawings is as follows:

- Arrow towards panel point = compression
- Arrow away from panel point = tension

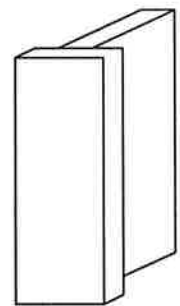
The members of flat roof trusses will change sign under extreme wind loading. Suction forces may exceed dead load and the lower chord will be under compression and the upper chord will be under tension.

Buckling of members

While tensile forces in roof truss members can be handled by very slender timber or steel sections, it is the compression members that require most attention by the designer. Compression members tend to buckle under load and need to be restrained laterally. Instead of using simple timber boards or flat steel sections, either composite or stiffened compression members must be used.



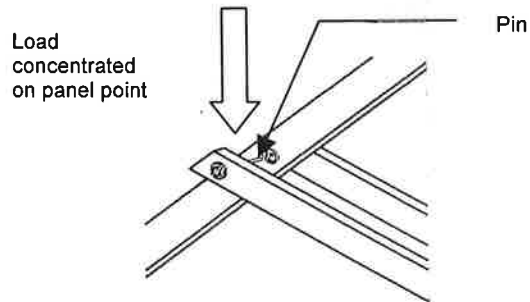
Composite member with two boards or flats and a packing plate in between



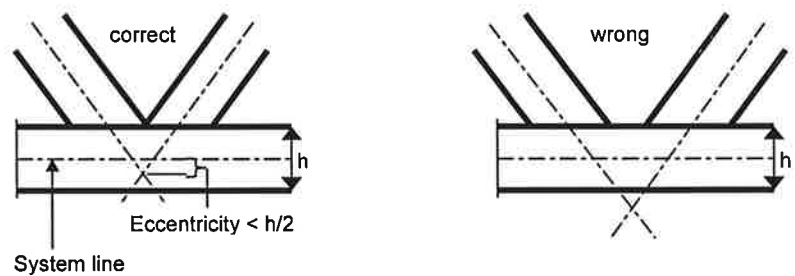
Stiffened member

Assumptions for structural analysis of trusses

Analyses of trusses assume **pin jointed connections** regardless of the actual type of connector used. **The loads are applied exclusively through the panel points** even though in reality this will not normally be the case.



Ideally, the system lines (centre lines) of truss members should precisely meet at the panel points. In practice, this can hardly be achieved. Trusses almost invariably have eccentric connections, which exert additional stresses on members and connectors. Adequate margins to stress limits need to be allowed for. Rule of thumb: If system lines of three truss members cannot meet in one point (e.g. with nail plates), the system lines of diagonals should meet at least within the chord member.



2.8 Roof truss selection step-by-step

The sample trusses of chapters 4 and 6 will not cover all the different spans and loads that may occur in practice. The philosophy is to maintain the basic design of the truss as per the samples given in chapter 4 and 6 and then adjust the span of the truss and the distance between individual trusses to suit the design of the building and the load of the roof.

Proceed as follows:

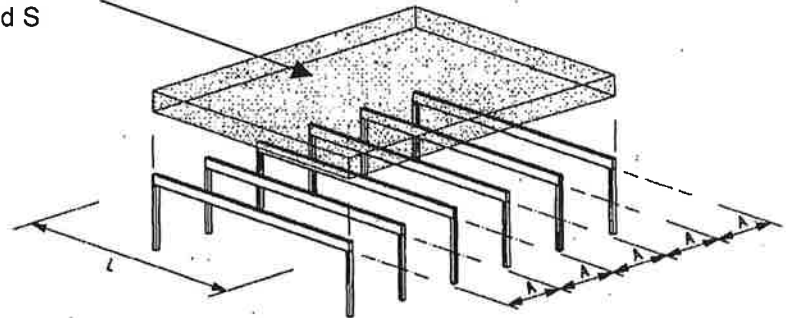
1. Determine the shape of your roof, the span of the truss and the loads (S') using the recommendations in chapter 2.5 above or consult your National Standards (Loading Code).
2. Select the desired truss from the samples given in chapters 4 and 6 considering the span that comes closest to your design.
3. Compare your design span with the span of the chosen sample. If the span differs, adjust the distance between the trusses (A') to suit your design span:

$$\text{new distance (A')} = \frac{(\text{span of standard truss})^2}{(\text{design span})^2} * \text{standard distance between trusses (A)}$$

4. Compare the load of your roof with the load of the sample. If the loads differ, adjust the distance between the trusses (A') to suit your load:

$$\text{new distance(A')} = \frac{\text{load of standard truss}}{\text{design load}} * \text{standard distance between trusses (A)}$$

Distributed load S



L = span, A = distance between trusses

Note: For the sizing of battens and purlins FCR / MCR Toolkit No. 24 can be used (Appendix 3.1 and 3.3).

A combination of steps 3 and 4 is possible!

Example:

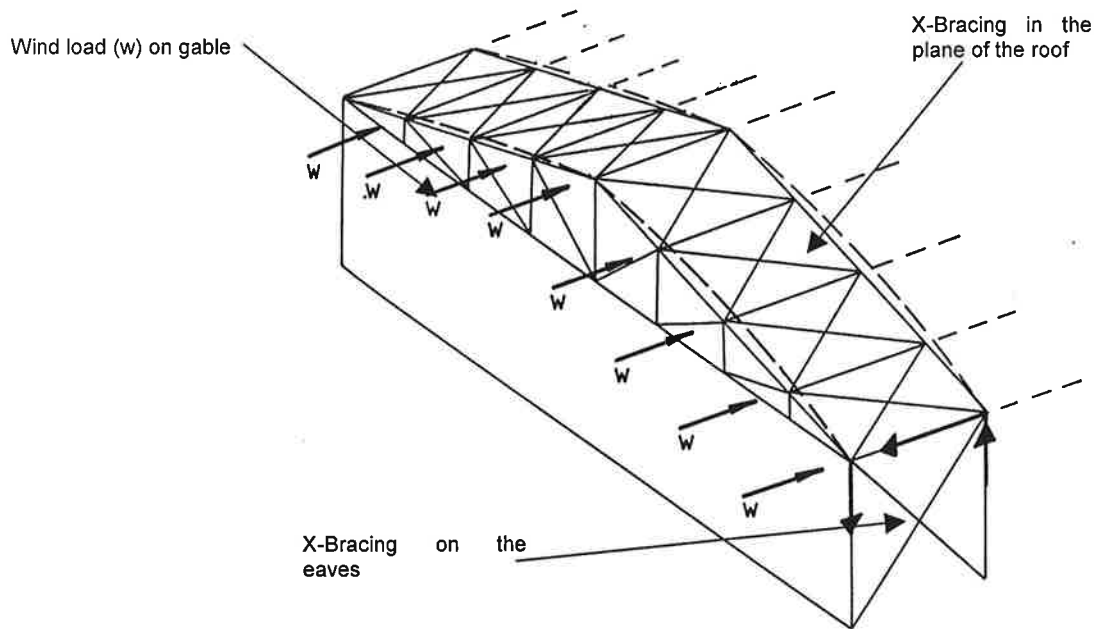
Standard distance A (as per given sample)	= 1.50m
Span of standard truss (as per given sample)	= 6.00m
Standard total load (as per given sample)	= 1.00kN/m ²
Design span	= 5.40m
Design load	= 0.95kN/m ²

$$\text{Solution: } \underline{\underline{A'}} = \frac{6.00^2}{5.40^2} \times 1.50 \times \frac{1.00}{0.95} = \underline{\underline{1.95m}}$$

2.9 Stability of the Truss

By using the sample trusses of Chapters 4 and 6, the structure will carry the vertical loads it was designed for. However, the stability of the truss against lateral movement is not yet ensured. Compression chords tend to buckle in a direction perpendicular to the plane of the truss. In addition, wind loads on gables are also exerting forces perpendicular to the plane of the truss. A lateral restraining or bracing system is therefore required.

Purlins and battens may form part of this lateral bracing system. It is important that at least each panel point is braced against out-of-plane movement. X-bracing in the plane of the roof is added to form a structurally sound system.

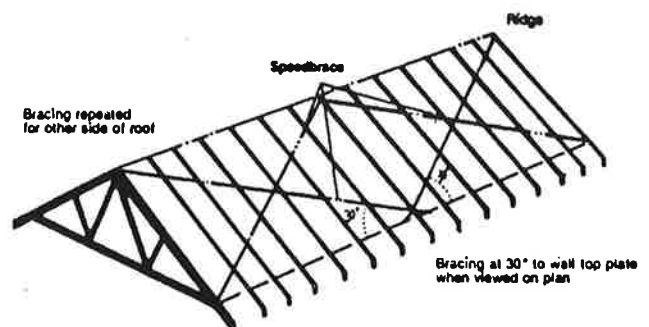


The eaves must take up the wind forces on gables and must lead these safely into the foundations either through solid walling or braces.

Lateral restraining systems including wind braces consist of minimum two braces in the plane of the upper chord. Alternatively, special bracing trusses in the upper chord plane may be used.



Special bracing truss



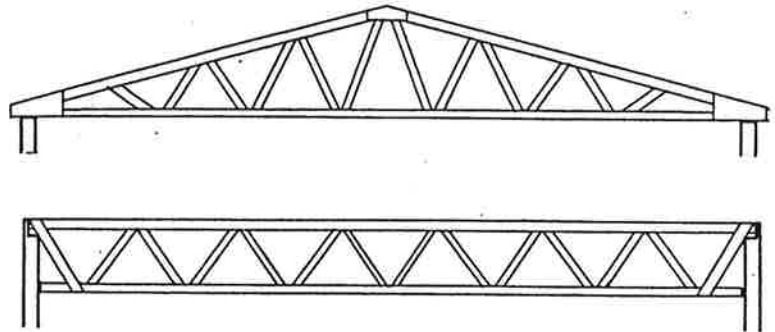
Standard bracing

3 Options for Static Systems

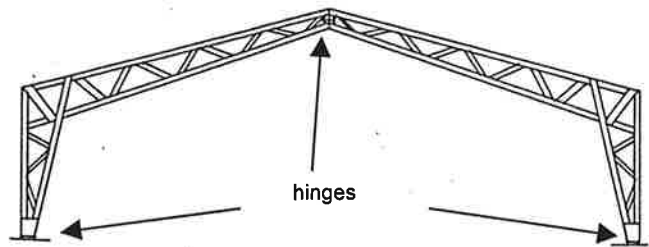
3.1 Overview

For spans up to 20 m, simple supported trusses can be used, which rests on the walls at the eaves. For larger spans and especially for structures with lightweight walling, frames may be used. The following sections provide an overview of the most common options.

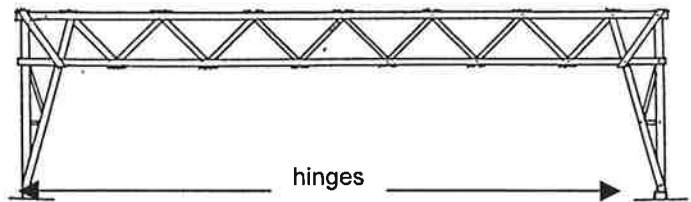
3.2 Simple supported Truss



3.3 Three-hinged Truss



3.4 Double-hinged Truss



Remark:

Double and three-hinged trusses require more elaborate designs than the simple supported beam truss and are thus beyond the scope of this guide.

4 Timber Trusses

4.1 *Design Considerations*

A number of design considerations need to be made before selecting timber as the basic material for the roof truss. Issues to be checked are the following:

Availability of suitable timber: In many countries timber has become very expensive or is no longer available at all because of widespread deforestation. Timber with good (natural) resistance against rot, insect and fungal attack should be used.

Exposure to the weather: Timber should not be used if the truss cannot be fully protected from the weather.

Roof form: This is generally a matter of roof drainage and architectural considerations. Timber trusses are highly suitable for common roof forms but may not be first choice for extravagant roofs. In this guide, only the flat, single and double pitch roof forms are dealt with.

Fire rating: Lightweight timber trusses have low fire resistance due to their slender dimensions (boards, 25 mm thick) and cannot be used for buildings requiring a high fire rating.

Jointing system: For timber trusses, the most common jointing systems are nails and bolts. Adequate drilling equipment is required.

Transport and on-site handling: Due to their light weight, timber trusses are particularly suitable for construction in remote areas and at sites without hoisting devices. Most timber trusses can be handled manually.

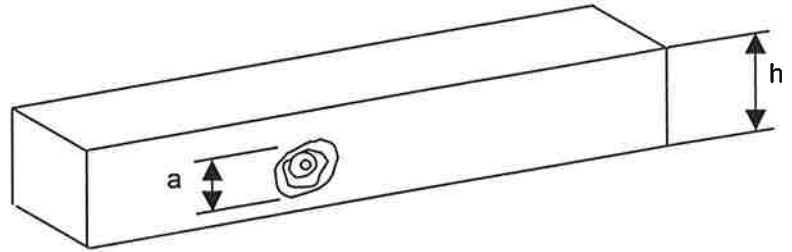
4.2 *Timber Quality*

A method for classifying sawn timber has been given in the MCR Toolkit No. 24, p. 66. Appendix 3 of the same guide allocates common timber species to the classes specified. Sample trusses of Section 4 are valid for lowest class C with admissible bending stress of between 8 to 10 N/mm².

Unlike the properties of most other construction materials, the properties of timber can vary considerably within a single element. Timber to be used in structural elements must be properly selected. Boards and sections with natural defects must be eliminated through visual inspection. The criteria to be applied are as follows:

Knots

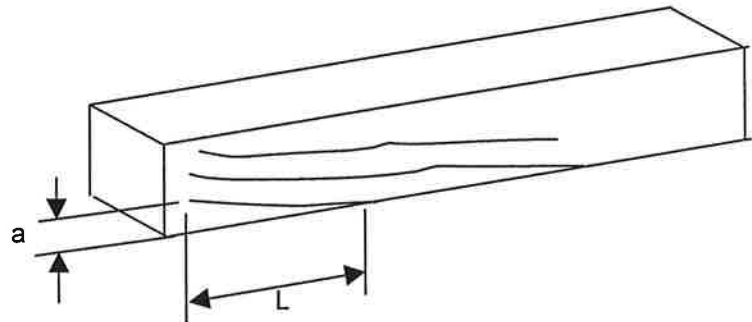
The size of knots must not exceed $\frac{1}{4}$ of the height of the element.



$$a < h / 4$$

Through-knots are knots extending through a piece of timber. Elements with through-knots must not be used for tension members of trusses (lower chords).

Sloping grain



$$a / L < 1 / 8 \Rightarrow a < L / 8$$

$$\text{or } L > 8 a$$

Pockets of decay, fungal and insect attacks are not tolerated for structural timber.

4.3 Fixings and Fastenings

4.3.1 System Options

The construction of timber trusses is governed to a large extent by the availability of suitable fastening systems that permit the jointing of truss members. In many cases, the sizes of truss members are determined by the connectors used and not by the stress in the member since connectors require a certain contact area.

An appropriately selected fastener can increase the quality, durability and the economic feasibility of a timber truss. The options available are the following:

Nails: The use of nails is the preferred option for many applications as nails are available throughout the world, come in various sizes and can be applied by simple means. Slip in nailed joints can be reduced if a large number of small diameter nails are used instead of a few large ones. Pilot-drilling improves the joint as the grains are less disturbed. For nailing in hardwood elements, pilot-drilling is indispensable.

Screws: Screws have practically identical performance to nails except for withdrawal resistance where the screw is highly superior. However, as screws are much more labour-intensive and joints in roof trusses seldom require particular withdrawal resistance, the nail joint is preferred in all standard timber trusses. Where there is a danger of joints becoming loose due to repeated swelling and shrinkage of the timber (moisture and temperature fluctuations), screws should be used instead of nails.

Bolts: Bolts can transmit relatively large loads. However, slip in bolted connections is high and bolted trusses tend to have extensive sag. This problem can be overcome if shear pins with close tolerances are used. The holes to be drilled have the same diameter as the metal pin, and slip of the joint can be considerably reduced. It is clear that for connections using tight fitting pins, the requirements on workmanship are high (precise drilling). In addition, the timber must be well seasoned otherwise shrinkage will cause the timber to split between pins. To conclude, the bolted truss is to be used only after careful consideration of its pros and cons.

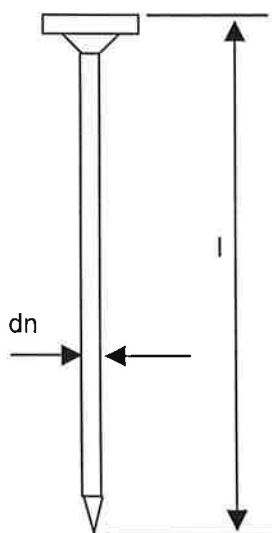
Split rings: The split-ring connector consists of a steel ring that is installed by cutting matching circular grooves in the faces of the lapped pieces of wood. The joint is held together by a bolt. As this type of connector requires special cutting tools and high levels of accuracy, the split ring connector is not recommended for standard roof trusses.

Nail or tooth plate connectors: A perforated or spiked metal plate is pressed into the sides of the joined timber pieces, functioning both as a gusset plate and a connecting device. A variety of multi-nail spiked connectors are now available in many countries under specific brand names. Those connectors that can be hammered in on site without the need of a hydraulic press and are very appropriate fasteners for timber roof trusses. Aesthetics of timber trusses using nail plait is, however, somewhat impaired.

Plywood gusset plates: As an alternative to metal connectors, plywood gusset plates can be used in combination with nails.

Glued finger or laminated joints: Glued structural joints require specific know-how and equipment and are therefore not readily applicable by general carpenters and contractors.

4.3.2 Nails



Steel quality: min. tensile strength 600 N/mm^2

Nails are available as galvanised or blank wire nails. They must be galvanised if timber is treated with copper-chromium-arsenic (CCA).

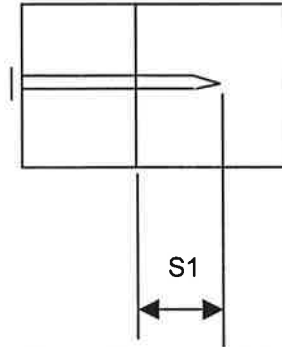
Designation: Nail connections are specified as follows:

No of nails; nominal diameter (dn) x length (l)

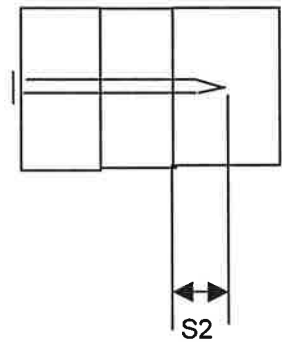
Generally, the length of the nail should not be less than twice the thickness of the timber being secured.

Nailed joints:

A nail may be used to connect one or two elements at the same time.

single shear plane of a nailed connection:

The nail must enter the second timber at least 12 times the diameter of the nail (penetration depth $S1 > \text{or} = 12 dN$)

double shear plane:

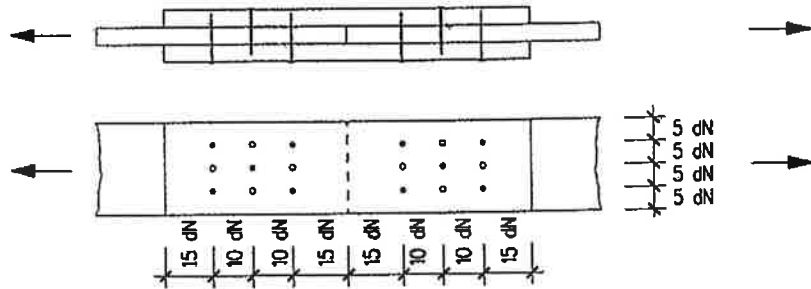
The nail must enter the third timber at least 8 times the diameter of the nail (penetration depth $S2 > \text{or} = 8 dN$)

Nail spacing and edge distance:

Nail connections often fail as a result of inadequate distance to the edge or centre to centre distance between nails. The grains of the timber act like a hammock for the nails preventing them from tearing the edge. In order to obtain the full loading capacity of a nail connection the following spacings and edge distances must be used.

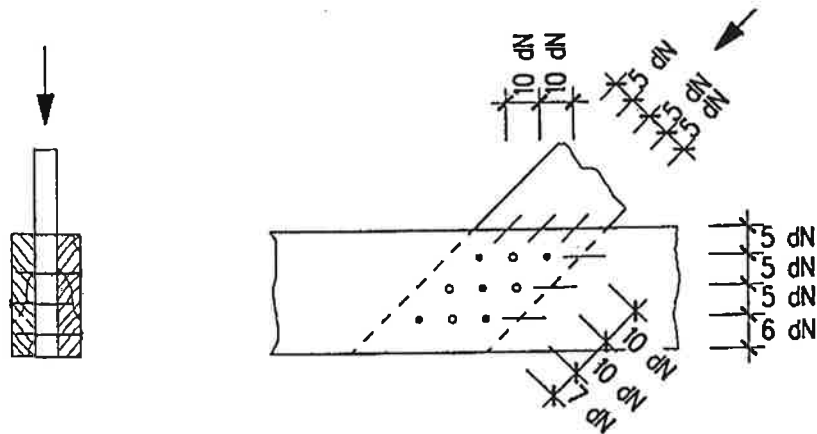
- from centre to centre
 - Parallel to the wood grain: min. 10 dN
 - Perpendicular to the grain: min. 5 dN
- Distance to loaded edge / direction of the force
 - Parallel to the wood grain: min. 15 dN
 - Perpendicular to the grain: min. 6 dN

- Distance to non-loaded edge
 - Parallel to the wood grain: min. 7 dN



- Nail at the front
- Nail at the back

- Perpendicular to the grain: min. 5 dN



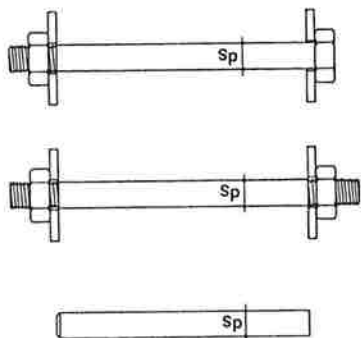
- Nail at the front
- Nail at the back

Admissible loads of nailed connections (load perpendicular to wood grain, softwood, class C)

Diameter (mm)	2.8	3.1	3.5	4.0	4.5	5.0	5.5	6.5	7.0
Length of nail (mm)	60	75	90	100	110	130	150	180	215
	70	80			120	140	160	200	230
Minimum thickness of the timber piece (mm)						150		215	
	18	20	20	25	30	40	45	60	60
	20	25	25	30	35	45	50	70	70
	25				45	50	60		80
Admissible load per nail									
	• Single shear plane (kN)	0.25	0.35	0.45	0.55	0.70	0.85	1.0	1.3
• Double shear plane (kN)	0.50	0.70	0.90	1.10	1.40	1.70	2.0	2.6	2.9

The admissible loads are valid if the edge and centre to centre distances of the nails as outlined above are observed.

4.3.3 Bolts / Pins



Steel quality: commercial bolt, strength grade 4.6 (nominal tensile strength 400 N/mm², nominal yield stress 240 N/mm²)

Bolted connections:

For timber trusses, only tight-fitting pins must be used. It is nevertheless usual practice to fit large-size washers on each side. This not only ensures that the pin cannot become loose, it also improves the rigidity of the joint.

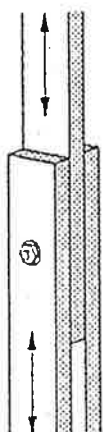
Note, tight-fitting bolted joints must not be used if the timber is not well seasoned as shrinking timber between two tight fitting bolts in different timber elements will cause at least one of the timbers to crack.

Admissible loads of bolted joints:

**Load parallel to wood grain,
single shear, softwood, class C**

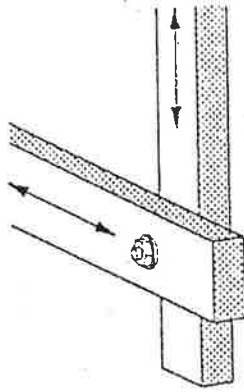
Bolt / pin diameter (mm)	Minimum thickness of timber piece (mm)	Admissible load per bolt (kN)
12	50	2.70
16	75	4.50
20	100	6.50
24	125	9.00

**Load parallel to wood grain,
double shear, softwood, class C**



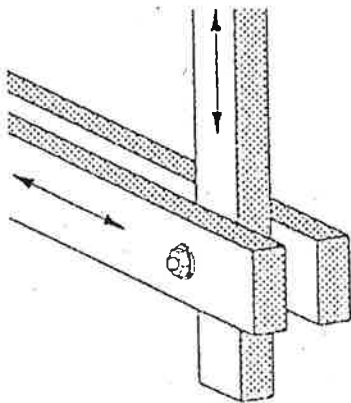
Bolt / pin diameter (mm)	Minimum thick-ness of timber piece (mm)		Admissible load per bolt (kN)
	outside	middle	
12	50	75	5.40
16	75	100	9.00
20	75	125	13.00
24	100	150	17.80

**Load perpendicular to wood grain,
single shear, softwood, class C**



Bolt / pin diameter (mm)	Minimum thickness of timber piece (mm)	Admissible load per bolt (kN)
12	75	1.90
16	100	2.90
20	125	4.00
24	150	5.30

**Load perpendicular to wood grain,
double shear, softwood, class C**



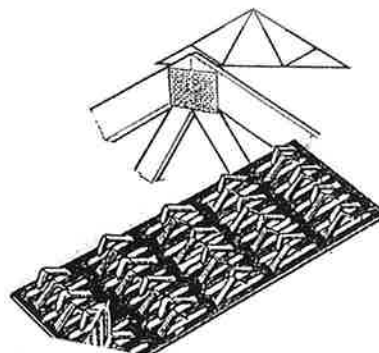
Bolt / pin diameter (mm)	Minimum thickness of timber piece (mm)		Admissible load per bolt (kN)
	outside	middle	
12	75	100	3.70
16	100	125	5.80
20	100	150	8.00
24	125	200	10.60

Values for load / grain angles between 0° and 90° may be interpolated from the above tables.

4.3.4 Nail Plates

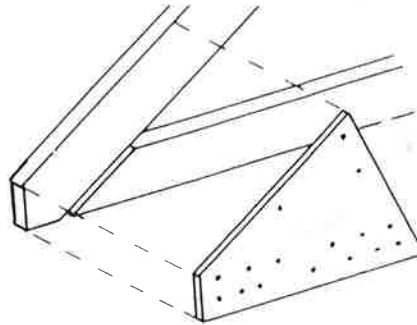
The multi-tooth connectors that are designed for on-site installation by a hammer are Tylok and Teco-Nail-on Plates. Admissible loads of these connectors may be obtained through their official outlets.

The use of nail plates eliminates the need of multiple-piece members since joints are made by gusset plates and by lapping the members. These single-piece members are thicker than those of the composite truss members. This is a genuine advantage as the availability of thin boards (25 mm) of adequate quality is still limited in many countries.



4.3.5 Plywood gusset plates

Only **structural** plywood must be used as gusset plates for timber trusses. The grain direction of the face ply is important for the load bearing capacity of the plywood gusset plate. The following symbol is usually used on drawings:



A nail truss with plywood gusset plates has the advantage that only single-piece members are used. These members are thicker than those of the simple nail truss and for example ceilings can better be fixed to the bottom chord.

The sample truss presented here uses a plywood sheet of 27 mm thickness.

4.4 Timber Seasoning and Preservative Treatment

The shrinking and swelling of well-seasoned timber due to climatic variations (moisture and temperature) is usually not a problem as the resulting dimensional changes are small. Special attention must, however, be paid to the greater changes in dimensions that accompany the drying of green timber. In hardwood, tangential shrinkage may amount to 15 % during drying from green to air-dry state. If a green truss member is used in conjunction with a plywood or metal gusset plate, disaster is inevitable. The green truss member will shrink but the gusset plate will not. Either the gusset plate is damaged or the timber member is split.

The timber truss samples presented in this guide are designed for seasoned timber only. The use of green timber will not give satisfactory results.

Preservative treatment of timber may be required for timber species, which are less resistant to biological hazards

4.5 Nail Truss

4.5.1 General

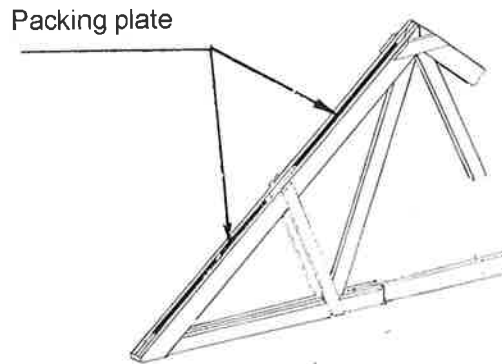
The nail truss makes a highly economic roof structure. However, it has a low fire rating and it sometimes does not fulfil the client's requirements on aesthetics when the truss remains visible. Spans of nail trusses can vary from 6m up to 20m. Larger spans are possible (30 m) but only for light loads and small distances between trusses.

The nail trusses presented in this manual require relatively thin timber boards as truss members. Cutting such boards may be

difficult in some areas as no adequate saws may be available. If circular saws or even chain saws are used, the loss of material may be excessive to produce such thin boards.

4.5.2 Design

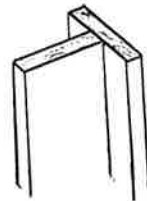
Upper and lower chords are usually composed of two parallel timber pieces with diagonals in between. The nails will then be loaded for double shear. In order to avoid buckling of the top chord members, **spacers or packing plates** are nailed between the two members to form a composite compression chord. The packing plate is fixed with two rows of nails at 300 mm spacing.



Note: In open buildings, the lower chords may at times also become compression members due to wind suction forces (see Section 2.4). It is essential that in such cases packing elements are introduced at the lower chord, too.

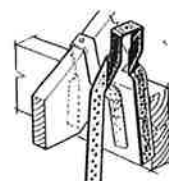
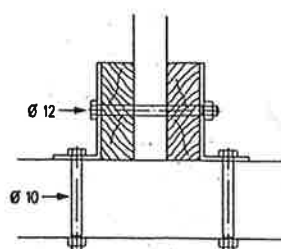
4.5.3 Details

Stiffened struts: One-piece diagonals with compression forces need to be stiffened to avoid buckling. Timber boards are nailed onto the small face of the strut and fixed with nails at 300 mm spacing.



Support details: For lightweight roofing materials, the trusses need to be secured against uplift from wind suction forces.

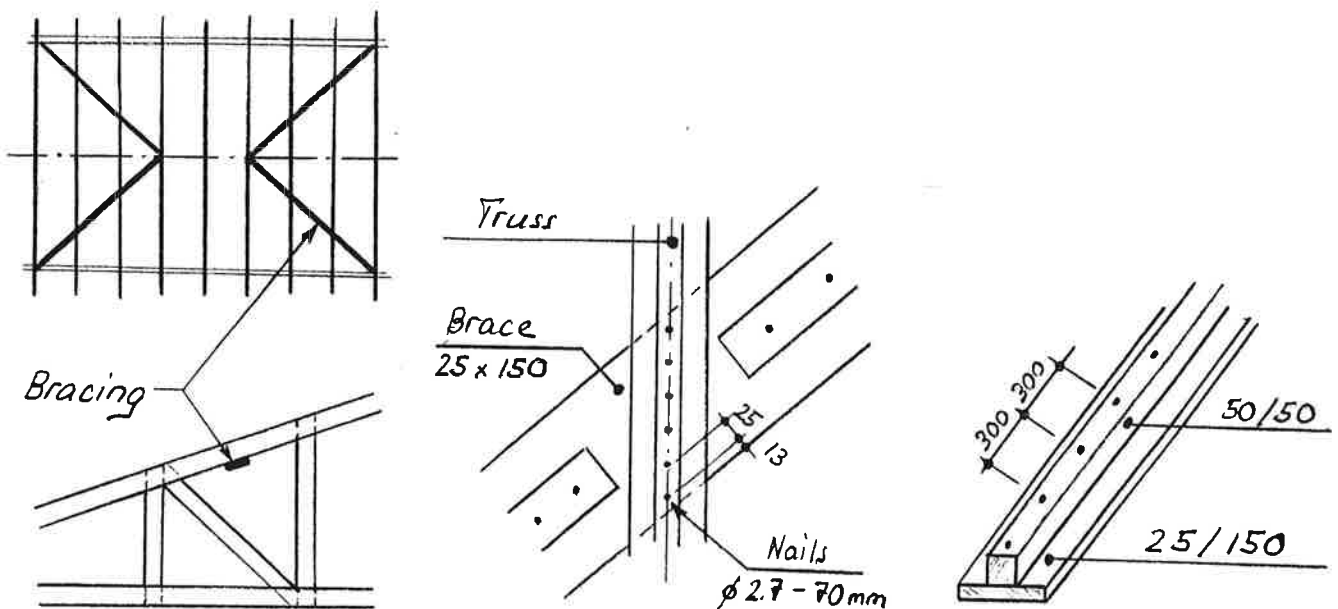
Trusses may be fixed to the wall plate by means of a bolt and galvanised wire. More elaborate supports include steel angle bars. In some countries, special cyclone ties and straps designed as nail-on plates are available to connect trusses to timber wall plates. Needless to say that the wall plate must itself be properly secured to the solid wall (brick, concrete, etc.) below.



4.5.4 Bracing / Lateral restraining system

Lateral restraining systems are designed to maintain the stability of the truss. Nail trusses receive a bracing system on the upper chord. The traditional bracing system consists of timber planks nailed in diagonal direction to the under side of the top chord. For roofs up to 10 m long, 4 diagonals are used. For roofs up to 20 m, 6 diagonals should be applied. Diagonals consist of a timber plank 25 x 150 mm stiffened by a lath of 50 x 50 mm fixed with nails 2.7 – 70 mm at 300 mm centres. Connections with the chord member of the truss involve six nails 2.7 – 70 mm at 25 mm centres.

More recent bracing systems consist of metal strips with pre-punched holes which allow easy fixing with nails. The strips must always come in pairs (crossed) as they are only good for tensile forces. The strips are placed onto the upper side of the top chord.



4.5.5 Manufacturing

Nail trusses are fabricated with the aid of a template. The truss is drawn to scale on a flat surface. All truss members can be cut and assembled on the basis of this template without repeating the measuring work. Each panel point requires a template that permits the marking of the nails.

4.5.6 Erecting

Installation of nail trusses can be done manually. The weight of the standard nail trusses presented in Section 4.6 is below 200 kg.

In order to arrive at a regular spacing of the trusses, a lath with the exact centre-to-centre distance needs to be prepared. This lath can be fitted together with the trusses.

Laths for temporary bracing need to be provided and fixed to the truss members with nails.

It is important that all trusses are properly aligned so that the final roof line will be level and free from waves.

4.6 *Nail Truss Samples*

4.6.1 Assumptions and Limits of Application

The nail truss samples given herein are valid under the following assumptions:

- Softwood, category C (see FCR / MCR Toolkit Element 24)
- Moisture content of timber: seasoned to approximately air-dry conditions.
- All structural members of the truss are protected from the weather.
- Nails: min. tensile strength 600 N/mm²
- Loads are permissible loads (not ultimate capacities)
- Loads are applied through the top chord

4.6.2 Flat roof nail truss, 6 m span

Mass of truss: 70 kg (softwood)

Volume of sawn timber: 0.12 m³ / truss (net)

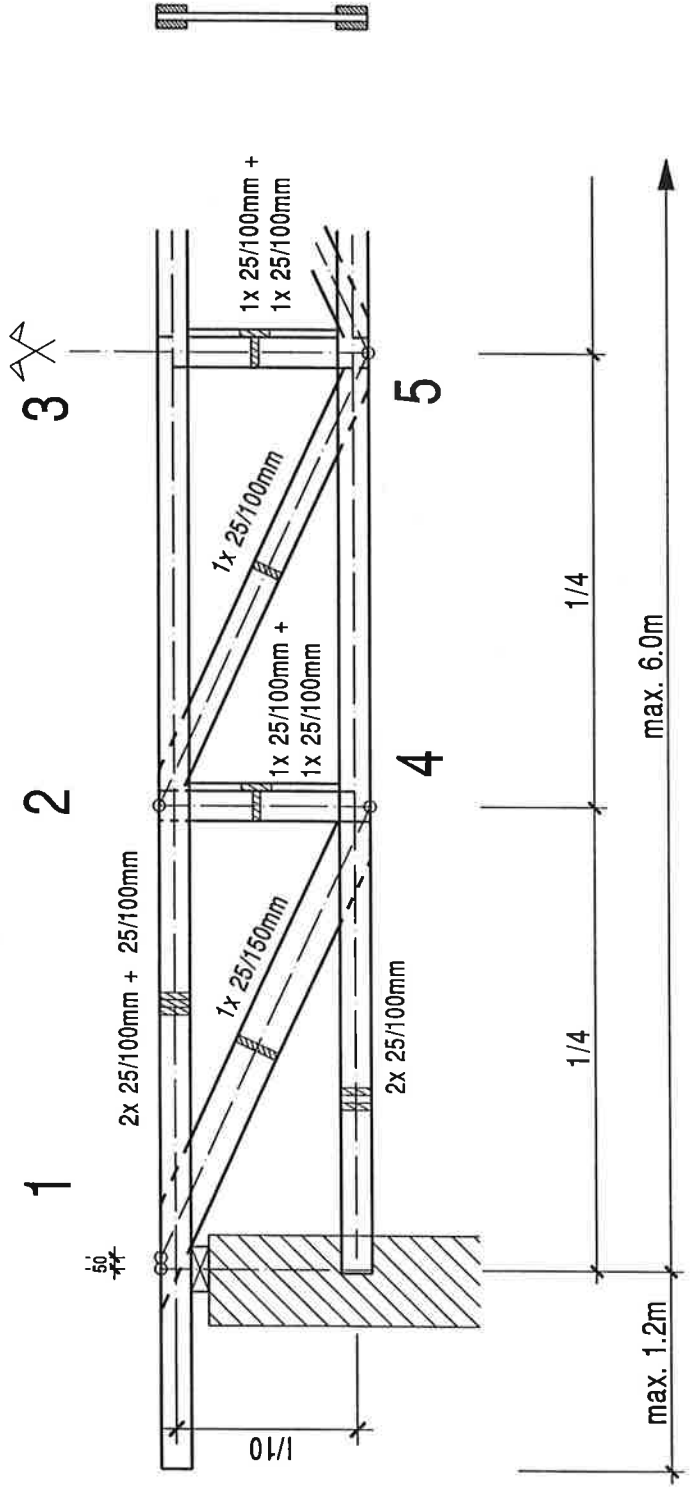
System



Distance between trusses 1.5m

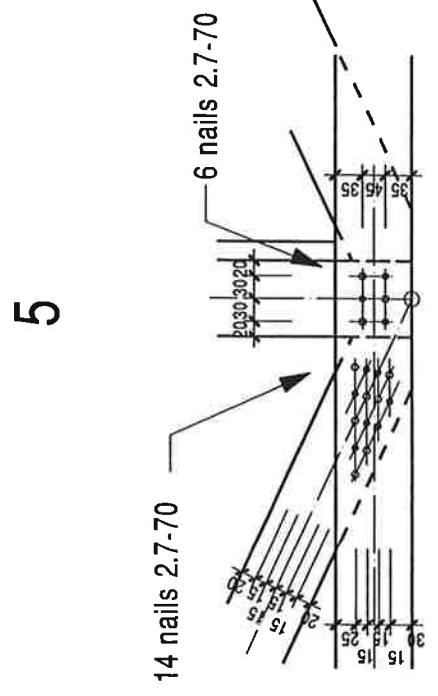
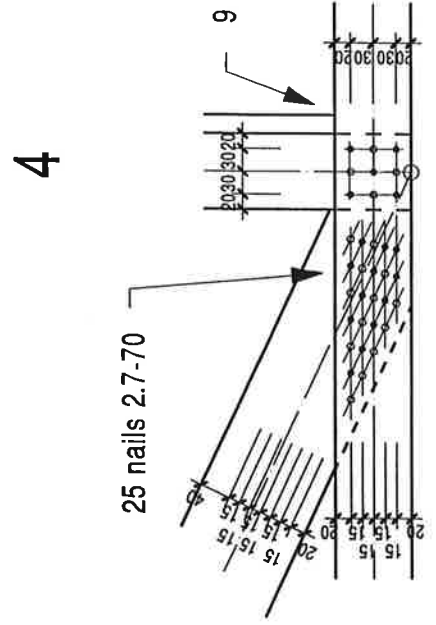
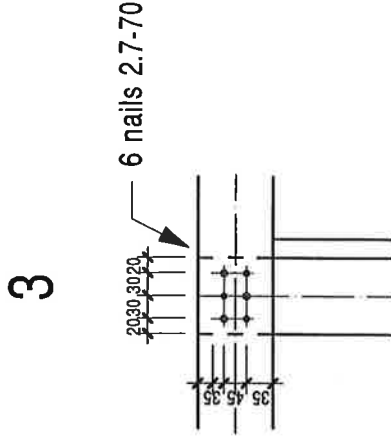
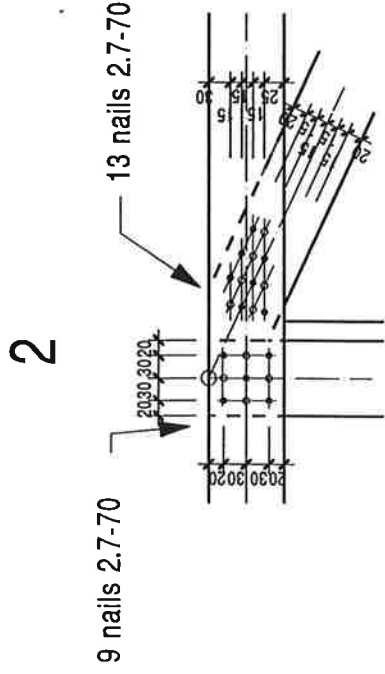
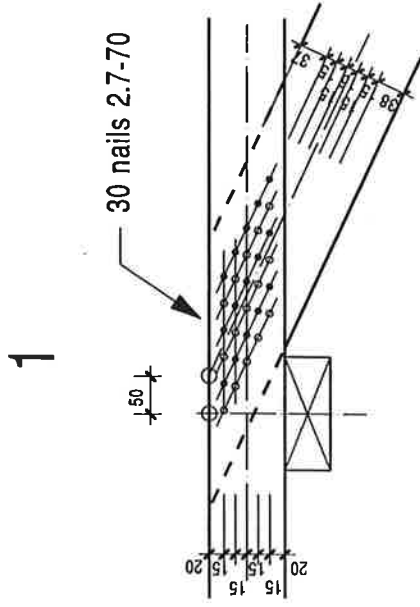
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of flat roof, 6.0m span

- Nails from the front
- Nails from the back (reverse side)



4.6.3 Flat roof nail truss, 8 m span

Mass of truss: 125 kg (softwood)

Volume of sawn timber: 0.22 m³ / truss (net)

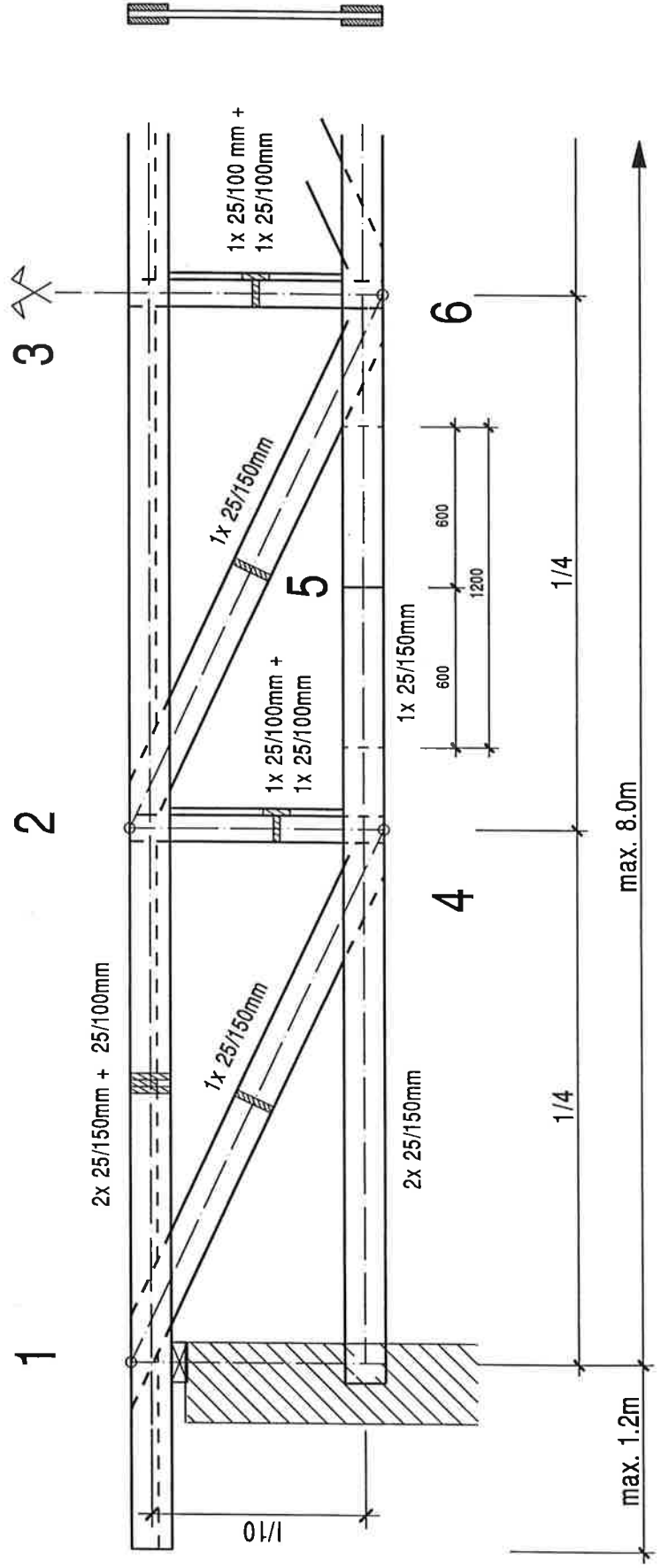
System



Distance between trusses 1.5m

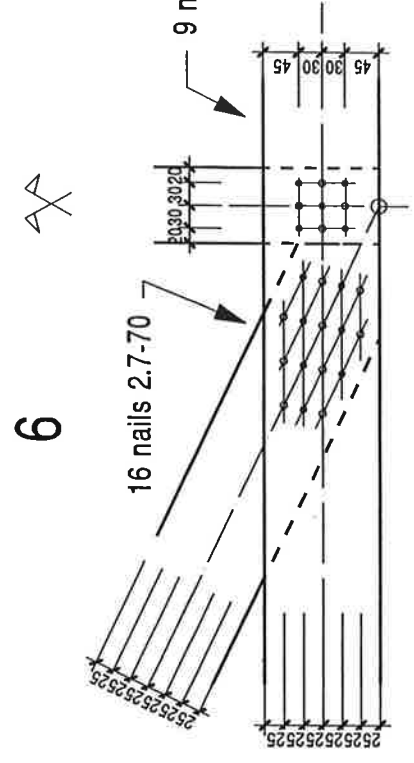
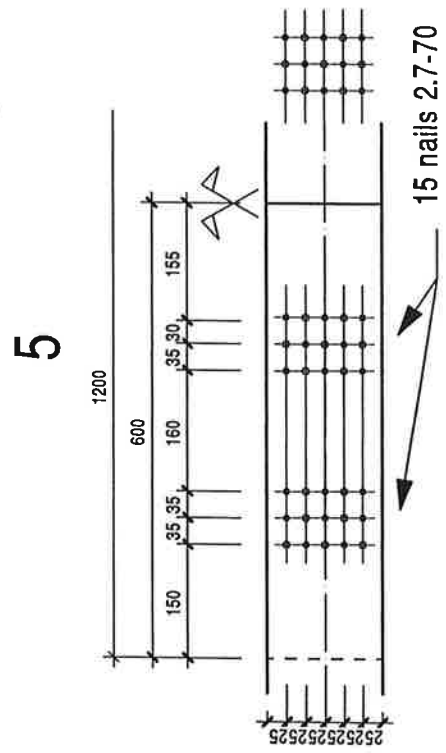
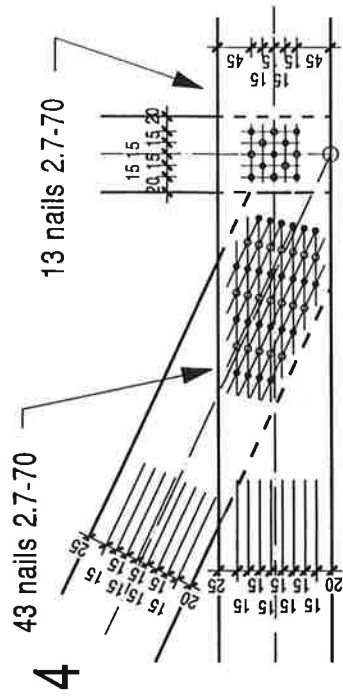
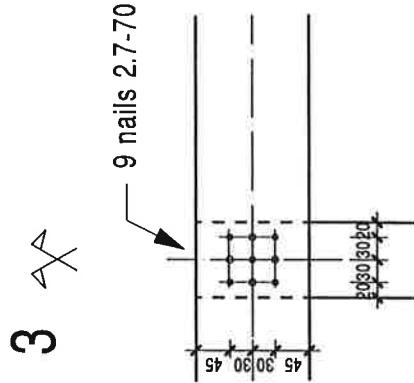
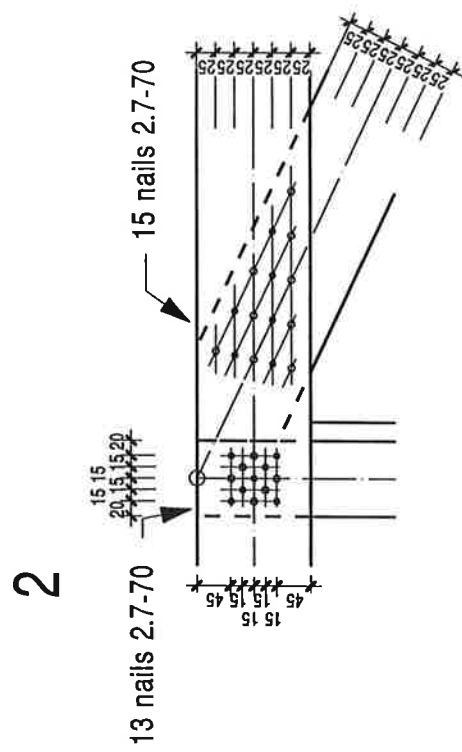
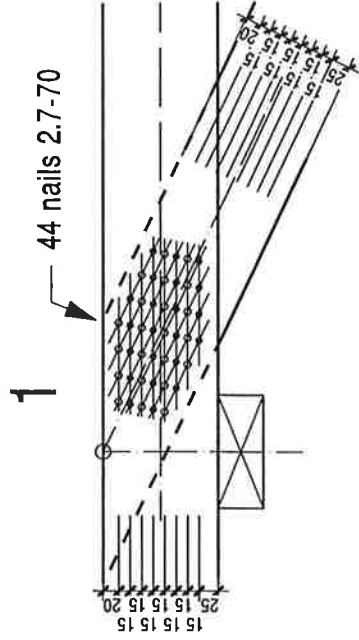
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of flat roof, 8.0m span

- Nails from the front
- Nails from the back (reverse side)



4.6.4 Flat roof nail truss, 10 m span

Mass of truss: 160 kg (softwood)

Volume of sawn timber: 0.28 m³ / truss (net)

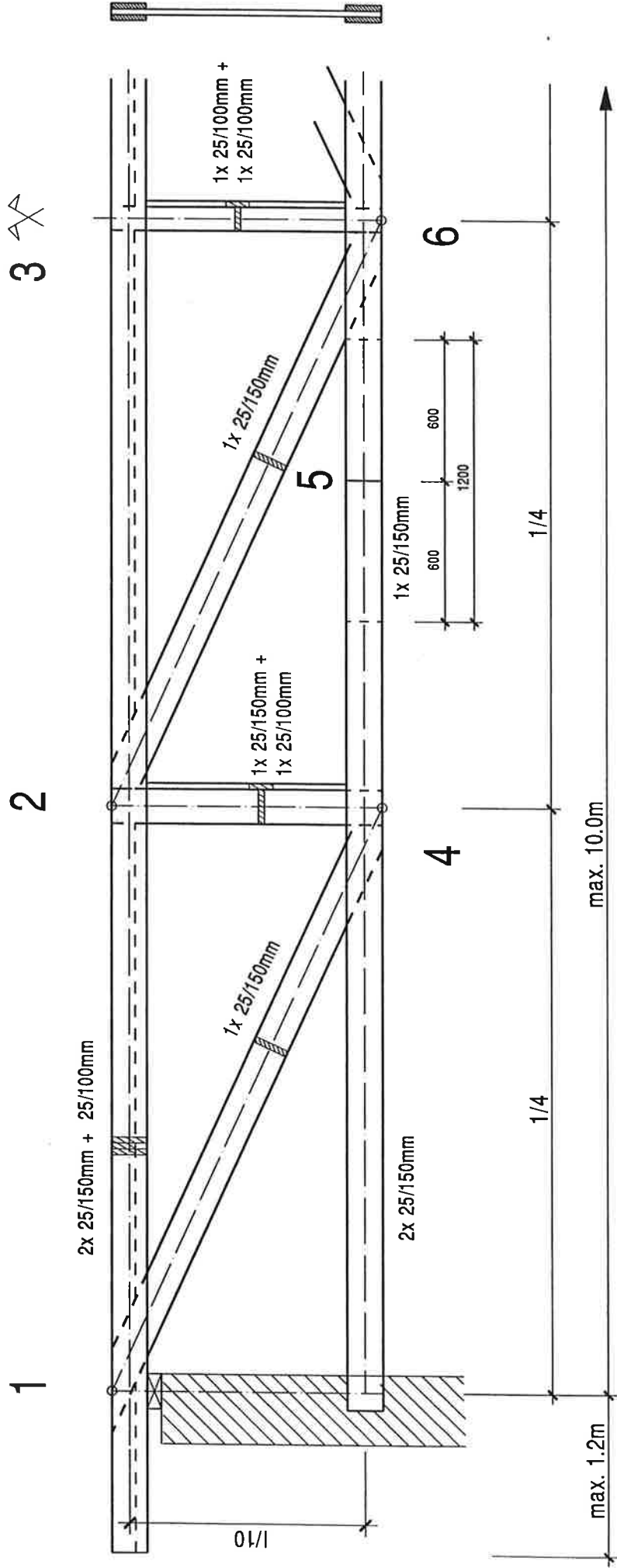
System



Distance between trusses 1.5m

Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



4.6.5 Single pitch roof nail truss, 6 m span

Mass of truss: 105 kg (softwood)

Volume of sawn timber: 0.19 m³ / truss (net)



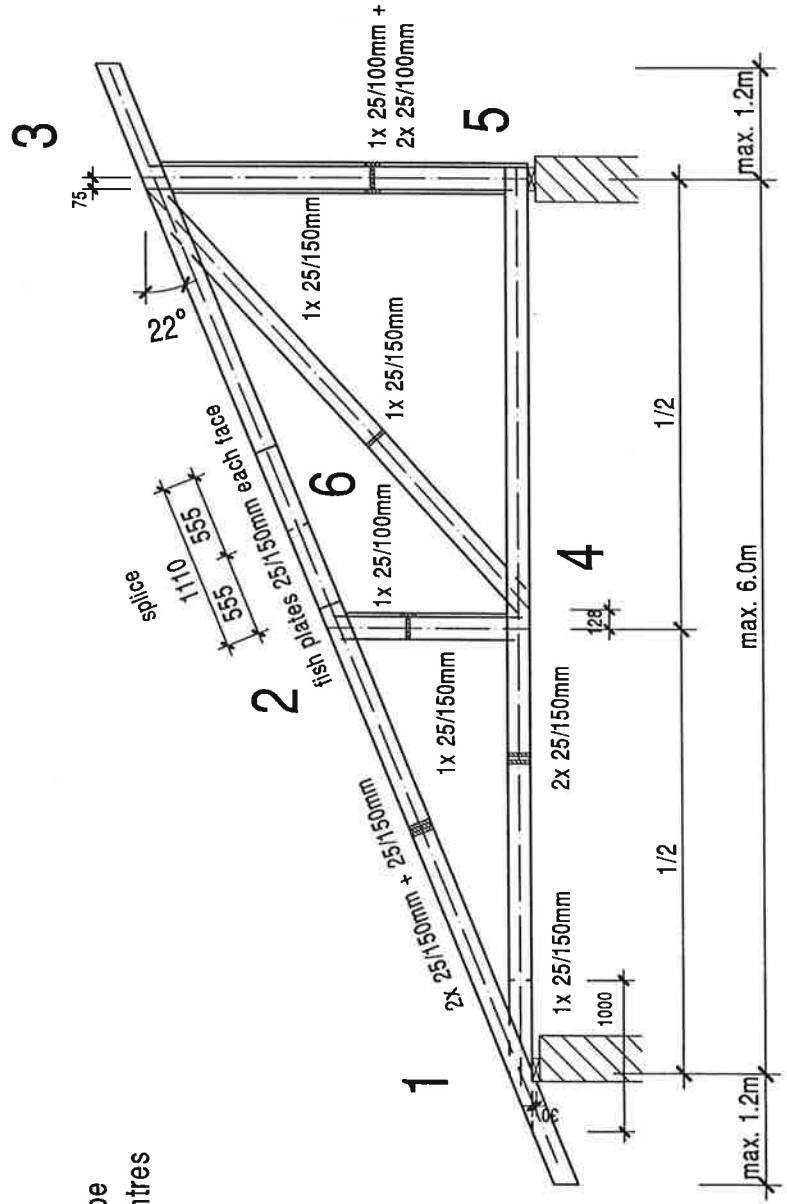
System

Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

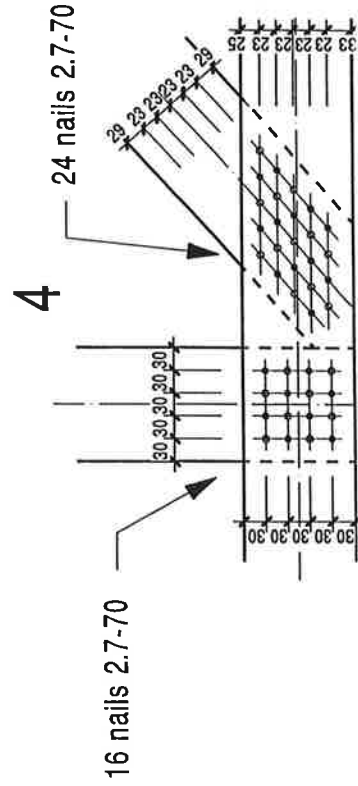
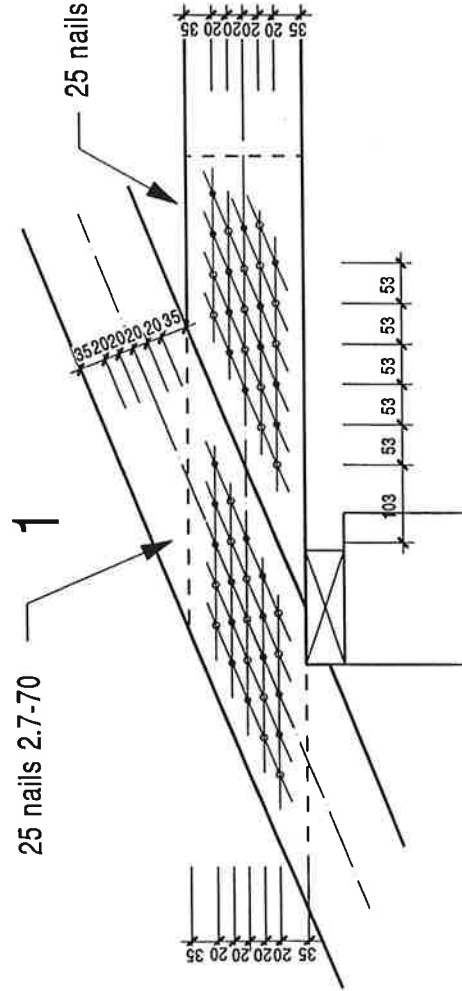
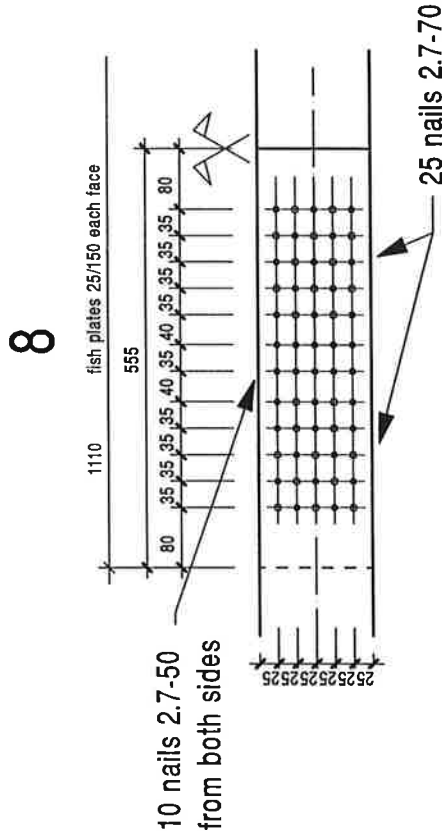
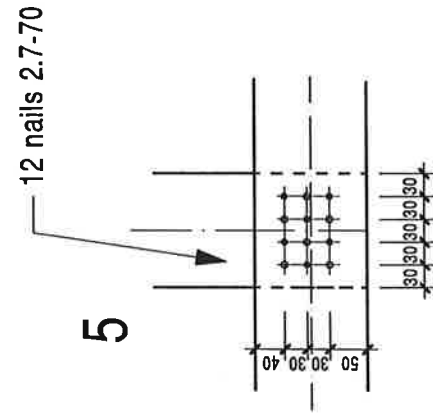
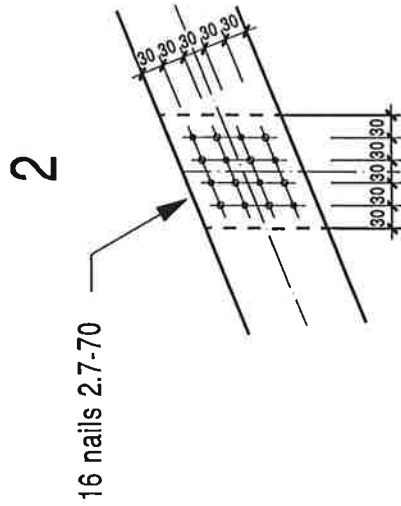
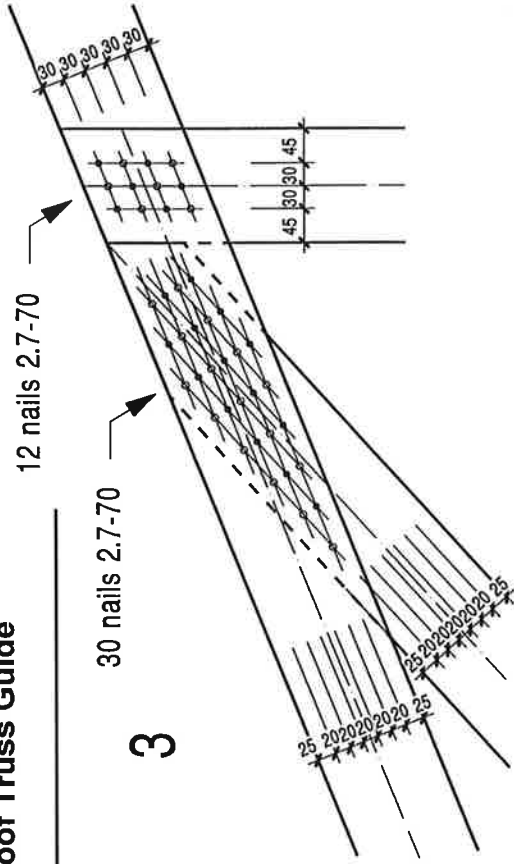
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of single pitch roof , 6.0m span

- Nails from the front
- Nails from the back (reverse side)

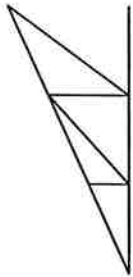


4.6.6 Single pitch roof, 8 m span

Mass of truss: 155 kg (softwood)

Volume of sawn timber: 0.27 m³ / truss (net)

System

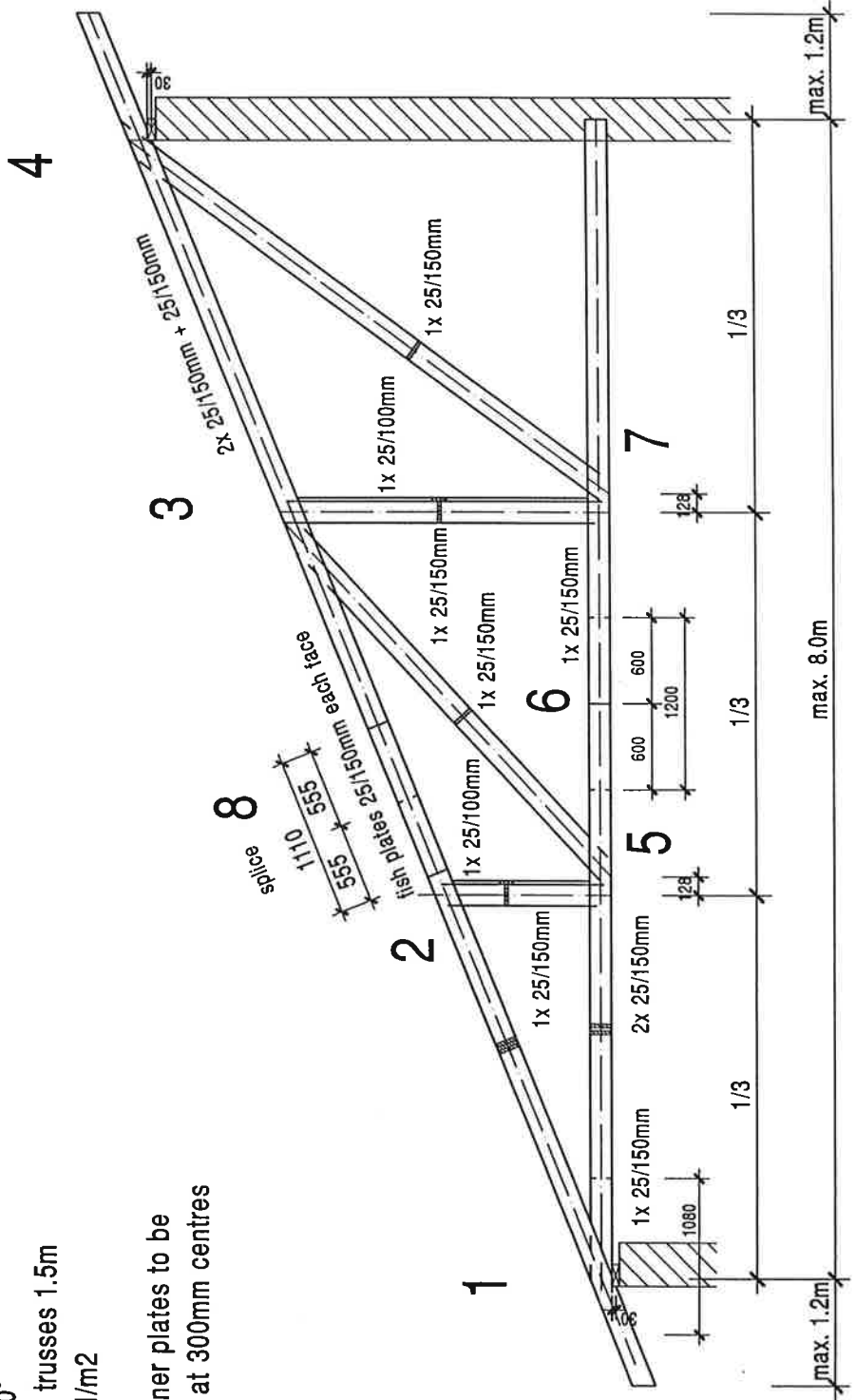


Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

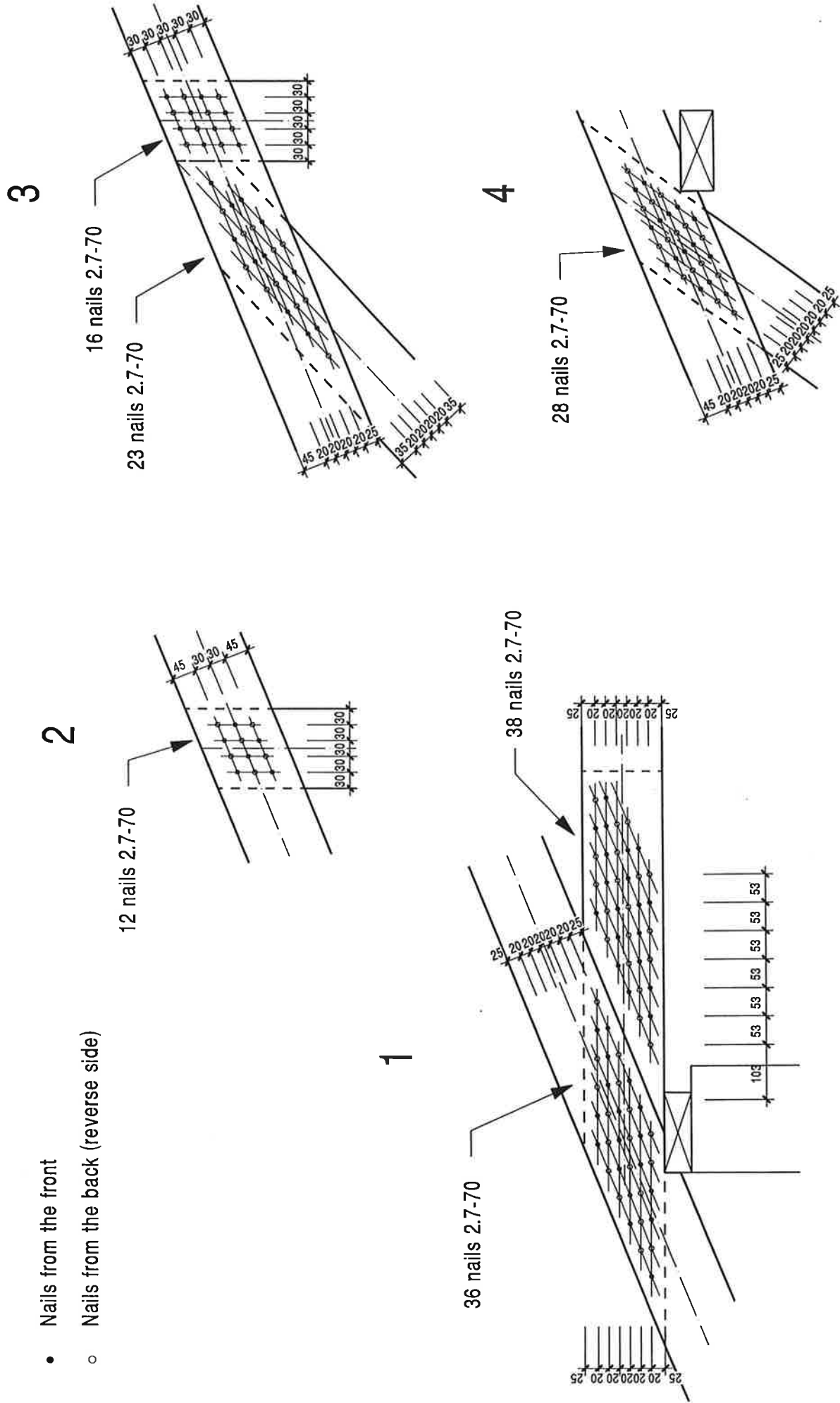
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of single pitch roof , 8.0m span

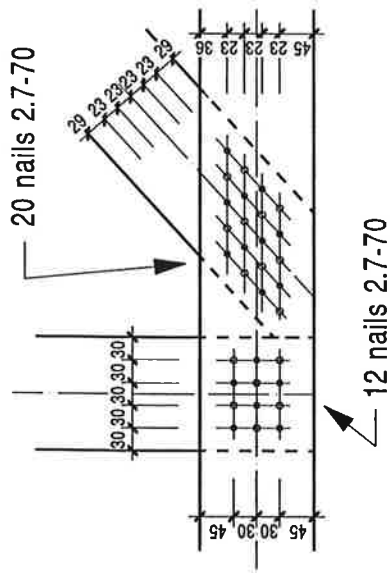
- Nails from the front
- Nails from the back (reverse side)



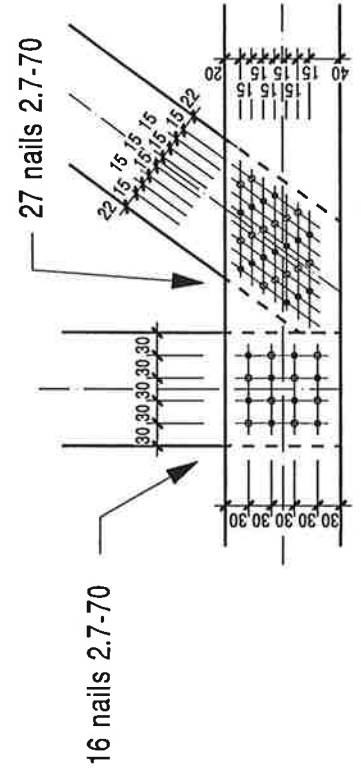
Panel points of single pitch roof , 8.0m span

- Nails from the front
- Nails from the back (reverse side)

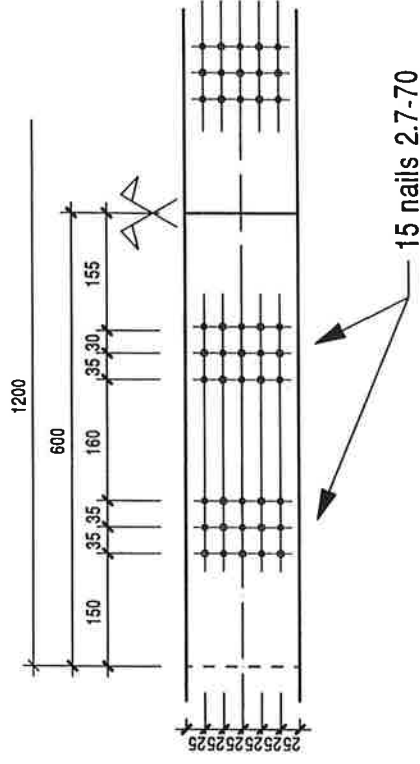
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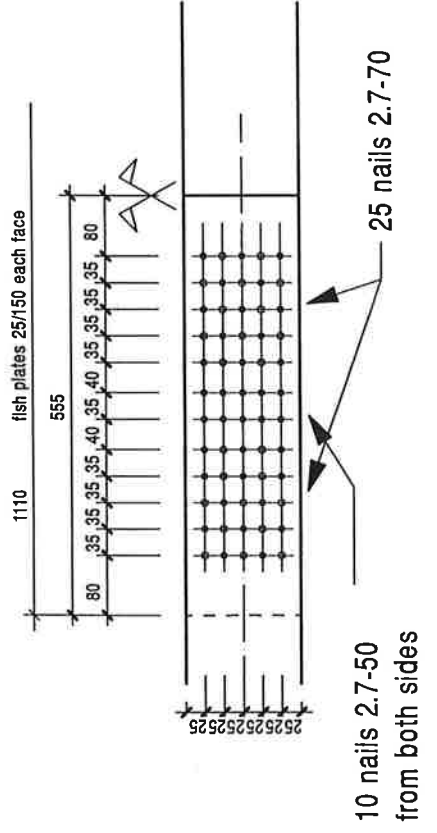
7



6



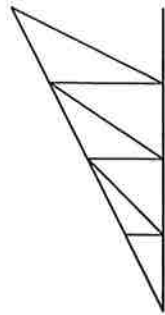
8



4.6.7 Single pitch roof nail truss, 10 m span

Mass of truss: 175 kg (softwood)

Volume of sawn timber: 0.30 m³ / truss (net)



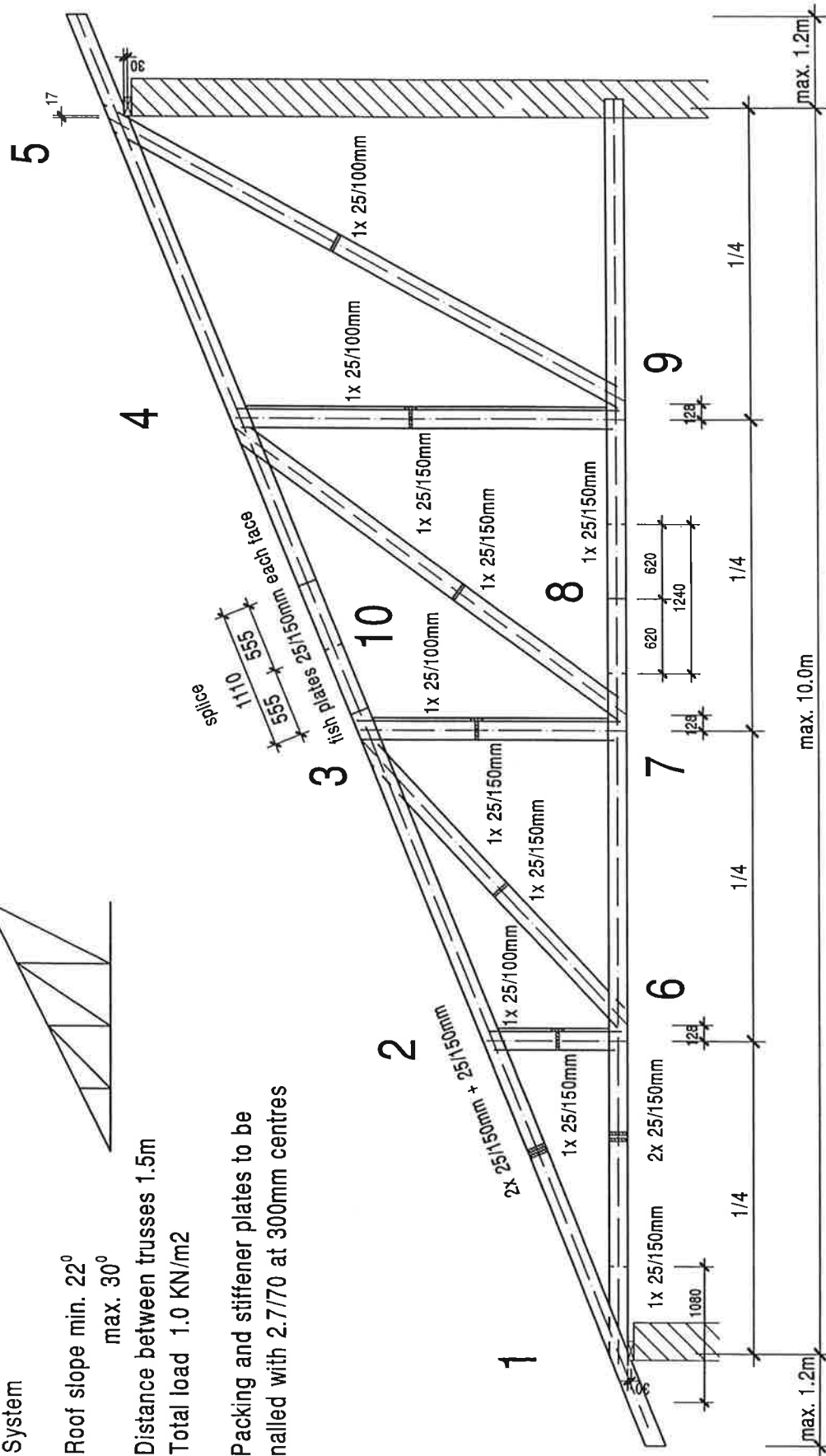
System

Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

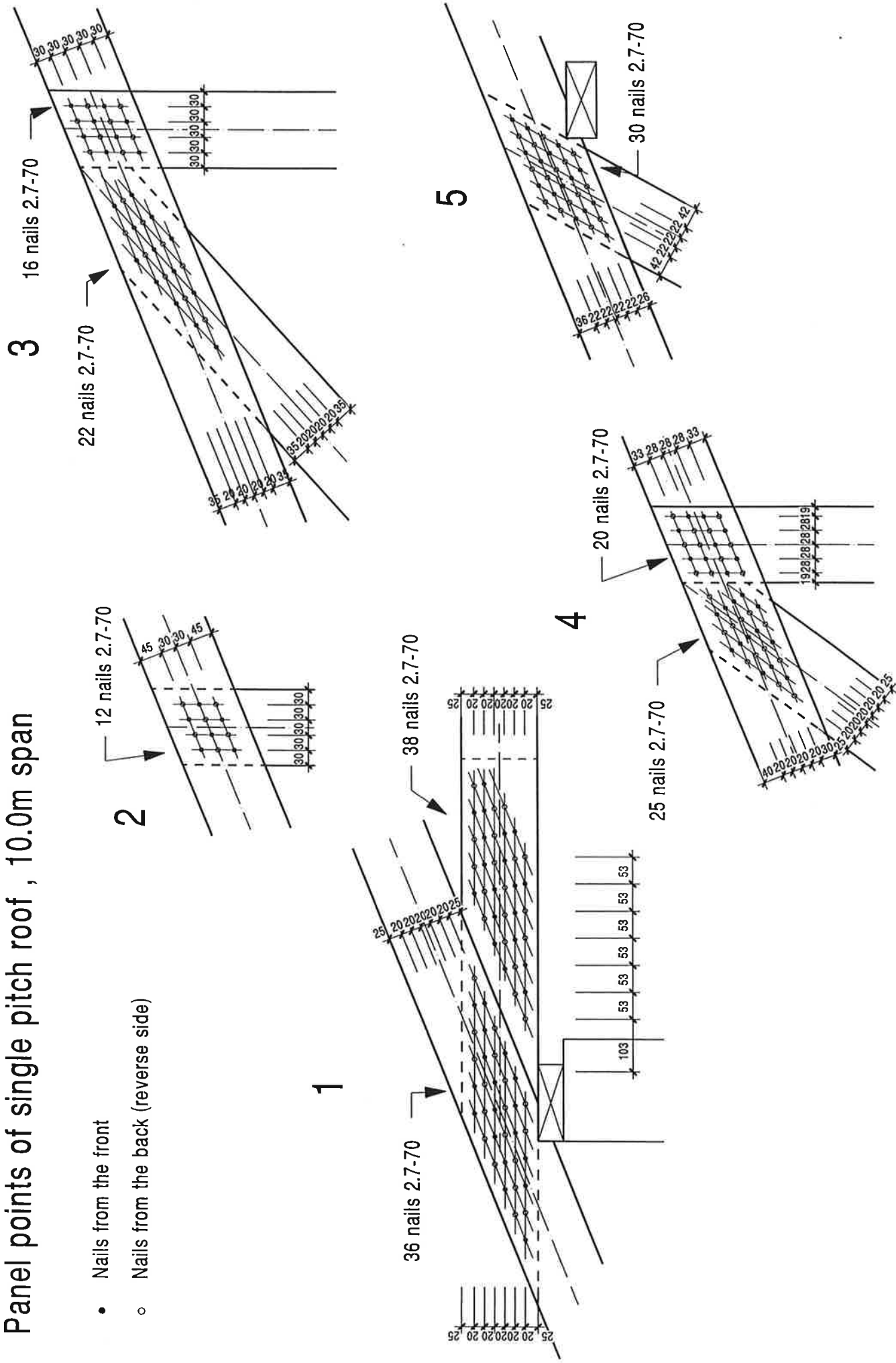
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of single pitch roof , 10.0m span

- Nails from the front
- Nails from the back (reverse side)



4.6.8 Double pitch roof nail truss, 6 m span

Mass of truss: 80 kg (softwood)

Volume of sawn timber: 0.14 m³ / truss (net)

System

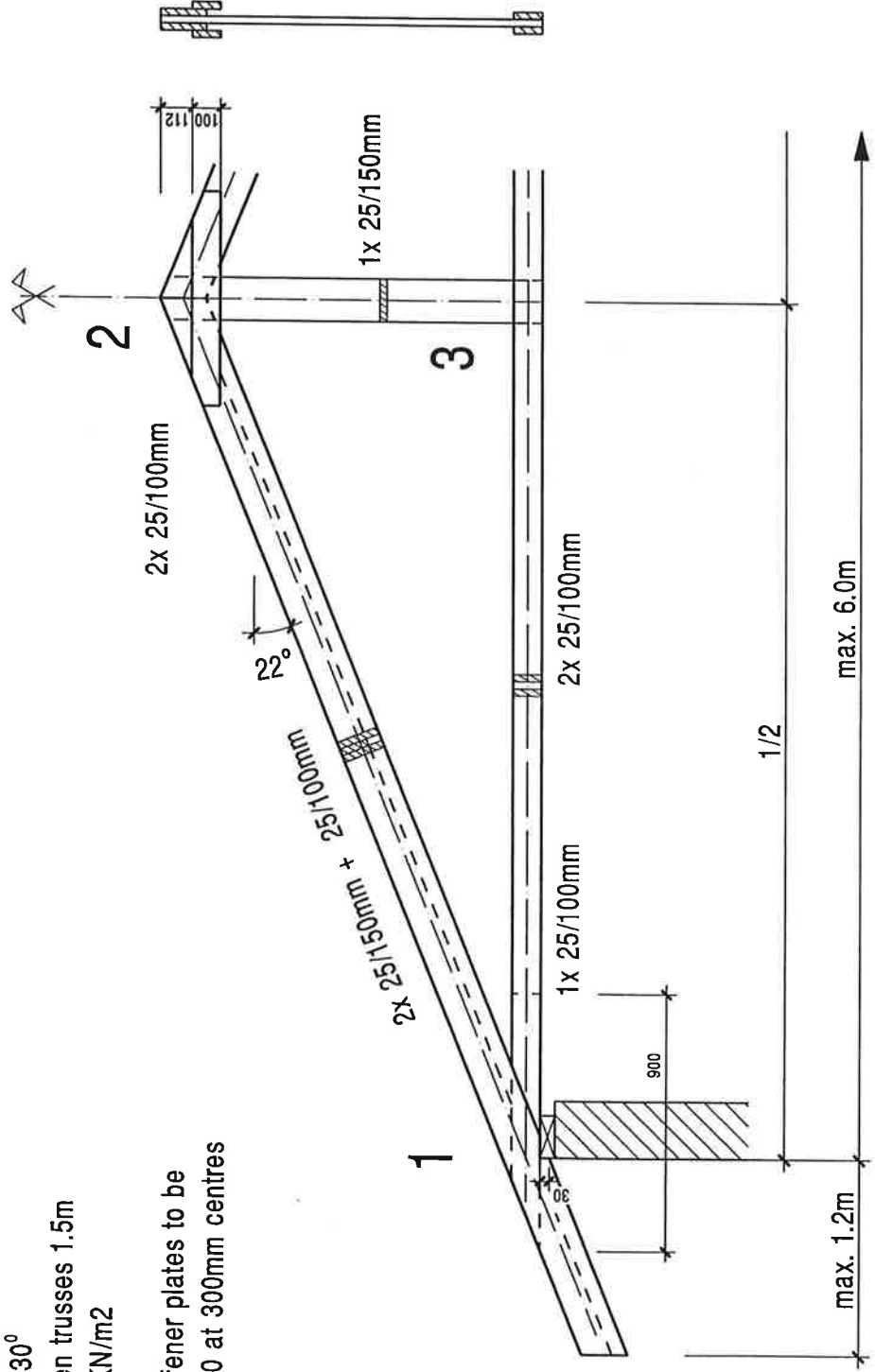


Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

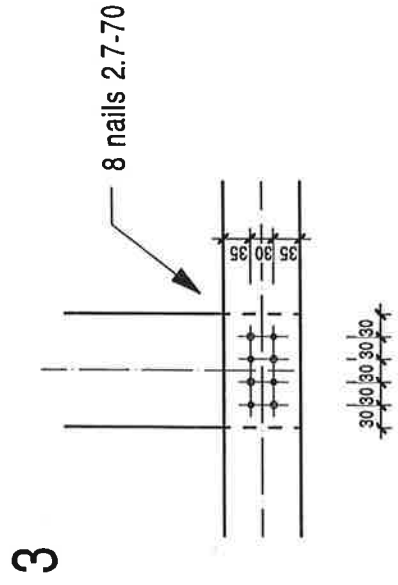
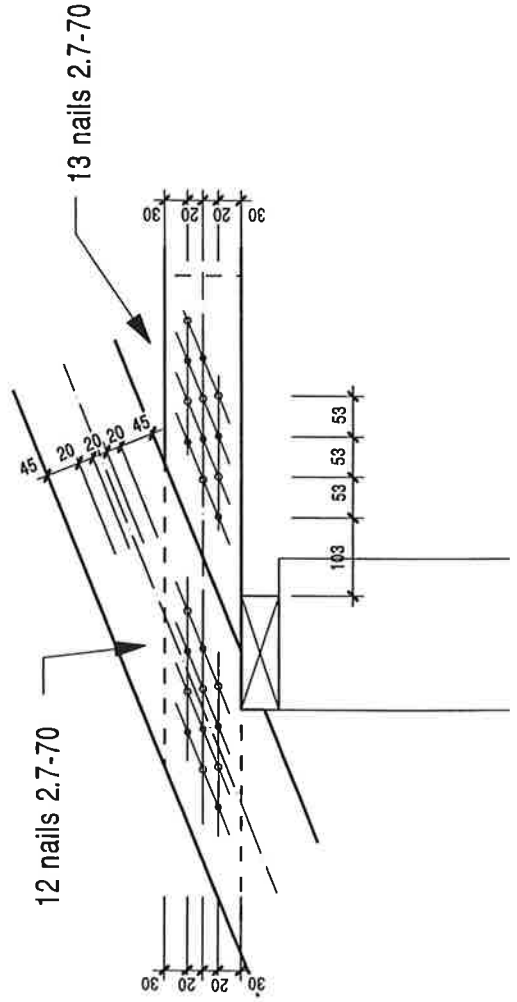
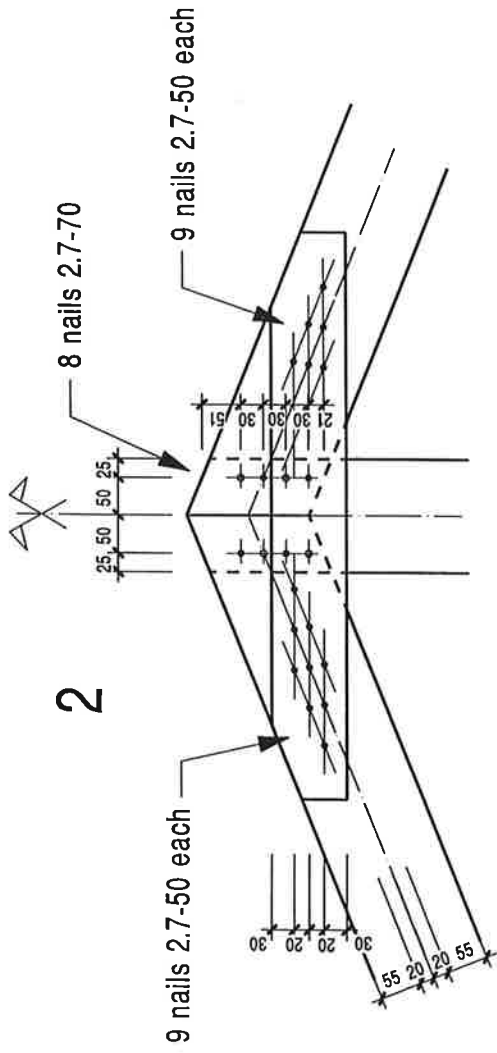
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres.



Panel points of double pitch roof , 6.0m span

- Nails from the front
- Nails from the back (reverse side)



4.6.9 Double pitch roof nail truss, 8 m span

Mass of truss: 120 kg (softwood)

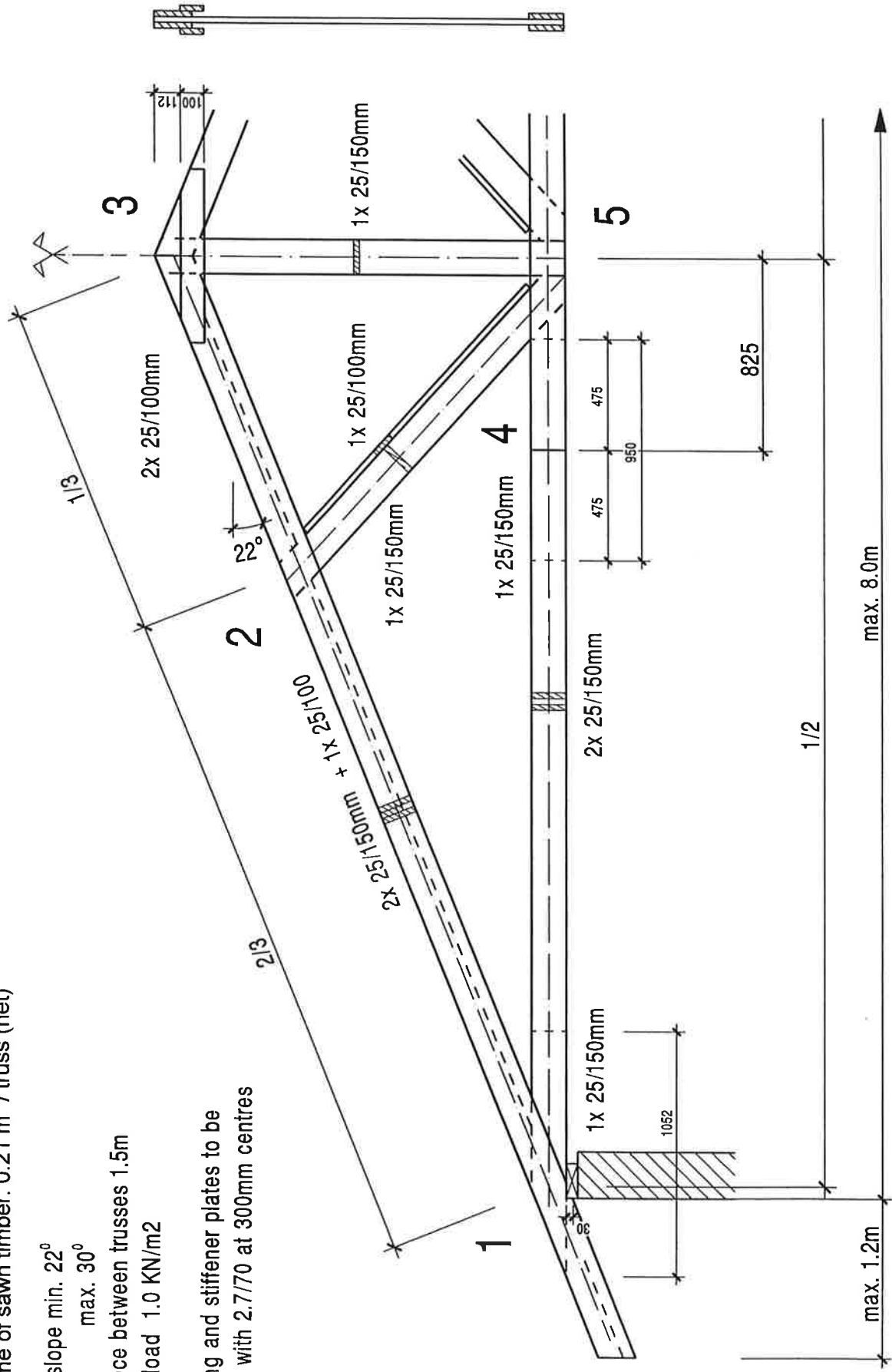
Volume of sawn timber: 0.21 m³ / truss (net)

Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



4.6.10 Double pitch roof nail truss, 10 m span

Mass of truss: 155 kg (softwood)

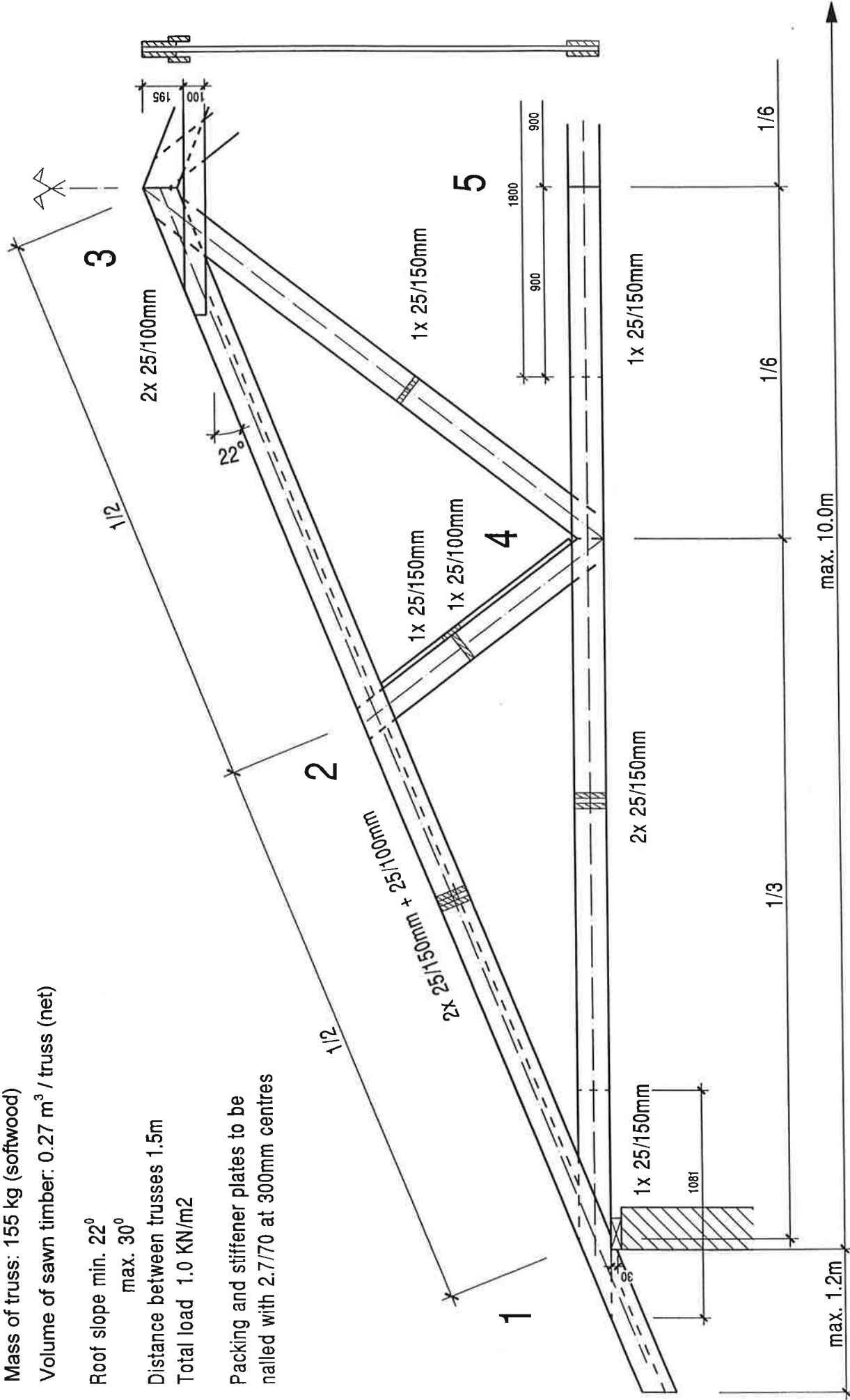
Volume of sawn timber: 0.27 m³ / truss (net)

Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

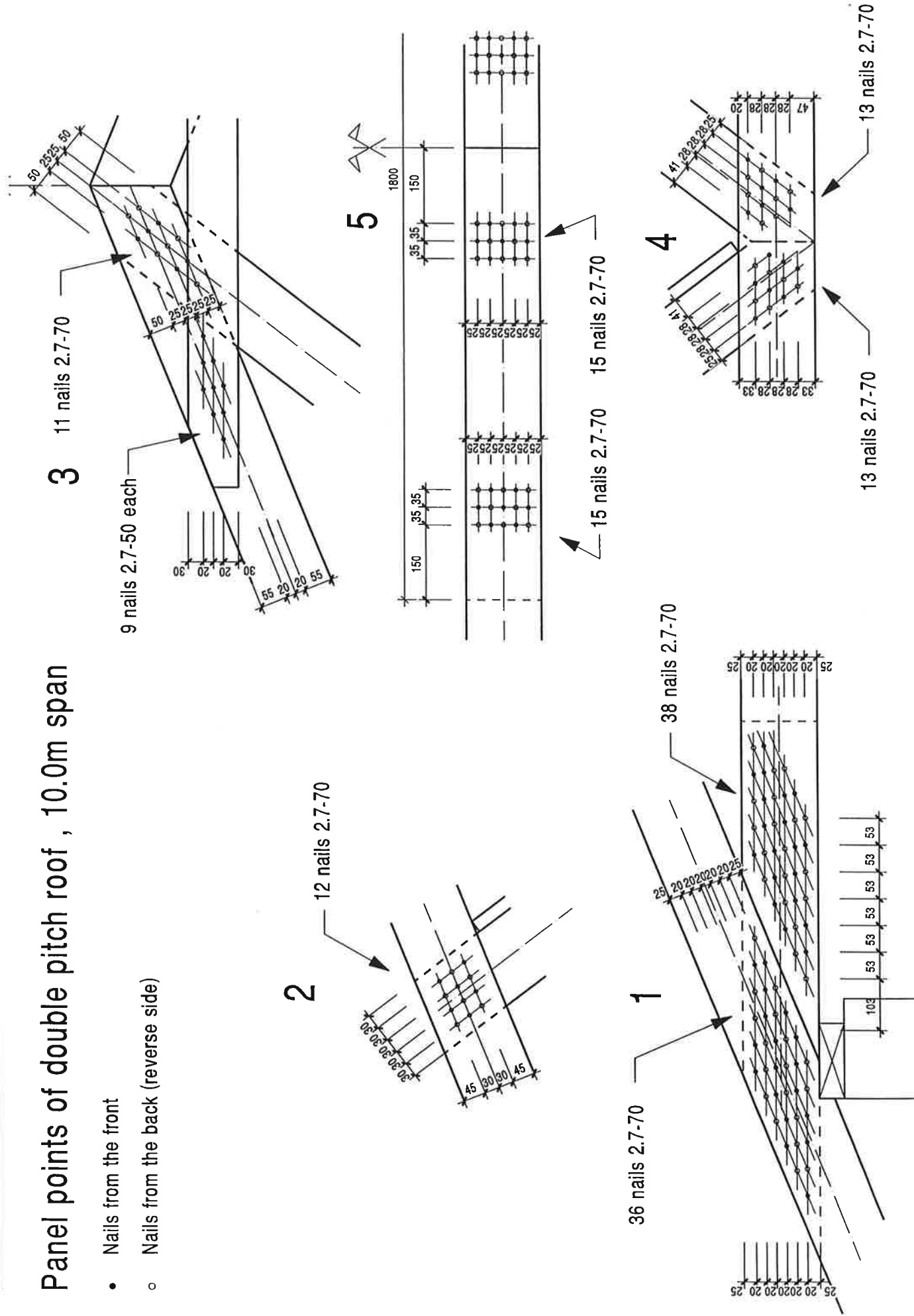
Total load 1.0 KN/m²

Packing and stiffener plates to be nailed with 2.7/70 at 300mm centres



Panel points of double pitch roof, 10.0m span

- Nails from the front
- Nails from the back (reverse side)



4.7 Nail Truss Sample with Plywood Gusset Plates

4.7.1 Assumptions and limits of application

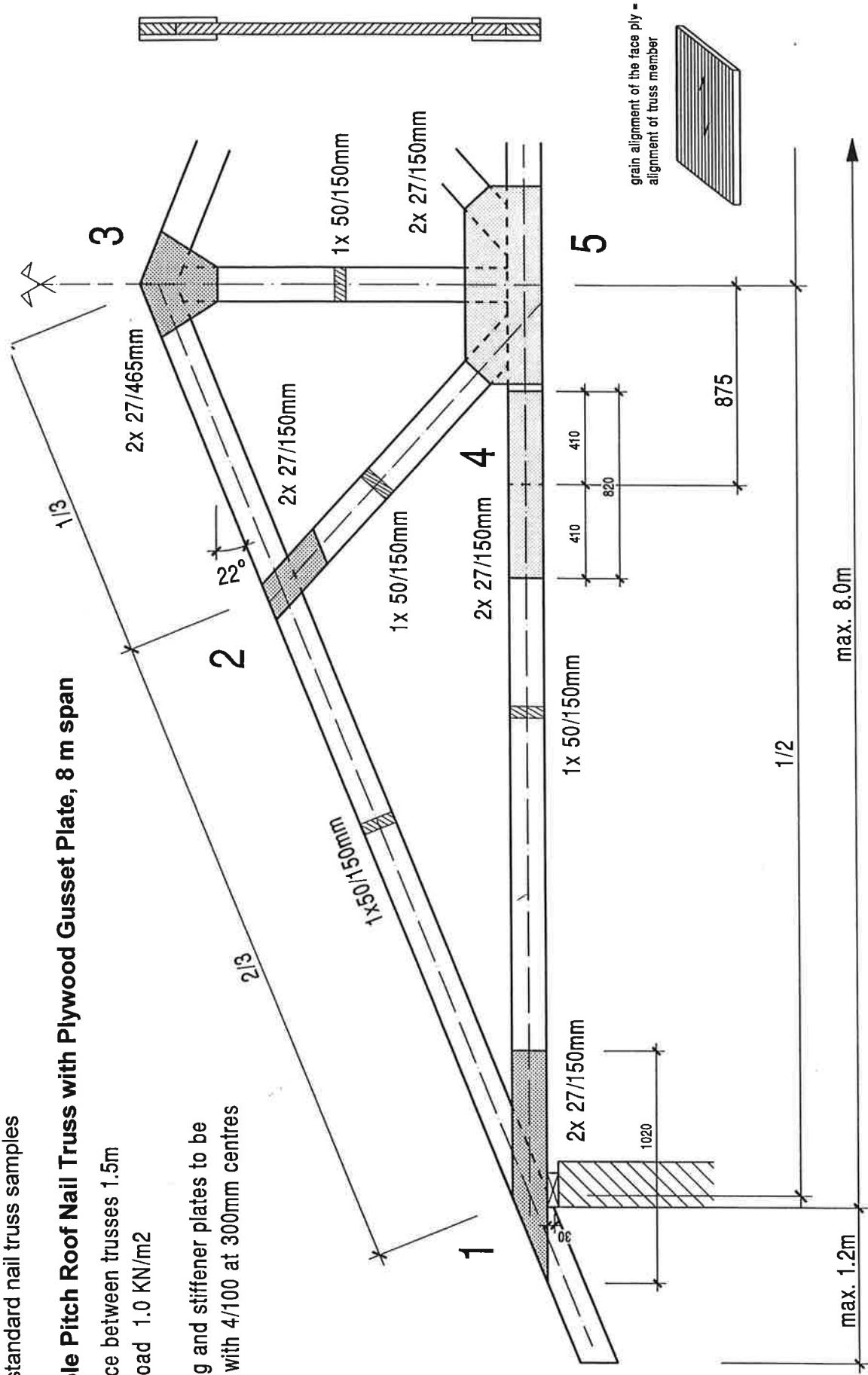
Same as for standard nail truss samples

4.7.2 Double Pitch Roof Nail Truss with Plywood Gusset Plate, 8 m span

Distance between trusses 1.5m

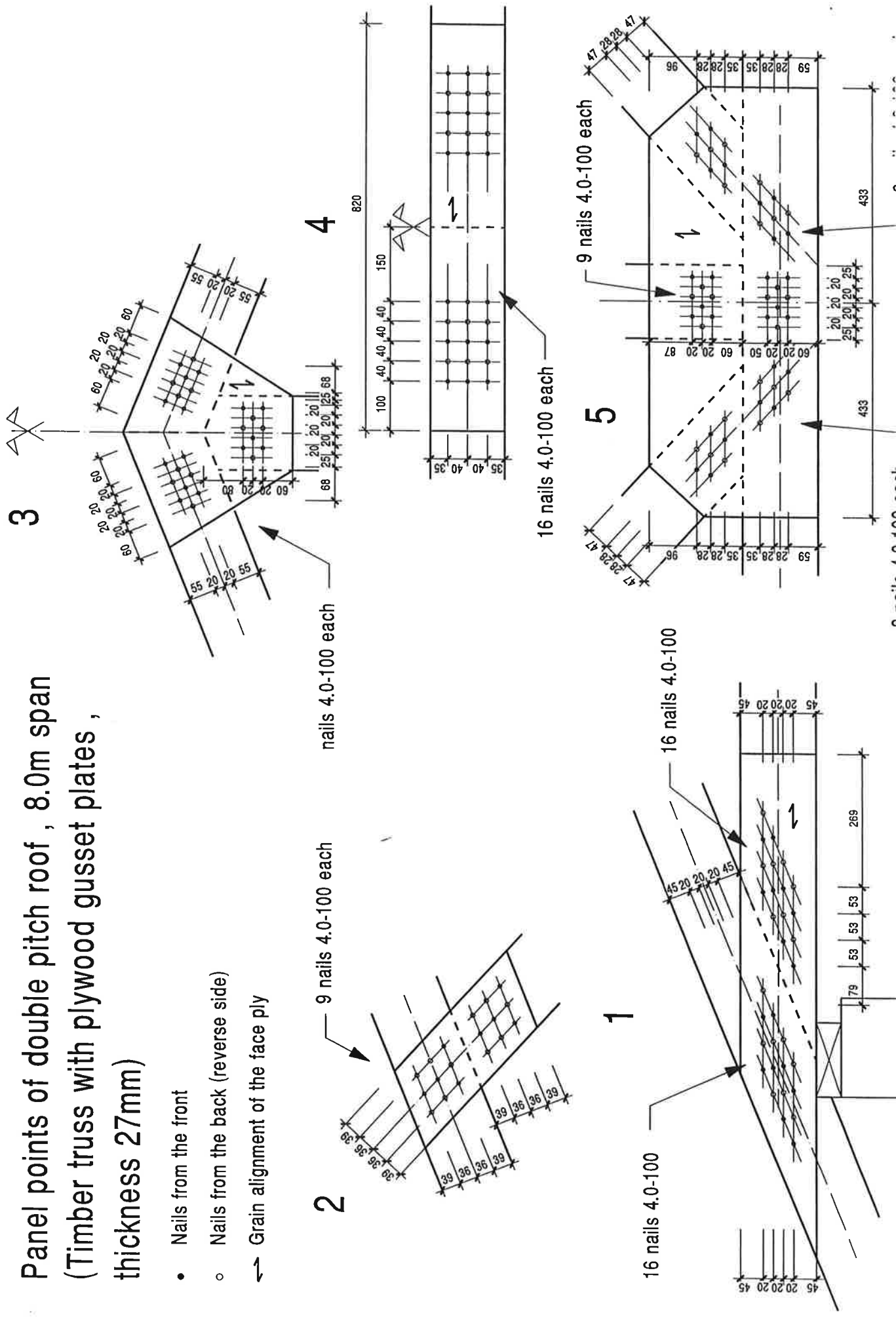
Total load 1.0 kN/m²

Packing and stiffener plates to be nailed with 4/100 at 300mm centres



Panel points of double pitch roof, 8.0m span
 (Timber truss with plywood gusset plates, thickness 27mm)

- Nails from the front
- Nails from the back (reverse side)
- ↔ Grain alignment of the face ply



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4.8 Bolted Timber Truss Sample

4.8.1 Assumptions and Limits of Application

The bolted truss sample given herein is valid under the following assumptions:

- Same as for nail truss sample
- Bolts: commercial bolt, strength grade 4.6 (nominal tensile strength 400 N/mm² , nominal yield stress 240 N/mm²)

4.8.2 Double Pitch Roof, Tight Fitting Bolt Truss, Span 8.0 m

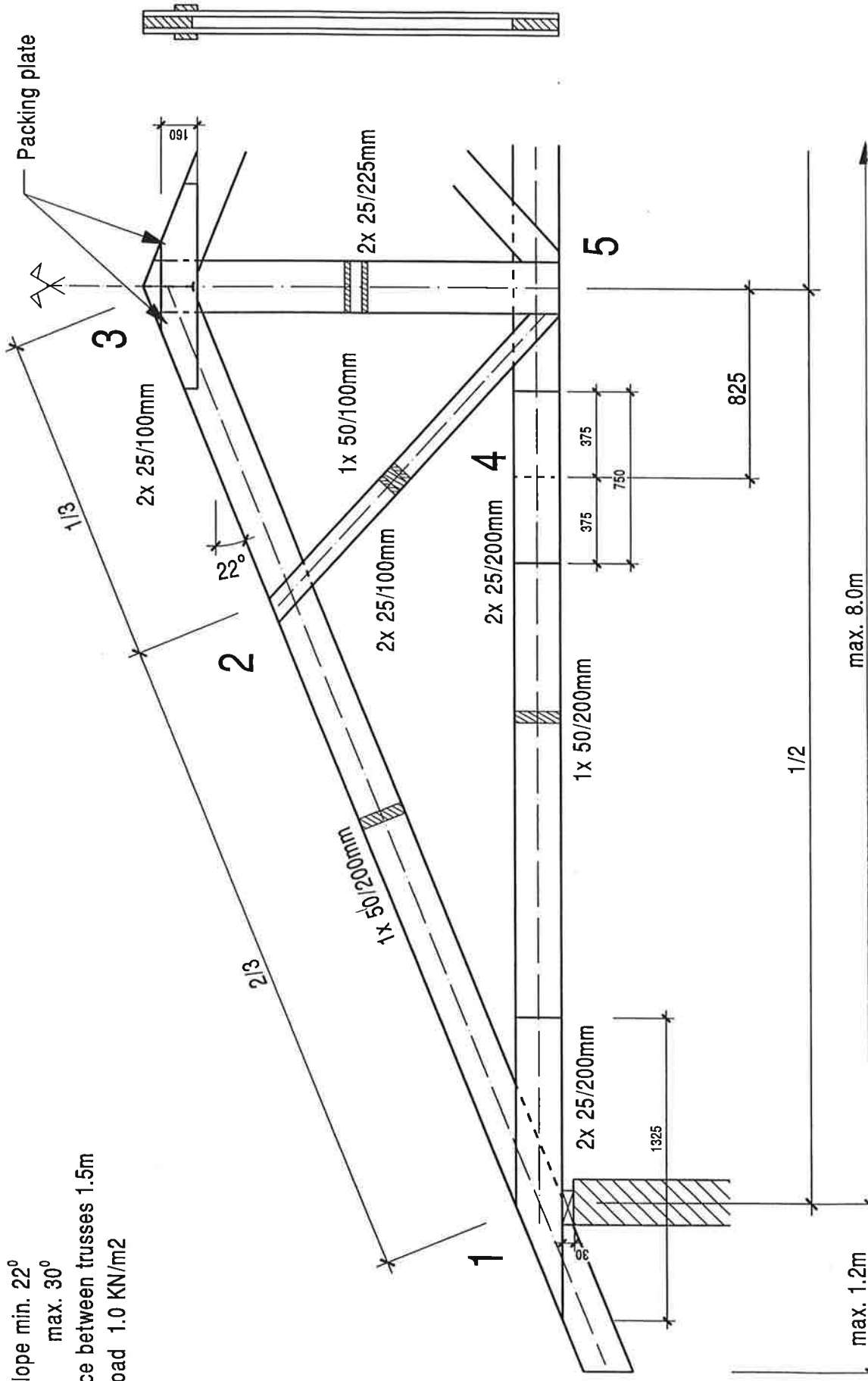
Mass of truss: 155 kg (softwood)

Volume of sawn timber: 0.27 m³ / truss (net)

Roof slope min. 22°
max. 30°

Distance between trusses 1.5m

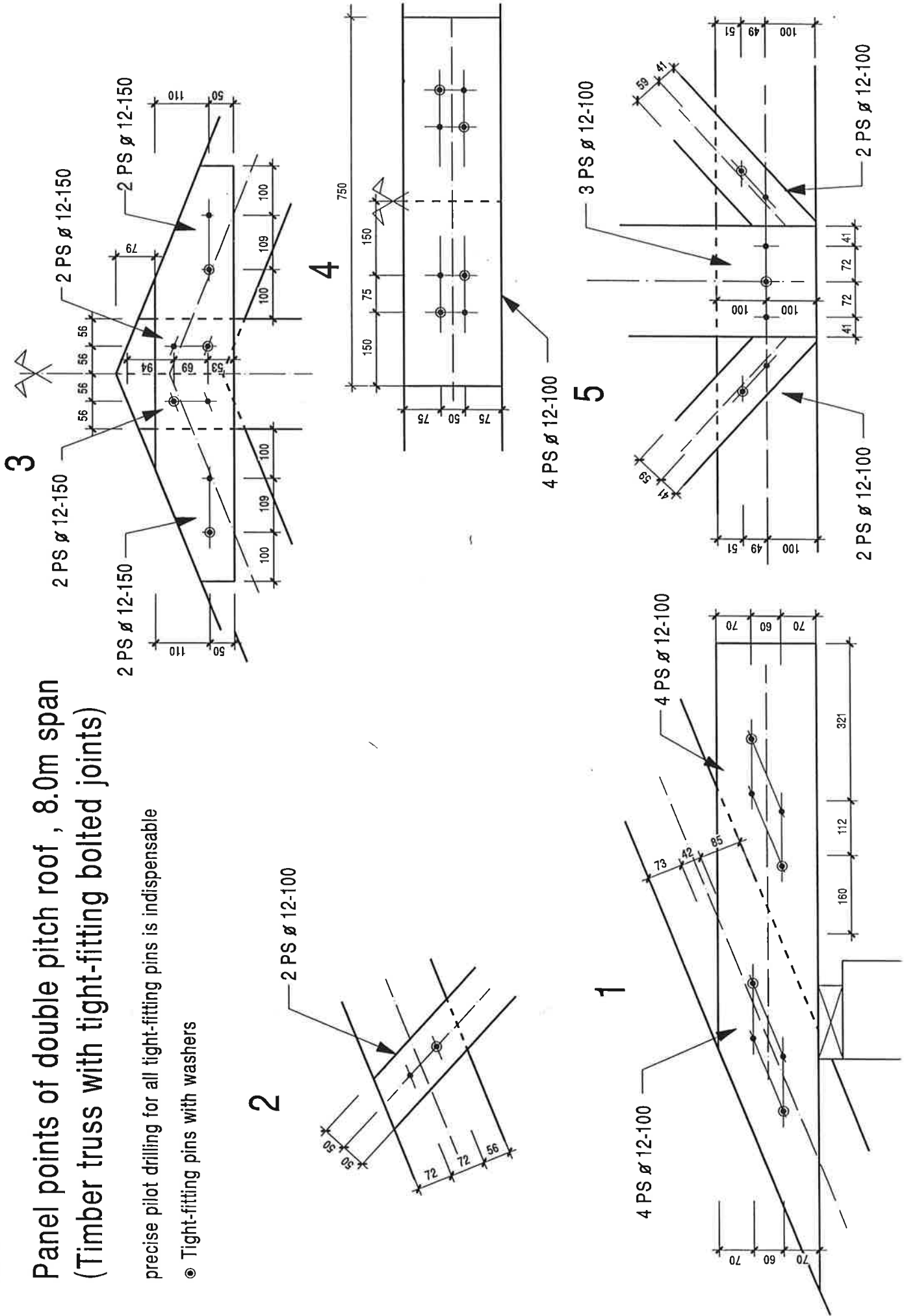
Total load 1.0 KN/m²



Panel points of double pitch roof, 8.0m span (Timber truss with tight-fitting bolted joints)

precise pilot drilling for all tight-fitting pins is indispensable

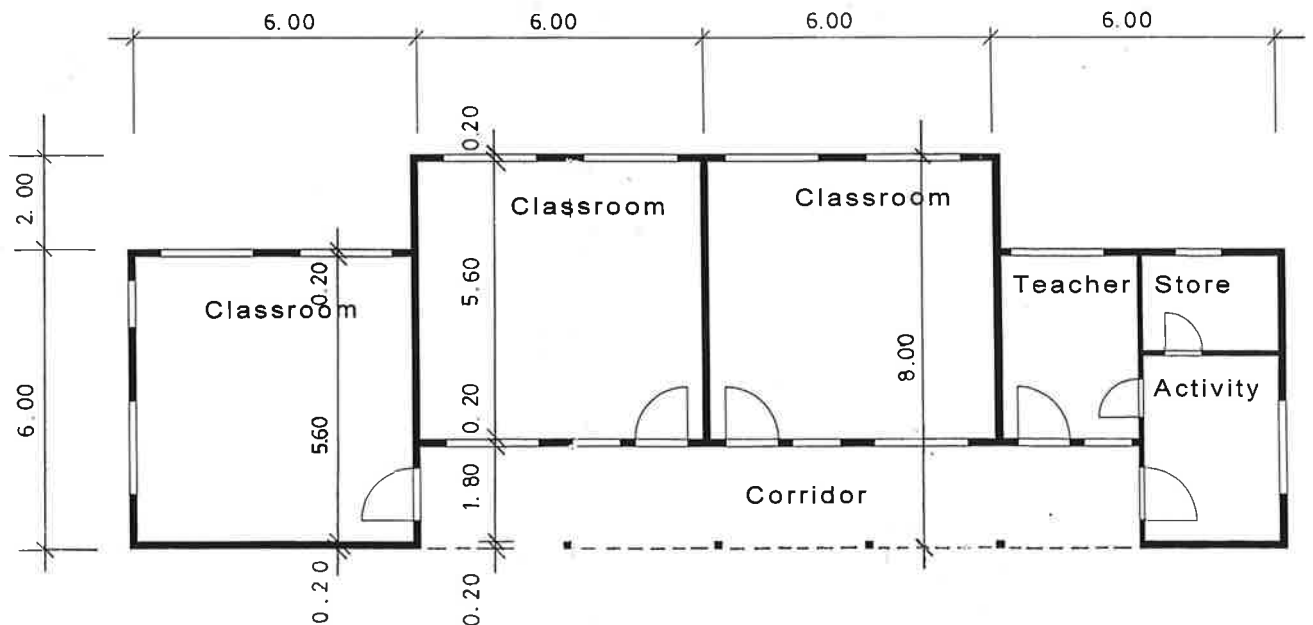
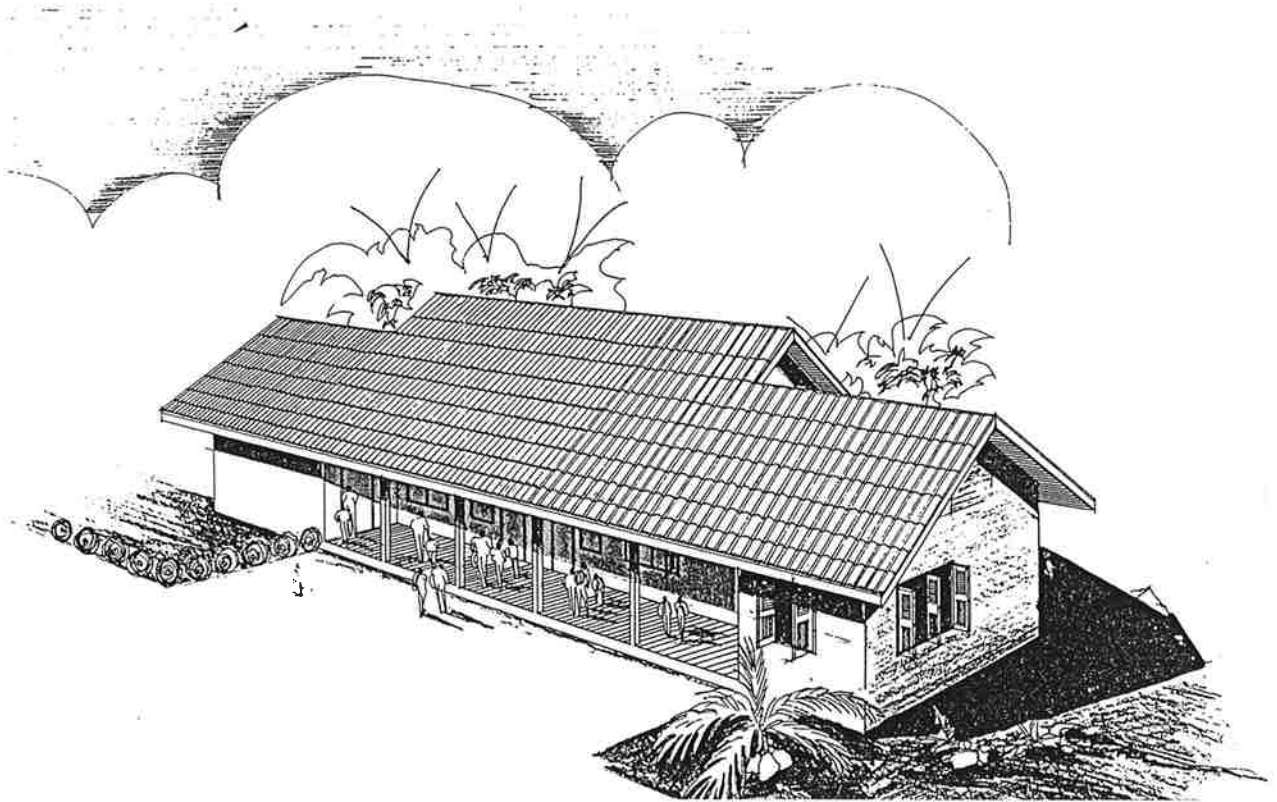
● Tight-fitting pins with washers



5 Worked Example of a Timber Truss

5.1 The task

The following primary school building needs to be covered by a timber roof truss and micro concrete tiles (MCR).



5.2 How to proceed (refer to 2.8 Roof truss selection step-by-step)

1. Shape of the roof: \Rightarrow double pitch

Design span:	truss (1)	\Rightarrow	$5.60 + (2 \times 0.10) = 5.80 \text{ m}$
	truss (2)		$5.60 + 1.80 + (2 \times 0.10) = 7.60 \text{ m}$

Loads (S'): \Rightarrow We assume the load as recommended in this guide for an MCR roof: 1.0 kN/m^2

2. Select truss from guide:

\Rightarrow	Truss (1)
	chapter 4.6.8, double pitch roof nail truss, 6 m span
\Rightarrow	Truss (2)
	chapter 4.6.9, double pitch roof nail truss, 8 m span

3. Compare design span with span of the selected sample truss and adjust distance between trusses:

Truss (1):	span of standard truss	=	6.00 m
	standard distance	=	1.50 m
	design span	=	5.80 m

\Rightarrow new distance (A') = $\frac{6.00^2}{5.80^2} \times 1.50 = 1.60 \text{ m}$

Truss (2):	span of standard truss	=	8.00 m
	standard distance	=	1.50 m
	design span	=	7.60 m

\Rightarrow new distance (A') = $\frac{8.00^2}{7.60^2} \times 1.50 = 1.66 \text{ m}$

4. Compare your design load (S') of the roof with the total load of the sample truss

Trusses (1) and (2):	total load of sample truss	=	1.0 kN/m^2
	total design load	=	1.0 kN/m^2

\Rightarrow no change in distance between trusses and the distance to be applied are:

Truss (1):	1.60 m
Truss (2):	1.66 m

These distances between trusses are the max. distances and they have to be compared with the dimensions of the building. To achieve an equal distribution of trusses, the distances can be reduced, but never increased. In our example the room on the left would require three trusses with a distance of 1.50 m between the trusses.

In case the design load had been calculated to be 1.10 kN/m², the following procedure would have to be applied:

Truss (1):	total load of sample truss	= 1.0 kN/m ²
	total design load	= 1.1 kN/m ²
	distance (A) (from step 3)	= 1.60 m

$$\Rightarrow \text{new distance (A')} = \frac{1.00}{1.10} \times 1.60 = 1.45 \text{ m}$$

Truss (2):	total load of sample truss	= 1.0 kN/m ²
	total design load	= 1.1 kN/m ²
	distance (A) (from step 3)	= 1.66 m

$$\Rightarrow \text{new distance (A')} = \frac{1.00}{1.10} \times 1.66 = 1.51 \text{ m}$$

- Adjust the design of the sample truss to your exact requirements!

6 Steel Trusses

With the increasing scarcity of quality timber in some areas, steel structures are enjoying quite some popularity despite the relatively high cost of the material and the requirements on tools and equipment for fabrication. Unlike timber, steel is a homogenous and isotropic (same characteristics in all directions) material that allows an accurate structural analysis resulting in light and economical roof trusses.

6.1 Design Considerations

A number of design considerations need to be made before selecting steel as the basic material for the roof truss. Issues to be checked are the following:

- Availability of skills and equipment for fabrication:**

Cutting steel bars and sections, welding, drilling and grinding for truss fabrication require power tools and the associated skills (qualified welders), which may not be readily available.

- **Availability and cost of steel:**

Steel is mass-produced in centralised factories. Due to transportation, costs increase with distance from such factories. The remoter the location, the less competitive is steel as roofing material. Local timber may then be more economic.

- **Compatibility with other elements of the building:**

Steel is a versatile material that can be combined with most other materials. When items such as rails for chain blocks, supported ceilings, ducts and piping need to be attached to the truss, the steel truss has advantages over timber. In any case, the structural analysis is to be modified accordingly. The standard trusses as presented in this manual may no longer be applicable.

- **Fire rating required:**

Steel structures rapidly lose their strength with high temperature. Avoid using thin sections (less than 6 mm thickness) if a high fire rating is required. A protective covering (insulating material, mortar, sprays or coating) may be employed to improve the fire rating.

- **Corrosive environment:**

With thorough wire brushing or sand blasting, several layers of primer and appropriate coating, steel structures can have remarkably long service lives even in corrosive (coastal) environments. The design of the building and the truss must allow for good accessibility of all members of the truss for repainting at regular intervals. When selecting the minimum thickness of the steel sections, allow for a loss of material from scaling (removal of oxide) and from corrosion. This allowance is usually in the order of 0.5 to 1 mm.

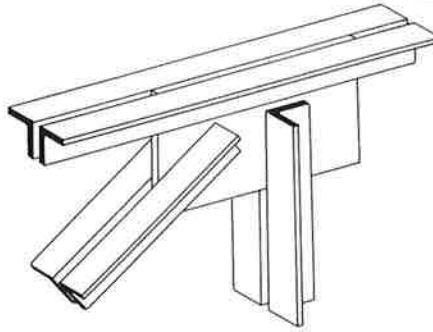
6.2 *System Options*

The options available for steel roof trusses are as follows:

- **Angle and flat bar truss:**

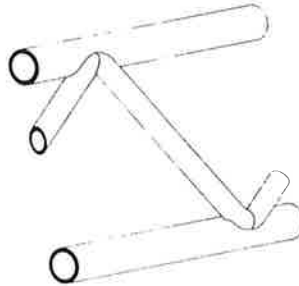
Small angle bars may be welded directly onto each other forming very light trusses up to about 12 m span. Due to the non-symmetrical shape of single angle bar truss members, the forces produce moments at the connections. Such eccentricities need to be considered in the structural analysis. The length of the compression members must be reduced as much as possible to avoid buckling. This results in trusses with a large number of diagonals (and connections) as for example with the Fink or Polonceau Truss.

For larger spans (> 12 m) and loads, double angle bar trusses with bolted connections on gusset plates are used. In some countries, angle bars are fairly expensive or not available in the required sizes and steel tubes may then be the preferred element.



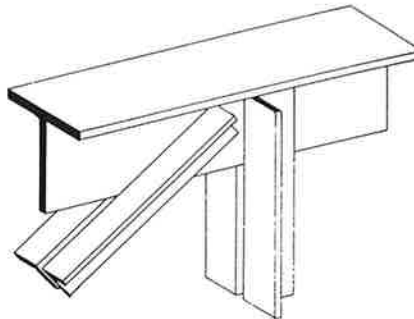
- **Steel tube truss:**

Steel tubes are readily available almost throughout the world at reasonable prices since these are not only used for structural steel work but also for water supply piping systems. However, the jointing of round surfaces is difficult; butt and fillet welding of properly cut and shaped tubes is possible but slow and expensive. The use of gusset plates is almost inevitable if structurally sound and efficient connections are expected. When using tubes, the number of connections per truss should be reduced as much as possible.



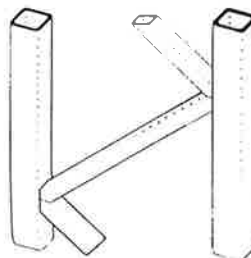
- **Rolled sections truss**

Rolled sections other than angle bars used in truss designs are the channel and universal beams. Half-section universal beams are particularly useful in truss design but their availability is limited. Rolled sections are used in trusses of large spans (> 12m) and loads.



- **Rectangular hollow section truss**

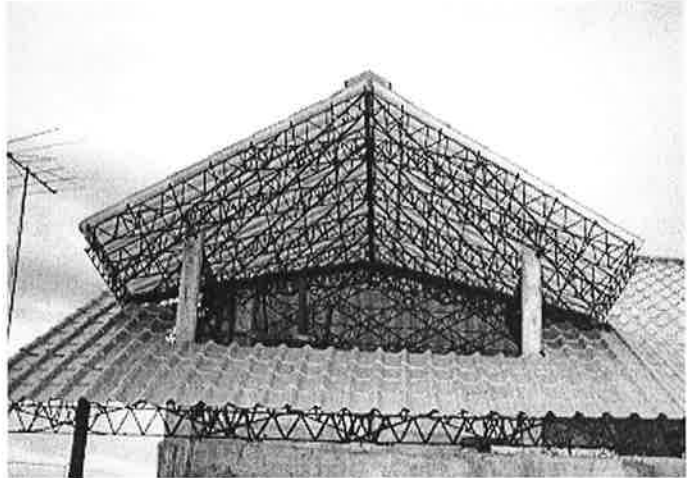
Rectangular hollow sections (RHS) provide a particularly neat appearance of steel trusses. Welded connections are common thanks to the regular shape of the RHS. But the RHS are expensive and not readily available in some countries. RHS trusses are not treated in detail here.



- **Reinforcing bar (rebar) truss**

Shallow trusses with parallel chords made of reinforcing bars can be used as joists in roof structures. The static system of the roof structure as a whole is then no longer a truss but can be a purlin roof (see Section 2.3), a double-hinged arch or bent.

The application of the rebar truss is limited to residential and commercial buildings with light loading (no snow loads). The rebar joist – if properly designed and fabricated – can offer an economic roof structure of very airy and attractive appearance.



6.3 *Materials*

With the exception of reinforcing bars, most commercial structural sections are mild hot-rolled steels with 0.15 to 0.25 % carbon content. Minimum yield strength is 200 MPa or slightly above. This manual uses a design yield strength of 200 MPa for all structural steel members.

When selecting a welded tube truss, do not use galvanised pipes. **Black pipes should be bought or, if only galvanised pipes are available, the galvanisation must be removed before welding.** When welding over the galvanisation, harmful smoke is emitted seriously affecting the health of the welder, and, in addition, the weld itself is not sound.

Reinforcing bars of the rebar joist may have much higher strength (400 MPa) due to heat treatment, drawing or from the addition of manganese, vanadium and nitrogen. Such deformed bars should, however, not be used for rebar joists as some of these steels have poor weldability and are expensive. Plain carbon reinforcing bars (deformed or not) with yield strength of 200 to 250 MPa are preferred.

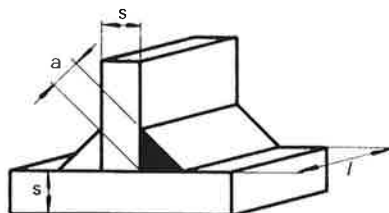
6.4 Fixing and Jointing

Welding and bolting are the most common jointing methods used in structural steel work. Riveting is no longer applied.

6.4.1 Welding

Welding may be used for shop and field connections. The latter should not be used on roofs high above ground or in confined spaces where welders would not be able to produce good quality welds. Welding on site requires additional cleaning of weld surfaces and repainting for corrosion protection. This is a task often underestimated; mill and weld slag remaining on the surface is the principle source of corrosion. Also, corrosion attacks near welds soon after commissioning are often the result of scorched paint that has not been properly removed before repainting.

For light steel trusses, fillet welding is commonly used. These are welds placed along the edges of the elements to be joined.



It is important that fillet welds are neither undersized nor oversized.

Min. throat thickness: $a_{\min} = 3 \text{ mm}$

Max throat thickness: $a_{\max} = 0.7 d$

where "d" is the smaller of the elements to be joined

min. length of fillet $l_{\min} = 8 a$

max length of fillet: $l_{\max} = 100 a$

Butt welds are welds that join two elements over their entire depth. Such welds require a preparation of the surfaces (beveling) and are thus very labour intensive. Butt welds are not recommended for steel truss construction except for joining small sections with material thickness of less than 3 mm.

A short introduction in good welding practices is presented in Annex 3.

6.4.2 Bolted with gusset plates

For heavier trusses, site assembly of individual elements is inevitable. Bolted connections are then the preferred method of joining the truss members.

There are two types of bolts available for structural steel work:

- Grade 4.6 ("black or mild steel bolt")
- Grade 8.8 (high strength bolt)

Grade 8.8 is used for rigid, slip-free joints where forces are transferred from one element to the other through friction at the contact surfaces. The bolts need to be fully tensioned using a torque spanner. This type of connection is not recommended for small trusses because of the difficulty in obtaining the bolts and the high requirements on site supervision.

Snug tightened, hot-dip galvanised Grade 4.6 bolts are recommended for steel trusses. As the holes are generally drilled 2 mm larger than the bolt shaft, a slip of 1 mm in each joint will occur resulting in considerable deflection of the truss. Camber of about 1/150 of the span is applied to make sure that the lower chord has a neat appearance (no sag).

6.5 Finishes

Surface preparation

Removing rust and grease from steel surfaces and roughening these are the main tasks of surface preparation. Sand blasting would be the best method but is often not available. Wire brushing (by power tool or manually), scrapers and hammers are the alternatives. Scale, rust and foreign objects are to be completely removed. After preparation, the surface should have a light metallic shine. The first coat of primer must follow immediately (within the same day).

Priming and Painting

A paint system for steel protection consists of a primer or rust inhibiting coat and a protective or weather coat, often called finishing coat. Primer and finishing coats cannot randomly be selected but must be compatible with each other. This is basically a question of the binder used in the primer (for details refer to supplier's specifications).

For relatively humid indoor conditions (60 to 80 % relative humidity) as encountered in roof truss applications the following two priming systems are in use:

- 2 coats of 30 mikron (μm) of red oxide primer, or
- 2 coats of 30 mikron (μm) of zinc based primer

Tar epoxy paints, which may be primer and finishing coat all in one, are seldom used for roof trusses due to their rough appearance.

The primer is preferably applied after all fabrication work is completed but prior to delivery to the site. The finishing coat is applied at site after erection where damaged primer is first repaired and the coverage of unprimed surfaces such as bolts and site welds are completed.

Steel work that is to be grouted in concrete such as anchors and the like are not painted.

6.6 Angle Bar Truss

6.6.1 General

Pros and cons

Single angel bars have limited capacity against buckling. In order to shorten buckling length a large number of web members and associated connections are required. This results in increased labour input for truss fabrication. Where labour costs are relatively low, economically competitive roof trusses can be fabricated.

The use of double angle members reduces eccentric connections but brings about inevitable corrosion problems as the space between the angle bars cannot be cleaned and repainted.

6.6.2 Design

An overhang of 10 % of the span but at least 0.8 m can be accommodated with the proposed designs.

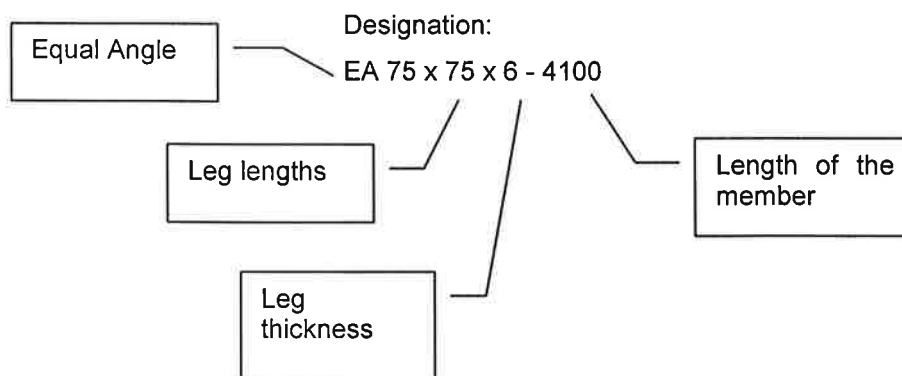
A sample structural analysis is presented in Annex 2.

6.6.3 Details

No gusset plates are used for the single angle bar truss. This makes its application particularly economic.

Do not weld too close to the root of the angle bars as this warps the section. Internal stress from fabrication is highest in the root zone and welding (heat introduction) provokes a release of this energy.

Seal the contact surface: Weld all around to avoid water entering the contact surface between the angel bars. This results in much longer welds than statically required but corrosion protection takes priority.



In order to keep stocks of different bar sizes to a minimum and to avoid confusion in the workshop with too many different designations, only a limited number of sizes are used for the sample trusses presented in this manual. The standard ones are as follows.

EA 100 x 100 x 6

EA 75 x 75 x 6

EA 65 x 65 x 6

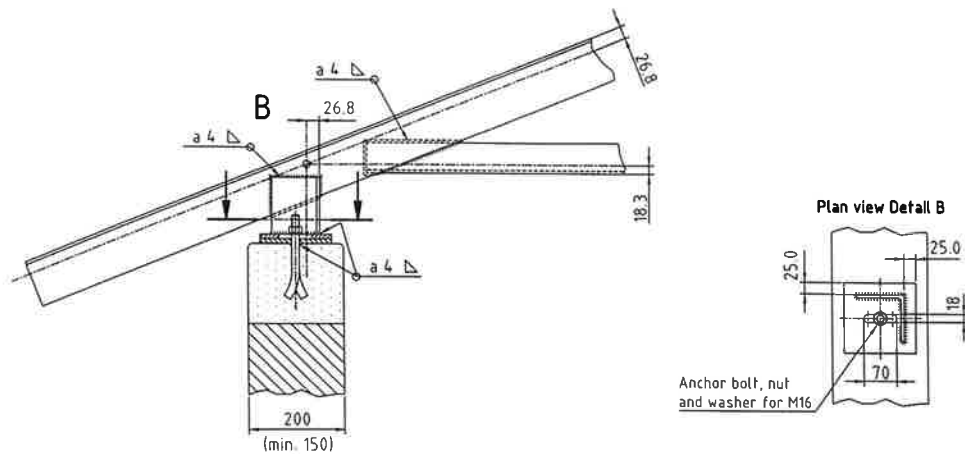
EA 50 x 50 x 5

EA 30 x 30 x 3

EA 25 x 25 x 3

Dimensions and design information of these bars are presented in Annex 4.

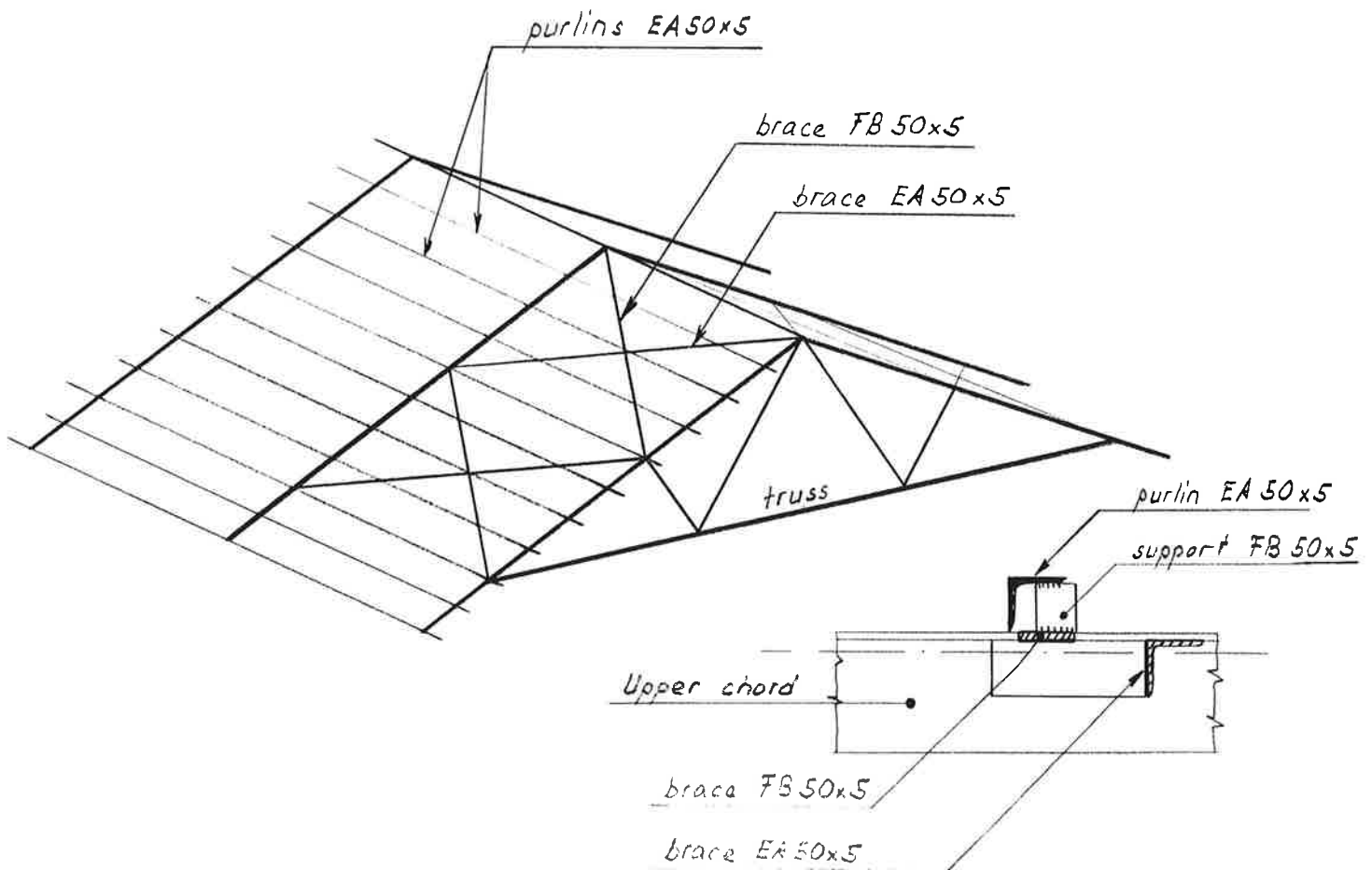
The supports rest on two bearing plates of which the top one has a slotted hole to allow horizontal movements from thermal expansion. A lot of grease must be applied to the sliding surfaces of the bearing plates to reduce friction.



6.6.4 Bracing

Bracing against overturning of the individual trusses due to wind loads on gables and buckling of the compression chords is accomplished by welding X-braces onto the top chord of the truss in every fifth field. These X-braces form lateral restraining (bracing) trusses together with the purlins.

For MCR roofing material, the purlins have a spacing of 400 mm and must be comprised of equal angle bars of at least EA 50 x 50 x 5 sizes. The X-brace uses the same angle size and a flat 50 x 5 as a cross brace. These cross braces are welded to the top chord members and also to the purlins at each intersection. As the purlins are welded with the leg facing upwards, a support made of a flat (from cuttings) is to be added to secure the connection at each truss.



6.7 Angle Bar Truss Samples

6.7.1 Assumptions and Limits of Application

- Yield strength of sections 200 MPa (N/mm²)
- Loads are permissible loads (not ultimate capacities)
- Loads are applied through the top chord

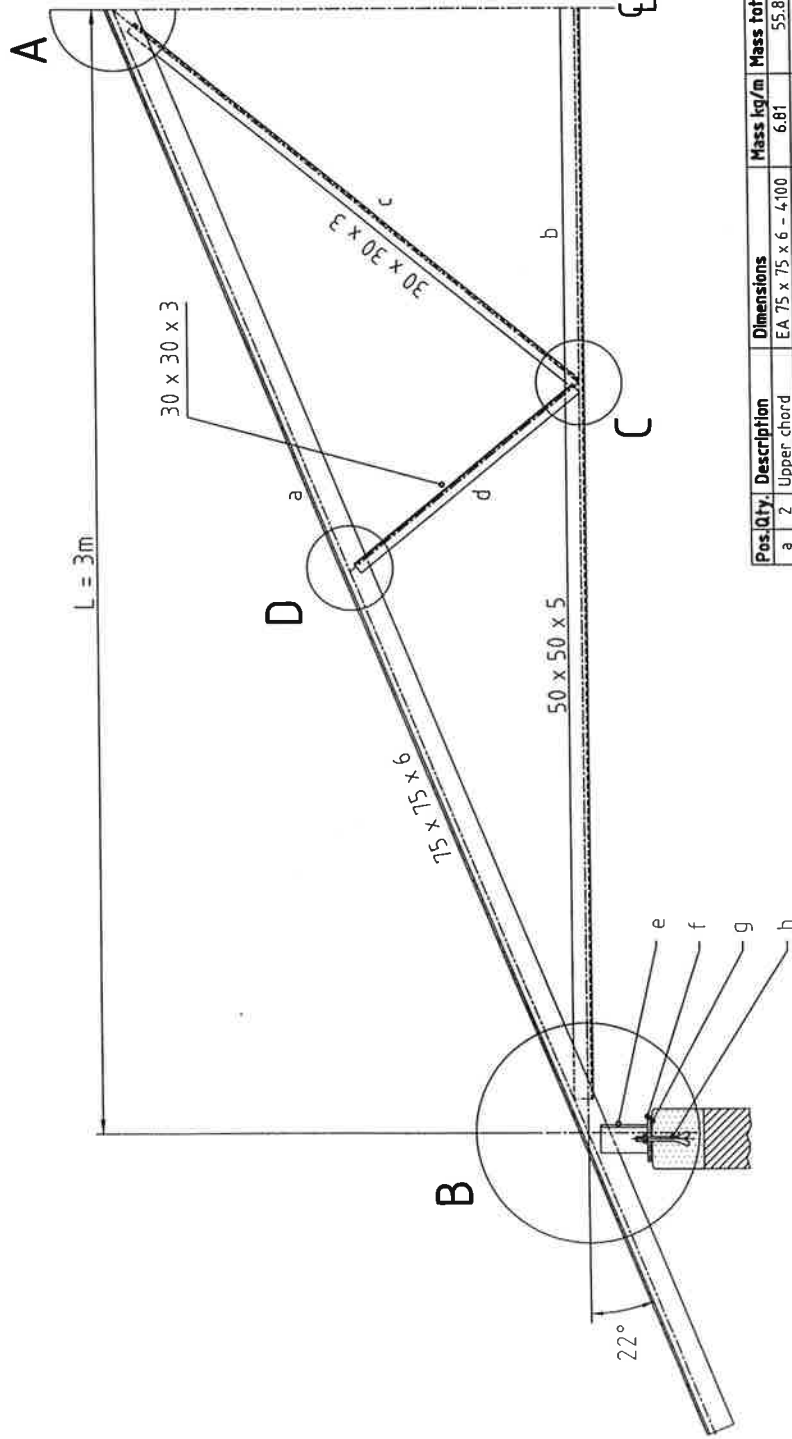
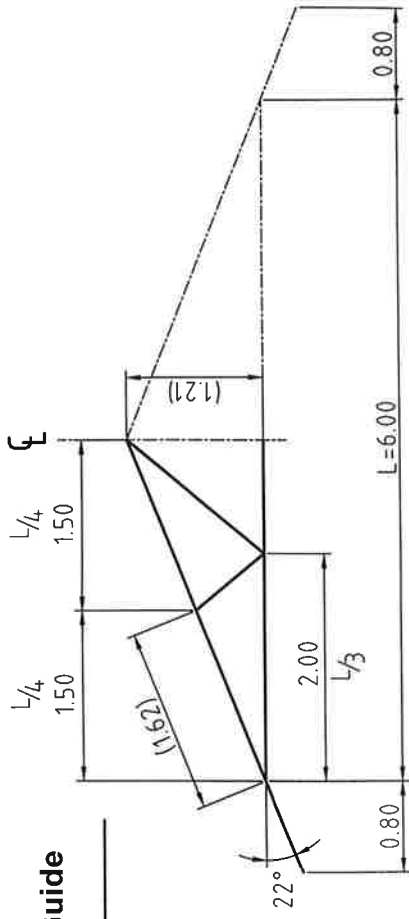
6.7.2 Double Pitch Roof; Single Angle Bars, 6 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

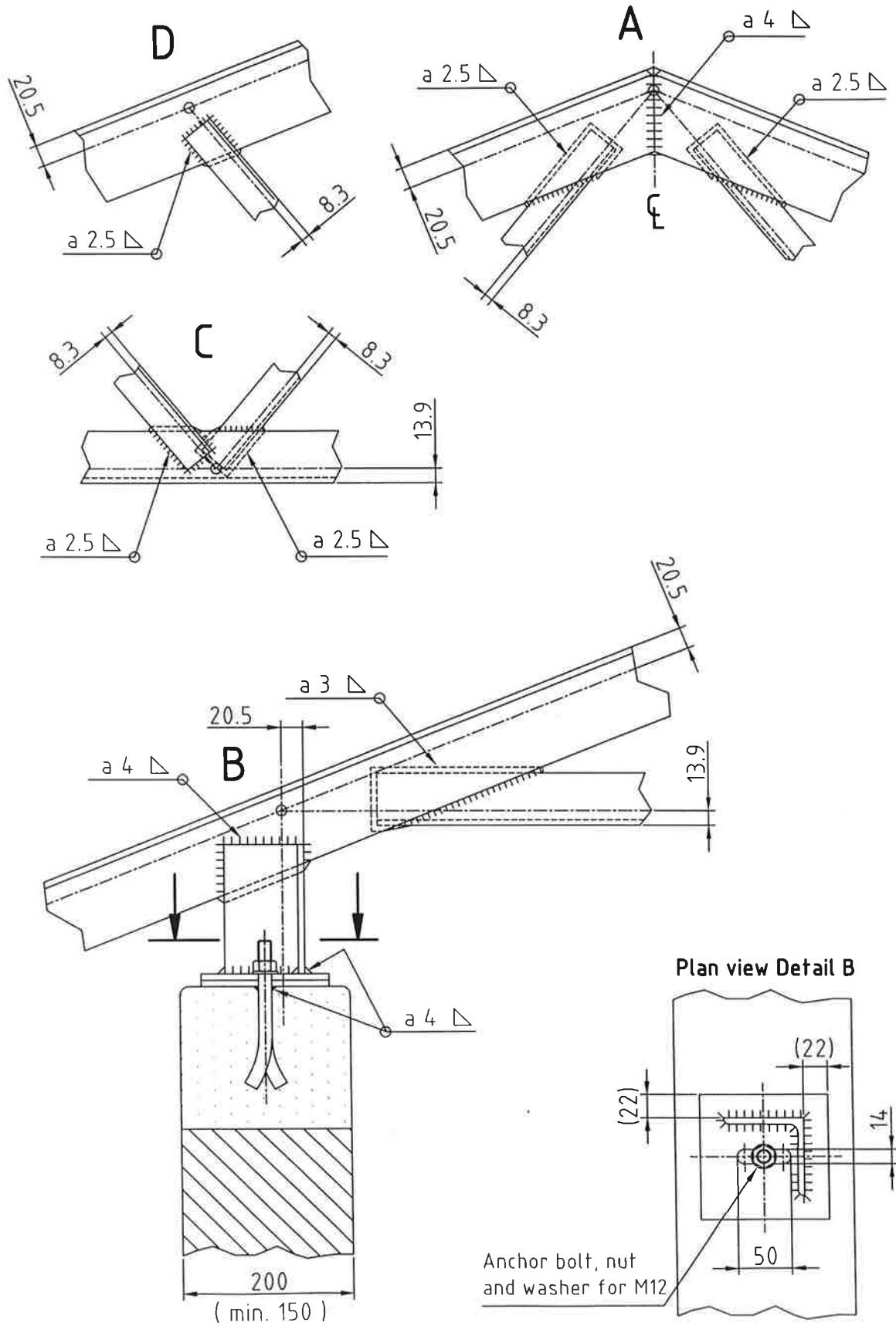
Spacing of truss 2.5 m

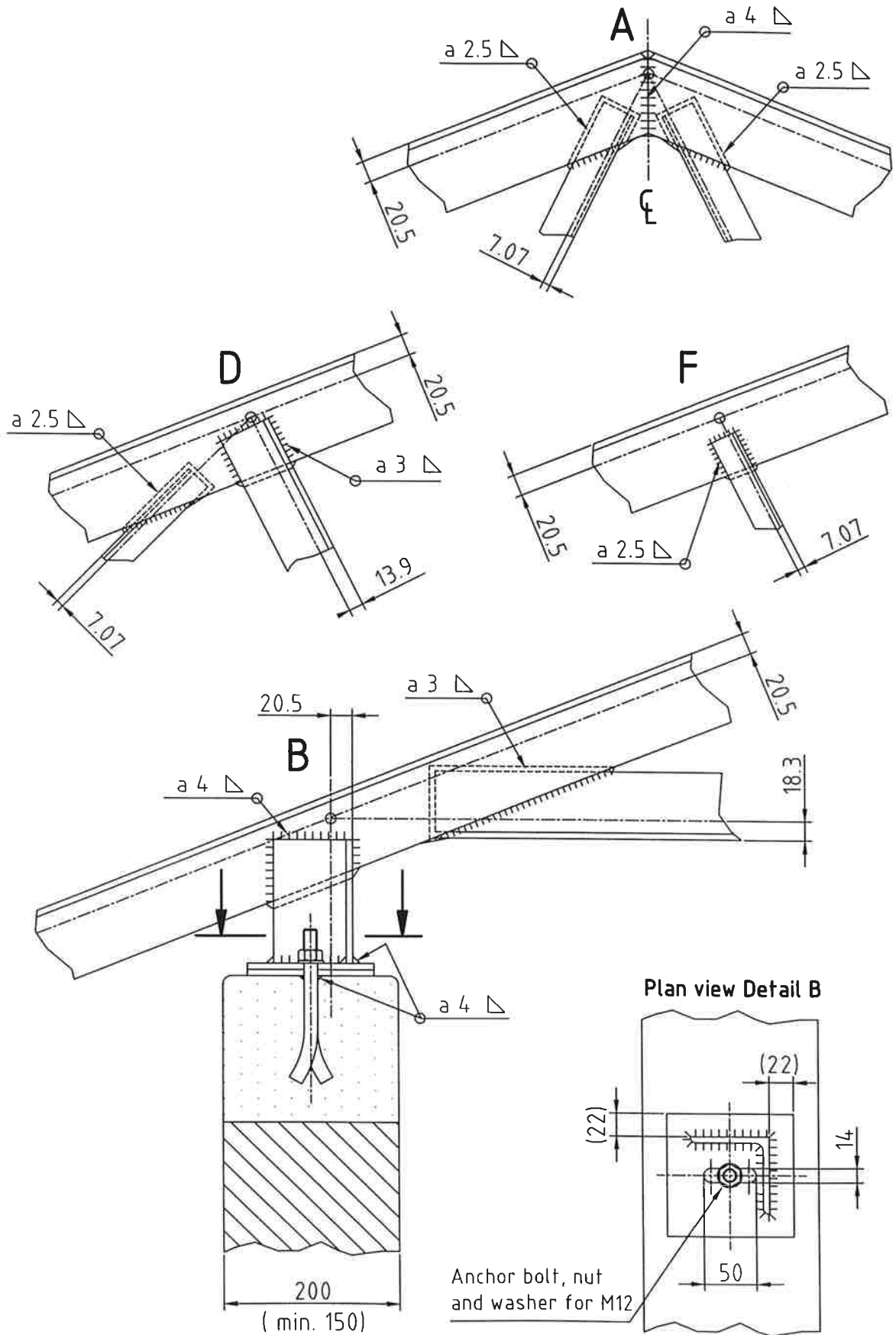
Total load 1.0 kN/m²

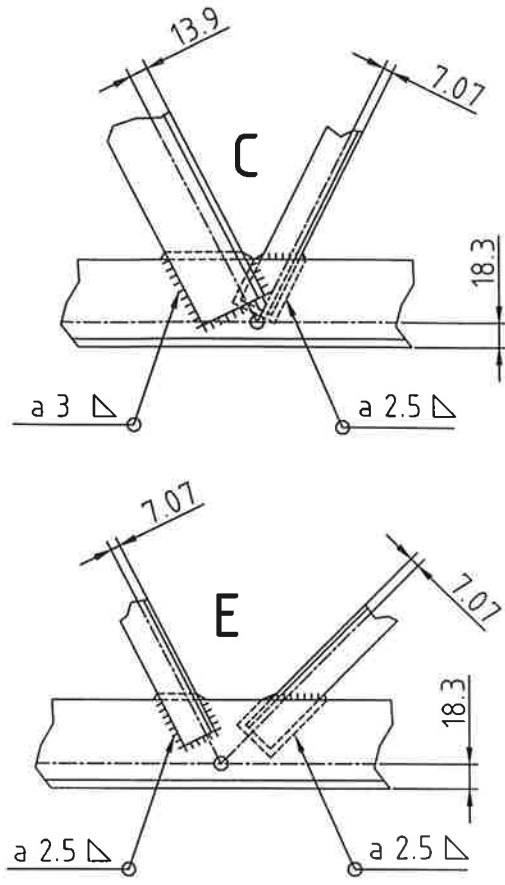


Pos.	Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	2	Upper chord	EA 75 x 75 x 6 - 4100	6.81	55.8
b	1	Lower chord	EA 50 x 50 x 5 - 5870	3.48	20.2
c	2	Tie	EA 30 x 30 x 3 - 1500	1.35	4.0
d	2	Strut	EA 30 x 30 x 3 - 750	1.35	2.05
e	2	Support	EA 75 x 75 x 6 - 120	6.81	1.65
f	2	Sliding plate	FB 120 x 6 - 120	5.65	1.35
g	2	Anchor plate	FB 120 x 6 - 120	5.65	1.35
h	2	Anchor bolt/nut/washer M12 - 120	----	0.6	0.6
				Mass total	87.0

{ EA = equal angel / FB = flat bar }







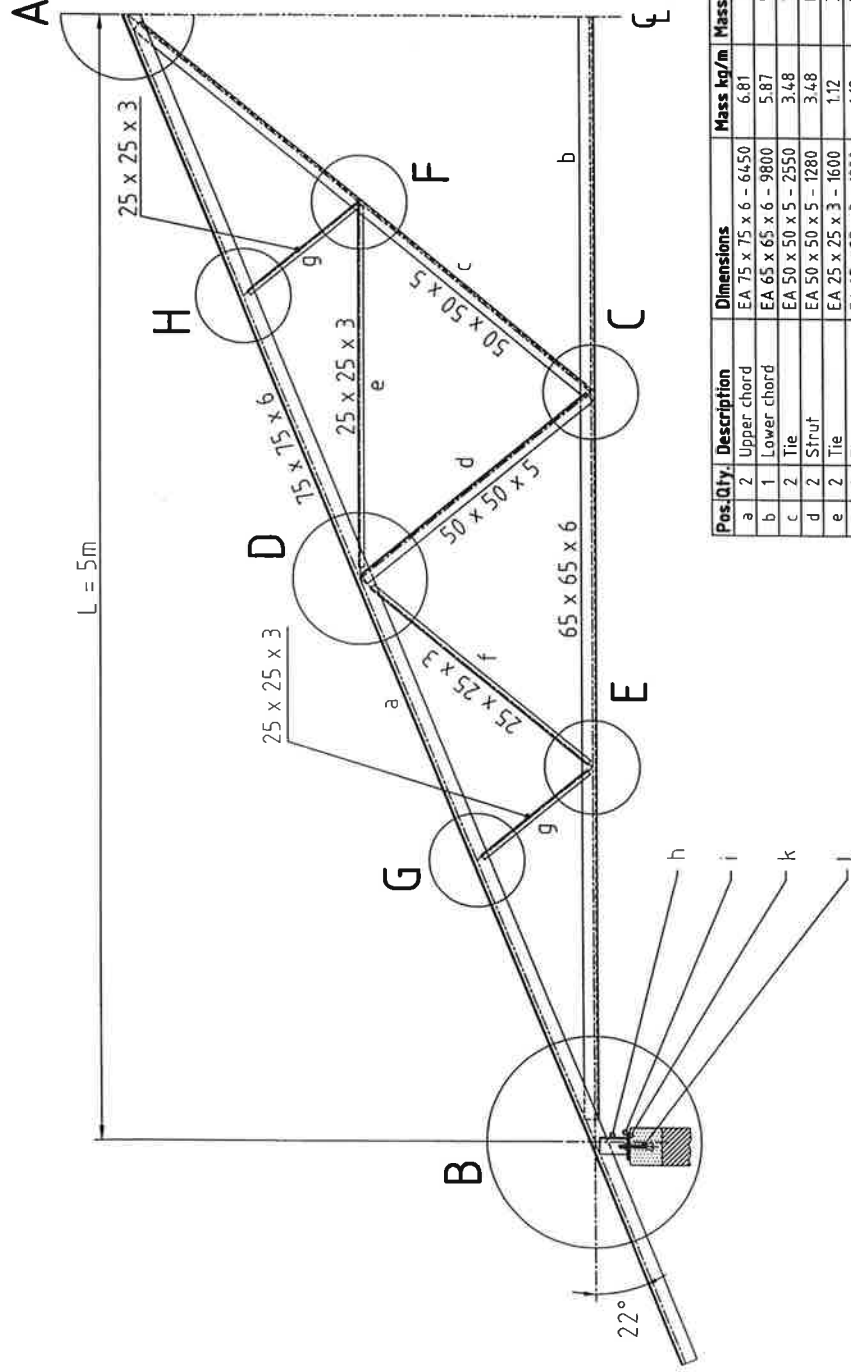
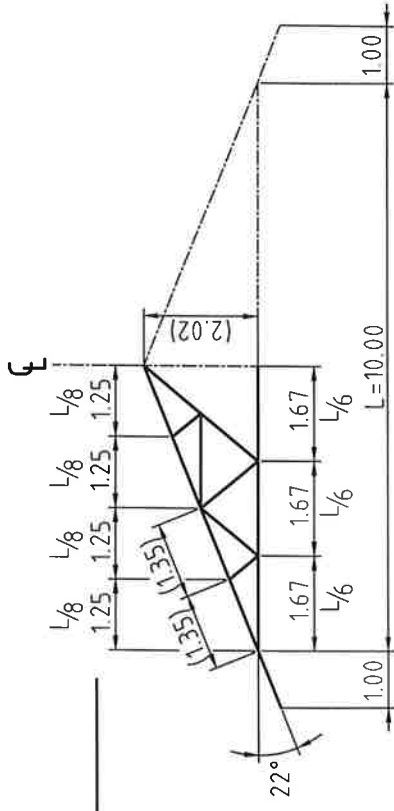
6.7.4 Double Pitch Roof; Single Angle Bars, 10 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

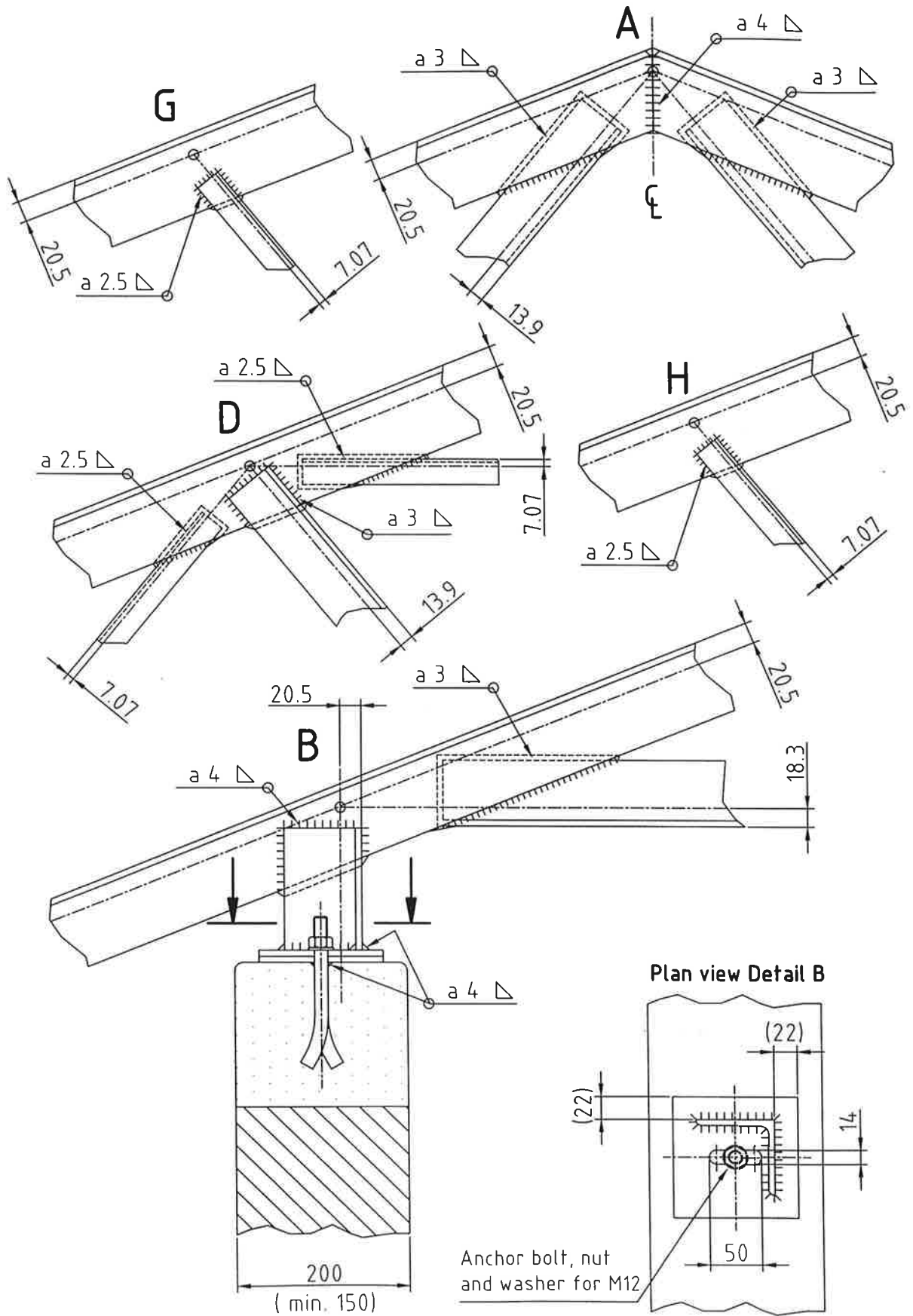
Spacing of truss 2.5 m

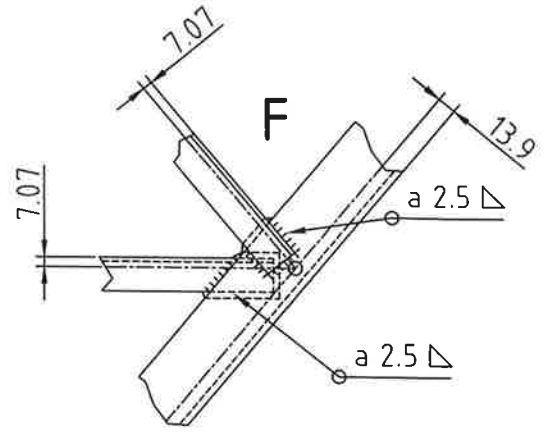
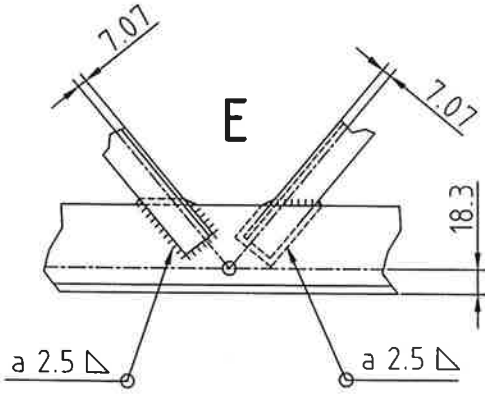
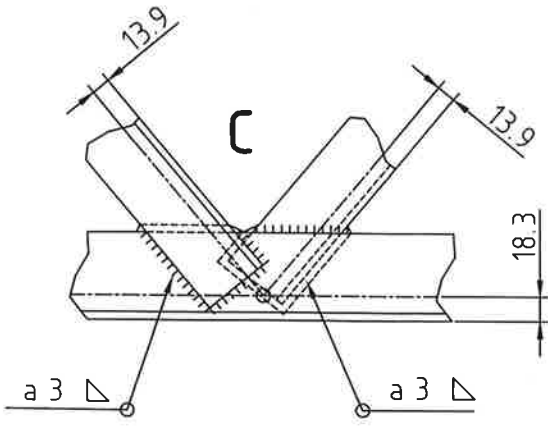
Total load 1.0 kN/m²

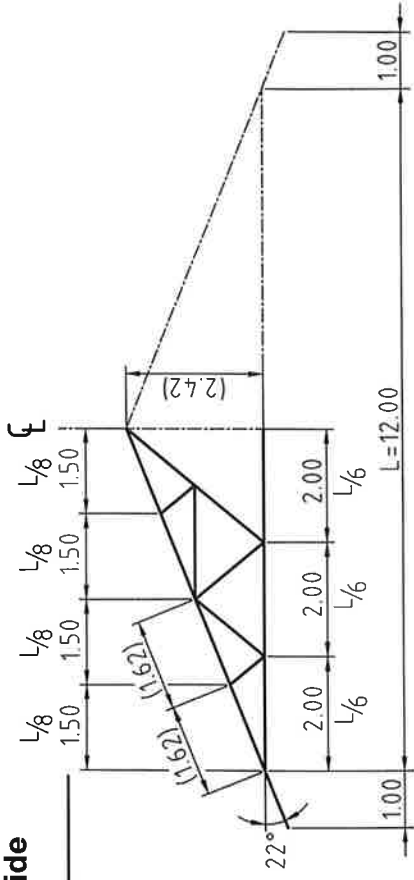


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	EA 75 x 75 x 6 - 6450	6.81	87.9
b 1	Lower chord	EA 65 x 65 x 6 - 9800	5.87	57.5
c 2	Tie	EA 50 x 50 x 5 - 2550	3.48	17.75
d 2	Strut	EA 50 x 50 x 5 - 1280	3.48	8.9
e 2	Tie	EA 25 x 25 x 3 - 1600	1.12	3.6
f 2	Tie	EA 25 x 25 x 3 - 1220	1.12	2.7
g 4	Strut	EA 25 x 25 x 3 - 600	1.12	2.7
h 2	Support	EA 75 x 75 x 6 - 120	6.81	1.65
i 2	Sliding plate	FB 120 x 6 - 120	5.65	1.35
k 2	Anchor plate	FB 120 x 6 - 120	5.65	1.35
l 2	Anchor bolt/nut/washer M12 - 120		---	0.60
			Mass total	186.0

(EA = equal angle / FB = flat bar)

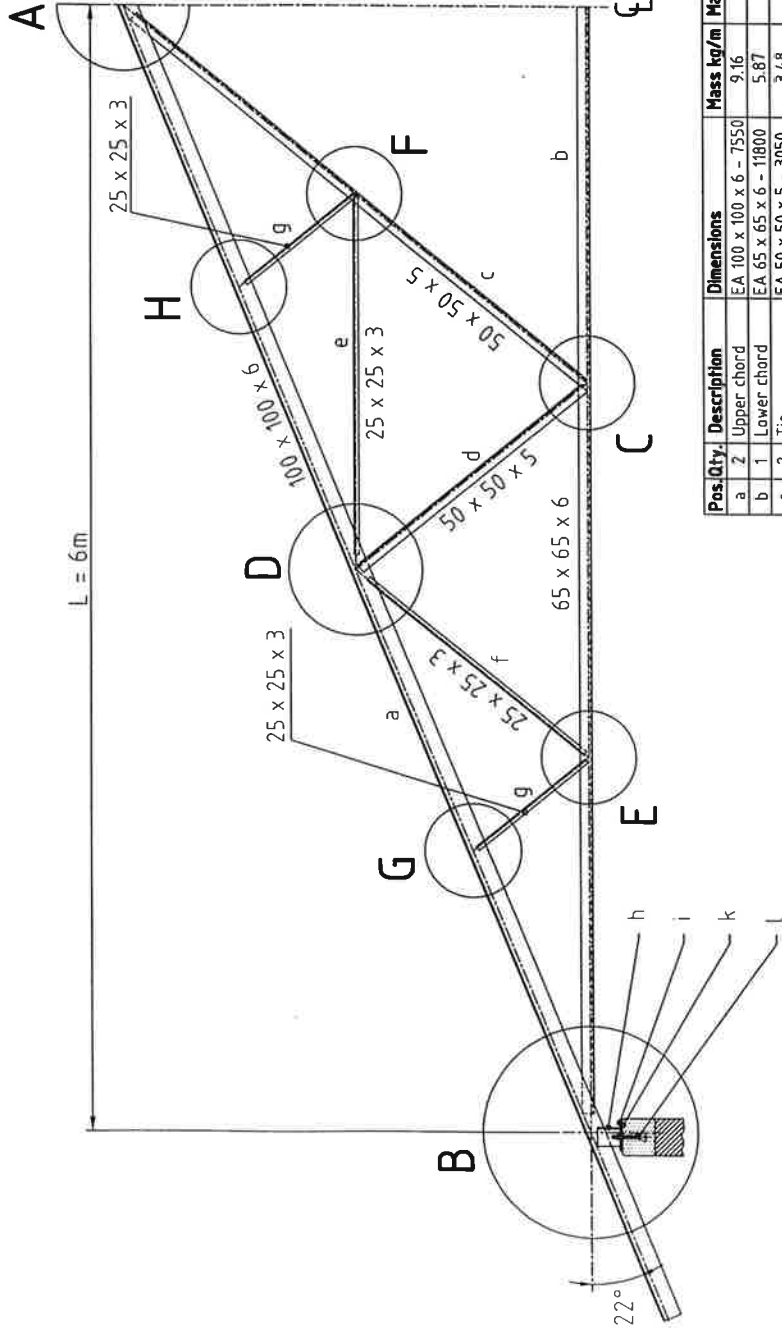






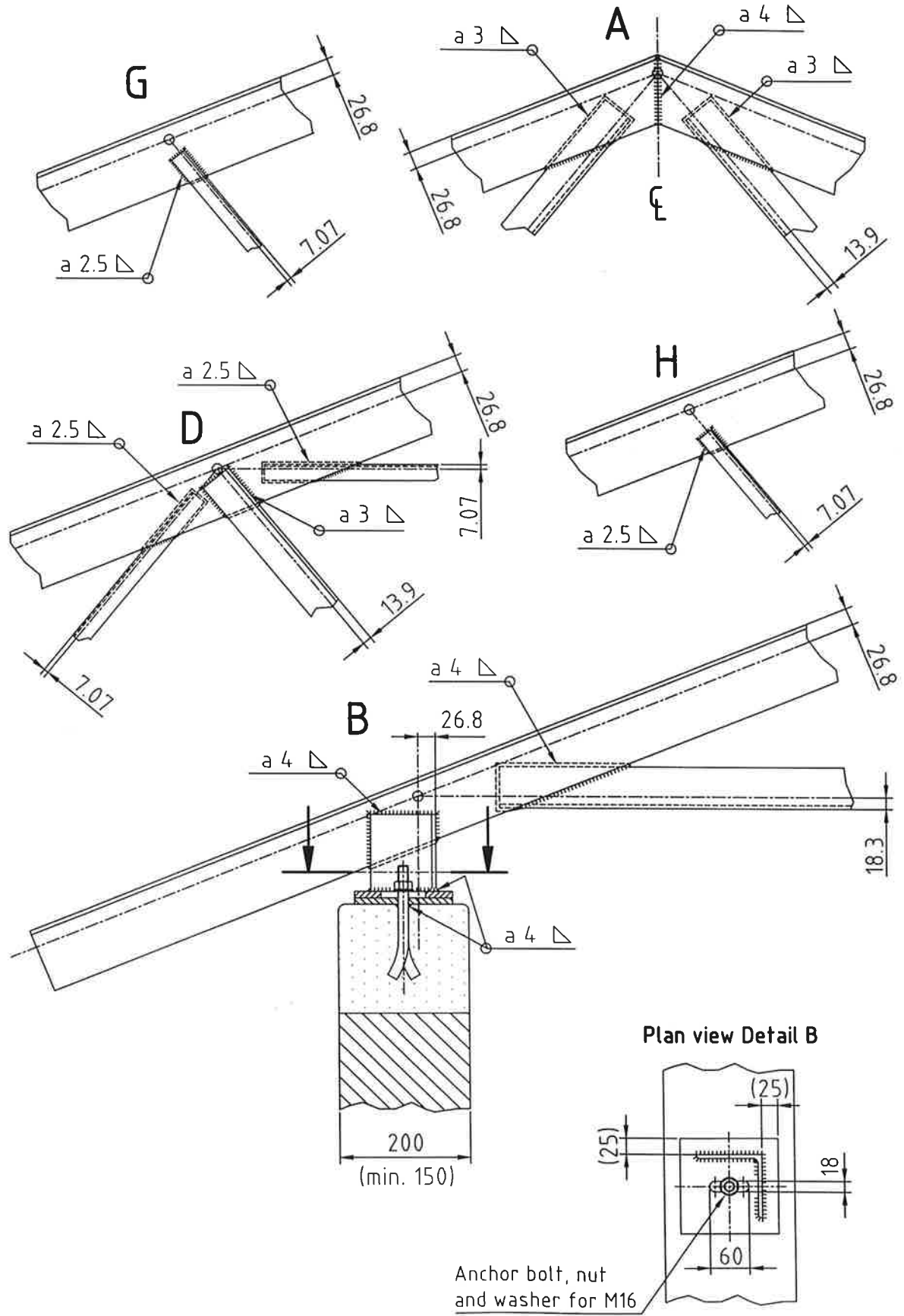
6.7.5 Double Pitch Roof; Single Angle Bars, 12 m span

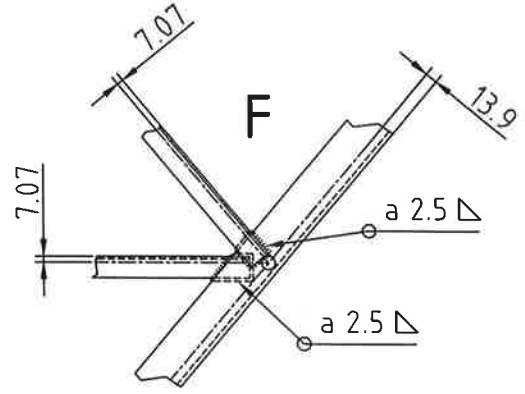
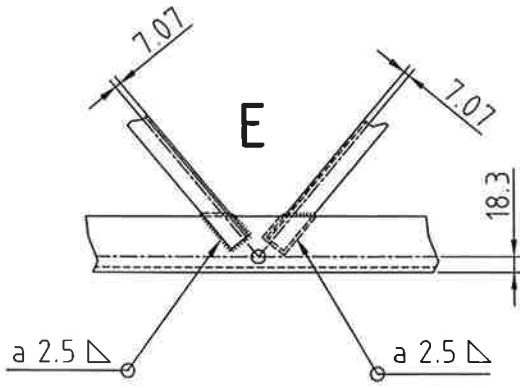
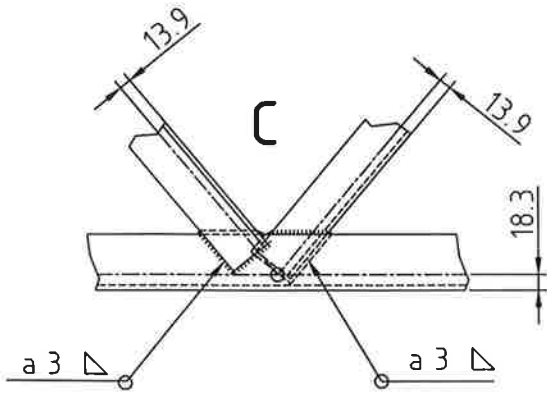
- Roof Slope min 19°, max. 30°
- Bracing system according to Section 6.6.4 above
- Spacing of truss 2.5 m
- Total load 1.0 kN/m²

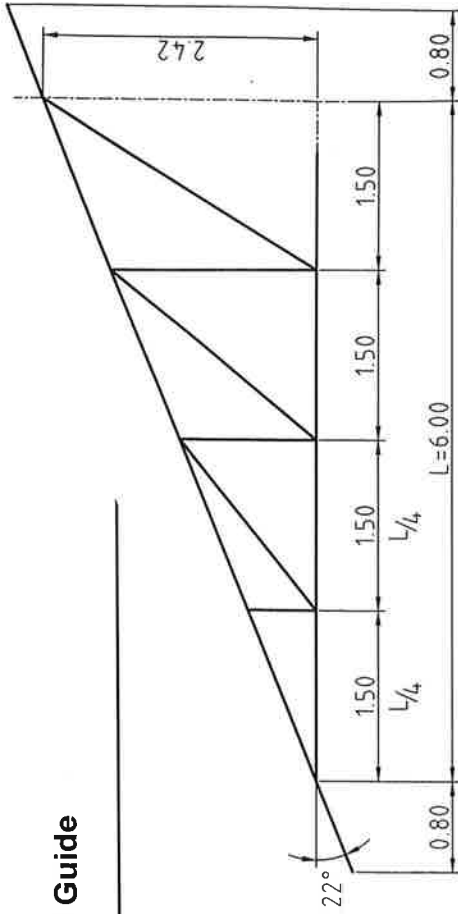


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	EA 100 x 100 x 6 - 7550	9.16	138.3
b 1	Lower chord	EA 65 x 65 x 6 - 11800	5.87	69.3
c 2	Tie	EA 50 x 50 x 5 - 3050	3.48	21.3
d 2	Strut	EA 50 x 50 x 5 - 1520	3.48	10.6
e 2	Tie	EA 25 x 25 x 3 - 1900	1.12	4.25
f 2	Tie	EA 25 x 25 x 3 - 1460	1.12	3.25
g 4	Strut	EA 25 x 25 x 3 - 740	1.12	3.3
h 2	Support	EA 100 x 100 x 6 - 120	9.16	2.2
i 2	Sliding plate	FB 150 x 6 - 150	7.07	2.15
k 2	Anchor plate	FB 150 x 6 - 150	7.07	2.15
l 2	Anchor bolt/nut/washer M16 - 150	---	---	0.7
			Mass total	257.5

(EA = equal angle / FB = flat bar)





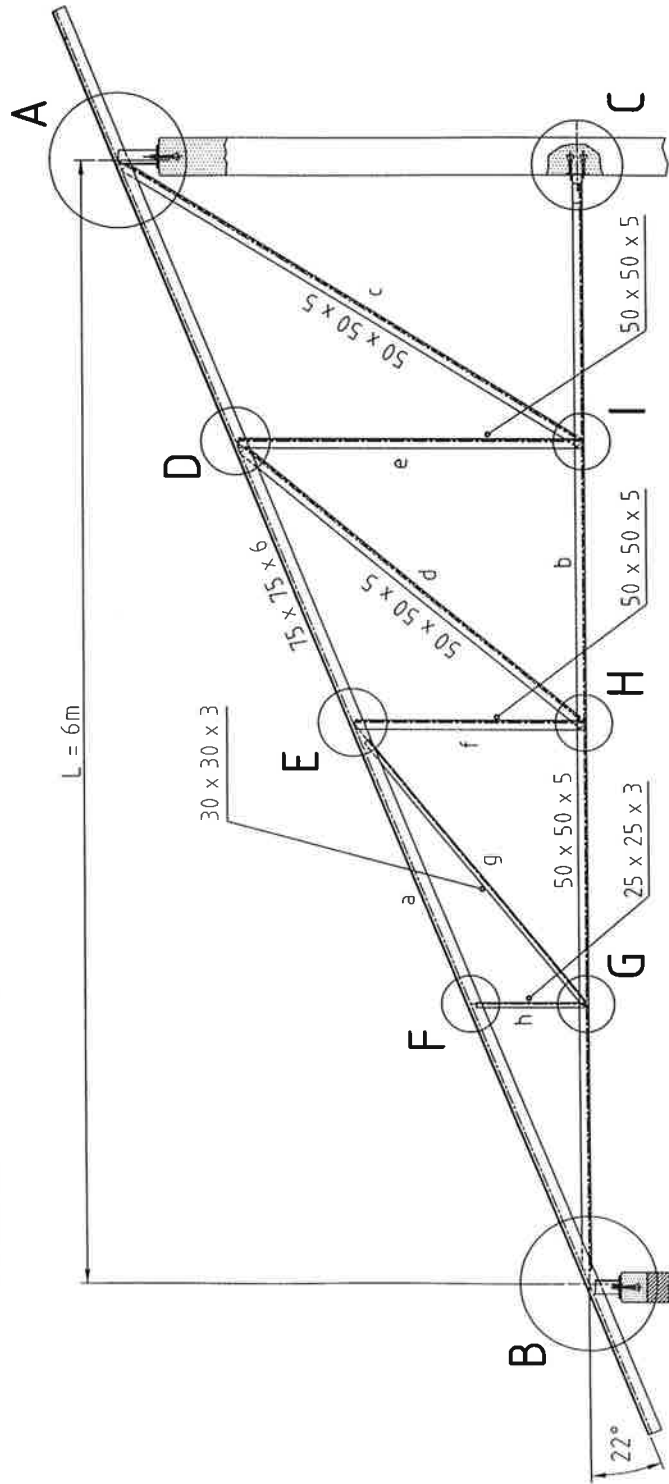


6.7.6 Single Pitch Roof; Single Angle Bars, 6 m span

Roof Slope min 19° , max. 30°
 Bracing system according to Section 6.6.4 above

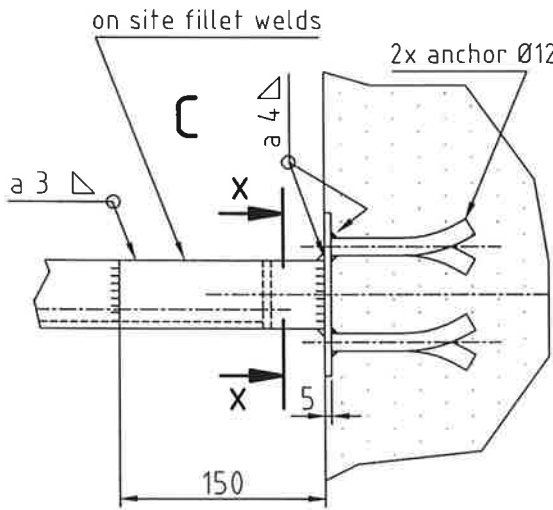
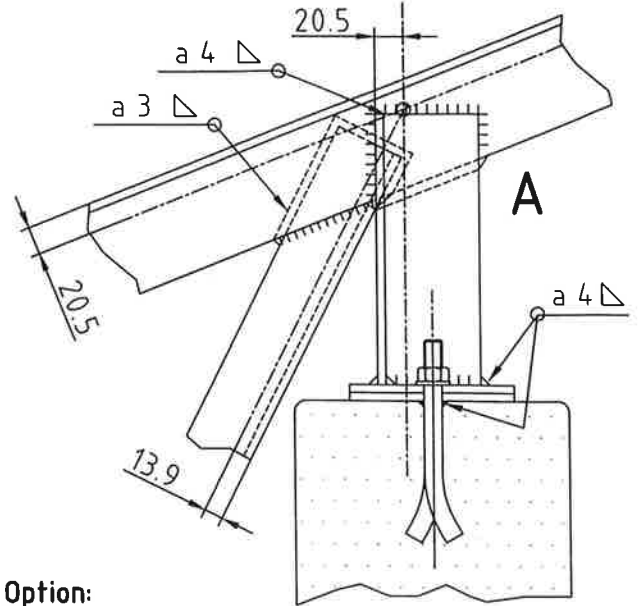
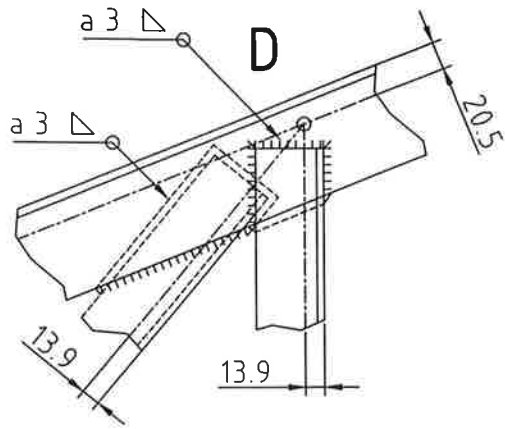
Spacing of truss 2.5 m

Total load 1.0 kN/m^2

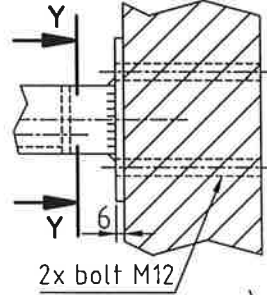


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Upper chord	EA 75 x 75 x 6 - 8200	6.81	56.0
b 1	Lower chord	EA 50 x 50 x 5 - 5800	3.48	20.2
c 1	Diagonal	EA 50 x 50 x 5 - 2800	3.48	9.8
d 1	Post	EA 50 x 50 x 5 - 2300	3.48	8.0
e 1	Diagonal	EA 50 x 50 x 5 - 1800	3.48	6.3
f 1	Post	EA 50 x 50 x 5 - 1200	3.48	4.2
g 1	Diagonal	EA 30 x 30 x 3 - 1800	1.35	2.5
h 1	Post	EA 30 x 30 x 3 - 570	1.12	0.7
A 1	Support A	Plates/Support/Bolts	---	3.3
B 1	Support B	Plates/Support/Bolts	---	2.8
C 1	Support C	Plates/Support/Bolts	---	1.2
Mass total				115.0

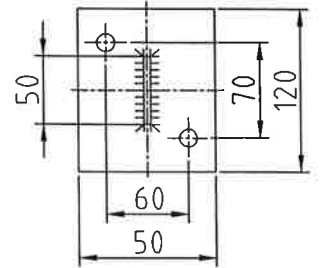
(EA = equal angle)



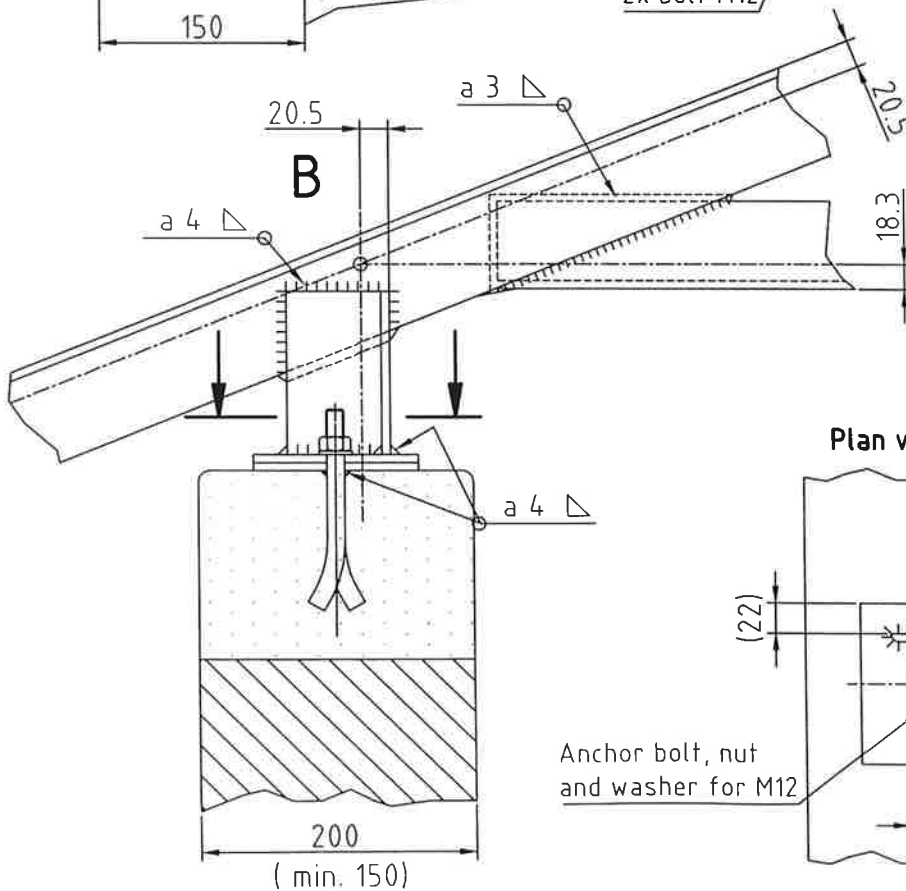
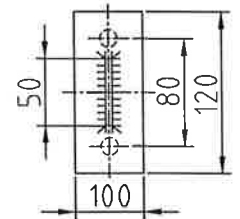
Option:
if wall is not concrete



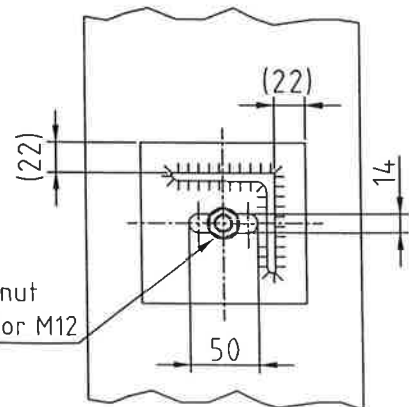
Plan view Detail Y



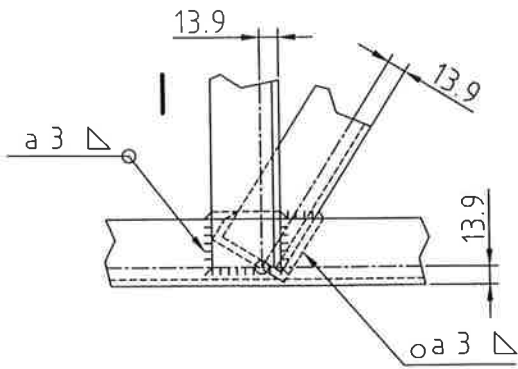
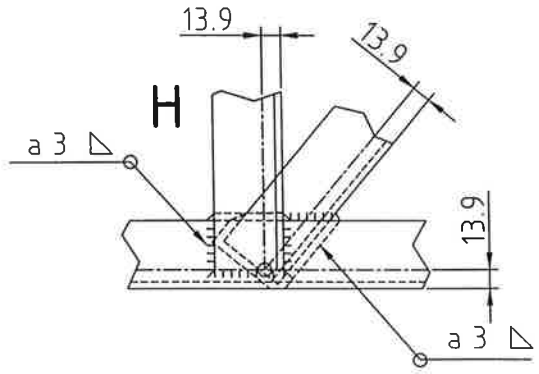
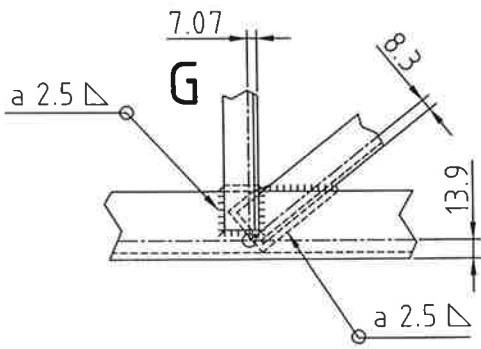
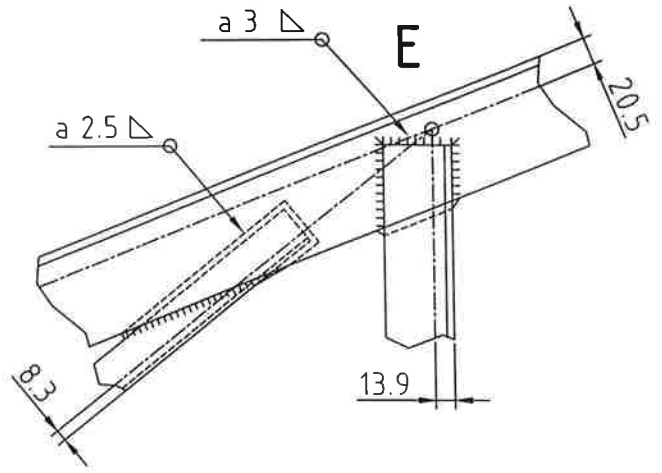
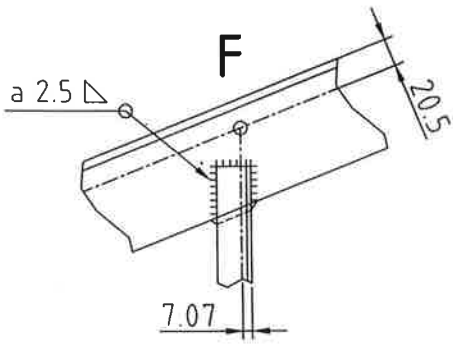
Plan view Detail X

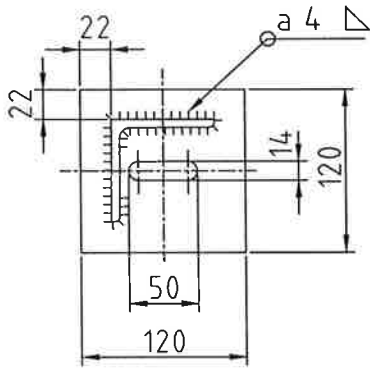
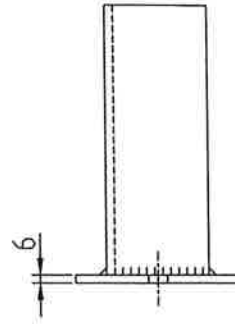
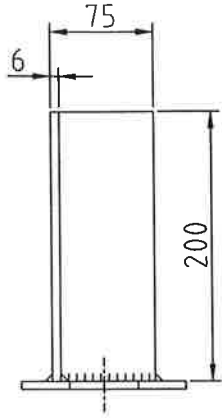


Plan view Detail B

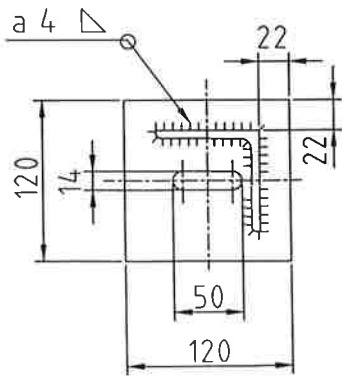
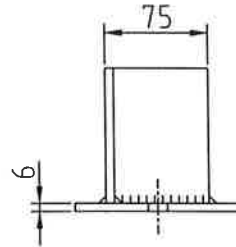
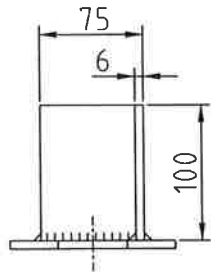


Anchor bolt, nut
and washer for M12





Detail Support A



Detail Support B

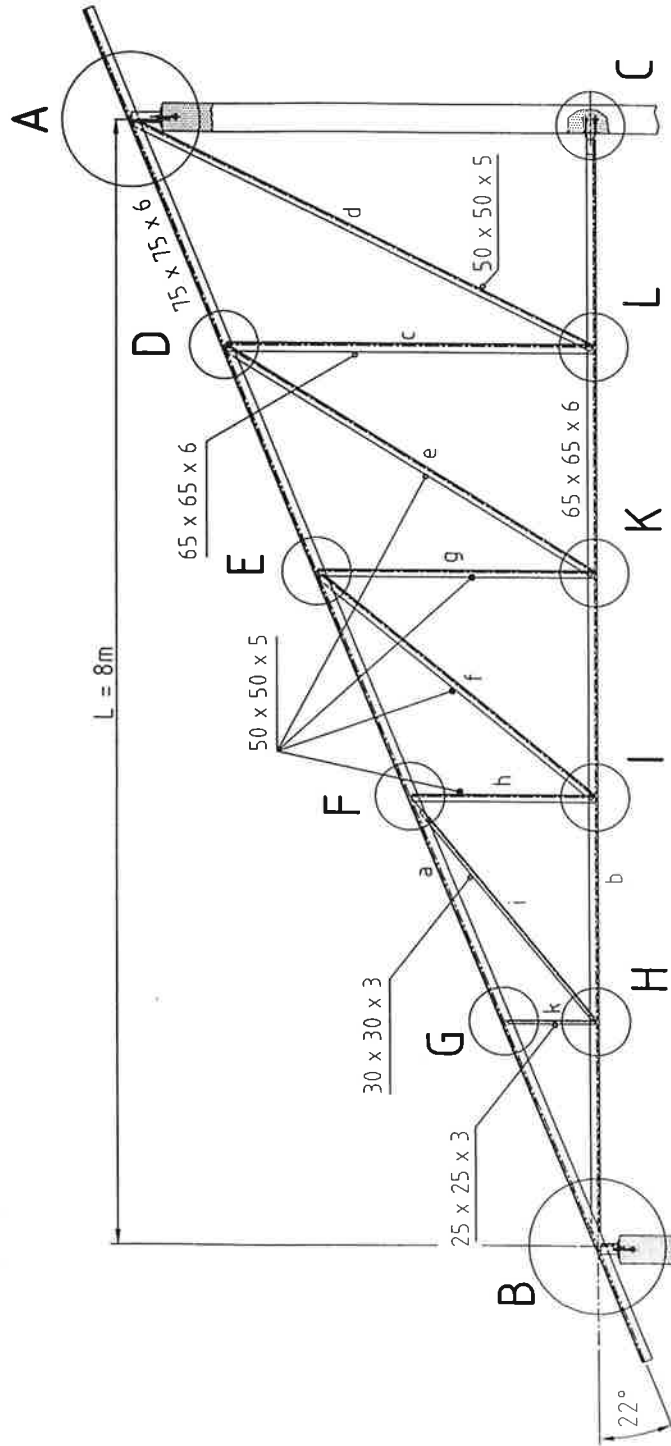
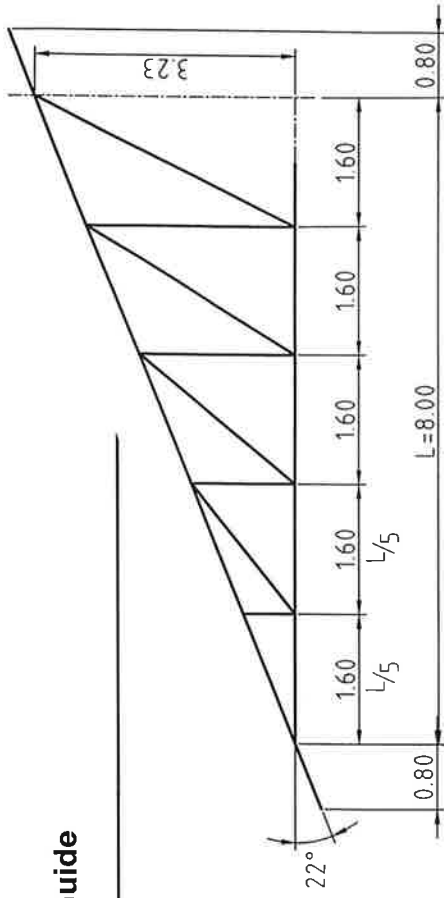
6.7.7 Single Pitch Roof; Single Angle Bars, 8 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

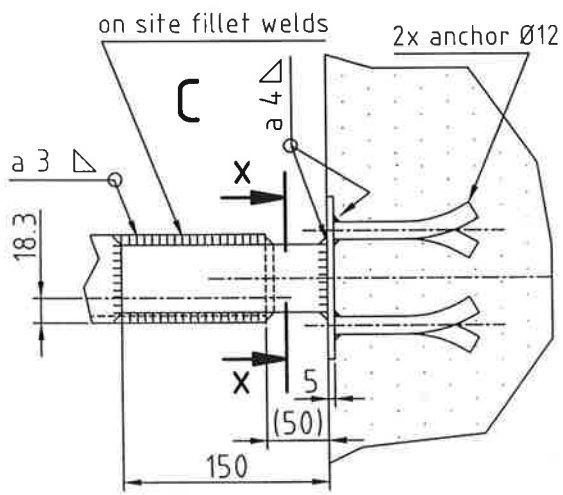
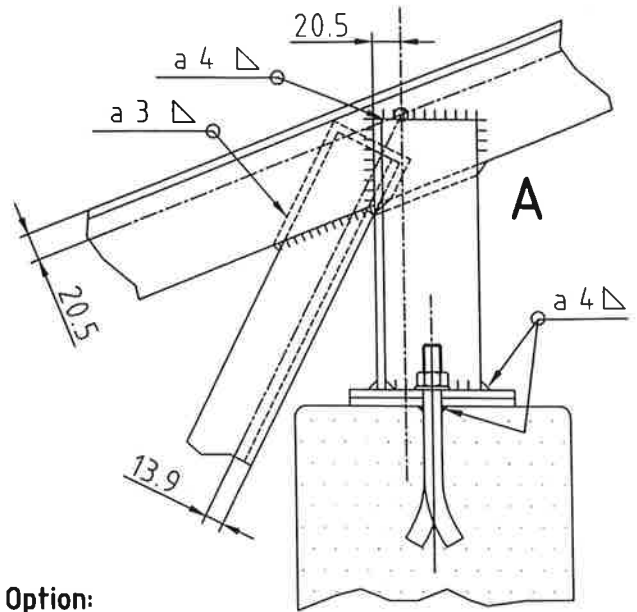
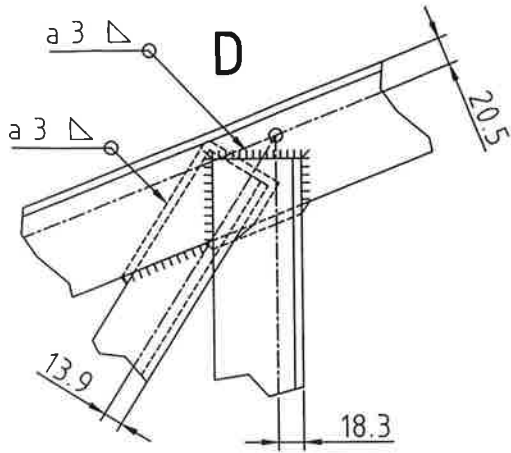
Spacing of truss 2.5 m

Total load 1.0 kN/m²

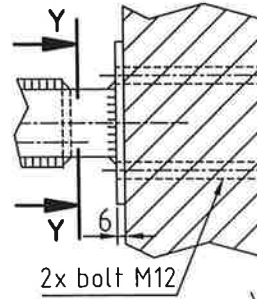


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Upper chord	EA 75 x 75 x 6 - 10350	6.81	70.5
b 1	Lower chord	EA 65 x 65 x 6 - 7770	5.87	45.7
c 1	Post	EA 65 x 65 x 6 - 2570	5.87	15.2
d 1	Diagonal	EA 50 x 50 x 5 - 3570	3.48	12.4
e 1	Diagonal	EA 50 x 50 x 5 - 3000	3.48	10.5
f 1	Diagonal	EA 50 x 50 x 5 - 2460	3.48	8.7
g 1	Post	EA 50 x 50 x 5 - 1930	3.48	6.8
h 1	Post	EA 50 x 50 x 5 - 1280	3.48	4.5
i 1	Diagonal	EA 30 x 30 x 3 - 1900	1.35	2.7
k 1	Post	EA 25 x 25 x 3 - 610	1.12	0.7
A 1	Support A	Plates/Support/Bolts	---	3.3
B 1	Support B	Plates/Support/Bolts	---	2.8
C 1	Support C	Plates/Support/Bolts	---	1.2
			Mass total	185.0

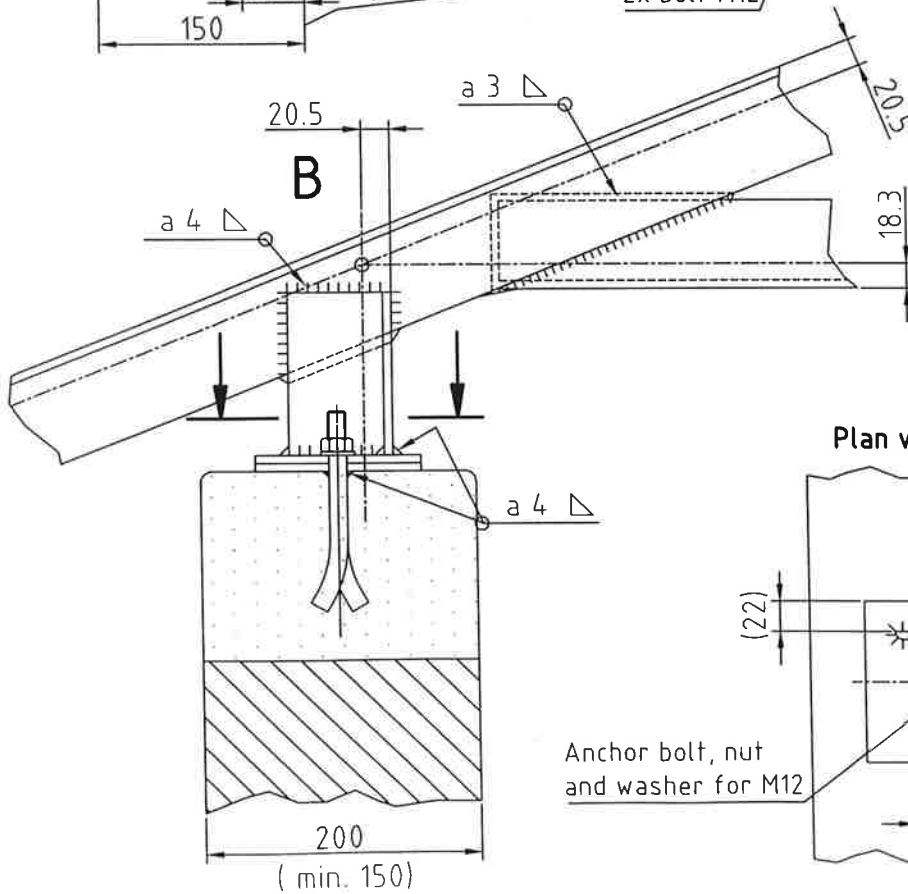
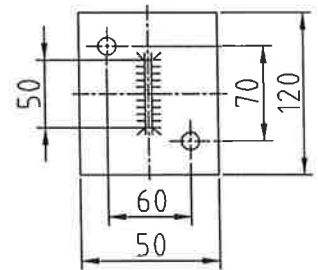
(EA = equal angle)



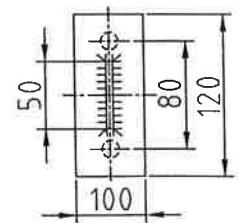
Option:
if wall is not concrete



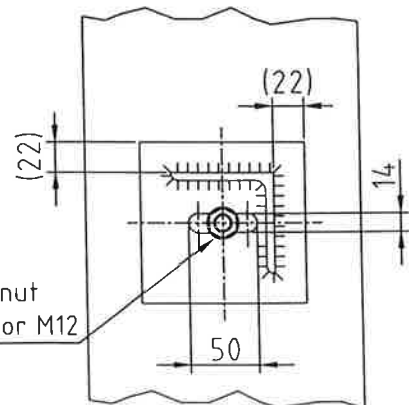
Plan view Detail Y



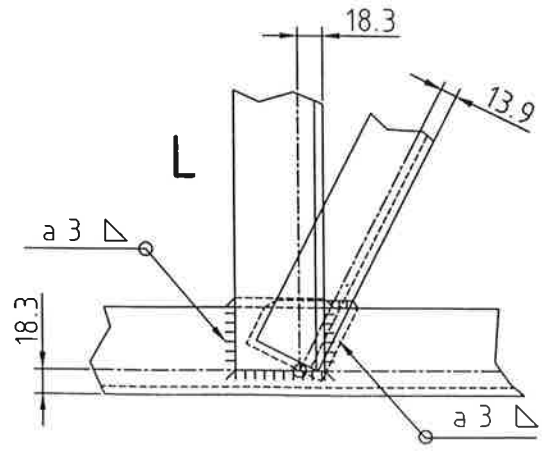
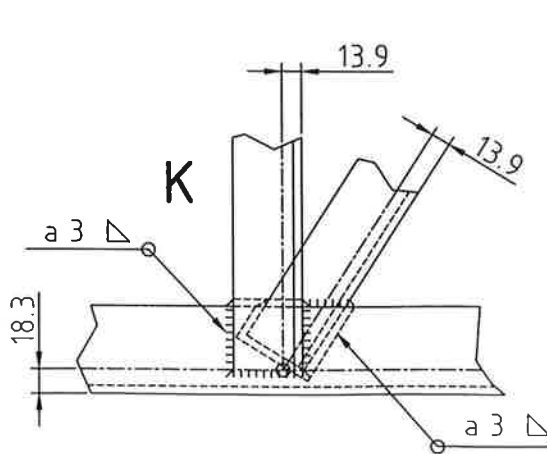
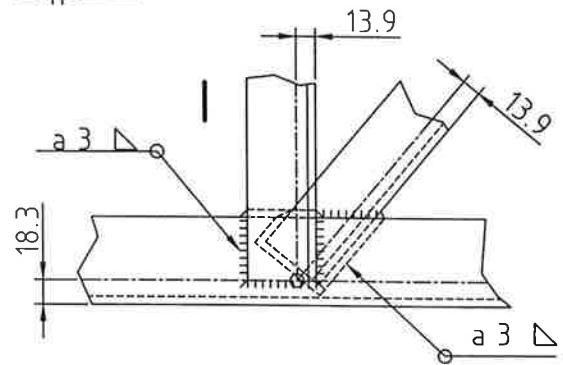
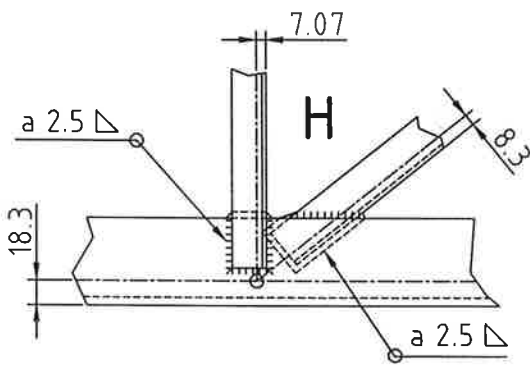
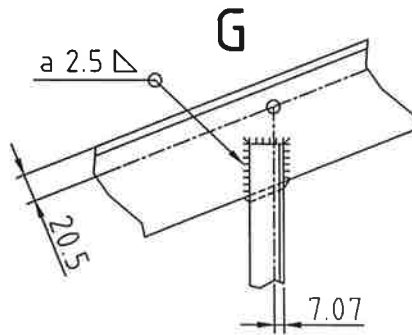
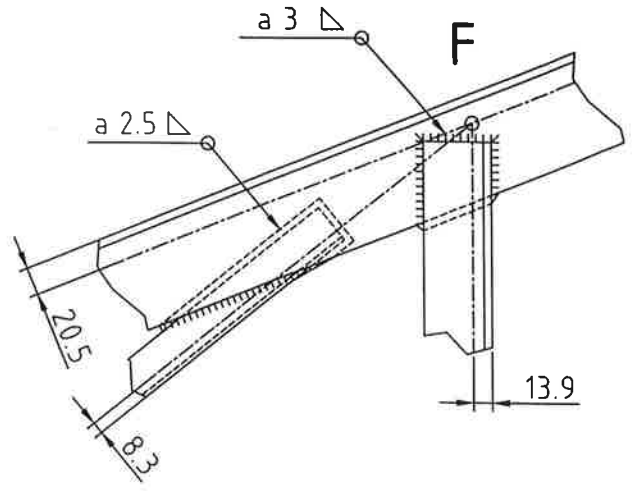
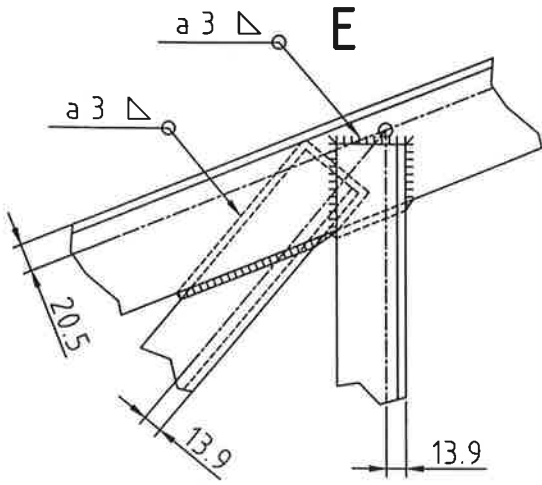
Plan view Detail X

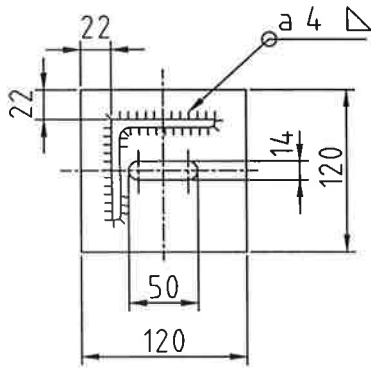
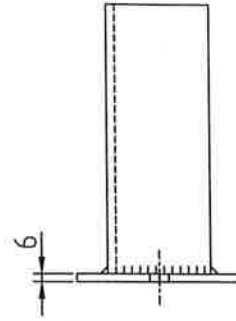
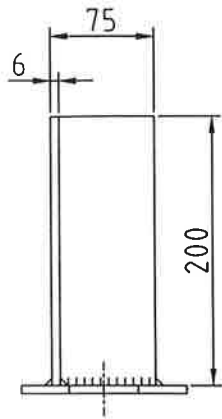


Plan view Detail B

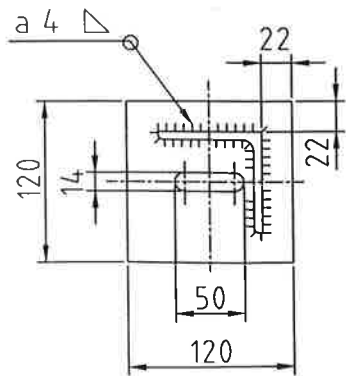
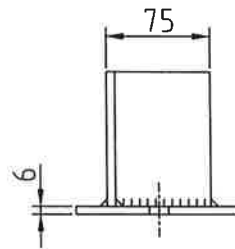
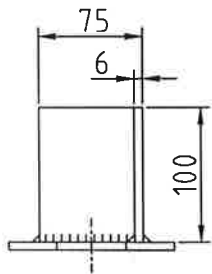


Anchor bolt, nut
and washer for M12





Detail Support A



Detail Support B

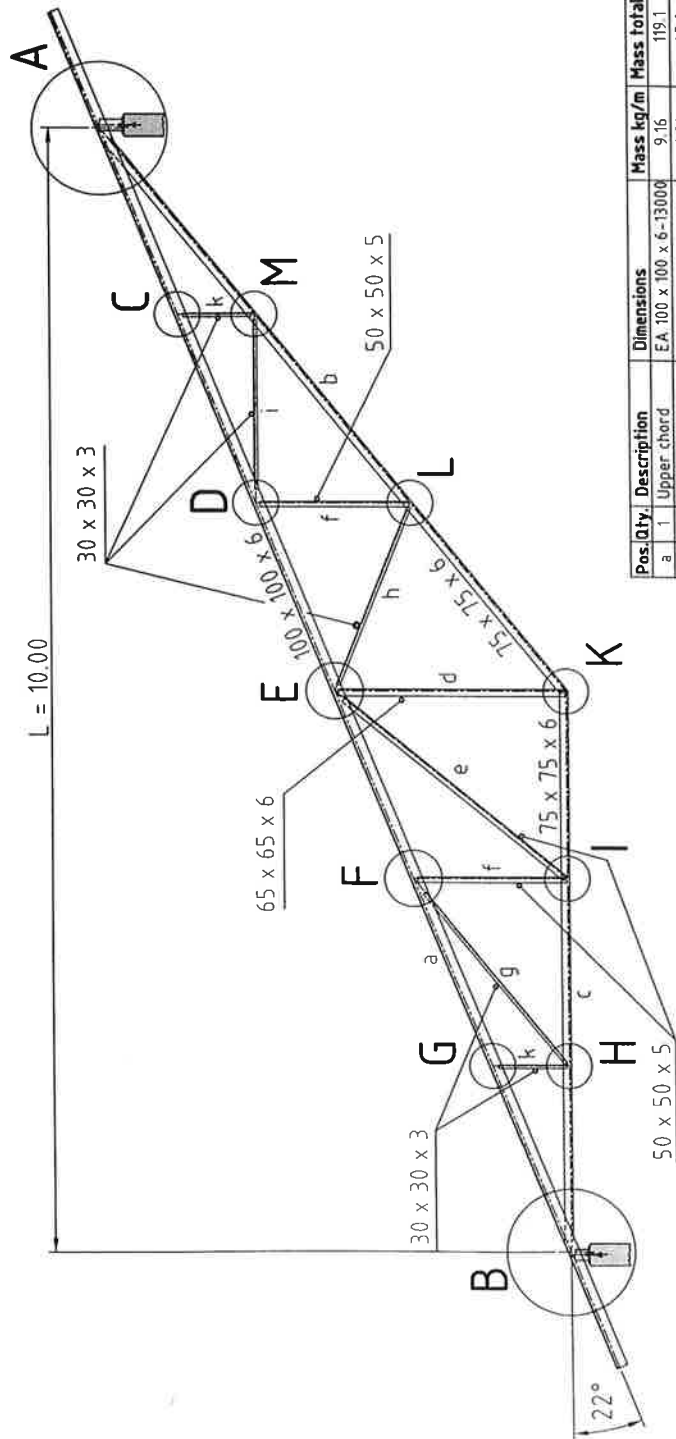
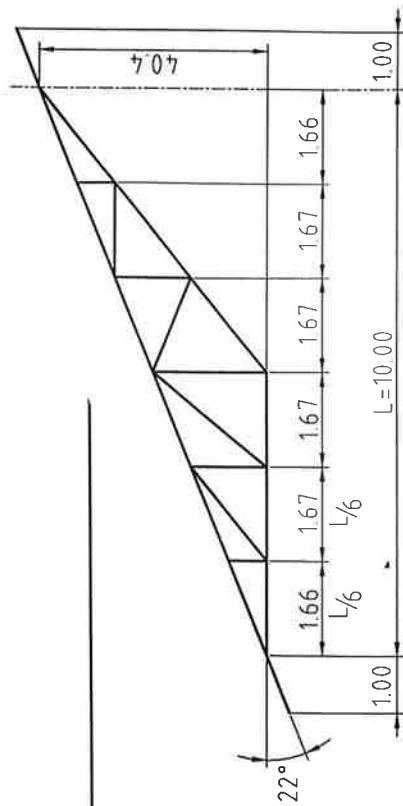
6.7.8 Single Pitch Roof; Single Angle Bars, 10 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

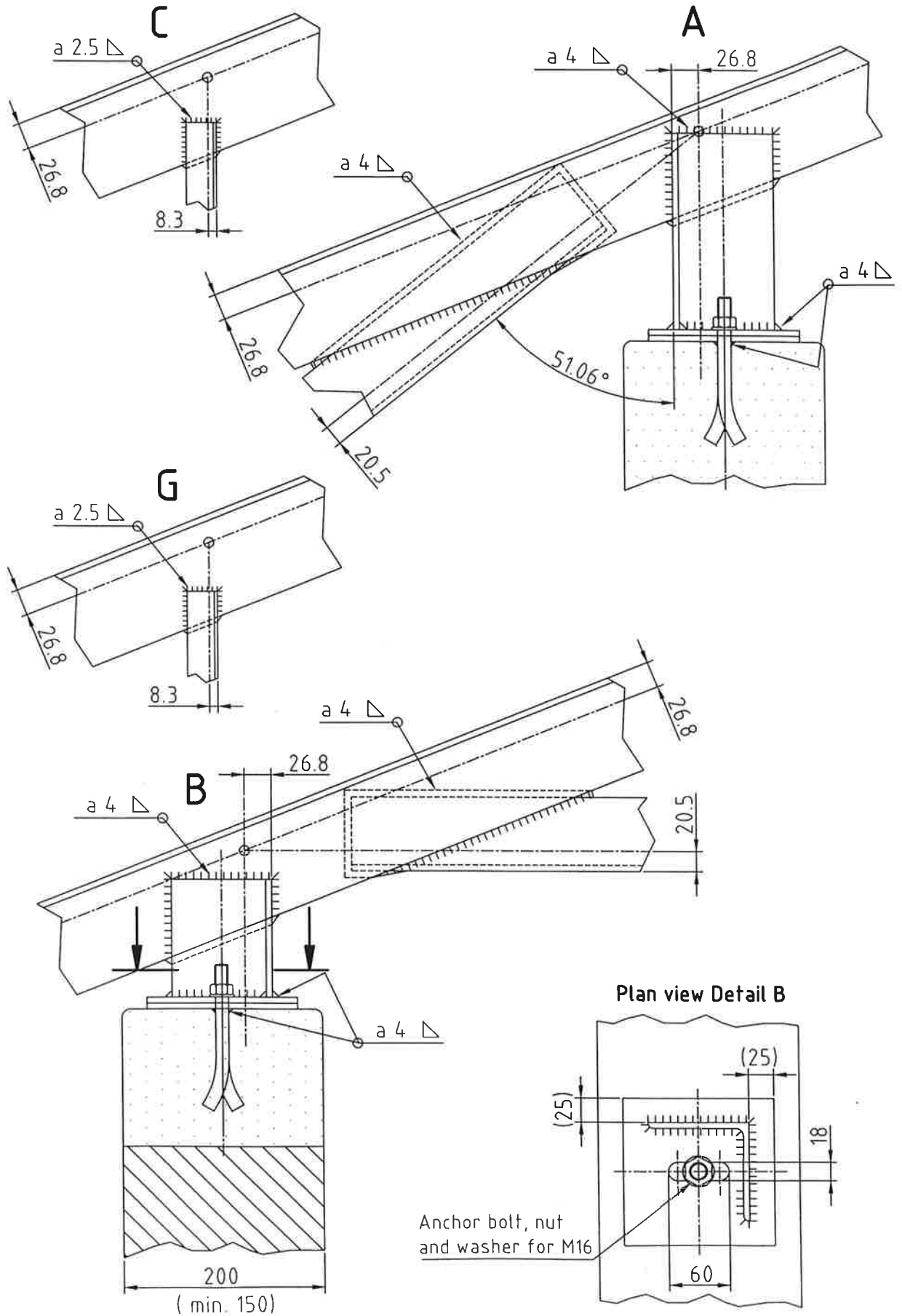
Spacing of truss 2.5 m

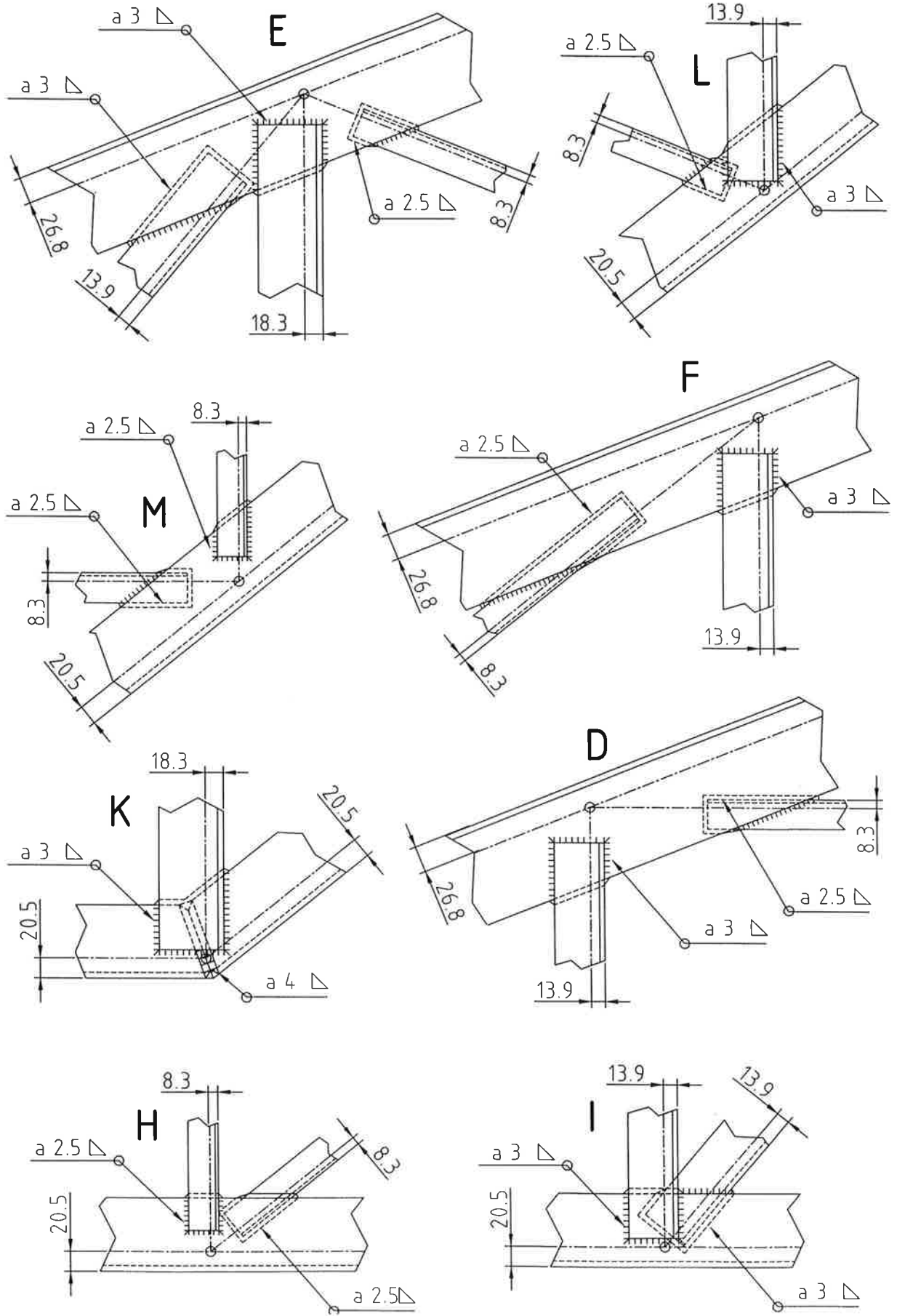
Total load 1.0 kN/m²

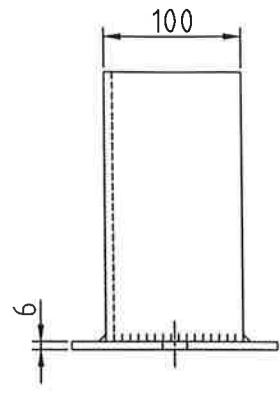
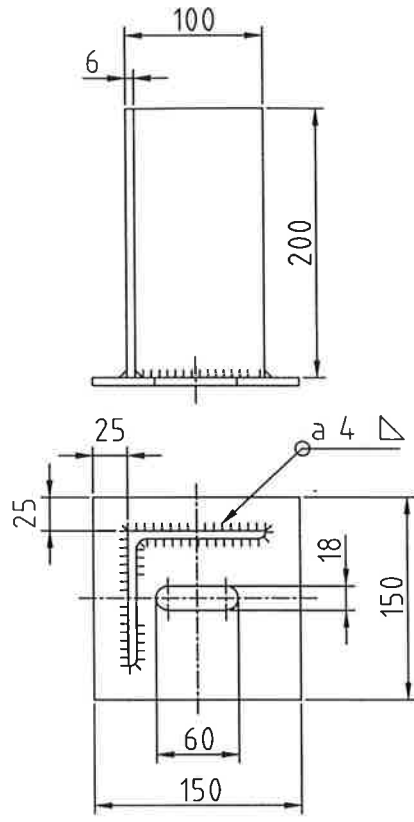


Pos. Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Upper chord	EA 100 x 100 x 6 - 13000	9.16	119.1
b 1	Lower chord	EA 75 x 75 x 6 - 6300	6.81	63.0
c 1	Lower chord	EA 75 x 75 x 6 - 4900	6.81	33.5
d 1	Post	EA 65 x 65 x 6 - 1980	5.87	11.6
e 1	Diagonal	EA 50 x 50 x 5 - 2500	3.48	8.7
f 2	Post	EA 50 x 50 x 5 - 1300	3.48	9.2
g 1	Diagonal	EA 30 x 30 x 3 - 1950	1.35	2.6
h 1	Diagonal	EA 30 x 30 x 3 - 1700	1.35	2.3
i 1	Diagonal	EA 30 x 30 x 3 - 1500	1.35	2.1
k 2	Post	EA 30 x 30 x 3 - 600	1.35	1.6
A 1	Support A	Plates/Support/Bolts	---	5.1
B 1	Support B	Plates/Support/Bolts	---	4.2
			Mass total	243.0

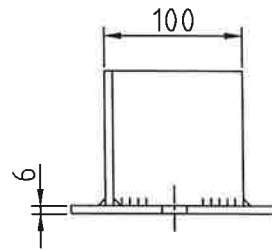
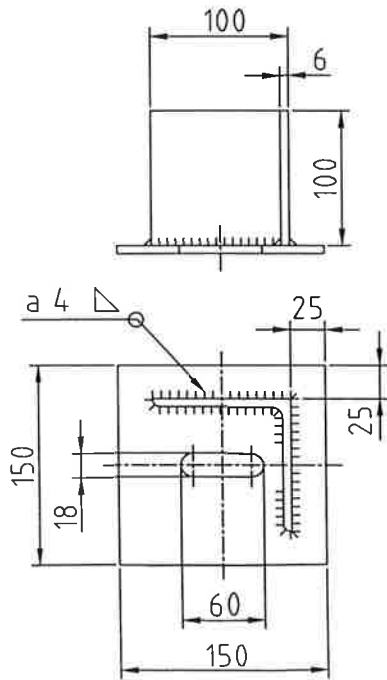
(EA = equal angle)







Detail Support A



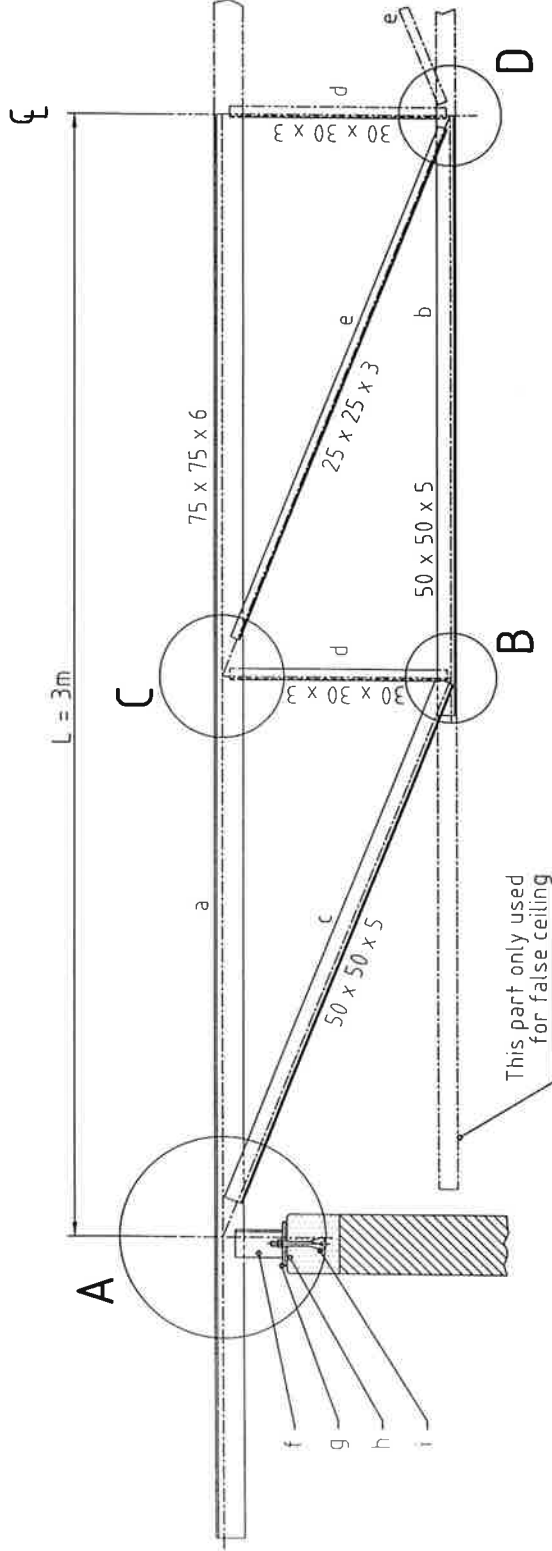
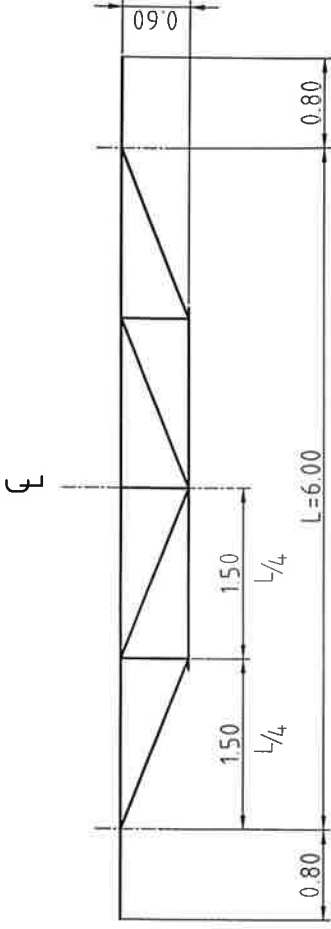
Detail Support B

6.7.9 Flat Roof; Single Angle Bars, 6 m span

Roof Slope min 19°, max. 30°
Bracing system according to Section 6.6.4 above

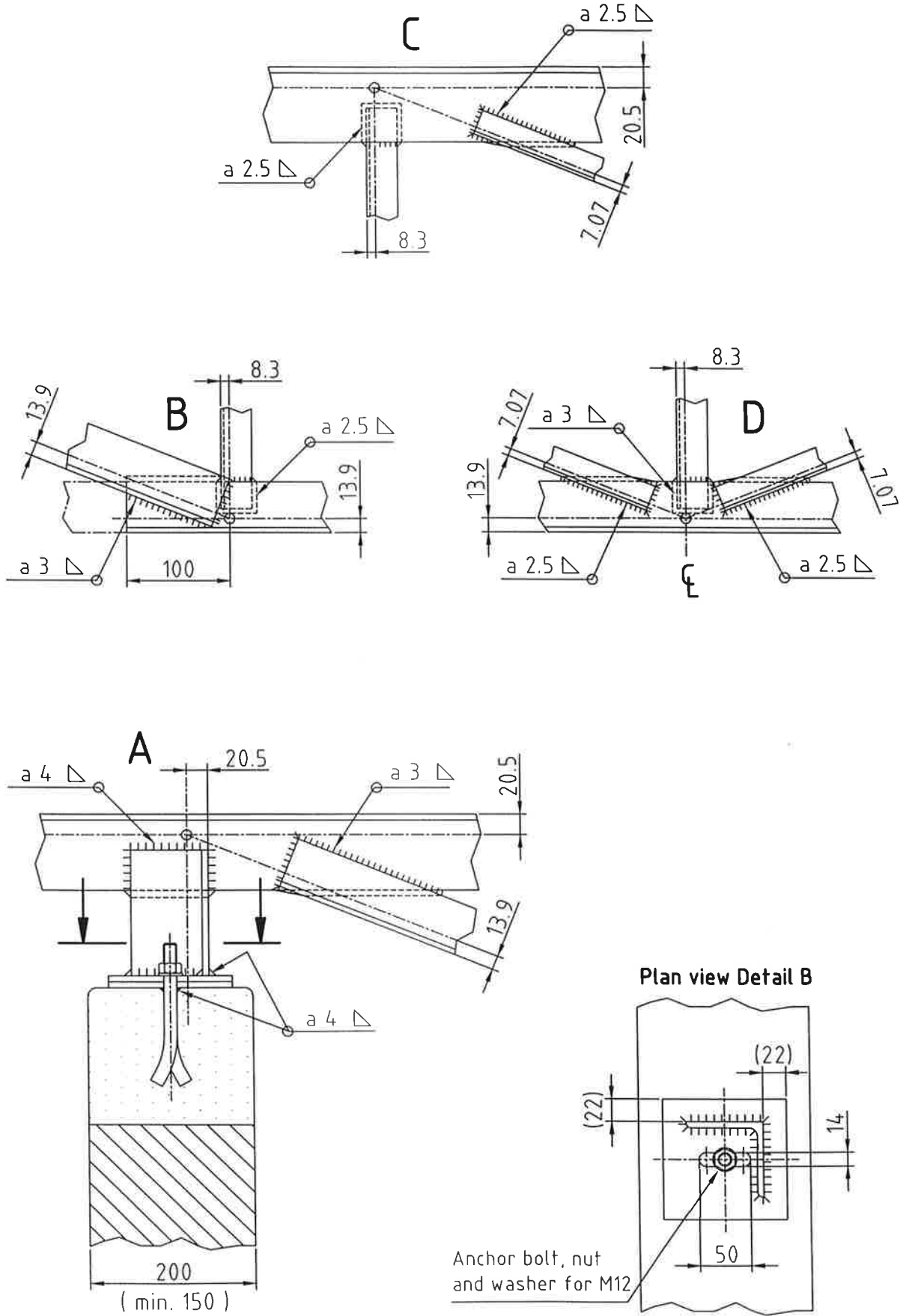
Spacing of truss 2.5 m

Total load 1.0 kN/m²



Pos./Qty.	Description	Dimensions	Mass kg/m	Mass Total kg
a 1	Top chord	EA 75 x 75 x 6 - 7600	6.81	518
b 1	Lower chord	EA 50 x 50 x 5 - 5700	3.48	20.0
c 2	Diagonal	EA 30 x 30 x 3 - 1500	1.35	4.2
d 3	Post	EA 30 x 30 x 3 - 750	1.35	3.1
e 2	Diagonal	EA 25 x 25 x 3 - 1470	1.12	3.3
f 2	Support	EA 75 x 75 x 6 - 120	6.81	1.7
g 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
h 2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
i 2	Anchor bolt/nut/washer M12 - 120		---	0.6
			Mass Total	87.5

(EA = equal angel / FB = flat bar)

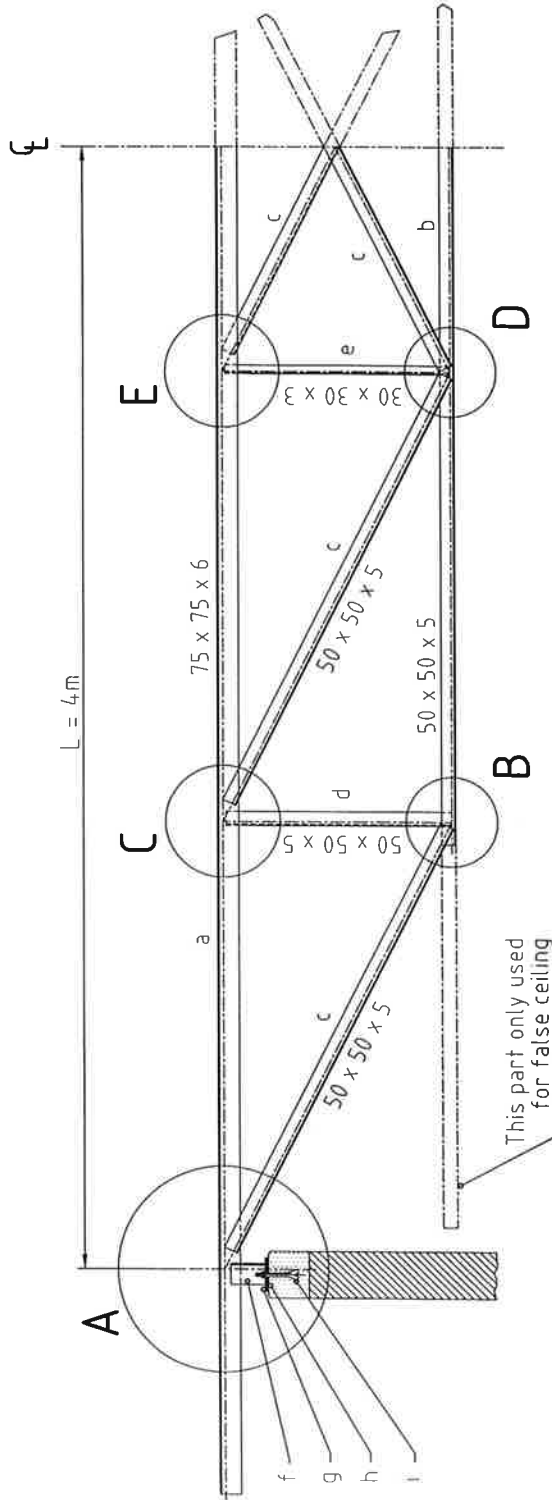
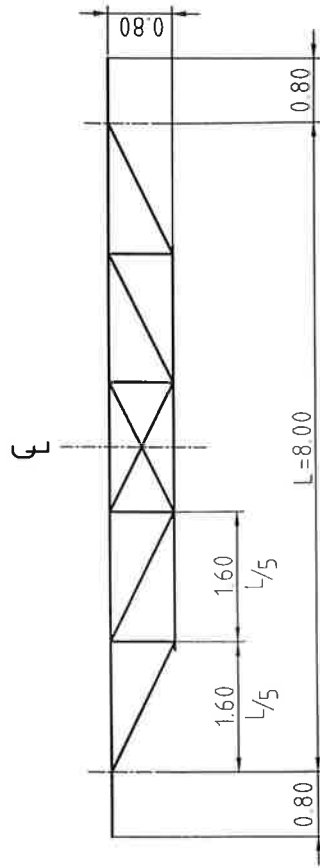


6.7.10 Flat Roof; Single Angle Bars, 8 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

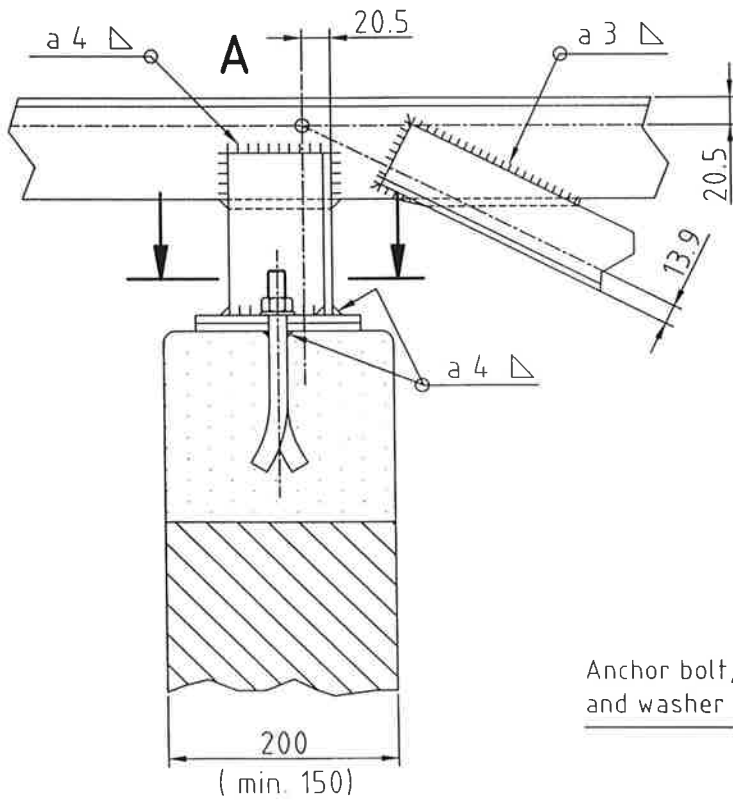
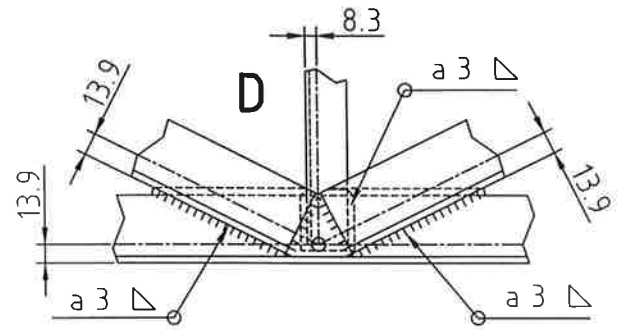
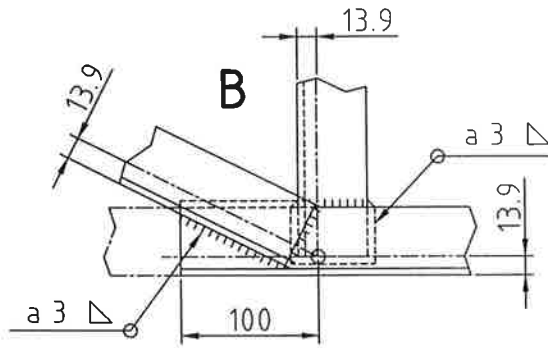
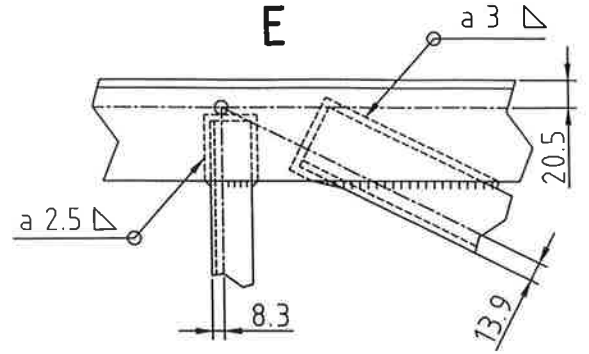
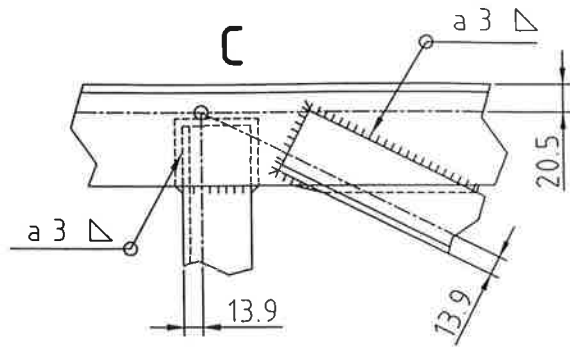
Spacing of truss 2.5 m

Total load 1.0 kN/m²

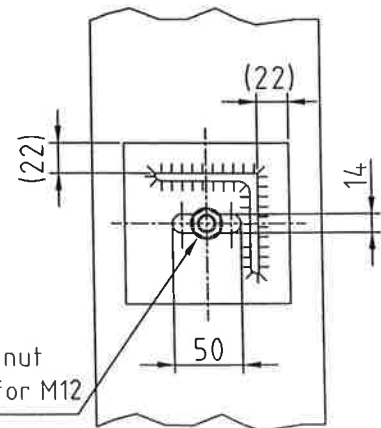


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Top chord	EA 75 x 75 x 6 - 9600	6.81	65.5
b 1	Lower chord	EA 50 x 50 x 5 - 7700	3.48	26.9
c 6	Diagonal	EA 50 x 50 x 5 - 1700	3.48	35.6
d 2	Post	EA 50 x 50 x 5 - 790	3.48	5.6
e 2	Post	EA 30 x 30 x 3 - 790	1.35	2.3
f 2	Support	EA 75 x 75 x 6 - 120	6.81	1.7
g 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
h 2	Anchor plate	FB 120 x 6 x - 120	5.65	1.4
i 2	Anchor bolt/nut/washer M12 - 120	---	---	0.6
Mass total			14.10	

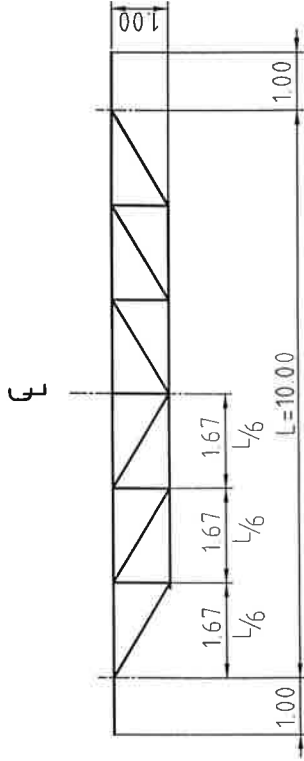
(EA = equal angle / FB = flat bar)



Plan view Detail A



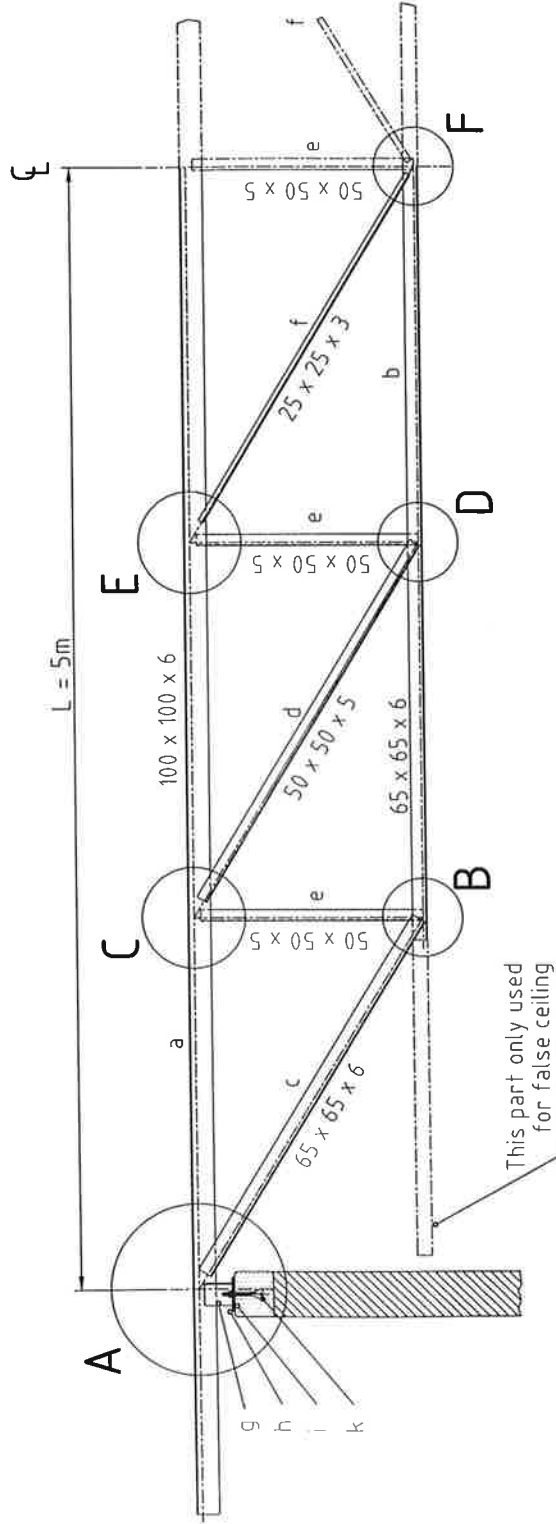
Anchor bolt, nut and washer for M12



6.7.11 Flat Roof; Single Angle Bars, 10 m spar

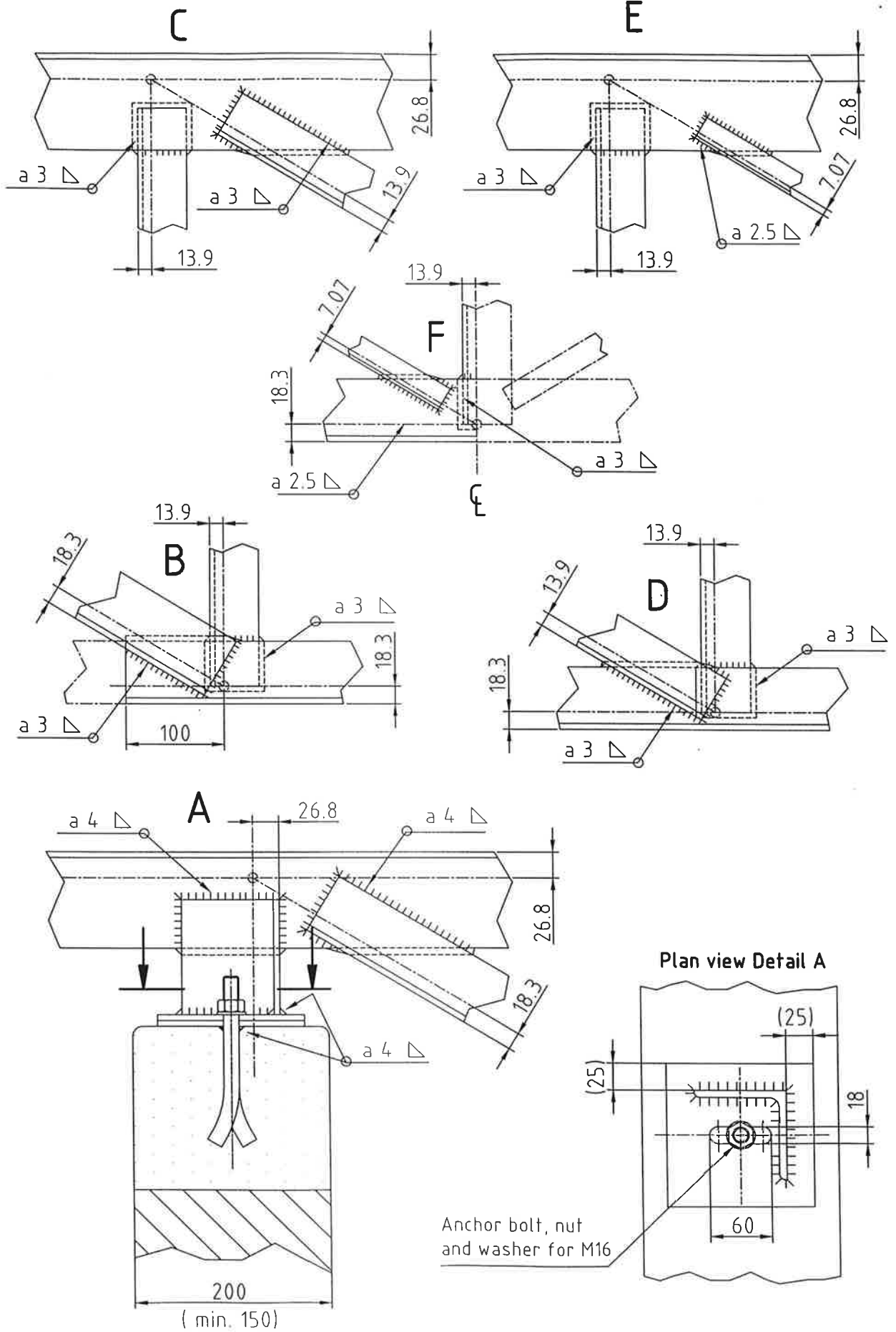
Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

Spacing of truss 2.5 m
Total load 1.0 kN/m²



Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Top chord	EA 100 x 100 x 6 - 12000	9.16	110.0
b 1	Lower chord	EA 65 x 65 x 6 - 9700	5.87	57.0
c 2	Diagonal	EA 65 x 65 x 5 - 1850	5.87	20.8
d 2	Diagonal	EA 50 x 50 x 5 - 1850	3.48	12.9
e 5	Post	EA 50 x 50 x 5 - 970	3.48	16.9
f 2	Diagonal	EA 25 x 25 x 3 - 1800	1.12	4.2
g 2	Support	EA 100 x 100 x 6 - 120	9.16	2.2
h 2	Sliding plate	FB 150 x 6 - 150	7.07	2.1
i 2	Anchor plate	FB 150 x 6 - 150	7.07	2.1
k 2	Anchor bolt/nut/washer M16 - 150	---	---	0.8
Mass total			229.0	229.0

(EA = equal angle / FB = flat bar)

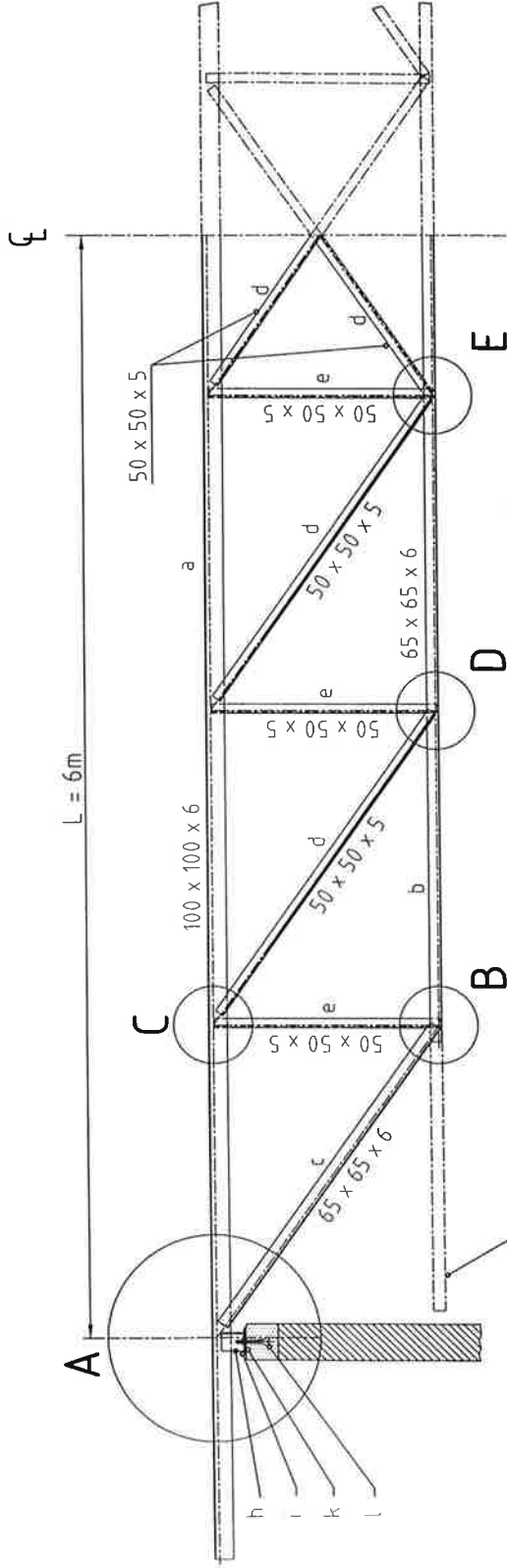
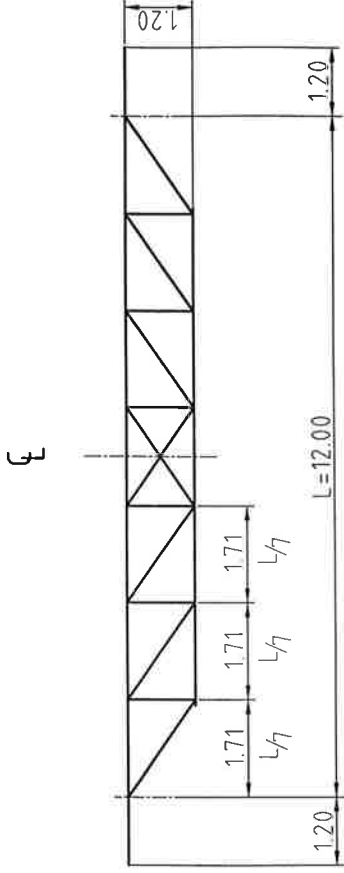


6.7.12 Single Pitch Roof; Single Angle Bars, 12 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

Spacing of truss 2.5 m

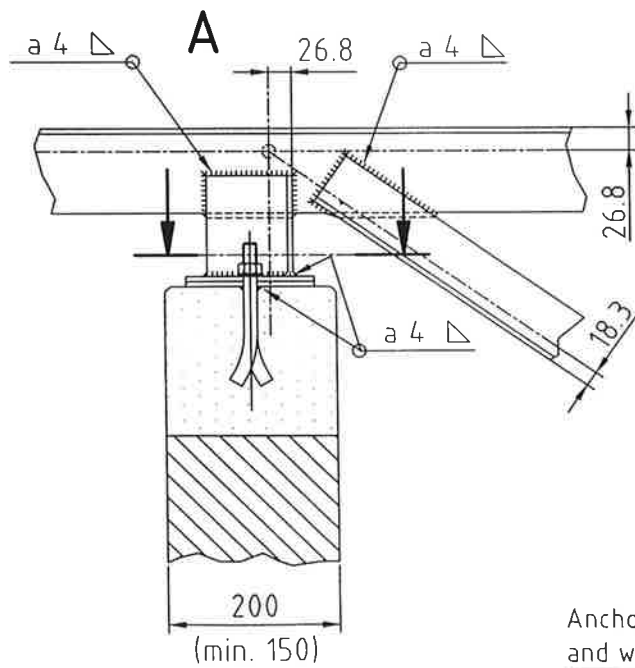
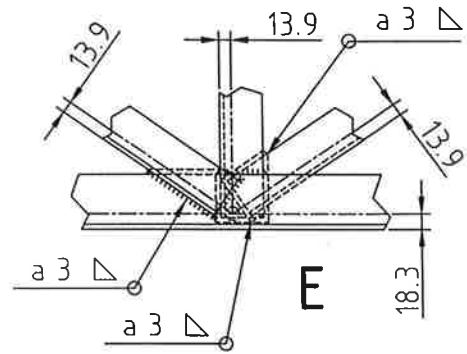
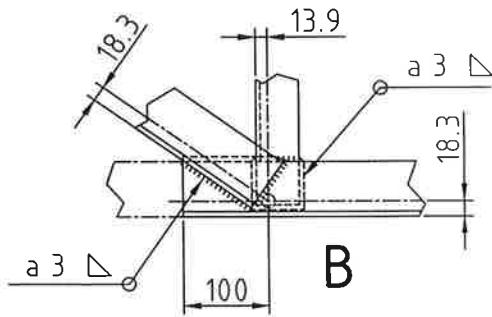
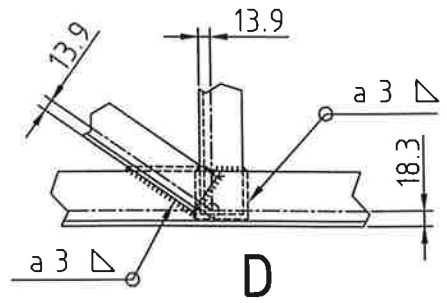
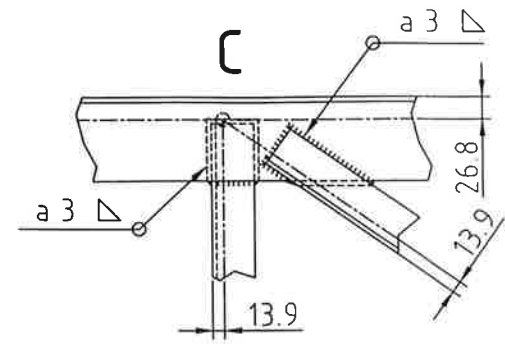
Total load 1.0 kN/m²



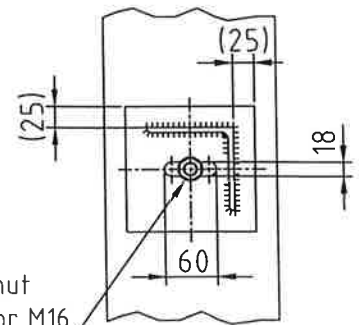
This part only used for false ceiling

Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	1 Top chord	EA 100 x 100 x 6 - 144.00	9.16	132.0
b	1 Lower chord	EA 65 x 65 x 6 - 117.00	5.87	68.8
c	2 Diagonal	EA 65 x 65 x 6 - 2000	5.87	23.8
d	6 Diagonal	EA 50 x 50 x 5 - 2000	3.48	42.0
e	6 Post	EA 50 x 50 x 5 - 1200	3.48	25.2
h	2 Support	EA 100 x 100 x 6 - 120	9.16	2.2
i	2 Sliding plate	FB 150 x 6 - 150	7.07	2.15
k	2 Anchor plate	FB 150 x 6 - 150	7.07	2.15
l	2 Anchor bolt/nut/washer M16 - 150	---	---	0.7
Mass total			---	299.0

(EA = equal angle / FB = flat bar)



Plan view Detail A



Anchor bolt, nut and washer for M16

Roof Truss Guide

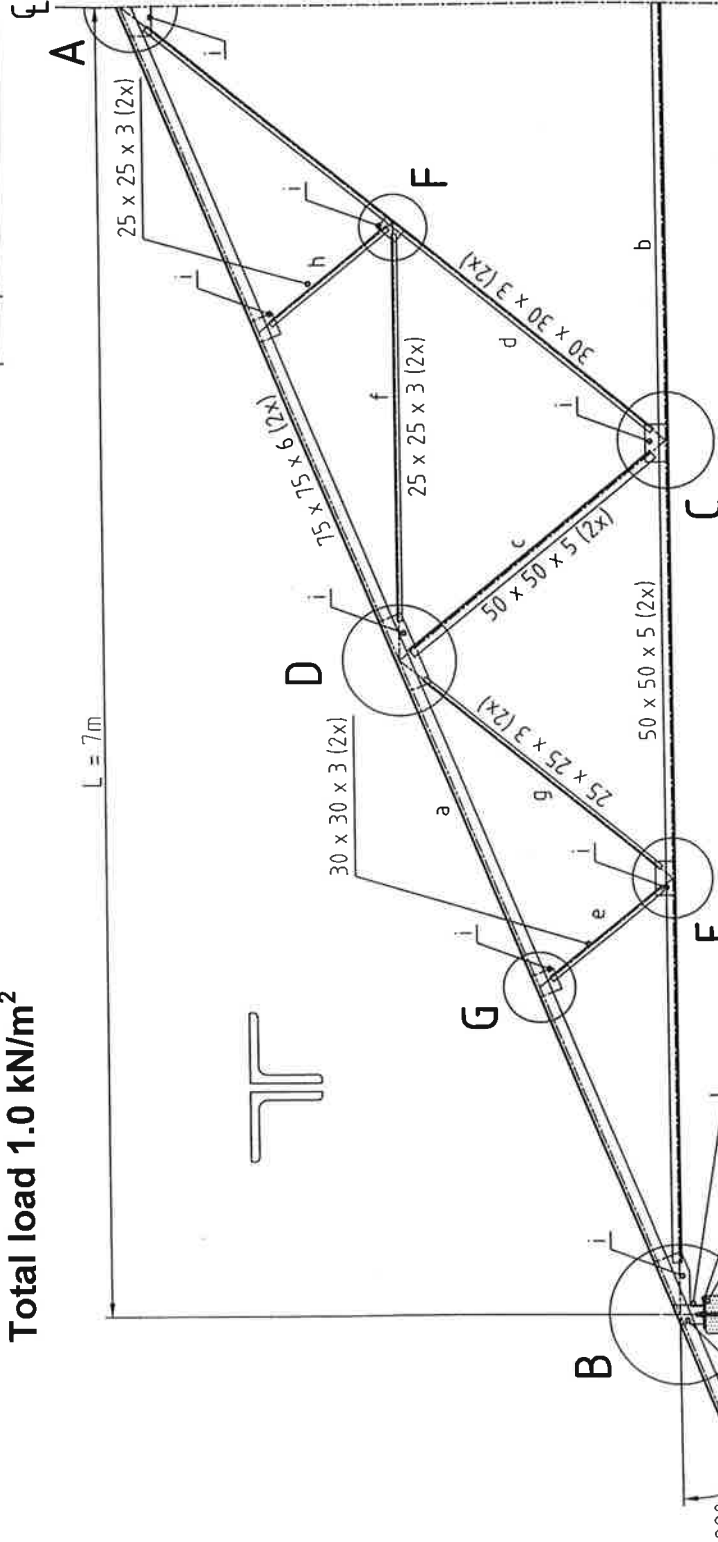
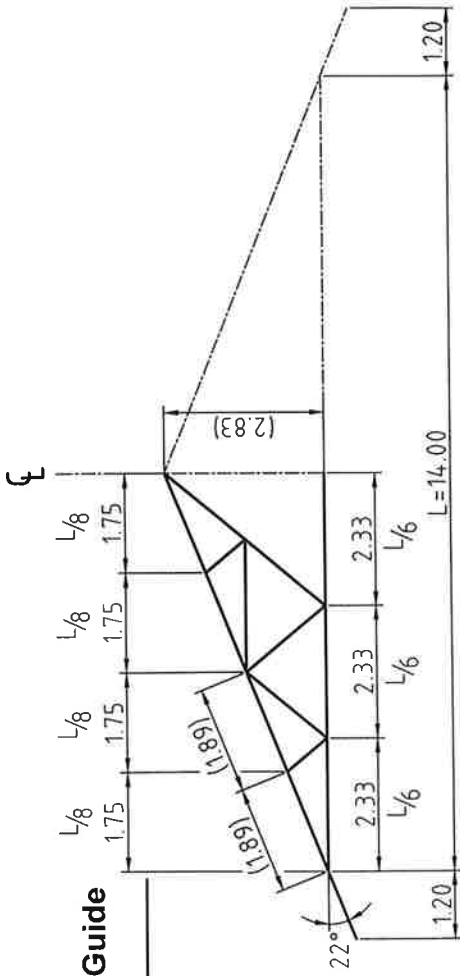
6.7.13 Double Pitch Roof; Double Angle Bars, 14 m span

Roof Slope min 19°, max. 30°

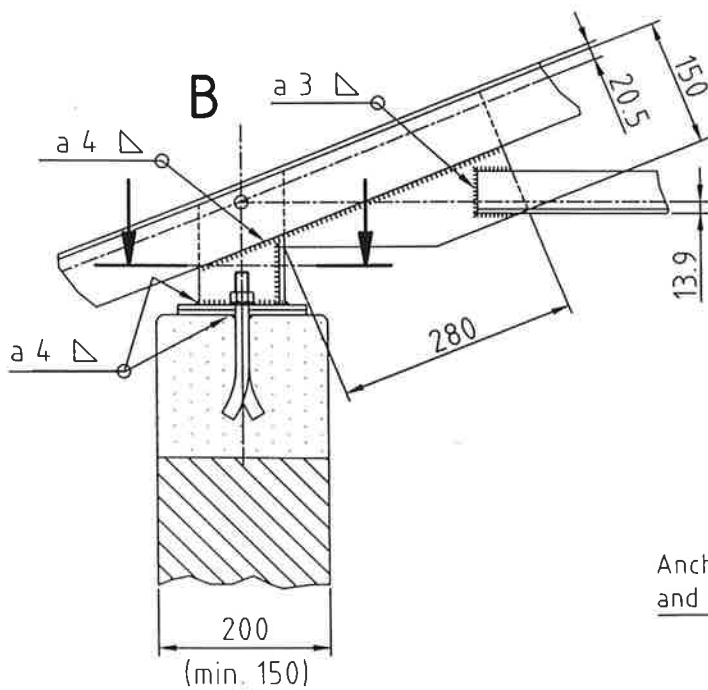
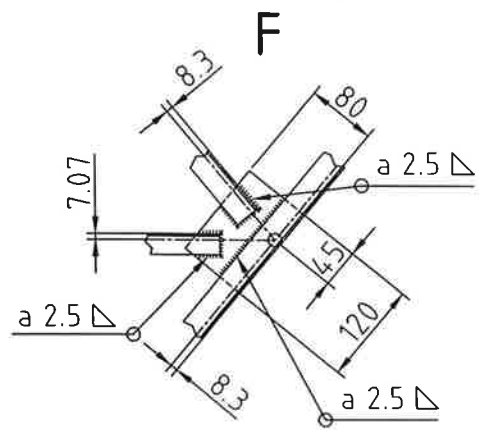
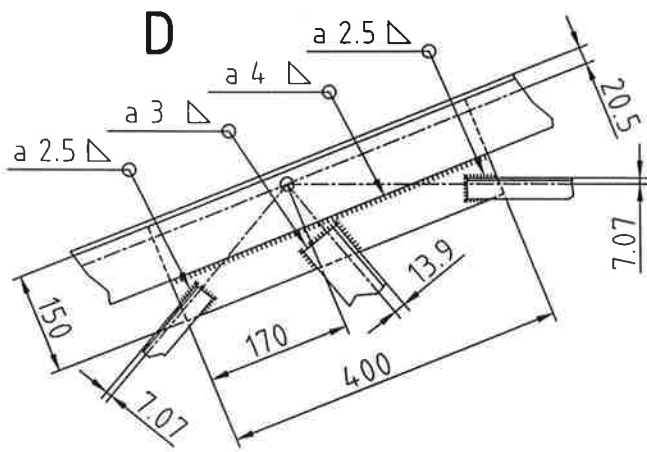
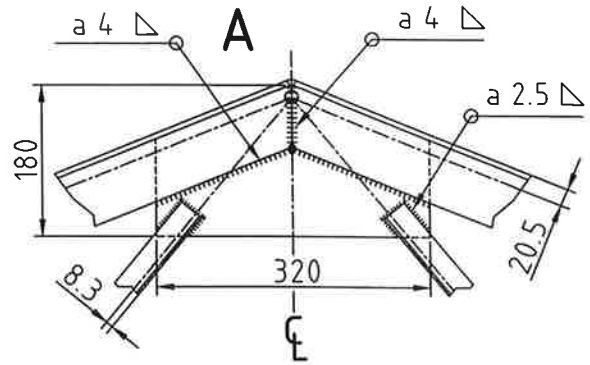
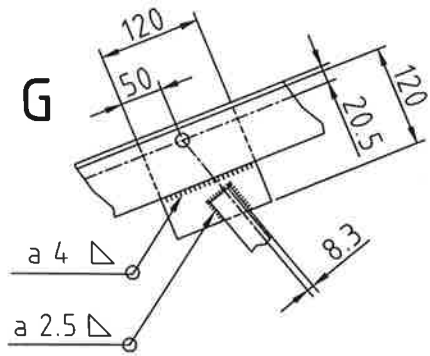
Bracing system according to Section 6.6.4 above

Spacing of truss 2.5 m

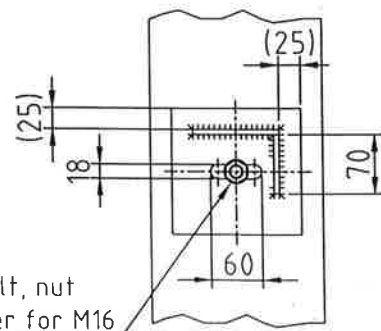
Total load 1.0 kN/m²



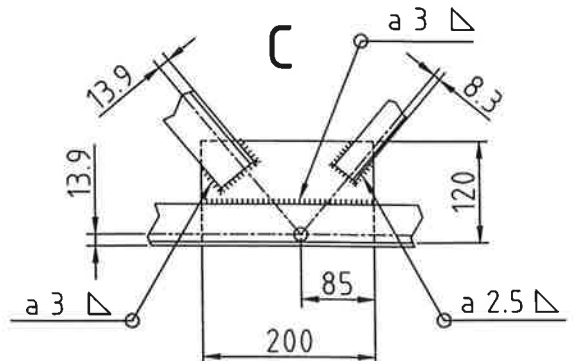
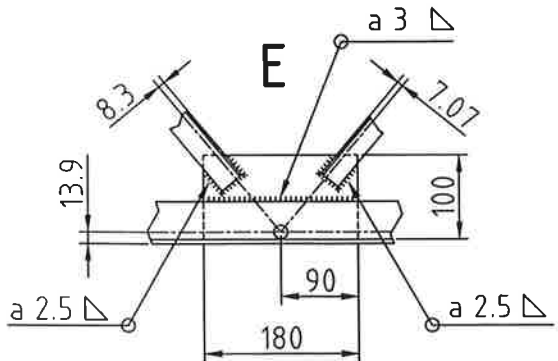
Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	4 Upper chord	EA 75 x 75 x 6 - 8800	6.81	239.8
b	2 Lower chord	EA 50 x 50 x 5 - 13x50	3.48	93.6
c	4 Strut	EA 50 x 50 x 5 - 1660	3.48	23.1
d	4 Tie	EA 30 x 30 x 3 - 3400	1.35	18.4
e	4 Strut	EA 30 x 30 x 3 - 760	1.35	4.1
f	4 Tie	EA 25 x 25 x 3 - 2060	1.12	9.3
g	4 Tie	EA 25 x 25 x 3 - 1590	1.12	7.2
h	4 Strut	EA 25 x 25 x 3 - 800	1.12	3.6
i	15 Gusset	FB 6mm different dim.	---	18.8
k	2 Support plate	FB 100 x 6 - 160	4.71	1.5
l	2 Stiffener plate	FB 70 x 6 - 70	3.30	0.5
m	2 Sliding plate	FB 150 x 6 - 150	7.07	2.2
n	2 Anchor plate	FB 150 x 6 - 150	7.07	2.2
o	2 Anchor Bolt/nut/washer M16 - 150	---	---	0.7
			Mass total	175.0



Plan view Detail B



Anchor bolt, nut and washer for M16



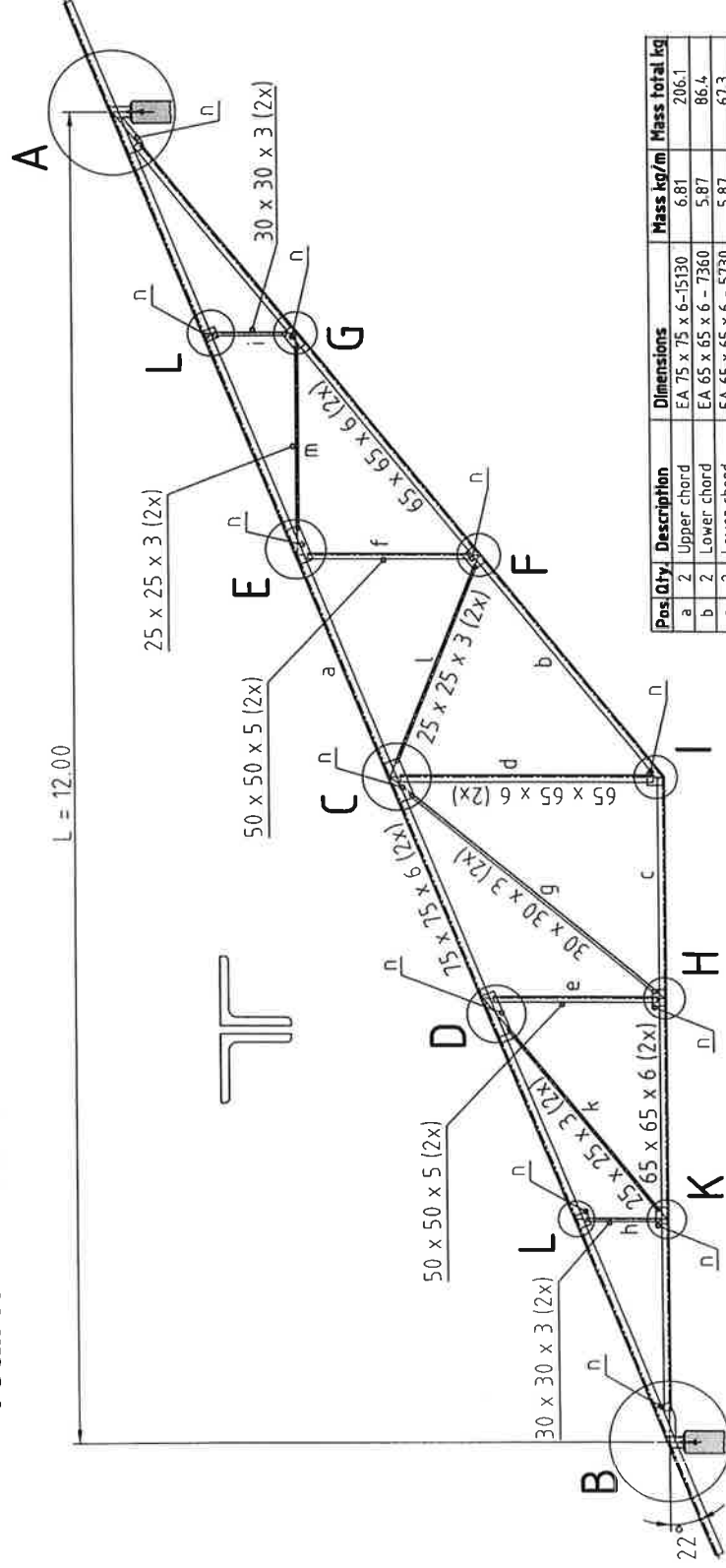
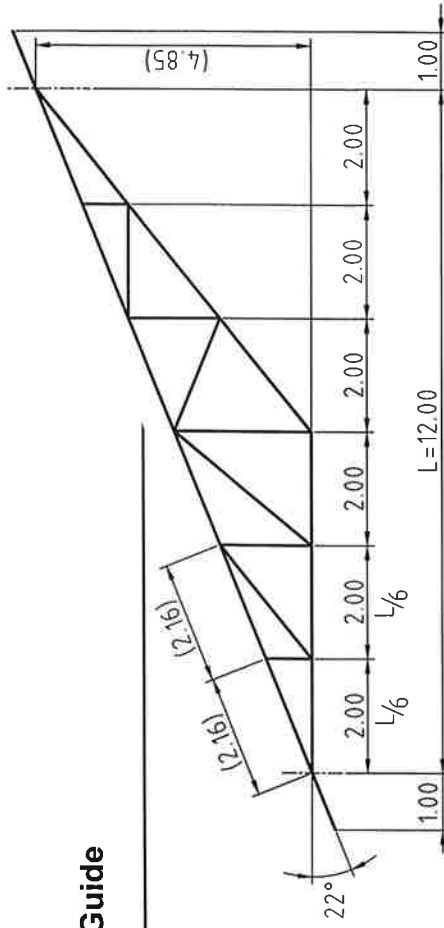
6.7.14 Single Pitch Roof; Double Angle Bars, Span 12 m

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

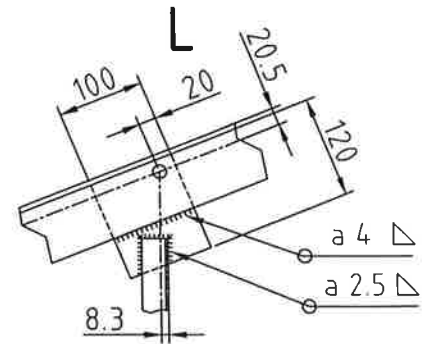
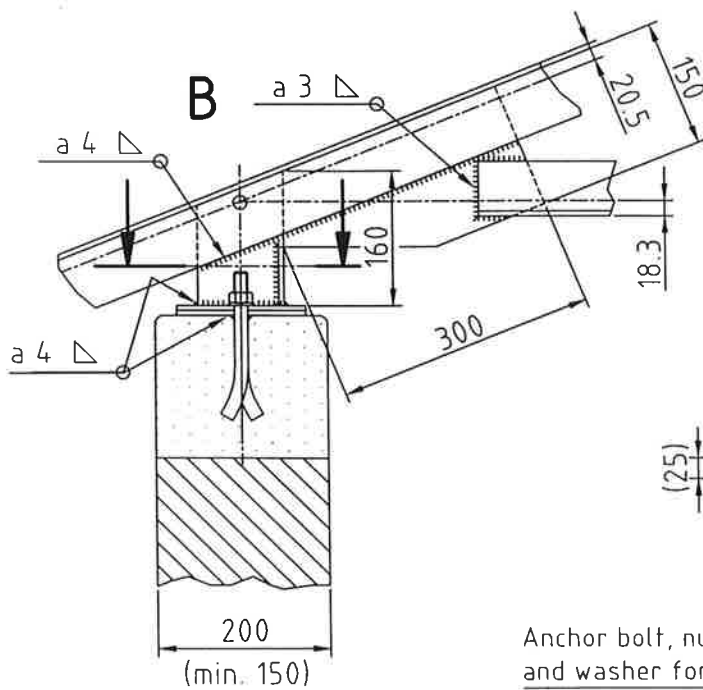
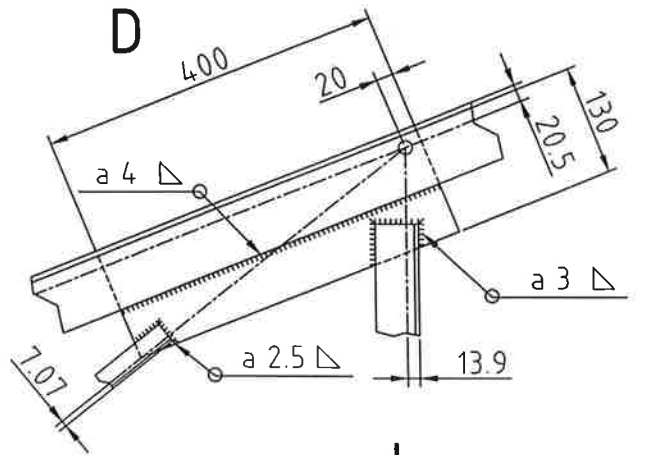
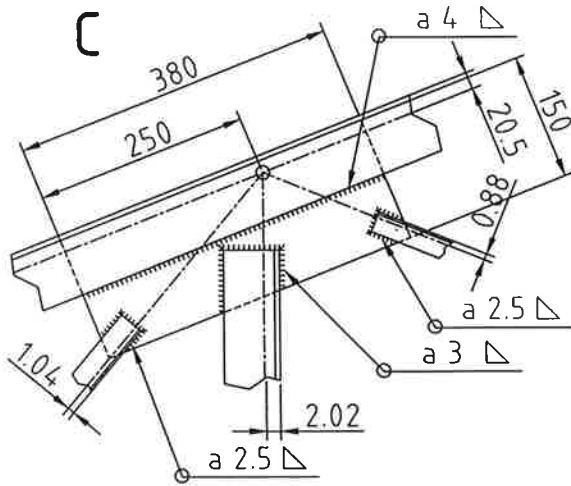
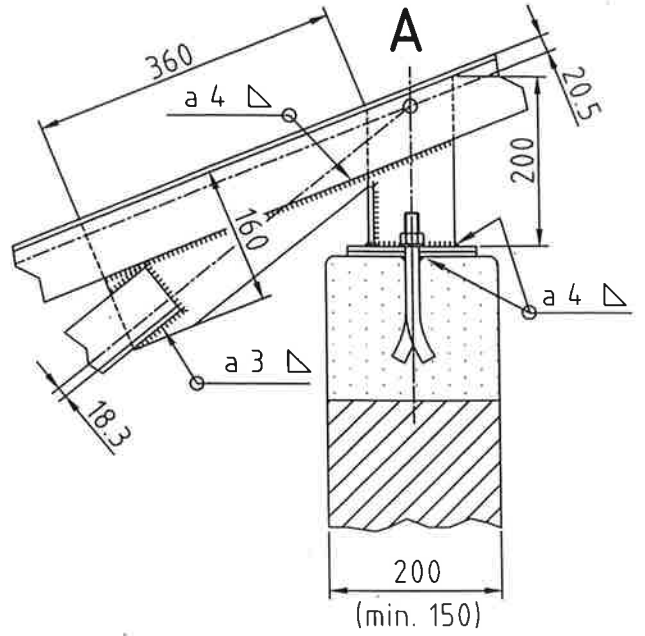
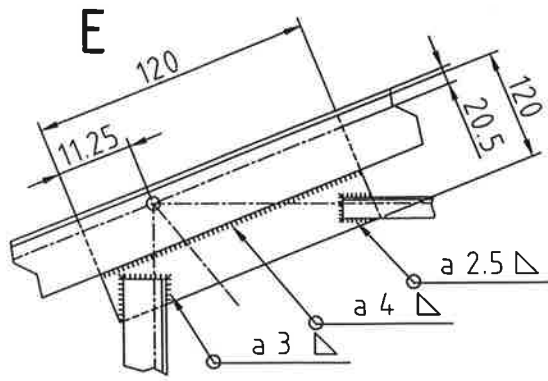
Spacing of truss 2.5 m

Total load 1.0 kN/m²

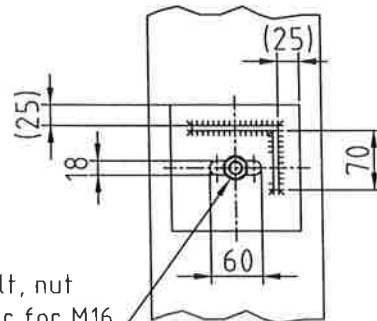


Pos	Qty	Description	Dimensions	Mass kg/m	Mass total kg
a	2	Upper chord	EA 75 x 75 x 6 - 15130	6.81	206.1
b	2	Lower chord	EA 65 x 65 x 6 - 7360	5.87	86.4
c	2	Lower chord	EA 65 x 65 x 6 - 5730	5.87	67.3
d	2	Post	EA 65 x 65 x 6 - 2250	5.87	26.5
e	2	Post	EA 50 x 50 x 5 - 1460	3.48	10.2
f	2	Post	EA 50 x 50 x 5 - 1440	3.48	10.0
g	2	Diagonal	EA 30 x 30 x 3 - 2820	1.35	3.8
h	2	Post	EA 30 x 30 x 3 - 660	1.35	1.8
i	2	Post	EA 30 x 30 x 3 - 650	1.35	1.8
k	2	Diagonal	EA 25 x 25 x 3 - 2110	1.12	4.8
l	2	Diagonal	EA 25 x 25 x 3 - 1920	1.12	4.3
m	2	Diagonal	EA 25 x 25 x 3 - 1660	1.12	3.7
n	12	Gusset	FB 6mm different dim.	---	17.5
A	1	Support A	Plates/Support/Bolts	---	6.9
B	1	Support B	Plates/Support/Bolts	---	6.9
				Mass total	458.0

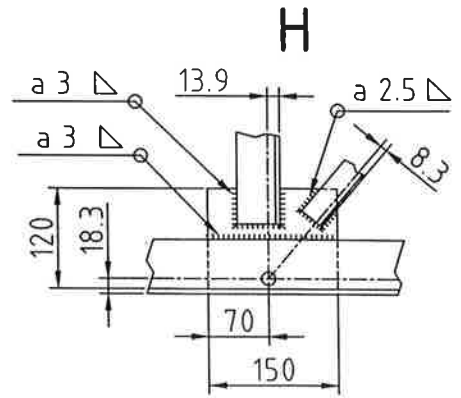
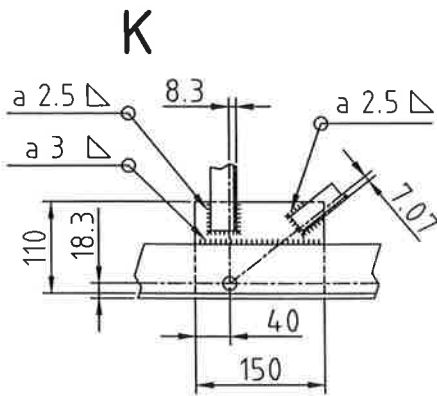
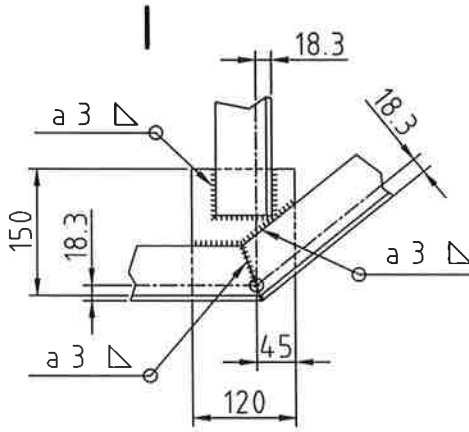
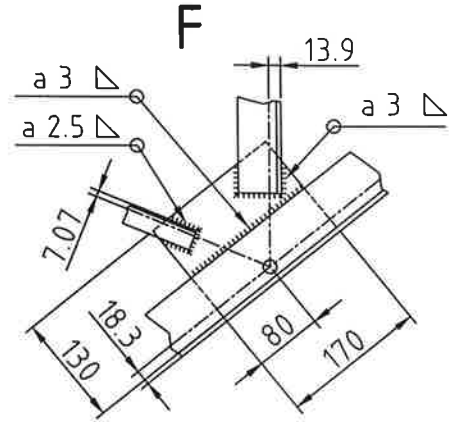
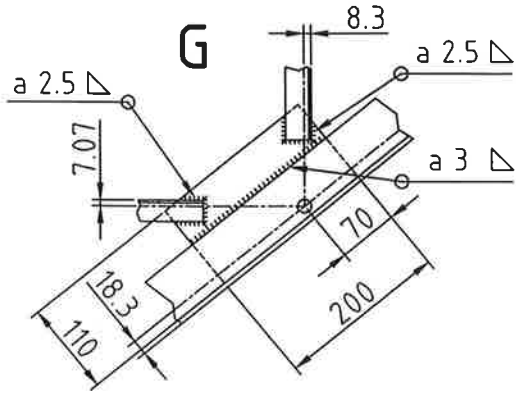
(EA = equal angle / FB = flat plate)



Plan view Detail B



Anchor bolt, nut and washer for M16



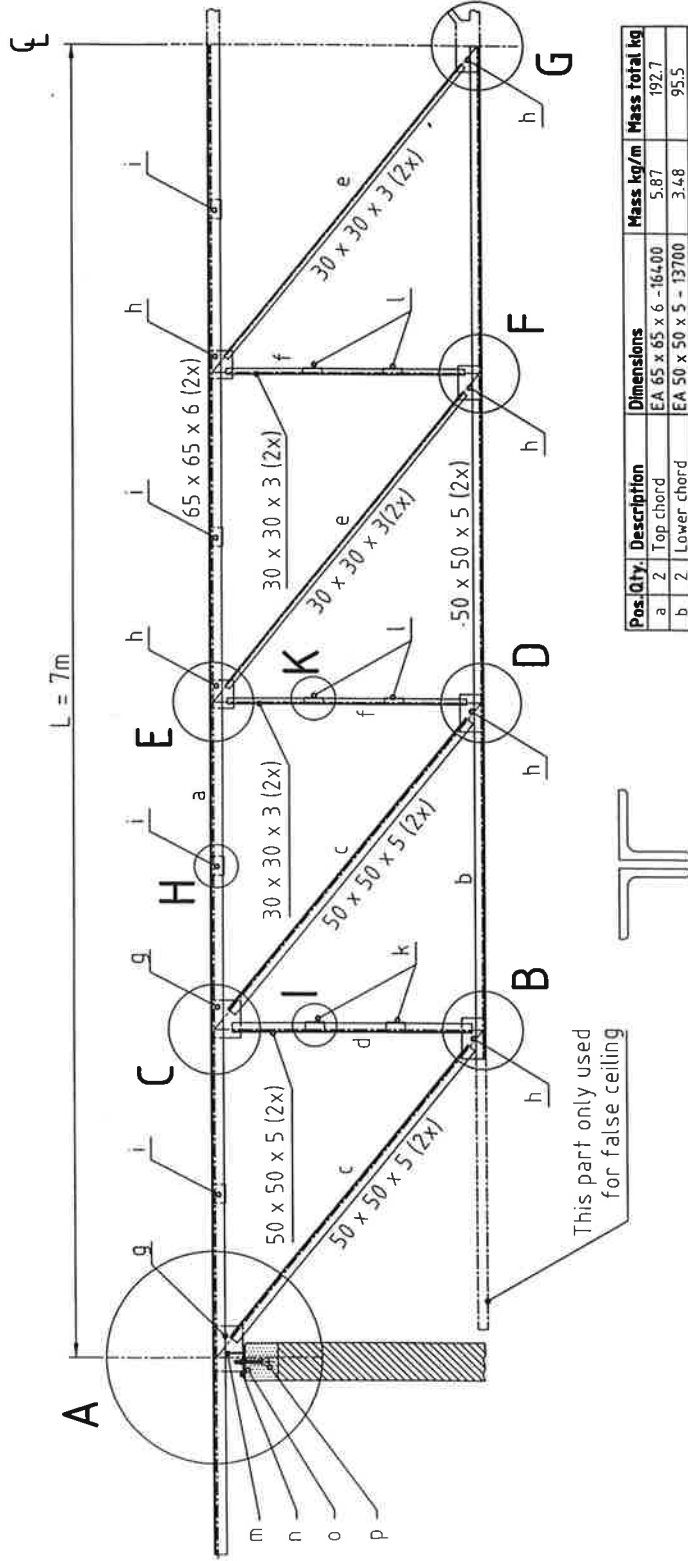
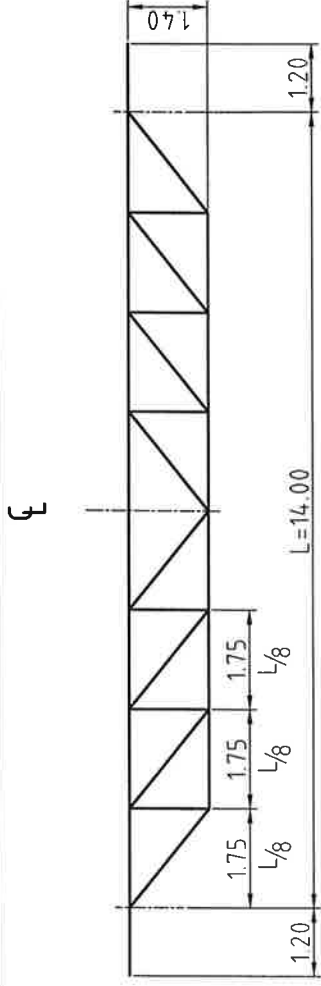
6.7.15 Flat Roof; Double Angle Bars, 14 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

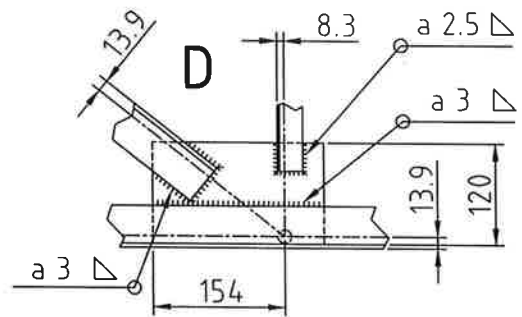
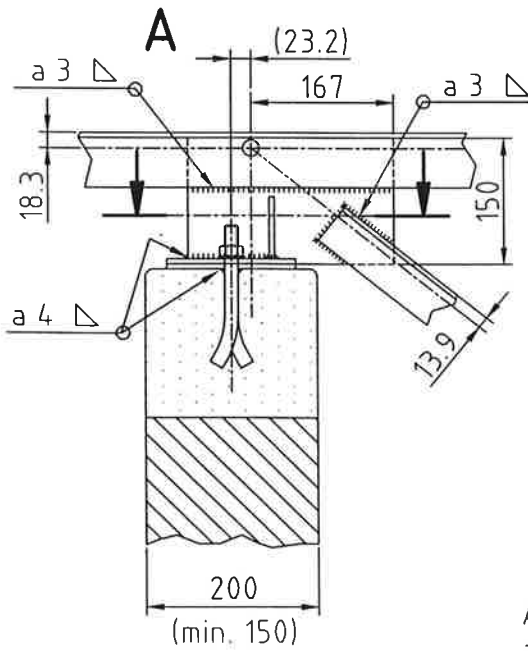
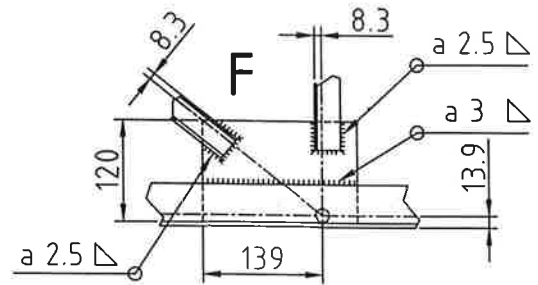
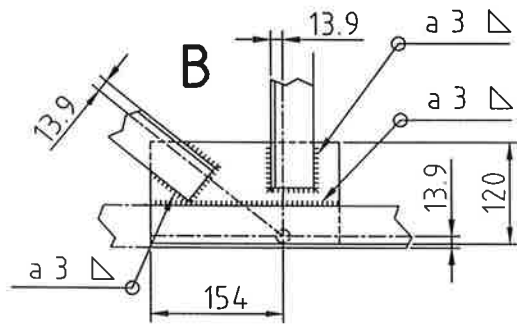
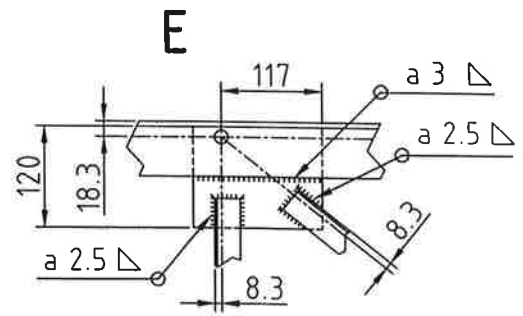
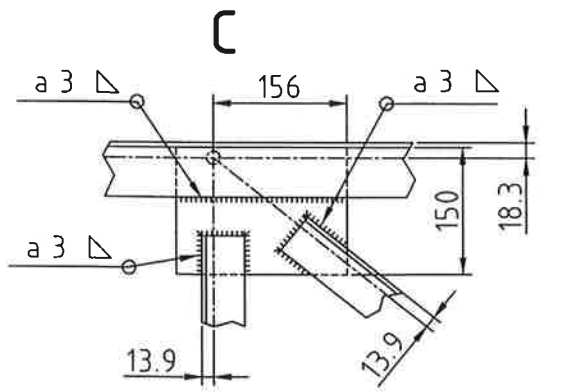
Spacing of truss 2.5 m

Total load 1.0 kN/m²

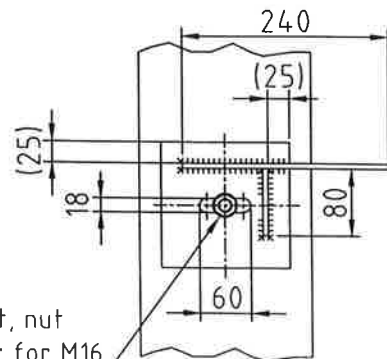


Pos.	Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	2	Top chord	EA 65 x 65 x 6 - 164.00	5.87	192.7
b	2	Lower chord	EA 50 x 50 x 5 - 137.00	3.48	95.5
c	8	Diagonal	EA 50 x 50 x 5 - 2000	3.48	55.7
d	4	Post	EA 50 x 50 x 5 - 1250	3.48	17.4
e	8	Diagonal	EA 30 x 30 x 3 - 2000	1.35	21.6
f	8	Post	EA 30 x 30 x 3 - 1250	1.35	13.5
g	4	Gusset	FB 150 x 6 - different l	7.07	6.4
h	11	Gusset	FP 120 x 6 - different l	5.65	11.8
i	8	Packing plate	FB 65 x 6 - 100	3.06	2.5
k	4	Packing plate	FP 50 x 6 - 100	2.36	1.0
l	8	Packing plate	FB 30 x 6 - 100	1.41	1.2
m	2	Stiffener plate	FB 80 x 6 - 80	3.77	0.6
n	2	Sliding plate	FB 150 x 6 - 150	7.07	2.2
o	2	Anchor plate	FB 150 x 6 - 150	7.07	2.2
p	2	Anchor bolt/nut/washer	M16 - 150	---	0.7
				Mass total	425.0

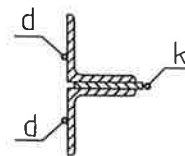
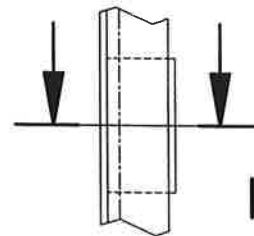
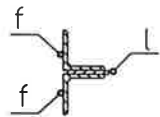
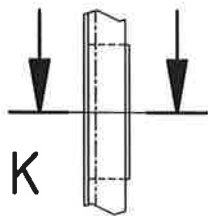
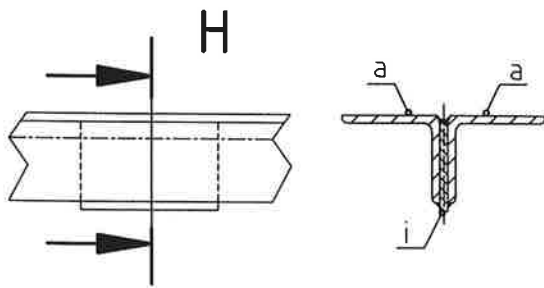
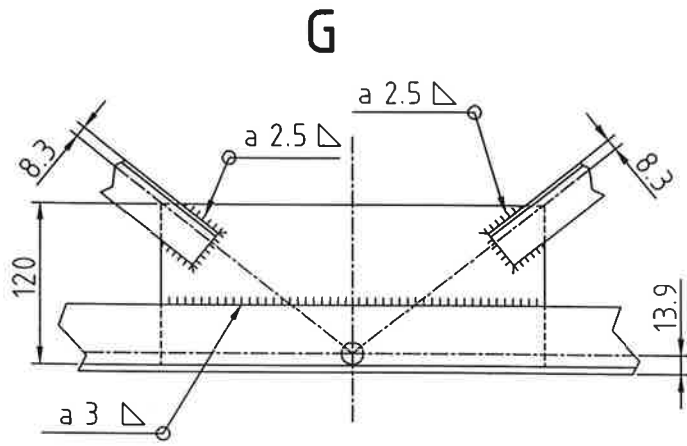
(EA = equal angle / FB = flat bar)



Plan view Detail A



Anchor bolt, nut and washer for M16



6.8 Steel Tube Truss

6.8.1 General

Tubular sections offer up to 40 % lower weight as compared with mild-steel angle bars of the same strength. Similar ratios apply for the surface areas of tubular sections compared with angle bars. Therefore the cost of total steel mass, surface preparation, priming, coating and repainting is reduced when using tubular sections instead of angle bars as discussed in the previous section.

But joints of tubular sections are more difficult than those of angle bars and the advantage of reduced weight and surface area is partly lost on increased labour costs for the connections.

6.8.2 Design

All members are single tube sections with varying diameters. In order to avoid confusion and errors in the fabrication process and difficult stock keeping, only a limited number of different tube types should be used.

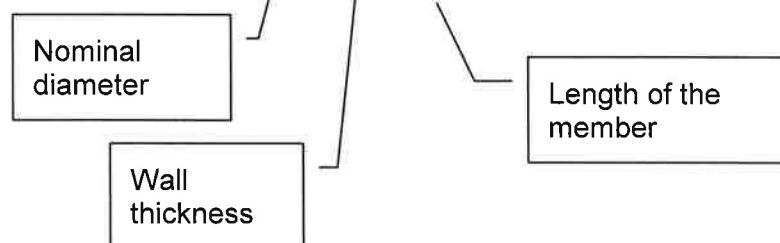
The tubes used in this manual are black mild steel pipes according to British and related standards (Australian, Indian) and the ISO recommendation R 65 and 336).

There are light, medium and heavy walled pipes on the market but the designation is sometimes misleading. It is important to always verify (by measuring with a vernier gauge at the dealer's warehouse) the actual wall thickness of the pipes.

Spans from 6 to 20 m are possible but spans above 15 m usually require either bolted connections (and scaffolding) or a crane for installation due to the weight and size of the truss.

Designation:

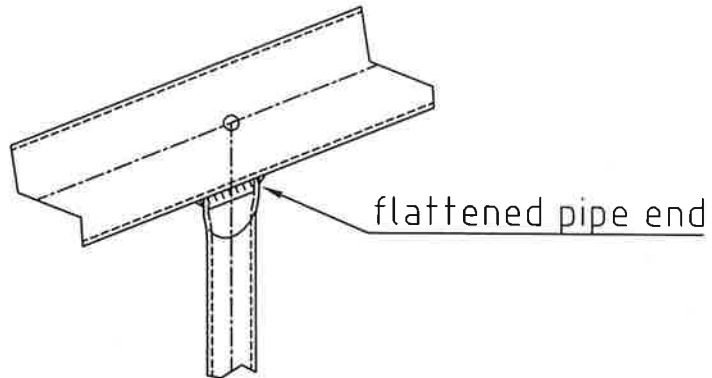
NB (Nominal Bore) 80 x 4.05 - 7800



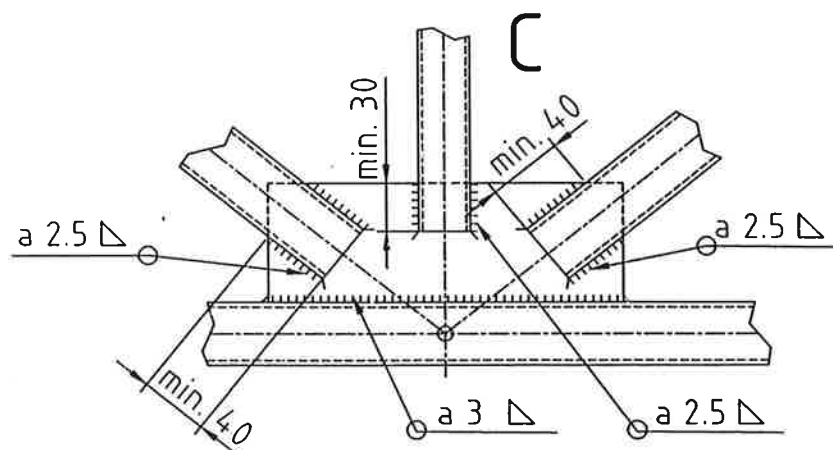
6.8.3 Details

Joints

Where small tubes are to be joined with a larger tubular member, direct connection without gusset plate is possible as pipe end preparation is not too difficult. In order to reduce the end preparation for tube to tube connections, the tube ends of struts and ties between chord members may be flattened using a press or a simple vice.

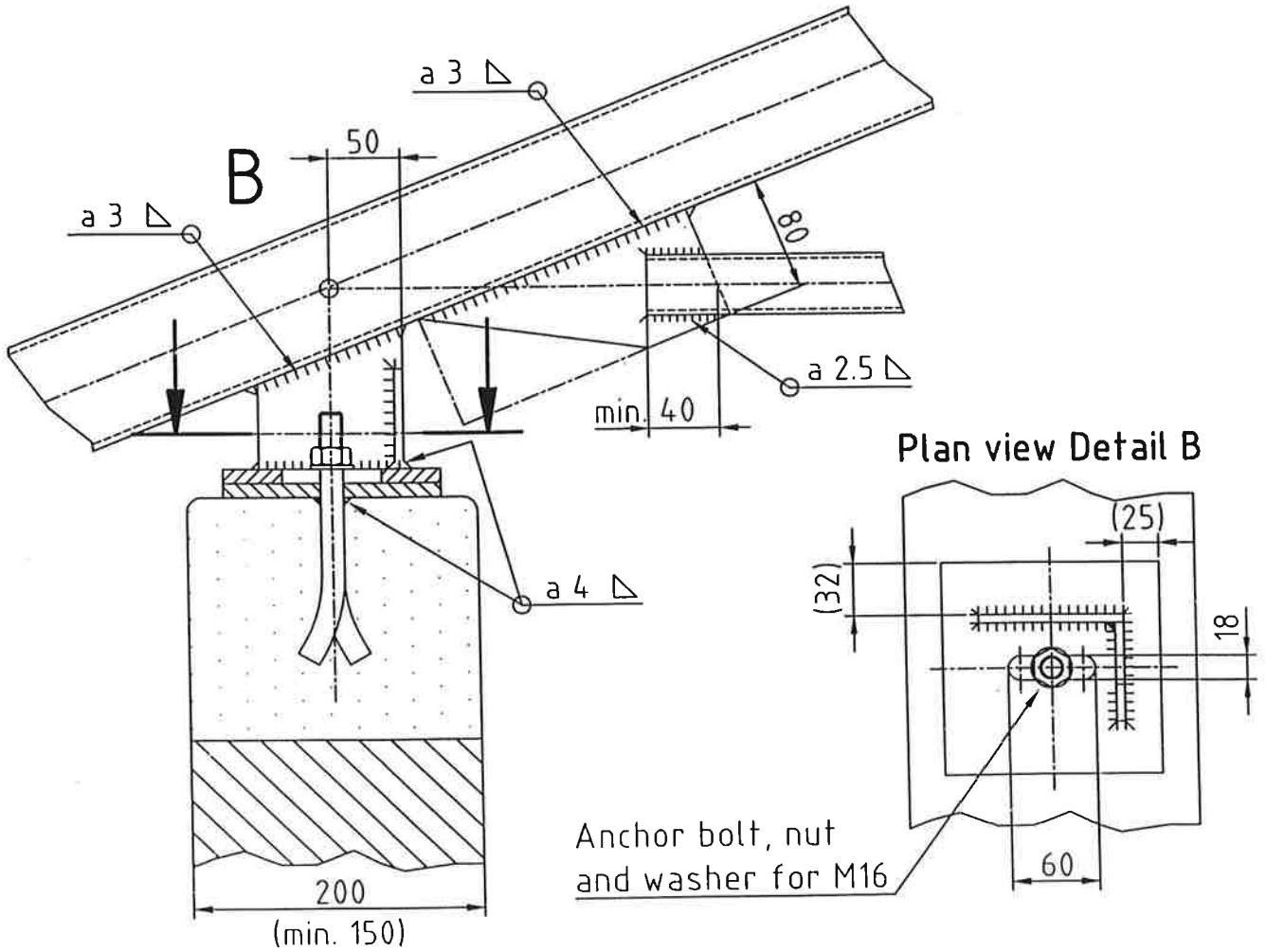


Where two tubes of similar size need to be connected it is better to use gusset plates. These are welded onto the circumference of continuous members or into slots cut into the end section of diagonals / web members.



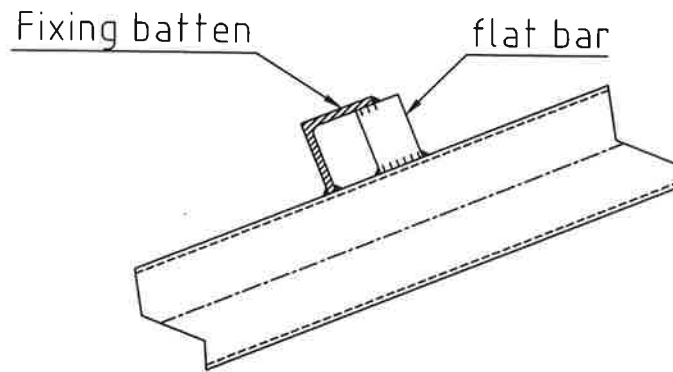
Support details

The same approach as with the single angle bar trusses is proposed. A support plate is resting on two bearing plates. The upper one is meant to slide on the lower one, the anchor plate, when movements occur due to thermal expansion. A stiffener plate welded laterally onto the support plate is designed to avoid buckling especially in those fields with the bracing system.



Fixation of battens

Fixing battens on to a tubular section is difficult since a tube provides only a very short point of support. It is recommended that short piece of flat bar (the same size as used for the X-brace) be added to make the connection more rigid.



6.8.4 Bracing

The bracing or lateral restraining system that avoids overturning of the individual trusses is the same as proposed for the angle bar truss.

6.9 *Steel Tube Truss Samples*

6.9.1 Assumptions and Limits of Application

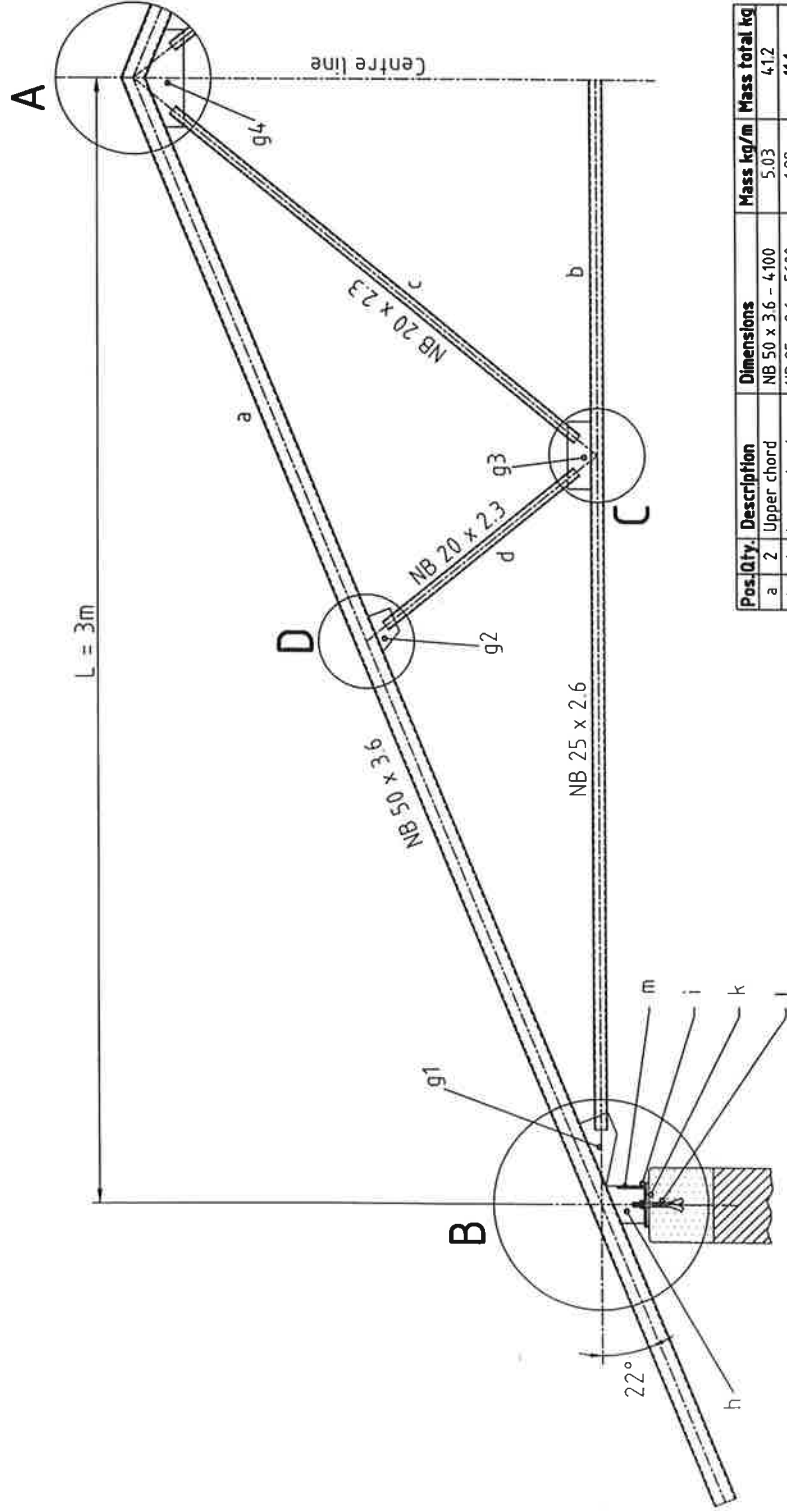
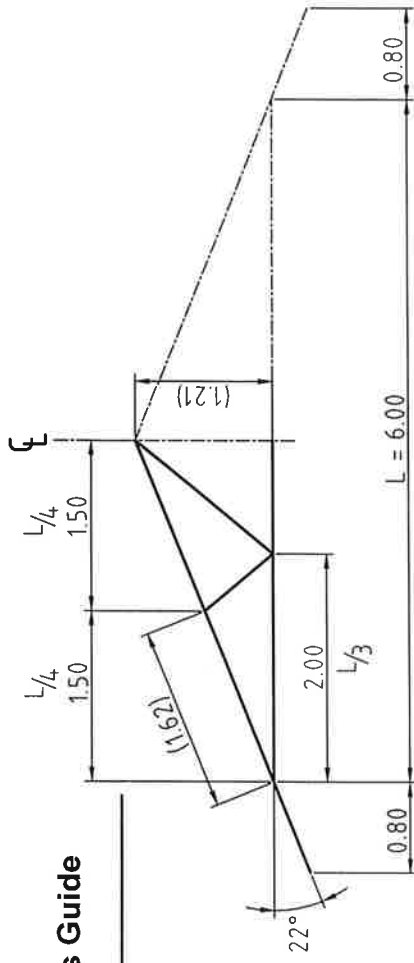
Ditto angle bar truss

6.9.2 Double Pitch Roof, Tube Truss, 6 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

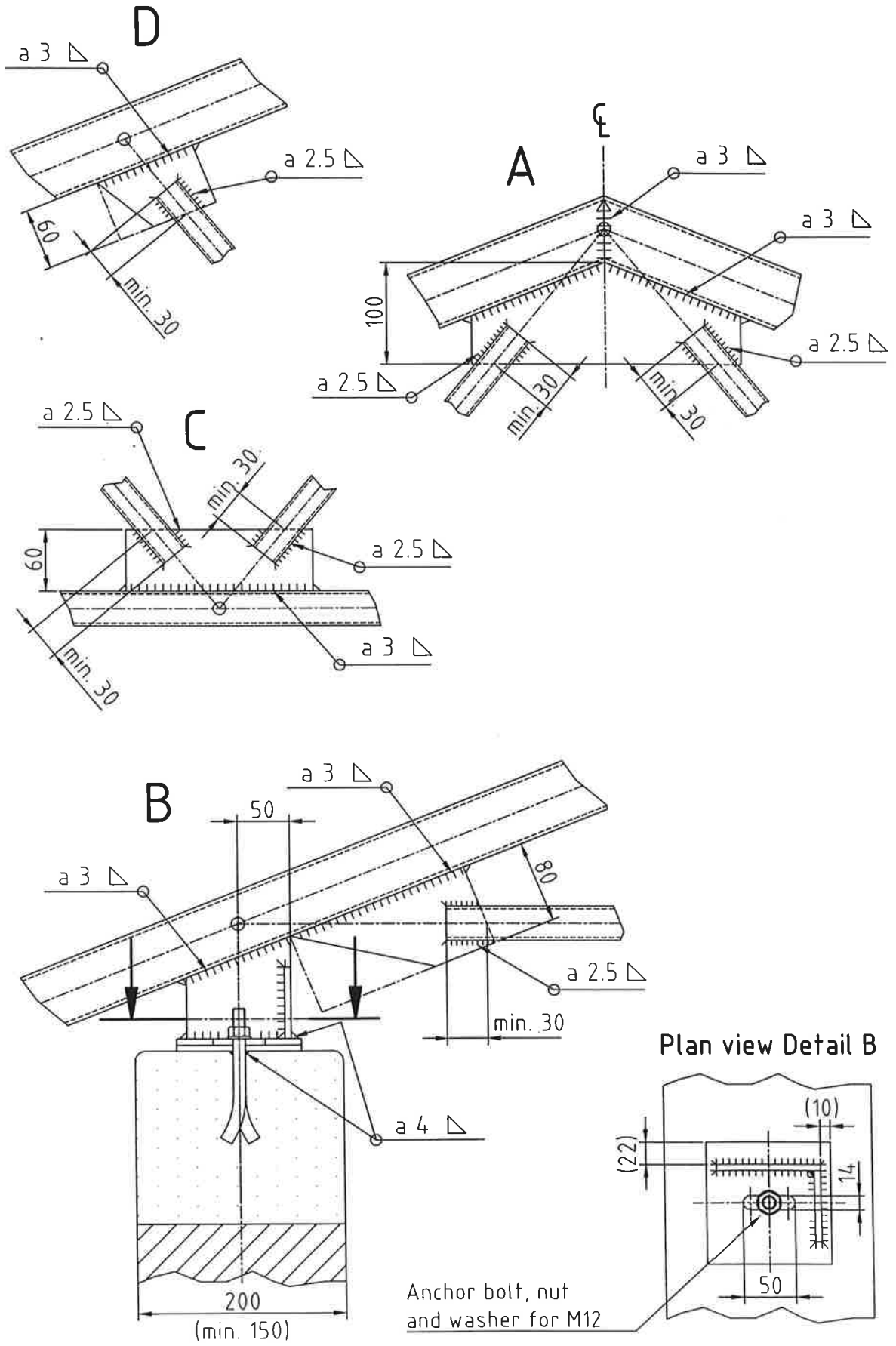
Spacing of truss 2.5 m

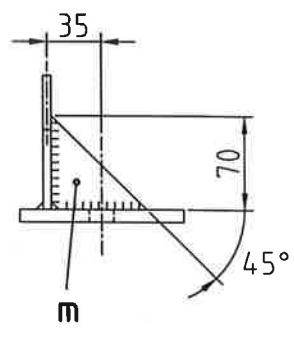
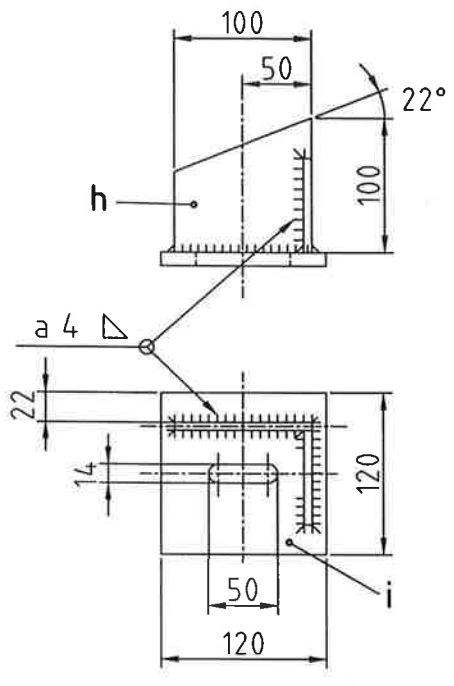
Total load 1.0 kN/m²



Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	NB 50 x 3.6 - 4100	5.03	4.12
b 1	Lower chord	NB 25 x 2.6 - 5600	1.99	1.11
c 2	Tie	NB 20 x 2.3 - 1370	1.40	3.9
d 2	Strut	NB 20 x 2.3 - 650	1.40	1.9
g	Gusset g1 - g4	FB div. x 6 thick	---	4.0
h 2	Support	FB 100 x 6 - 100	4.71	1.0
i 2	Sliding plate	FB 120 x 6 - 120	5.65	1.35
k 2	Anchor plate	FB 120 x 6 - 120	5.65	1.35
l 2	Anchor bolt/nut/washer M12 - 120	---	---	0.7
m 2	Stiffener	FB 70 x 6 - 70	3.30	0.5
Mass Total				67.0

(NB = nominal bore / FB = flat bar)



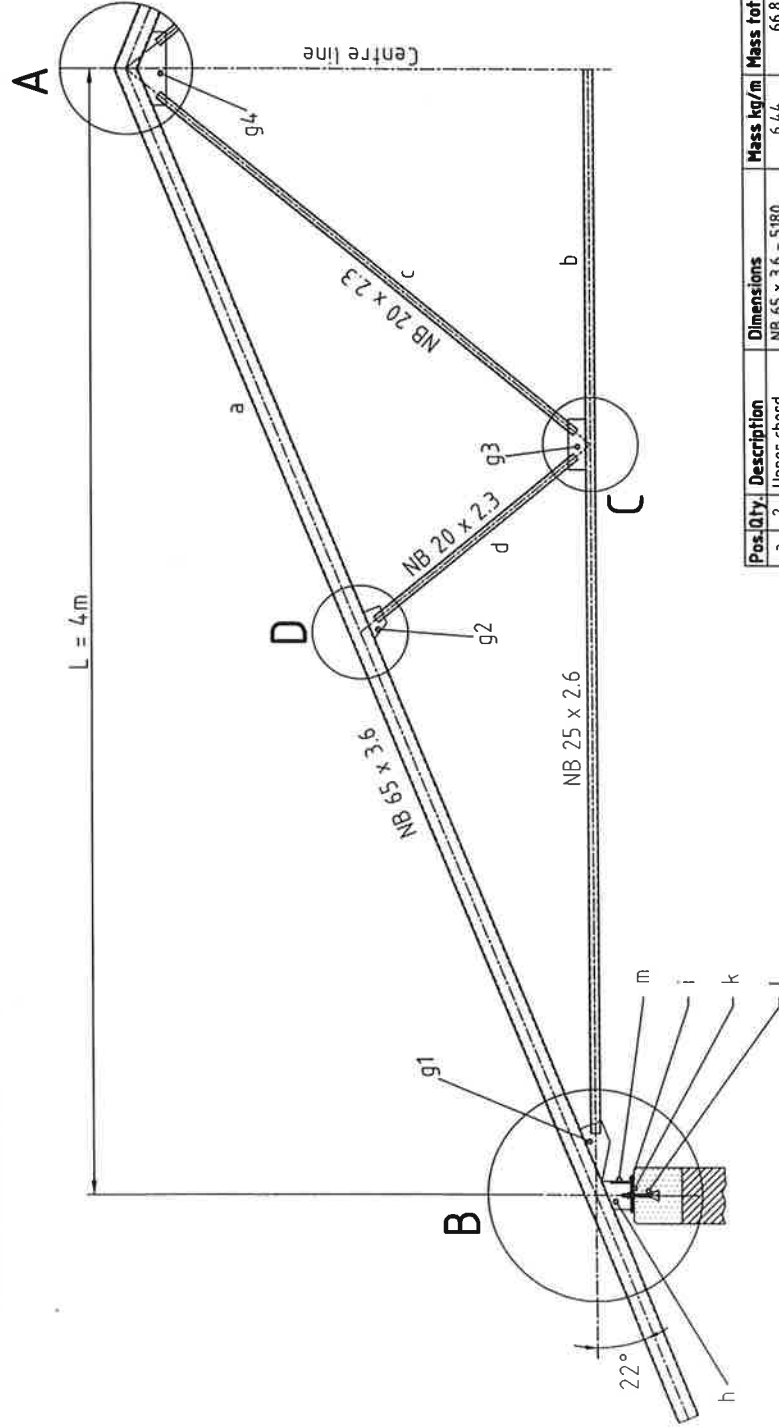
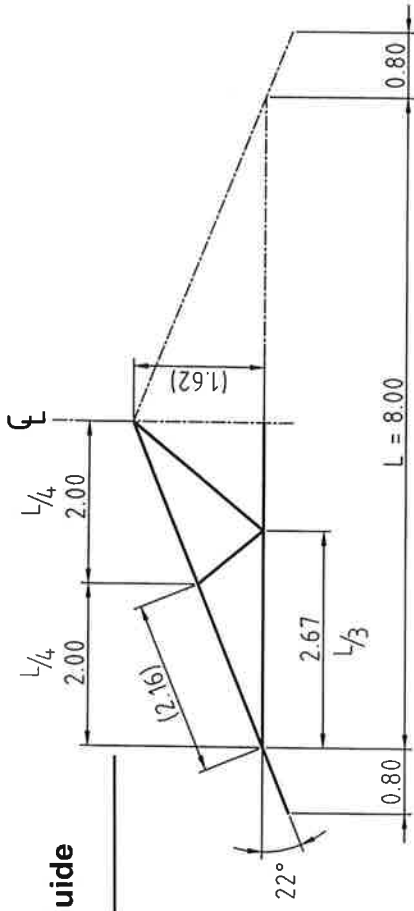


6.9.3 Double Pitch Roof, Tube Truss, 8 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

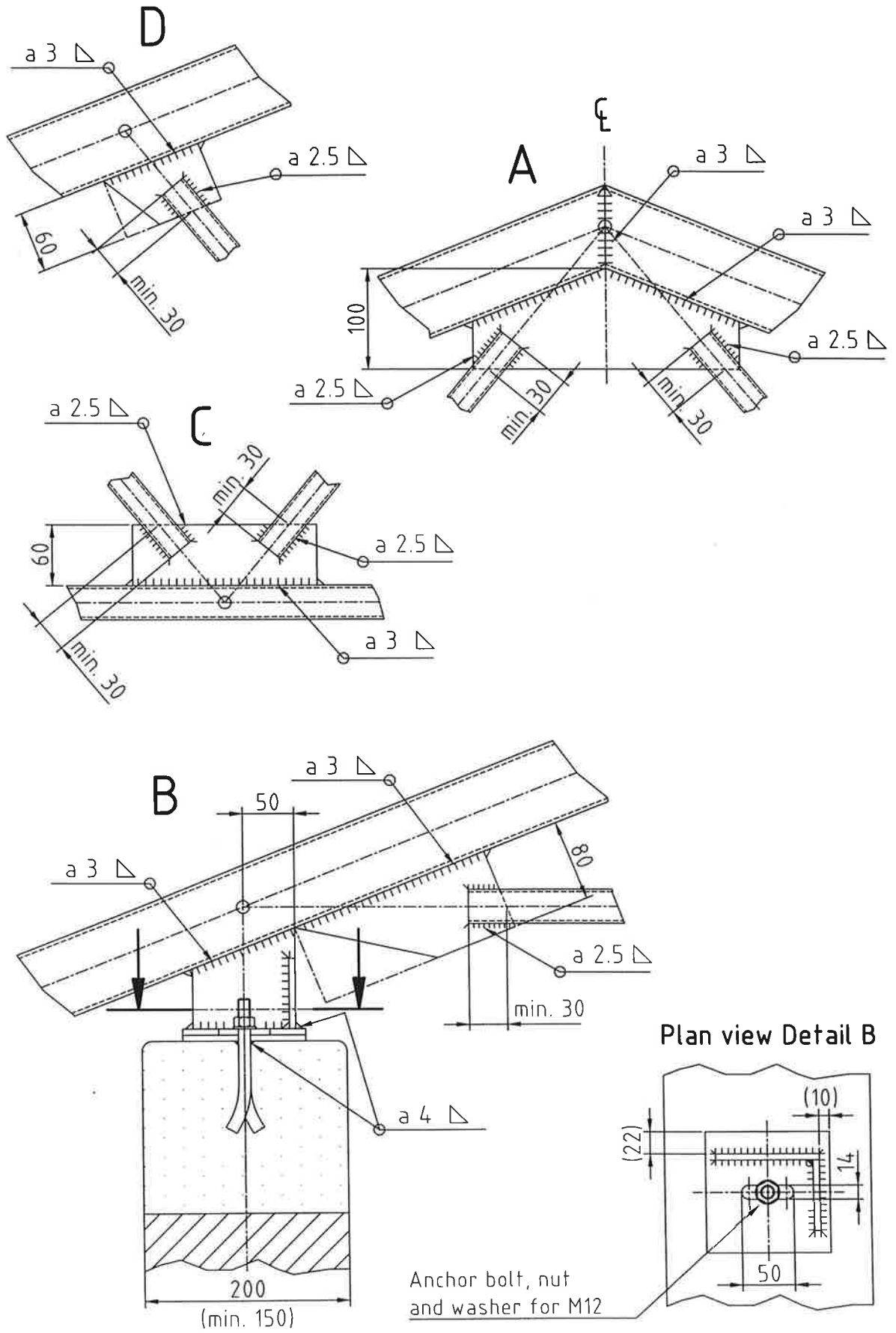
Spacing of truss 2.5 m

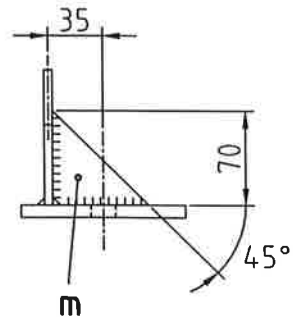
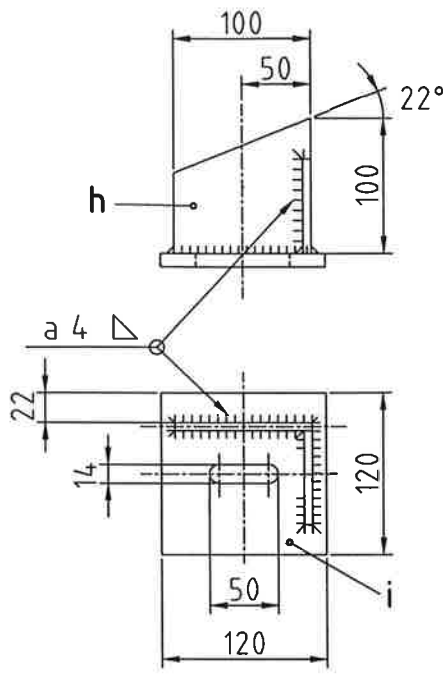
Total load 1.0 kN/m²



Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	NB 65 x 3.6 - 5180	6.44	66.8
b 1	Lower chord	NB 25 x 2.6 - 7560	1.99	15.1
c 2	Tie	NB 20 x 2.3 - 1880	1.40	5.3
d 2	Strut	NB 20 x 2.3 - 910	1.40	2.6
g	---	FB div. x 6 thick	---	4.3
h 2	Gusset g1 - g4	FB 100 x 6 - 100	4.71	1.0
i 2	Support	FB 120 x 6 - 120	5.65	1.35
k 2	Sliding plate	FB 120 x 6 - 120	5.65	1.35
l 2	Anchor plate	FB 120 x 6 - 120	5.65	1.35
m 2	Anchor bolt/nut/washer M12 - 120	---	---	0.7
l 2	Stiffener	FB 70 x 6 - 70	3.30	0.5
			Mass total	99.0

(NB = nominal bore / FB = flat bar)





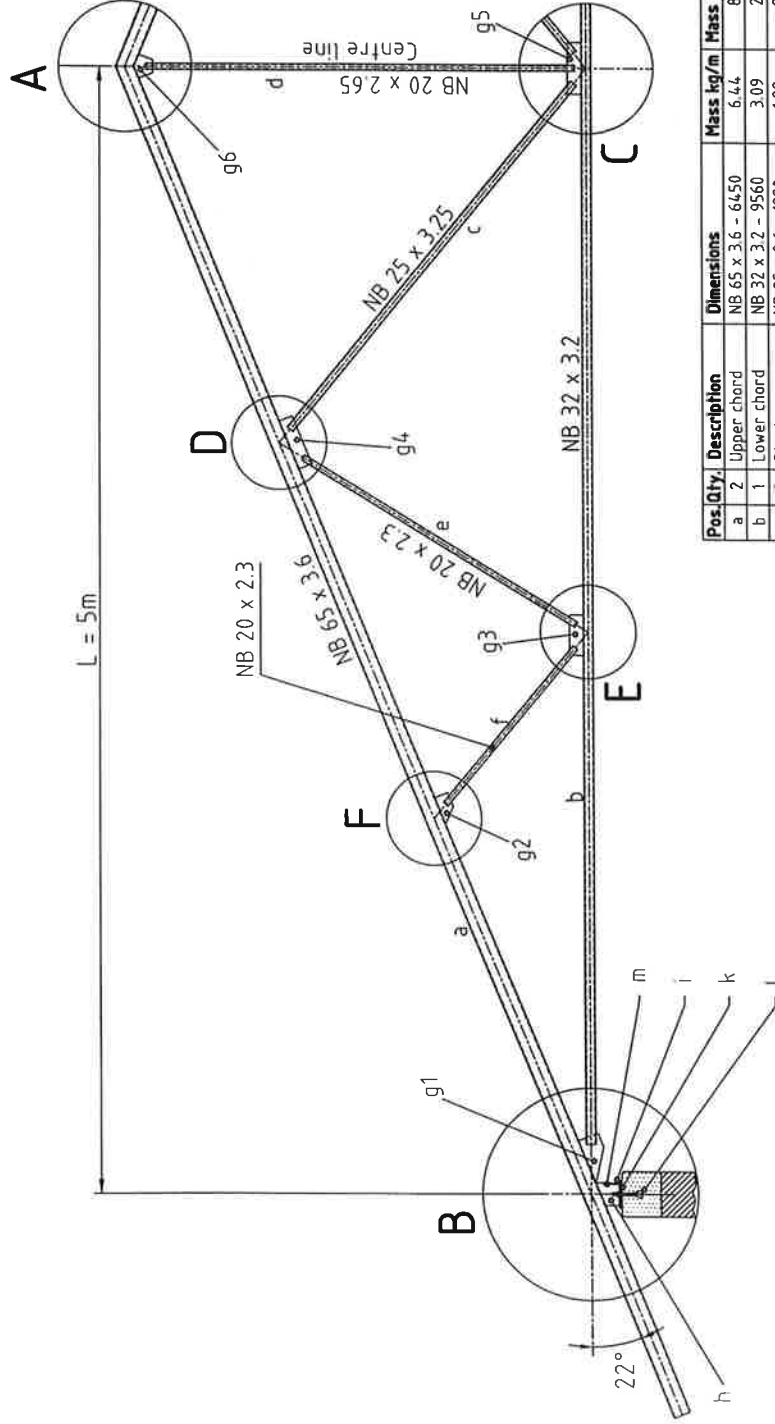
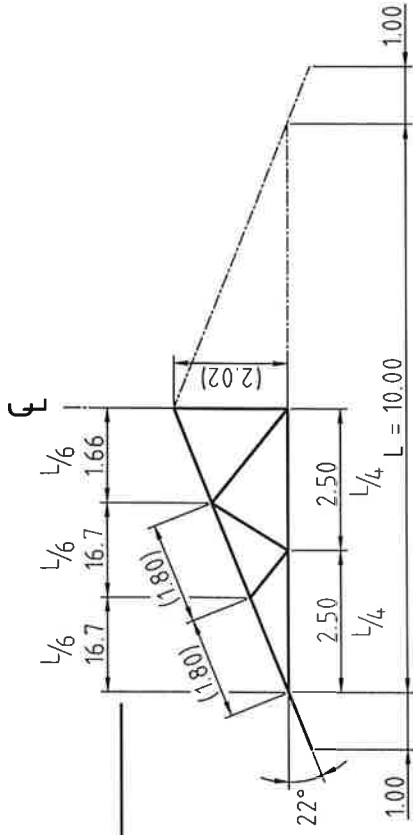
6.9.4 Double Pitch Roof, Tube Truss, 10 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

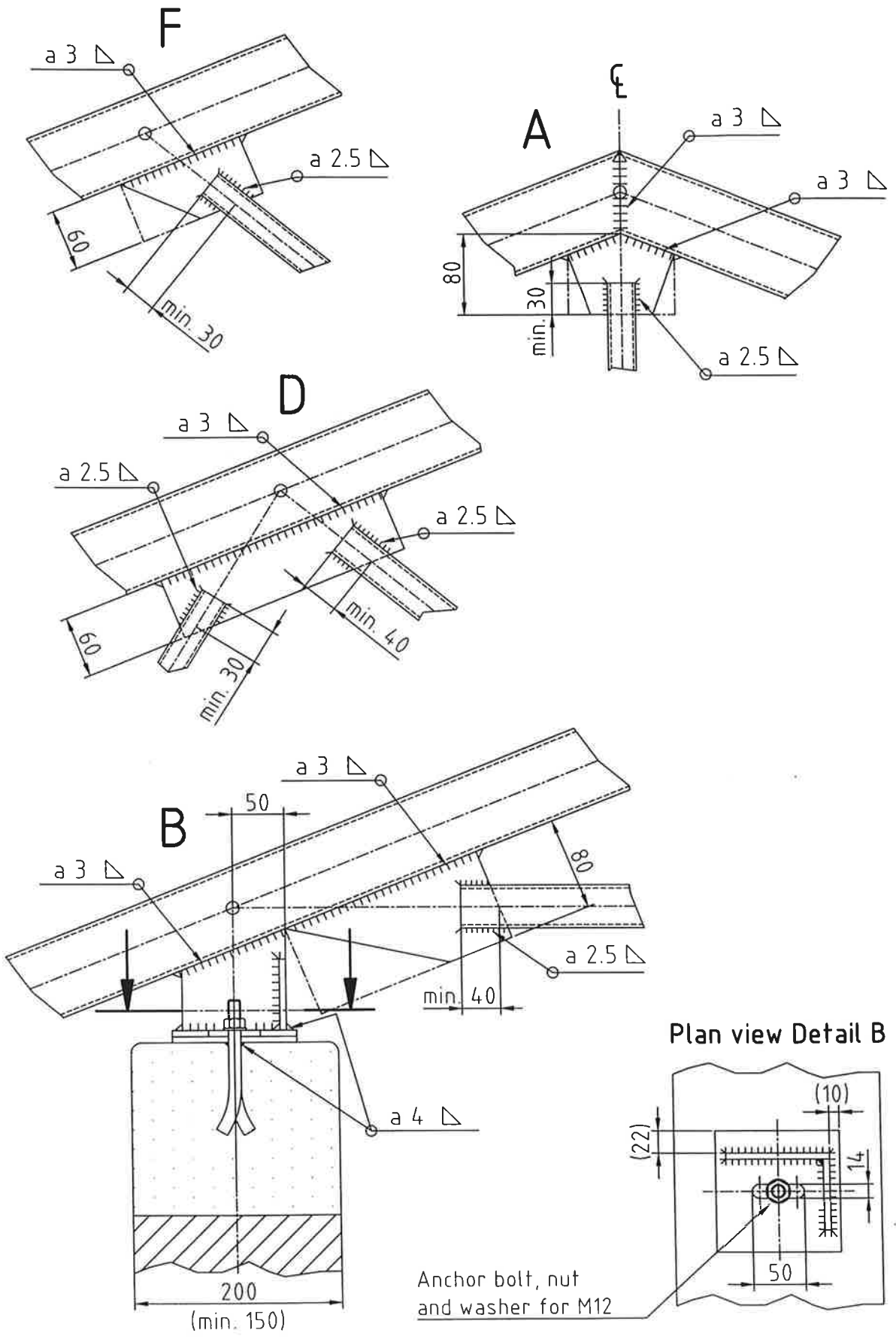
Spacing of truss 2.5 m

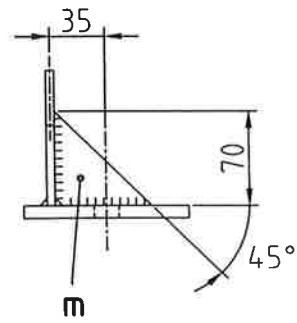
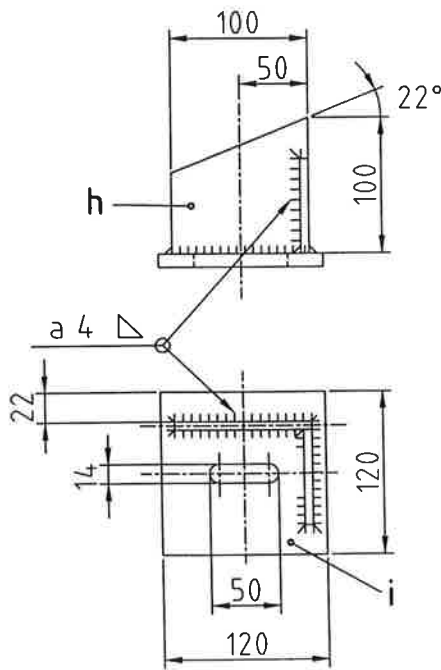
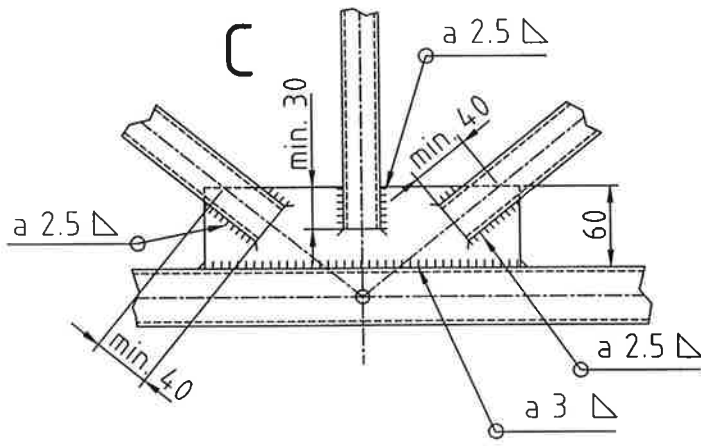
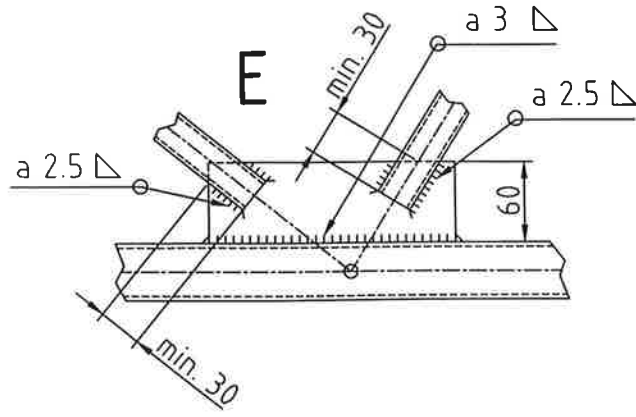
Total load 1.0 kN/m²



Pos. Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	NB 65 x 3.6 - 6450	6.44	83.1
b 1	Lower chord	NB 32 x 3.2 - 9560	3.09	29.6
c 2	Strut	NB 25 x 2.6 - 1980	1.99	8.0
d 1	Tie	NB 20 x 2.3 - 1880	1.40	2.7
e 2	Tie	NB 20 x 2.3 - 1400	1.40	4.0
f 2	Strut	NB 20 x 2.3 - 900	1.40	2.6
g ---	Gusset g1 - g6	FB div. x 6 thick	---	6.1
h 2	Support	FB 100 x 6 - 100	4.71	1.0
i 2	Sliding plate	FB 120 x 6 - 120	5.65	1.35
k 2	Anchor plate	FB 120 x 6 - 120	5.65	1.35
l 1	Anchor bolt/nut/washer M12 - 120	---	---	0.7
m 2	Stiffener	FB 70 x 6 - 70	3.30	0.5
	Mass total			74.10

(NB = nominal bore / FB = flat bar)



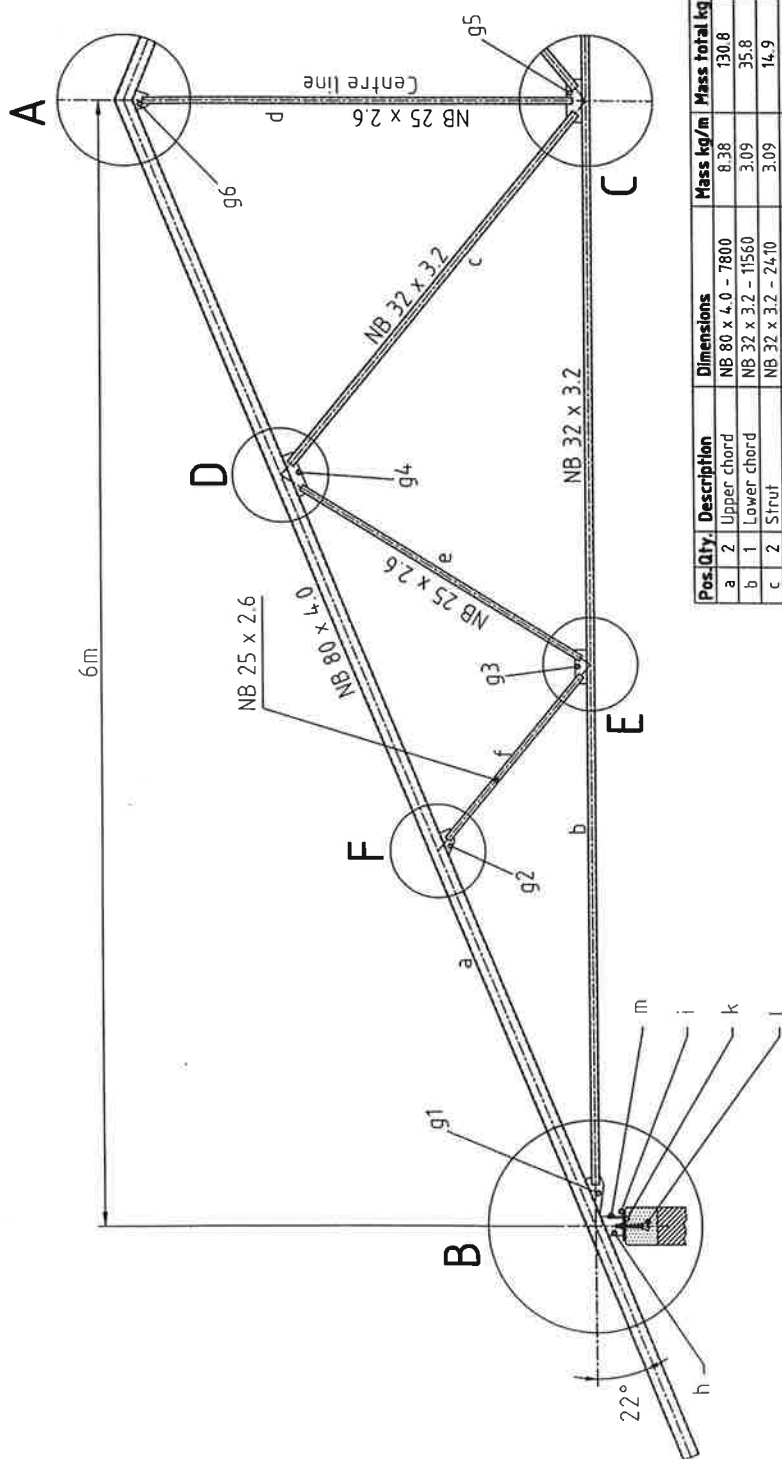
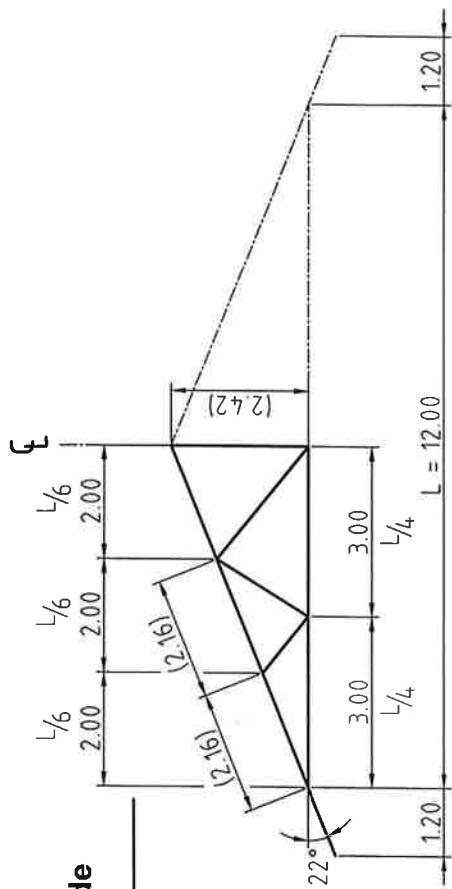


6.9.5 Double Pitch Roof, Tube Truss, 12 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

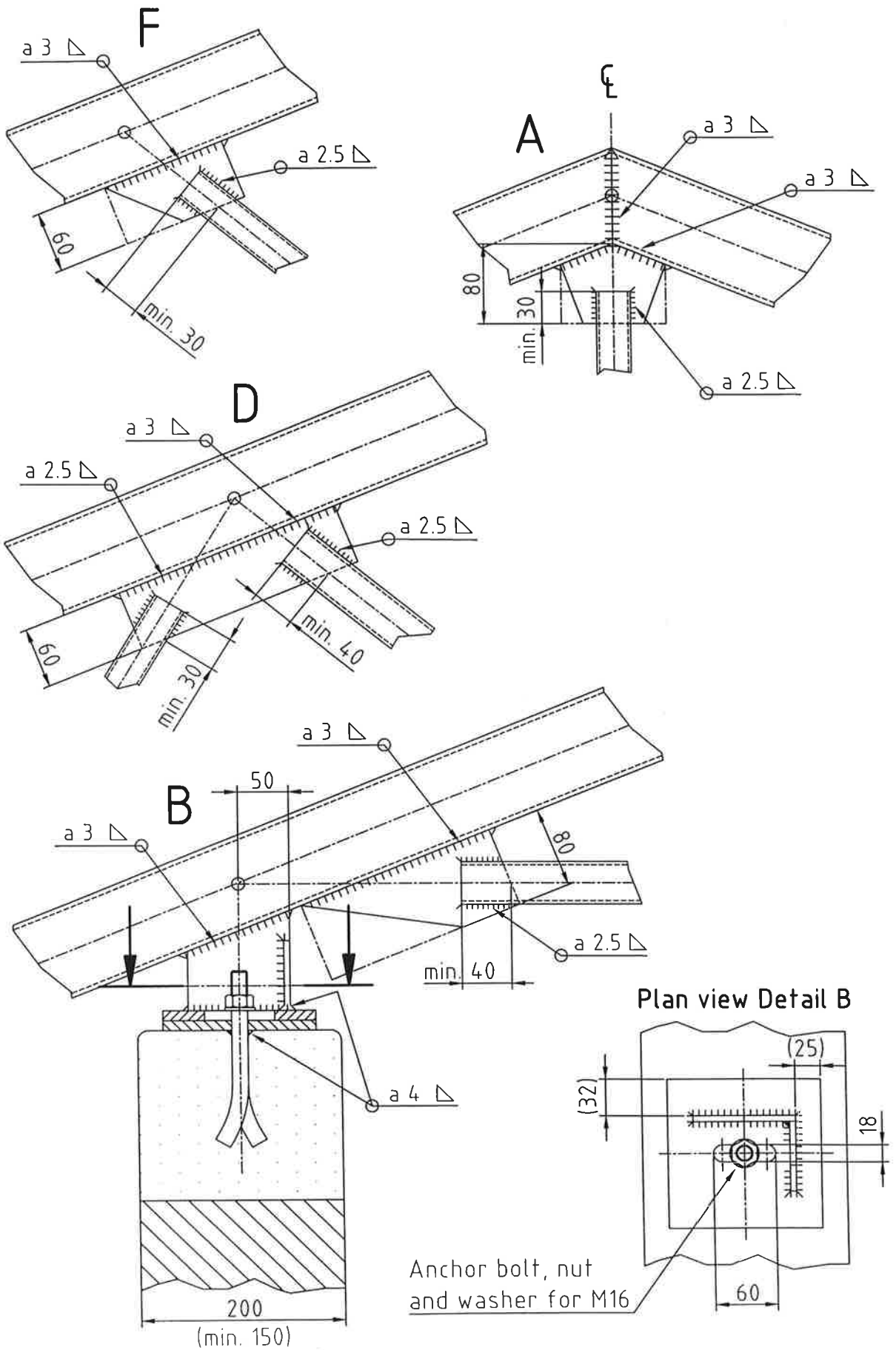
Spacing of truss 2.5 m

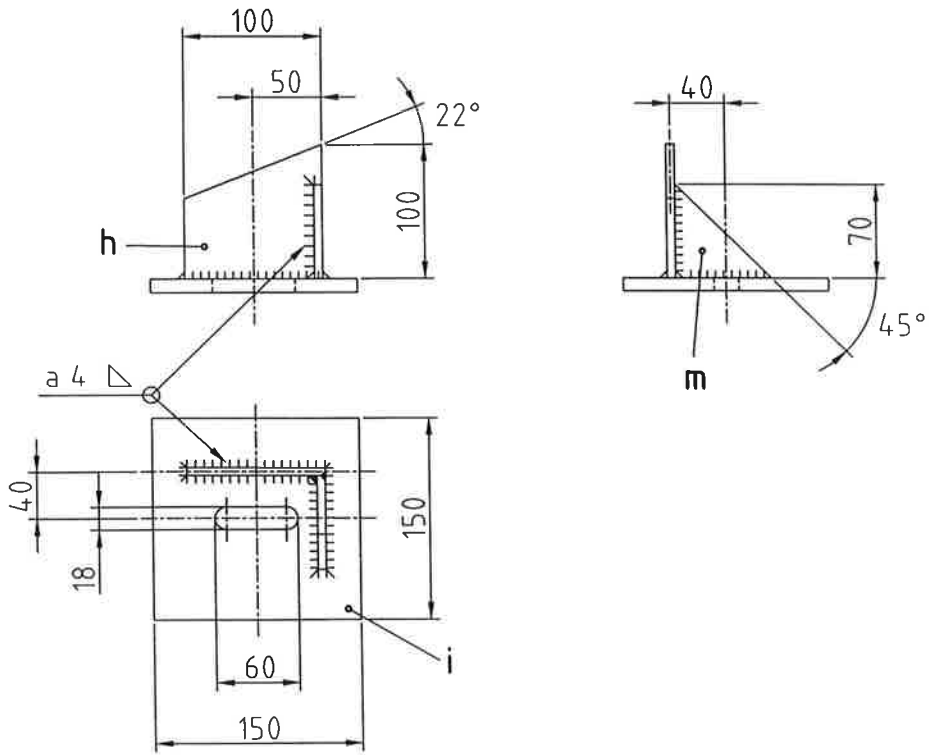
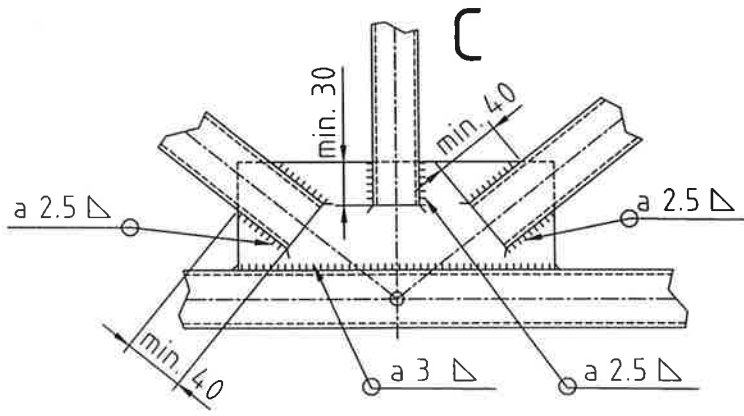
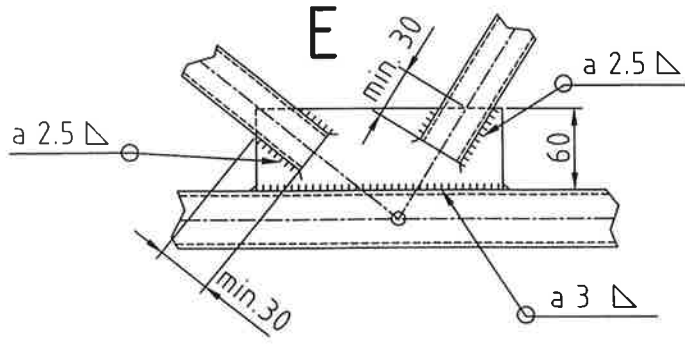
Total load 1.0 kN/m²



Pos./Qty	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Upper chord	NB 80 x 4.0 - 7800	8.38	130.8
b 1	Lower chord	NB 32 x 3.2 - 11560	3.09	35.8
c 2	Strut	NB 32 x 3.2 - 2410	3.09	14.9
d 1	Tie	NB 25 x 2.6 - 2260	1.99	4.5
e 2	Tie	NB 25 x 2.6 - 1720	1.99	6.9
f 2	Strut	NB 25 x 2.6 - 1125	1.99	4.5
g	--- Gussel g1 - g6	FB div. x 6 fthick	---	7.2
h 2	Support	FB 100 x 6 - 100	4.71	1.0
i 2	Sliding plate	FB 150 x 6 - 150	7.07	3.6
k 2	Anchor plate	FB 150 x 6 - 150	7.07	3.6
l 1	Anchor bolt/nut/washer M16 - 150		---	0.7
m 1	Stiffener	FB 70 x 6 - 70	3.30	0.5
			Mass total	214.0

(NB = nominal bore / FB = flat bar)



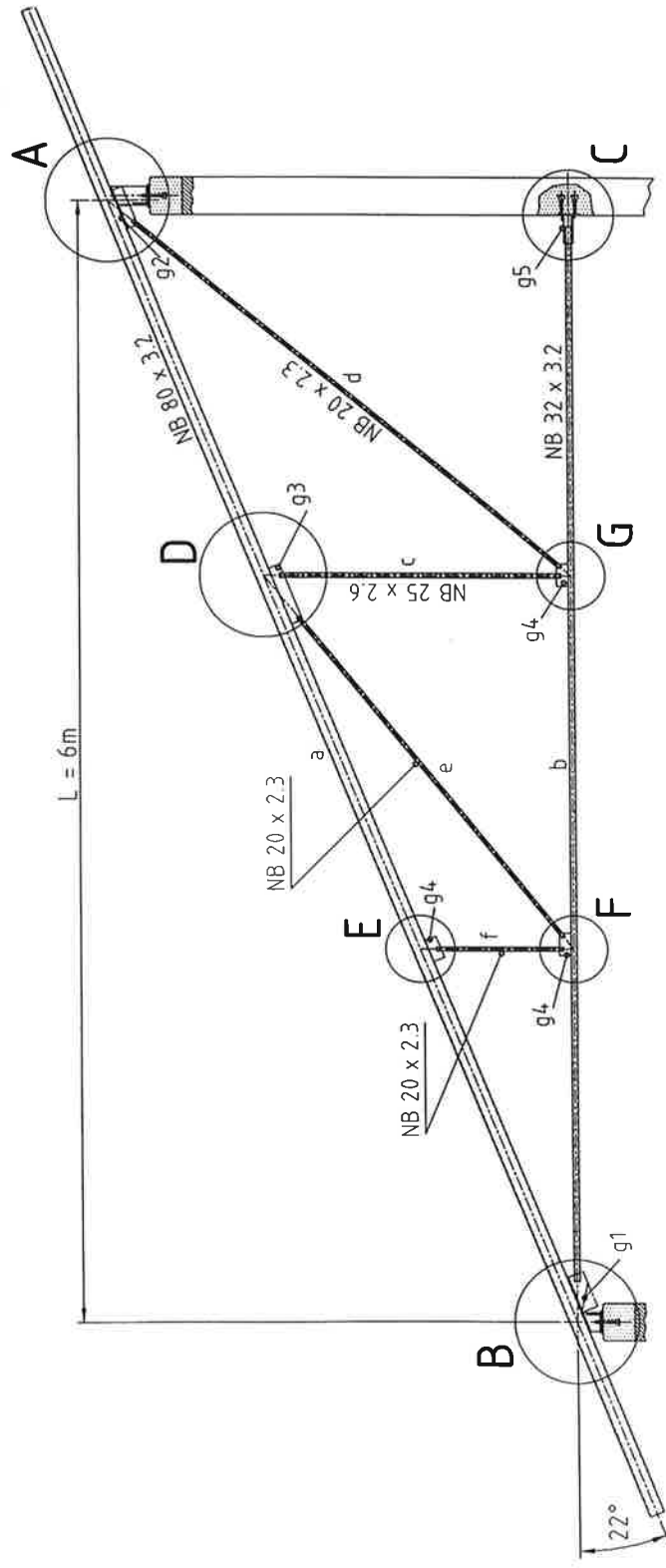
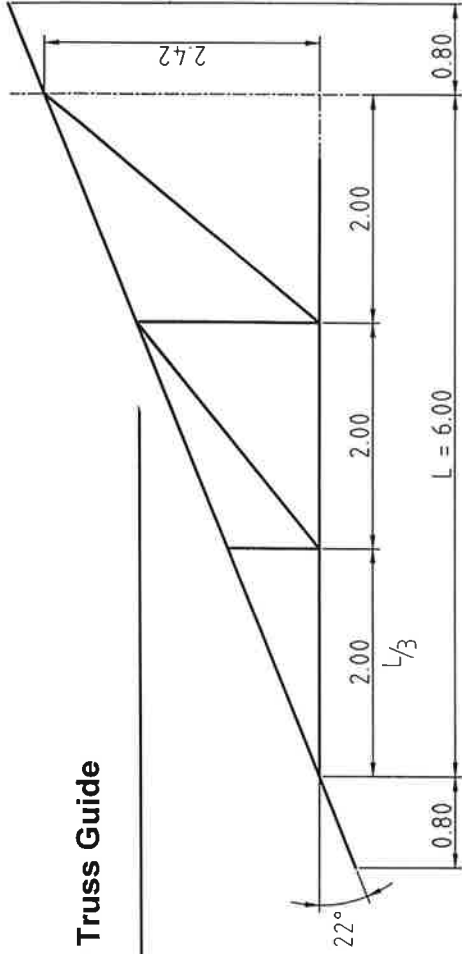


6.9.6 Single Pitch Roof, Tube Truss, 6 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

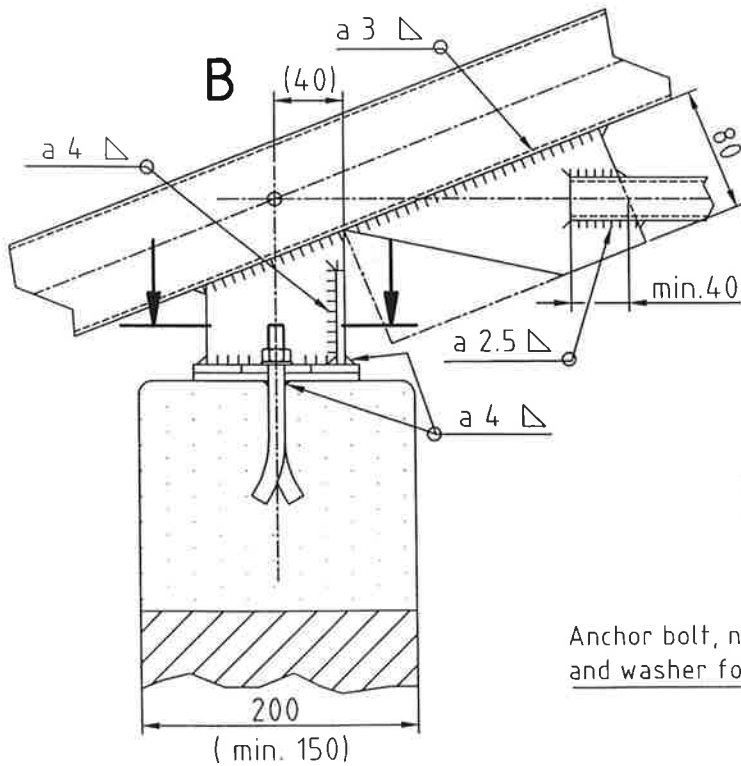
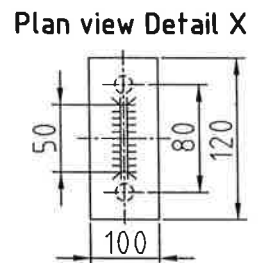
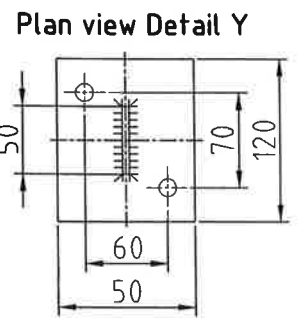
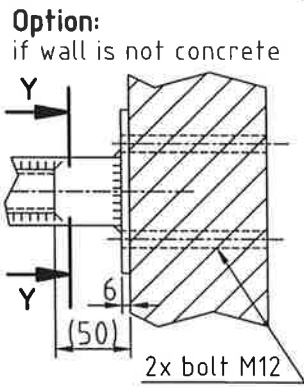
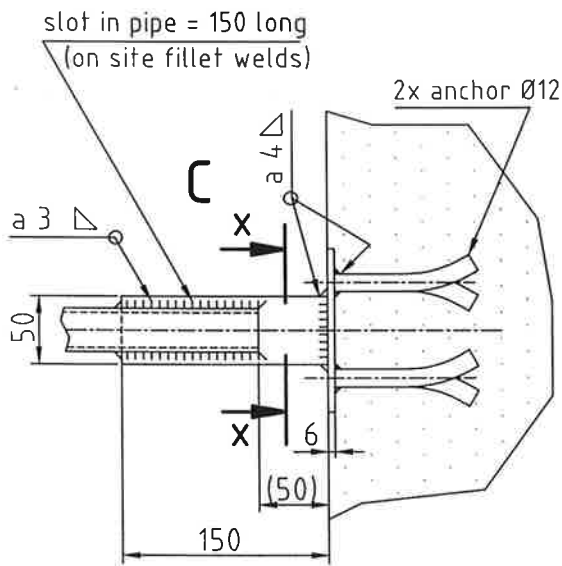
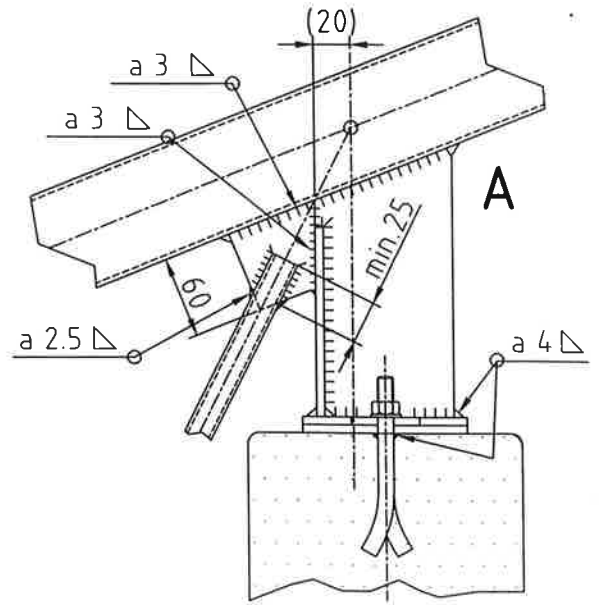
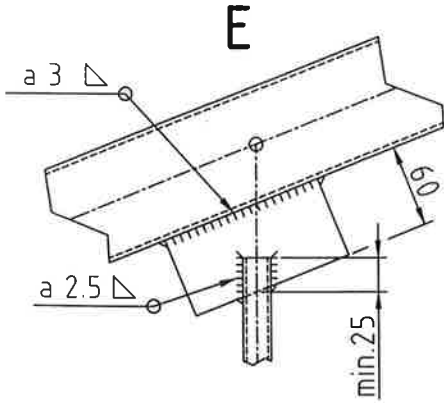
Spacing of truss 2.5 m

Total load 1.0 kN/m²

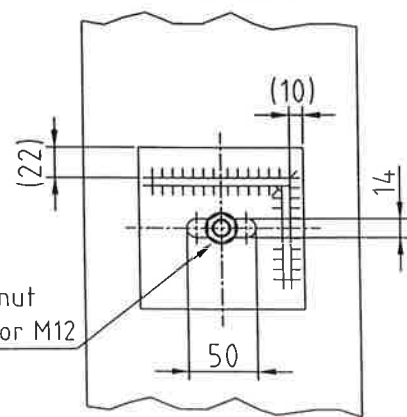


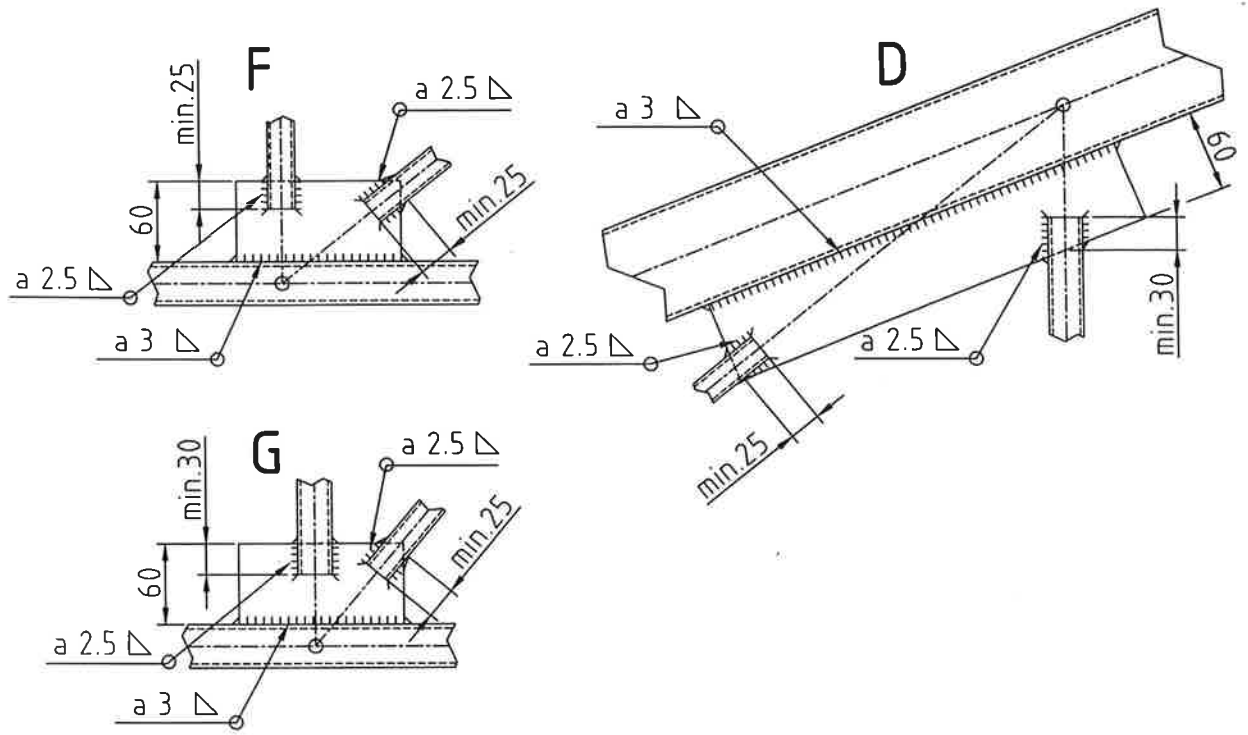
Pos.	Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	1	Upper chord	NB 80 x 32 - 8700	6.76	58.9
b	1	Lower chord	NB 32 x 32 - 5650	3.09	17.6
c	1	Post	NB 25 x 2.6 - 1480	1.99	3.0
d	1	Diagonal	NB 20 x 2.3 - 2900	1.40	4.3
e	1	Diagonal	NB 20 x 2.3 - 2200	1.40	3.1
f	1	Post	NB 20 x 2.3 - 670	1.40	1.0
g	---	Gusset g1 - g5	FB div. x 6 thick	---	5.8
A	1	Support A	Plates/Support/Bolts	---	3.3
B	1	Support B	Plates/Support/Bolts	---	2.8
C	1	Support C	Plates/Support/Bolts	---	1.2
				Mass total	101.0

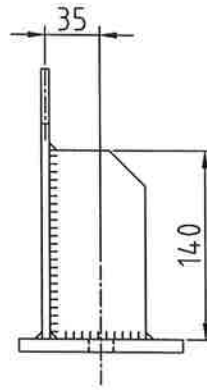
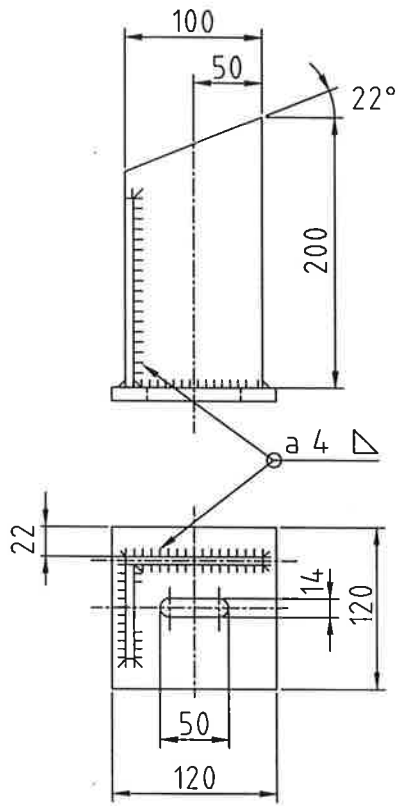
(NB = nominal bore / FB = flat bar)



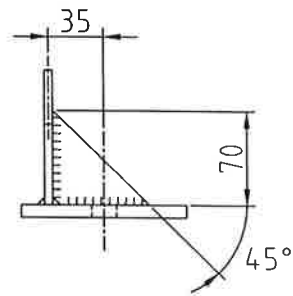
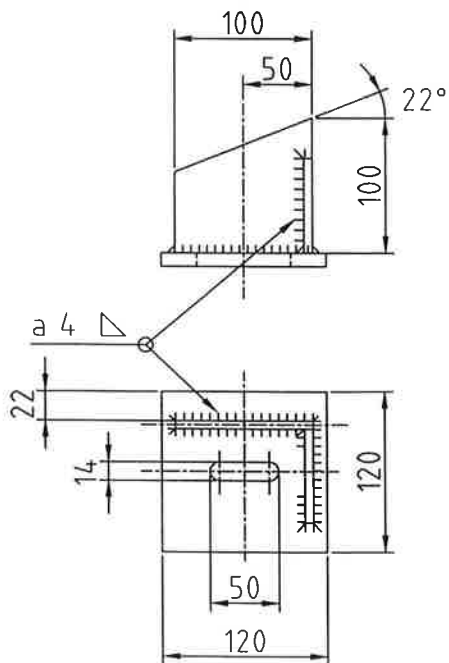
Plan view Detail B



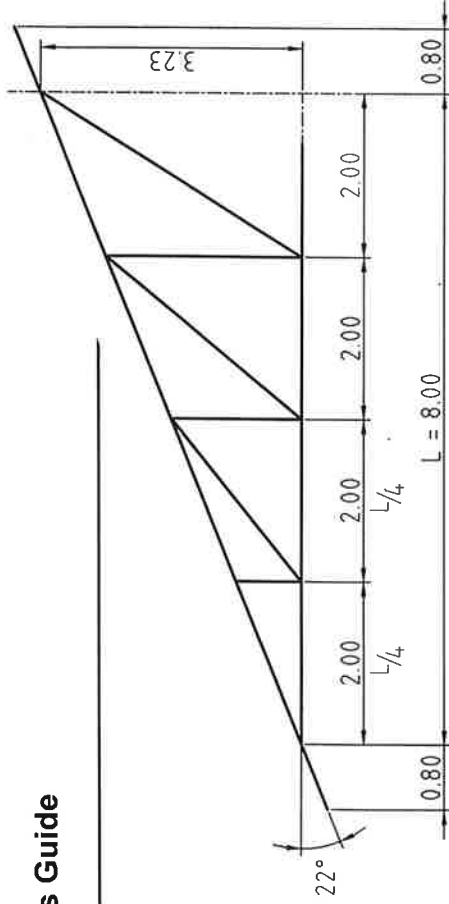




Detail Support A



Detail Support B



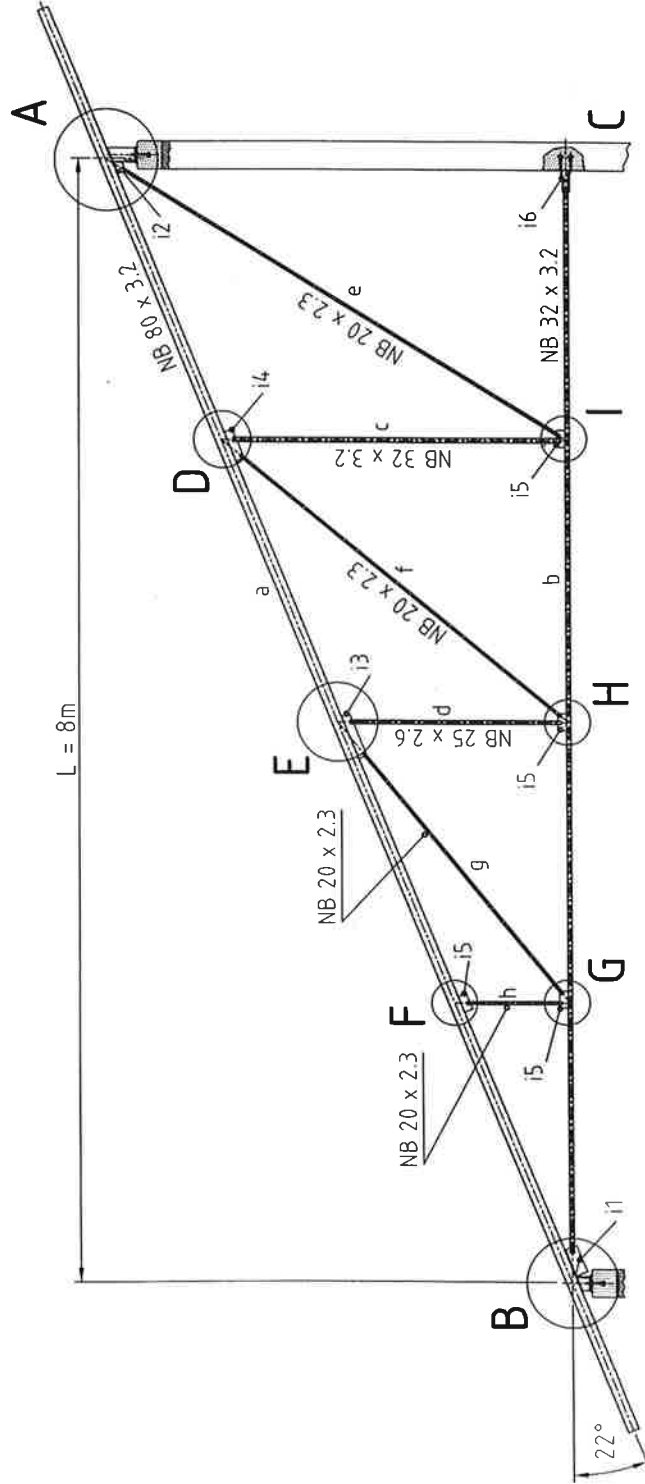
6.9.7 Single Pitch Roof, Tube Truss, 8 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

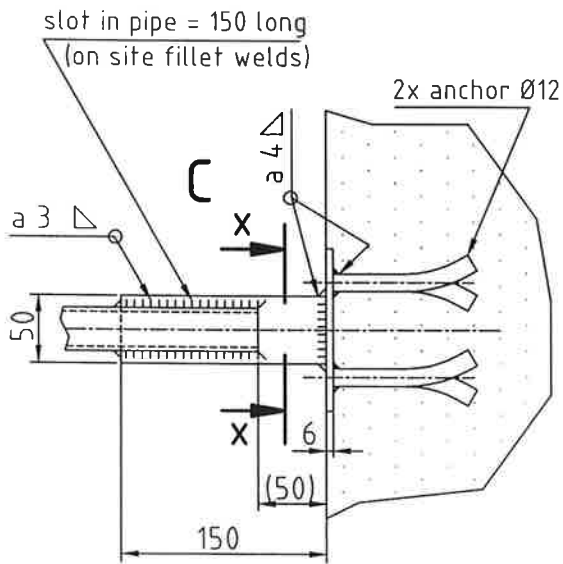
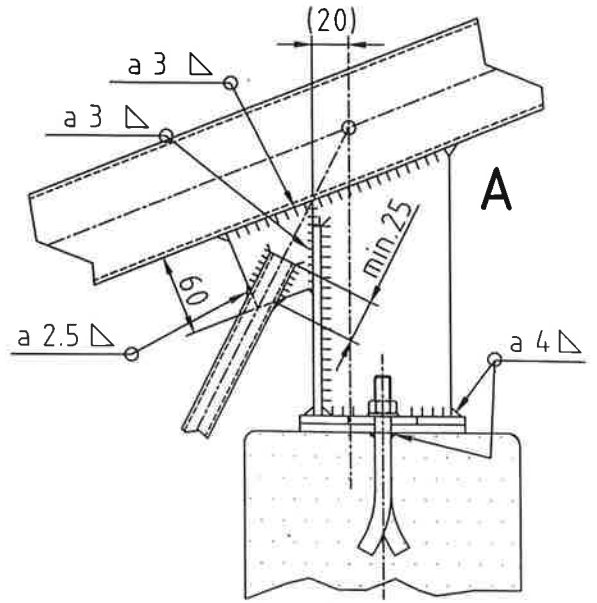
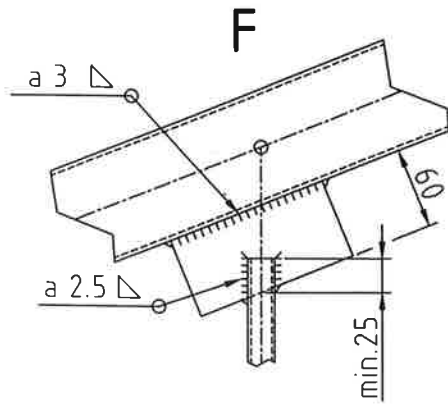
Spacing of truss 2.5 m

Total load 1.0 kN/m²

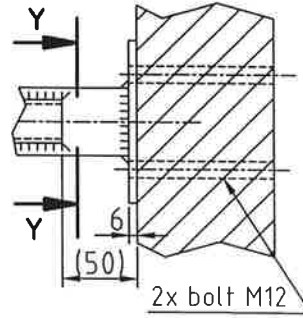


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Upper chord	NB 80 x 3.2 - 10900	6.76	73.8
b 1	Lower chord	NB 32 x 3.2 - 7650	3.09	23.8
c 1	Post	NB 32 x 3.2 - 2300	3.09	7.2
d 1	Post	NB 25 x 2.6 - 14.80	1.99	3.0
e 1	Diagonal	NB 20 x 2.3 - 3900	1.40	5.5
f 1	Diagonal	NB 20 x 2.3 - 2900	1.40	4.3
g 1	Diagonal	NB 20 x 2.3 - 2200	1.40	3.1
h 1	Post	NB 20 x 2.3 - 670	1.40	1.0
i	Gusset i1 - i6	FB div. x 6 thick	---	7.0
A 1	Support A	Plates/Support/Bolts	---	3.3
B 1	Support B	Plates/Support/Bolts	---	2.8
C 1	Support C	Plates/Support/Bolts	---	1.2
			Mass total	136.0

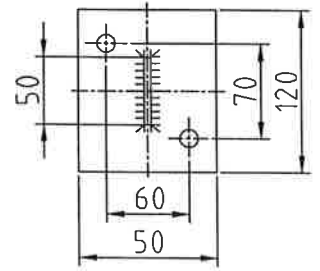
(NB = nominal bore / FB = flat bar)



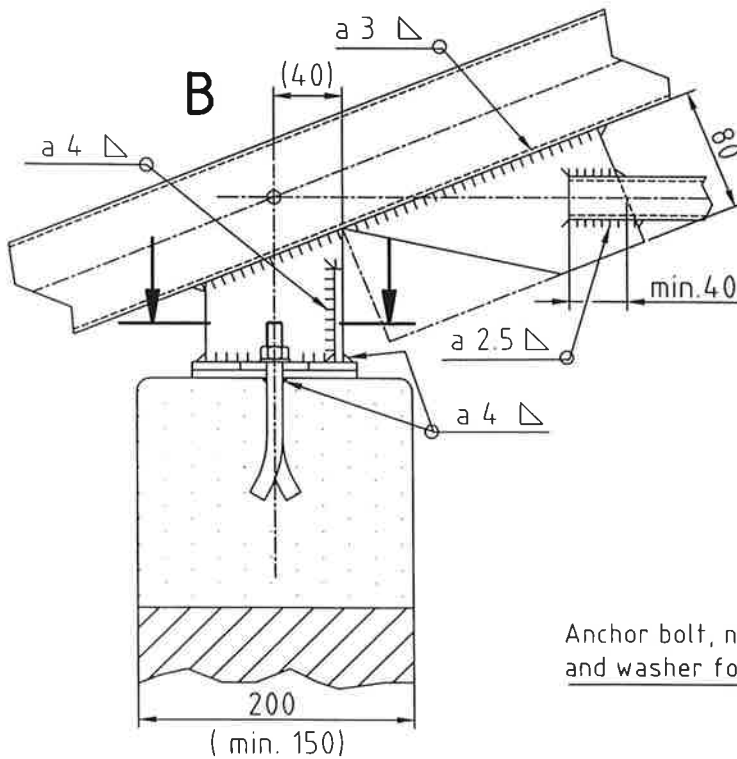
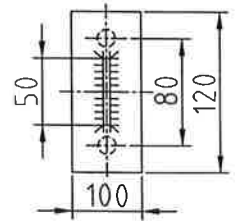
Option:
if wall is not concrete



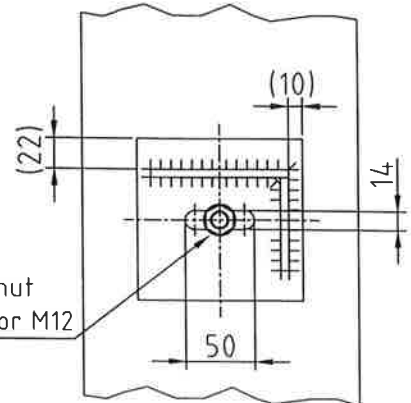
Plan view Detail Y



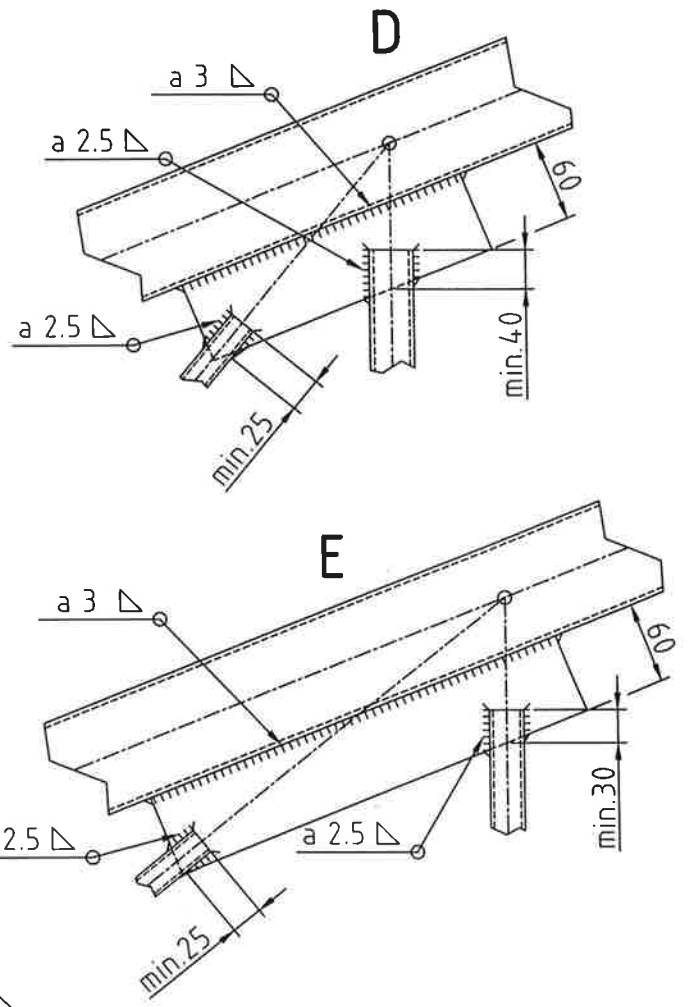
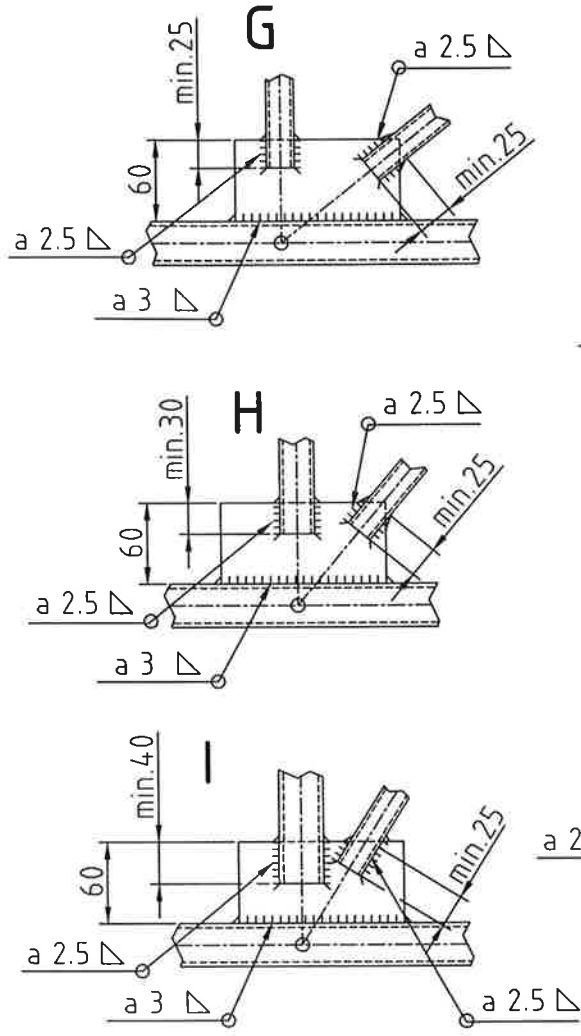
Plan view Detail X

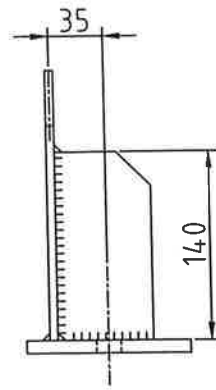
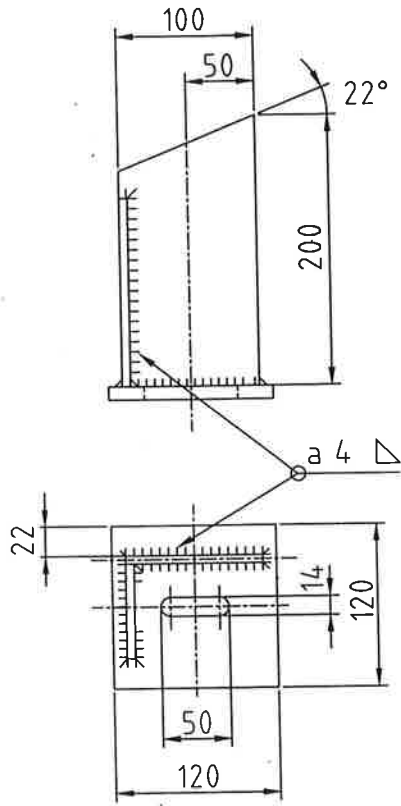


Plan view Detail B

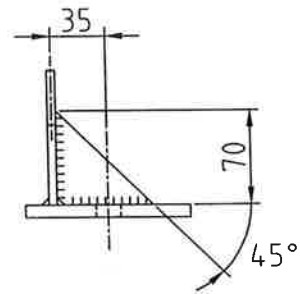
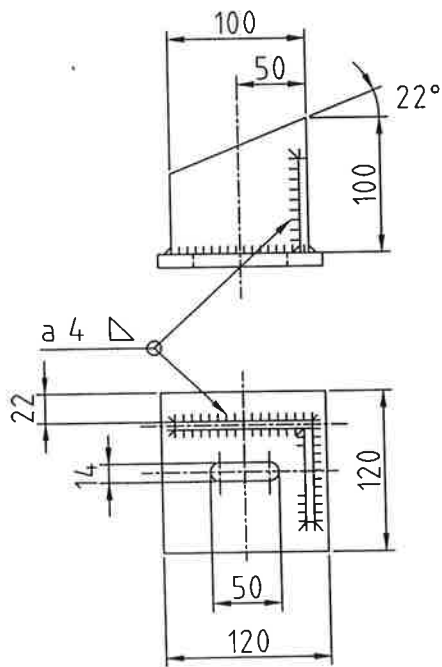


Anchor bolt, nut
and washer for M12





Detail Support A



Detail Support B

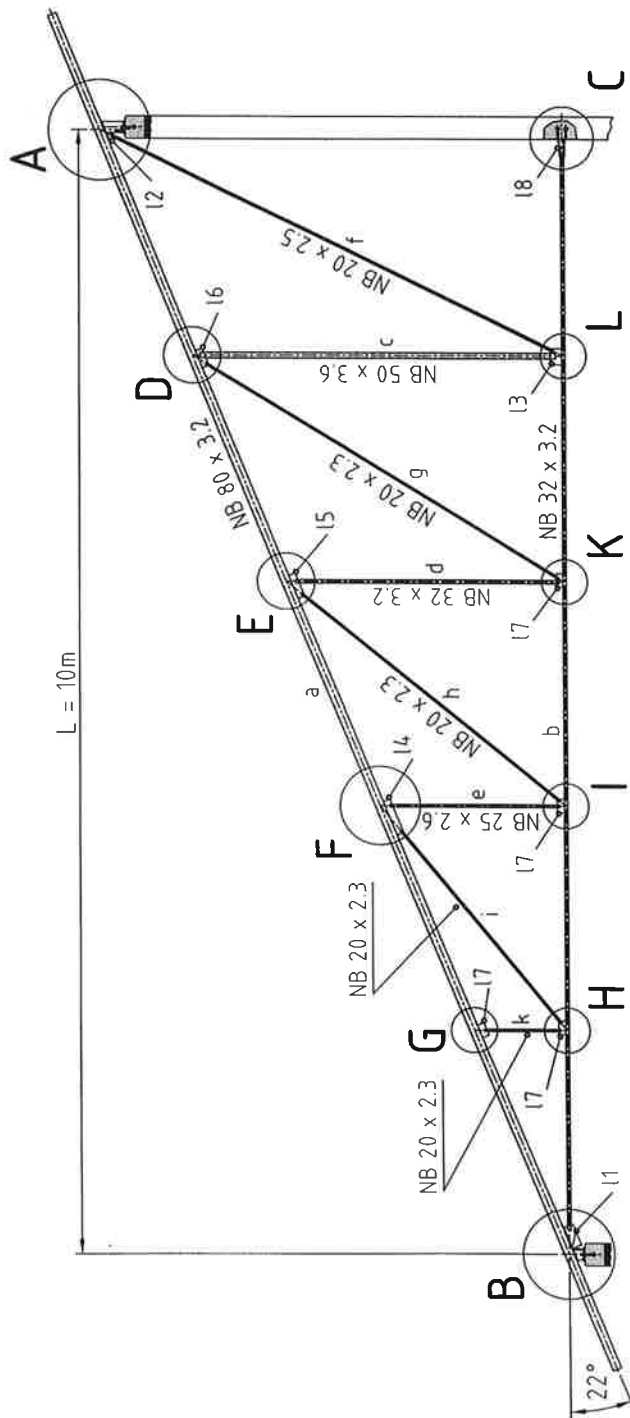
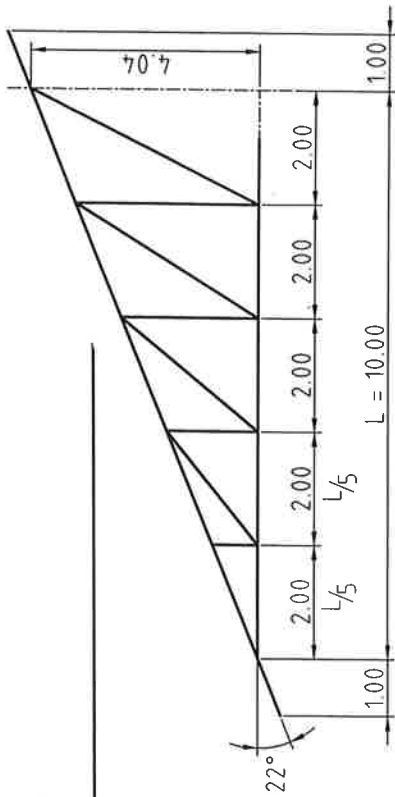
6.9.8 Single Pitch Roof, Tube Truss, 10 m span

Roof Slope min 19°, max. 30°

Bracing system according to Section 6.6.4 above

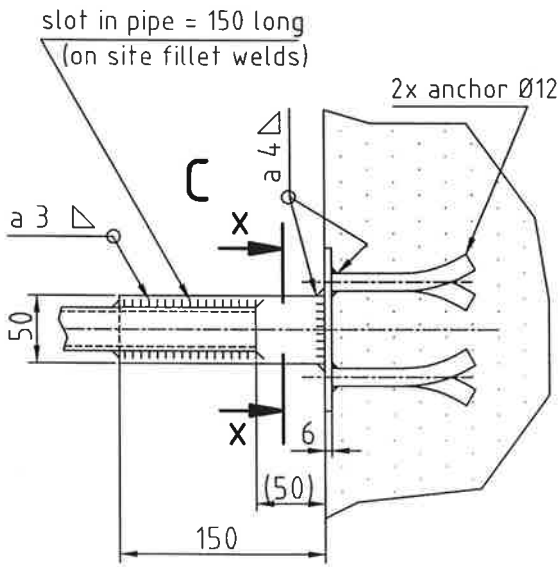
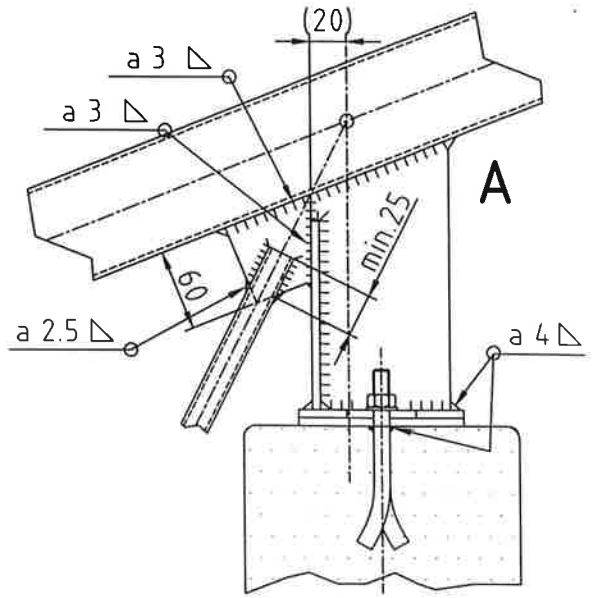
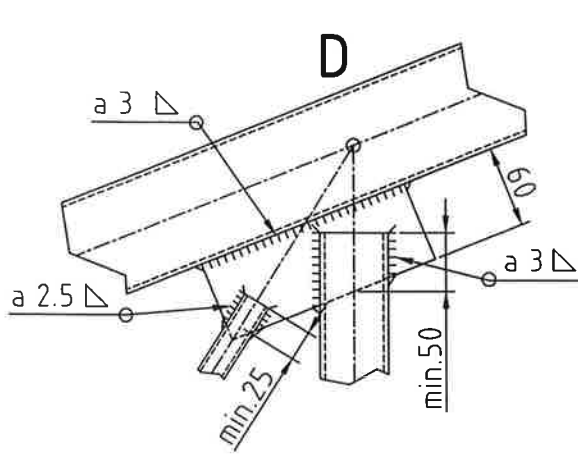
Spacing of truss 2.5 m

Total load 1.0 kN/m²

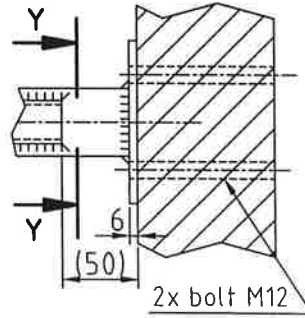


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Upper chord	NB 80 x 3.2 - 13000	6.76	86.0
b 1	Lower chord	NB 32 x 3.2 - 9650	3.09	29.8
c 1	Post	NB 50 x 3.6 - 3100	5.03	15.6
d 1	Post	NB 32 x 3.2 - 2300	3.09	7.2
e 1	Post	NB 25 x 2.6 - 1480	1.99	3.0
f 1	Diagonal	NB 20 x 2.3 - 4300	1.40	6.2
g 1	Diagonal	NB 20 x 2.3 - 3900	1.40	5.5
h 1	Diagonal	NB 20 x 2.3 - 2900	1.40	4.3
i 1	Diagonal	NB 20 x 2.3 - 2200	1.40	3.1
k 1	Post	NB 20 x 2.3 - 670	1.40	1.0
l ----	Gusset (1 - 18)	FB div. x 6 thick	----	8.0
A 1	Support A	Plates/Support/Bolts	----	3.3
B 1	Support B	Plates/Support/Bolts	----	2.8
C 1	Support C	Plates/Support/Bolts	----	1.2
			Mass total	179.0

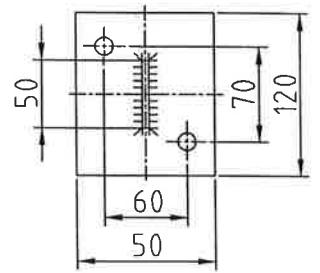
(NB = nominal bore / FB = flat bar)



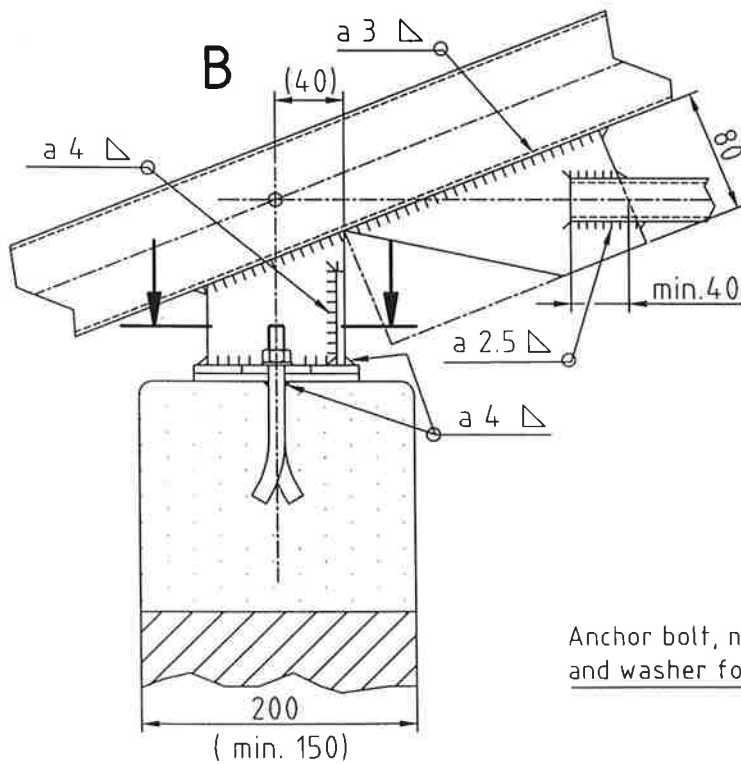
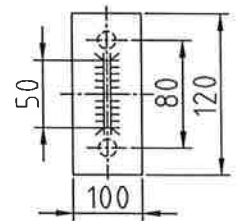
Option:
if wall is not concrete



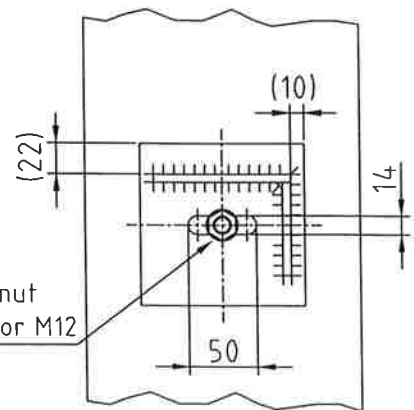
Plan view Detail Y



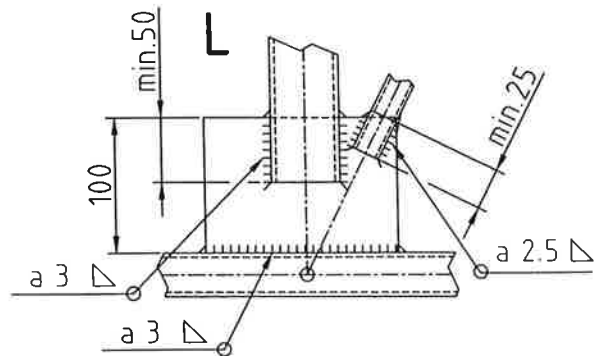
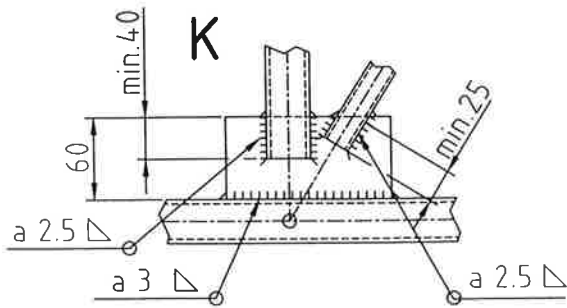
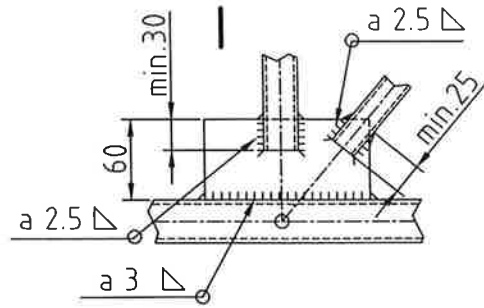
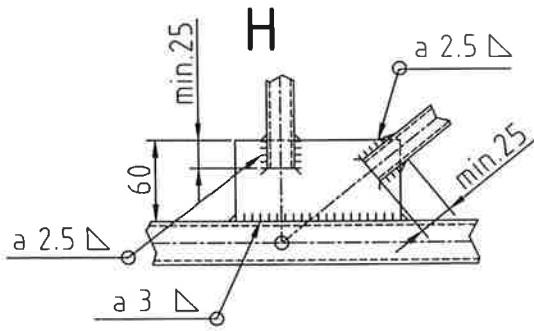
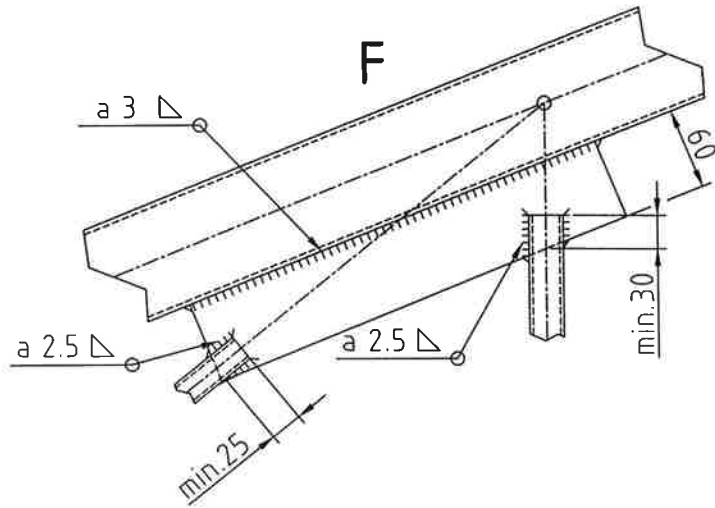
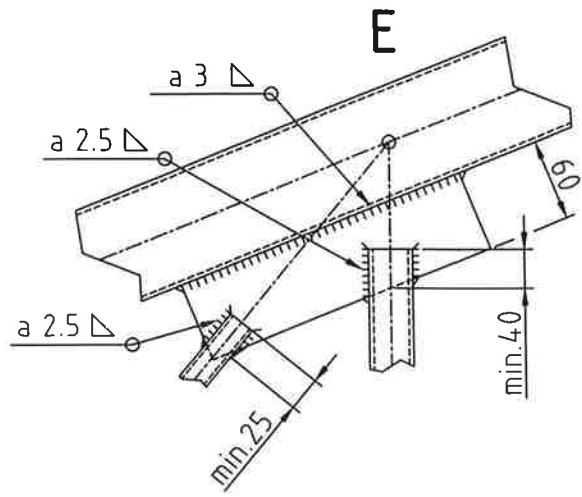
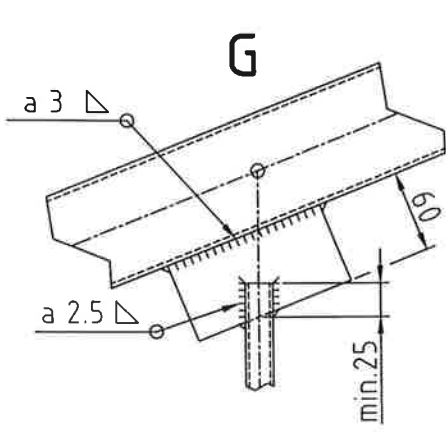
Plan view Detail X

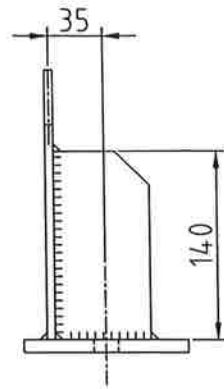
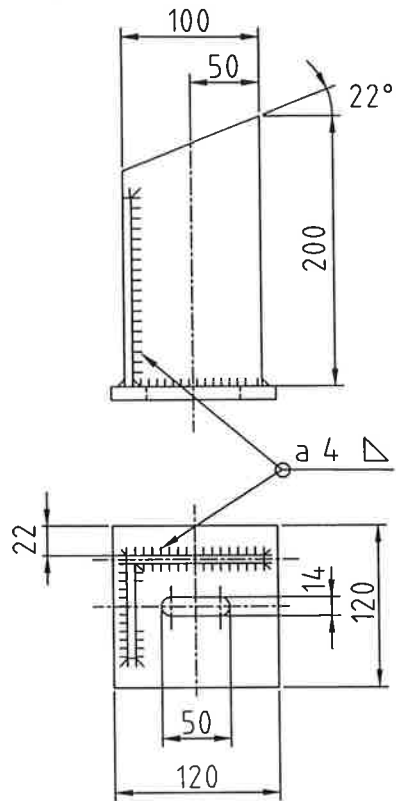


Plan view Detail B

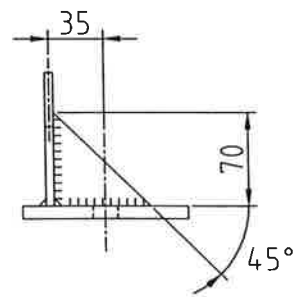
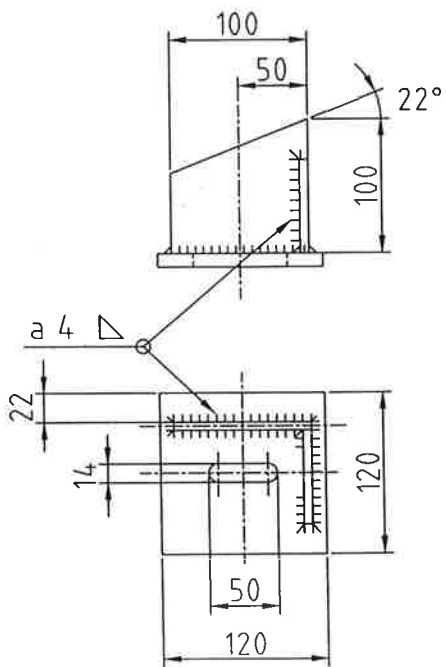


Anchor bolt, nut
and washer for M12

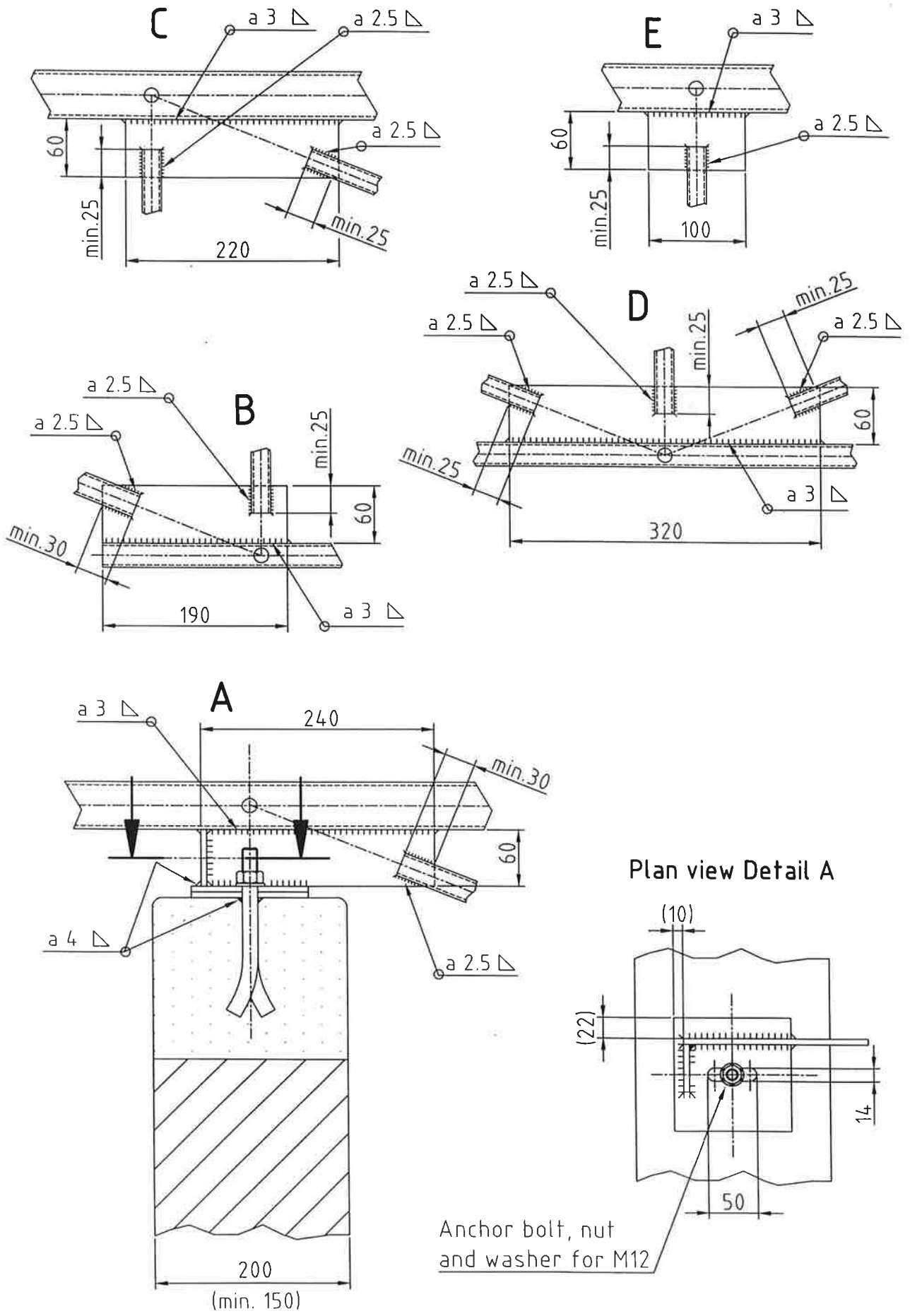


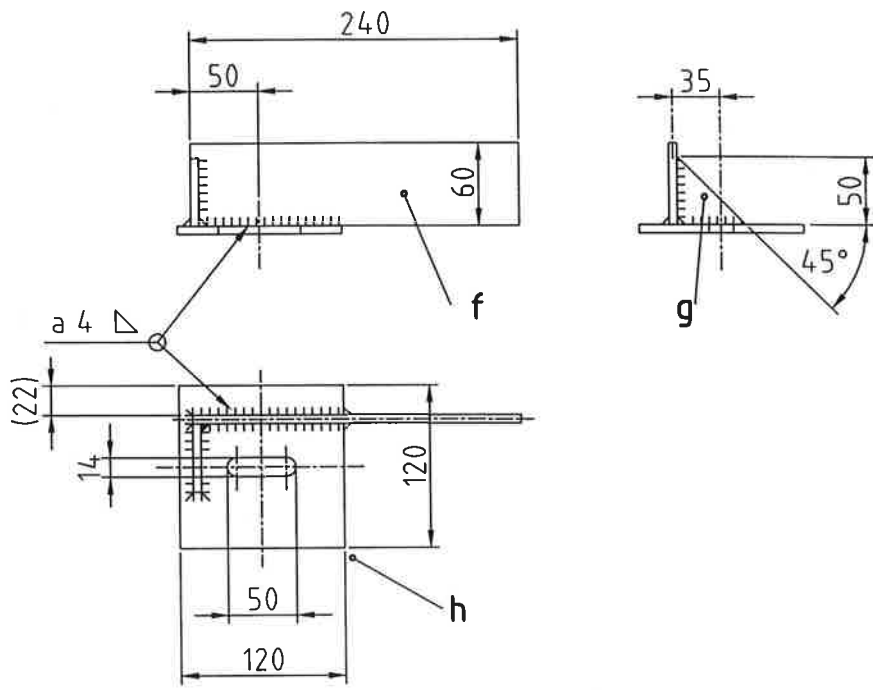


Detail Support A



Detail Support B



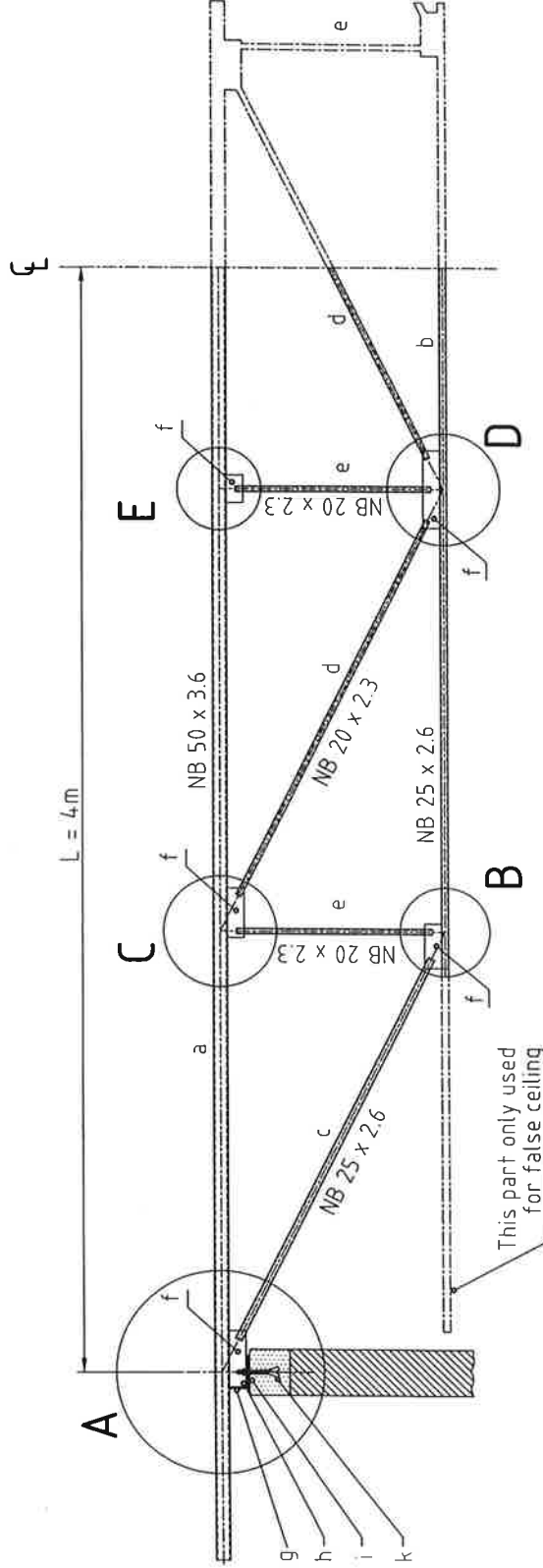
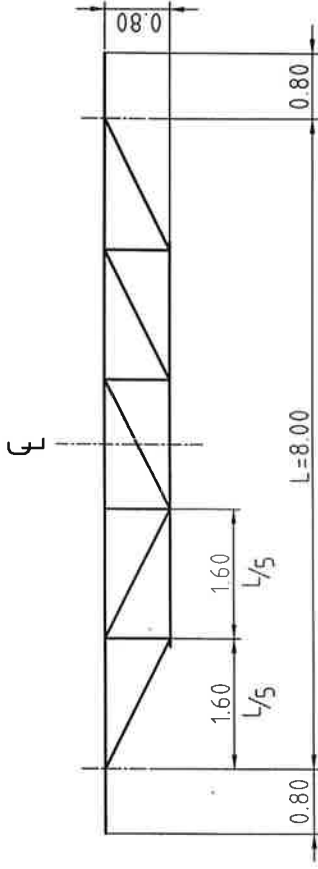


6.9.10 Flat Roof, Tube Truss, 8 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

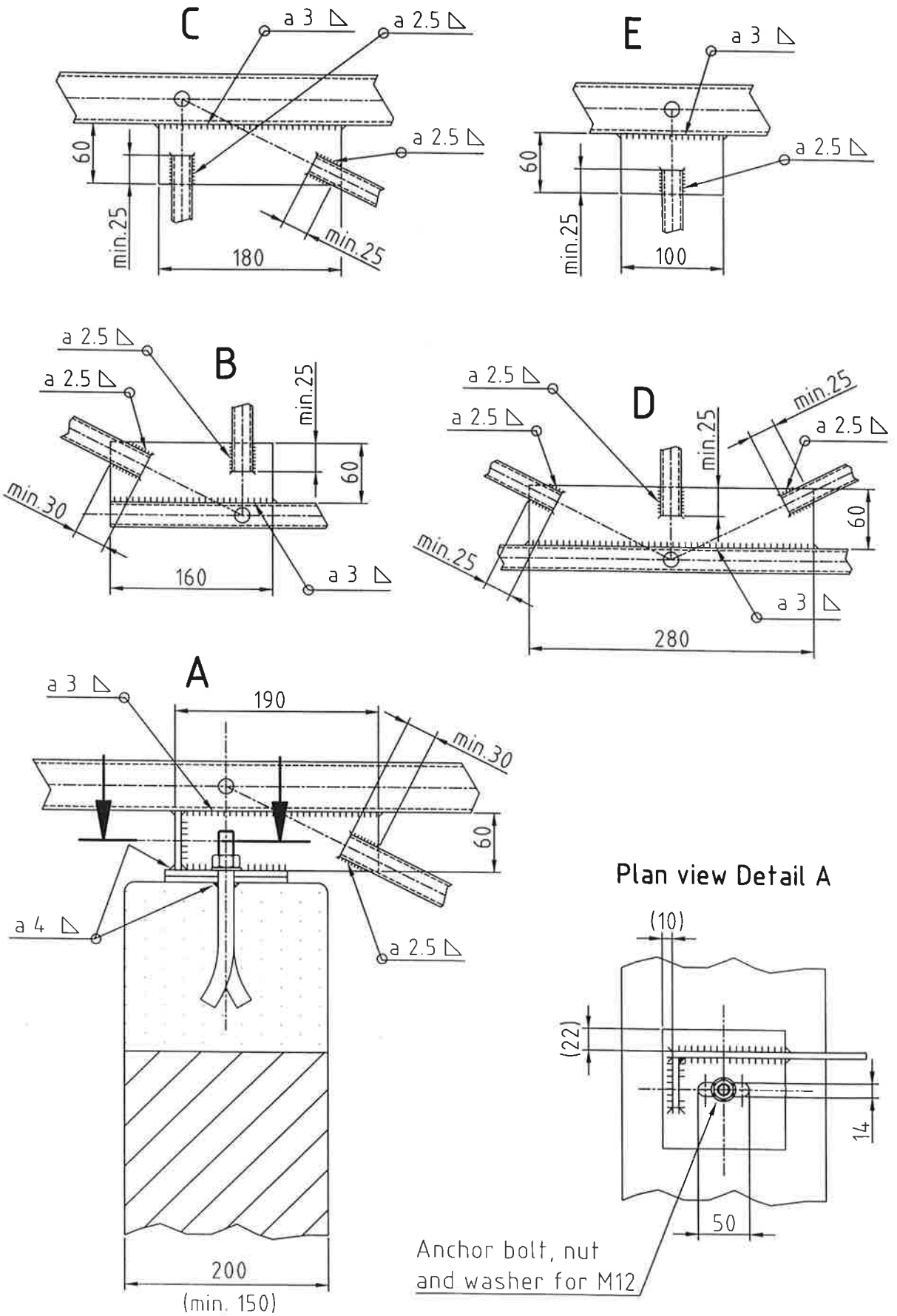
Spacing of truss 2.5 m

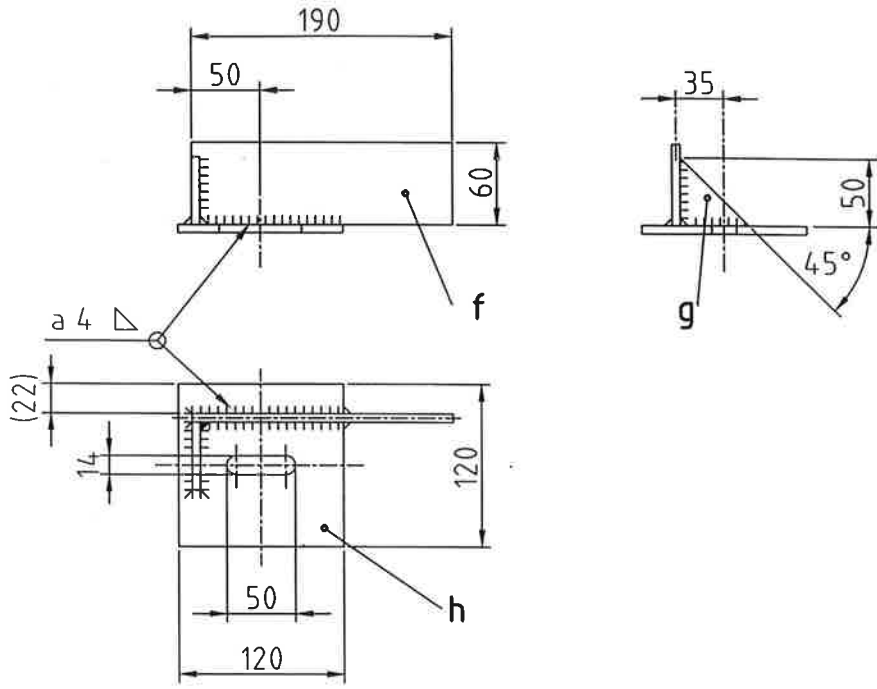
Total load 1.0 kN/m²



Pos.	Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	1	Top chord	NB 50 x 3.6 - 9600	5.03	48.5
b	1	Lower chord	NB 25 x 2.6 - 7700	1.99	15.6
c	2	Diagonal	NB 25 x 2.6 - 1550	1.99	6.3
d	2	Diagonal	NB 20 x 2.3 - 1520	1.4	4.4
e	4	Post	NB 20 x 2.3 - 700	1.4	4.1
f	10	Gusset	FB 60 x 6 - different l	2.83	6.4
g	2	Stiffening plate	FB 50 x 6 - 50	2.36	0.3
h	2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
i	2	Anchor plate	FB 120 x 6 x - 120	5.65	1.4
k	2	Anchor bolt/nut/washer	M12 - 120	---	0.6
				Mass total	89.0

(NB = nominal bore / FB = flat bar)



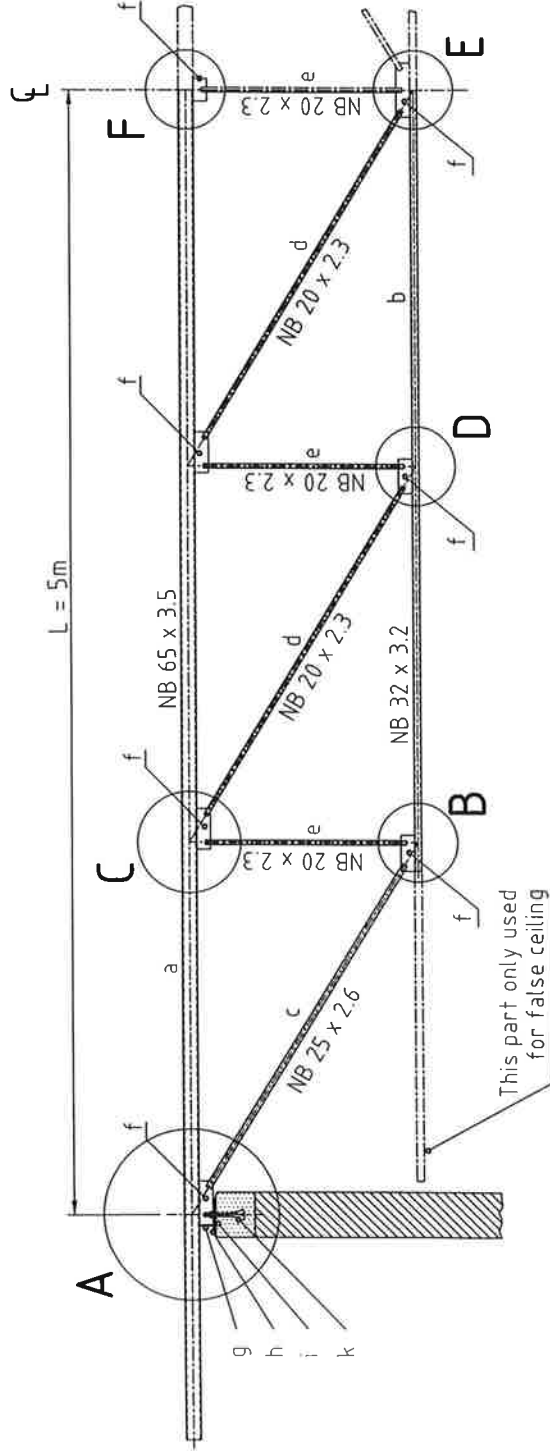
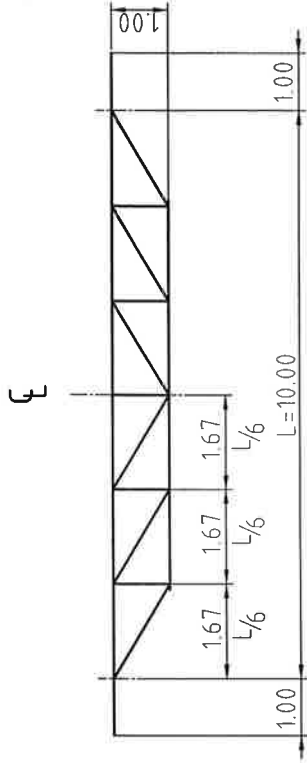


6.9.11 Flat Roof, Tube Truss, 10 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

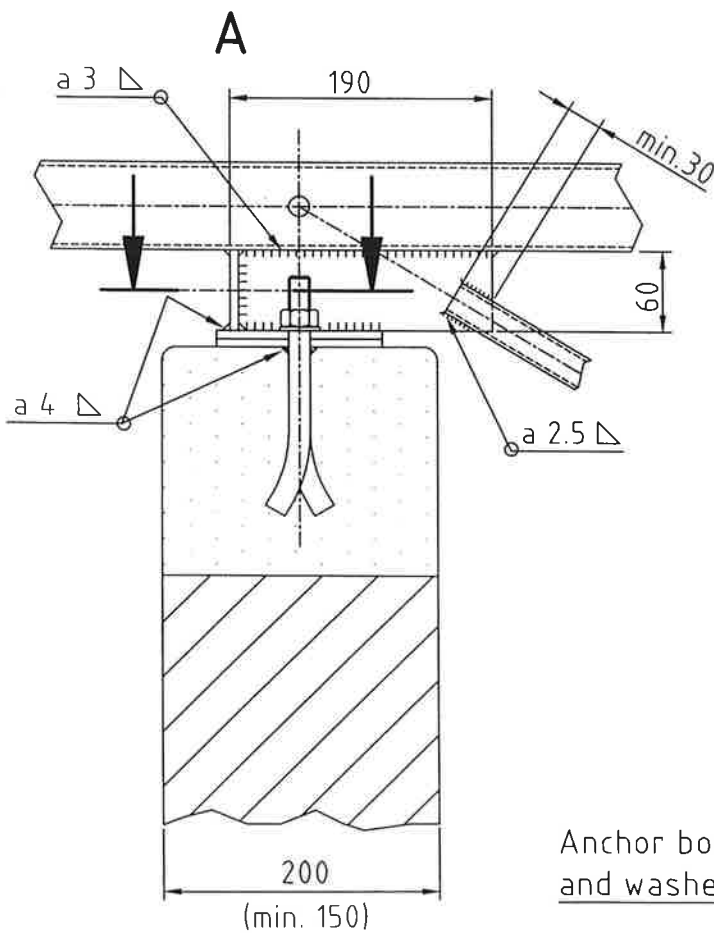
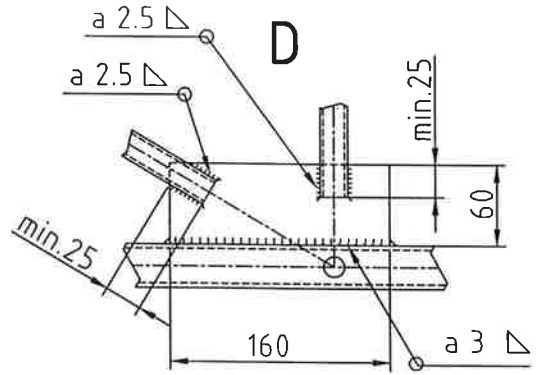
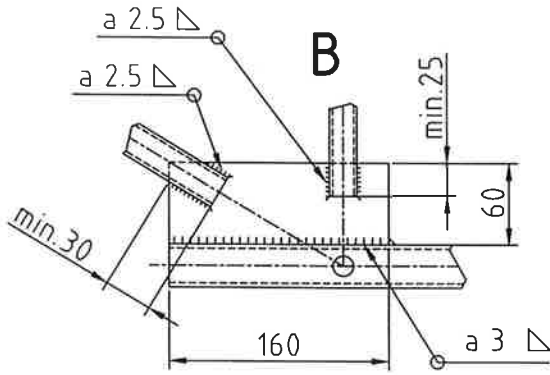
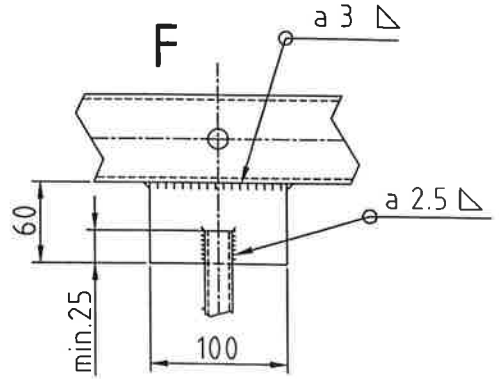
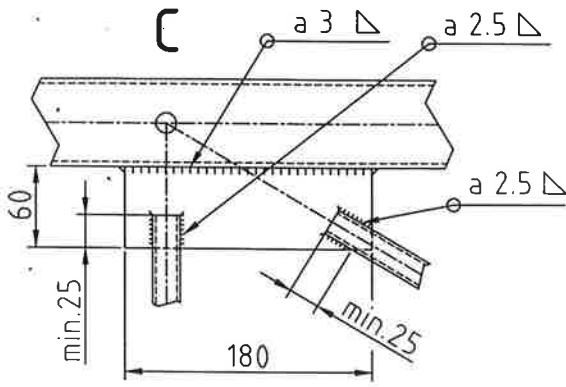
Spacing of truss 2.5 m

Total load 1.0 kN/m²

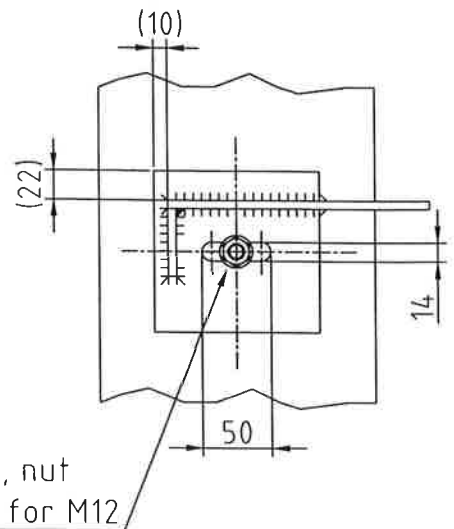


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	1 Top chord	NB 65 x 3.5 - 12000	6.44	771.3
b	1 Lower chord	NB 32 x 3.2 - 9700	3.09	30.0
c	2 Diagonal	NB 25 x 2.6 - 1720	1.99	6.8
d	4 Diagonal	NB 20 x 2.3 - 1700	1.4	9.6
e	5 Post	NB 20 x 2.3 - 880	1.4	6.2
f	14 Gusset	FB 60 x 6 - different L	2.83	6.4
g	2 Stiffening plate	FB 50 x 6 - 50	2.36	0.3
h	2 Sliding plate	FB 120 x 6 - 120	5.65	1.4
i	2 Anchor plate	FB 120 x 6 - 120	5.65	1.4
k	2 Anchor bolt/nut/washer M12 - 120		---	0.6
Mass total				140.0

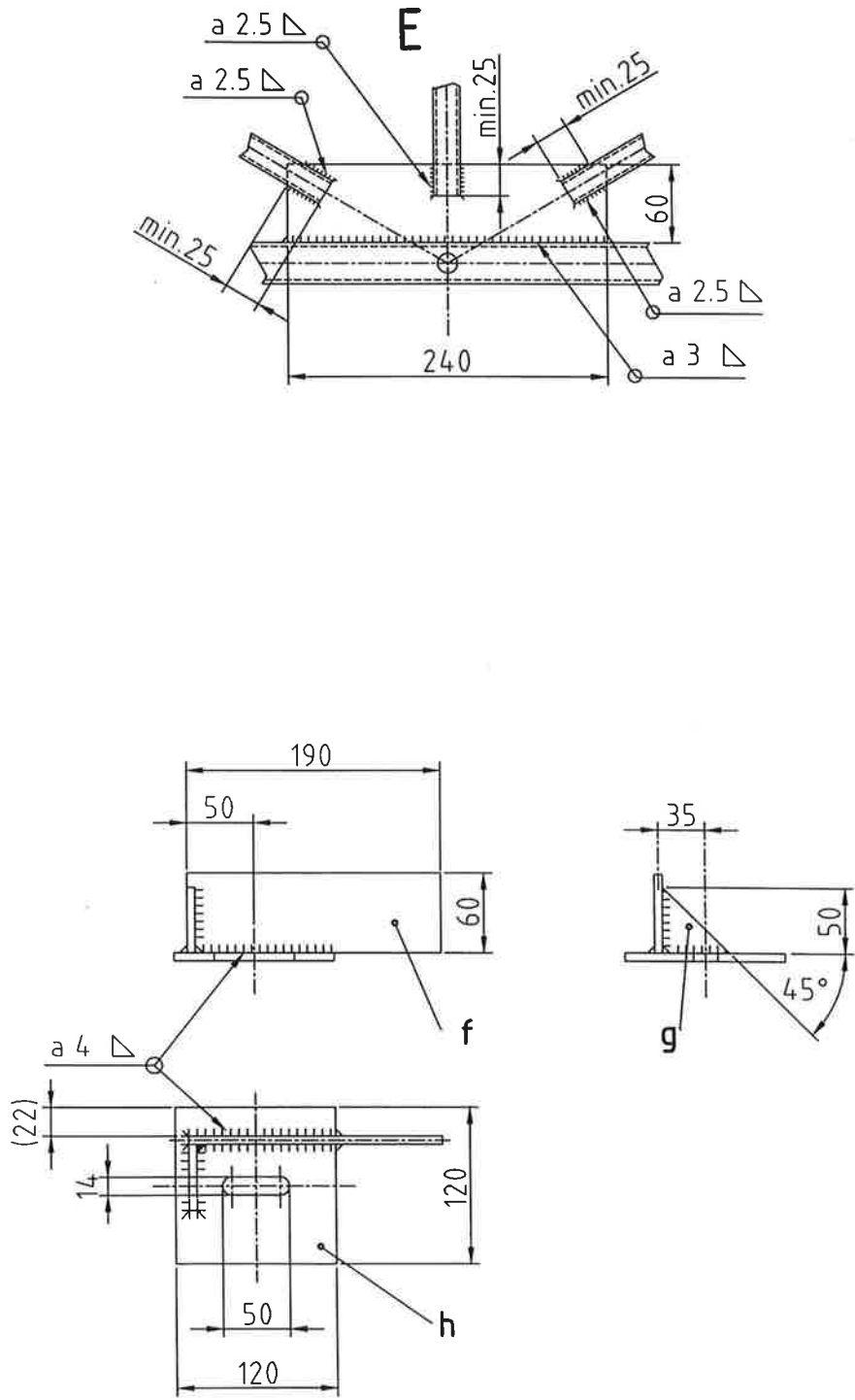
(NB = nominal bore / FB = flat bar)



Plan view Detail A



Anchor bolt, nut and washer for M12

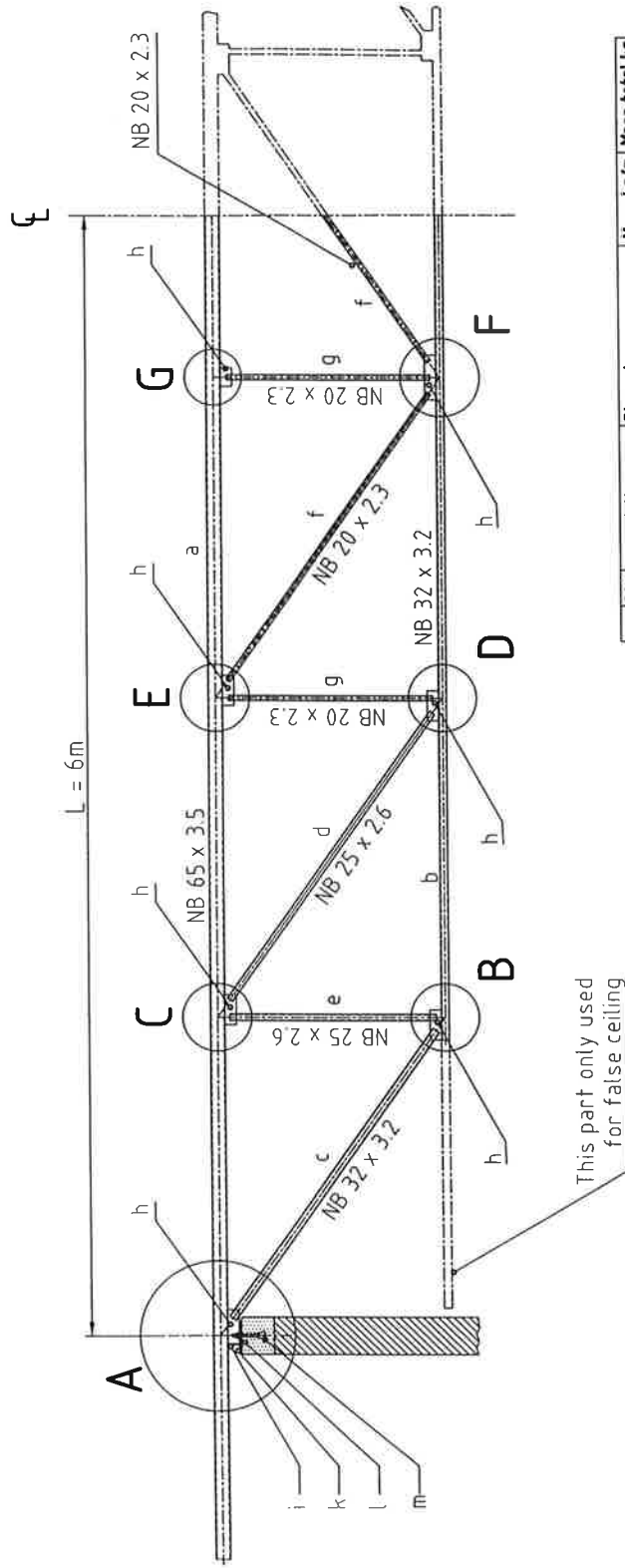
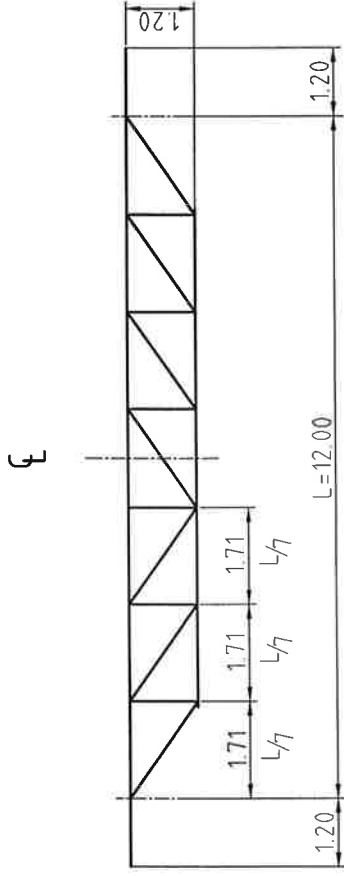


6.9.12 Flat Roof, Tube Truss, 12 m span

Roof Slope min 19°, max. 30°
 Bracing system according to Section 6.6.4 above

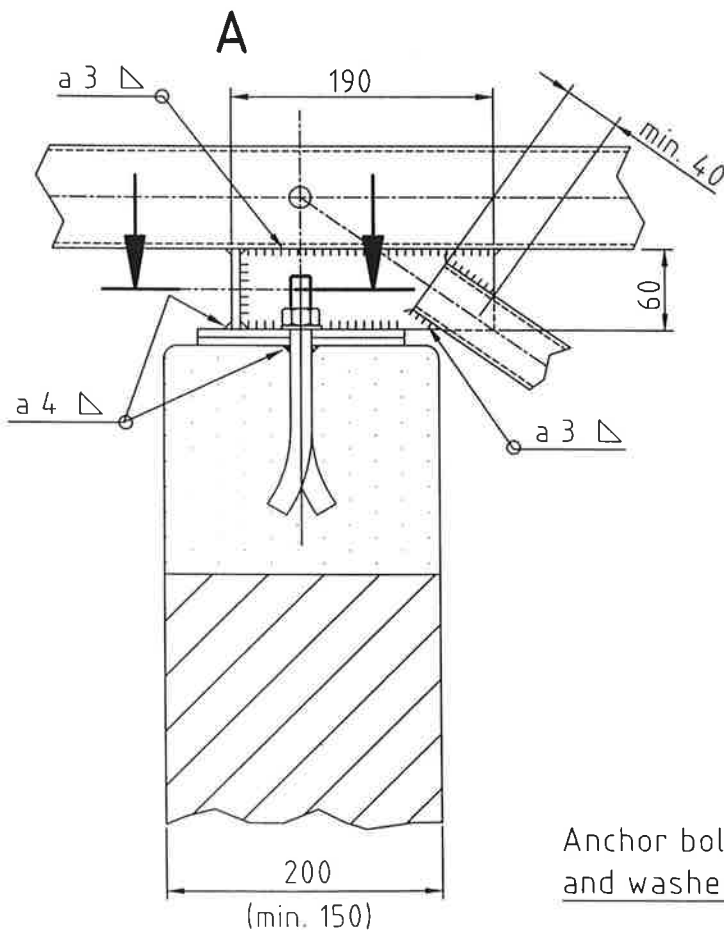
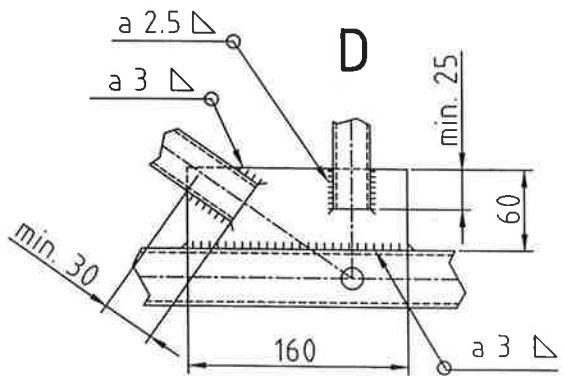
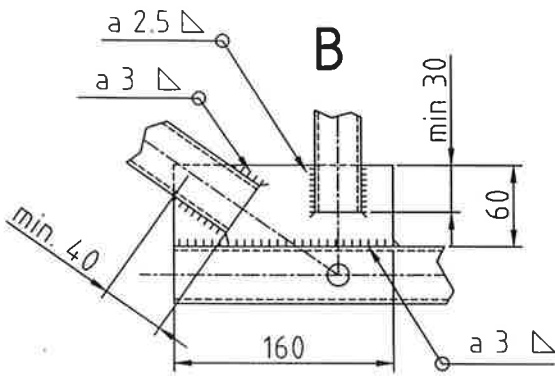
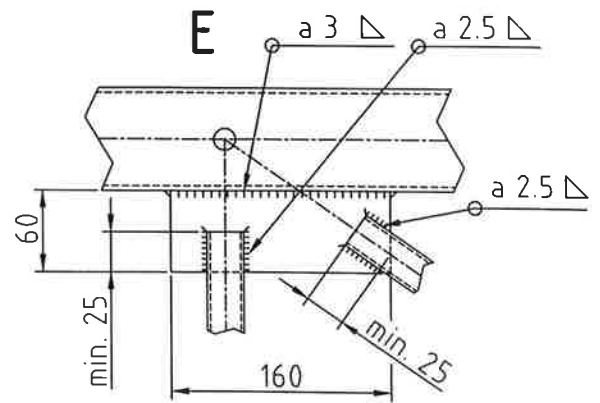
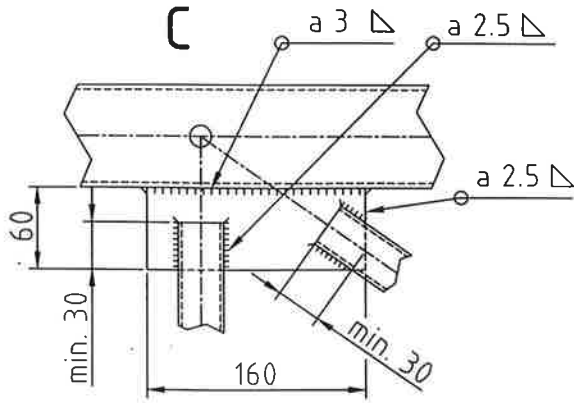
Spacing of truss 2.5 m

Total load 1.0 kN/m²

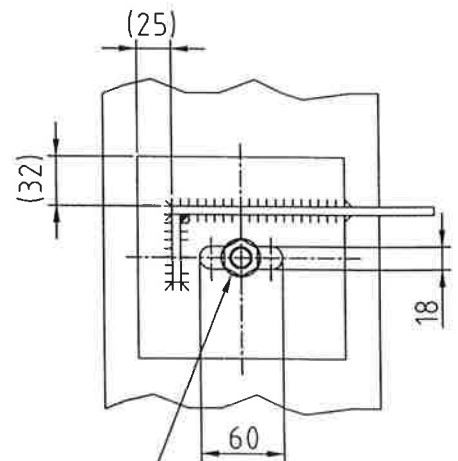


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	1 Top chord	NB 65 x 3.5 - 14.400	6.44	92.8
b	1 Lower chord	NB 32 x 3.2 - 11700	3.09	36.3
c	2 Diagonal	NB 32 x 3.2 - 1890	3.09	11.7
d	2 Diagonal	NB 25 x 2.6 - 1880	1.99	7.5
e	2 Post	NB 25 x 2.6 - 1090	1.99	4.4
f	2 Diagonal	NB 20 x 2.3 - 1870	1.4	5.3
g	4 Post	NB 20 x 2.3 - 1080	1.4	6.2
h	14 Gusset	FB 60 x 6 - diverse	2.83	6.4
i	2 Stiffening plate	FB 50 x 6 - 50	2.36	0.3
k	2 Sliding plate	FB 150 x 6 - 150	7.07	2.2
l	2 Anchor plate	FB 150 x 6 - 150	1.07	2.2
m	2 Anchor bolt/nut/washer	M16 - 150	---	0.7
Mass total			---	176.0

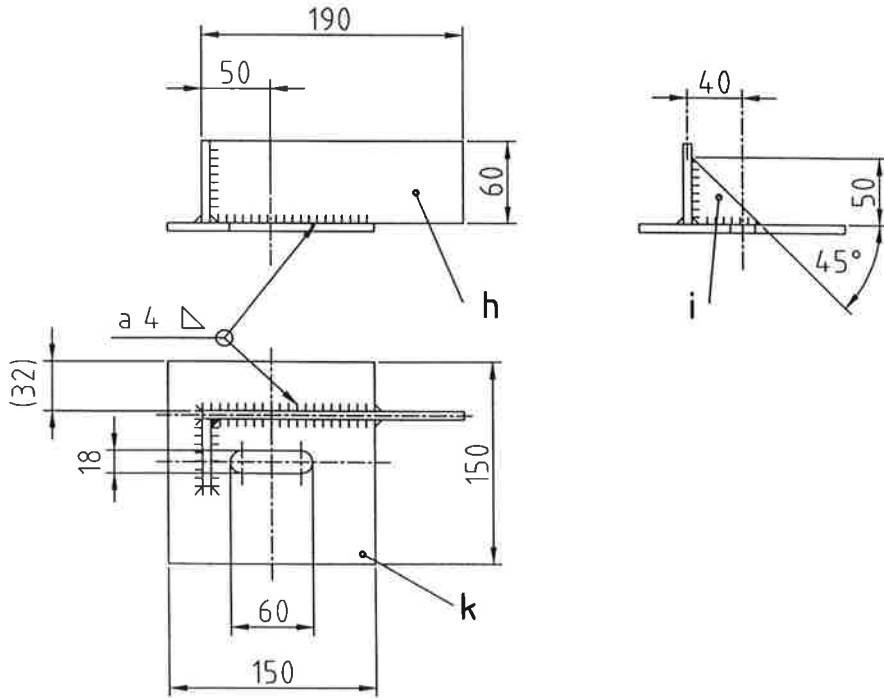
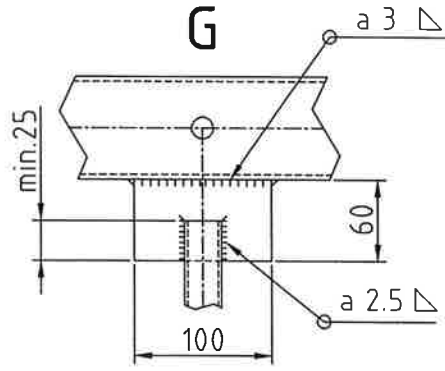
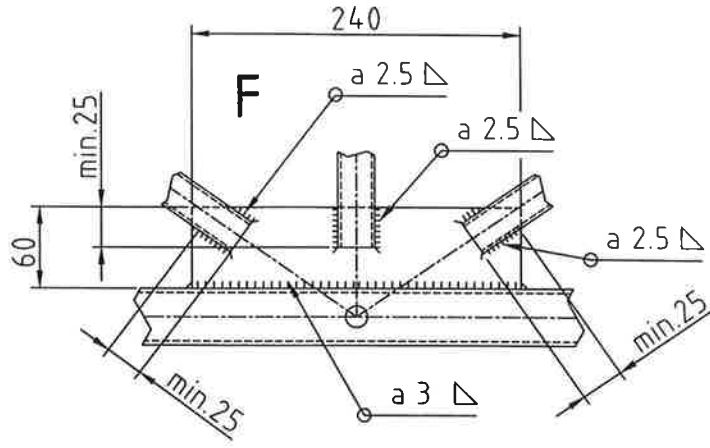
(NB = nominal bore / FB = flat bar)



Plan view Detail A



Anchor bolt, nut and washer for M16



6.10 Reinforcing Bar Truss

6.10.1 General

Pros and cons

The reinforcing bar truss is not the most economical option for roof truss design as solid bars do not make efficient compression members. Rebars have poor strength against buckling due to the concentration of the mass in the centre (tubes are much better in that regard). Nevertheless, reinforcing bar trusses may be selected for basically three reasons:

- Their airy and light, open appearance is highly attractive from the architectural point of view;
- The reinforcing bars can easily be cut and welded on site. The rebar truss is thus preferred by local workshops with limited (planning) capacities for pre-fabrication in the workshop and with few skilled personnel. Welding solid bars requires less skill than welding thin-walled tubes or angle bars.
- Thanks to its low weight, the rebar truss can easily be handled at the construction site and put in place by manual labour without the use of lifting devices.

6.10.2 Design

Rebar trusses come in the form of joists with parallel chords. These are used in roofs as simply supported beams between walls (single pitch roof) or between wall and ridge purlins (double pitch roof). The ridge purlins, which span the distance between gable or intermediate walls, cannot be designed as rebar joists. The load is too large for the slender compression members. Tube trusses with parallel chords are proposed instead.

Only diameters 8, 10 and 12 mm are normally used for the simple rebar joists. This is because larger diameter bars cannot be easily cut on site using cutters. Only one bar size should be used for a particular truss. The use of two or three different bar sizes would result in confusion and errors on the construction site. Assumed yield stress of the rebars is 200 MPa.

The depth of the joists as proposed in this manual is limited to 300 mm. The spacing of the web members is 400 mm for all joists proposed. This is to make sure that the battens, which have a spacing of 400 mm for MCR tiles, coincide with the panel points of the joist and do not provoke bending of chord members due to loading off the panel points.

An overhang of maximum one metre can be accomplished with the proposed designs. The standard joists consists of two longitudinal bars for the top chord and two longitudinal bars for the lower chord. Web members are welded in between the two chord members. For the sections with increased stresses such as at mid-span and at the supports, additional bars are welded in parallel to the standard bars where required.

6.10.3 Details

Joints

The rebars are jointed by fillet welding without the use of gusset plates.

Support detail

A vertical support plate is welded in between the lower chord bars. The support plate rests on two bearing plates, which are anchored into the masonry wall with a concrete pad to distribute the load. The top one of the two bearing plates has a slotted hole to allow horizontal movements due to thermal expansion of the steel bars. A lot of grease must be applied to the sliding surfaces of the bearing plates to reduce friction.

Battens

A standard truss spacing is 1.50 m. If rebars are also used for the battens then their diameter must be at least 16 mm. The use of light weight angle bars (EA 40 x 40 x 6 or EA 45 x 45 x 5) may be considered.

6.10.4 Bracing

X-bracing in end fields of the roof (or at least in every fifth field) is proposed to avoid overturning of individual trusses and to provide a lateral restraining system against buckling of compression members. The X-braces consist of rebars welded diagonally onto the top chord of the truss. They form bracing trusses together with the battens.

In addition to the X-bracing, lateral support structures are needed at the support and at the free overhanging end of the joist. These support structures are similarly built bar joists but with single chord members.

6.11 *Rebar Truss Samples*

6.11.1 Assumptions and Limits of Application

- Yield strength of bars is 200 MPa (N/mm²)
- Loads are permissible loads (not ultimate capacities)
- Loads are applied through the top chord

Designation:

The bar joists are designated as follows:

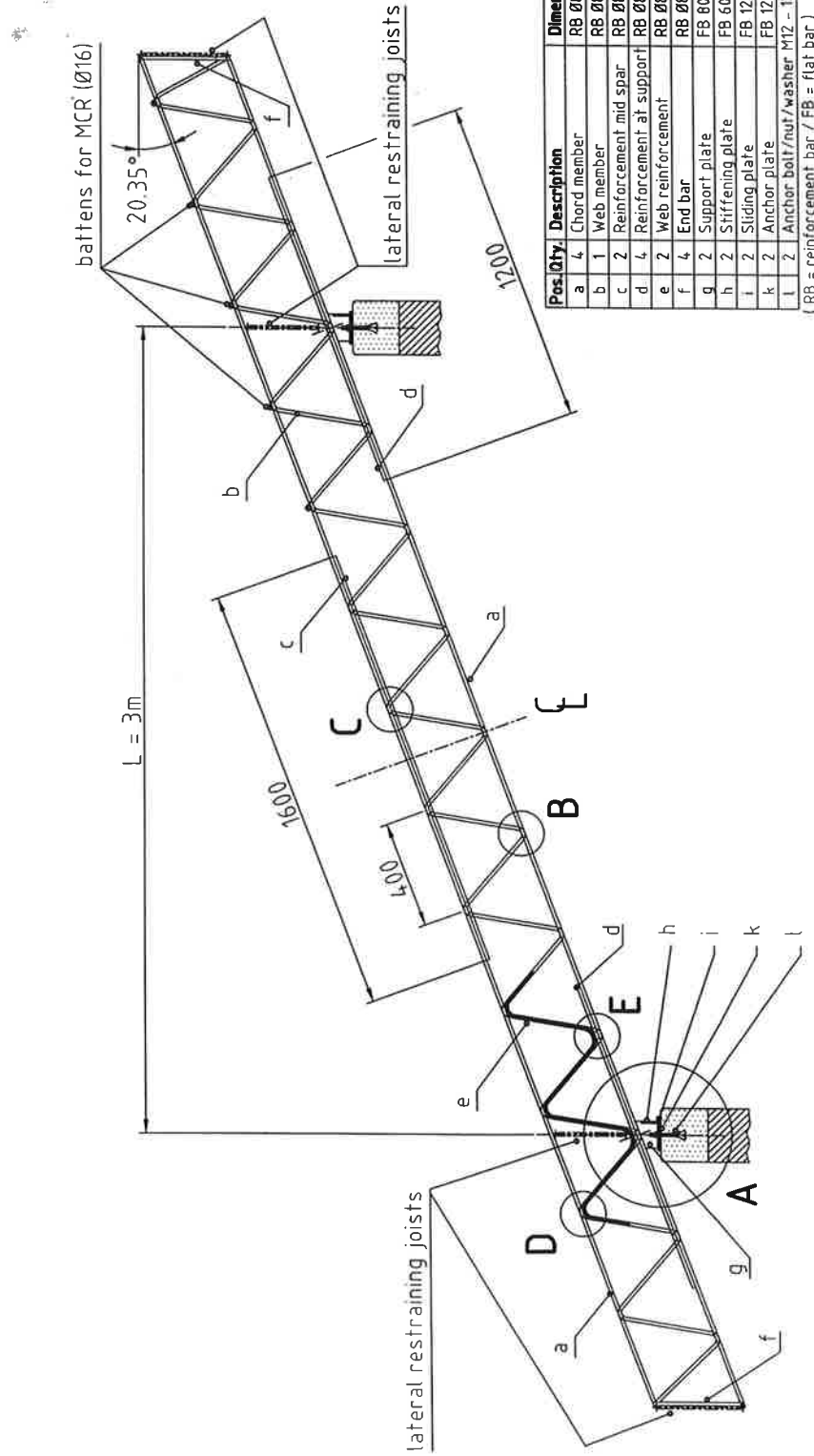
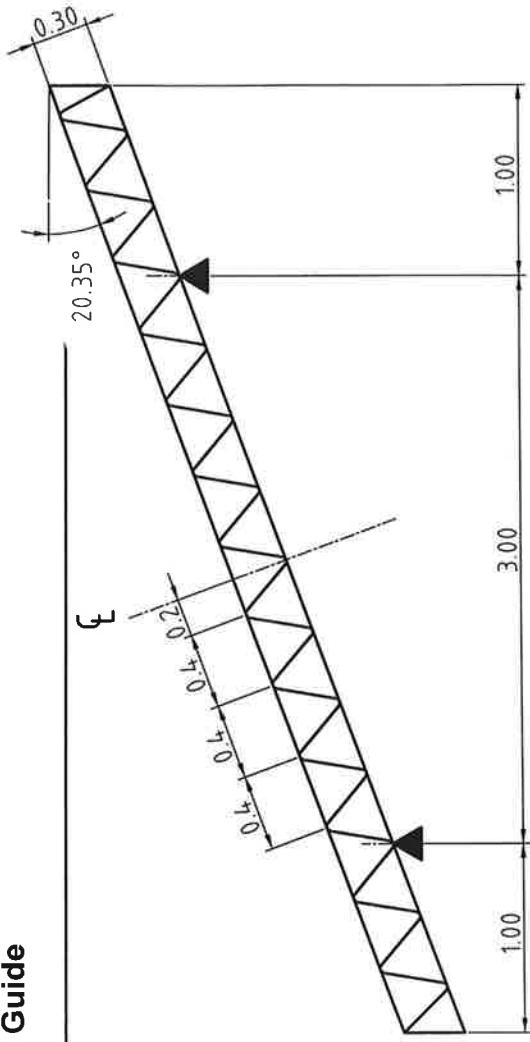
- The depth of the joist in mm is preceding the abbreviation "BJ" for bar joist
- The diameter of the rebars used is added to BJ.
- A "300BJ08" is a joist made of 8 mm rebars and with a depth of 300 mm

6.11.2 Rebar Joist 300 BJ08 for 3 m span (± 0.5 m)

Bracing system according to Section 6.10.4 above

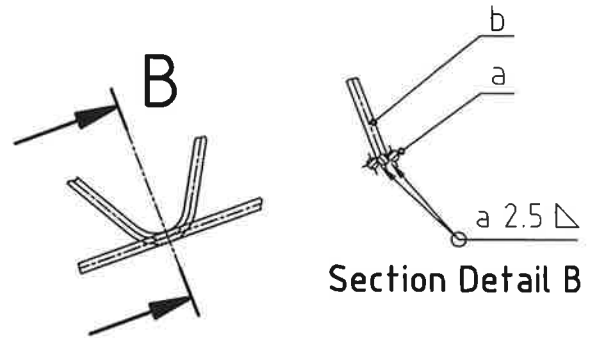
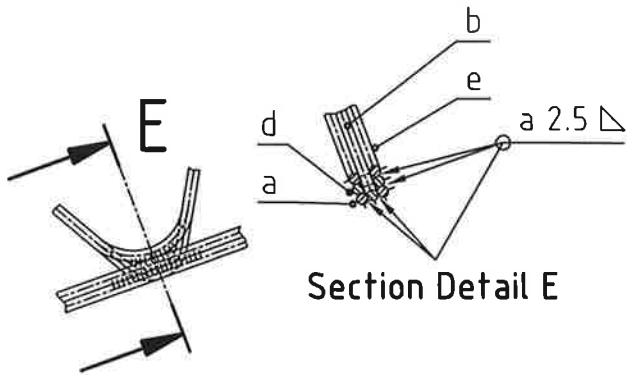
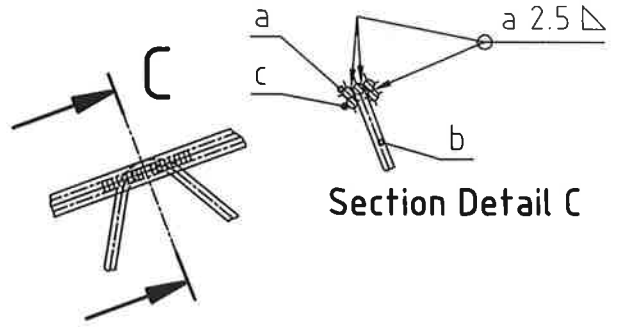
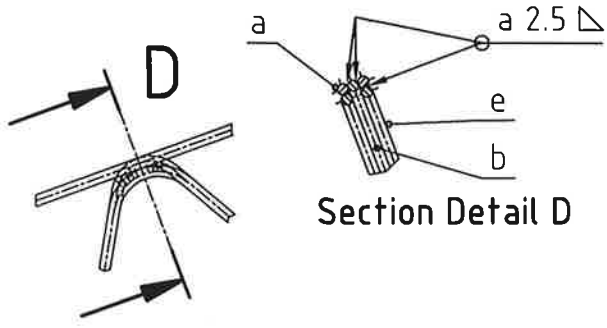
Spacing of truss 1.5 m

Total load 1.0 kN/m²

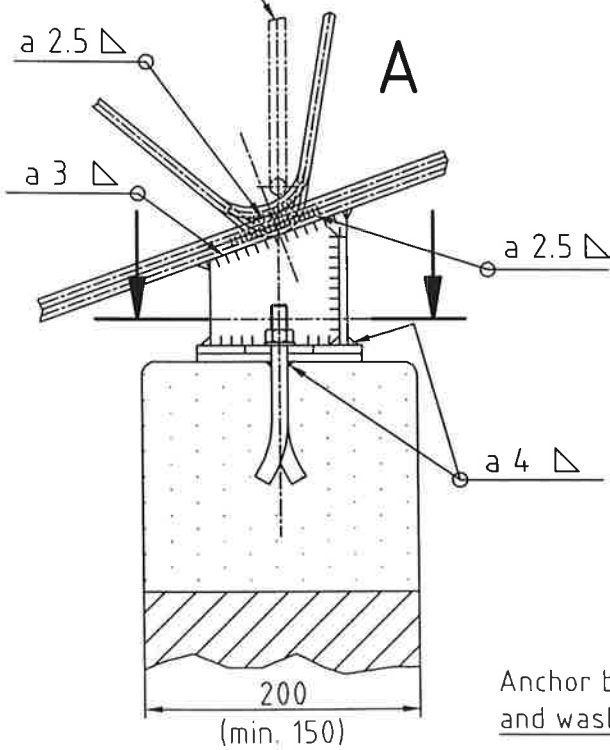


Pos./Qty	Description	Dimensions	Mass kg/m	Mass Total kg
a	4 Chord member	RB Ø8 x 5350	0.4	8.8
b	1 Web member	RB Ø8 x 9450	0.4	4.2
c	2 Reinforcement mid spar	RB Ø8 x 1600	0.4	1.3
d	4 Reinforcement at support	RB Ø8 x 1200	0.4	2.0
e	2 Web reinforcement	RB Ø8 x 875	0.4	1.5
f	4 End bar	RB Ø8 x 350	0.4	0.6
g	2 Support plate	FB 80 x 6 - 100	2.83	0.8
h	2 Stiffening plate	FB 60 x 6 - 60	2.36	0.4
i	2 Sliding plate	FB 120 x 6 - 120	5.65	1.4
k	2 Anchor plate	FB 120 x 6 - 120	5.65	1.4
l	1 2 Anchor bolt/nut/washer M12 - 120		---	0.6
			Mass Total	24.0

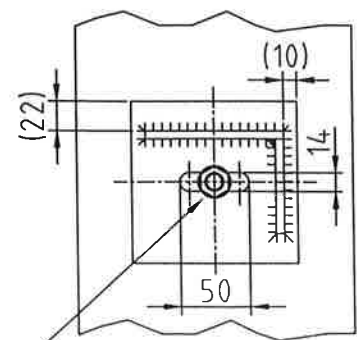
(RB = reinforcement bar / FB = flat bar)



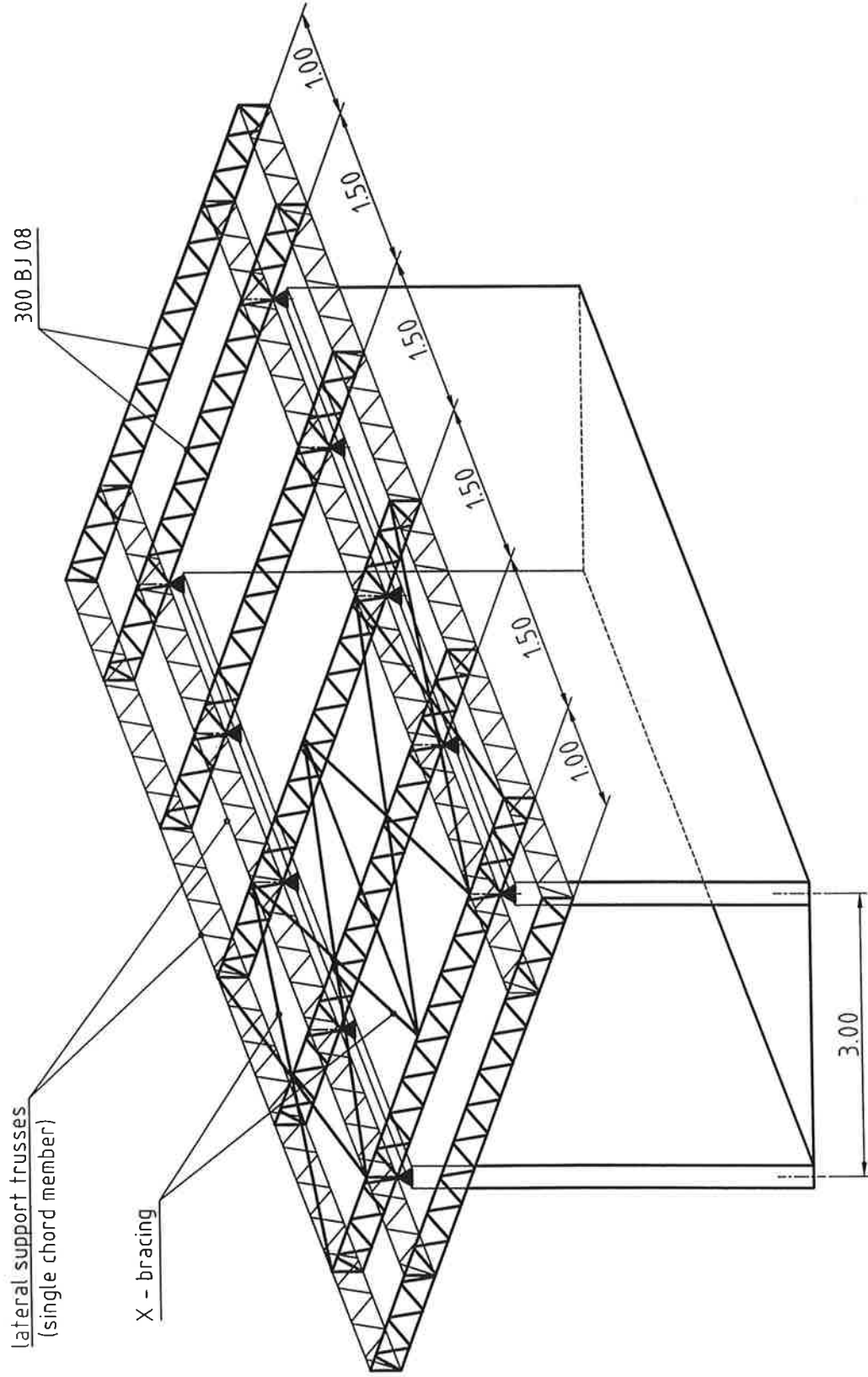
Position of lateral
restraining joist

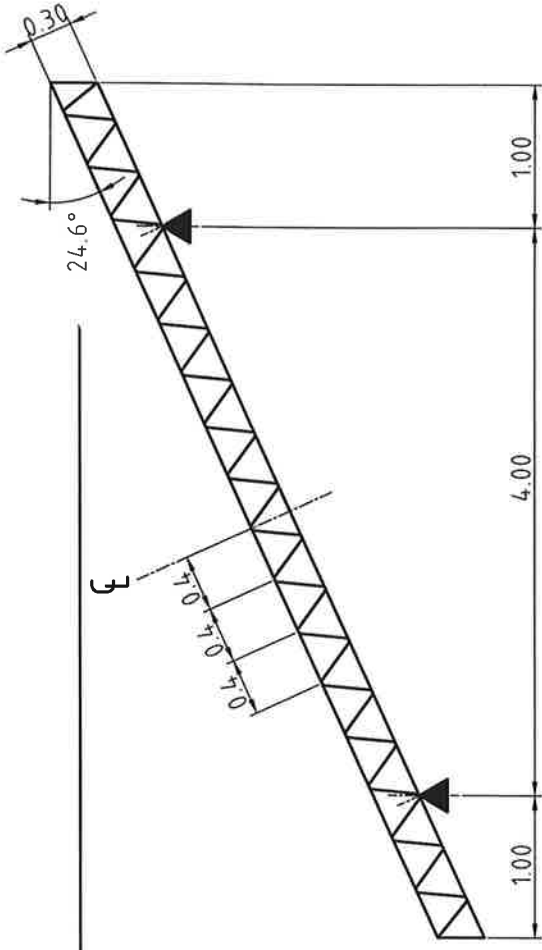


Plan view Detail A



Anchor bolt, nut
and washer for M12



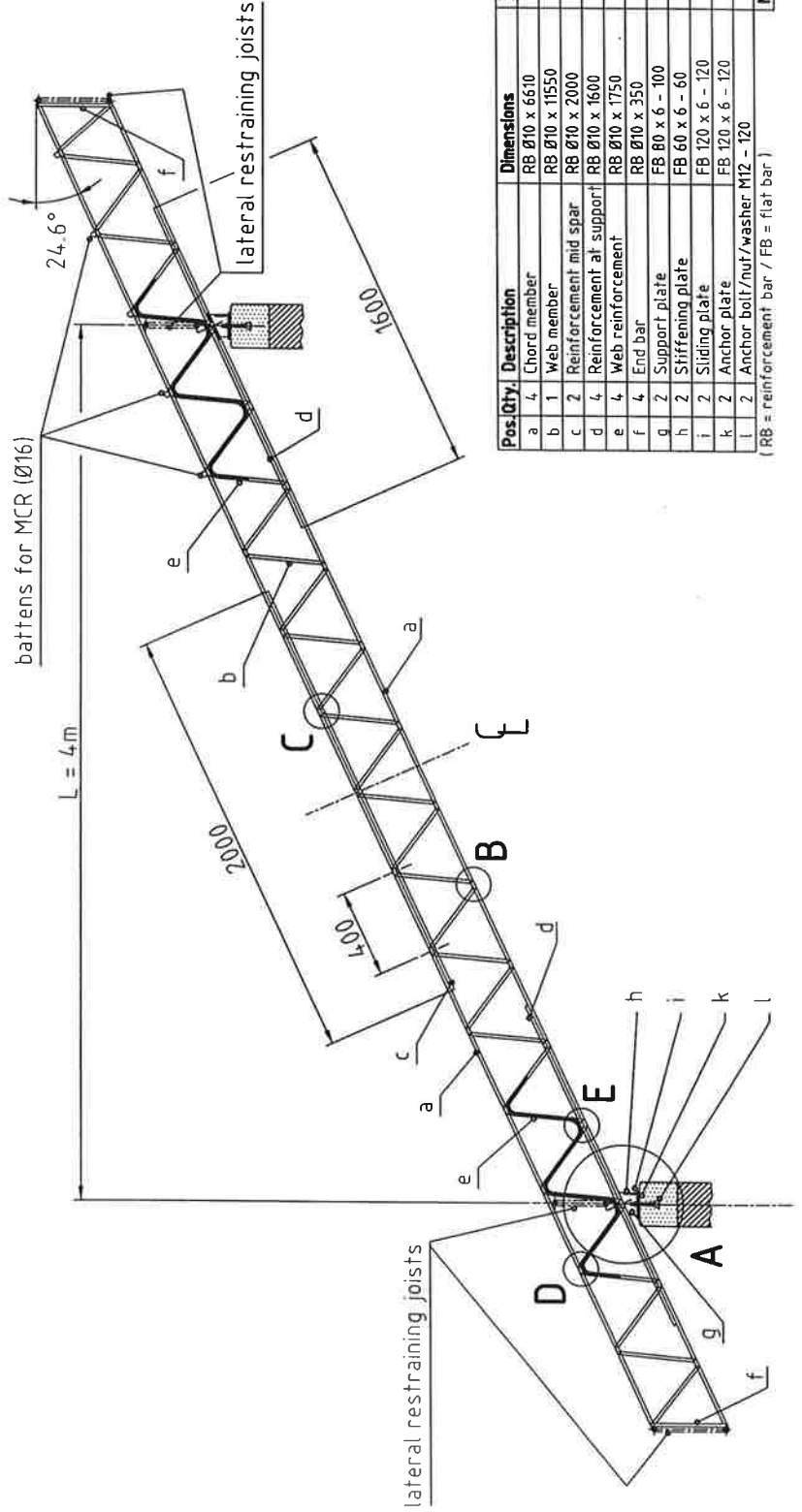


6.11.3 Rebar Joist 300 BJ10 for 4 m span (± 0.5 m)

Bracing system according to Section 6.10.4 above

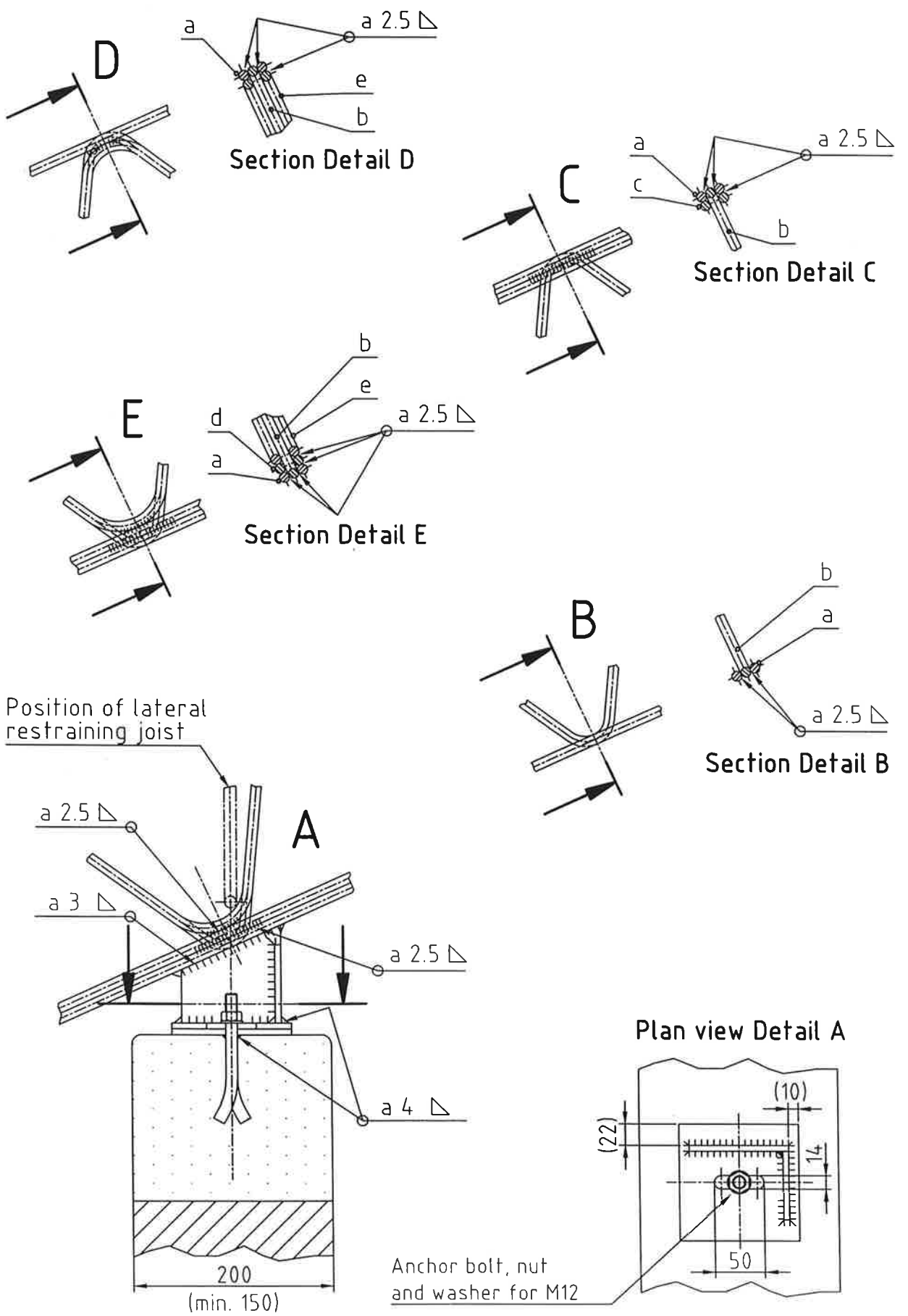
Spacing of truss 1.5 m

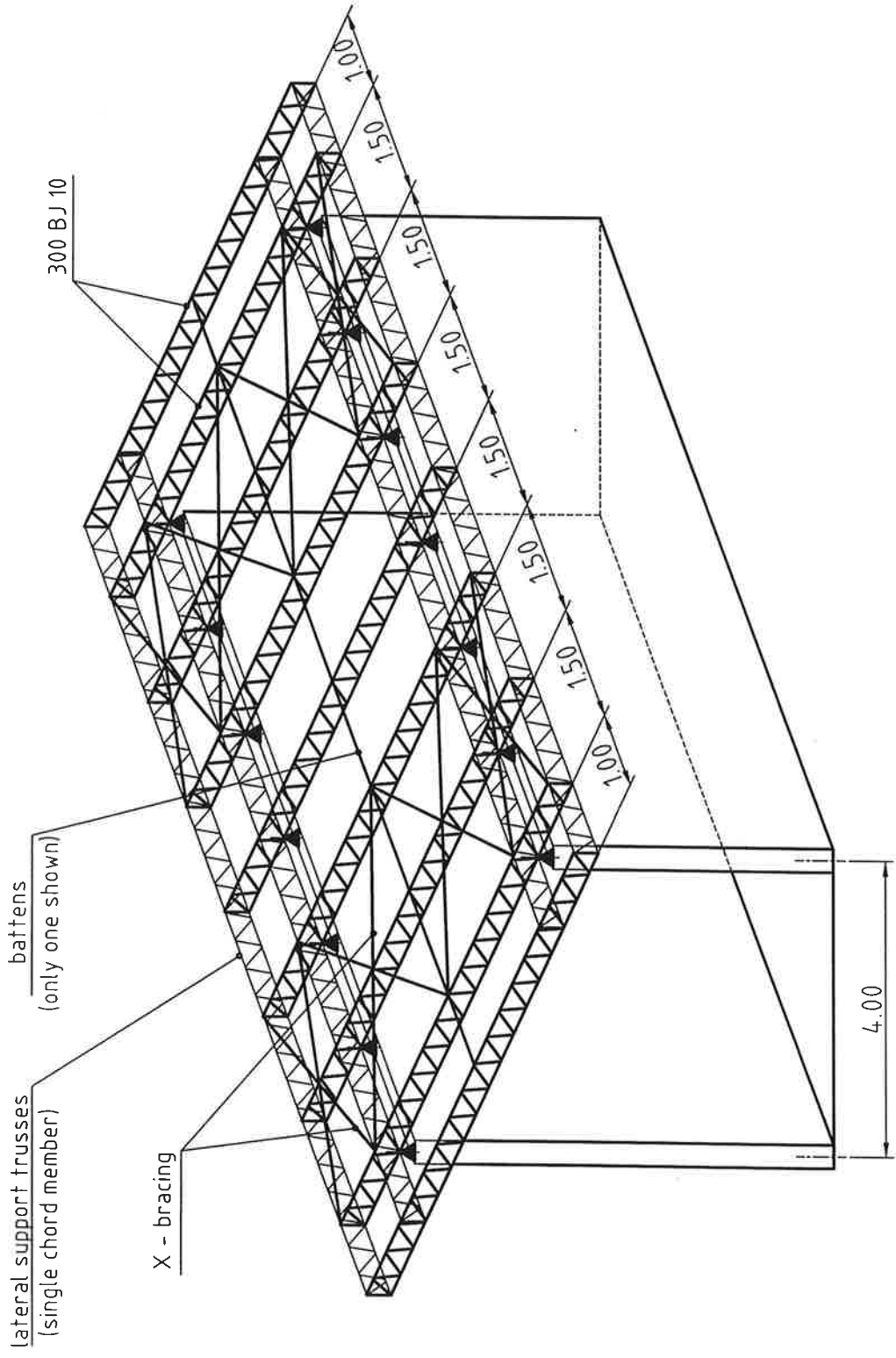
Total load 1.0 kN/m²

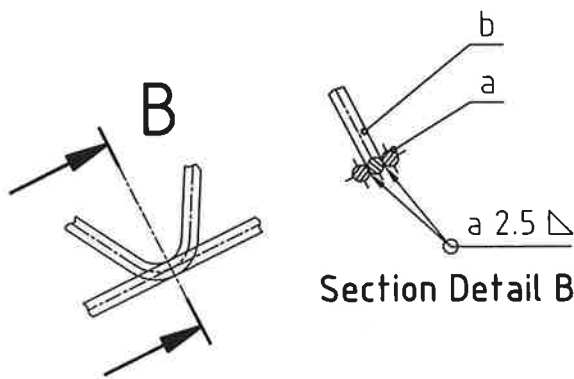
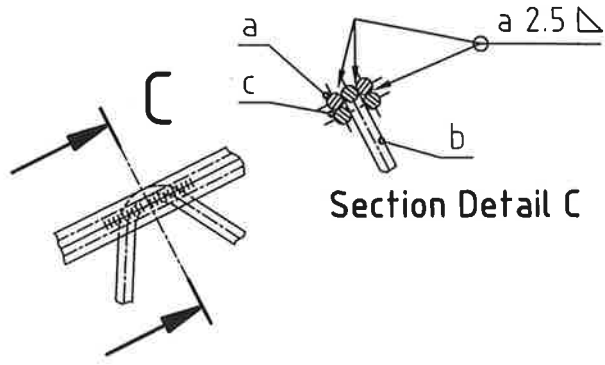


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 4	Chord member	RB Ø10 x 6610	0.62	16.4
b 1	Web member	RB Ø10 x 11550	0.62	7.2
c 2	Reinforcement mid spar	RB Ø10 x 2000	0.62	2.5
d 4	Reinforcement at support	RB Ø10 x 1600	0.62	4.0
e 4	Web reinforcement	RB Ø10 x 1750	0.62	4.4
f 4	End bar	RB Ø10 x 350	0.62	0.9
g 2	Support plate	FB 80 x 6 - 100	2.83	0.8
h 2	Stiffening plate	FB 60 x 6 - 60	2.36	0.4
i 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
k 2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
l 2	Anchor bolt/nut/washer M12 - 120		---	0.6
	Mass total			40.0

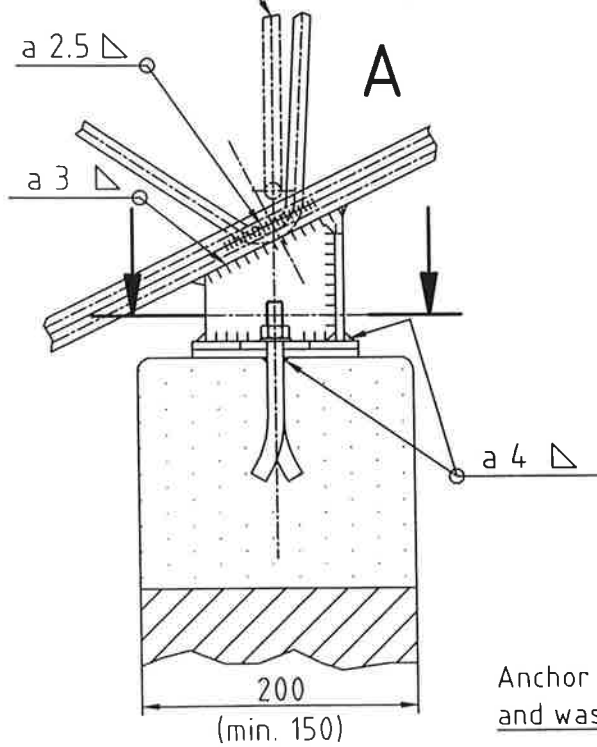
(RB = reinforcement bar / FB = flat bar)



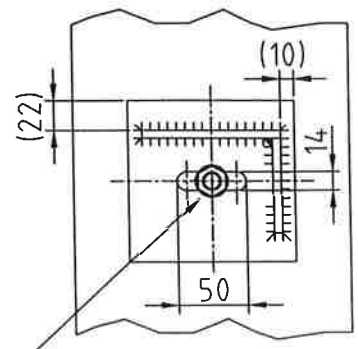




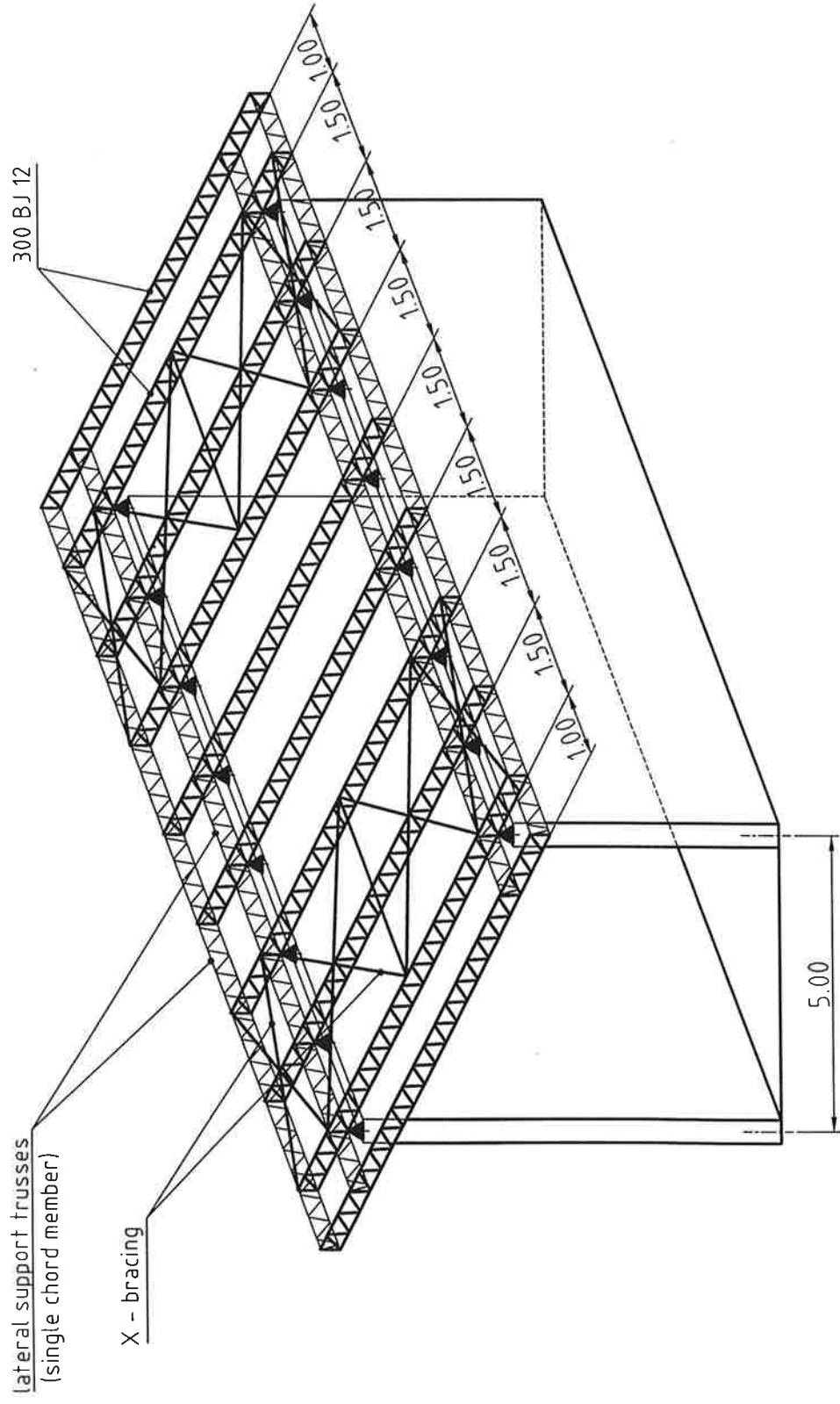
Position of lateral restraining joist



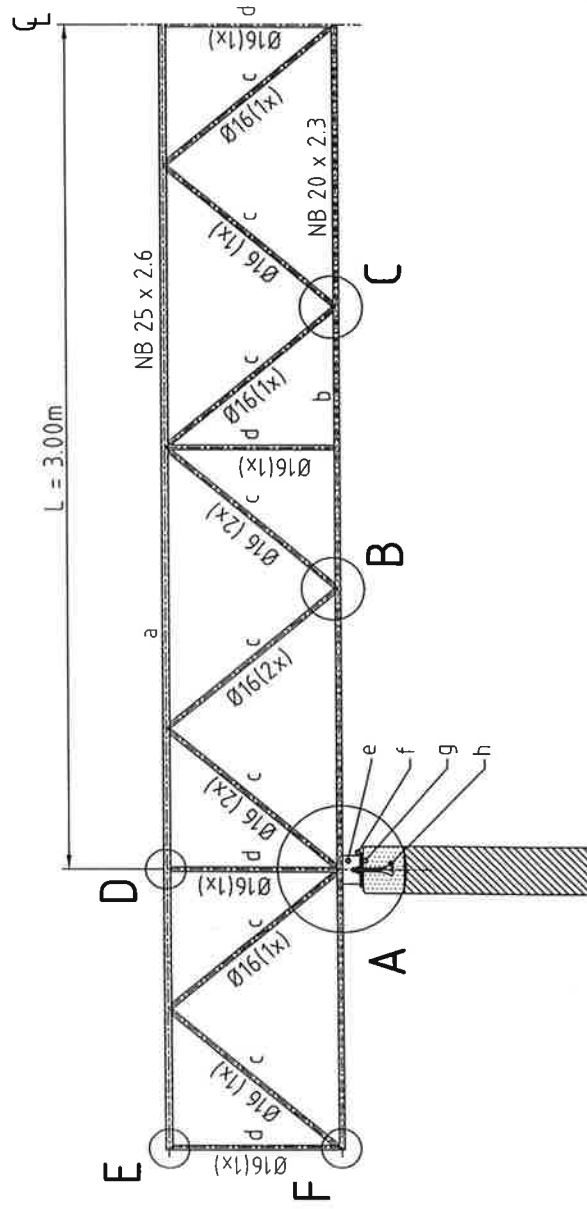
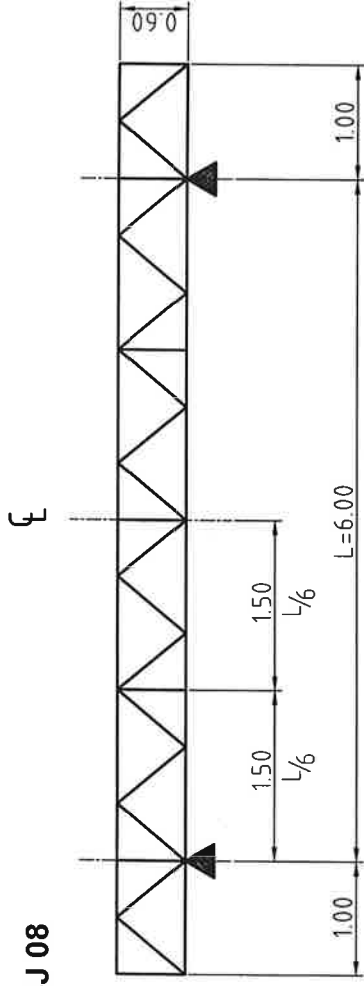
Plan view Detail A



Anchor bolt, nut and washer for M12



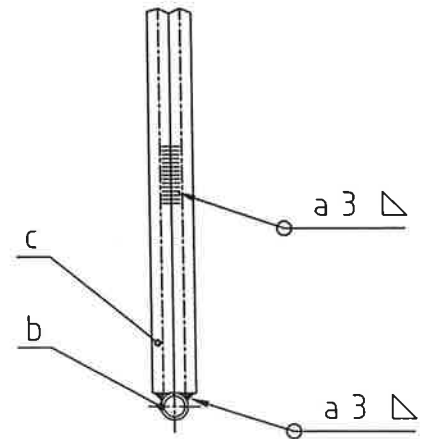
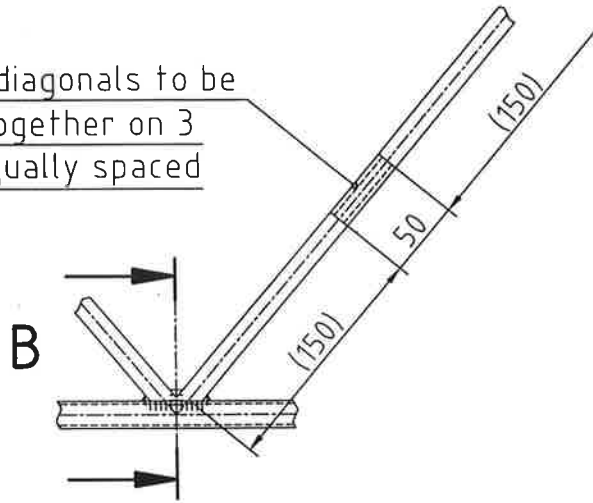
**6.11.5 Double Pitch Roof (6 m span) for Rebar Joists 300 BJ 08
Associated Ridge Purlin (Tube truss), 6 m span**



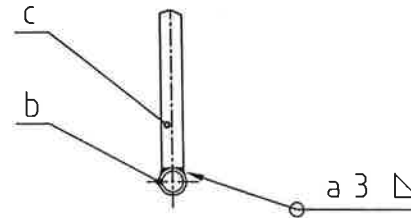
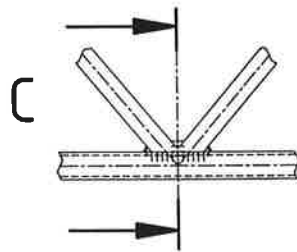
Pos./Qty.	Description	Dimensions	Mass kg/m	Mass Total kg
a 1	Top chord	NB 25 x 2.6 - 8000	1.99	16.1
b 1	Lower chord	NB 20 x 2.3 - 8000	1.4	11.4
c 22	Diagonal	RB Ø16 x 745	1.58	26.0
d 7	Post	RB Ø16 x 575	1.58	6.5
e 2	Support plate	FB 60 x 6 - 100	2.36	0.6
f 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
g 2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
h 2	Anchor bolt/nut/washer M12 - 120		---	0.6
	Mass total			64.0

(NB = nominal bore / RB = reinforcement bar / FB = flat bar)

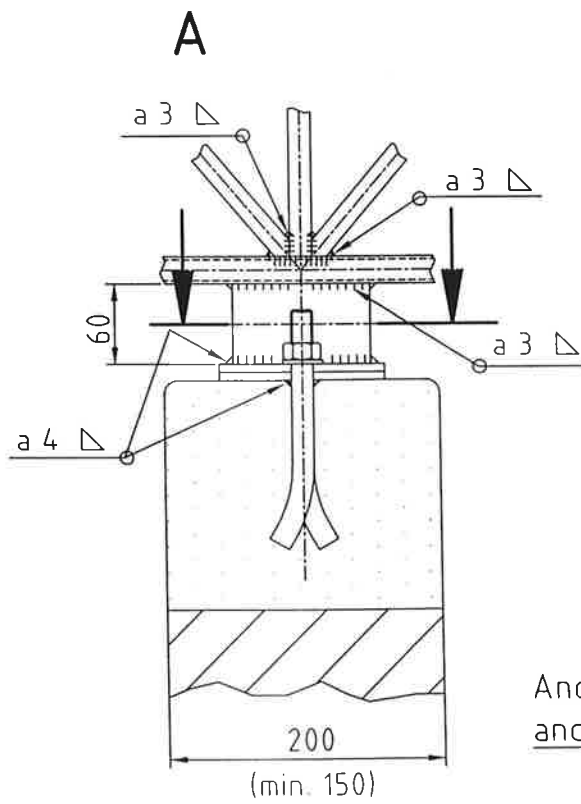
The two diagonals to be welded together on 3 places equally spaced



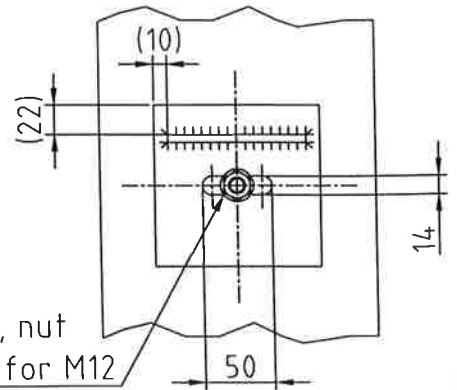
Section Detail B



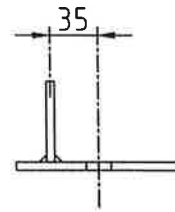
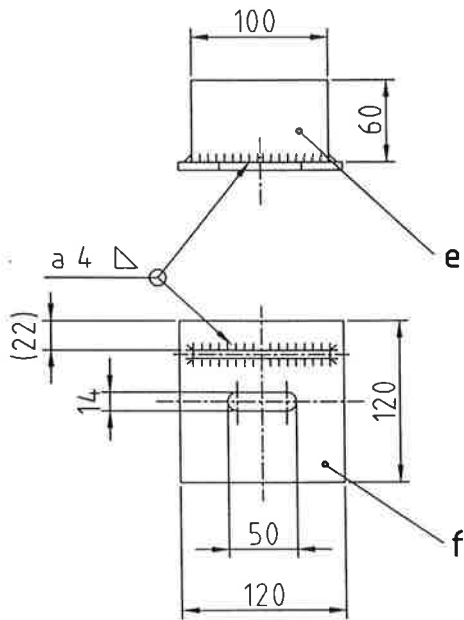
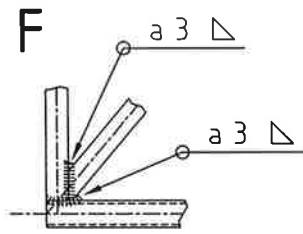
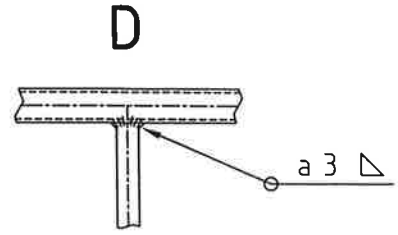
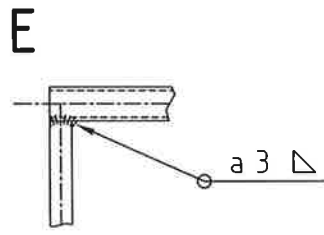
Section Detail C

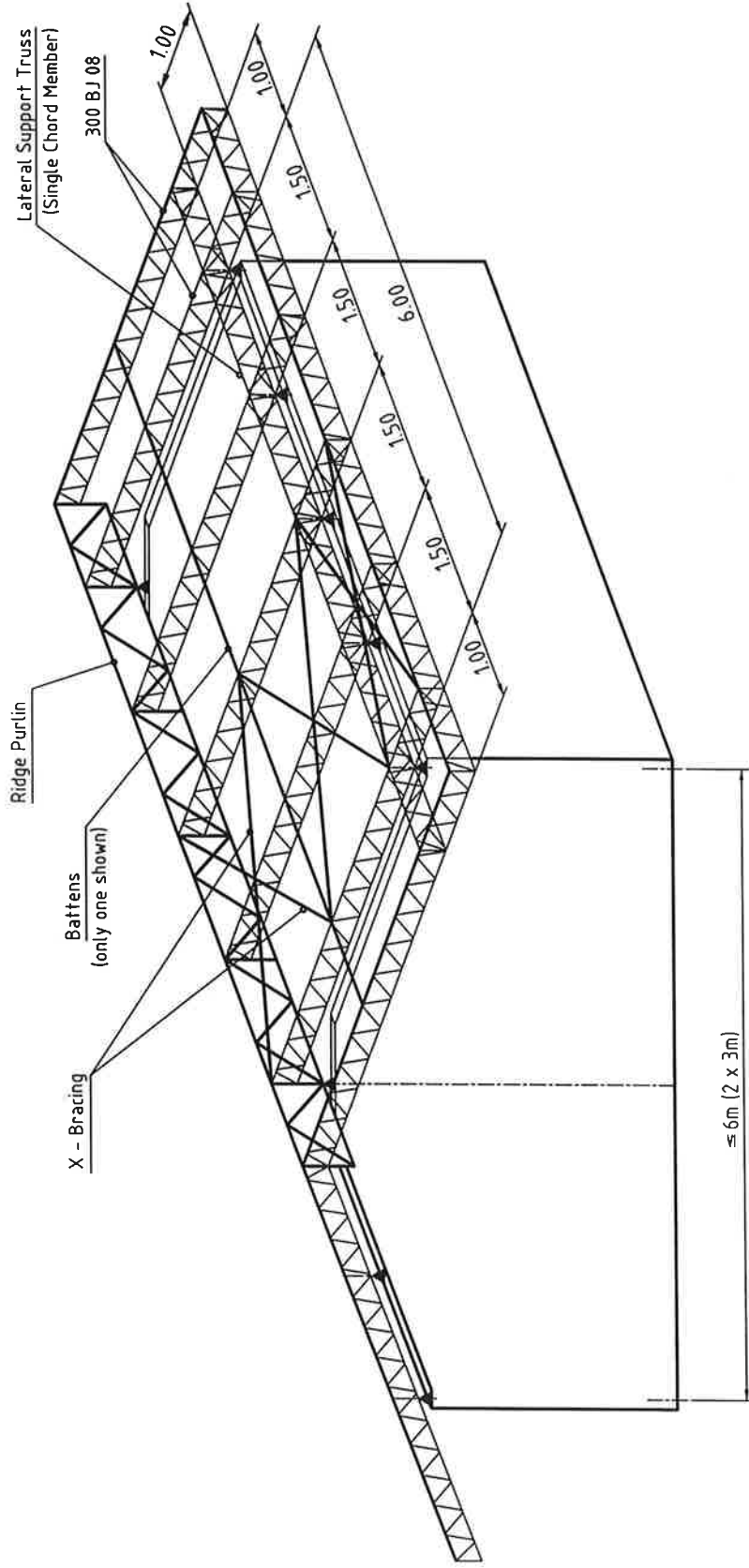


Plan view Detail A

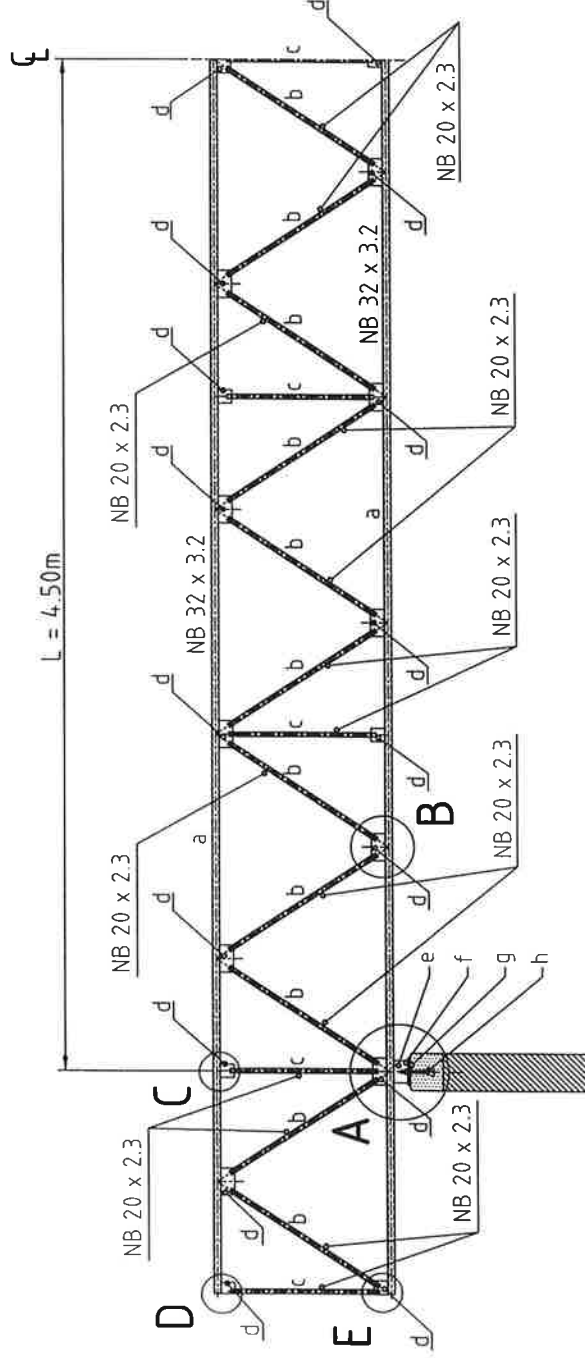
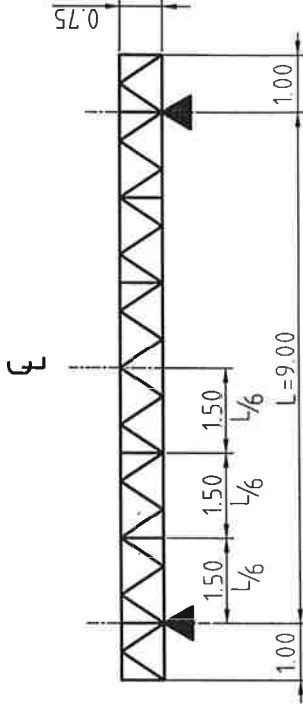


Anchor bolt, nut and washer for M12



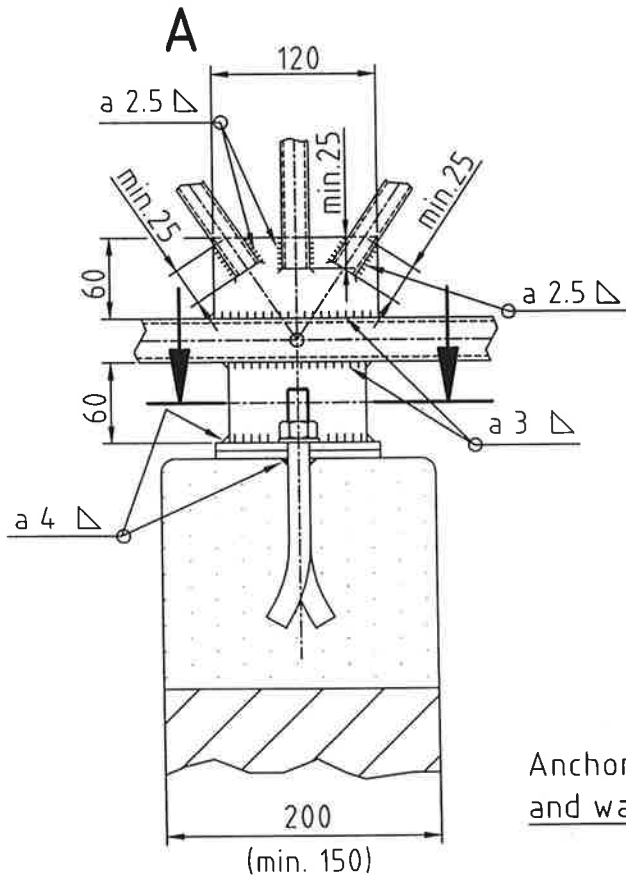
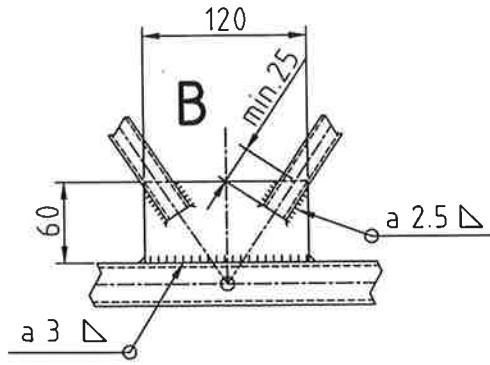


**6.11.6 Double Pitch Roof (6 m span) for Rebar Joists 300 BJ 08
Associated Ridge Purlin (Tube truss), 9 m span**

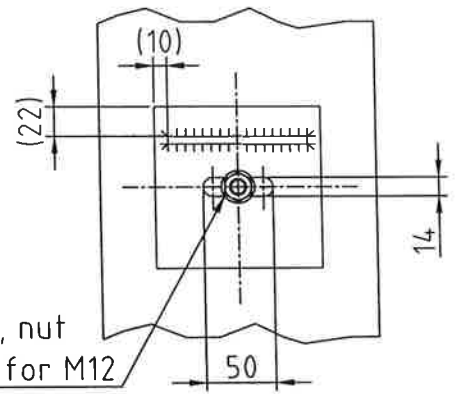


Pos. Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 2	Chord member	NB 32 x 3.2 - 11000	3.09	68.1
b 22	Diagonal	NB 20 x 2.3 - 770	1.4	23.8
c 9	Post	NB 20 x 2.3 - 640	1.4	8.1
d 32	Gusset	FB 60 x 6 - different I	2.83	9.0
e 2	Support plate	FB 60 x 6 - 100	2.36	0.6
f 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
g 2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
h 2	Anchor bolt/nut/washer M12 - 120	----	----	0.6
Mass Total			113.0	113.0

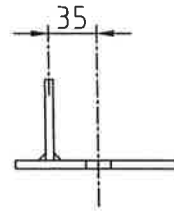
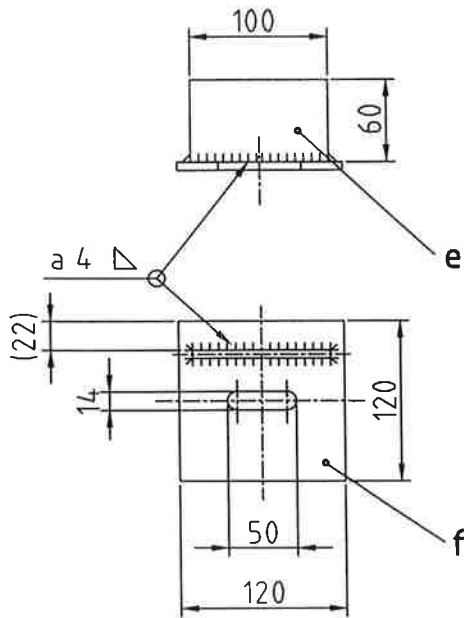
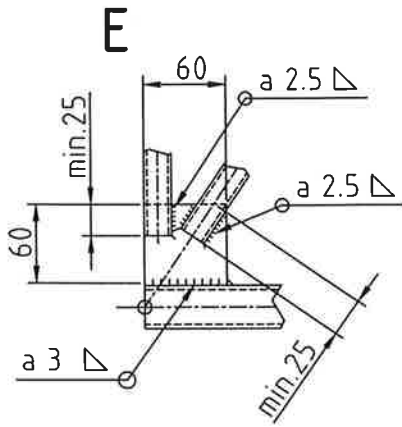
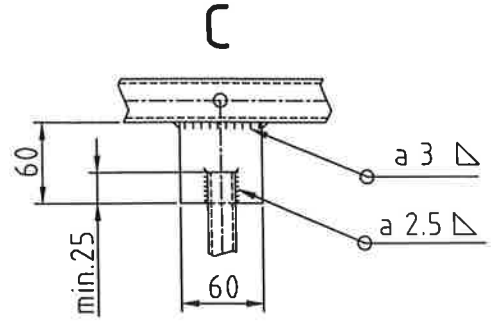
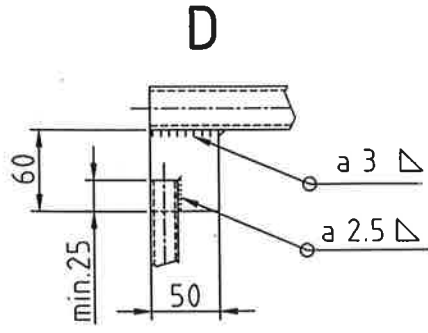
(NB = nominal bore / FB = flat bar)

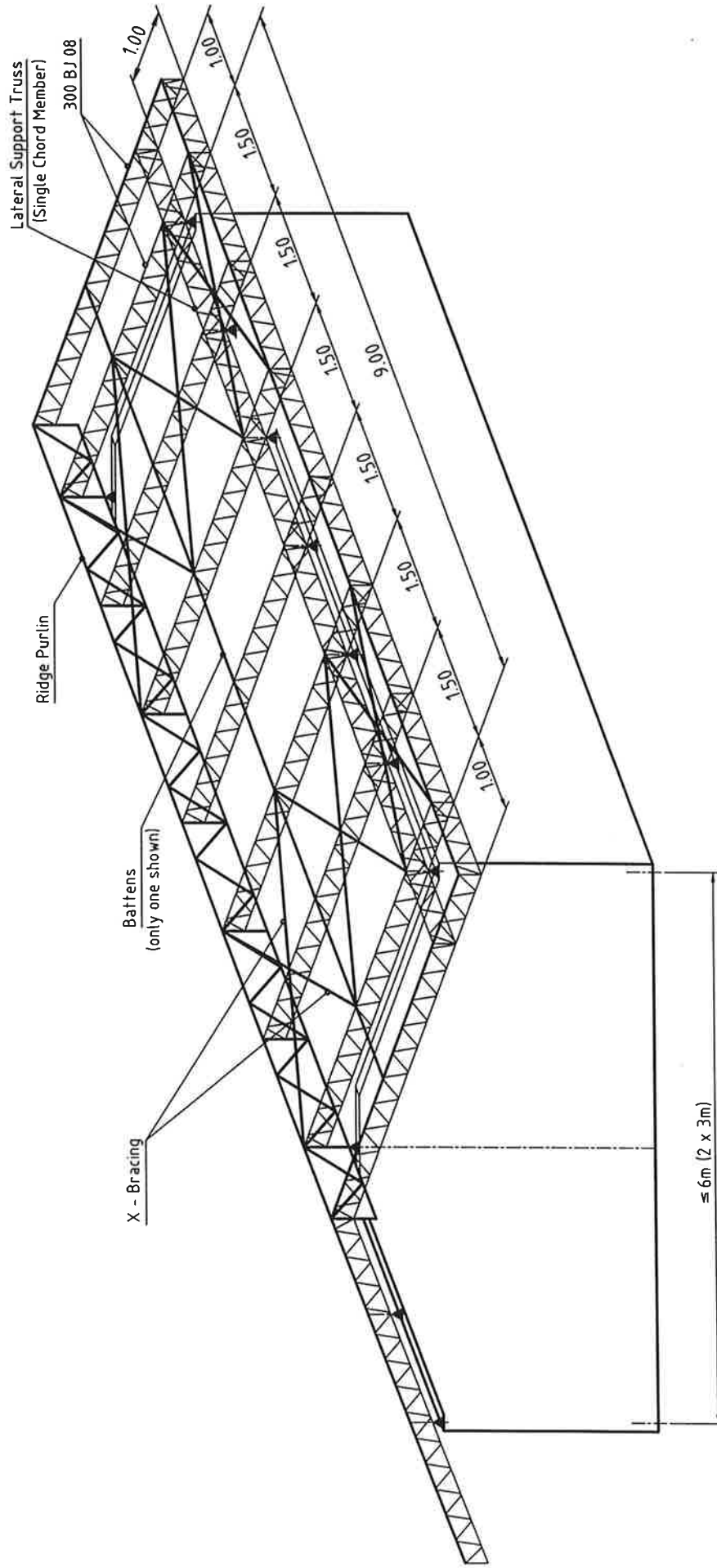


Plan view Detail A

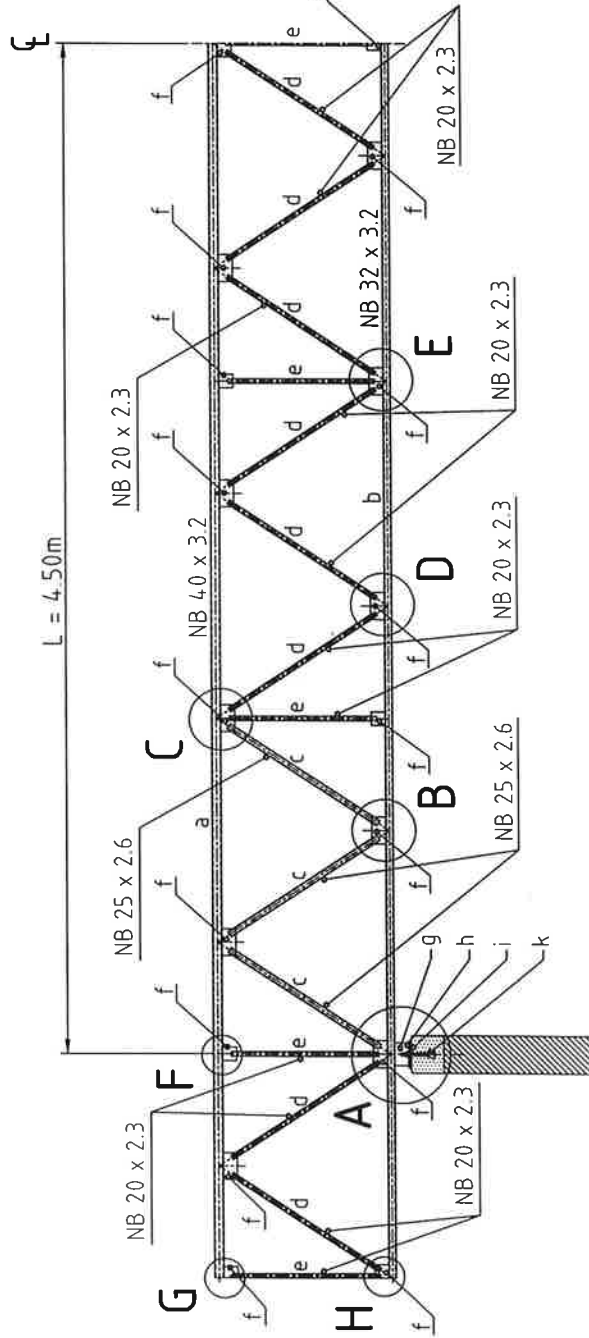
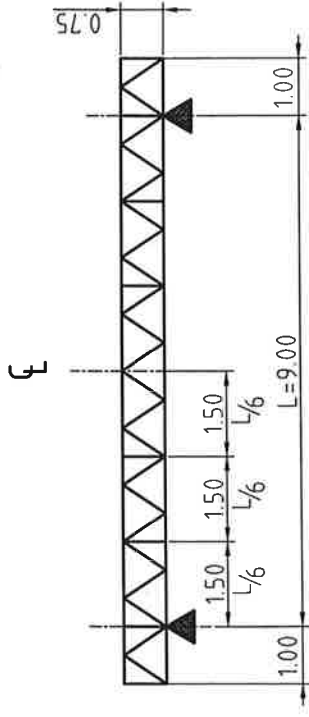


Anchor bolt, nut and washer for M12



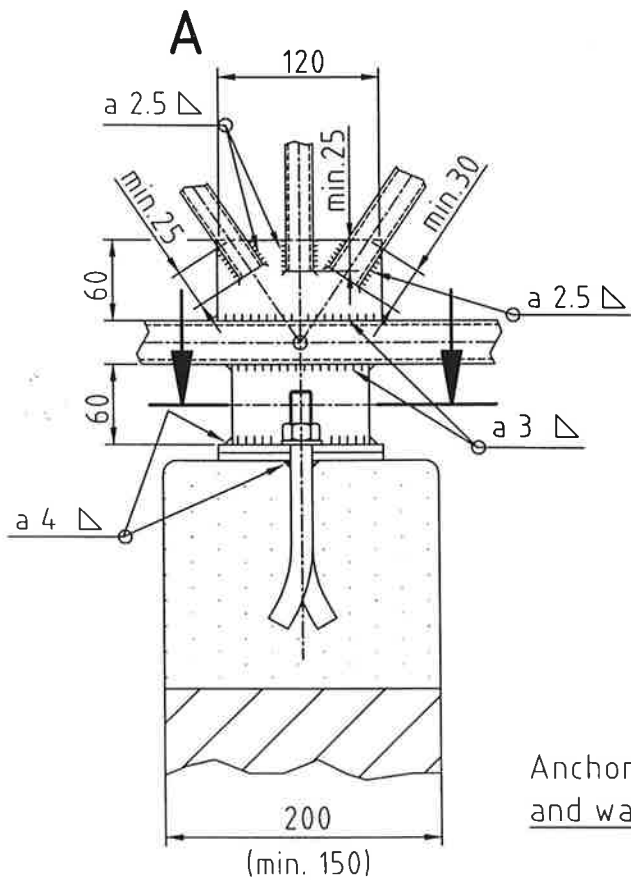
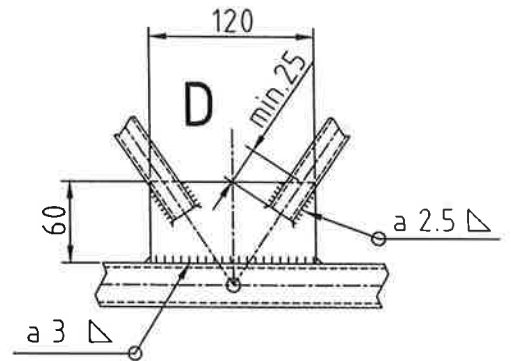
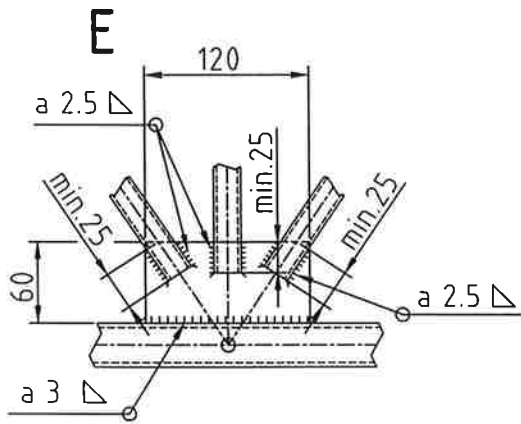
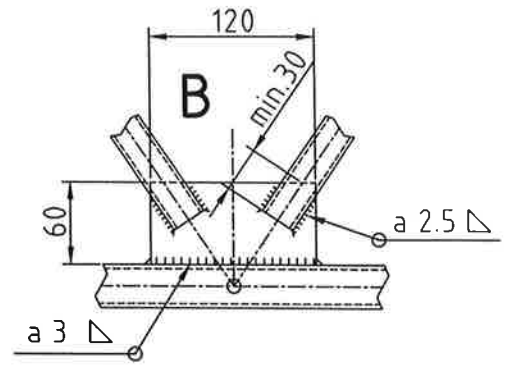
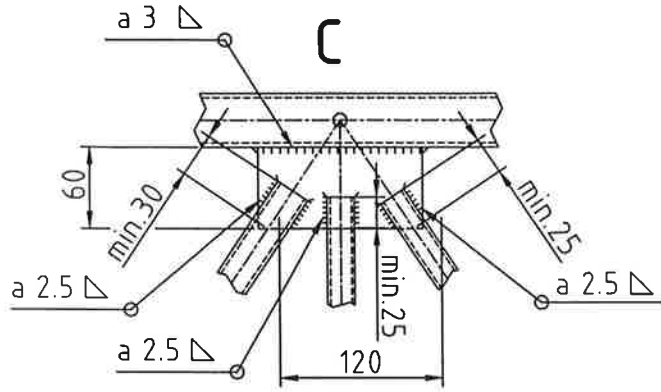


**6.11.7 Double Pitch Roof (8 m span) for Rebar Joists 300 BJ 10
Associated Ridge Purlin (Tube truss), 9 m span**

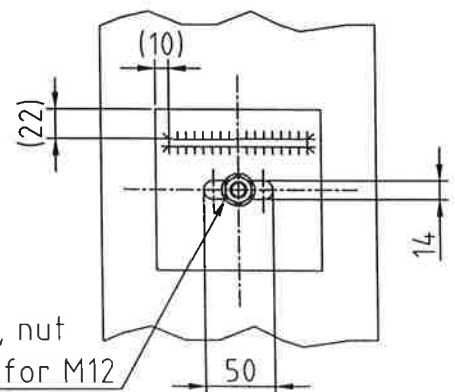


Pos./Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a 1	Top chord	NB 40 x 32 - 11000	3.56	39.2
b 1	Lower chord	NB 32 x 32 - 11000	3.09	34.0
c 6	Diagonal	NB 25 x 2.6 - 780	1.99	9.5
d 16	Diagonal	NB 20 x 2.3 - 770	1.4	17.4
e 9	Post	NB 20 x 2.3 - 640	1.4	8.1
f 32	Gusset	FB 60 x 6 - different I	2.83	9.0
g 2	Support plate	FB 60 x 6 - 100	2.36	0.6
h 2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
i 2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
k 2	Anchor bolt/nut/washer M12 - 120		---	0.6
	Mass total			119.0

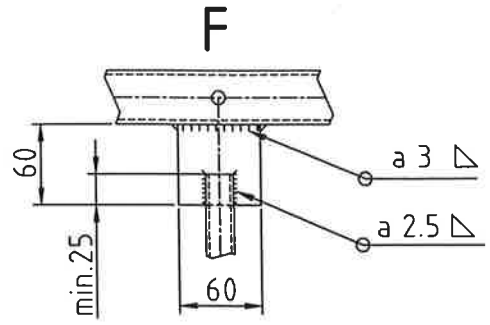
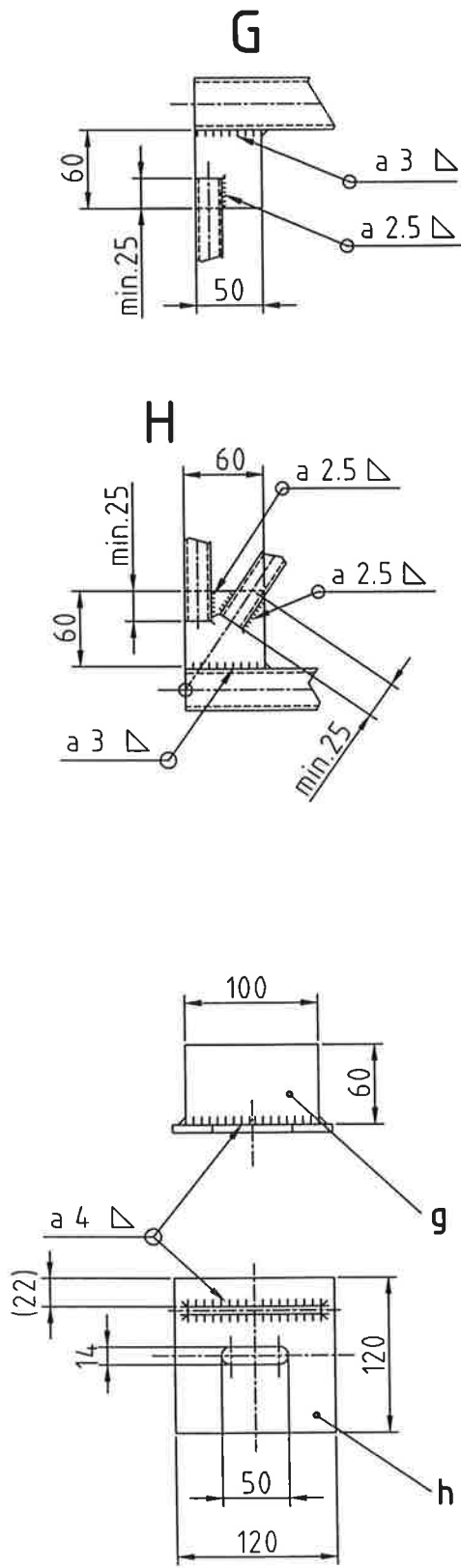
(NB = nominal bore / FB = flat bar)

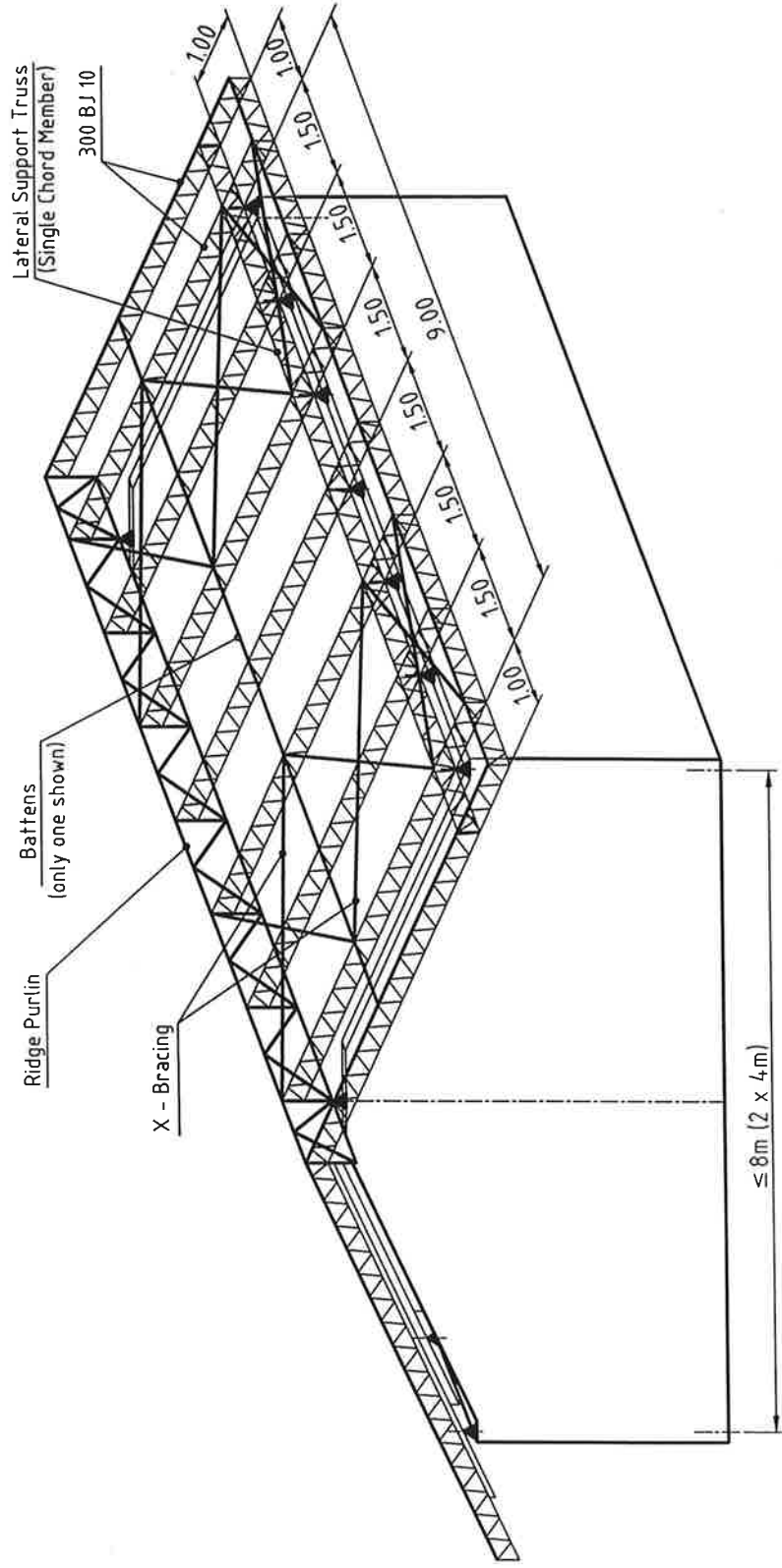


Plan view Detail A

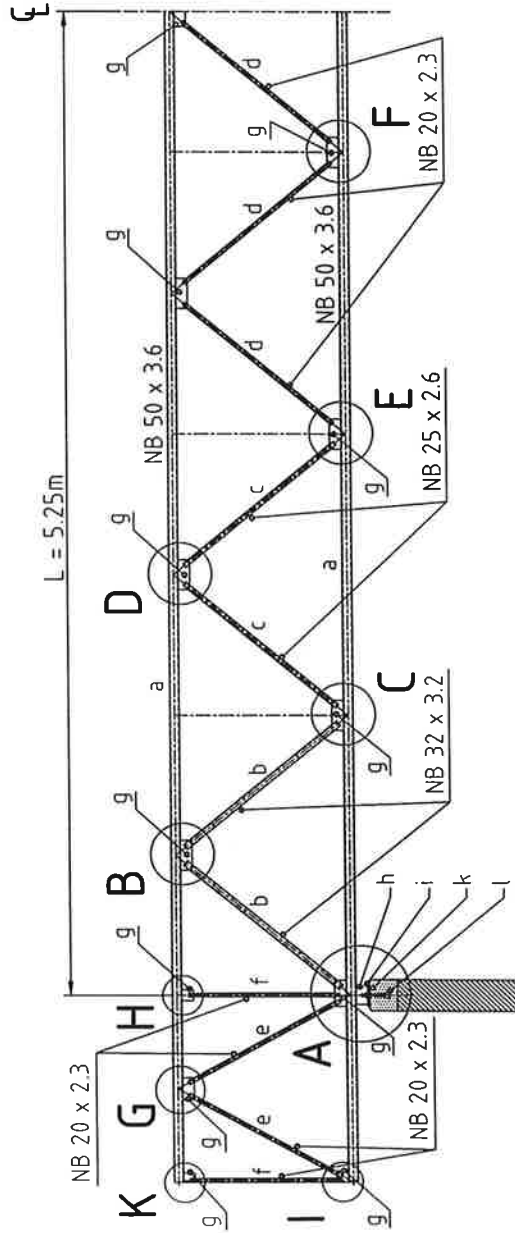
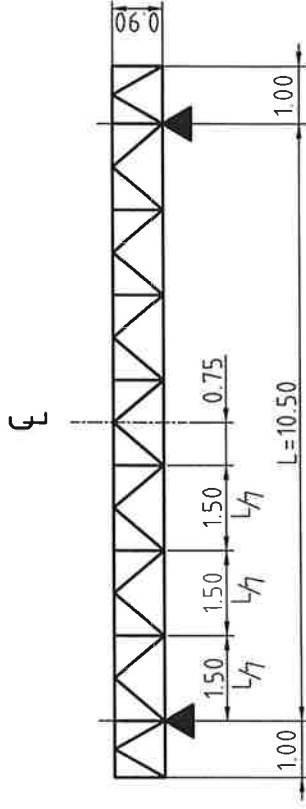


Anchor bolt, nut and washer for M12



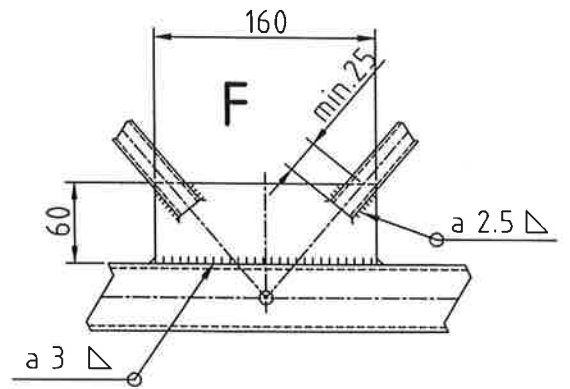
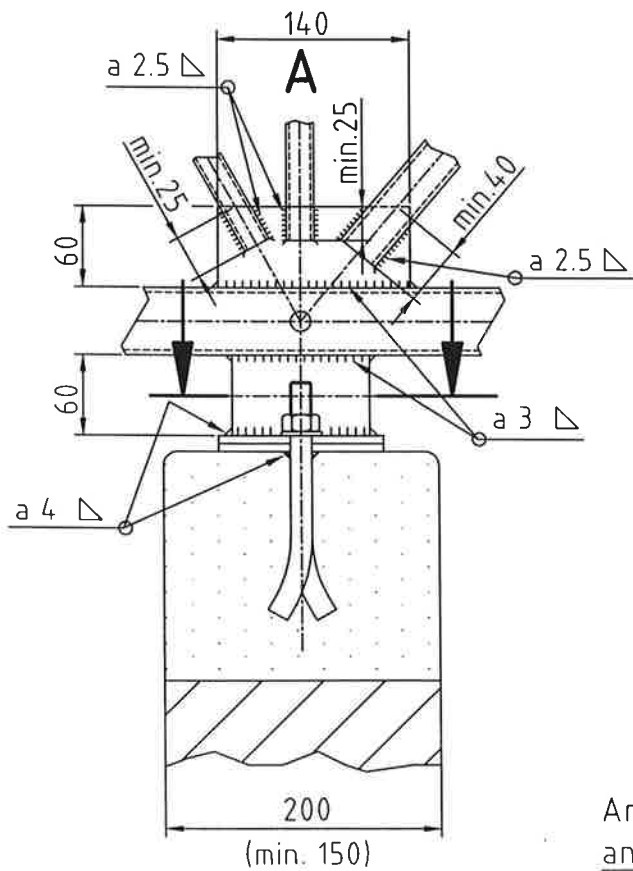
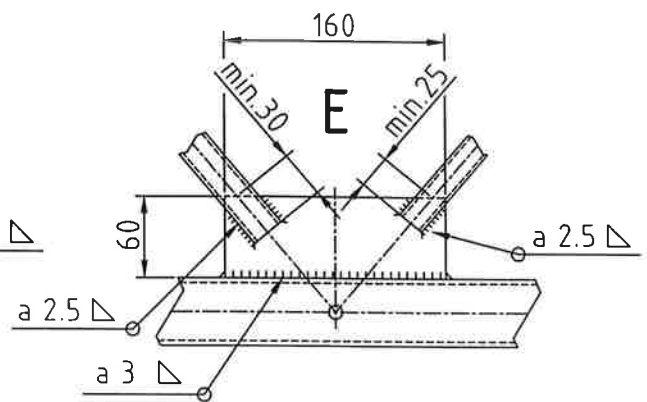
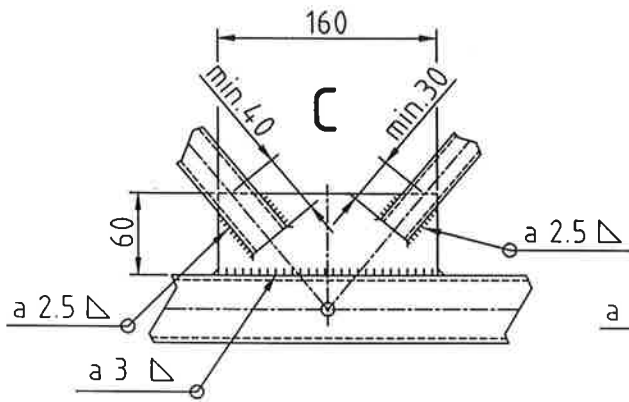
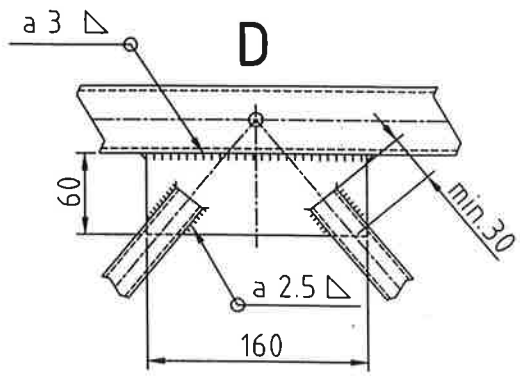
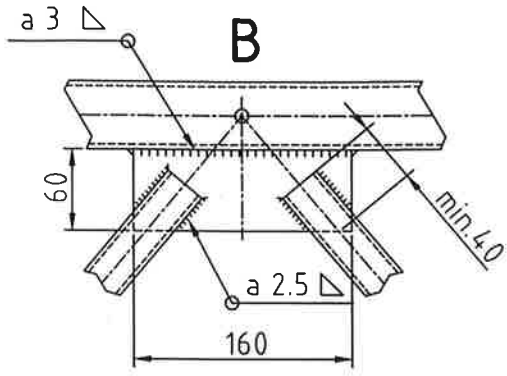


**6.11.8 Double Pitch Roof (10 m span) for Rebar Joists 300 BJ 12
Associated Ridge Purlin (Tube truss), 10.5 m span**

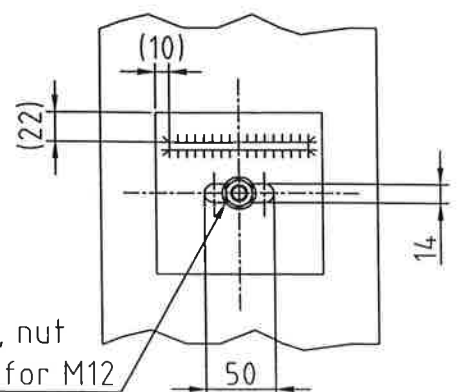


Pos	Qty.	Description	Dimensions	Mass kg/m	Mass total kg
a	2	Chord member	NB 50 x 3.6 - 12500	5.03	126.0
b	4	Diagonal	NB 32 x 3.2 - 1040	3.09	13.0
c	4	Diagonal	NB 25 x 2.6 - 1020	1.99	8.2
d	6	Diagonal	NB 20 x 2.3 - 1000	1.4	8.4
e	4	Diagonal	NB 20 x 2.3 - 900	1.4	5.1
f	4	Post	NB 20 x 2.3 - 780	1.4	4.5
g	23	Gusset	FB 60 x 6 - different l	2.83	8.8
h	2	Support plate	FB 60 x 6 - 100	2.36	0.6
i	2	Sliding plate	FB 120 x 6 - 120	5.65	1.4
k	2	Anchor plate	FB 120 x 6 - 120	5.65	1.4
l	2	Anchor bolt/nut/washer M12 - 120		---	0.6
Mass total					178.0

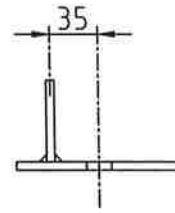
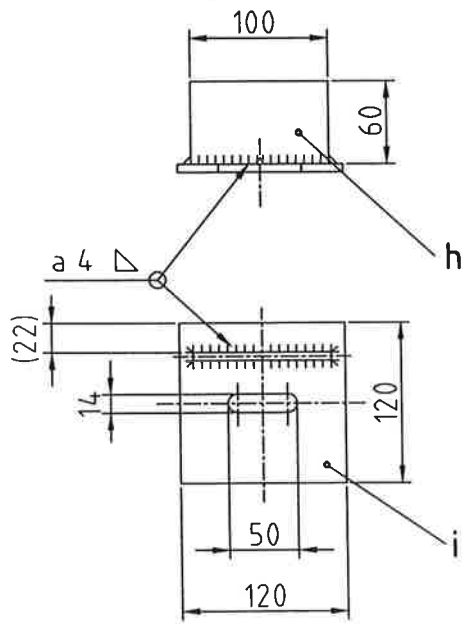
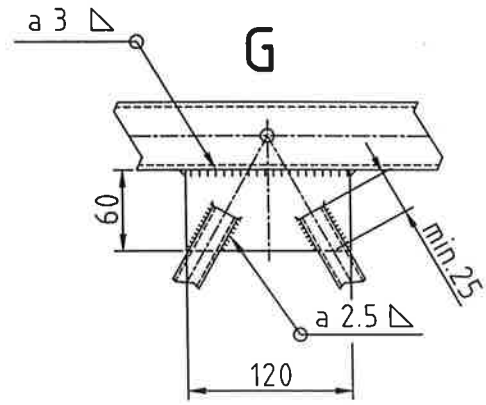
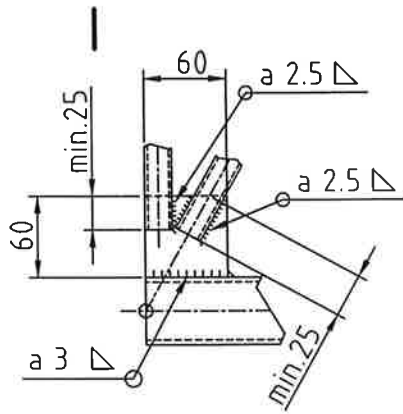
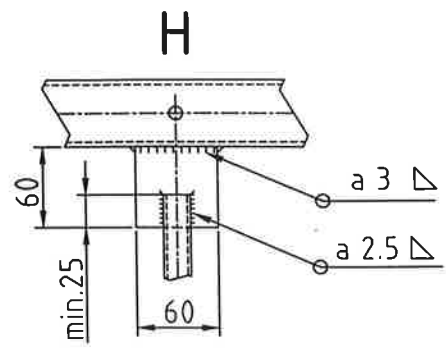
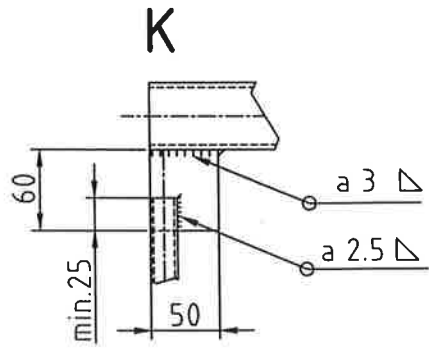
(NB = nominal bore / FB = flat bar)



Plan view Detail A



Anchor bolt, nut and washer for M12



7 Worked Example Steel Truss

7.1 The task

The primary school building of Chapter 5.1 needs to be covered by a steel truss and micro concrete tiles (MCR).

The building is located in a tropical but non-cyclonic area without snow load. Architectural considerations have determined the roof slope to be 30° in a double pitch design.

7.2 How to proceed

- Shape of the roof: ⇒ double pitch
 Design span of trusses: ⇒ $5.60 + (2 \times 0.075) = 5.75 \text{ m}$
 $5.60 + 1.80 + (2 \times 0.075) = 7.55 \text{ m}$
 Loads (S'): ⇒ We assume the load as commended in this guide for an MCR roof: 1.0 kN/m^2
- Select truss from guide:

Which one of the three options do you want to use:

- tube truss (lowest weight but requires gusset plates for the connection of the members)
- angle bar truss (ease of fabrication but slightly more steel required than with tube truss)
- rebar truss 300BJ08 (for 6m span) and 300BJ10 (for 8 m span) with ridge purlins (6 m span); since the roof structure will not be visible from inside the classrooms (covered by a ceiling) and the loft is not being used, the rebar truss is not a preferred option.

We decide to use the tube trusses:

chapter 6.9.2, Double Pitch Roof, Tube Truss, 6 m span
 chapter 6.9.3, Double Pitch Roof, Tube Truss, 8 m span

- Compare design span with span of the selected sample truss and adjust distance between trusses:

Truss (1):	span of standard truss	= 6.00 m
	standard distance	= 2.50 m
	design span	= 5.75 m

$$\Rightarrow \text{new distance (A')} = \frac{6.00^2}{5.75^2} \times 2.50 = 2.72 \text{ m}$$

Truss (2):	span of standard truss	= 8.00 m
	standard distance	= 2.50 m
	design span	= 7.55 m

$$\Rightarrow \text{new distance (A')} = \frac{8.00^2}{7.55^2} \times 2.50 = 2.81 \text{ m}$$

4. Compare your total design load (S') of the roof with the total load of the sample truss.

Trusses (1) and (2):	total load of sample truss	= 1.0 kN/m ²
	total design load	= 1.0 kN/m ²

⇒ no change in distances between trusses and the distances to be applied are:

Truss (1):	2.72 m
Truss (2):	2.81 m

These distances between trusses are the max. distances and they have to be compared with the dimensions of the building. To achieve an equal distribution of trusses, the distance can be reduced, but never increased. In our example the room on the left would require two trusses with a distance of 2.00 m between the trusses.

In case the design load had been calculated to be 1.25 kN/m², the following procedure would have to be applied:

Truss (1):	total load of sample truss	= 1.0 kN/m ²
	total design load	= 1.25 kN/m ²
	Distance (A)	= 2.72 m

$$\Rightarrow \text{new distance (A')} = \frac{1.00}{1.25} \times 2.72 = 2.18 \text{ m}$$

Truss (2):	total load of sample truss	= 1.00 kN/m ²
	total design load	= 1.25 kN/m ²
	distance (A)	= 2.81 m

$$\Rightarrow \text{new distance (A')} = \frac{1.00}{1.25} \times 2.81 = 2.25 \text{ m}$$

5. Adjust the design of the sample truss to your exact requirements!

8 Alternative Roof Trusses

8.1 Timber Pole Truss

Using timber poles for truss construction has basically the advantage of eliminating cost and wastage of sawing. But jointing round logs is more difficult than connecting sawn timber. In addition, an even roof surface is difficult to achieve due to the rough nature of most timber poles. The rough appearance of a timber pole truss is no disadvantage for many rural applications and might even give a special decorative touch to buildings in an urban context. More details on timber pole trusses can be found in the it publication "Timber Pole Construction" by Lionel Jayanetti.

8.2 Bamboo Truss

Due to its hollow form, bamboo is relatively strong and stiff and lends itself easily for roof trusses in the same manner as timber roof trusses. Bamboo as a local building material can increase the local content of a house construction is therefore an opportunity to increase the economic independence and self-reliance of local populations. However, bamboo must be treated in order to increase durability and it is also not completely straight which can cause problems for the achievement of an even roof surface. In addition, structurally sound joints are difficult to construct without the use of expensive materials such as steel bolts and plywood or metal sheets. These materials also reduce the attractiveness of the truss as a truly natural element for aesthetic reasons. For more details on bamboo trusses refer to the handbook by Dr. J.J.A. Janssen "Building with Bamboo".

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Annex 1: Sample Structural Analysis

Annex 2: Dimensions and Design Information of Angle Bars and Tubes Used in this Manual

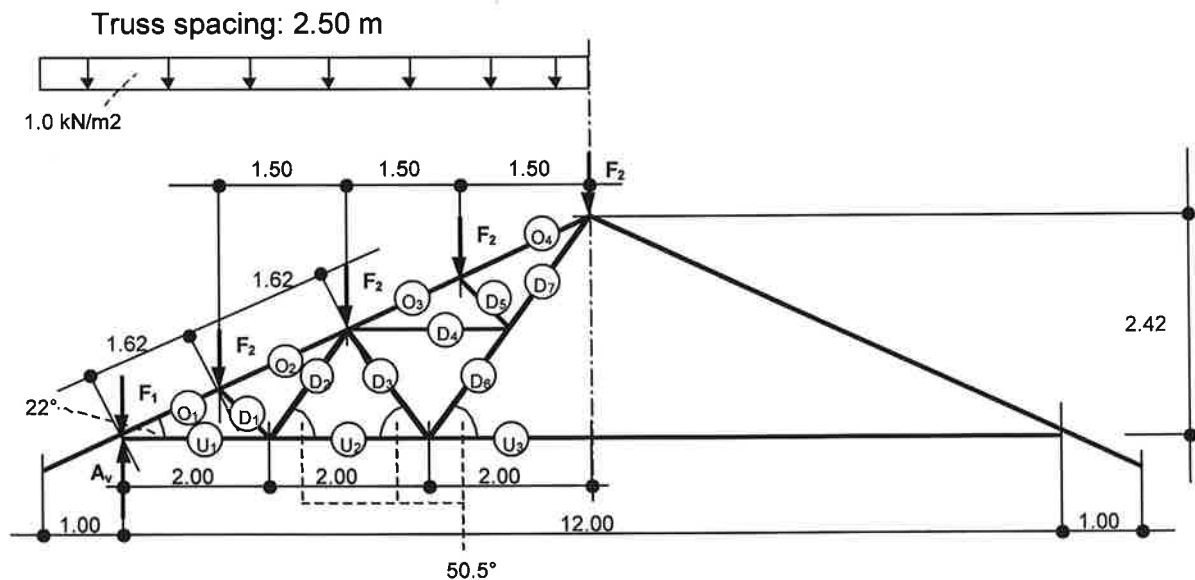
ANNEX 1: SAMPLE STRUCTURAL ANALYSIS

Angle Bar Truss, Double Pitch Roof, Polonceau Truss, 12 m Span

1 Basis of the design

- Structural steel; yield stress: $f_y = 200 \text{ N/mm}^2$
 $E = 210'000 \text{ N/mm}^2$
- Swiss Standard SIA 161/1990
- Safety factors for ultimate stress calculation:
 $\gamma_{g/q} = 1.4$ (load)
 $\gamma_R = 1.1$ (section resistance)

2 Structural system, loads



$$F_1 = 1.0 \text{ kN/m}^2 \cdot 2.50 \text{ m} \cdot (1.00 \text{ m} + \frac{1}{2} \cdot 1.50 \text{ m}) = 4.375 \text{ kN}$$

$$F_2 = 1.0 \text{ kN/m}^2 \cdot 2.50 \text{ m} \cdot 1.50 \text{ m} = 3.750 \text{ kN}$$

3 Structural analysis

$$A_v = F_1 + 3.5 \cdot F_2 = 17.5 \text{ kN}$$

$$O_1 = \frac{1}{0.75} [-2.0 (A_v - F_1)] = -35.0 \text{ kN}$$

$$O_2 = \frac{1}{0.75} [-2.0 (A_v - F_1) + 0.5 F_2] = -32.5 \text{ kN}$$

$$O_4 = \frac{1}{0.50} [-4.0 (A_v - F_1) + 2.5 F_2 + 1.0 F_2 - 0.5 F_2] = -27.5 \text{ kN}$$

$$U_1 = 1/0.61 [1.5 (A_V - F_1)] = 32.3 \text{ kN}$$

$$U_2 = 1/1.21 [3.0 (A_V - F_1) - 1.5 F_2] = 27.9 \text{ kN}$$

$$U_3 = 1/2.42 [6.0 (A_V - F_1) - (4.5 + 3.0 + 1.5) F_2] = 18.6 \text{ kN}$$

$$D_1 = 1/1.54 [-1.5 \cdot F_2] = -3.65 \text{ kN}$$

$$D_2 = 1/1.54 [1.5 \cdot F_2] = 3.65 \text{ kN}$$

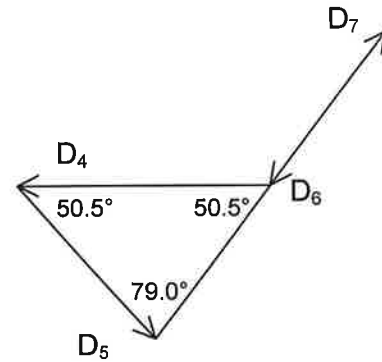
$$D_5 = D_1 = -3.65 \text{ kN}$$

$$D_7 = 1/3.09 [F_2 (1.5 + 3.0 + 4.5)] = 10.9 \text{ kN}$$

$$D_4 = 2 \cdot D_5 \cdot \cos 50.5^\circ = 4.64 \text{ kN}$$

$$D_6 = D_7 - D_5 = 7.25 \text{ kN}$$

$$D_3 = 1/3.09 [-F_2 (1.5 + 3.0) - 1.21 \cdot D_4] = -7.3 \text{ kN}$$



4 Dimensioning members

4.1 Top chord

$$M_{\max} = 2.50 \text{ kN/m} \cdot \frac{1}{2} \cdot 1.00^2 \text{ m}^2 = 1.25 \text{ kNm}$$

$$M_{\min} \cong 0.083 \text{ m} \cdot 2.50 \text{ kN/m} \cdot 1.50^2 \text{ m}^2 = 0.47 \text{ kNm}$$

Bending and compression (in the plane of the truss)

$$\text{buckling length } l_{kx} = 0.9 \cdot 1.63 = 1.46 \text{ m}$$

Buckling out of the plane

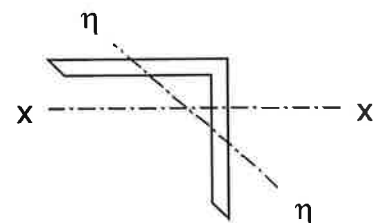
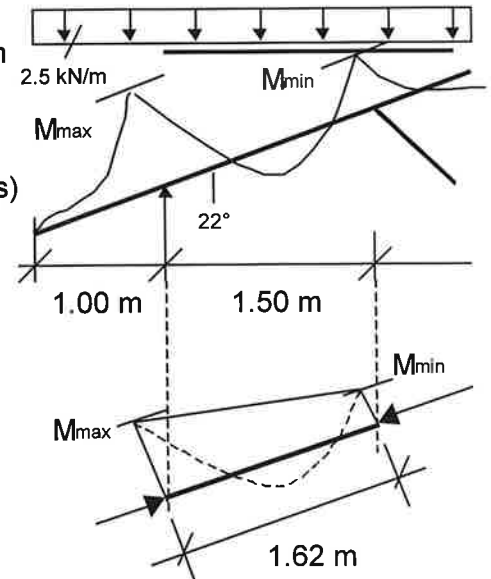
$$\text{design load } N_d = \gamma_q \cdot O_1 = 1.4 \cdot 35 = 49 \text{ kN}$$

$$l_{k\eta} = 1.62 \text{ m}$$

selection: EA 100x100x6

cross sectional area $A = 1170 \text{ mm}^2$, buckling radius

$$i_\eta = 19.8 \text{ mm}, i_x = 31.0 \text{ mm}$$



buckling around η :

$$\lambda_{k\eta} = l_{k\eta} / i_{\eta} = 1620 / 19.8 = 81.8$$

$$\bar{\lambda}_{k\eta} = \lambda_{k\eta} / \pi \sqrt{E/f_y} = 0.80$$

from buckling stress curve c) $\kappa = 0.66$

$$\sigma_{k\eta} = \kappa \cdot f_y = 132 \text{ N/mm}^2 \quad N_{k\eta} = \sigma_{k\eta} \cdot A = 154 \text{ kN}$$

$$N_d = 1.4 \cdot 35 = 49 \text{ kN} < N_{k\eta} / 1.1 = 140 \text{ kN} \quad \text{okay}$$

bending and compression in x-plane:

Interaction formula SIA 161 (18)

$$\frac{N_d}{N_k / \gamma_R} + \frac{1}{1 - \frac{N_d}{N_{cr}}} \cdot \frac{\omega \cdot M_{d,max}}{M_R / \gamma_R} \leq 1.0$$

distribution of bending moments (field moment not considered) $\omega = 0.6 + 0.4 \cdot M_{min} /$

$$M_{max} = 0.6 + 0.4 \cdot 0.47 / 1.25 = 0.75$$

$$\text{section resistance } M_R = f_y \cdot W_x = 200 \text{ N/mm}^2 \cdot 15.3 \cdot 10^3 \text{ mm}^3 = 3.06 \text{ kNm}$$

critical load acc. to Euler:

$$N_{cr} = \pi^2 E I_x / l_{kx}^2 = \pi^2 \cdot 2.1 \cdot 10^5 \cdot 1.12 \cdot 10^6 / (1.46 \cdot 10^3)^2 = 1089 \text{ kN}$$

$$\lambda_{kx} = l_{kx} / i_x = 1460 / 31.0 = 47 \quad \sigma_{kx} = 172 \text{ N/mm}^2$$

$$N_{kx} = A \sigma_{kx} = 201 \text{ kN}$$

$$\frac{49.0}{201 / 1.1} + \frac{1}{1 - \frac{49}{1089}} \cdot \frac{0.75 \cdot 1.4 \cdot 1.25}{3.06 / 1.1} = 0.76 < 1.0 \quad \text{okay}$$

4.2 Lower chord

$$N_d = 1.4 \cdot 32.3 \text{ kN} = 45.2 \text{ kN (tension)}$$

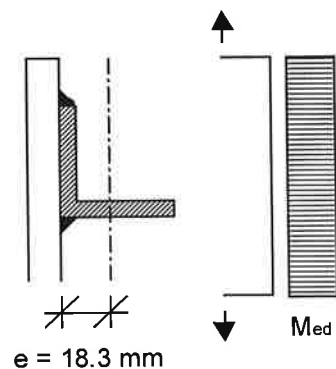
$$A_{min} = N_d / (f_y / \gamma_R) = 249 \text{ mm}^2$$

selection: EA 65x65x6

$$A = 748 \text{ mm}^2 \cdot W_x = 6.34 \cdot 10^3 \text{ mm}^3$$

since only one leg is welded onto the top chord there is a bending moment due to this eccentric connection (or use reduced cross sectional area, only one leg of the angle bar):

$$M_{ed} = e \cdot N_d = 0.0183 \text{ m} \cdot 45.3 \text{ kN} = 0.83 \text{ kNm}$$



$$M_R = f_y \cdot W_x = 1.27 \text{ kNm} \quad N_R = A \cdot f_y = 149.6 \text{ kN}$$

$$\frac{N_d}{N_R / \gamma_R} + \frac{M_d}{M_R / \gamma_R} \leq 1.0$$

$$\frac{45.2}{149.6 / 1.1} + \frac{0.83}{1.27 / 1.1} = 0.33 + 0.72 = 1.05 \approx \text{okay}$$

Fillet weld for lower chord:

$$N_d = 1.4 \cdot 32.3 \text{ kN} = 45.2 \text{ kN}; \quad a = 2.5 \text{ mm}$$

$$R = a\sqrt{2} \cdot l \cdot 0.7 \cdot f_y \Rightarrow l_{\min} = \frac{R}{a\sqrt{2} \cdot 0.7 \cdot f_y}$$

$$l_{\min} = \frac{45.2 \cdot 1.1 \cdot 10^3}{2.5\sqrt{2} \cdot 0.7 \cdot 200} = 100 \text{ mm}$$

4.3 Diagonals

$$D_1: \quad N_d = 1.4 \cdot 3.65 \text{ kN} = 5.1 \text{ kN (compression)}$$

selection: EA 25x25x3

$$A = 143 \text{ mm}^2, \quad i_{\eta} = 4.73 \text{ mm}, \quad l_{k\eta} = 790 \text{ mm}$$

buckling out of plane (weakest axis η):

$$\lambda_{k\eta} = l_{k\eta} / i_{\eta} = 790 / 4.73 = 167$$

$$\sigma_{k\eta} = 54 \text{ N/mm}^2, \quad N_{k\eta} = A \cdot \sigma_k = 7.7 \text{ kN}$$

$$N_d = 5.1 \text{ kN} < N_{k\eta} / 1.1 = 7.0 \text{ kN} \quad \text{okay}$$

bending (due to eccentric connection) and compression:

$$\frac{N_d}{N_k / \gamma_R} + \frac{1}{1 - \frac{N_d}{N_{cr}}} \cdot \frac{\omega \cdot M_{d,\max}}{M_R / \gamma_R} \leq 1.0$$

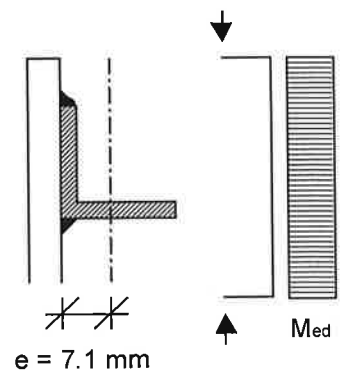
$$\omega = 1.0; \quad M_{ed} = 0.0071 \text{ m} \cdot 5.1 \text{ kN} = 0.036 \text{ kNm}$$

$$M_R = f_y \cdot W_x = 200 \text{ N/mm}^2 \cdot 0.426 \cdot 10^3 \text{ mm}^3 = 0.085 \text{ kNm}$$

$$N_{cr} = \pi^2 EI_x / l_{kx} = \pi^2 \cdot 2.1 \cdot 10^5 \cdot 0.00765 \cdot 10^6 / (790)^2 = 25.4 \text{ kN}$$

$$\lambda_{kx} = l_{kx} / i_x = 790 / 7.33 = 107.8 \quad \sigma_{kx} = 100 \text{ N/mm}^2$$

$$N_{kx} = A \sigma_{kx} = 14.3 \text{ kN}$$



$$\frac{5.1}{14.3/1.1} + \frac{1}{1 - \frac{5.1}{25.4}} \cdot \frac{1.0 \cdot 0.036}{0.085/1.1} = 0.98 < 1.0 \quad \text{okay}$$

$$D_2: \quad N_d = 1.4 \cdot 3.65 \text{ kN} = 5.1 \text{ kN (tension)}$$

selection: EA 25x25x3

$$D_3: \quad N_d = 1.4 \cdot 7.3 \text{ kN} = 10.2 \text{ kN (compression)}$$

selection: EA 50x50x5

$$A = 443 \text{ mm}^2, \quad i_{\eta} = 9.78 \text{ mm}, \quad l_{k\eta} = 1570 \text{ mm}$$

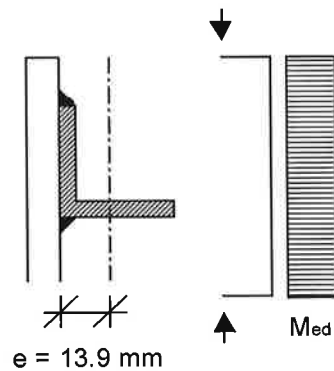
buckling out of plane / around η -axis:

$$\lambda_{kx} = l_{kx} / i_x = 1570 / 9.78 = 160.5$$

$$\sigma_{kx} = 57 \text{ N/mm}^2, \quad N_{k\eta} = 25.3 \text{ kN}$$

$$N_d = 10.2 \text{ kN} < N_{k\eta} / 1.1 = 23.0 \text{ kN} \quad \text{okay}$$

eccentric connection: bending and compression



$$M_{ed} = 0.0139 \text{ m} \cdot 10.2 \text{ kN} = 0.142 \text{ kNm}; \quad \omega = 1.0$$

$$M_R = f_y \cdot W_x = 200 \text{ N/mm}^2 \cdot 2.85 \cdot 10^3 \text{ mm}^3 = 0.57 \text{ kNm}$$

$$N_{cr} = \pi^2 E I_x / l_{kx} = \pi^2 \cdot 2.1 \cdot 10^5 \cdot 0.103 \cdot 10^6 / (1570)^2 = 86.6 \text{ kN}$$

$$\lambda_{kx} = l_{kx} / i_x = 1570 / 15.2 = 103.3 \quad \sigma_{kx} = 108 \text{ N/mm}^2$$

$$N_{kx} = A \sigma_{kx} = 18.7 \text{ kN}$$

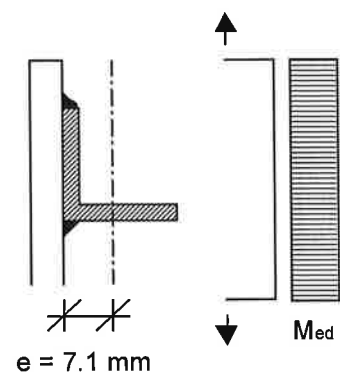
$$\frac{10.2}{18.7/1.1} + \frac{1}{1 - \frac{10.2}{86.6}} \cdot \frac{1.0 \cdot 0.142}{0.570/1.1} = 0.91 < 1.0 \quad \text{okay}$$

$$D_4: \quad N_d = 1.4 \cdot 4.64 \text{ kN} = 6.5 \text{ kN (tension)}$$

selection: EA 25x25x3

eccentric connection:

$$M_{ed} = e \cdot N_d = 0.0071 \text{ m} \cdot 6.5 \text{ kN} = 0.046 \text{ kNm}$$



$$M_R = f_y \cdot W_x = 200 \text{ N/mm}^2 \cdot 0.426 \cdot 10^3 \text{ mm}^3 = 0.085 \text{ kNm}$$

$$N_R = A \cdot f_y = 173 \text{ mm}^2 \cdot 200 \text{ N/mm}^2 = 28.6 \text{ kN}$$

$$\frac{N_d}{N_R / \gamma_R} + \frac{M_d}{M_R / \gamma_R} \leq 1.0$$

$$\frac{6.5}{28.6 / 1.1} + \frac{0.046}{0.085 / 1.1} = 0.25 + 0.60 = 0.85 < 1.0 \quad \text{okay}$$

D_5 : ditto D_1

selection: EA 25x25x3

D_6 / D_7 : $N_d = 1.4 \cdot 10.9 \text{ kN} = 15.3 \text{ kN}$ (tension)

selection: EA 50x50x5

eccentric connection:

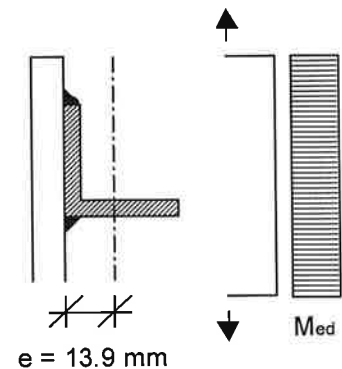
$$M_{ed} = e \cdot N_d = 0.0139 \text{ m} \cdot 15.3 \text{ kN} = 0.213 \text{ kNm}$$

$$M_R = f_y \cdot W_x = 200 \text{ N/mm}^2 \cdot 2.85 \cdot 10^3 \text{ mm}^3 = 0.570 \text{ kNm}$$

$$N_R = A \cdot f_y = 443 \text{ mm}^2 \cdot 200 \text{ N/mm}^2 = 88.6 \text{ kN}$$

$$\frac{N_d}{N_R / \gamma_R} + \frac{M_d}{M_R / \gamma_R} \leq 1.0$$

$$\frac{15.3}{88.6 / 1.1} + \frac{0.213}{0.570 / 1.1} = 0.19 + 0.41 = 0.60 < 1.0 \quad \text{okay}$$



$e = 13.9 \text{ mm}$

5 Panel point details

see drawing under section 6.7.5 of the main text

6 Total mass of truss

Truss

Description	Section EA	mass [kg/m']	Length [m]	Total Mass [kg]
Top chord	100x100x6	9.16	15.10	138.3
Lower chord	65x65x6	5.87	12.00	70.4
Diagonal D_1	25x25x3	1.12	0.80 x2	1.8
D_2	25x25x3	1.12	1.60 x2	3.6
D_3	50x50x5	3.48	1.60 x2	11.1

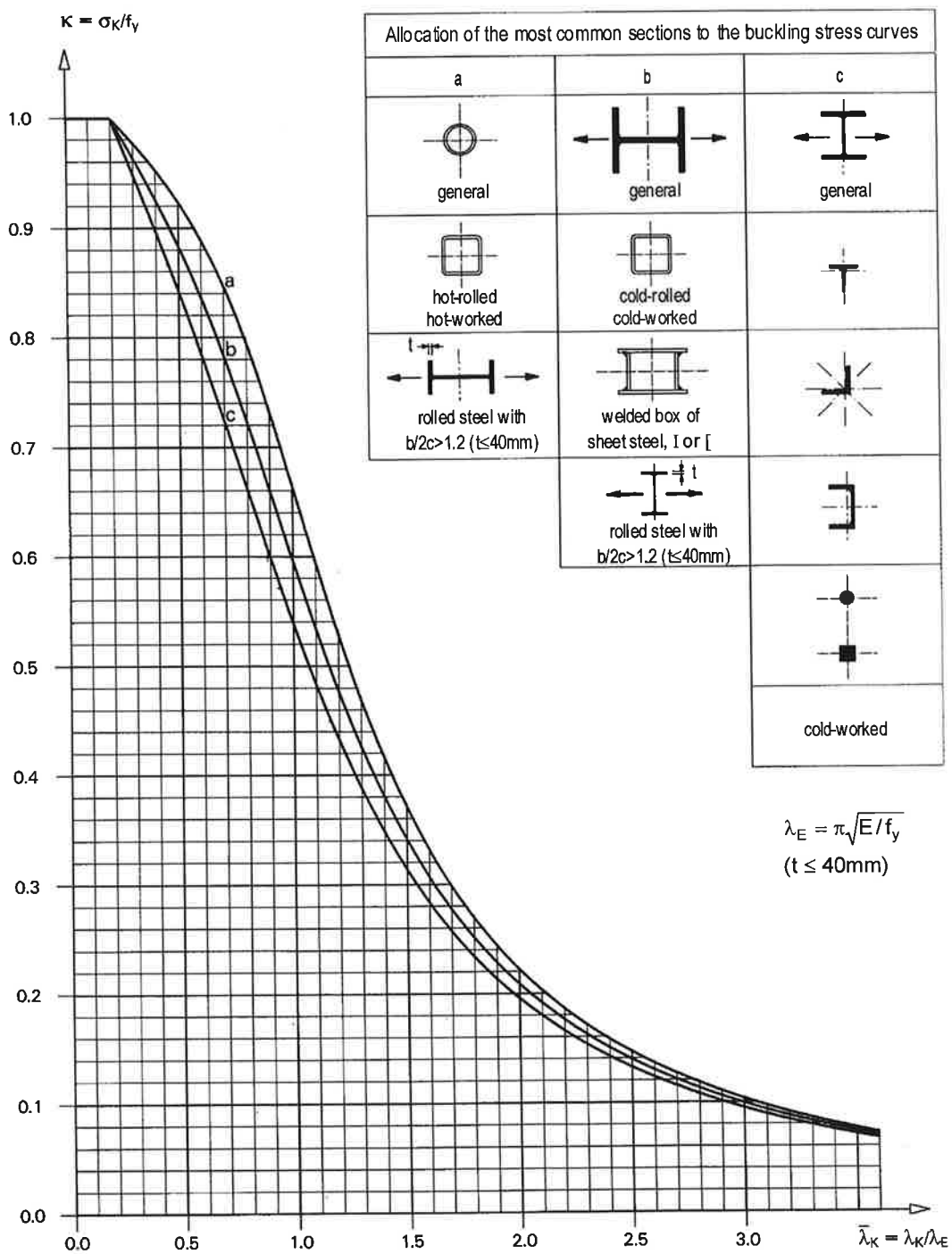
D ₄	25x25x3	1.12	2.00 x2	4.5
D ₅	25x25x3	1.12	0.80 x2	1.8
D _{6/7}	50x50x5	3.48	3.15 2	21.9
Support		9.16		3.7

Description	Dimension	Mass [kg/pc.]	Quantity [pcs.]	Total Mass [kg]
Base plate		1.8	4	7.2
Dowels		0.2	2	0.4

$\Sigma = 264.7 \text{ kg}$

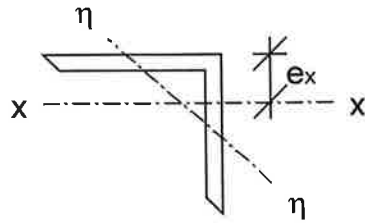
$$\begin{aligned} \text{weight per m}^2: & \frac{264.7 \text{ kg} \cdot 9.81 \text{ ms}^{-2} \cdot 10^{-3}}{12 \text{ m} \cdot 2.5 \text{ m}} = 0.087 \text{ kN/m}^2 \\ \text{Purlins} & \\ \text{EA 50x50x5} & \text{ spacing 0.4 m for MCR} = 0.085 \text{ kN/m}^2 \\ \text{Bracing} & = 0.010 \text{ kN/m}^2 \\ \\ \text{Total weight} & = \underline{\underline{0.18 \text{ kN/m}^2}} \end{aligned}$$

Buckling stress curves



Annex 2: Dimensions and Design Information of Angle Bars and Tubes Used in this Manual

Equal angle bars



Designation	g [kg/m]	A [mm ²]	i _x [mm]	i _η [mm]	W _x [10 ³ mm ³]	I _x [10 ⁶ mm ⁴]	e _x [mm]
EA 100 x 100 x 6	9.16	1170	31.0	19.8	15.3	1.12	26.8
EA 75 x 75 x 6	6.81	867	22.9	14.7	8.35	0.455	20.5
EA 65 x 65 x 6	5.87	748	19.9	12.8	6.34	0.296	18.3
EA 50 x 50 x 5	3.48	443	15.2	9.78	2.85	0.103	13.9
EA 30 x 30 x 3	1.35	173	8.93	5.76	0.635	0.0138	8.3
EA 25 x 25 x 3	1.12	143	7.33	4.73	0.426	0.00765	7.1

Plain-ended black pipes

Designation	Name	D _{ext} [mm]	Wall thickness [mm]	D _{int} [mm]	Mass [kg/m]	A [mm ²]	Radius i [mm]	W [10 ³ mm ³]	I [10 ⁶ mm ⁴]
NB 80 x 4.0	medium-walled 3" black pipe	88.9	4.0	80.9	8.38	1067	30.0	21.7	0.9634
NB 80 x 3.2	light-walled 3" black pipe	88.9	3.2	82.5	6.76	862	30.3	17.8	0.7921
NB 65 x 3.6	medium-walled 2 ½" black pipe	76.1	3.6	68.9	6.44	820	25.7	14.2	0.5401
NB 50 x 3.6	medium-walled 2" black pipe	60.3	3.6	53.1	5.03	641	20.1	8.58	0.2587
NB 40 x 3.2	medium-walled 1 ½" black pipe	48.3	3.2	41.9	3.56	453	16.0	4.80	0.1159
NB 32 x 3.2	medium-walled 1 ¼" black pipe	42.4	3.2	36.0	3.09	394	13.9	3.59	0.0762
NB 25 x 2.6	light-walled 1" black pipe	33.7	2.6	28.5	1.99	254	11.0	1.84	0.0309
NB 20 x 2.3	light-walled ¾" black pipe	26.9	2.3	22.3	1.40	178	8.7	1.01	0.0136