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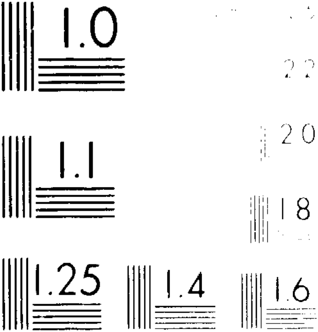
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26 March 1982
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DEVELOPMENT OF NEW TIMBER PRODUCTS

DP/KEN/77/007

KENYA

Technical report: A trussed rafter system *

Prepared for the Government of Kenya
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of C.R. Francis, project team leader and
F. Sorensen, associate expert

003986

United Nations Industrial Development Organization
Vienna

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INTRODUCTION

This report contains recommendations for the fabrication, design and erection of trussed rafters in domestic construction. It is not a code of practice although much of it draws on the codes of practice of Australia, Canada and Great Britain. Once a trussed rafter industry is established in a developing country it could provide a basis for preparation of a local code of practice or adoption or amendment of an existing code from a developed country if this is deemed appropriate.

This report is concerned primarily with the manufacturing aspects of trussed rafters. It has been assumed that potential manufacturers are familiar with the timber industry and therefore matters concerned with timber selection and processing have received little emphasis. Also, it has been assumed that a manufacturer will not have the necessary background to understand structural engineering, so detailed design procedures for trussed rafters have not been touched on beyond giving a list of references.

The author was for many years engineer for a company which introduced trussed rafter construction in his own country and he has been instrumental there in getting this industry going from an unknown form of construction to a stage where over 80 per cent of all domestic roofs are built in this way.

GLOSSARY

Building terminology varies around the world and some of the terms in this report may be unfamiliar. The specialised words used in this report are given below with alternative usages in brackets where these exist. Other specialised terms are defined or illustrated in the text.

Strut, tie (web members) Interior members of a truss which carry primarily compression or tension forces.

Rafter (top chord) The upper sloping member of a truss.

Ceiling tie (bottom chord) The lower usually horizontal member of a truss.

Node (panel point) A point where two or more members of a truss join.

Monochord - A truss in which all members are the same thickness and lie in the same place.

1. ESTABLISHMENT OF A TRUSSED RAFTER INDUSTRY

Traditional timber roof construction consists of rafters supported by under purlins, struts, collar ties etc. all cut and assembled on site. This is a highly skilled operation which takes time.

Prefabricated roof trusses can perform the same function and are quickly erected using much less skilled labour. A saving of timber of about 30% is made. Also the possibility of theft from the building site is much reduced.

The principle of using trusses to support roof structures is very old but it is only in the last 20 to 30 years that use of closely spaced trusses in domestic construction has become common. There are a variety of reasons for this, some technical, some economic. Rising site costs and general acceptance of prefabricated construction have been powerful incentives to develop systems of truss construction which are suitable for smaller particularly domestic buildings.

The term "trussed rafter" applies to a light-weight roof truss where the top chord performs the same functions as a rafter in framed construction and the bottom chord directly supports the ceiling lining. Spacing is quite close and although practices may vary it is generally around 1 metre, ranging from 600 mm to 1200 mm. occasionally up to 1800 mm. Beyond that spacing truss loads demand special wall construction considerations and the term "roof truss" becomes more appropriate.

In this report where no confusion can arise the words "trussed rafter" are frequently abbreviated to "truss" where no ambiguity can arise.

A variety of connections and configurations of trussed rafters have been tried over the years in different countries but a fairly consistent pattern of successful systems has emerged.

Factors which are common include the following:

1. Within the normal range of spans and pitches, all trusses are pre-designed, so that no professional engineering advice is needed either by the architect, builder or truss manufacturer.

2. Trussed rafters are of monochord type, that is, all members in the truss are of the same thickness and in the same plane. This simplifies erection and subsequent framing, roofing and lining operations.

3. Easily applied strong and rigid connections of a gusset plate type are used. These minimise the cross section of web members required merely to contain the necessary number of connections, compared with lapped joint construction with nails or bolts.

4. Fabrication is done in jigs in a factory, which ensures dimensional accuracy and uniformity of shape.

This report provides the information required to manufacture a basic range of trussed rafters which will cover most domestic and similar gable roof construction.

2. CONNECTION SYSTEMS

Various types of gusset plate connections are in use and in an appropriate technical and economic environment all of them can produce a satisfactory system of trussed rafters.

Nailed Plywood Gussets Appropriately shaped pieces of plywood are nailed to both sides of the joint. The plywood must be of a suitable structural grade and bonded with waterproof exterior glue. The high temperatures encountered in roof spaces can hydrolyse interior type glues relatively quickly. Load transfer is through the nails which must therefore be correctly spaced from each other and also from the edges and ends of the timber. This can be difficult to achieve with consistent results unless a nailing pattern is marked on the gussets and rigid inspection procedures are necessary.

The capital costs are relatively low and there is a fairly high component of unskilled labour.

Nailed-glued Plywood Gussets This is very similar to the last system, but the gussets are glued to the truss members with exterior type glue. Nails are used only to apply pressure on the glue line while it sets. The shear transfer capability of a well glued joint is very high and quite small gusset plates can be used and relatively few nails. However, structural glueing is a skilled operation and the timber must be dry, not more than about 15% moisture content, and freshly planed. The thickness of all truss members must be the same within narrow limits. While this applies to all gusseted joints the tolerances required for glueing are much smaller than for many mechanical fastening systems. The pot life of suitable glues is shortened by high temperatures and this system may therefore not be suitable for use in tropical countries. With adequate sized gussets this system results in the strongest and most rigid trussed rafters for a given timber size.

Steel Nail Plates

These are galvanised steel plates of about 1 mm. thickness, prepunched with nail holes in a suitable pattern to regulate the nail spacing. They are supplied in a range of sizes and shapes. Nails are driven through the holes to the truss and they are similar in factory requirements to nailed plywood gussets. Because of superior nail slip characteristics when driven through steel, 20% fewer nails are required compared with plywood.

The plates must be punched by a metalworking shop but relatively simple dies are used. Highly precise machinery is not essential.

The comments on capital and labour made under "Nailed Plywood Gussets" apply also to steel nail plates.

Toothed Plates

There are numerous designs of steel plates which have projecting teeth of various patterns which are pressed out of the body of the plate. Of all the mechanical fastenings these provide the most rigid joints and consequently the strongest trusses. These plates have various features in common:

> Manufacture is done with expensive dies on accurate presses with precise feeding gear.
>
> The plates can only be fixed to timber by large, expensive platen or roller presses, or by smaller but still expensive mobile hydraulic presses.

Toothed plates form the basis of the trussed rafter industries in most industrialized countries since plate manufacture presents no major problems and the large demand for trusses can sustain the capital required for a truss fabricating plant.

There are a few types of toothed plates (such as the "grasshopper plate") which can be fixed with hand tools under certain circumstances, but their manufacture is just as demanding as other types and their rigidity is not as high.

The properties of the various joints described are summarized in Table 1.

Toothed Plate	D	E	L	H	H	L	H	L

Abbreviations:

E	easy
D	difficult
H	high
M	medium
L	low

TABLE 1 - Comparison of Trussed Rafter Joints

	Plate Manufacture	Ease of Assembly	Quality Control Required	Joint Rigidity	Capital Required for Truss Factory	Skill Level Required in Fabrication	Gusset Material Quality	Timber Quality (Dimensional accuracy, Moisture content)
Nailed Ply	E	E	M	L	L	L	H	L
Glued Ply	E	D	H	H	M	M	H	H
Nail Plate	M	E	L	M	L	L	L	L

	Plate Manufacture	Ease of Assembly	Quality Control Required	Joint Rigidity	Capital Required for Truss Factory	Skill Level Required in Febrication	Gusset Material Quality	Timber Quality	
Nailed Ply	3	3	1	1	3	3	1	3	18
Glued Ply	3	1	1	3	2	2	1	1	14
Nail Plate	2	3	3	2	3	3	3	3	21
Toothed Plate	1	3	3	3	1	3	1	3	18

TABLE 2 - Evaluation of Trussed Rafter Joints

3 = **good quality,**

2 = **medium quality,**

1 = **bad quality.**

Awarding points on an arbitrary basis - 3 for a good quality and 1 for a bad quality, the totals for the properties compared are as shown in Table 2 with in a possible range of 8 - 24. These judgements are subjective and are the writer's opinions only on what is good or bad in a developing country. In other situations the ratings would change, for example where exterior structural plywood and dry planed timber are readily available the ratings in Columns 7 and 8 would be quite different.

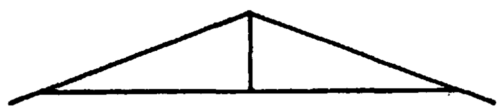
Choice of Systems

In a developing country with a trussed rafter market to be created it is the writer's opinion that the Nail Plate system is most appropriate. Capital requirements for plate manufacture and truss fabrication are low and since in many developing countries light metalworking industries are already established, to a moderate level of sophistication it is very likely that facilities already exist for plate manufacture and for the manufacture of the relatively simple dies. Because of the number of nails required to be hand driven, productivity will not be high, but if the productive capacity of several nail plate fabricating plants is reached then the country is probably ready to take the next step and embark in toothed plate connections. At this stage acceptance of the trussed rafter system will have been gained and there will be a cadre of skilled fabricators so the capital involved in both plate manufacture and truss fabrication can be immediately employed profitably without a market development stage.

3. TRUSSED RAFTER TYPES

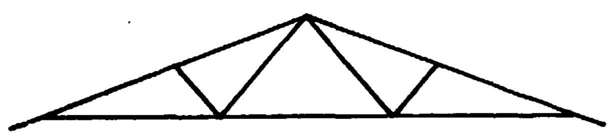
Numerous systems of web member arrangement are possible within a gable truss and most of them have been used. Some arrangements have been given names after their original designers. A description of the commonest types which have been used for trussed rafters follows:

1. Kingpost



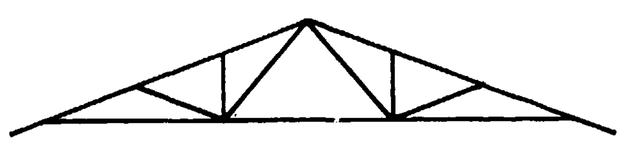
This simple arrangement is suitable for low pitches and spans up to about 4 or 5 m. Above this span, bending in rafter and ceiling tie becomes excessive.

2. W or Fink



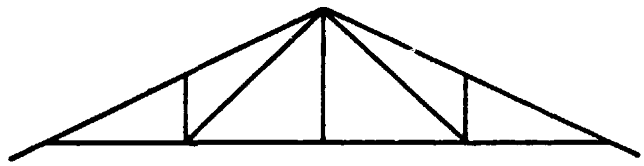
This is probably the most widely used configuration. The rafters are supported at the quarter points and the ceiling tie at the third points. With equal sized rafter and ceiling tie this gives a good balance between the roof and ceiling loads and the bending and direct stresses in the timber. The usual span range is about 6 to 9 m. which covers the bulk of domestic building requirements.

3. Fink Fan



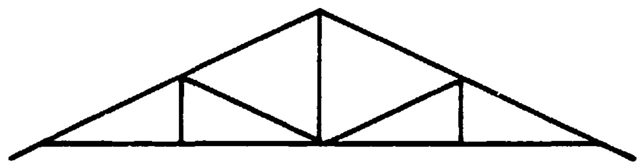
This arrangement reduces the span of the rafter elements compared with the ceiling elements and is useful where heavy snow loads are encountered on top of heavy weight roof coverings such as tiles or slates.

4. Pratt



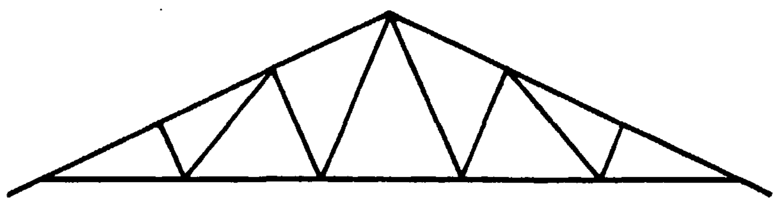
This arrangement is not much used unless high ceiling loads or a very rigid ceiling is required. This arrangement can also conveniently be used as a girder truss at a hip end with hip trusses framed into the kingpost. Another use is a girder truss in a "T" shaped building.

5. Howe



In this arrangement the long interior ties are replaced by shorter compression members. In monochord designs there is no particular advantage of either Pratt or Howe trusses.

6. Belgian or Double W

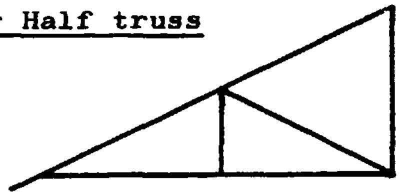


This arrangement is also widely used for longer span trussed rafters. With heavy roof coverings the usual spans are about 8 to 11m. and with lightweight coverings about 9 to 12m. taking over from W trusses but using the same timber sections.

Special Shapes

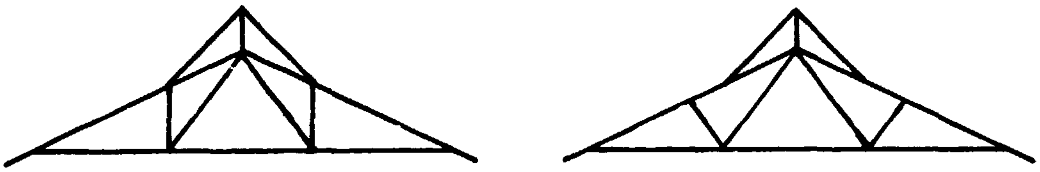
Trussed rafters are not limited only to the gable shape. Any roof shape can be supported on trussed rafters.

7. Monopitch or Half truss



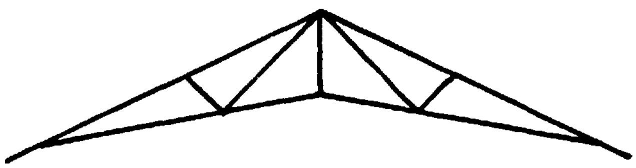
This shape is used for a shed roof or as a jack truss at a hip end.

8. Cripple



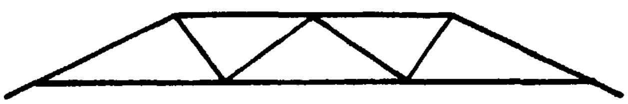
This shape may be required for architectural reasons. Ideally all members should meet at node points but in practice the cripple rafters may meet the common rafter at any point as shown in the second sketch and the main truss can then be fabricated in the normal manner using the standard cutting tables. Costs are reduced in this manner.

9. Scissors



This shape may be required in a building with a sloping ceiling.

10. Truncated



This shape is frequently used in hip roofs of steep pitch.

These shapes all require special design by a structural engineer familiar with trussed rafter design and manufacture.

In this report only W and Belgian types are covered as it is considered that these are adequate for all normal requirements, and of course snow load does not have to be considered in tropical countries.

4. TRUSSED RAFTER DESIGN

Triangulated trusses are generally designed on the assumption of pin jointed connections and discontinuous members. In trussed rafters both these assumptions are invalid since rafters and ceiling ties are continuous and the joints are more or less rigid. Direct application of the simple theory leads to conservative and uneconomic designs. A further source of overall roof strength comes from the close spacing of trussed rafters. Roofing and ceiling supports and bracing members impart a fair degree of load sharing to the roof structure and a weak flexible truss can shed a large proportion of its load to its neighbours.

These facts have been demonstrated by a very large number or laboratory tests, factory proof trials and in-service tests all over the world.

Accurate analysis is possible but is very complex owing to the high degree of redundancy of a semi-rigid continuous member truss. A computer programme has been prepared (1)[1/] but even with this, much of the data on joint rigidity is generally not available.

Semi-empirical methods are generally used and these are widely accepted. Design methods have been published by the British Standards Institution and the Truss Plate Institute (2, 3).

The requirements for joint design have been published by the above two bodies also the Standards Association of Australia and the Canadian Standards Association. All these bodies recognize the difficulties of accurate analysis and allow truss design on the basis of prototype testing (4, 5).

Several points in trussed rafter design should be noted.

There is considerable amount of rotational force in the heel joint of a gable truss and unit nail or tooth loads should be derated about 15% to allow for this. AS 1720 gives a detailed table of factors to cover this situation.

Although ceiling ties may be lightly stressed and where high grades of strong timber are available it may appear that shallow sections will suffice, a fairly rigid member is required to allow suitable nailing of ceiling linings without excessive bounce and to avoid any tendency to sag.

[1/] Numbers refer to references on page 48.

Deflexion and Camber

All structures deflect under load and trussed rafters are no exception. The deflexion is small - of the order of $\frac{1}{1000}$ of the span under normal loads. The elastic deflexion may be calculated by strain energy methods which are described in text books of structural mechanics. In addition to the elastic deflexion slip at the nail plates also occurs. It has been found in practice that an increase of about 50% over the calculated elastic deflexion gives a good estimate of the total at the ceiling tie.

It is not normal for any camber to be built into trussed rafters for domestic construction since this complicates manufacture and construction of interior partitions and the amount of the deflexion is small.

5. PLATE DESIGN AND MANUFACTURE

Nail plates are punched from galvanised mild steel sheet of about 1.2 mm. (18 gauge) thickness. The raw material is best supplied in coil form slit to the finished plate width. If this is not available, strips guillotined from sheet material can also be used.

In the large number of joint situations which can arise, a large number of widths add to manufacturing difficulties. Lengths are easily varied, but width changes require resetting of machines. Also numerous sizes entail additional inventory costs for both plate manufacture and truss fabricator.

The range of sizes shown is a compromise between a minimum number of sizes and efficiency in plate use. It allows manufacture of the full range of trusses shown in the design sheets. Situations may arise where additions to the range are required. There is no objection to this.

The hole spacing and layout shown has been found to be adequate for most medium density timbers to be nailed without excessive splitting. The spacings used are considerably closer than are normally permitted by timber design codes but there are two very important points which do not occur in the situation envisaged in design codes:

1. Nails do not penetrate the full thickness of the timber, and so leave some undisturbed timber beyond the points.

2. The fixity of the steel plate does not allow the timber to expand laterally, so a potential split cannot widen and develop fully.

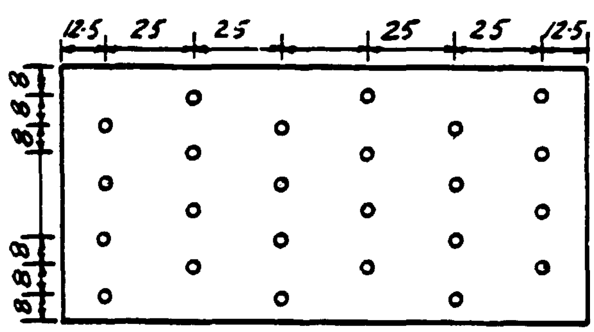


Fig 1 - Nail Plate Details

Nail plates can be made in any size using the hole spacings and edge distances shown in the drawings. A typical plate is shown in Fig 1 above. In practice the number of different sized plates should be limited to as small a range as possible consistent with economy.

The plates are described by the number of holes in a row in the width direction by the number of rows of holes in the length direction. The abbreviation NP (Nail Plate) may be used on drawings. The plate shown in Fig 1 would be described as NP 4 x 6. Note that for symmetry, nail plates should always be even numbers in both directions.

The designs in this Report use 13 sizes, namely

NP 2 x 6	NP 6 x 6	NP 8 x 4
NP 4 x 6	NP 6 x 8	NP 8 x 6
NP 4 x 8	NP 6 x 10	NP 8 x 10
NP 6 x 4	NP 6 x 12	NP 12 x 6
		NP 12 x 10

Manufacturers may wish to extend the range of sizes to suit other applications. Variations in length are easy to accommodate since this is only varying the cut-off length. Variations in width require a different width of steel strip and alterations to the punching dies.

Steel for nail plates should be 18 gauge (1.2mm) galvanised mild steel complying with British Standard 2989 Class 2A, Australian Standard 1397 - minimum yield stress 250 MPa, or equivalent local standards. **The minimum weight of zinc galvanizing should be 300gm/m^2 per side.**

<u>Plate Strength</u>

The strength of a pair of plates in tension is 3200 Kg per 100 mm of width.

The strength of a pair of plates in compression is limited by their tendency to buckle. Across a compression joint there will usually be a row of holes not filled with nails. The buckling length will then be equivalent to 0.85 x 50 mm and the plate strength is 1400 Kg per 100 mm of width for a pair of plates.

Many design codes do not allow the use of calculated plate compression loads and require these forces to be taken solely by timber bearing. However, there is no doubt that in many structures which have been fabricated with joints which do not fit tightly heavy compression forces are being carried by toothed or nail plates with no obvious ill effects.

It is the author's opinion that in plates of the thickness recommmended here (1.2mm) plates can be used to carry compression forces, but this should not be used as an excuse for joints which do not fit tightly and gaps in either tension compression or shear joints should not be accepted.

6. NAILS

Short, thick flathead nails (clouts) should be used for fixing the plates. For 50mm thick timber they should be about 35mm long x 3.3. mm diameter.

Nail strengths should be established by test in typical joints. Not less than 10 tests should be performed on each type of joint and the design load calculated from the lesser of the mean load at 0.5 mm wood to wood slip or one-sixth of the mean ultimate load.

Preliminary designs can safely be prepared in medium density softwoods using a unit nail load of $6d^{1.5}$ where d is the nail diameter in mm and the load is in Kg. In practice since identical plates are fixed on both sides of a joint, the load per nail in a joint as drawn is taken as double the value given above. The designs in this report have been prepared using a value of 72 Kg per nail in the joints as drawn.

Nails must be kept clear of edges and ends of members to avoid splitting. Recommended end and edge distances are 15 mm for the nails specified above.

7. TIMBER

Trussed rafters can be made from any suitable species and grade of timber. That used will generally be the species and grade commonly used for traditional framed roof construction in the area since the requirements for both are much the same.

The designs in this report[1] have been prepared for softwoods of Second Strength Grade:

Pine . . . . Pinus patula, P. radiata
Podo . . . . Podocarpus gracilior
Cypress . . . Cupressus lusitanica

This allows for the following defects:

Edge knots - half the thickness (25mm)
Margin knots - one quarter of the width (25mm)
Centre, Splay and Cluster knots - one third of the width (33mm)
Slope of grain - one in eight

(Figures in brackets to refer to 100mm x 50mm timber)

Timber which is recut for struts and ties must be regraded before use.

Trussed rafters should be manufactured from timber which is seasoned to 22 per cent maximum moisture content. Seasoning should be carried out in carefully filleted stacks, shaded from direct sunlight, so that the timber dries straight and free of sun checks.

In areas subject to insect attack, timber should be preservative treated. Insect attack may come from carpenter bees or drywood termites. Rarely will subterranean termites attack roof timbers although this can happen. Preservation by either vacuum-pressure treatment using copper chrome arsenic salts or by controlled diffusion using boron fluoride arsenic salts is satisfactory. For full details of these processes, readers should refer to the appropriate local standards.

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[1] The Kenya Timber Rules 1971 Legal Notice No. 173 allow for First, Second, Third and Fourth Strength Grades.

8. TRUSS GEOMETRY

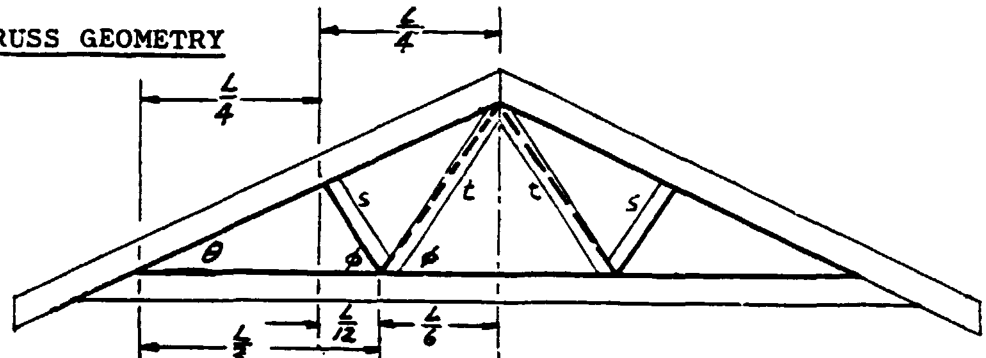


Fig 2 - W Truss Layout

W TRUSS

The standard truss layout, referred to the INSIDE triangle formed by the rafters and ceiling tie is shown in Fig 2 above. Details of W and Belgian trusses which shows the way in which the joints fit together are included in the drawings. From this layout it can be shown that there is a relationship between the angles θ (the pitch angle) and ϕ (the tie angle).

$$\tan \phi = 3 \tan \theta \quad - \quad (1)$$

In turn it can be shown by solving the triangels that

t, the tie length $= 6 \dfrac{L}{\cos \phi}$

s, the strut length $= \dfrac{L}{12 \cos \phi}$

where L is the effective span, that is the length of the upper or inside edge of the ceiling tie. Consequently the tie is exactly twice the length of the strut.

Coefficients for these lengths have been included in Tables 3 and 3a (pages 23 and 24). Note that if the strut length is calculated first then the tie length is found by multiplying this length by 2. The layout of the strut and tie is such that variations in width of these members has no effect on their length or accuracy of fit in the assembled truss.

The difference between full span and effective span depends on the pitch angle θ and the actual depth of the ceiling tie. The relationship is:

Difference between full and effective span

$$= \frac{2}{\tan\theta} \times \text{depth of ceiling tie.}$$

A table of coefficients of $\dfrac{2}{\tan\theta}$ is included in Table 3.

The angles at the ends of these members can also be calculated from equation (1) above and are shown in Table 4 (page 26). However, a slight adjustment must be made to these angles to allow for the fact that the intersection of the tie and the apex is not along the edge of the tie, but is displaced 25mm. This is in order to bring more area of the tie under the apex plate. This constant displacement results in a varying amount of rotation from the theoretical angle, depending on the span of the truss. The average rotation is slightly over 1 degree and the angles in Table 4 have been adjusted accordingly.

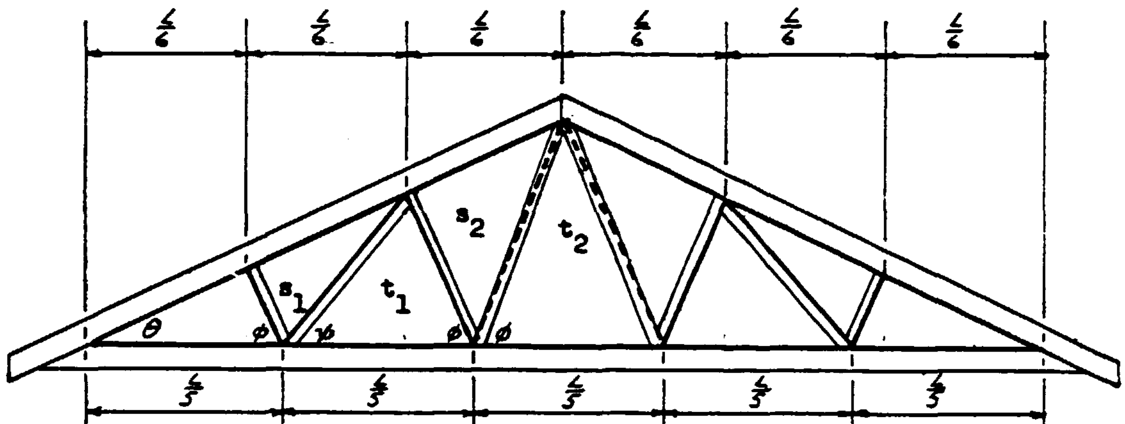
Coefficients to calculate the slope length of the rafter and the slope length of the overhang have also been included in Table 3. These are included since normally only the plan dimensions are included in architects' drawings. These coefficients are $\frac{1}{2\cos\phi}$ and $\frac{1}{\cos\phi}$ respectively.

Note that the rafter length coefficient refers to the FULL span as measured on the underside of the ceiling tie NOT the effective span which is used to calculate the strut and tie lengths.

When determining the overhang, care should be taken to check whether the dimension on the drawings refers to inside or outside of the fascia board. In the latter case which is general, the fascia board thickness must be subtracted from the overhang dimension before calculating the overhang slope length.

The trussed rafter order and fabricating sheet shown in Fig. 8 includes space for all these calculations in a conveniently laid out arrangement.

Fig. 3 - BELGIAN TRUSS



This is slightly more complex than the W truss but the principles of calculation are exactly the same.

There are two subsidiary angles as shown in Fig 3 above and it can be shown that

$$\tan \phi = 5 \tan \theta \quad - \quad (2)$$

$$\tan \psi = \frac{5}{2} \tan \theta \quad - \quad (3)$$

The strut and tie lengths are calculated from

$$s_1 = \frac{L}{30 \cos \phi} \qquad s_2 = \frac{L}{15 \cos \phi}$$

$$t_1 = \frac{2L}{15 \cos \psi} \qquad t_2 = \frac{L}{10 \cos \phi}$$

The angles for cutting the struts and ties are calculated similarly. However, the adjustment to the angles for t_2 is taken as only 0.7° since this type of truss is used in the longer span range of about 9-12 metre span. Length coefficients and cutting angles are given in Tables 3, 3a, 4 and 5 (pages 24, 25, 26 and 27 respectively).

CALCULATION OF TRUSS MEMBER LENGTHS & SETTING-OUT DIMENSIONS

The geometrical principles described in the preceeding part of this Section have been summarised in Table 3 to allow quick calculation of the various member lengths. The Truss Order Form shown in Fig 4 has been laid out to give space for these calculations to be made in an orderly manner so as to avoid as far as possible any mistakes.

It is assumed that an electronic calculator with memory store is used for these calculations. All dimensions should be expressed in millimetres and rounded to the nearest whole millimetre. There is no point in trying to be more precise.

The procedure for calculating the various lengths is as follows. The results of each calculation are entered in the appropriate space on the order form.

1. From the architect's drawing or information supplied by the builder, enter the span, pitch and overhang on the order form. If the overhang is measured to the outside of the fascia board, subtract the fascia board thickness to give the rafter overhang.

2. Multiply the rafter overhang by the coefficient in Column 2 to find the overhang slope length and enter on the order form.

3. Multiply the span by the coefficient in Column 3.

4. Add (2) and (3) together to give the rafter length.

5. Multiply the width of the timber to be used for the ceiling tie by the coefficient in Column 4 to find the deduction for the effective span.

6. Subtract (5) from the span to find the effective span.

7. Multiply (5) by the coefficient in Column 5 to get the internal height.

8. Multiply width of the timber to be used for the ceiling tie by the coefficient in Column 6 to get the plumb cut depth.

9. Add (7) plus (8) plus the width of the ceiling tie to find the overall height. This figure is used to set out the truss on the jig table.

W TRUSSES

10. Multiply the effective span (6) by the coefficient in column 7 to find the strut length.

11. Multiply (10) by 2 find the tie length.

BELGIAN TRUSS

12. Multiply the effective span (6) by the coefficient in column 9 to find the length of Strut 1.

13. Multiply (12) by 2 to find the length of Strut 2.

14. Multiply the effective span (6) by the coefficient in column 11 to find the length of Tie 1.

15. Multiply the effective span (6) by the coefficient in column 12 to find the length of Tie 2.

A sample truss order form complete with these calculations is shown in Fig 5.

After the length calculations are completed the cutting angles from Table 4 or 5 are entered on the form. Then by reference to the design section, details of nail plate sizes and nail numbers are also entered.

One copy of the order form should now be sent to the factory for use as a manufacturing job sheet and then as a delivery note.

TRUSS ORDER SHEET

Builder:
Account address:
Phone: Contact Name: Order No.:

Date order received: By:
Delivery Address:

Span: mm Pitch: ° Overhang: mm inside) outside) mm thick fascia

Number of trusses: Roof covering:
Truss spacing: Truss type :

Details confirmed - Builders Signature: ____________________

	coeff	span	length
Rafter	x	=	
Overhang	x	=	

Total rafter length ______ Number

Span

CT depth x = ______ span reduction

Effective span = ______ x ht coeff = internal height

CT Depth x = plumb cut

CT depth = ______

overall height

coeff

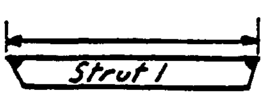
Effective span x = Strut 1 length

== Strut 2 length

= Tie 1 length

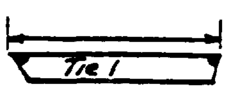
= Tie 2 length

CT Cut Angle ° Rafter Cut Angle °



CT Cut Angle ° Rafter Cut Angle °

CT Cut Angle ° Rafter Cut Angle °



CT Cut Angle ° ° Rafter Cut Angle °

Plumb Cut Angle °

		Number	Nails		
Plates	Heel :		R	CT	
	Splice :				
	Apex :		R	T	
	Rafter 1:		R	S	
	Rafter 2:		R	T	S
	CT 1 :		CT	S	T
	CT 2 :		CT	S	T

FIG 4 : TRUSS ORDER FORM

(CT = Ceiling Tie)

TRUSS ORDER SHEET

Builder: A.R.C. Construction Ltd
Account address: P.O. Box 13 Waikikamukau.
Phone: 123 Contact Name: Mr Muangi Order No.: 321

Date order received: 10-11-90 By: AJF
Delivery Address: Site 27 Council Project No 3

Span: 7820mm Pitch: 25° Overhang: 600 mm ~~inside~~) outside) 30 mm thick fascia

Number of trusses: 38 Roof covering: corr galv. steel
Truss spacing: 1000 Truss type : W

Details confirmed - Builders Signature: [signature]

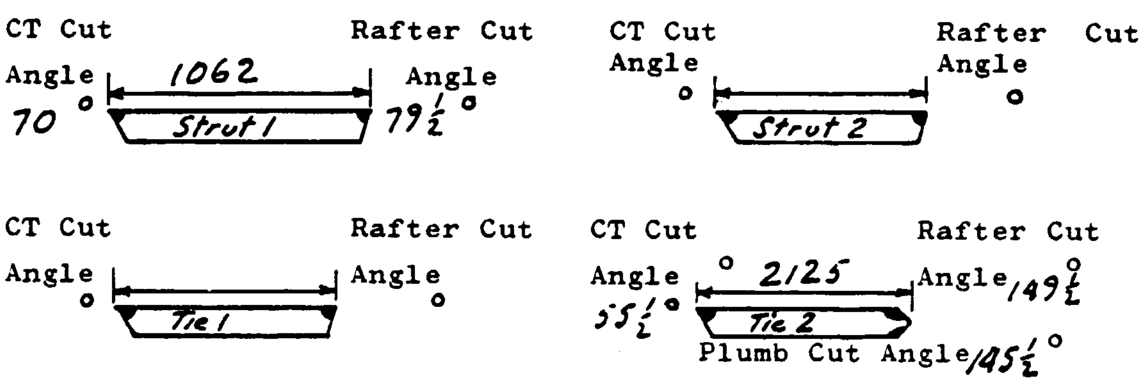
	coeff		span		length
Rafter	·5517	x	7820	=	4314
Overhang	1·103	x	570	=	629

Total rafter length 4943 Number 76

Span			7820
CT depth	95	x 4·289 =	407 span reduction
Effective span		=	7413 x ht coeff ·2332 = 1729 internal height

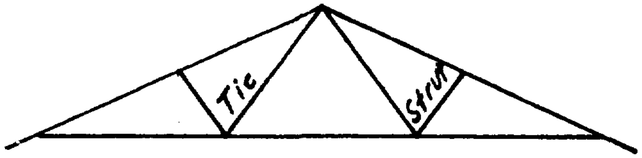
CT Depth 95 x 1·10 = 105 plumb cut
CT depth = 95
1929 overall height

	coeff			
Effective span x	·1433	=	1062	Strut 1 length
		=		Strut 2 length
		=		Tie 1 length
		=	2125	Tie 2 length

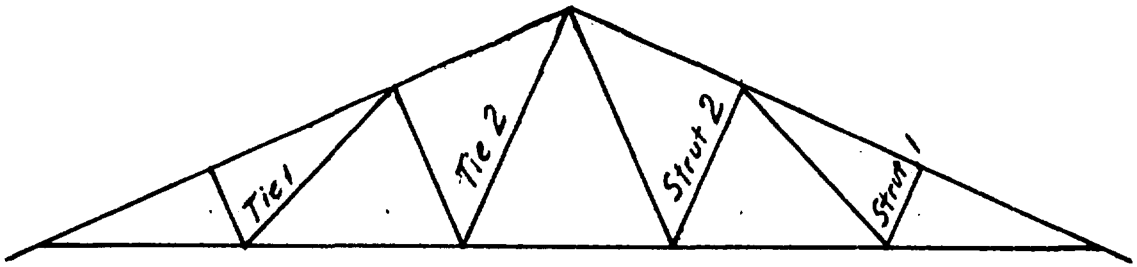


Plates		Number	Nails		
Heel	: 6x8	152	R 12	CT 10	
Splice	: 4x8	76	12		
Apex	: 6x10	76	R 10	T 2	
Rafter 1	: 2x6	152	R 5	S 5	
Rafter 2	:		R	T	S
CT 1	: 6x6	152	CT 3	S 3	T 4
CT 2	:		CT	S	T

FIG 5 : COMPLETED TRUSS ORDER FORM



W TRUSS



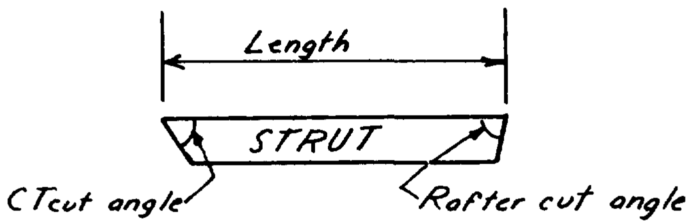
BELGIAN TRUSS

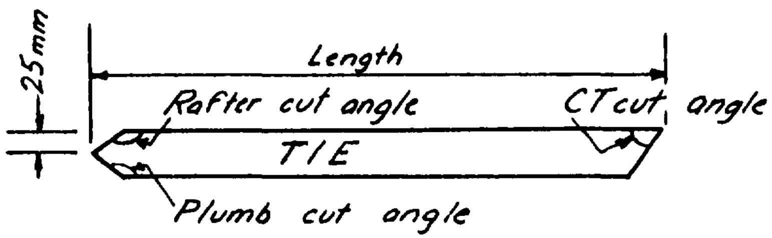
1	2	3	4	5	6	7	8	9	10	11	12
Pitch	Overhang	Rafter	Deduction x CT depth for eff span	Height	Plumb cut depth	W Truss		Belgian Truss			
						Strut	Tie	Strut 1	Strut 2	Tie 1	Tie 2
15	1.035	.5176	7.468	.1340	1.04	.1069	.2138	.0557	.1115	.1605	.1672
17½	1.048	.5243	6.343	.1576	1.05	.1147	.2294	.0622	.1245	.1698	.1867
20	1.064	.5321	5.495	.1820	1.06	.1234	.2468	.0692	.1384	.1803	.2077
22½	1.082	.5412	4.828	.2071	1.08	.1329	.2658	.0767	.1533	.1919	.2230
25	1.103	.5517	4.289	.2332	1.10	.1433	.2866	.0846	.1691	.2048	.2537
27½	1.127	.5637	3.842	.2603	1.13	.1545	.3091	.0929	.1859	.2188	.2788
30	1.155	.5744	3.464	.2887	1.15	.1667	.3333	.1018	.2037	.2341	.3055

TABLE 3 : W & BELGIAN TRUSSES - LENGTH COEFFICIENTS

1	2	3	4	5	6	7	8	9	10	11	12	13
						S Truss		Belgian Truss				
Pitch	Overhang	Rafter	Deduction xCT Depth for Effective Span	Height	Plumb Cut Depth	Strut	Tie	Strut 1	Strut 2	Tie 1	Tie 2	Pitch Angle
1 in3.5	1.040	.5200	7	.1429	1.04	.1098	.2195	.0581	.1163	.1639	.1744	15°57'
1 in3	1.054	.5270	6	.1667	1.05	.1179	.2357	.0648	.1296	.1736	.1944	18°26'
1 in2.5	1.077	.5385	5	.200	1.08	.1302	.2603	.0745	.1491	.1886	.2236	21°48'
1 in2.25	1.094	.5472	4.5	.2222	1.09	.1389	.2778	.0812	.1625	.1993	.2437	23°58'
1 in2	1.118	.5590	4	.2500	1.12	.1502	.3005	.0898	.1795	.2134	.2693	26°34'
1 in1.75	1.152	.5759	3.5	.2857	1.15	.1654	.3308	.1009	.2018	.2325	.3027	29°45'

Table 3a: W + BELGIAN TRUSSES - LENGTH COEFFICIENTS - RISE AND RUN

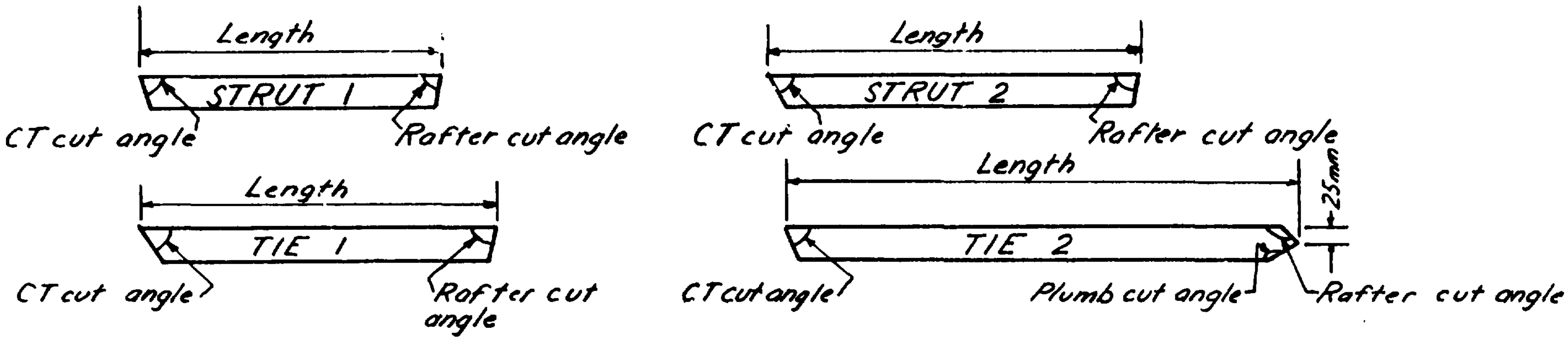




Pitch	STRUT		TIE		
	CT Cut angle	Rafter cut angle	CT cut angle	Plumb cut angle	Rafter cut angle
15	101	54	40	130	155
17½	92	61	44½	134½	153
20	84	67½	48½	138½	151½
22½	76½	73½	52½	142½	150
25	70	79½	55½	145½	149½
27½	64	85	58½	148½	149
30	59	90	61	151	149

TABLE 4 W TRUSS - STRUT & TIE CUTTING ANGLES

Note: Angles given to nearest half degree



Pitch	Strut 1		Tie 1		Strut 2		Tie 2		
	CT cut angle	Rafter cut angle	CT cut angle	Rafter cut angle	CT cut angle	Rafter cut angle	CT cut angle	Rafter cut angle	Plumb cut angle
15	93	68½	34	93	73	68½	54	141	144
17½	84	75	38	84	64	75	58½	139	148½
20	76½	81	42½	76½	57	81	62	138	152
22½	70	86½	46	70	51	86½	55	137½	155
25	64	92	49½	64	45½	92	67½	137½	157½
27½	58½	96½	52½	58½	41½	96½	69½	138	159½
30	54	101	55½	54	37½	101	71½	138½	161½

Note: Angles given to nearest half degree

TABLE 5 BELGIAN TRUSS - STRUT & TIE CUTTING ANGLES

9. CANTILEVERS

Frequently it is necessary that trusses are supported back from the heel point, as over a porch or similar set back in the supporting wall. In this case reinforcement of the ceiling tie with an additional member is required.

The cantilever distance is measured from the heel point back to the outside of the supporting wall plate.

For cantilivers up to 20 cm a reinforcing wedge is fixed between the rafter and ceiling tie. This wedge is made from the offcut from the ceiling tie. Fixing is with a pair of plates the same size as the heel plate. See Fig 6.

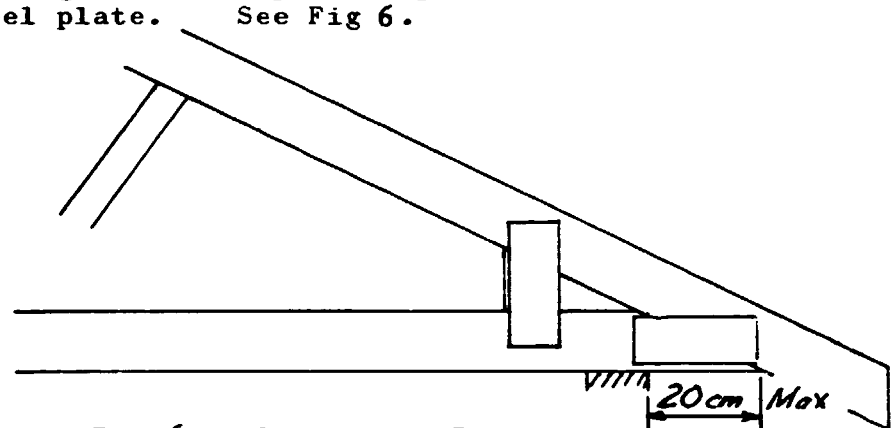


Fig 6. - Cantilever Reinforcement at Heel

For cantilevers from 20 cm up to one sixth of the span an additional strut must be fixed running up to the rafter-strut connection. This additional strut should be the same size as the rafter. It must be cut so that its outer end is 5 cm inside the outer face of the wall plate. Its upper end should be cut to give a 5 cm bearing against the strut and a long cut bearing snugly against the rafter. Both ends are fixed with plates the same size as the heel plate as in Fig. 7.

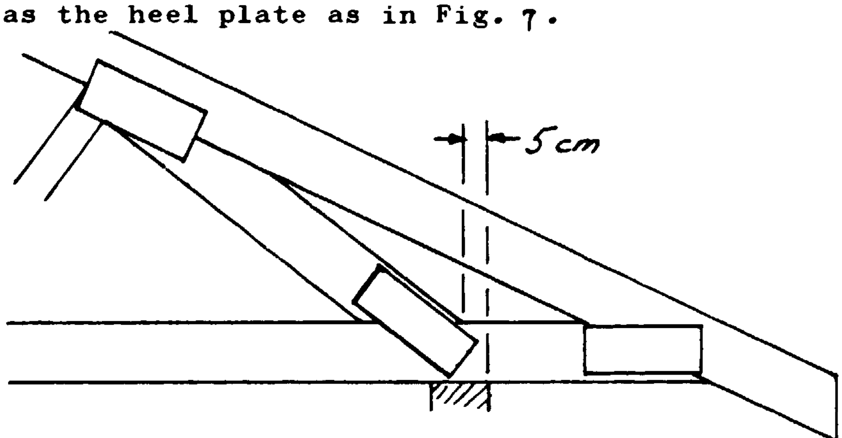


Fig 7. - Cantilever Strut

Cantilevers which exceed the scope of these rules must be the subject of a special engineering design.

When erecting cantilever trusses care must be taken to see that they are in fact erected the right way round and that ordinary trusses are not confused with cantilever trusses. This is a very easy mistake to make. It is a good idea to have a stencil made with the work CANTILEVER and an arrow which is placed over the cantilever point as in Fig 8.

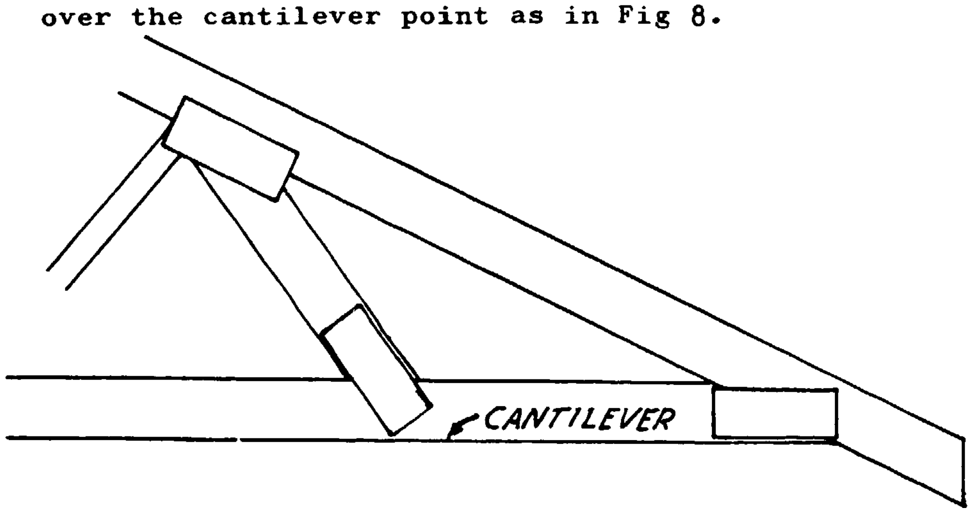


Fig 8. - "CANTILEVER" Stencil

10. CEILING TIE SPLICE

For trusses over 6 m. span a joint will be necessary in the ceiling tie. This joint should not be placed in the centre of the span, but should be offset towards one of the ceiling tie panel points. The ideal position of the joint is one-fifth of the panel length away from the panel point, but this positioning is not critical and it can be moved a few cm either way to suit the standard timber lengths or to give round numbers for simplicity of cutting.

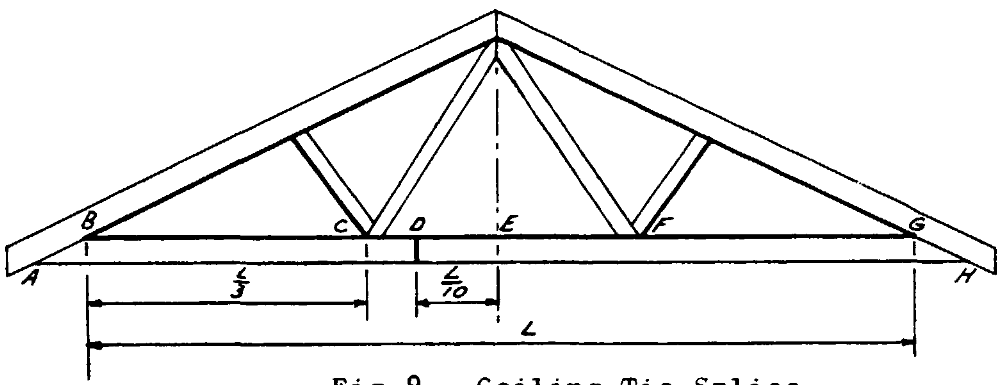


Fig 9 - Ceiling Tie Splice

The position of the splice can most easily be calculated from the centre of the span. In Fig. 9 above,

$$BC = CF = FG = \frac{\text{effective span}}{3}$$

$$CD = \frac{CF}{5} \quad \text{as recommended above}$$

$$DE = \frac{3}{10} \quad CF$$

$$= \frac{BG}{10}$$

To determine the length of the long and short parts of the ceiling tie=

Halve the full span AH
Subtract from this one-tenth of the effective span BG
Round this to a convenient figure. This will be the length of the shorter piece of ceiling tie.
Subtract this length from the full span to give the longer length of ceiling tie.
Check by adding the two ceiling tie lengths together that they total to the span.

For example consider a truss with span 7400, pitch 25°
ceiling tie 90 x 45.

Span	= 7400	
Effective span	= 7014	(Calculated on the truss order sheet, step 6)
$\frac{7400}{2}$	= 3700	
minus $\frac{7014}{10}$	= 701	
Difference	= 2999	
Make shorter length	= 3000	
Longer length	4400	
Check total	7400	

In the case of the Belgian truss, the procedure is similar but because the ceiling tie now has five panels the effective span should be multiplied by $\frac{3}{50}$ = .06 to give the same relative position of the splice in the centre panel.

If the truss in the example above were of Belgian configuration the calculation would be:

Span	= 7400
Effective Span	= 7014
$\frac{7400}{2}$	= 3700
minus 7014 x.06	= 421
Difference	= 3279
Make shorter length	3300
Longer length	4100
Check total	7400

11. FACTORY ORGANISATION AND LAYOUT

The operations carried out in a truss factory are:

- Thicknessing
- Grading and sorting
- Ripping to make web material
- Cutting components to length and angle
- Truss assembly and nailing first side
- Nailing second side

Thicknessing

The maximum permissible thickness variation in timber joints made with nail plates is 2 mm. If timber can be purchased to this tolerance either sawn or planed then thicknessing at the factory will not be required. If sawmill tolerances exceed this amount then a thicknessing operation will be required. For top quality trusses the width of the timber should also be accurate since variations in width will result in irregular fascia and roof lines.

Planer gauging on all four sides is ideal, but either planer or saw gauging on one face and one edge will produce timber which is adequate for good quality trusses. If saw gauging is used then a heavy plate with carbide tipped teeth should be used to resist the abrasion which will frequently occur when the saw just skims the surface. A radial arm feed is desirable to hold the timber firmly against the saw fence.

Grading and Sorting

Timber should be length sorted for minimum waste. Timber with excessive defects can be cross cut for use in web members. Short pieces should also be reserved for webs.

Ripping

In many designs of trusses web members need be only 50mm wide and these can be economically produced from reject chord material. This can be done on the same machine used for saw gauging although a narrow kerf saw is preferable for economy, low power consumption and high production rate.

Cutting Components to Length and Angle

This is a key operation in truss manufacture. Precision in angles and lengths is essential for the production of uniformly sized and shaped trusses. Various specialised machines have been developed for high production factories. These include computer-set multiple fixed saws with the timber travelling through, along the lines of a double-ended tenoner, and a rotatable rising crosscut saw with various angle stops.

For a small truss plant the most appropriate machine is a radial arm crosscut saw. This should be adjustable in angle relative to the rear fence. Height and compound angle adjustments are also useful, though not essential.

The saw should be mounted on a rigid foundation. It should be located near one end of a bench 6 m long on the left of the saw and 3 m long on the right. The bench must have a rear fence and preferably should have its surface of medium or heavy duty conveyor rollers spaced about 30 cm apart except for the area which the saw can reach which should have a 50 mm thick timber working surface.

In most models of radial arm saw the length of saw travel is considerably reduced when cutting very acute angles, that is nearly parallel with the fence.

This can make the sawing of the heel cut on ceiling ties difficult. In this case a support should be fixed to the floor about 2.5 m. in front of the saw and adjustable relative to the line of the saw when it is cutting square to the fence. The deviation from square of the saw when making a heel cut is then much reduced.

For higher production two radial arm saws fixed about 4.5 m. apart on a common bench can considerably speed production. One end of a component is cut on one saw and it is then pushed along to the other saw which makes the other cut.

Subsidiary tools and aids should include a large protractor two sliding bevels, try-square and steel tape. Length stops of scraps of timber are G-clamped to the rear fence.

When cutting web members use should be made of temporary fences nailed or clamped to the wooden bench. These will allow the two cuts in a strut or the three cuts in a tie to be made in a single handling. There are 18 cuts to be made in a W type truss and all time saved in these operations is worthwhile.

Detailed instructions for sawing components are given in Sections 12 and 13.

Truss Assembly and Nailing First Side

It is possible for this work to be carried out on a concrete floor. This means the workmen spend much of their time on their knees, not a position conducive to high productivity. Also the components should be accurately located so that the outside shape of all trusses in a batch is identical and this is not easy on a concrete surface.

The best arrangement for nailing would consist of a large triangular bench covered with 50mm T and G timber.[1/] This has numerous 14mm holes drilled through it to take angle cleats which define the shape of the truss. The bench should have supports to a solid floor to provide a surface satisfactory for nailing. It should be big enough to take the largest truss commonly manufactured but not too big or difficulties will be experienced when nailing smaller trusses.

In using such a bench the first truss of a batch is carefully laid out using parallel and perpendicular lines which have been accurately marked in its surface with shallow saw cuts. The angle cleats are positioned around the truss perimeter and fixed. Additional cleats are fixed inside the truss a few cm away from the timber to take wedges. The webs are positioned and cleats fixed to align them. Then the plates are nailed on, the wedges knocked out and the truss is turned over the other side to have its plates fixed. Depending on production rates this second nailing may be done on the same table or on a second similar one without any cleats.

Details of a suitable bench and cleats are shown in the drawings on page 64.

A general arrangement drawing of a suitable factory layout is also shown on page 64. This allows for a rational flow of timber from the timber store through the cutting and assembly areas to the finished truss stacking area. Intermediate stacking areas are included. Lockers for storage of hand tools, nails and plates should be provided.

[1/] T and G = tongued and grooved

12 STAFF

Office Staff

A trussed rafter factory will require the usual management and administrative services. The manager should be experienced in carpentry, particularly roof construction. He should also have a good knowledge of the timber industry in his own area. It would also be helpful if he had a knowledge of structural engineering although this is not essential. Routine designs are included in this Report. He should have access to structural engineering advice to be able to cope with special designs. Possibly as production expands it may be possible to hire a technician as assistant manager to handle technical matters including design, promotion, supervision of timber quality, advice to builders etc.

Office assistance will depend on the volume of production. Initially a typist-clerk should be sufficient.

Factory Labour

The exact duties of factory personnel will vary depending on the production rate. The job descriptions which follow are for a very small factory. As production increases and additional labour is hired so some of these jobs will become more specialised and the range of duties will decrease.

Foreman - one

Set out components for cutting

Set up saws, stops etc. for component cutting

Set up jig for nailing

Supply correct size nail plates to each joint position

Check on: accuracy of thicknessing
accuracy of component cutting
correct placing of nail plates
correct number of nails in joints
overall accuracy of truss dimensions

Supervise factory safety and efficiency.

Sawyer - one

Saw gauge timber to dimension.

Rip shorts for struts and ties.

Grade timber for rafters, ceiling ties and recutting, also regrade timber for struts and ties.

Cut components on radial arm saw.

Nailing Hands - five

Assist foreman in jig set up.

Nail on plates as instructed.

Labourers - four

Move timber and components around factory as required.

Tail out for sawyer.

Assist sawyer in cross cutting.

It is expected that a production team as above would be able to make 20-25 8m trusses per 8-hour shift.

Materials required:

Wood - 420m of 100 x 50mm sawn wood, gauged to width
60m of 100 x 50mm ripped to 50 x 50mm.

Say	500mm ripped at 5m per minute =	100 mins.
and	360cm cuts at 3 per minute =	180 mins.
		280 mins.
Allow 120 mins for saw setting, etc.		120 mins.
Nails -	(8m HW8 20°)	
	460 per man per day = 2,300	
Allow 15 sec per nail		115 mins.
	Total	515 mins.

This allows plenty of time for handling timber, positioning plates, loading trusses, etc..

13 SAWING OF TRUSS COMPONENTS

Accuracy of sawing components to length and angle is vital for the production of quality trusses. There are eighteen cuts to be made in a W truss and even more in a Belgian truss so sawing must be fast as well as accurate. It is worthwhile planning sawing operations with care to assure maximum production together with accuracy.

The rules which should be followed are:

1. Once a piece of timber is picked up and placed on the bench all cuts should be completed on it before it is put down.
2. Cutting to length should always be done to a stop clamped to the rear fence of the sawing bench.

Rafter (Fig 10)

Set the saw to cut the plumb cut angle, that is 90° minus the pitch angle. For a 20° pitch the saw should cut 70°.

1. Cut the angle at one end.

2. Slide the timber along the bench to the stop.

3. Cut the other end which will be to lenth and angle.

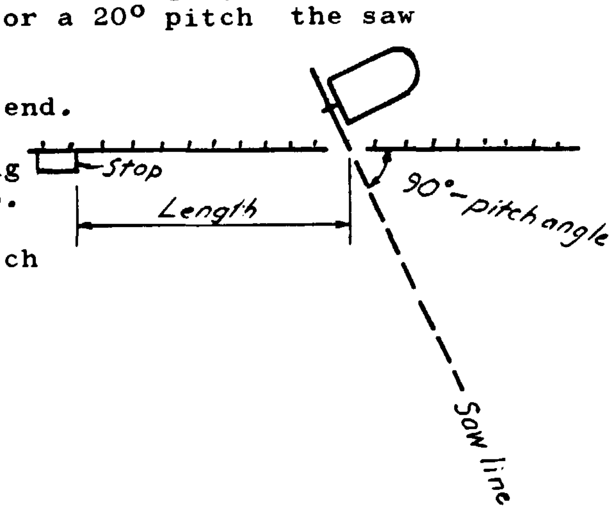
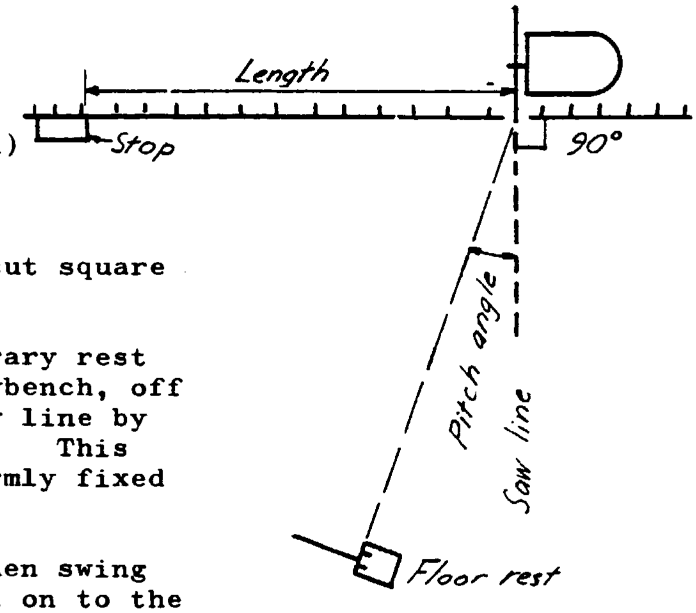


Fig 10 Saw Setting for Rafter



Ceiling Tie (Fig 11)

1. Set the saw to cut square across.

2. Erect the temporary rest out from the sawbench, off set from the saw line by the pitch angle. This rest must be firmly fixed to the floor.

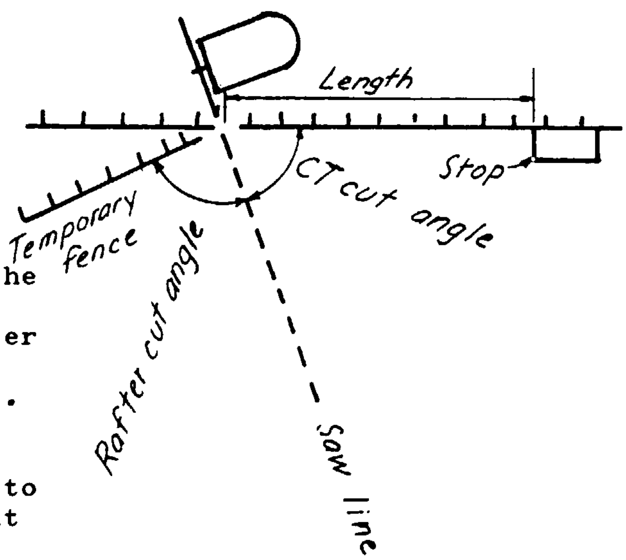
3. Cut the heel, then swing the timber round on to the bench and push the point up to the stop.

4. Cut the ceiling tie to length.

Fig 11 Saw Setting for Ceiling Tie

The long ceiling ties should be cut first, then if any prove to be too short they can be cut to the length of the shorter ceiling tie.

Strut (Fig 12)



1. Set the saw to the CT Cut angle.

2. On the other side of the saw, fix a temporary fence to give the rafter cut angle between this fence and the saw line.

3. Cut the rafter angle, push the timber along to the length stop and cut the CT angle.

Fig 12 Saw Setting for Strut

Tie (Fig 13)

Three cuts are required and two lengths, the 25 mm offset at the rafter cut and the overall length.

1. Set the saw to the CT cut angle.

2. Fix a stop on the fence 25 mm from the new saw line, (Stop A).

3. Fix a temporary fence (Fence B) on the front of the bench to give the rafter cut angle. Make the rafter cut.

4. Fix a temporary fence (Fence C) to the bench to give the plumb cut angle from the saw line with the tie turned the other way up. Make the plumb cut.

5. Pack the length stop D out from the fence the same thickness as Stop A. Cut to length and CT cut angle.

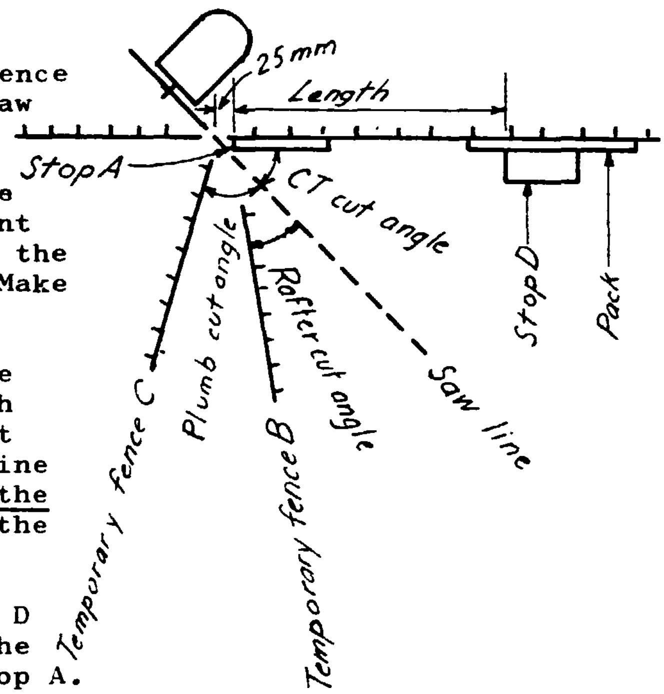


Fig 13 Saw Setting for Tie

It is best to carefully mark out a prototype of each piece and use this to set the angle and length fences and stops. Fences and stops should be made from hard straight wood and kept for that purpose. A distinguishing coat of paint will help to avoid them being swept away as rubbish.

The face or better edge of struts and ties is the one which must be kept against the fence when cutting. Care should be taken to stack these members the same way when taking them to the truss assembly area. This applies particularly to struts where the angles at each end are quite similar.

14. HANDLING, ERECTION, BRACING

After manufacture, trusses must be handled carefully. They should be carried upside down (apex to the ground) by two men. When stacked on the building site they should be supported on several firm level bearers, clear of the ground and without any distortion.

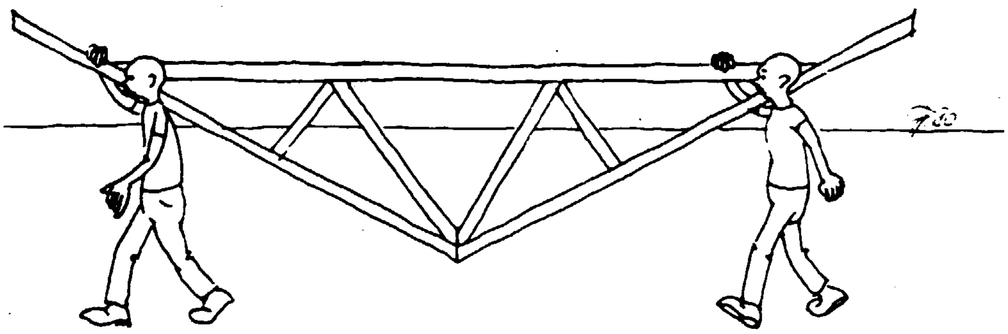


Fig 14 Carrying Trusses

Trusses should be erected on a level accurately aligned timber plate. The distance between the heel point and the outer edge of the plate must not exceed 50 mm unless a cantilever truss designed for such support is used.

Roofs are subjected to uplift forces in strong winds and must be tied down. This tie down strength is particularly important in trussed roofs where all the roof forces are concentrated at the heel points with no additional interior fixing as normally occurs in a strutted roof. In a tile roof, the weight of the tiles largely counteracts the uplift forces, but special provisions must be taken in a corrugated iron roof.

Wiring over the rafter to the plate should be fixed to every rafter. It is quicker and stronger to use twisted wire dogs or sheet metal framing anchors. These are shown in Fig 15.

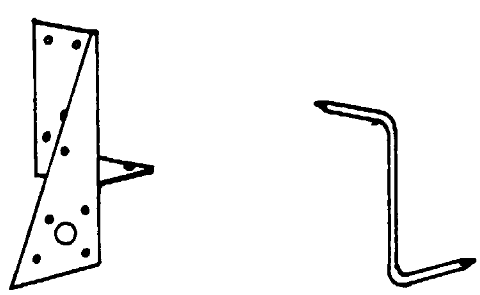


Fig 15 Framing Anchor and Wire Dog

Setting Out

Truss positions should be set out on the plates before the trusses arrive on the job. If framing anchors are used to hold the trusses down, these should be fixed at this stage. Alternatively a nail should be partly driven on the side of the truss away from the direction from which they will arrive.

Erection

In a well coordinated job, trusses should be unloaded from the truck on which they arrive directly on to the roof. This saves double handling and also gives a height advantage of nearly 2 metres. The trusses should be hung upside down between the plates. Alternatively the trusses are approximately positioned as they are unloaded, the first with its apex resting against the gable wall or on the end wall plate. Successive trusses are then rested on each other along the building (See Fig 16).

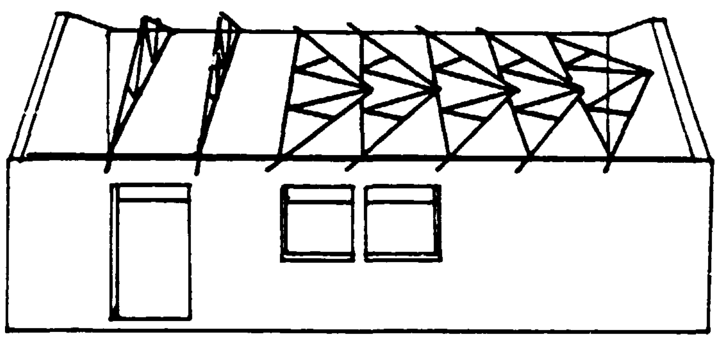


Fig 16 Trusses Laid in Position, Being Erected from Left Hand End

The truss nearest the far gable end is moved into position, turned right way up, and one man nails a temporary purlin from the gable end to the apex of the truss. The heels are nailed to the framing anchors or skew-nailed to the plates. The next truss is then positioned against the nails or framing anchors, its apex secured as before, and the process repeated.

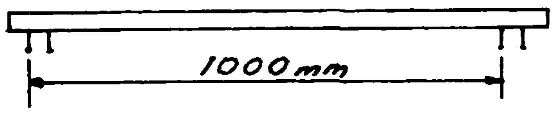


Fig 17 Truss Spacing Gauge

Spacing of the trusses at the apex is maintained with a stick gauge with four nails driven at the correct spacing (See Fig 17) to space the next truss from the one secured last. The temporary spacing purlins should all be on one side of the apex. As soon as the erection procedure is clear, the first permanent purlin should be fixed on the clear side of the apex.

A gang of five men is required - one at each heel, one at the apex fixing the temporary purlins, one on the floor turning the trusses right way up and one nailing the permanent purlin. In a straightforward gable roof an erection rate of one truss every six minutes should be achieved.

Bracing

Trusses are extremely strong in their own plane but are very flexible in other directions. Consequently they require bracing to maintain them in position and to prevent buckling of the rafter, under normal loads, and the ceiling tie under wind uplift conditions.

If trusses are placed between rigid gable walls then the tile battens or purlins fixed to the gable plates will provide ample bracing to the rafters.

Hip roofs when complete require no additional bracing, but temporary bracing to maintain the gable trusses vertical between the hip ends will be required until roof construction is finished.

Where gable ends are formed separately from the end walls, permanent diagonal bracing in the roof plane at each end must be provided as in Fig 18. This may be either 100 x 50 timbers on edge mitred to fit between the rafters or 150 x 50 boards nailed to the undersides of the rafters. This bracing should run at about 45° on plan, that is approximately in the position a hip rafter would occupy in a hip roof.

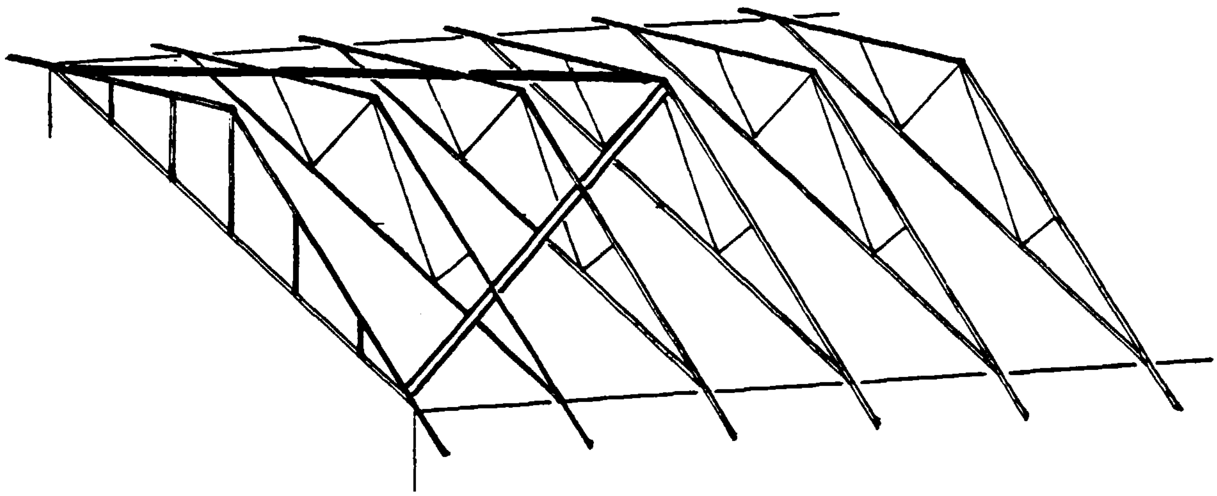


Fig 18 Diagonal Bracing

Ceiling Ties

These also require to be braced in a direction parallel to the ridge. This can be provided by 75 x 50 runner fixed on top of the ceiling tie at the ceiling tie panel point and securely fixed to the ceiling plate at each end of the building.

If the ceiling lining requires noggings running continuously from one end of the building to the other or battening underneath the ceiling ties for fixing, then this nogging or battening will supply adequate restraint.

The truss manufacturer must be prepared to demonstrate these techniques to builders new to trussed rafter roof construction, and also to educate architects and building inspectors in the minimum safe requirements for bracing and the circumstances where it is and is not specifically required. These circumstances can be visualised by imagining the building.

(a) tipped completely upside down (wind uplift)

(b) stood on one end (earthquake or wind forces)

If in either of these situations the trusses are stable with no tendency to buckle or collapse, no additional bracing is required. If the framing is not stable then bracing must be provided.

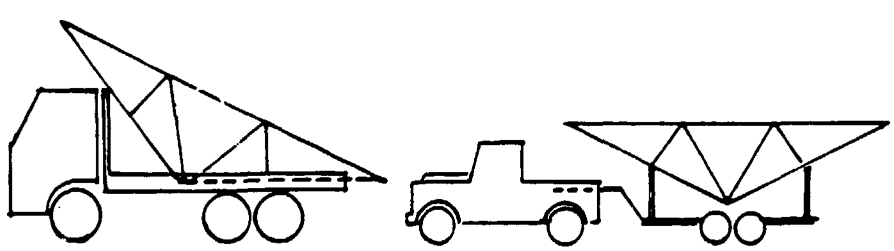
15. TRANSPORT

Trussed rafters, being prefabricated components must be transported from the factory to the building site. By their nature they are bulky items and transport and associated handling costs are a significant proportion of the delivered price.

These costs are so significant that frequently proposals are made that trussed rafters should be factory cut, bundled and then nailed together on site. Superficially this argument is attractive. However, several of the principal advantages of trussed rafters are intangible. Particular points in their favour are uniformity of shape and exact positioning and nailing of nail plates. Both these can only be achieved under factory conditions. Lack of jigs and skilled supervison results in loss of quality and reduces a sophisticated engineering component back to a piece of rough bush carpentry. Any apparent savings in transport will be more than paid for by the builder in unnecessary site costs.

Proposals for site fabrication of trussed rafters should be strenuously resisted by fabricators.

Trussed rafters can conveniently be transported on the tray of a 3 or 5 ton truck with one rafter resting on the tray and the other over the cab.

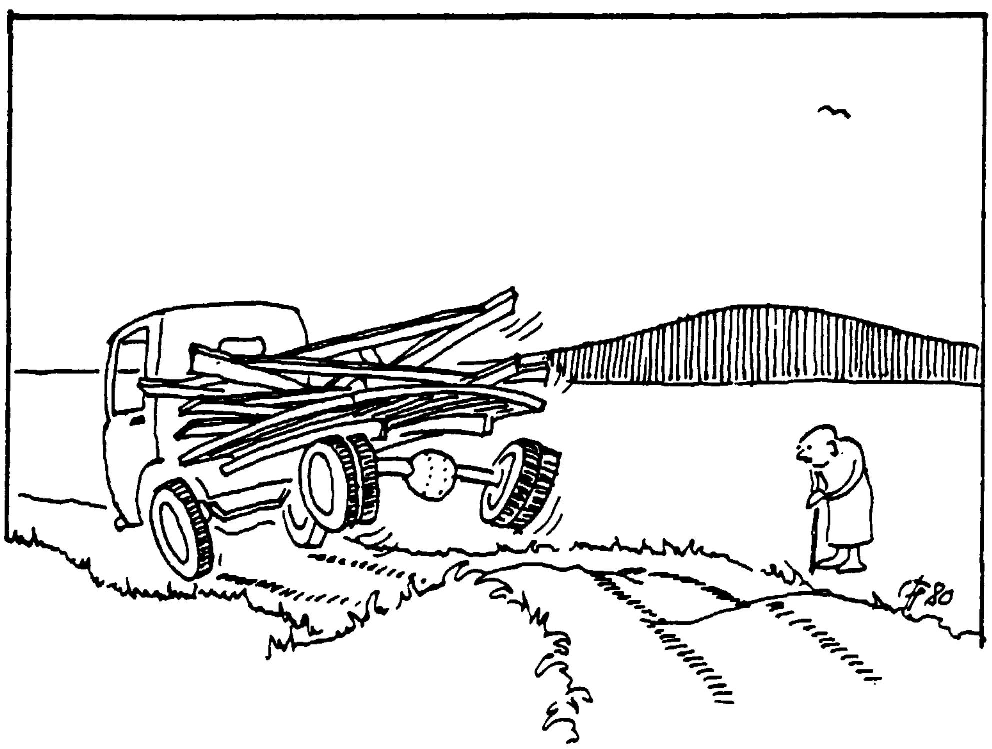


If job lots of trusses are regularly carried over medium to long distances, a purpose made lightweight semi-trailer may be worthwhile. One very successful such vehicle was built with a "fifth wheel" to attach on to a pick-up truck. The weight of a house lot is well within the towing capacity of a pickup and the high fuel consumption of a 5 ton truck is not necessary.

When planning transport operations, it should be remembered that the average truss weighs only about 50 to 60 Kg although the overall length is about 9 m. Individual trusses should be banded or wired together into a solid unit for transport, even if they are manhandled on to the truck or trailer. They should also be securely fastened on to the tray to avoid shifting during transport.

The worst possible way to transport trusses is on the flat with part of the truss overhanging the tray. Jolting in this manner of cartage will certainly weaken and may very well break the connections.

Only if the trusses are completely supported over their whole length should they be carried flat. This normally requires a semi-trailer with a very long tray.



16. INTERPRETATION OF DESIGN CHARTS

The design charts included in this report cover only W and Belgian trusses of 8 and 10 m. maximum spans respectively. All designs are for a truss spacing of 1 m. Obviously many more situations can arise - different spacings and different shapes.

The use of the tables can be extended to cover only a few other cases without recourse to a structural engineer's advice.

Variations to Spacing

The load in any part of a truss is proportional to the product of the span and the spacing other things being equal. Thus the joints and members in a 6 m truss spaced at 1.5 m. will carry the same forces and stresses as the corresponding shaped 9 m span truss spaced at 1.0 m. $6 \times 1.5 = 9 \times 1$.

Example: 8 m span building, truss spacing 1.2 m. The equivalent truss design would be for a span of 8 x 1.2 m. = 9.6 m. Consequently the design chart for a 10 m. span truss of the same pitch and roof covering would be appropriate.

Half Truss

A gable truss design of twice the span may safely be used. The connection of the vertical member to the rafter should have the same number of nails as the apex plate to rafter connections.

Scissors Truss

Use a design with a pitch equal to the difference between the rafter and ceiling pitches and a span equal to the slope distance measured along the ceiling. The ceiling tie splice now comes at the centre of the span and must have the same number of nails into each ceiling tie as before. The central vertical member must be fixed to ceiling tie and apex with twice the number of nails shown for the tie to apex connection.

For example roof pitch 25°, ceiling pitch 10°, span 7.5 m. by measurement or calculation , the slope length is 7.616 m. The difference in pitches is 15°. Use a design for 15° pitch and 8 m. span.

Cripple Truss

The cripple rafters add very little to the weight of the roof and the truss design appropriate to the lower pitch may be used unchanged. The connections for the cripple rafter and vertical strut can be quite light as the loads are small and can be designed by eye.

These "rules of thumb" are conservative but should not be stretched too far. Do not make two adjustments in succession, for instance do not design a scissors truss at 1.5 m. spacing from these rules.

Truncated trusses and girder trusses should always be designed by an engineer.

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2. British Standards Institution "Code of Practice for the Structural Use of Timber: Part 3 Trussed rafters for roofs of Dwellings" CP 112 : Pt 3 : 1973 London.

3. Truss Plate Institute Inc. "Design specification for light metal plate connectored wood Trusses" 6th ed. Washington D.C.

4. Standards Association of Australia "SAA Timber Engineering Code" AS 1720:1975 Sydney.

5. Canadian Standards Association "Code of Recommended Practice for Engineering Design in Timber" CSA Standard 086-1970 Ontario.

6. Ozelton E.C. and J.A. Baird "Timber Designers Manual" 1976 Crosby Lockwood Staples, London.

ANNEX 1

DESIGN SHEETS

The trussed rafters in the design sheets are for the following conditions.

Spacing: 1.0 m.

Roof Coverings:

HW Heavy weight - up to 95 Kg per sq m. roof load (clay or concrete tiles).

LW Lightweight - up to 35 Kg per sq. m. roof load (corrugated sheets of steel, aluminium or asbestos).

Ceiling Lining:

Up to 15 Kg per sq. m. (12.5 mm gypsum board).

Timber:

Medium density softwood (pine, podo, cedar)
of second strength grade.
Rafters and ceiling ties - basic size 100 mm x 50 mm
Struts and ties - basic size 50 mm x 50 mm

Spans:

As shown on the sheets. W trusses up to 8 m.
Belgian trusses up to 10 m.

Pitches:

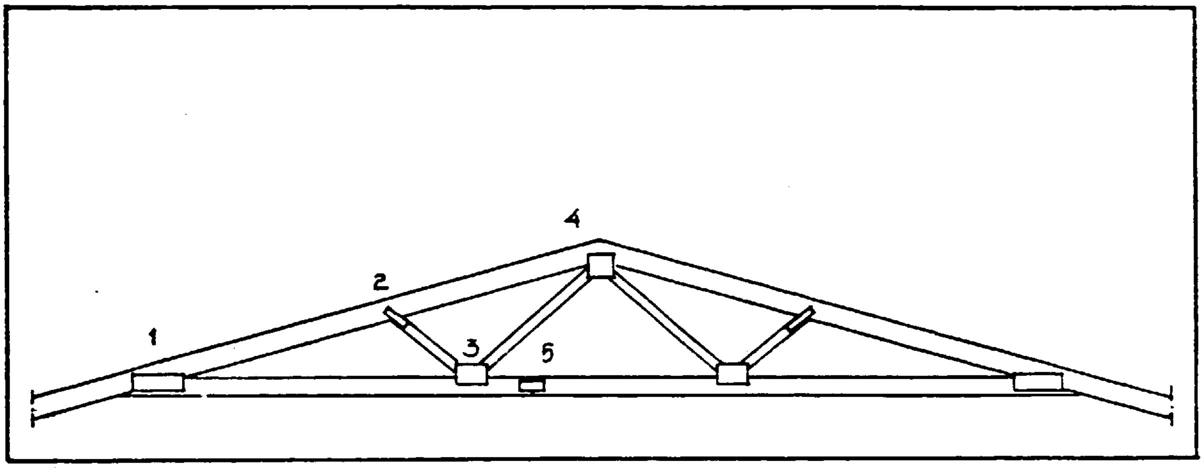
15^o $17½^o$ 20^o $22½^o$ 25^o $27½^o$ 30^o

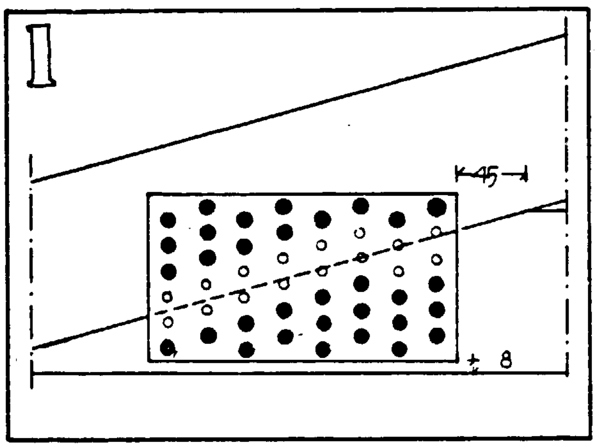
Nails:

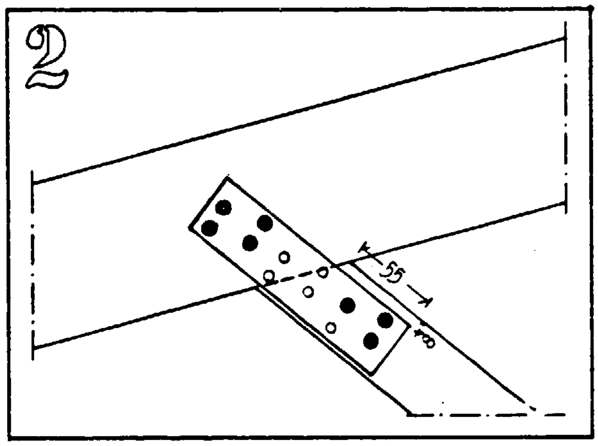
35mm x 3.3 mm Nail positions are shown by solid circles on the nail plates.

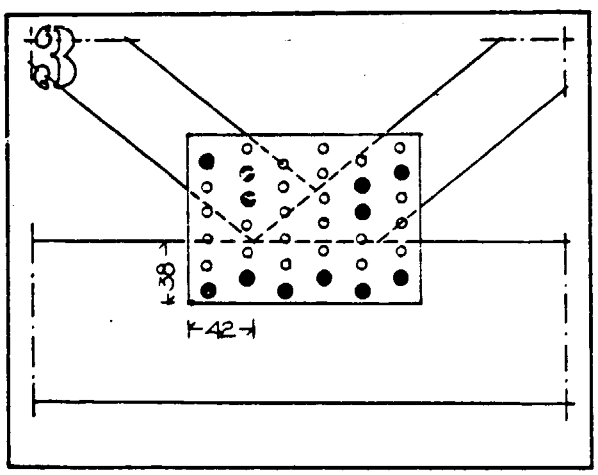
Trusses for tile roofs do NOT require intermediate rafters supported by under-purlins. Instead tile battens 50 mm x 50 mm placed on the flat should be used.

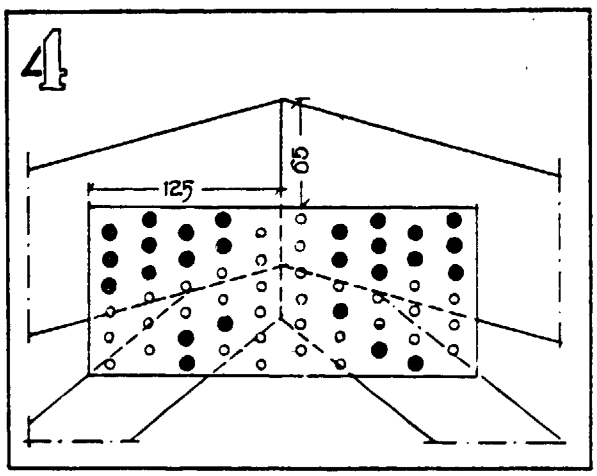
W-TRUSS LW 8 15°











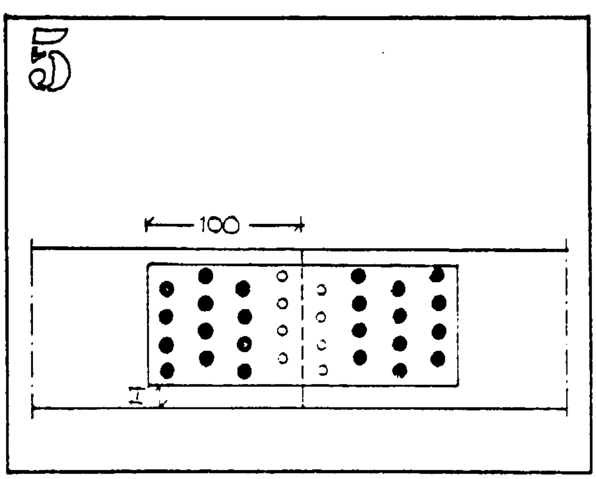
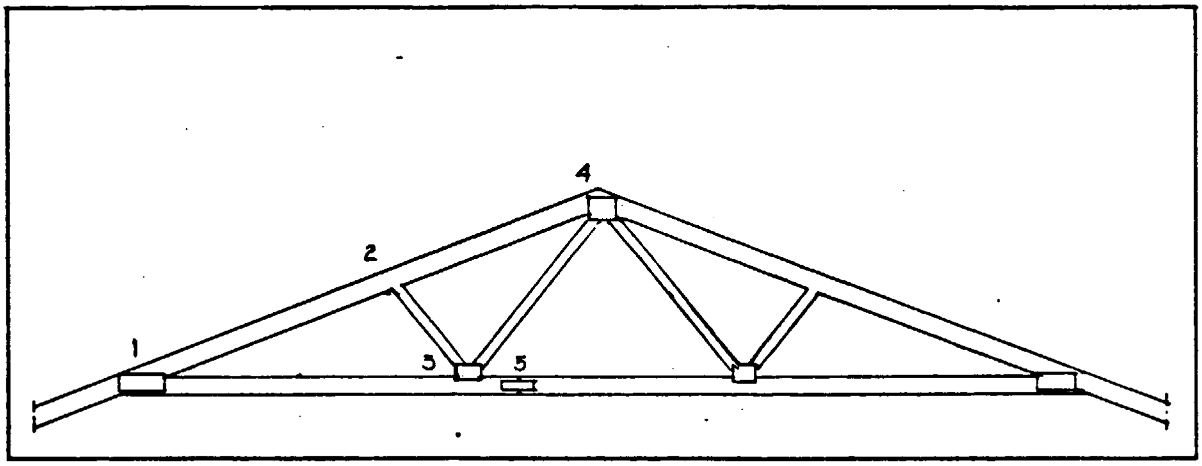
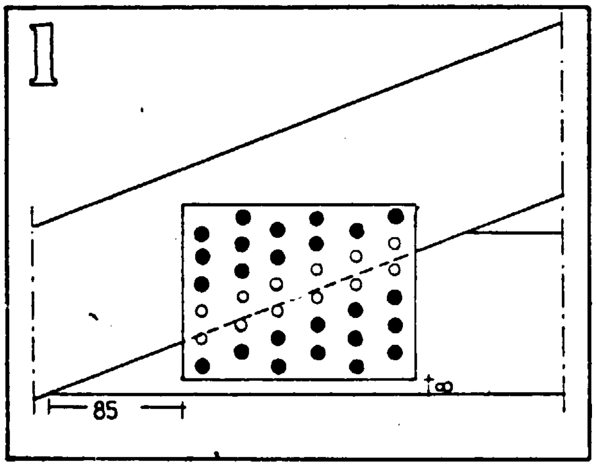
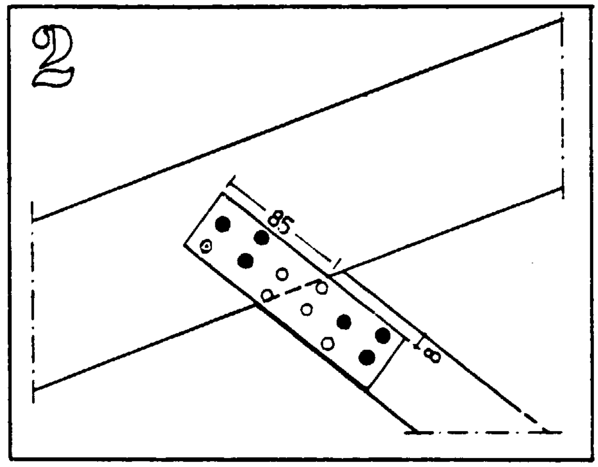


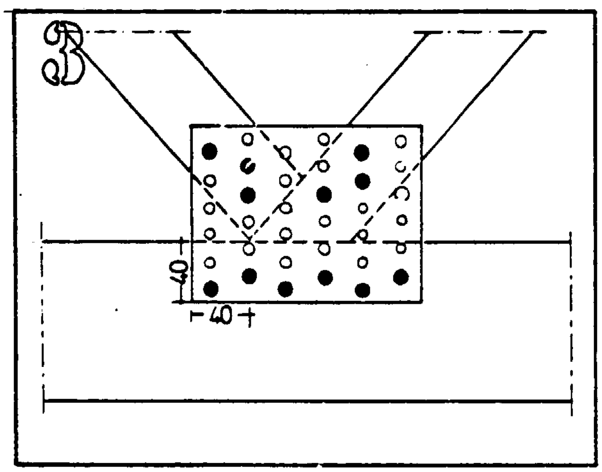
	PLATE	SIZE	NAILS
1	6 × 8	104 - 200	14 + 18
2	2 × 6	40 - 150	4 + 3
3	6 × 6	104 - 150	3 - 3 - 6
4	6 - 10	104 - 250	2 - 10 + 2 - 3
5	4 × 8	72 - 250	12 + 12

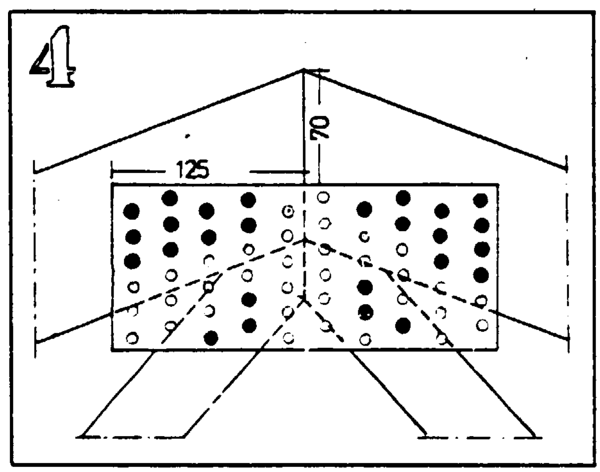
W-TRUSS LW 8 20°











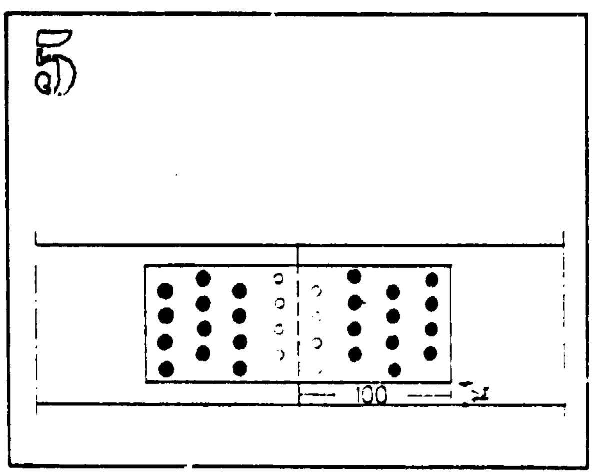
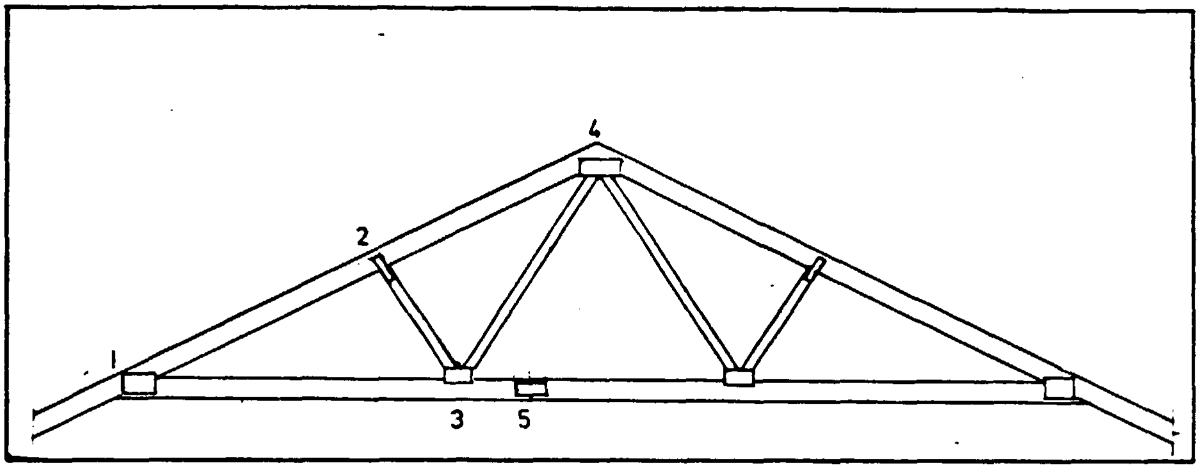
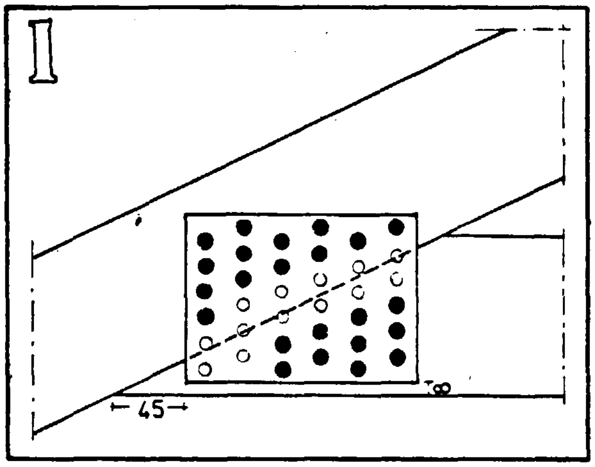
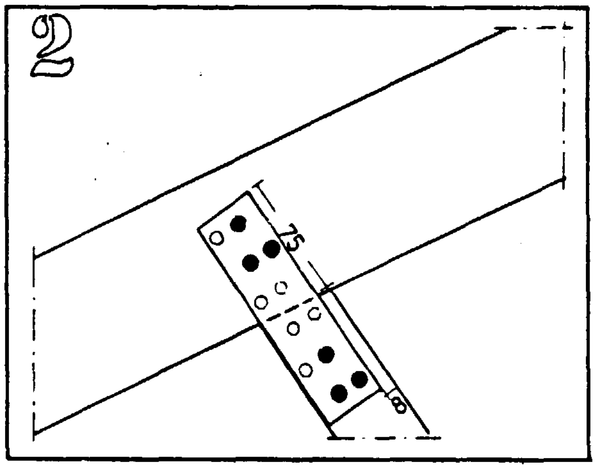


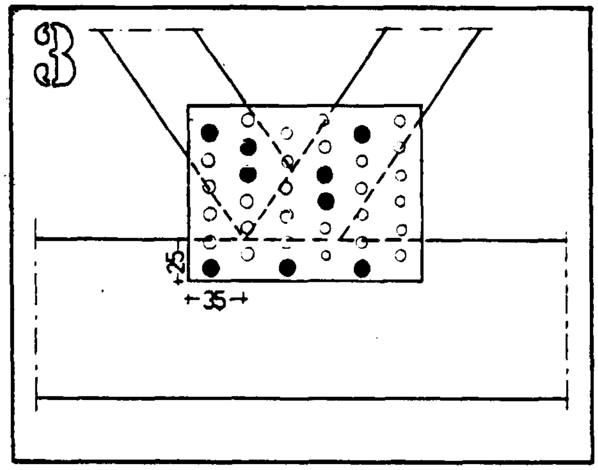
	plate	size	nails
1	6x6	104x150	12+12
2	2x6	40x150	3+3
3	6x6	104x150	3+3+6
4	6x10	104x250	2x(10+3)
5	4x8	72x200	12+12

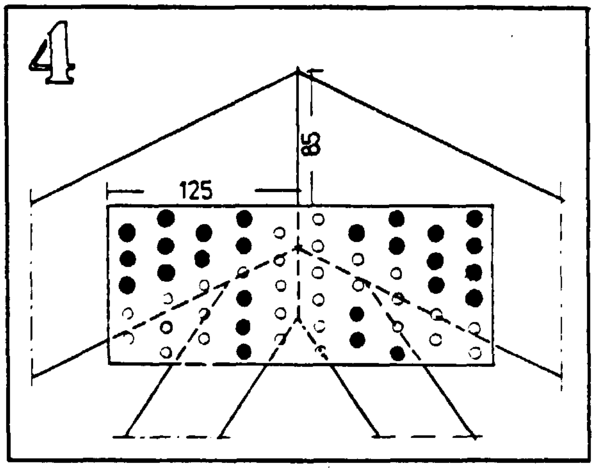
W-TRUSS LW 8 25°











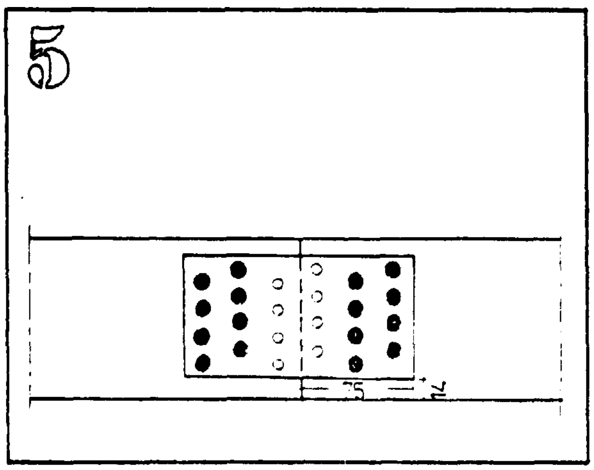
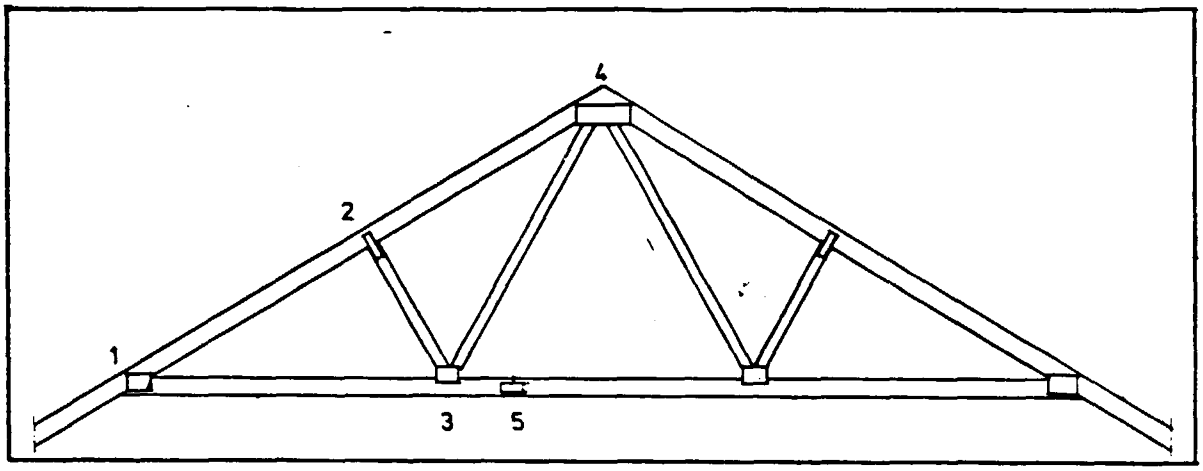
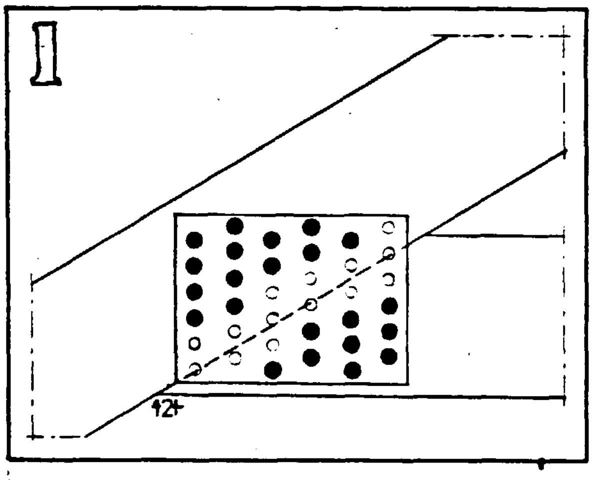
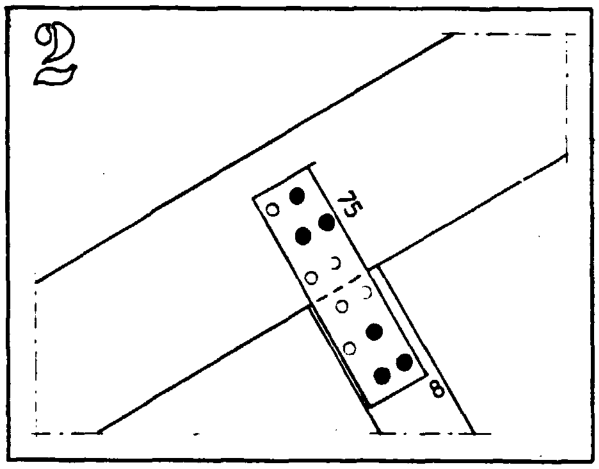


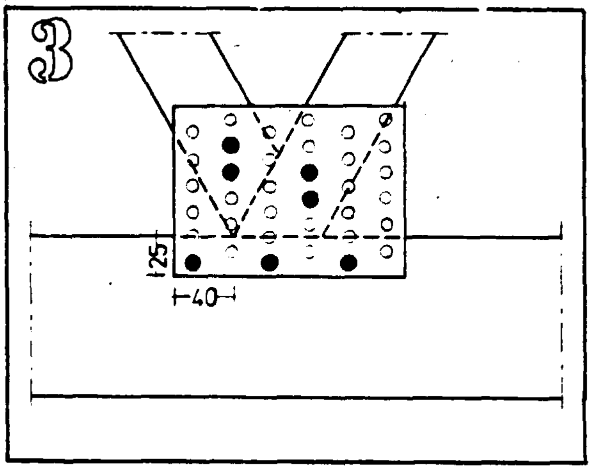
	plate	size	nails
1	6x6	104x150	13+10
2	2x6	40x150	3+3
3	6x6	104x150	3+3+3
4	6x10	104x250	2x(10+3)
5	4x6	72x150	8+8

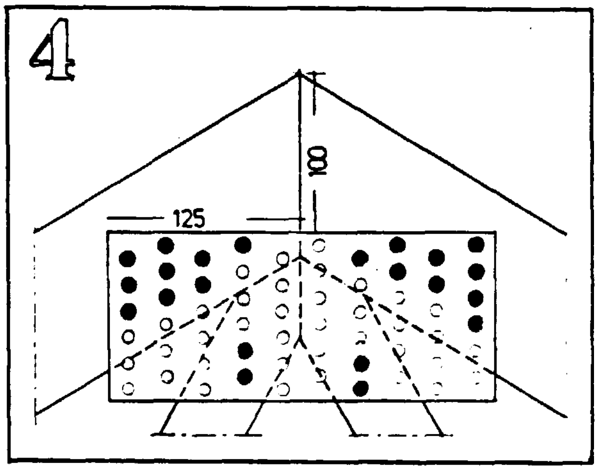
W-TRUSS LW 8 30°

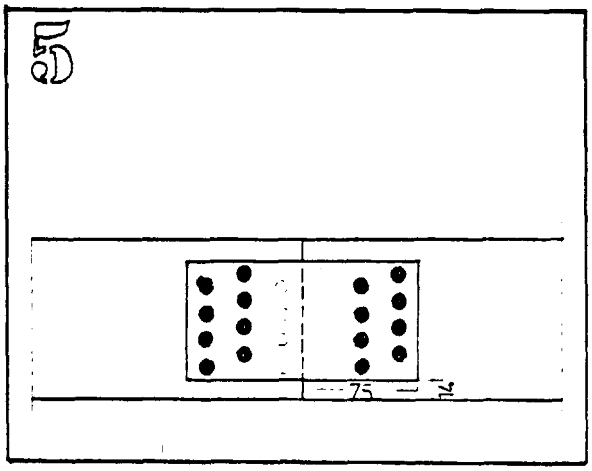












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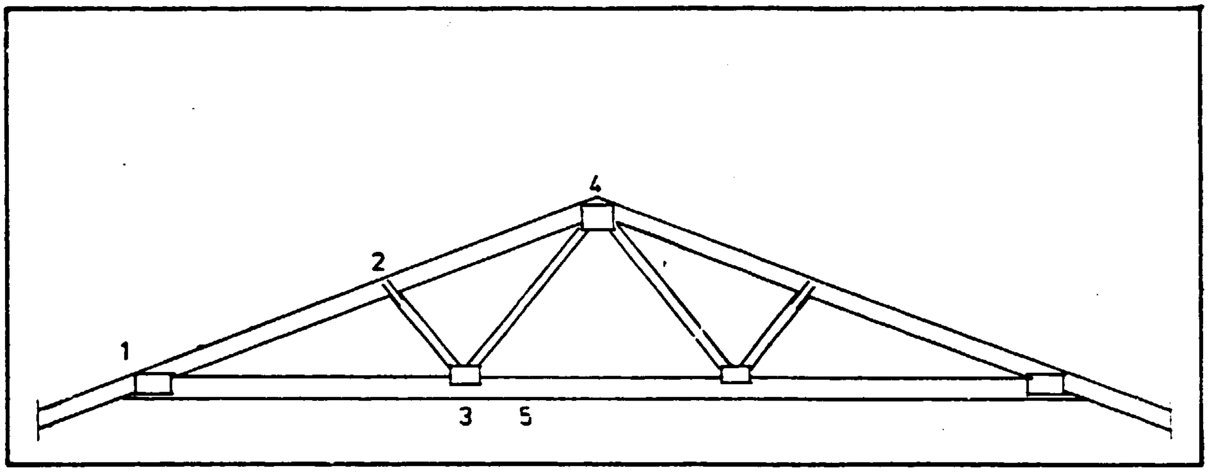
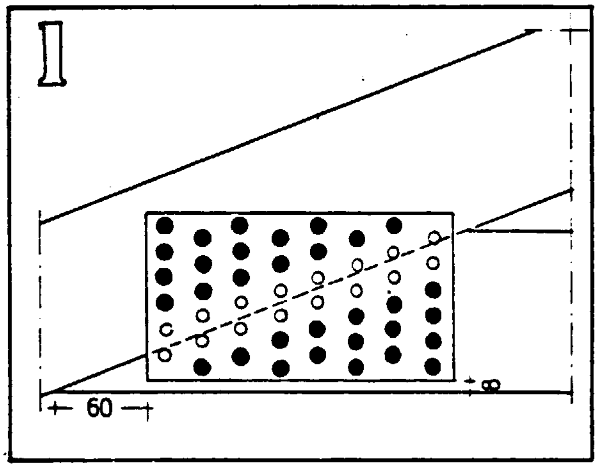
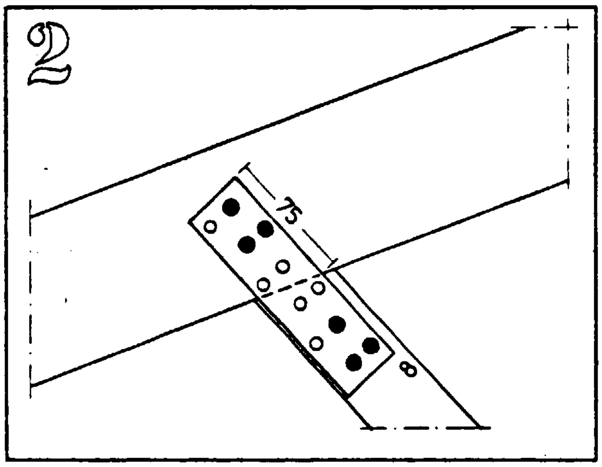
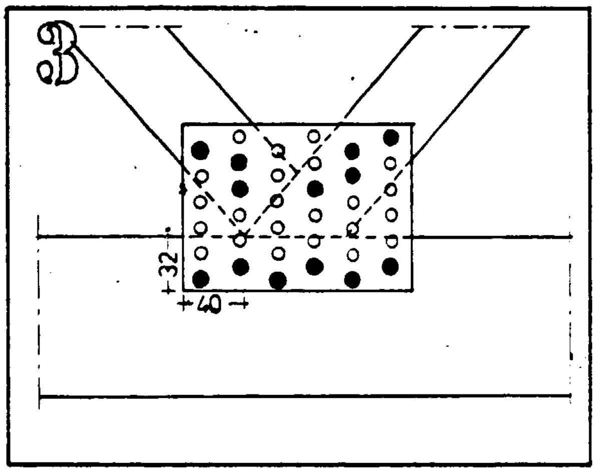
1	6x6	104x150	13+9
2	2x6	40x150	3+3
3	6x6	104x150	2+2+3
4	6x10	104x250	2(9+2)
5	4x6	72x150	8+8

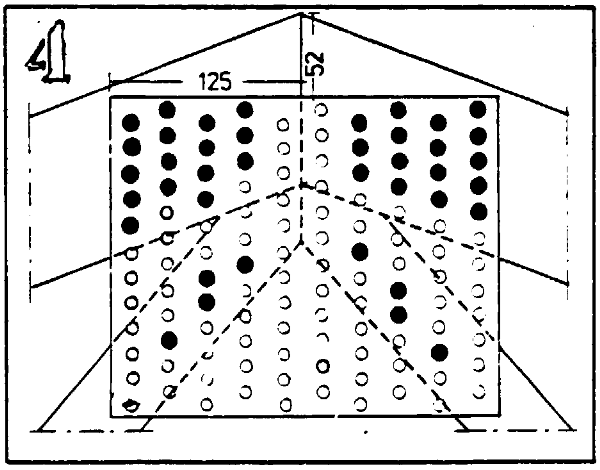
W-TRUSS HW 8 20°











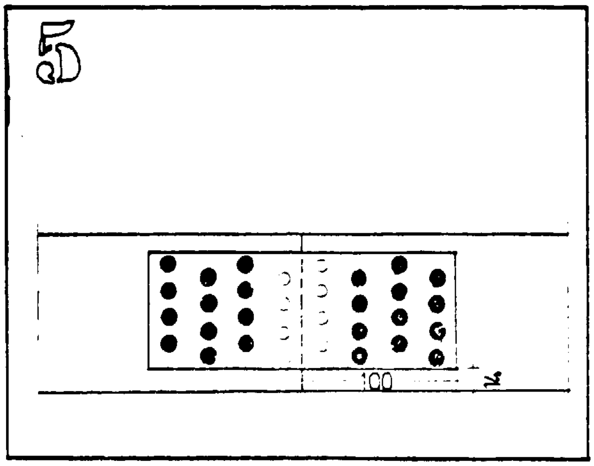
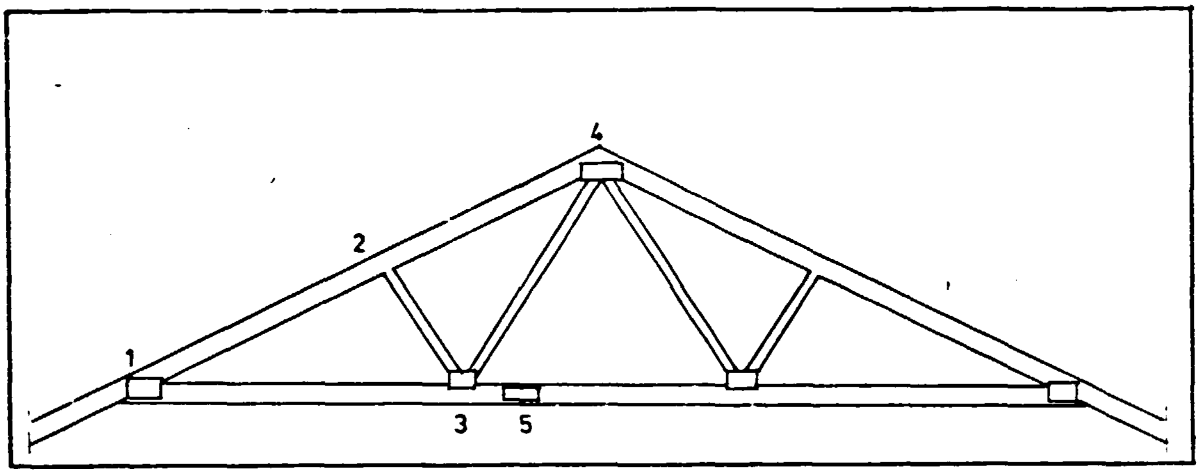
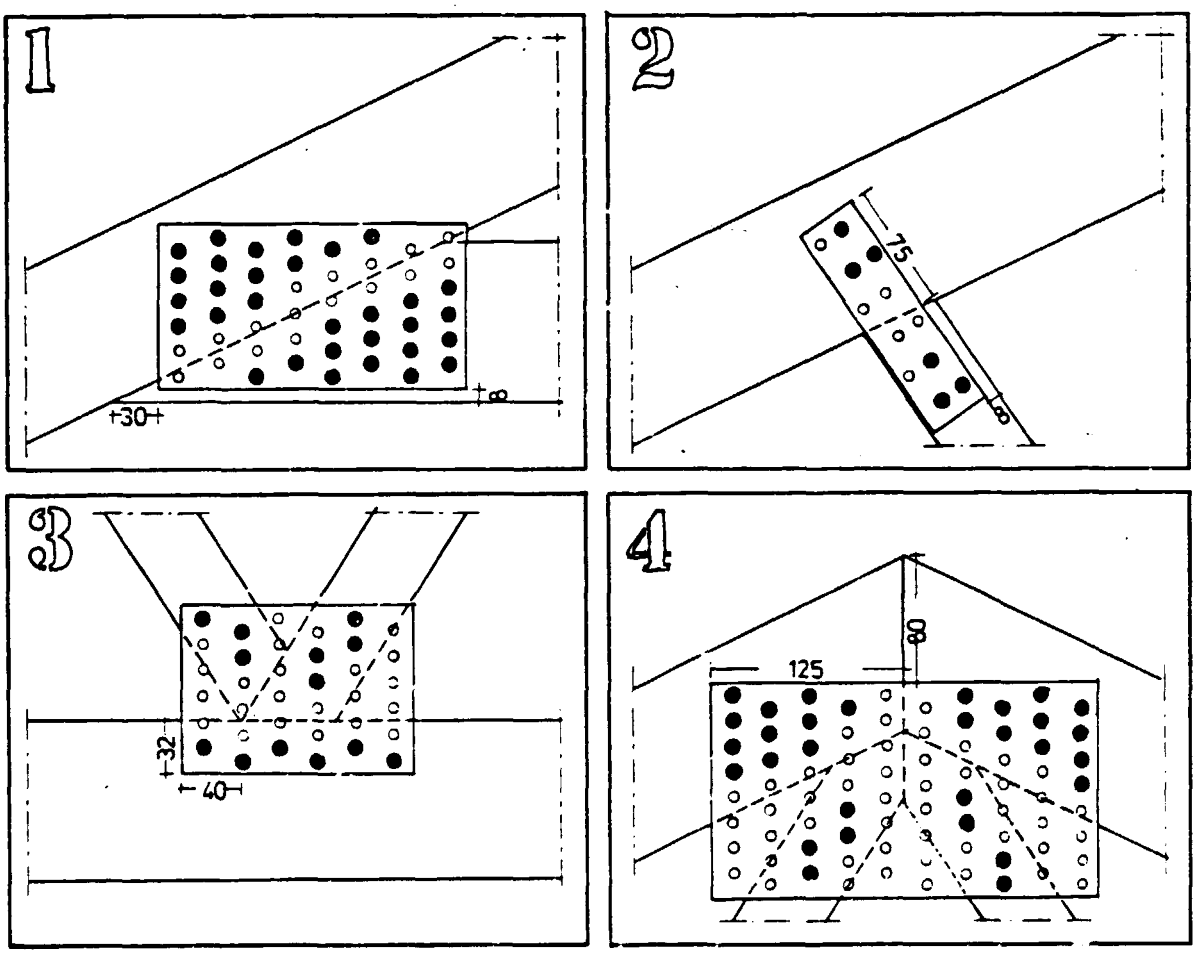


	plate	size	nails
1	6x8	104x200	16+16
2	2x6	40x150	3+3
3	6x6	104x150	3+4+6
4	12x10	200x250	2x(16+4)
5	4x8	72x200	12+12

W-TRUSS HW 8 25°





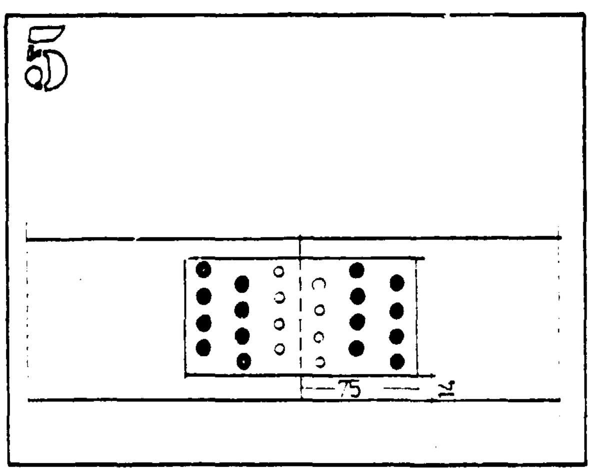
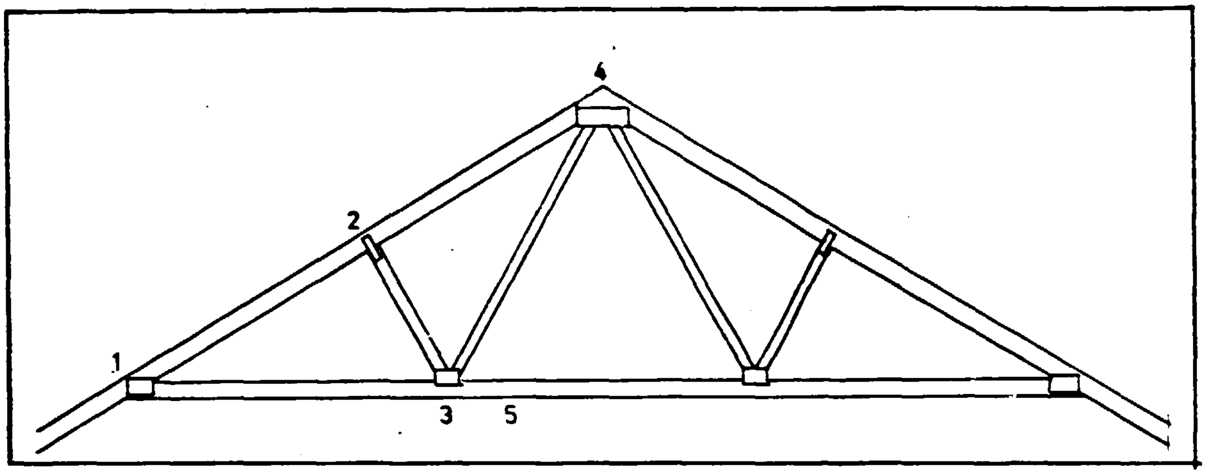
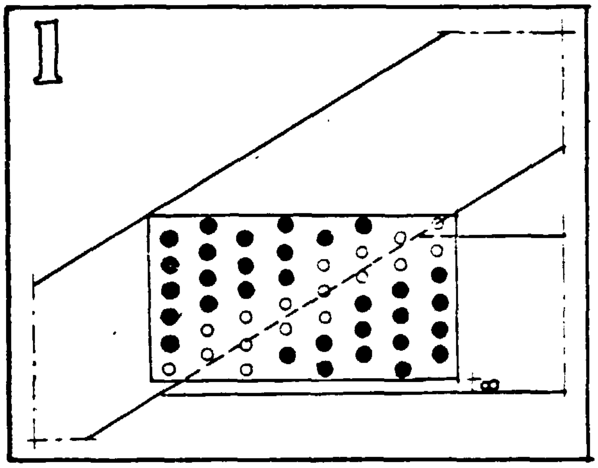
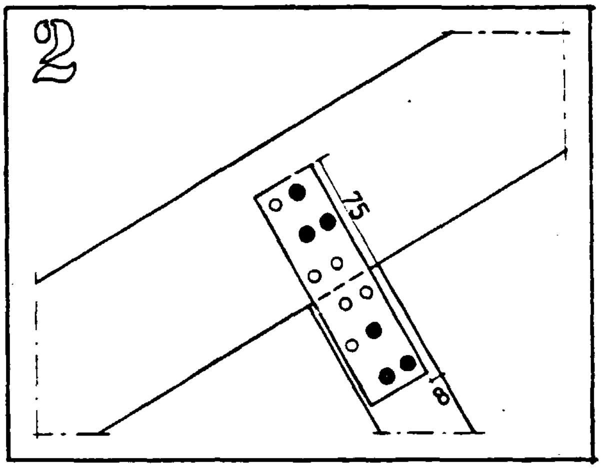


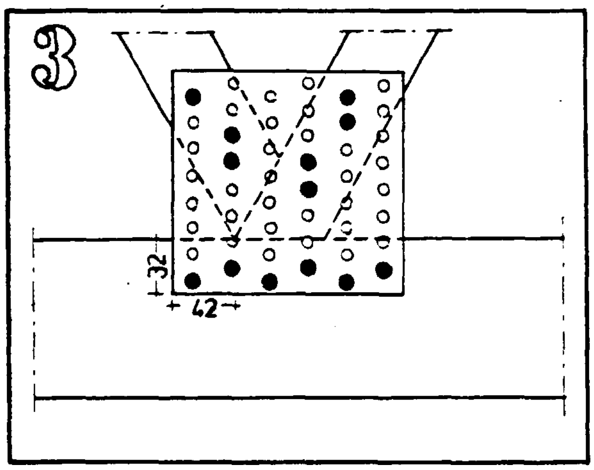
	plate	size	nails
1	6x8	104x200	15+6
2	2x6	40x150	3+3
3	6x6	104x150	3+4+6
4	8x10	136x250	2x(11+4)
5	4x6	72x150	8+8

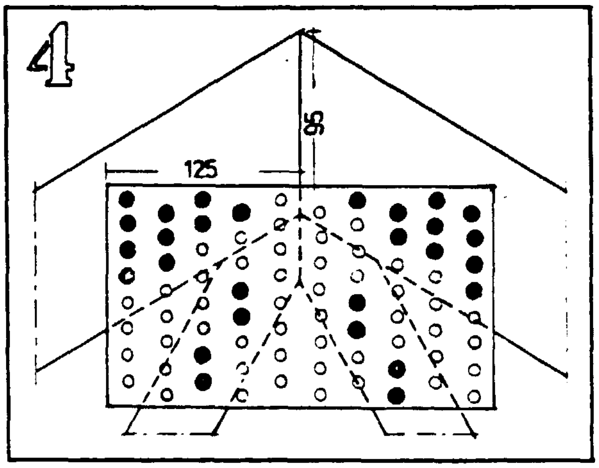
W-TRUSS HW 8 30°











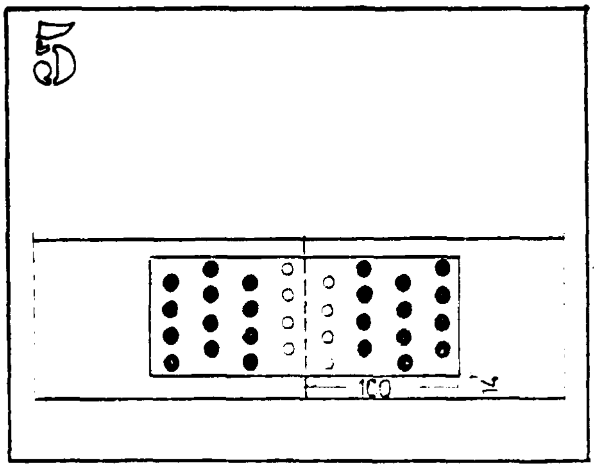
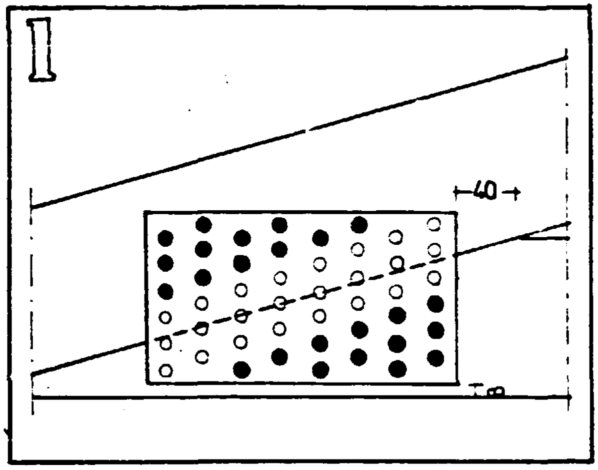
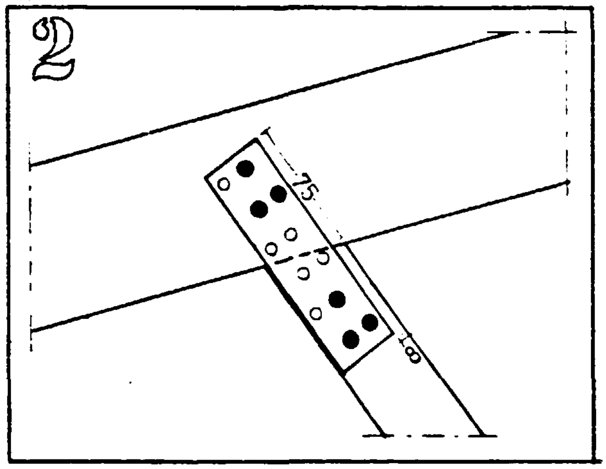
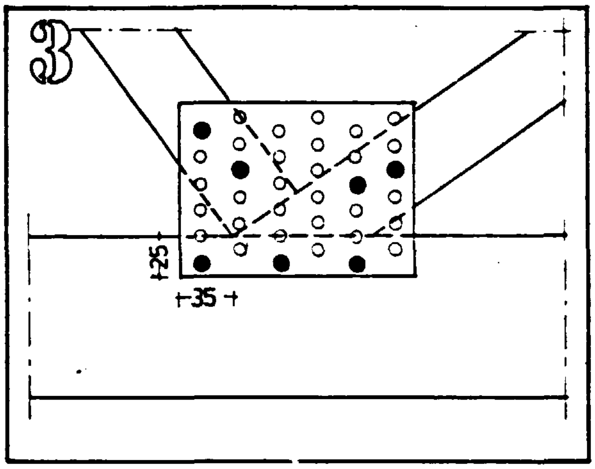


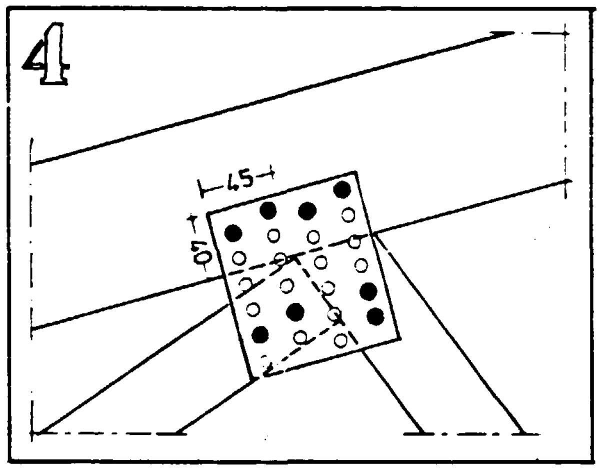
	plate	size	nails
1	6x8	104x200	17+14
2	2x6	40x150	3+3
3	8x6	136x150	3+4+6
4	8x10	136x250	2x(10+4)
5	4x8	72x200	12+12

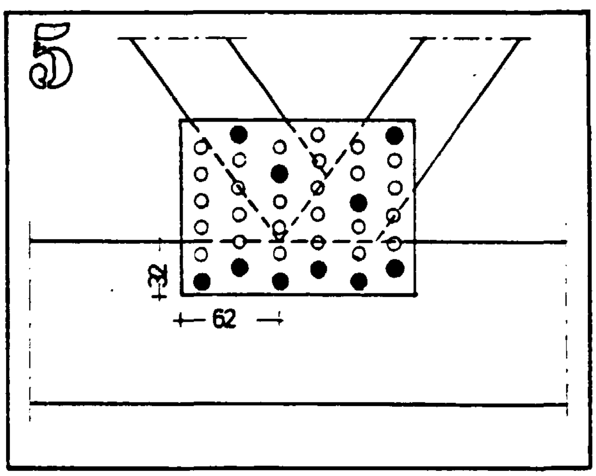
BELGIAN TRUSS LW 10 15°

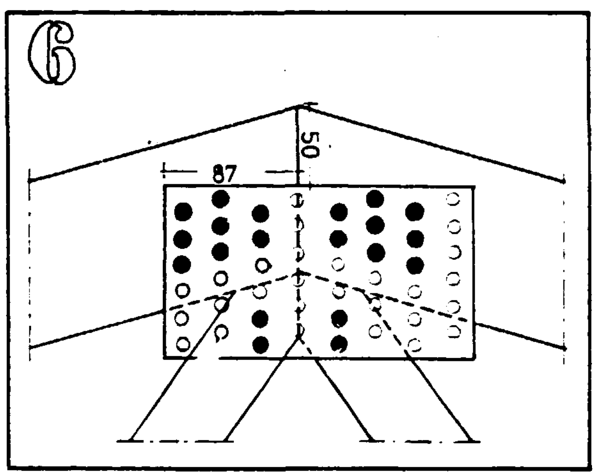












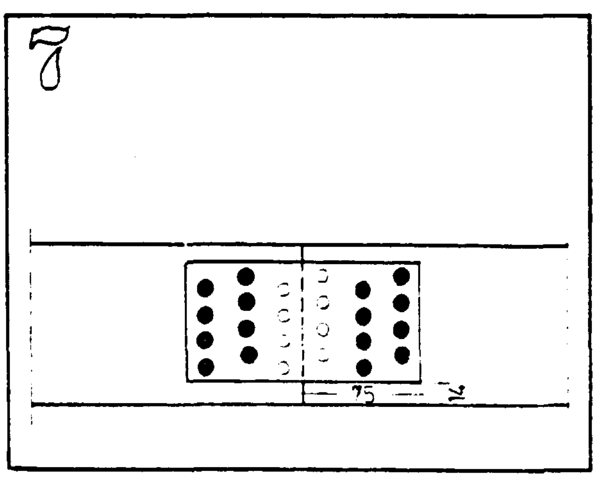
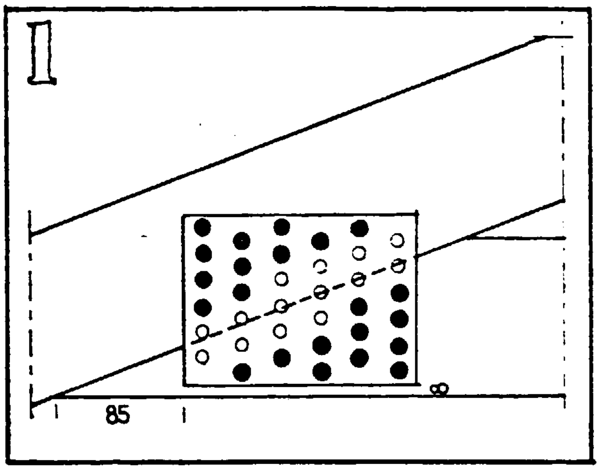
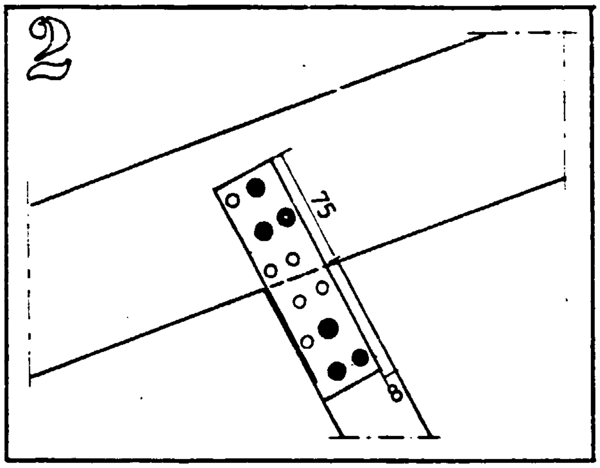
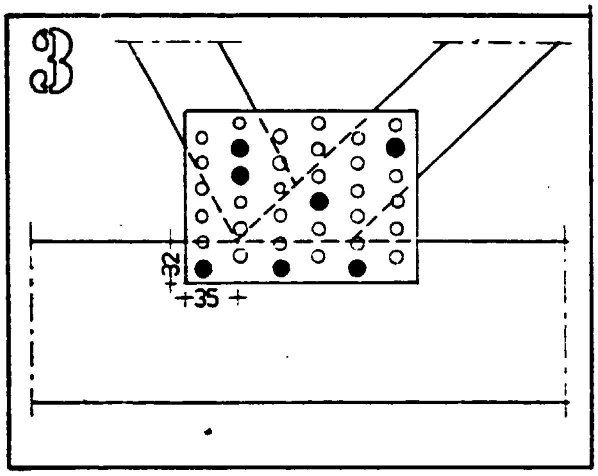


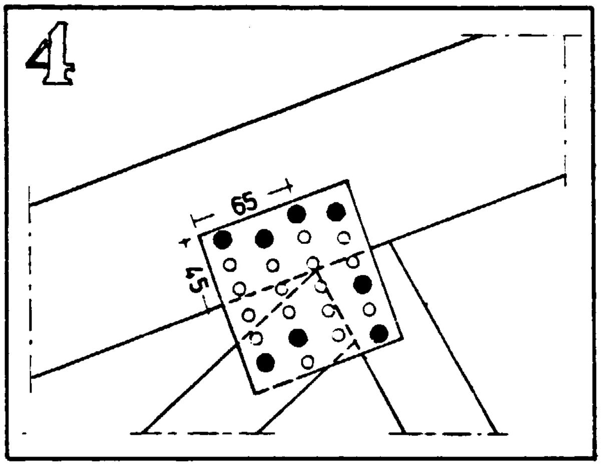
	plate	size	nails
1	6x8	104x200	12+12
2	2x6	40x150	3+3
3	6x6	104x150	2+2+3
4	6x4	104x100	4+2+2
5	6x6	104x150	2+2+6
6	6x8	104x200	2x(8+2)
7	4x6	72x150	8+8

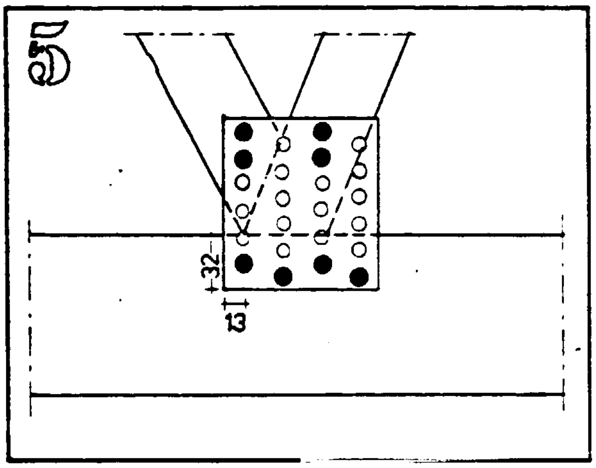
BELGIAN TRUSS LW10 20°

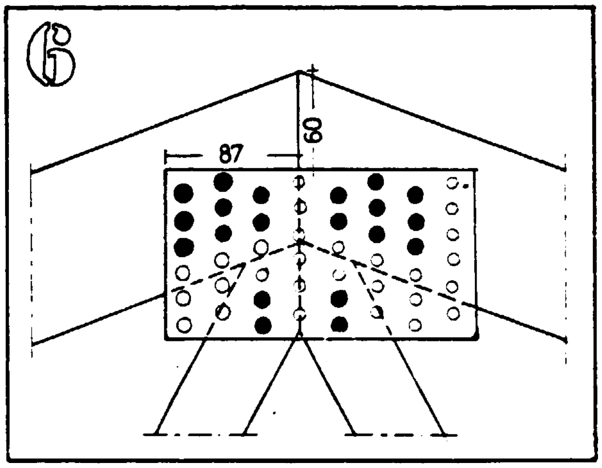












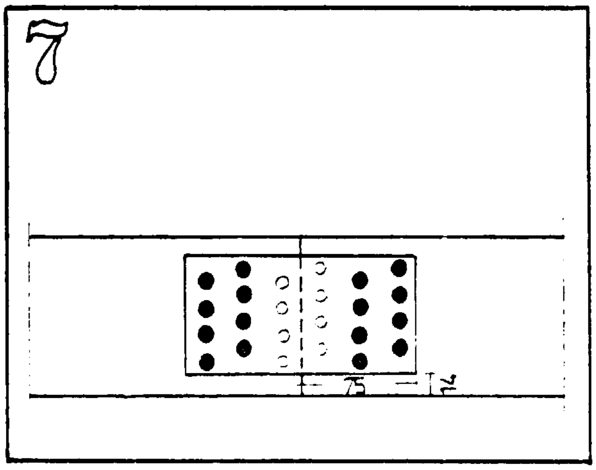
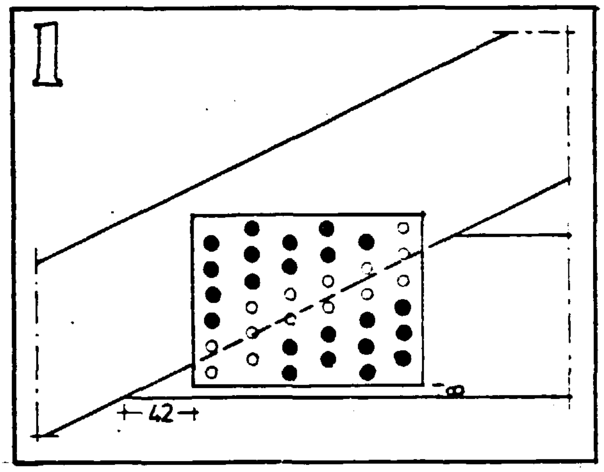
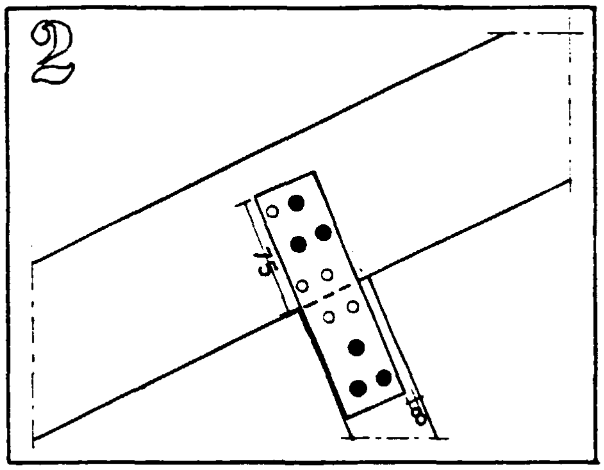
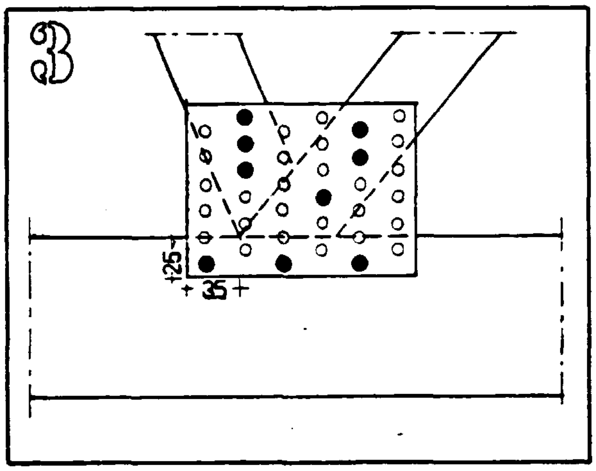


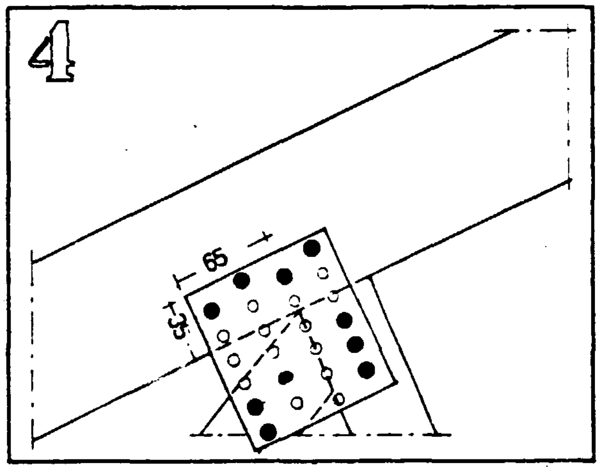
	plate	size	nails
1	6x6	104x150	11x11
2	2x6	40x150	3+3
3	6x6	104x150	2+2+3
4	6x4	104x100	4+2+2
5	6x4	104x100	2+2+4
6	6x8	104x200	2(8+2)
7	4x6	72x150	8+8

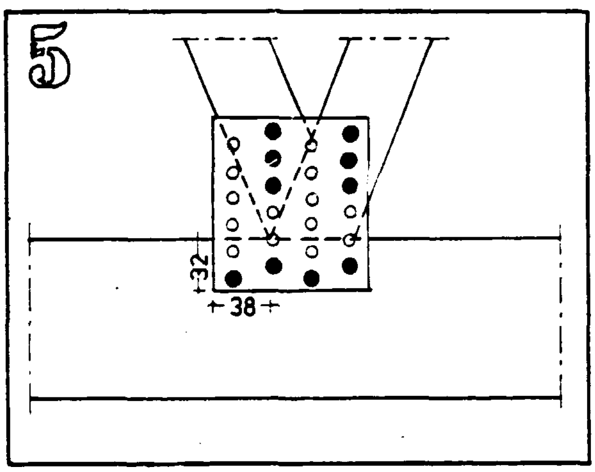
BELGIAN TRUSS LW 10 25°

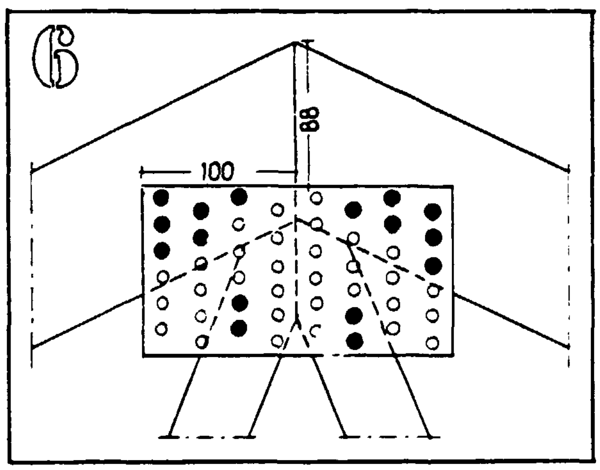












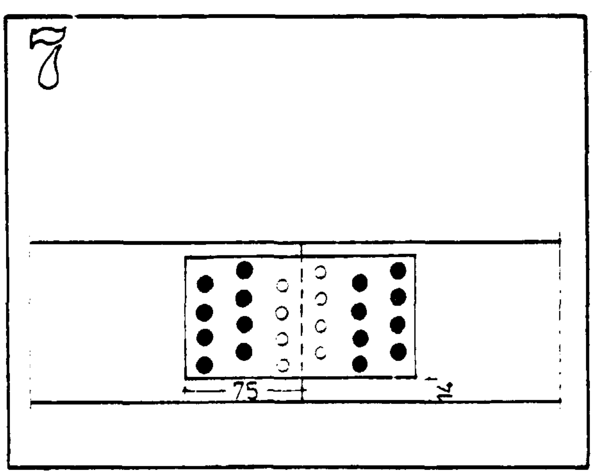
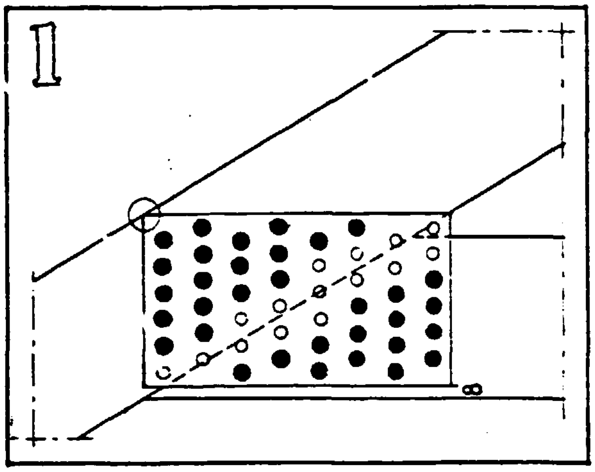
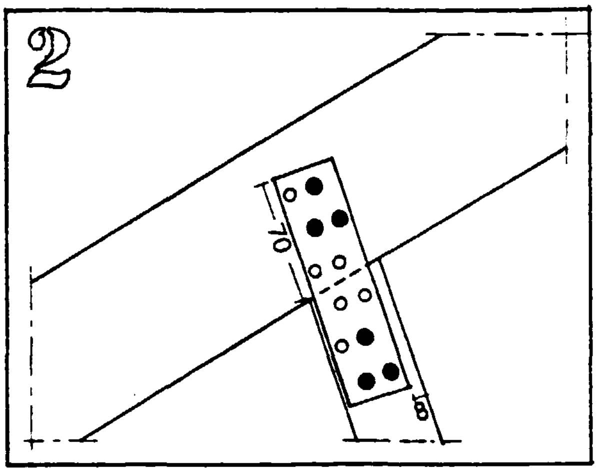
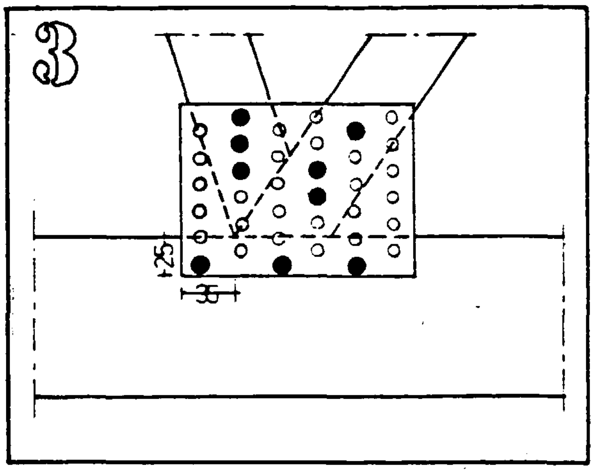


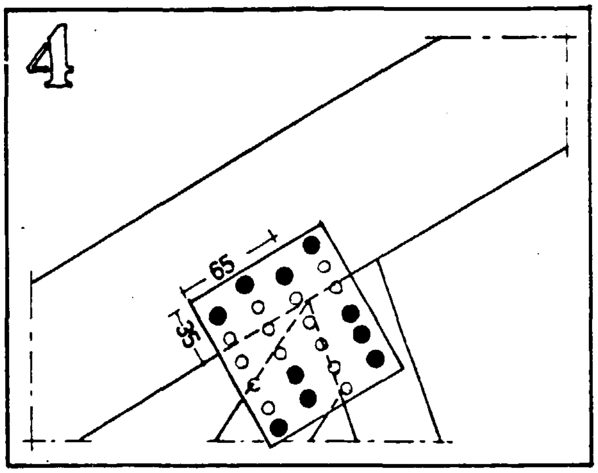
	plate	size	nails
1	6x6	104x150	12+10
2	2x6	40x150	3+3
3	6x6	104x150	3+3+3
4	6x4	104x100	4+3+3
5	6x4	104x100	3+3+4
6	6x8	104x200	2x(6+2)
7	4x6	72x150	8+8

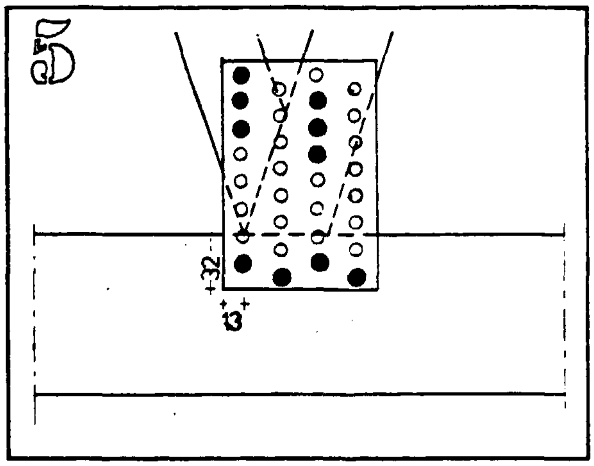
BELGIAN TRUSS LW 10 30°

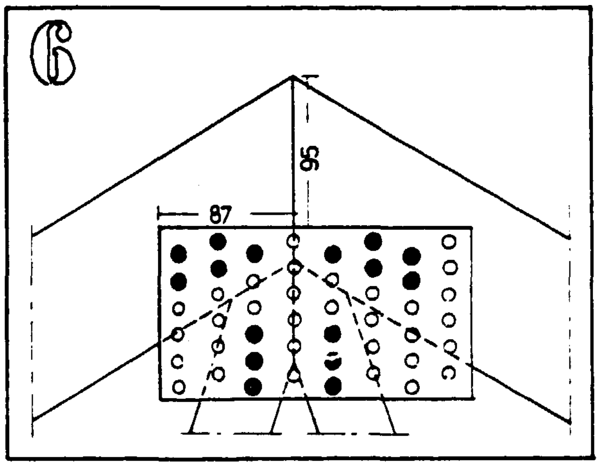












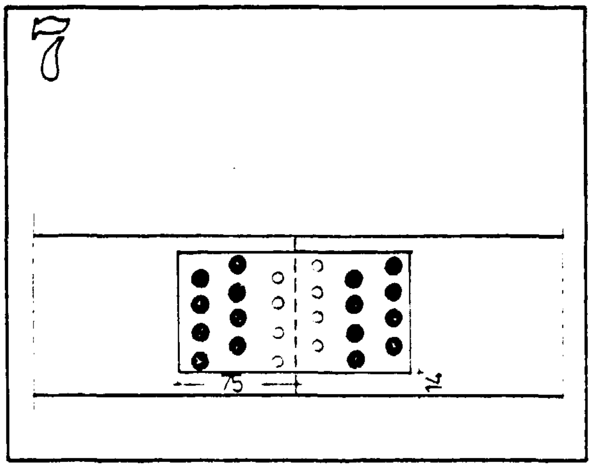
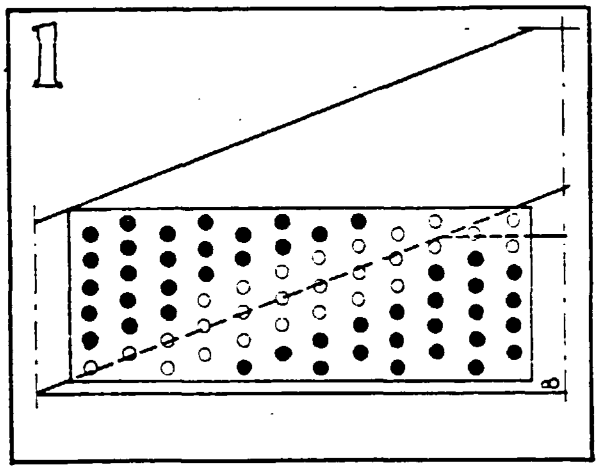
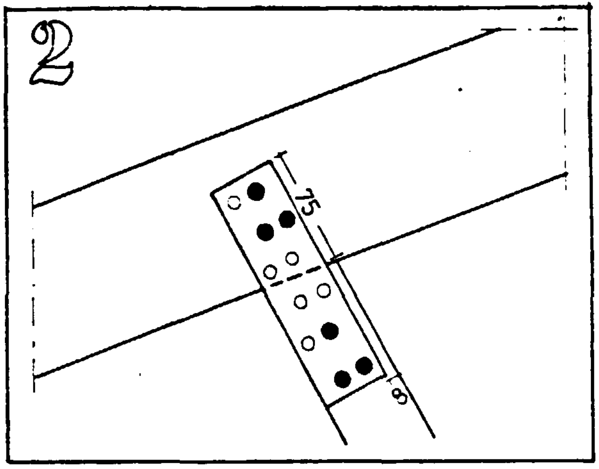
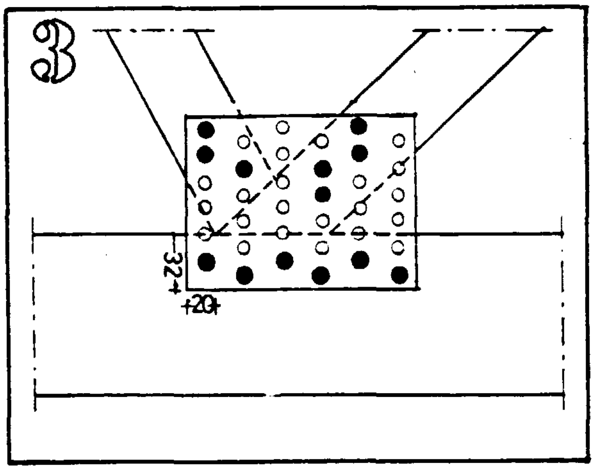


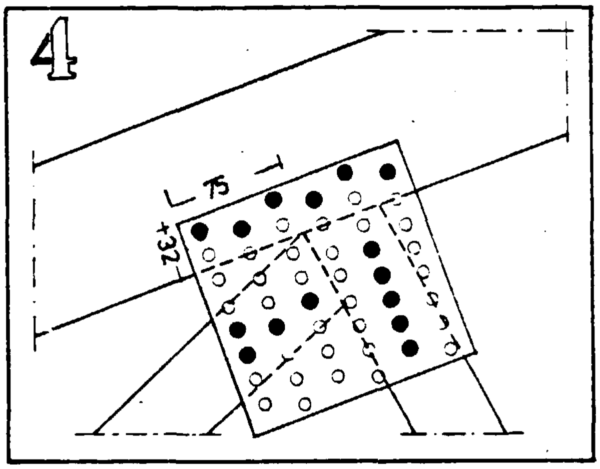
	plate	size	nails
1	6x8	104x200	18+15
2	2x6	40x150	3+3
3	6x6	104x150	3+3+3
4	6x4	104x100	4+3+3
5	8x4	136x100	3+3+4
6	6x8	104x200	2x(5+3)
7	4x6	72x150	8+8

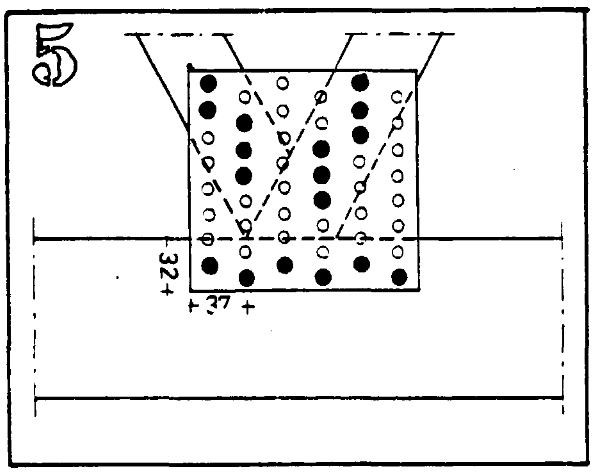
BELGIAN TRUSS HW10 20°

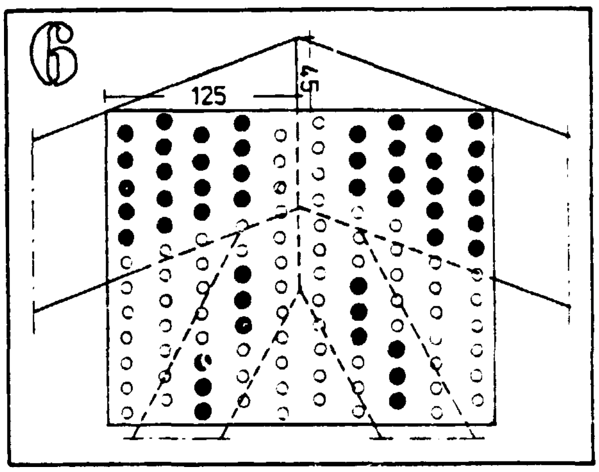












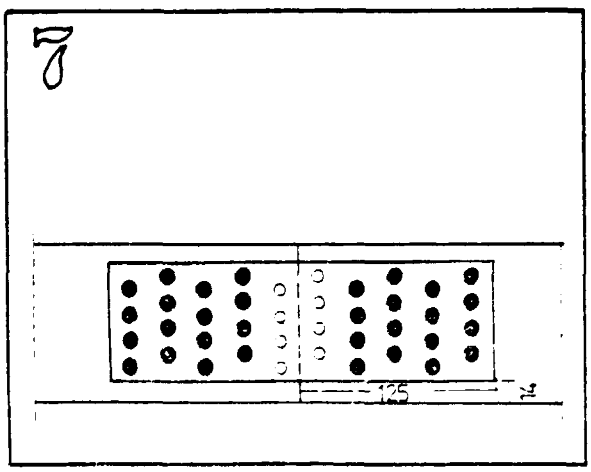
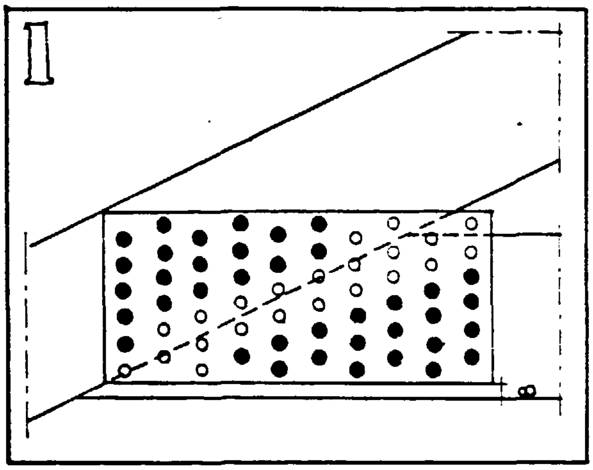
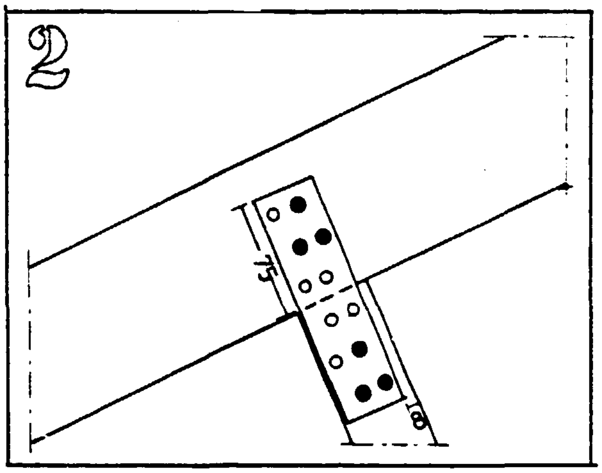
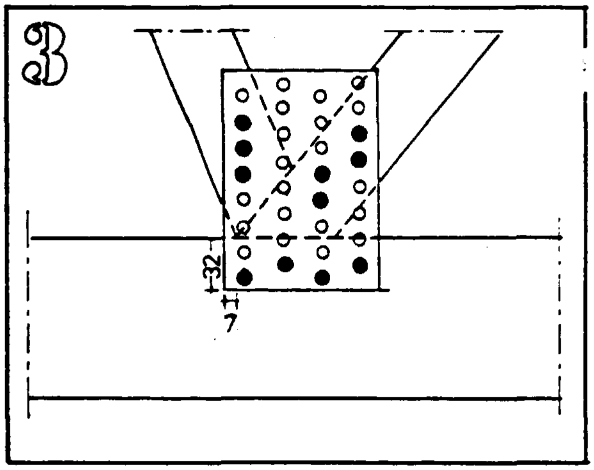


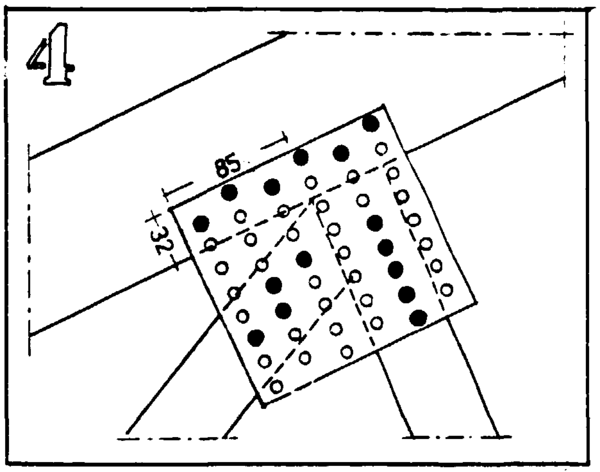
	plate	size	nails
1	6x12	104x300	23+22
2	2x6	40x150	3+3
3	6x6	104x150	3+4+6
4	8x6	136x150	6+5+4
5	8x6	136x150	5+6+5
6	12x10	200x250	2x(18+6)
7	4x10	72x250	16+16

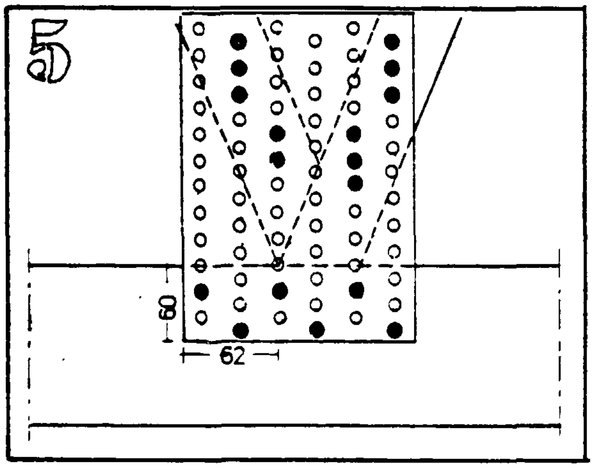
BELGIAN TRUSS HW10 25°

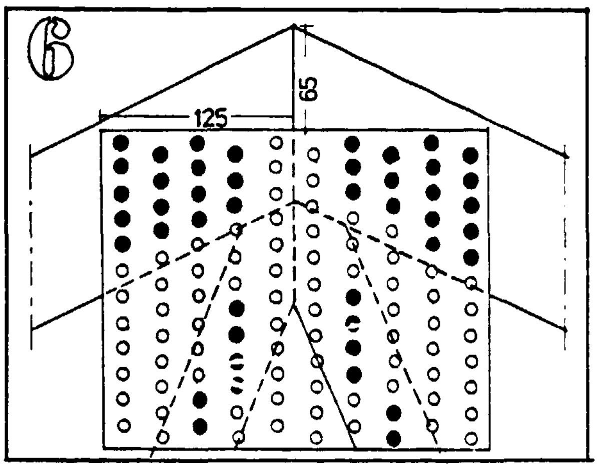












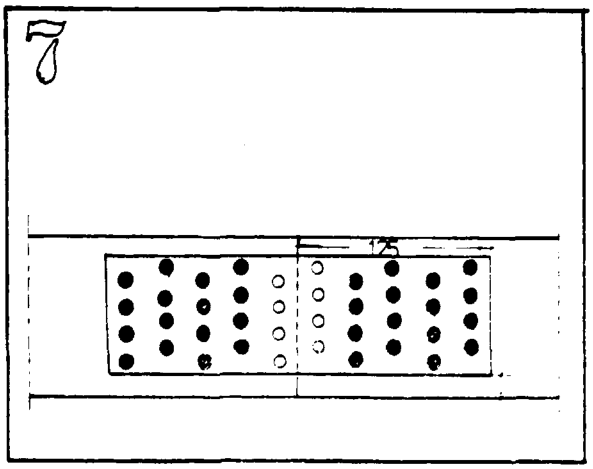
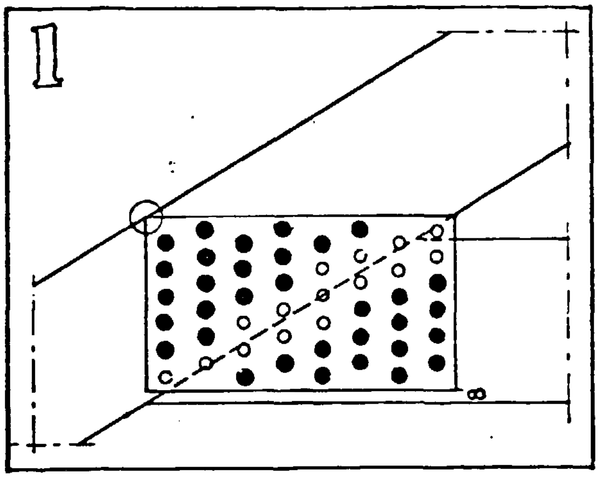
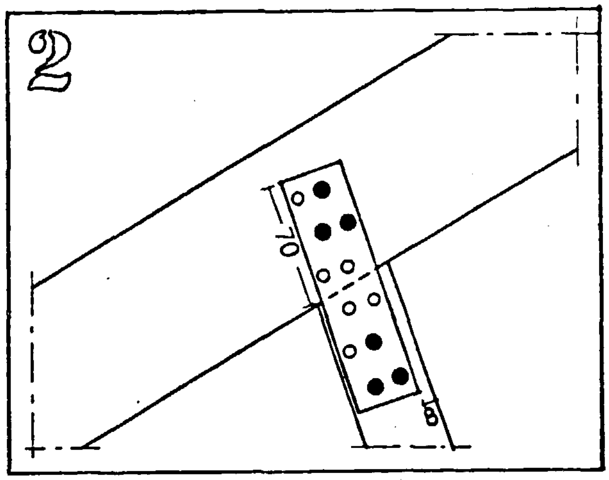
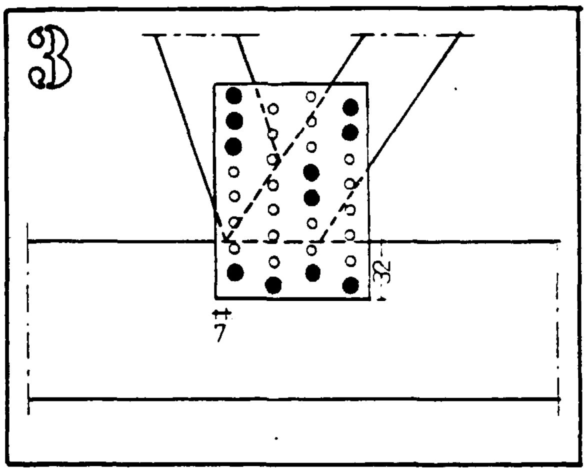


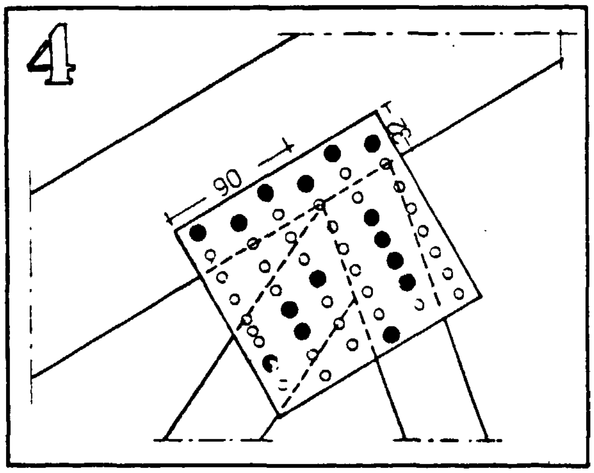
	plate	size	nails
1	6x10	104x250	19+19
2	2x6	40x150	3+3
3	8x4	136x100	3+4+4
4	8x6	136x150	6+5+4
5	12x6	200x150	5+6+6
6	12x10	200x250	2x(16+6)
7	4x10	72x250	16+16

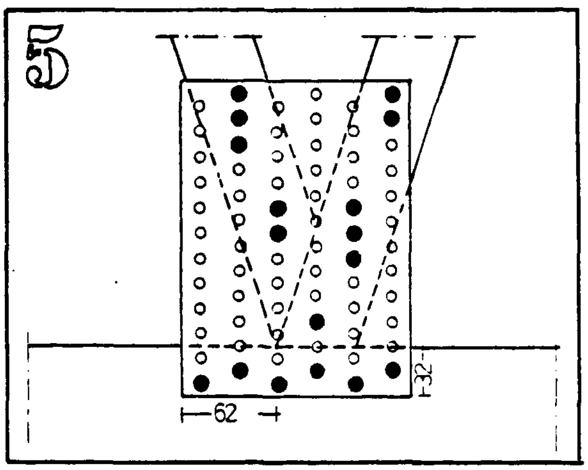
BELGIAN TRUSS HW10 30°

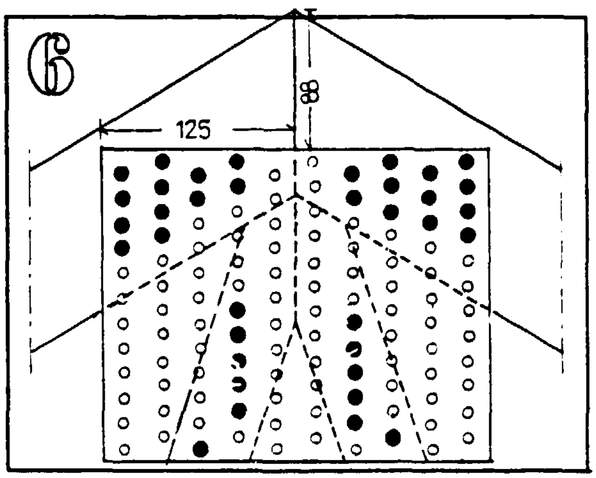


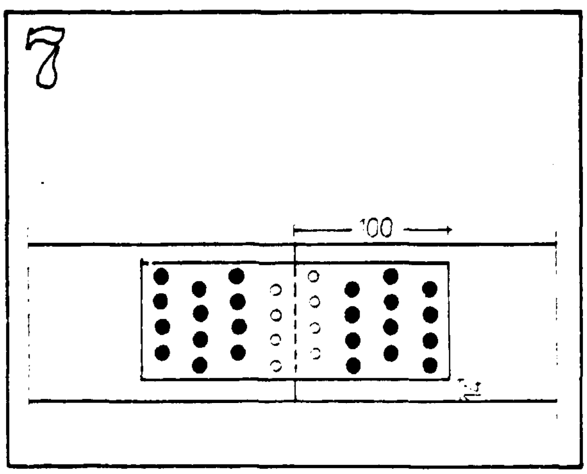






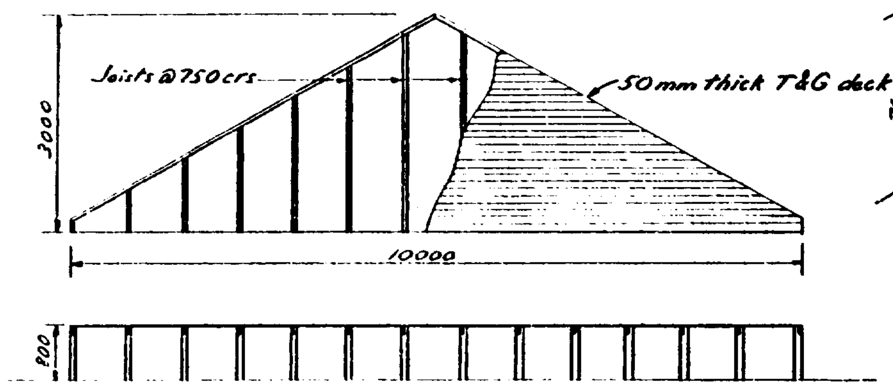




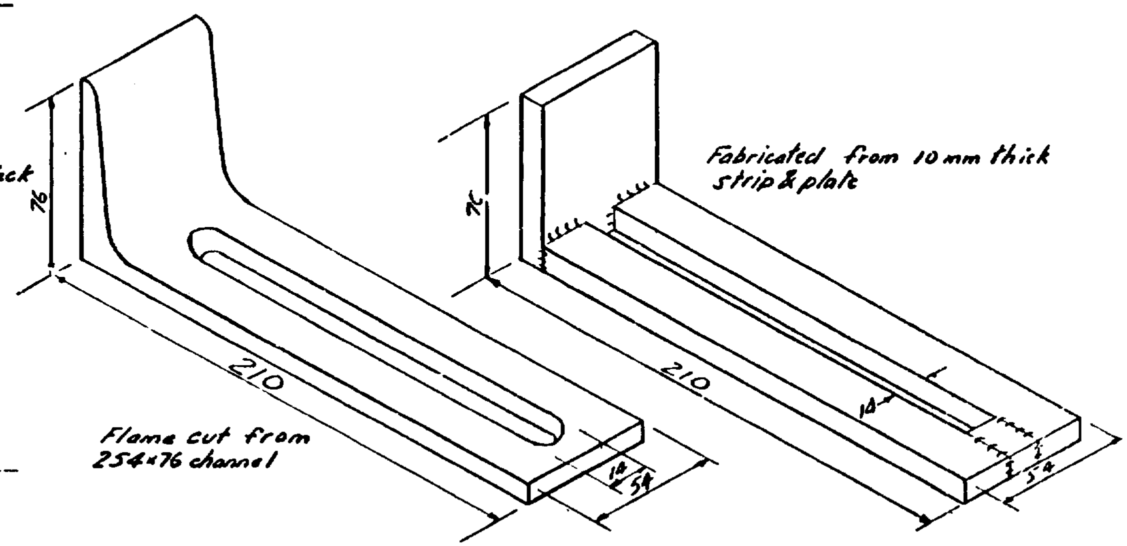


	plates	sizes	nails
1	6x8	104x200	18+15
2	2x6	40x150	3+3
3	8x4	136x100	3+4+4
4	8x6	136x150	6+5+4
5	12x6	200x150	5+6+6
6	12x10	200x250	2x(12+6)
7	4x3	72x200	12+12

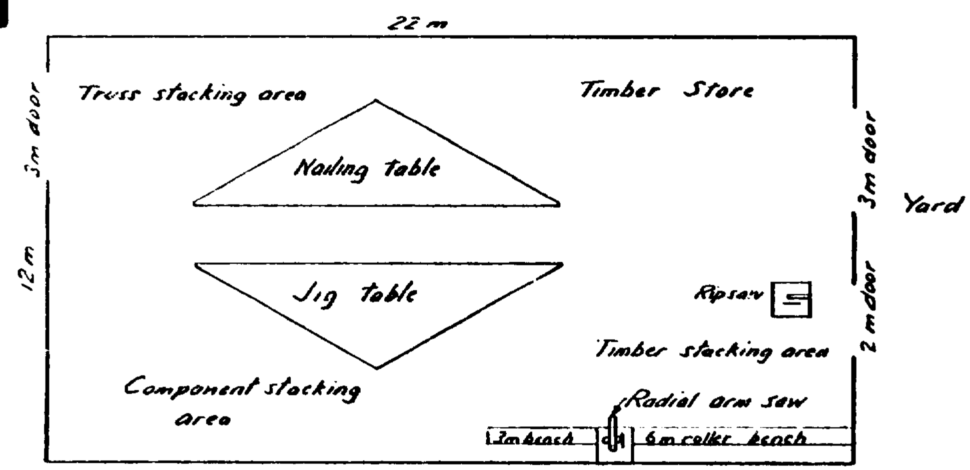
ANNEX 2 FACTORY LAYOUT JIGS AND CLAMPS



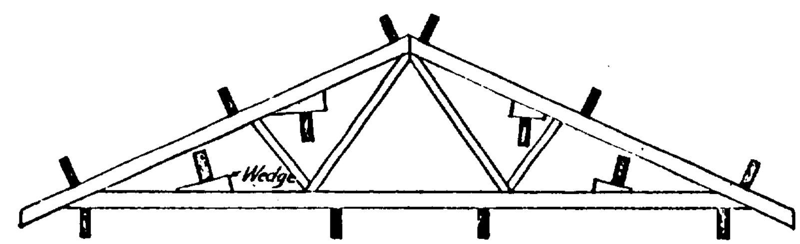
Nailing & Jig Tables



Jig Clamps



Truss Factory Layout



Truss clamped on Jig