

BLACK BOOK

PROLYTE TECHNICAL MATTERS



IMPRESSUM

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BASIC TECHNICAL INFORMATION

INTRODUCTION

This Black Book contains basic technical information about our trusses and complimentary products. We will be looking at the truss with its technical properties, its potential and practical limits.

We are aware that this information is basic knowledge and cannot cover all areas. However, although this documentation is not exhaustive, we believe it provides a good introduction to our products. All information complies with the latest standards and developments. The compositions and designs for aluminium trusses are described below, as well as the different types of connections, forces within the trusses and the different load types. We will discuss standards, regulations and laws relating to trusses, followed by calculation methods and loading tables.

Furthermore we describe hoisting trusses, lifting persons, truss maintenance, criteria for rejection and discard, and accepted practical rules. In our opinion good customer service consists primarily in continuously improving the information available to users.

This means that all users can select and use different truss types depending on the specific structural properties of the truss.

Better and appropriate use of trusses is of great benefit both to our customers and to us as manufacturers.

In the long term this means enhanced safety, satisfied customers and greater awareness of users when working with trusses.

Our prime objective is quality. This applies not only to our products but also to the relevant information. Both are key to a successful and safe product range.

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1. THE TERM: TRUSS

1.1 A SHORT HISTORICAL REVIEW

When the first lattice spans appeared in event technology in the 1970's, hardly anyone would have described a truss as follows: „A modular structural element made of aluminium tubes welded to each other used to create temporary supporting structures for lighting and audio equipment used in event technology.”

At that time anything was used, from round steel tubes to antenna masts.

The word truss or lattice girder used to describe the wooden construction framework that was used to build roofs or medieval cathedrals.

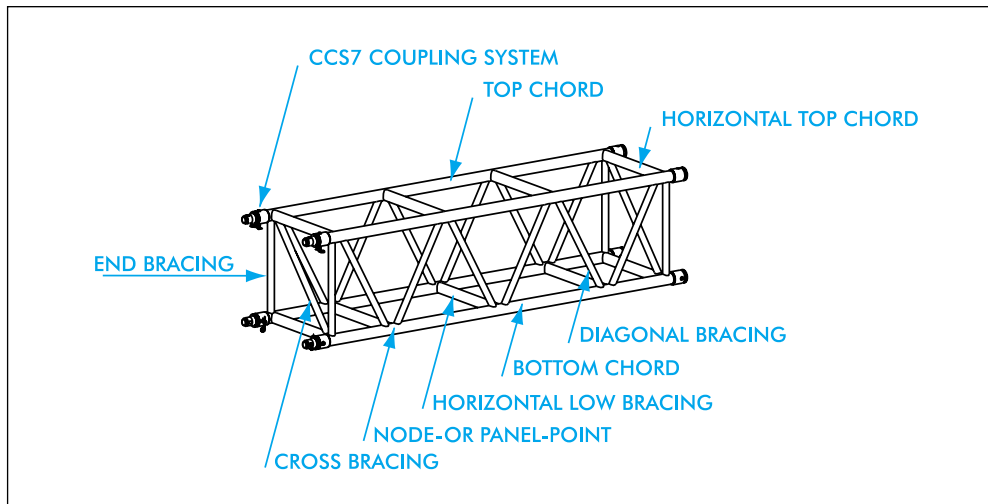
The development of trusses as we know them today began towards the end of the 1970's when the entertainment industry was searching for a simple and efficient means of manufacturing light but safe supporting structures.

Designers used know-how about spatial structures employed in bridge construction to develop today's products. Apart from the bearing capacity, other practical considerations were important when developing trusses.



A truss is defined as:
a spatial lattice beam:

- Made from welded round tubes.
- Composed of modular coupled parts.
- Manufactured in several standardised lengths.
- Used to support equipment in in the entertainment industry.
- Supported or suspended at almost any desired point.



1.2 MATERIAL FOR TRUSSES

Trusses are made of aluminium because:

- Aluminium has a self-weight ca. 65% less than steel.
- Aluminium is corrosion resistant and therefore requires less maintenance and no corrosion protection.
- Aluminium has a relatively high tensile strength
- Aluminium has an attractive appearance due to its natural lustre.
- Aluminium is 100% recyclable.

The basic elements of a truss:

- Chords or main tubes (mostly 48 - 51 mm outer diameter).
- Braces or verticals and diagonals (the webbing or lattice structure).
- Connection parts (to connect the individual structural modules).

All trusses should have the following properties:

- Rigidity and stability appropriate for the intended use.
- A simple, reliable and quick connection system.
- Easy to handle thanks to light, compact elements.
- Efficient for application, transport and storage purposes.
- Multiple applications.
- Basic information available to users on allowable load bearing capability and deflection provided in tables and diagrams.

Trusses are available in various geometric profiles: double chord truss, triple chord truss, quadruple chord truss in square and triangle design and various types of folding trusses.

There are considerable differences between these profiles which are decisive for:

- Safety; structural rigidity and stability.
- Cost effectiveness; efficiency for connecting, storage and transport.
- Multiple applications, a broad range of uses for various construction designs with a special truss type.

Each of these designs has its specific advantages, disadvantages and field of application.

The user should carefully consider the intended purpose before selecting a system.

PROLYTE manufactures trusses for almost all applications in event technology, from decorative trusses of the E-series for shops and displays to universal trusses for trade fairs, exhibition stand construction and rental to heavy duty trusses for the high standards of the events and stage building industry. Although a fairly new development, trusses have become an indispensable product for the events industry of today.



2. CONNECTION SYSTEMS

Trusses are manufactured in standard lengths which can be combined to provide any overall length required. It is not usual to manufacture large truss lengths in one piece, since this would make them unmanageable for handling, transport and various other applications.

2.1 THE FOUR MOST COMMON CONNECTION TYPES

The majority of trusses are 2-3 metres long (6 to 10 feet). However, longer lengths are normally needed.

For this reason a rapid, efficient and simple connection system is needed to connect the trusses. Although there are many types of truss connections, only a small number are used today. Connection systems with a significant market share can be divided into four categories:

1. Plated connection:

The end plates are connected using bolts. These are exposed to tension far away from the main chord axes. This causes a bending moment, in the joint which in general reduces the load capacity significantly.

Disadvantages:

- Inexact axis alignment of chord tubes to each other.
- Many individual parts.
- Complicated assembly.
- Easy to confuse vertical and horizontal plane when using square trusses.
- Tools needed to bolt parts.
- Relatively low bearing capacity.
- Danger when using bolts with low rigidity.
- Special hinges needed for tower applications.

Advantages:

- Universal connection system.
- Installation length equals truss length.
- Robust connection points.
- Easy to use nodal elements.

2. Tube connection:

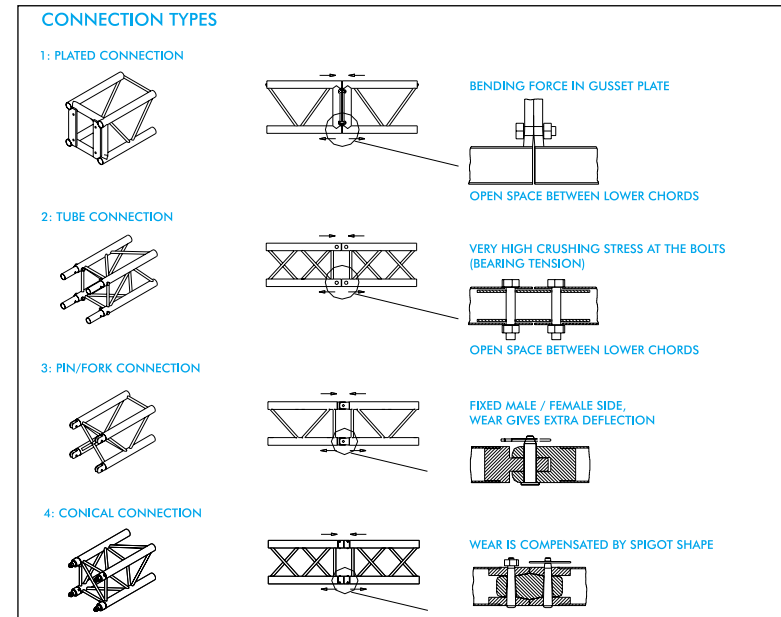
The connection is made by inserting tubes with an outside diameter smaller than the inner diameter of the chord tubes into the ends of the chord tubes. The inserted tubes are then bolted to the chord tube. The bolts are exposed to shear forces but can absorb these without any problem in contrast to the material of the chord tubes. The drillholes for the chord and connector tubes are therefore exposed to very high bearing stress. This type of connection is used primarily for trusses with fairly low requirements regarding bearing capacity.

Disadvantages:

- Relatively complicated assembly.
- Many individual parts.
- Complicated assembly.
- Head room in the connection between main tube and connecting tube.
- Tools needed.
- Rapid overloading of the connection through bearing stress.
- Tube ends are easily damaged when used frequently (means the truss may not be used).

Advantages:

- Universal connection system.
- Installation length equals truss length.



3. Pin / Fork connection:

The "female" fork is connected to the "male" pin via a cylindrical bolt. The load transmission is exerted in the axes of the main chords, the connecting bolts are exposed to shear forces.

Disadvantages:

- More planning needed because the direction of installation is fixed.
- Large number of different nodal elements needed.
- Installation length is shorter than truss length.
- Connecting elements can be easily damaged (means truss may not be used).
- Wear on connecting elements leads to head room between two truss elements (inner bore in the drillholes of the connecting elements cannot be repaired).

Advantages:

- Few individual parts.
- Very quick and simple assembly.
- No hinges needed for tower applications.

4. Conical connection

Connection with a solid double conical connector which is secured with conical bolts in the ends of the chord tubes. The conical bolts are exposed to double shear force.

A fully non-positive connection is created and the force is transmitted in the axes of the main chords.

Disadvantages:

- Special hinges needed for tower applications.

Advantages:

- Universal system.
- Exact alignment of elements.
- Very quick and simple assembly.
- Connection is 100% rigid.
- Construction length corresponds to truss length.
- Compensation for wear in the drillholes using conical bolts.
- Connecting elements are not easily damaged and are easy to replace.

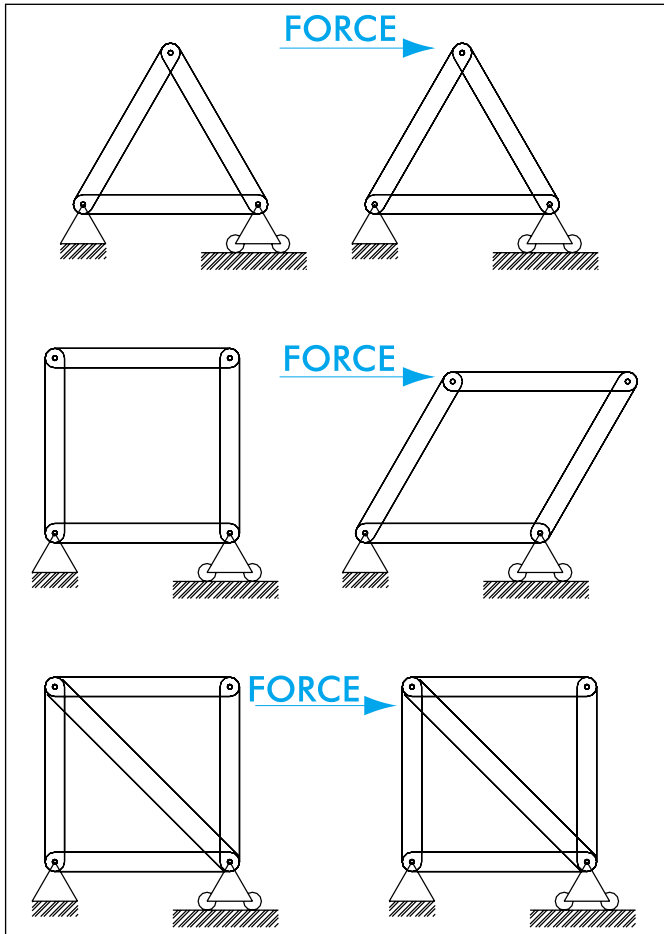
2.2 THE TRIANGULAR STRUCTURE OF LATTICE STRUCTURE

Why is a triangular shape the most dominant feature of a truss?

A triangle is the only geometric shape which retains its shape when it is exposed to a load at connection points or joints, even if these joints are hinged. Only if one side is deformed (elongated, compressed, rolled) does a triangle lose its shape.

The behaviour of a triangular structure under load is easy to calculate and predict if the loads are exerted only in the nodal points.

Structural engineers must be able to determine the results of their work within very narrow tolerances in order to guarantee a safe basis for users to work with. Certain basic assumptions must be made in order to perform calculations.



The triangle is the only geometric shape that retains its form when being loaded at the joints.



Each side of a triangle should only be exposed to compression or tensile forces. Since no other influences such as flexural load are assumed, loads should be directed into the nodal points. Trusses from the 30 series have relatively large diagonal braces compared to the overall height of the truss and a fairly compact framework.

It should be emphasised that a truss with one or two-sided diagonal bracing (at right angles to the main chord) may not be used for the same types of load as trusses with a diagonal lattice structure on all sides. For example, this applies to the truss series S36R, S52F, S52V, S66R and S66V. Without consulting a structural engineer it means that forces should impact in a plane with the diagonal lattice structure and at 90° to the plane of the support braces.

3. FORCES ON TRUSS

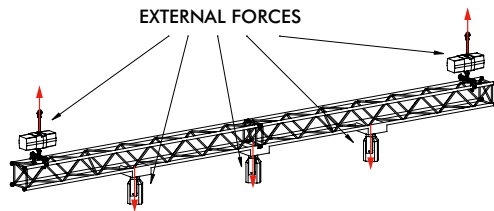
3.1 DEFINITION OF EXTERNAL AND INTERNAL FORCES

In a truss construction we can define two different types of forces.

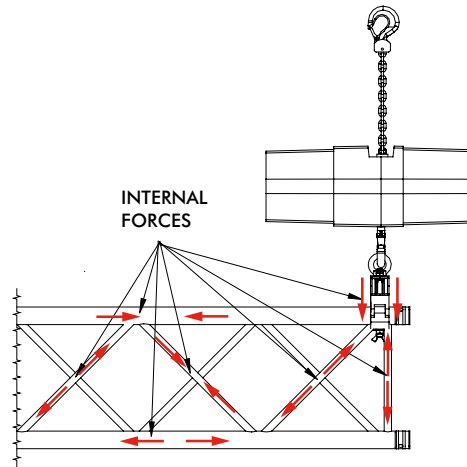
The first type of forces we can define are external forces, which are imposed through external influences on the truss construction.

Examples of these external forces are:

- Live loading such as lighting fixtures or sound equipment.
- Curtains, drapes.
- Dynamics caused by movement of (electrical) chain hoists.
- Environmental influences like: wind force, snow loads, ice.



When the different components of truss, such as main tubes or bracing, are not capable of bearing these internal forces the truss will fail.



In the next paragraphs we will explain by using examples from daily practice, the different kinds of external forces on a truss and what the reaction forces inside the truss will be. We will also explain how to increase the allowable forces by changing the truss components.

3.2 NORMAL FORCE.

The second type of forces we can define are internal forces. Internal forces are reaction forces of the structure due to the external forces.

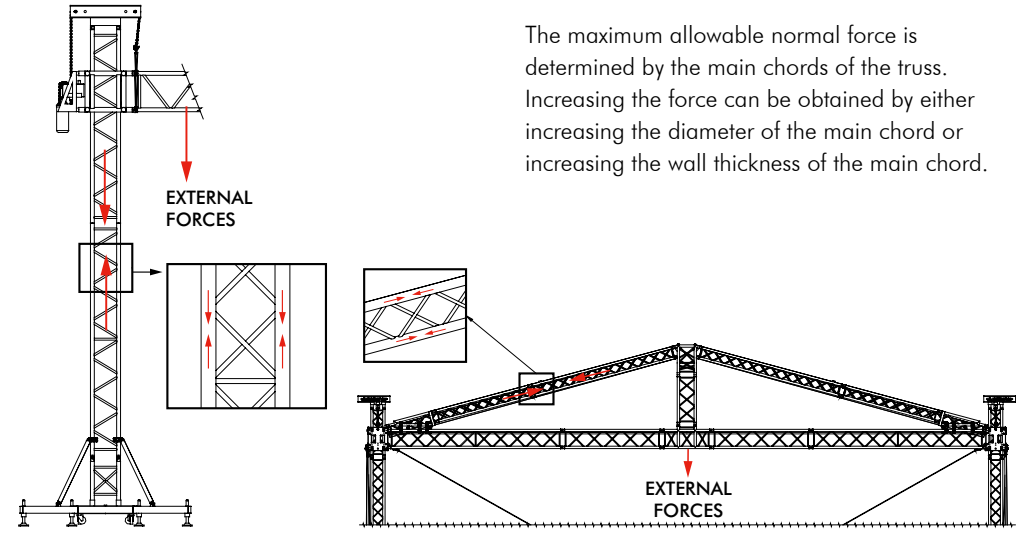
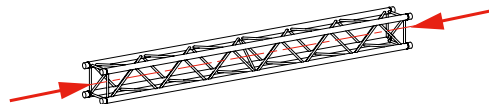
These internal forces can be defined inside a particular section of a truss or inside a particular section of a truss construction.

When we consider a particular section of a truss or a particular section of a truss construction, all forces must be in balance or we would have a mechanism. In other words, the sum of all the external and internal forces in a horizontal or a vertical plane needs to be zero.

The normal force is a force which works longitudinal to the centre line of the truss.

Example's of situations where a normal force occurs:

- Towers.
- Columns.
- Rafter trusses in a MPT or ST roof.



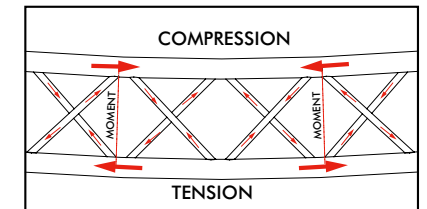
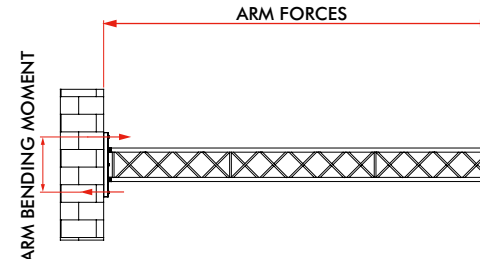
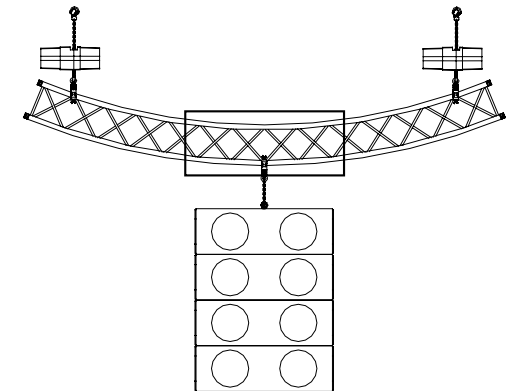
The maximum allowable normal force is determined by the main chords of the truss. Increasing the force can be obtained by either increasing the diameter of the main chord or increasing the wall thickness of the main chord.

3.3 BENDING MOMENT

The bending moment is the sum of all the moments and reaction loads passing through the centre axis of the truss considered at any point. In simple words "the force which is needed to deflect a truss."

Example's of situations where a bending moment occurs:

- Self weight caused by the force of gravity.
- Live loading such as lighting fixtures or sound equipment.
- Curtains, drapes.
- Environmental influences like: wind force, snow loads, ice.



The Bending moment acts as a compression force in the top main chord and as a tension in the bottom main chord. The braces are used to maintain the distance between the top and bottom main chords.

The maximum allowable bending moment can be increased by choosing truss with a larger distance between the top and bottom main chord (e.g. larger truss). This will create a greater distance between the forces.

The second way to increase the allowable bending moment is to increase the normal force in the main chord, by increasing the diameter of the main chord or by increasing the wall thickness of the main chord.

The main chords of a truss can also be subject to a bending moment, this can be caused by mis-nodding or by placing high loads between the node points.

Figure: Occurrence of internal forces caused by mis-nodding.

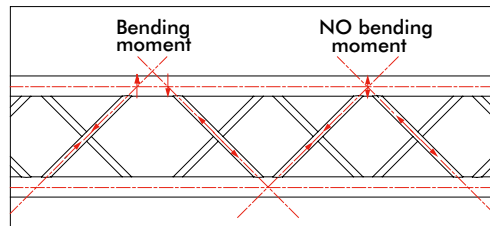
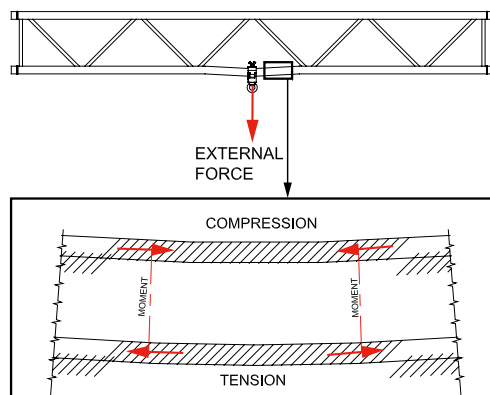


Figure: Occurrence of forces when a load is placed between two node points.

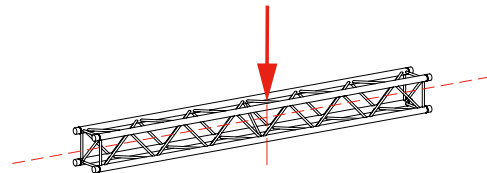


3.4 TRANSVERSAL FORCE / SHEAR FORCE

The transversal force is the force which works perpendicular to the centre line of the truss.

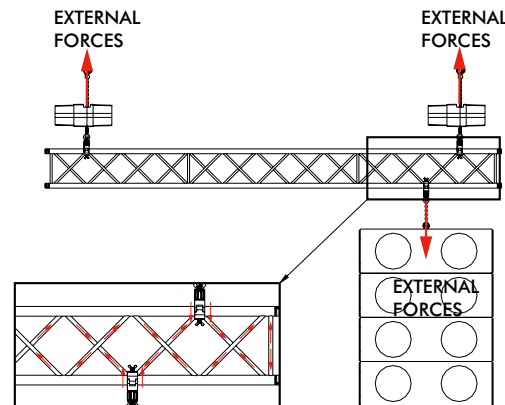
Examples of situations where transversal forces occur are:

- A heavy load on a short span.
- A heavy load near to the suspension point.
- Truss constructions underneath a stage floor.



The transversal force acts as a normal force in the bracing and as shear force in the main chords of a truss. The normal force in the bracing can be either compression or tension force. The shear force on the main chord tries to "cut" the main chord.

The allowable transversal force can be increased by increasing the diameter of the bracing or by increasing the wall thickness of the main chords.

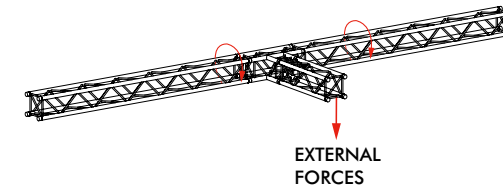


3.5 TORSION FORCE

This force works perpendicular to the centre line of the truss but is not positioned in the same plane as the centre line. This force tries to twist the truss.

Examples of situations where torsion will occur:

- Equipment on a boom arm.
- Equipment all positioned on one side (main chord) of a truss.
- Live loading on a central span in a ground support system.



3.6 DEFLECTION

The deflection of a truss shows the bending forces at work. Deflection is defined as "deformation under load".

Deflection within the allowable limits is a normal reaction and does not imply any danger regarding stability and safety. When your truss manufacturer does not supply any details on the allowable deflection limits, this can lead to a deceptive feeling of safety.

Prolyte provides two types of loading information; first, the allowable load without a deflection limit and secondly allowable load with a deflection limit of $L/100$. The loading tables in the catalogue contain the values without deflection limit. Loading tables which include deflection as a limiting factor are available on our website (see: TUV certificates).

Other truss manufacturers may use other deflection limits in their calculations.

However, if no details on deflection of a truss type are given, the load values should be viewed with caution. The user has no possibility to recognise the loading limit.

Bad connections can be another cause of truss deflection. Insufficient secured bolts, worn connection elements or deformed end plates all cause extra deflection within a truss span. Prolyte's conical coupler connections (CCS®) have been designed to compensate a certain amount of wear through their tapered design. Other connection systems do not offer this possibility and hence are subject to deflection from the very beginning.

The height of a truss determines, to large extend, the stiffness of this truss. The greater the overall height of the truss section (in the direction of the load), the greater the stiffness and the smaller the deflection under the same load.

Values given by various manufacturers on the deflection of trusses differ.

This has two reasons:

1. Not all manufacturers allow for 15% greater deflection of a truss in contrast to a girder made of solid material
2. The self-weight of the truss is ignored.

Prolyte adheres to the practice of including full deflection in the technical information and giving deflection as a limiting factor for the bearing capacity. Prolyte believes it makes no sense to publish load values that do not consider deflection.

The result is a feeling of insecurity for observers when they see a strongly deflected truss, even if the truss is within the limits of its bearing capacity.

There are also applications where deflection must remain within certain limits. For example, when drapes are hung from a truss span, deflection will cause the drapes to sweep the floor in the middle, while being too short on the outer ends. Or when curtain or camera tracks are used, a completely level truss is required.

Deflection of a truss is by no means simply an “optical shortcoming”; it can be of technical significance in practical applications as well. Manufacturers who do not include deflection in their data, or who do not see the bearing capacity as a limiting factor, demonstrate little understanding of the practical requirements of their customers and users.

Prolyte is following a considered strategy of providing open and transparent information on the material specifications and calculation basis for our trusses. In our opinion it is in the interest of the user to understand the calculation basis to ensure safe application of the trusses if these are used within the limits of the load stresses given.

Example 1: allowable load for a truss with a certain deflection

Truss X30D, self-supporting span	L = 10 m
Self weight total c. 39 kg, self weight per metre	DW = 3.9 kg/m
Distributed load excluding admissible deflection	U = 32.9 kg/m
Deflection under this load is	f = 89 mm

What is the allowable distributed load if allowable deflection is set at maximum $d = 1/200$ of the self-supporting span?

$$UL/200 + E_g = ((L \times d) / f) \times (U + E_g)$$

$$= ((10000 \text{ mm} \times 1/200) / 89 \text{ mm}) \times (32,9 \text{ kg/m} + 3,9 \text{ kg/m})$$

$$= (50/89) \times 36,8 \text{ kg/m}$$

$$UL/200 + E_g = 20,67 \text{ kg/m}$$

$$UL/200 = 20,67 \text{ kg/m} - DW$$

$$= 20,67 \text{ kg/m} - 3,9 \text{ kg/m}$$

$$= 16,77 \text{ kg/m}$$

Including the factor 0.85 for possible wear (see 8.2) this gives:

$$U_{max} = 16.77 \text{ kg/m} \times 0.85 = 14.25 \text{ kg/m}$$

This results in an additional “safety factor” of: $S = 32,9 \text{ kg/m} / 14,25 \text{ kg/m} = 2,31$

Example 2: calculation of deflection at a given load

Truss X30D, self-supporting span	L = 10 m
Self weight total c. 39 kg, self weight per metre	DW = 3.9 kg/m
Distributed load excluding admissible deflection	U = 32.9 kg/m
Deflection under this load is	f = 89 mm
Distributed load U + self weight of truss DW	UE = 36.8 kg/m

How big is the deflection for a load of $U_{vor} = 20 \text{ kg/m}^2$?

$$f_{vor} = ((U_{vor} + DW)/UE) \times f$$

$$= ((20 \text{ kg/m} + 3,9 \text{ kg/m})/36,8 \text{ kg/m}) \times 89 \text{ mm}$$

$$f_{vor} = 57,8 \text{ mm}$$

The truss will deflect approx. 58 mm with an applied load of 20 kg/metre.

3.7 WHAT IS DESIGN LOAD

There is often confusion about the term “design load”. Design load is a term used in standards in which the calculation is based on what is referred to as the Load Resistance Design Factor or LRDF. It also involves a safety factor being applied to the load and the material. Standards based on the LRDF principle are EuroCodes, such as DIN 18800, BS 8118 etc.

An example is a crowd barrier which has a design load of 450 kg/m^2 which means, that the SWL is $450/1.5 = 300 \text{ kg/m}^2$.

Apart from LRDF standards, there are also the so-called ASD standards. ASD stands for Allowable Stress Design.

The principle on which these standards are based is that a safety factor is applied to the maximum permissible tension. In the case of aluminium, and according to DIN 4113, this factor is 1.7 over and above the yield strength. An example of an ASD standard is DIN 4113.

In many countries it is still permissible to apply both principles. However, considerable problems can arise if calculations of steel constructions have to be combined with those of an aluminium construction.



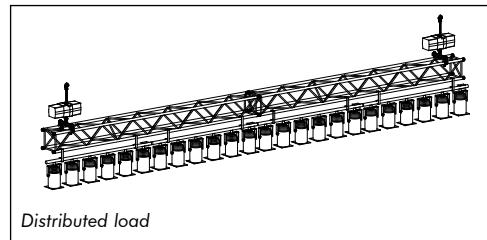
4. TYPES OF LOAD

Load can be defined as:

The sum of the forces resulting from mass, self weight or stress which a span is subject to. The types of load in question can be divided into two categories: uniformly distributed loads and point loads.

Uniformly distributed loads

A load with identical weight along the whole span of a truss or a load which is distributed evenly over the nodal points of the lower chord tube of a truss is called a uniformly distributed load (UDL). Examples of uniformly distributed loads are curtains, decorations, cables and spotlights of the same weight distributed at regular intervals across the truss span. The formula symbol for uniformly distributed load is Q , the unit is given in kg or kN. A uniformly distributed load per metre uses the symbol q and is given in kg/m or kN/m.



Distributed load

KYLO „KNOW YOUR LOAD“

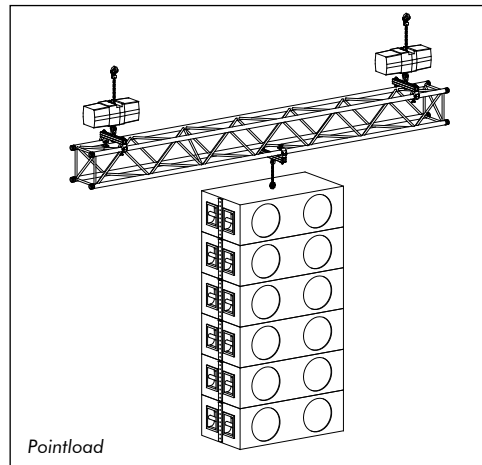
For simplified determination of a Prolyte truss for specific structural systems (single field spans with projections), Prolyte provides the MS-Excel based „KYLO“ tool on our website www.prolyte.com. The load capacity of a truss or a suitable truss for a specific load case can be determined with KYLO. However, Prolyte would like to emphasise that KYLO values by no means replace structural calculations!

Point load

A point load describes a single load at a single point in the truss span. The most unfavourable position for a single point load is in the middle of the truss span. This type of load is called the centre point load (CPL). If this point load is placed at another point in the truss span, this results in a lower bending moment and hence smaller flexural stress, although the shear force at the active point of the force remains the same. However, the shear force increases on the support which the force is moved towards. Examples of point loads are loudspeaker units, follow spot seats, suspension points for hanging trusses and technicians.

Prolyte regards all loads with the self weight of a person or higher as a point load and recommends all users to do the same.

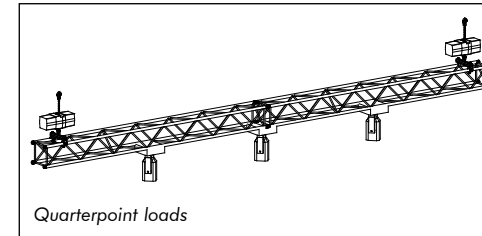
A technician on a truss causes a point load of at least 1kN.



Pointload

Several point loads

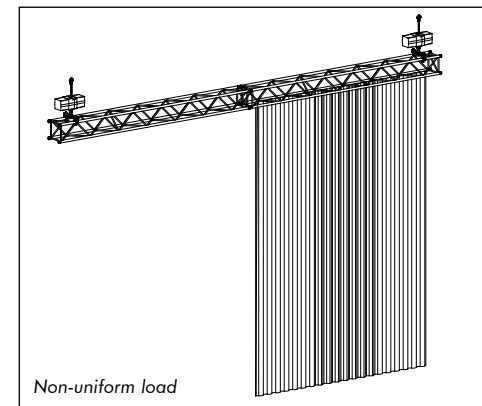
Frequently not just one single point load is found in a truss span, normally several equal point loads are found at the same regular intervals. In our loading tables we give the allowable load caused by two equal point loads which divide the truss span into three equal sections (third point loads). Three equal point loads which divide the truss span into four equal sections are called quarter point loads, and four equal point loads which divide the span into five equal sections are called fifth point loads. For a greater number of point loads the load data for a uniformly distributed load can be used.



Quarterpoint loads

Non-uniform loads

A non-uniform load occurs when only part of the span is subject to a uniformly distributed load or when several point loads are exerted in a limited zone while the rest of the span remains free of loads.



Non-uniform load

The safest way to estimate the bearing capability of a truss under non-uniform load is to determine the total load and then to consider this load as a centre point load (CPL). It is obvious that these different types of load can have extremely different effects on the stability of a truss and hence need to be dealt with separately.

Two fundamental criteria should be considered when selecting a suitable truss:

- The length of the allowable truss span – the distance between two supports.
- The allowable load of the truss for a determined truss span.

The span between two supports and the allowable load are two factors which are linked. The bigger the span, the lower the allowable load and the bigger the load, the shorter the allowable truss span. In the few cases where the shear force and not deflection is the limiting factor, a very high load in a very short truss span can cause failure in the support zone.

This will result in buckling of the chord tubes, buckling of the diagonals under load, or in a rupture of the welding seams in braces under load. Each truss type, independent of the manufacturer, has its specific failure criteria. It is the responsibility of each manufacturer to ensure that these criteria never represent a lasting danger when calculating the allowable loads and spans.

5. SPECIFIC LOAD SCENARIOS

5.1 FOR USE OUTDOORS OR IN ENCLOSED SPACES

The difference regarding loading whether trusses are used outdoors or in enclosed spaces is as important as it is apparent: climatic conditions have a great influence on the safety of the construction.

Wind:

- Can cause horizontal loads on a truss section.
- Can cause the construction to tilt, lift off the ground or slide.
- Can cause overload on the trusses which have to absorb forces transmitted via drapes or other surfaces exposed to wind.
- Can damage the roof, side and rear covers.

Rain and snow:

- Can cause overload if water masses build up.
- Loads caused by the weight of snow must be avoided.
- Can soften up the ground and hence lessen its bearing capability.
- Increases the risk of slipping when climbing along a truss.
- Can affect the electric installations which is used to lift the construction.

Lightning:

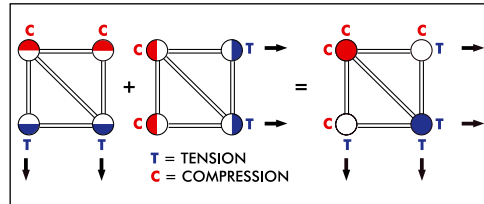
- Can endanger persons and electric installations.

Temperature:

- Towers and trusses can heat up considerably in strong sunshine. This can be a danger when climbing, in particular if additional heat is generated by lighting equipment. Appropriate protective clothing must be worn and textile lifting accessories must be protected against the effects of heat.

5.2 HORIZONTAL LOADS

Horizontal loads are often underestimated. They are caused by many factors, e.g. wind, tension forces created by canopies, drapes, screens, etc. The values given in the loading tables refer to loading of the truss in a vertical direction. If a second bending force in horizontal direction is added, this can cause overloading of the truss even though the vertical load is within the limits of the table. Due to their design the truss types S36R, S52F & V, S66R & V and S100F may not be subjected to any horizontal loads without consulting a structural engineer. If this cannot be avoided, these forces must be transferred, e.g. via other trusses for transferring compression forces or steel wires for transferring tension forces.



5.3 DYNAMIC FORCES

When hoisting and lowering weights, the starting and stopping cause additional dynamic forces which must be taken into consideration when determining the overall load. When using standard hoisting normally a factor of 1.2 to 1.4 is used to determine the dynamic loads. If higher speeds are expected, e.g. very fast running chain hoists and winches or artistic performances, the loads and bearing capability should be calculated by a professional.

5.4 THEORY AND PRACTICE

Although all our calculations and theoretical models reflect state-of-the-art technology, it is not possible to cover all situations in daily life. For us as a manufacturer, feedback on such situations is an important source of information which helps us to provide satisfactory solutions and long-term quality ratings for our products. In our Engineering and Sales Departments we employ experts with practical experience in the areas of rigging and trusses. Their invaluable knowledge, together with the knowledge which we have gathered over many years as a professional manufacturer of Prolyte, represents an enormous advantage which we would like to share with our users. Awareness of possible gaps in our theoretical knowledge about trusses and their applications reminds us of our responsibility to help our users by sharing knowledge. This way we can help to ensure safe working conditions and high durability of our products.

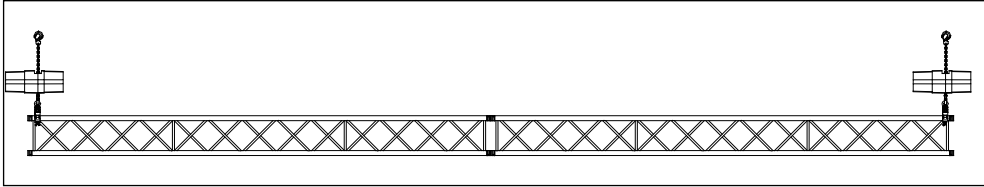


Photo: Spijkerman Evenementen, The Netherlands

6. TRUSSES AND LOADS

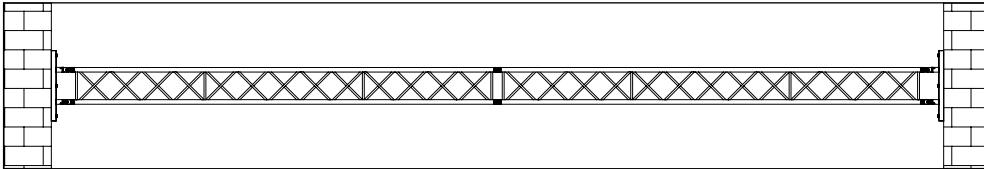
6.1 SPAN ON TWO SUPPORTS

The simplest version of a span is a span on two supports, the so-called single span. The loading tables give the load values for a single span. This is the most common type of truss application in events technology. The truss is supported at both ends and hence allows for vertical deflection of the truss under load between these supports.



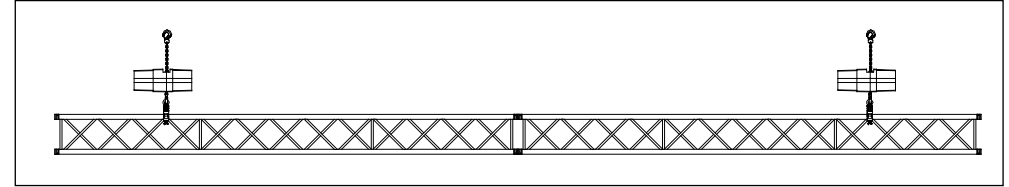
6.2 RIGID RESTRAINT (FIXED SPAN)

Load values which refer to bilaterally mounted spans are difficult to produce since this type of application is very unusual in event technology. Manufacturers who publish such load values appear to be interested in demonstrating high bearing capabilities which, however, are viable in very few cases.

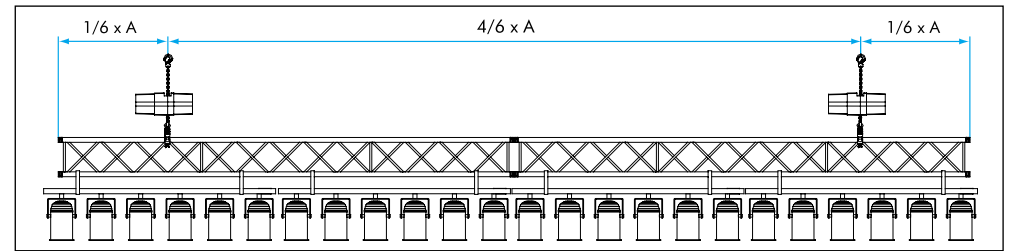


6.3 CANTILEVER SPAN

Spans with projections are single span spans with the supports placed inwards so that the end of the truss projects over the supports. The total load on the truss and its self weight influence the shear force in the zone of the supports. The larger the cantilever, the greater the bending moment at the point of support. Furthermore, cantilevers are only protected against torsion forces by the support they cantilever over and therefore are very susceptible to non-uniform loads.



If truss spans are limited, the trusses can be extended beyond the supports in the case of single span spans. As a rule of thumb, as shown in the diagram, one sixth of the span can be assumed as an allowable cantilever.



6.4 CONTINUOUS SPAN

Continuous spans on more than two supports are described as statically undetermined systems. The load in one span – the area between two supports – influences the behaviour of the span in the neighbouring areas.

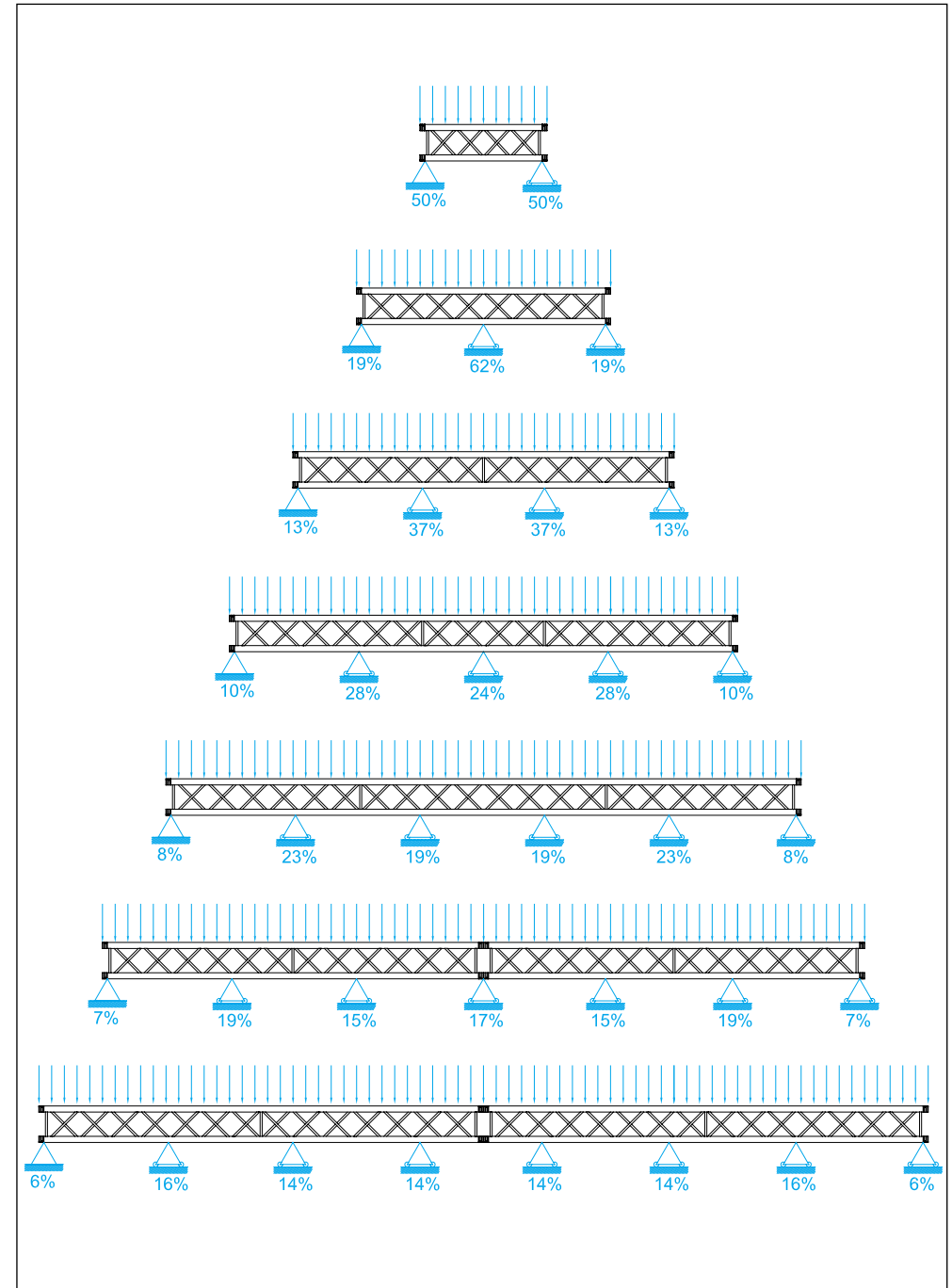
The potential load scenarios are practically endless. The possible consequences for the allowable load are so complex that it is impossible to publish a specific loading table for the numerous load combinations.

However, information about the support reaction in multiple supported spans is very important, because the shear force at all support points must remain within the allowable range for the truss and for the support point.

Furthermore the property of the bending moment over the inner supports is the reverse to that in the middle of the span. In the middle of the span the bending moment causes tension in the lower chords and compression in the upper chords. Over the middle supports the bending force causes tension in the upper chords and compression in the lower chords. In this respect Prolyte complies with the requirements of German Industrial Norms (DIN) as well as the latest developments in ESTA-ANSI (USA), PLASA-BSI (UK), NEN (NL), VPLT (D) and CWA 25 A/B drafts on the design, manufacture and application of trusses in event technology.



Photo: Qatar Vision, Qatar



6.5 LOADING OF TRUSS CORNERS

The exact determination of the allowable loading of corner elements is a complicated matter. The design and construction of a corner element will influence the allowable load on that element. Not all corner elements can absorb the load applied by the connected truss sections when these are under a maximum load. Many manufacturers do not take this into consideration when referring to their load values. Furthermore, not only the construction is decisive for the allowable load on a corner element, but also its position in a 2D or 3D truss construction.

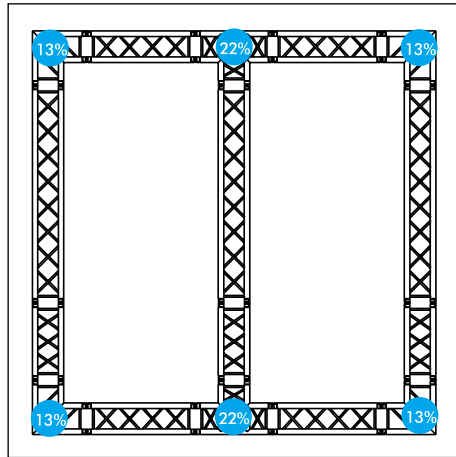
Therefore the load on corner elements must be checked for each individual case, including the lengths and loads on the adjoining truss sections. Over the last two years Prolyte has improved its welded corner elements or redesigned them in order to increase the allowable capacity.

As a rule of thumb it can be assumed that truss sections adjoining welded Prolyte corner elements may be loaded with around 50% - 100% of their allowable load.

If we look at the loading tables for the allowable central point load of the shortest span, for example 4 m X30D = 451.3 kg, only 50 % of this value, that is 225.7 kg, should be assumed. The supports with the highest percentage should never be subjected to a higher load than this. Hence we can calculate a maximum allowable uniformly distributed load for a construction using X30D trusses of c. 1026 kg.

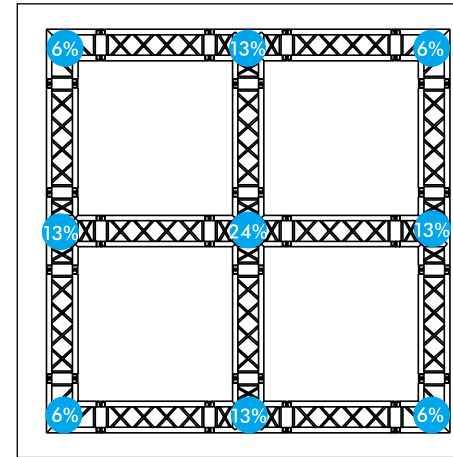
This means support loads of:

140,6 kg	225,7 kg	140,6 kg
140,6 kg	225,7 kg	140,6 kg



Assuming that each truss node represents a support, the approximate support reactions are given here as a percentage of the total uniformly distributed load of a square construction with a central truss.

Assuming that each truss node represents a support, the approximate support reactions are given here as a percentage of the total uniformly distributed load of a square construction with a truss cross in the centre.



If we look at the loading tables for the allowable central point load of the shortest span, for example 4 m X30D = 451.3 kg, only 50 % of this value, that is 225.7 kg, should be assumed in order to determine the allowable load of the C-016 node. The support with the highest percentage should never be subjected to a higher load than this. Hence we can calculate a maximum allowable uniformly distributed load for a construction with X30D trusses of c. 1026 kg. This means support loads of:

56 kg	122 kg	56 kg
122 kg	225,7 kg	122 kg
56 kg	122 kg	56 kg

Here it should be emphasised that almost one quarter of the uniformly distributed total load is concentrated in the central cross node.

6.6 CIRCULAR TRUSSES BASIC TECHNICAL INFORMATION

Prolyte is known for its full range of truss series for the widest range of applications. In addition, Prolyte manufactures trusses in circular form, arcs and ellipses.

Prolyte manufactures these curved trusses with an especially high level of precision to ensure good fitting accuracy without distortion.

All circular trusses are manufactured in a specialised department within the company.

This department is equipped with state-of-the-art welding jigs that are designed in-house.

This welding jigs allows all circular segments to be manufactured as standard elements, from the decorative E20 truss to the robust S66 series.

This ensures that each curved segment can be inserted at any position in a circle without impacting the overall shape of the circle.

Circular trusses and arcs can be made with any truss series, except for S52F and S100F.

Circular truss production

Although Prolyte has raised the production of circular trusses to the same standard as straight trusses, the two are always differentiated.

The production of curved trusses requires considerably more time. Each individual chord tube has to be rolled to the specific radius it needs in order to function as a chord tube of a circular truss. This means that a curved truss has at least two different chord tube radii: the inner and the outer radius. Each tube can only be rolled over a limited length by the rollers of the bending machine. The loss during bending is ca. 20-25 cm at each tube end. This means that a semi-finished product length of 6 m has a curved length of around 5.5 m. This is the segment length for curved trusses that form a circle. A further factor that affects circle and arc production is the position of the diagonals.

This is defined exactly by the welding equipment when producing straight trusses. However, for circular production no practicable solution exists.

All vertical braces have to be positioned manually. There is a lower limit for the bending radius for each type of tube. If the radius is made smaller, the chord tube assumes an oval shape (10% deformation is the maximum limit) and it loses its shiny surface due to the strong compressive forces on the inner edge.

The degree to which a tube can be rolled with satisfactory results depends on 3 factors:

- outer diameter of the tube; this has a direct influence on the geometrical moment of inertia and the resistance to bending
- wall thickness of the tube; this also has a direct influence on the geometrical moment of inertia and the resistance to bending, with thicker walls being less susceptible to surface changes but requiring considerably more time and energy to bend.
- composition of the tube; the lower the rigidity, the easier the cold forming process is.

Prolyte gives the values of the circular truss dimensions as the outer radius of the outer chord tube. The inner radius of the inner chord tube limits the bending process. The values given are minimum circle dimensions which ensure that the tube surface and the stability do not deteriorate greatly.

Ordering a circular truss

For applications in event technology we always recommend a division into 4, 8, 12, 16... segments. With this division circles can be used in different constructions as shown in the following figures. The number of segments of a circle depends on the radius of the circle. The maximum tube length that can be bent is 5.5 m, which means that circular segments cannot be longer. Average lengths between 2 m and 4 m are the easiest to handle, transport and store. We recommend that our customers adhere to these values when ordering a circle. Furthermore, for three-chord circular trusses the position of the triangle – point up/down, outside or inside – should not be forgotten.

E -Serie (32 x 1,5 mm)	Minimum tube bending radius 400 mm Minimum circle diameter 1,3 m
X -Serie (51 x 2 mm)	Minimum tube bending radius 1.000 mm
X30 -Serie	Minimum circle diameter 2,2 m
X40 -Serie	Minimum circle diameter 2,4 m
H -Serie (48 x 3 mm)	Minimum tube bending radius 800 mm
H30 -Serie	Minimum circle diameter 2,2 m
H40 -Serie	Minimum circle diameter 2,4 m
S -Serie (50 x 4 mm)	Minimum tube bending radius 1.300 mm
S36R	Minimum circle diameter 3,2 m
S36V	Minimum circle diameter 3,4 m
S52V	Minimum circle diameter 3,7 m
S66R	Minimum circle diameter 3,6 m
S66V	Minimum circle diameter 4,2 m

Loads on circular trusses

Circular trusses in a horizontal position – and to an extent also arc segments – can absorb less load than straight trusses.

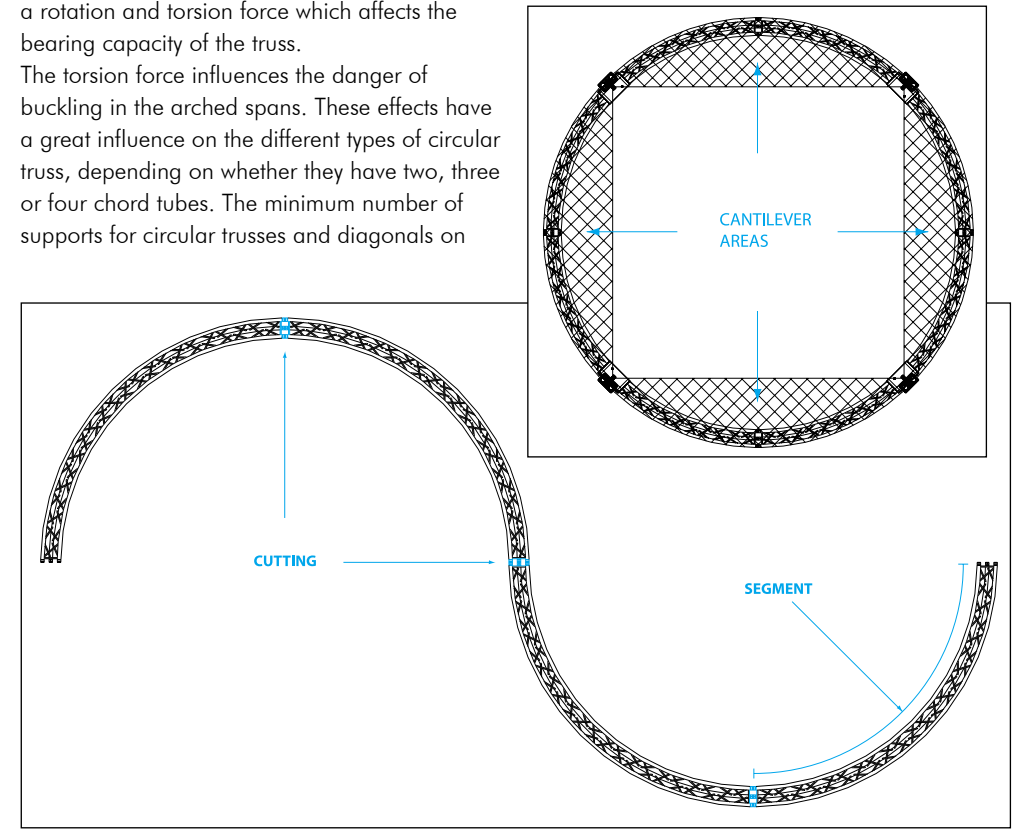
Since the number of supports for circular trusses should always be kept to a minimum, this means the circle segments overhang with cantilevers. In an arc segment the braces in the vertical plane for the inner and outer side is fundamentally different. Hence the effective length of the braces is always greater on the outside than on the inside. This means that an asymmetrical distribution of force is built into the truss.

The result is not only a different load on the chord tube, diagonals and connection elements through bending and shear forces, but also a rotation and torsion force which affects the bearing capacity of the truss.

The torsion force influences the danger of buckling in the arched spans. These effects have a great influence on the different types of circular truss, depending on whether they have two, three or four chord tubes. The minimum number of supports for circular trusses and diagonals on

all sides used in a horizontal position without causing problems of stability or balance is “three”.

Circular trusses with only two supports are principally unstable and therefore considered unsafe. If a circular truss is tilted from a horizontal position or is moved during an event, it is extremely difficult to calculate the allowable load because it is not possible to predict the resulting load for every possible angle of tilt. In such cases we urgently recommend to enlist the aid of a structural engineer.



6.7 ALLOWABLE LOAD ON TOWER TRUSSES

Our engineer department is frequently asked for loading tables for trusses used as towers. In such applications buckling can lead to failure easily before reaching the allowable compression loading. By compression the truss tower wants to deflects laterally (side ways).

Important factors here are:

- The height of the tower.
- The cross sections dimensions.
- Restraining of the (top/bottom) tower at both ends.

Eulerian buckling situations:

Euler 1: Mast is fully restrained at the bottom, cantilever effect on top.

Euler 2: Mast has hinged connections at bottom and topside.

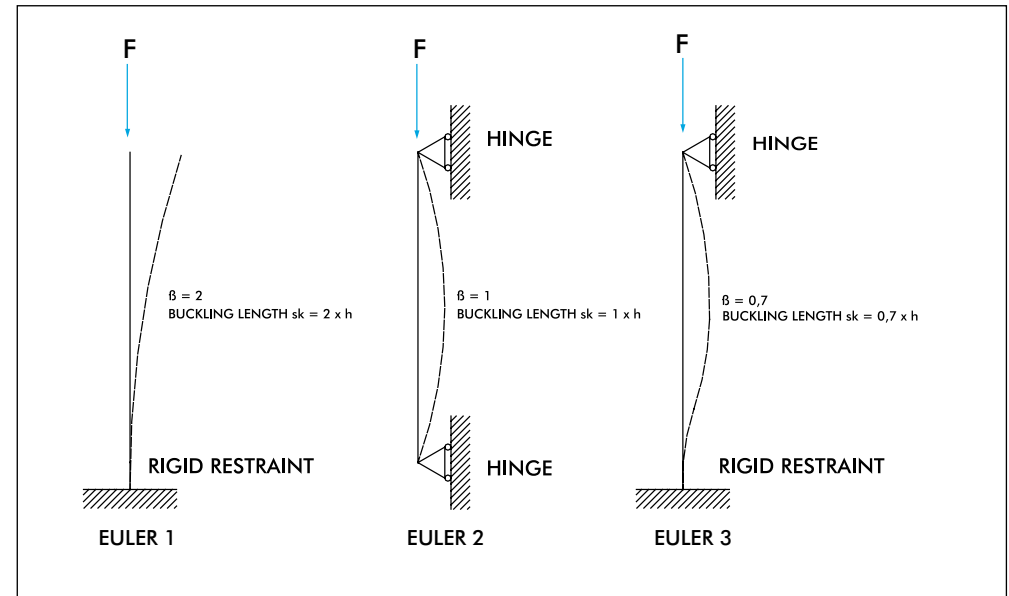
Euler 3: Mast is a rigid restrained at bottom, a hinged connection on top.

Since many further factors play a role when calculating the risk of buckling, it is not possible to give allowable load values when only the height of the tower is known.

A table which includes all factors is not practicable. In situations where the load deviates from the values given in the catalogue and described in the following section, specific calculations for the individual case are required. We strongly recommend that these calculations are carried out by a specialist.



Photo: Studio Berat, Serbia



Single Tower

Free-standing tower on a base or on a base construction made of trusses; a purely vertical load is assumed (no horizontal forces such as wind load).

Truss: H30V

Tower height h : 6,0m

Assumed factor β to determine the effective length: $\beta = 2.5$

This gives an effective length of: $sk = \beta \times h$

For example:

$$sk = 2,5 \times 6m = 15m$$

The Omega tables in DIN 4113 contain a factor to determining the allowable normal force for this type of truss and the effective length.

The maximum allowable compressive force is $P = 15kN$, corresponding to a load of ca. 1500 kg.

A standard base section with long outriggers can be treated similarly.

7. CALCULATION METHODS

7.1 A CLOSER LOOK

In the last few years the events technology market has expanded considerably, with many new truss manufacturers entering the arena.

More competition in the market means more selection with lower prices, which is a definite advantage for the consumer. A disadvantage is the fact that this situation can create confusion because trusses from different manufactures all look alike at first glance. For the average user it is very difficult to judge quality simply on the basis of the outer appearance.

It can even be dangerous, because there are some manufacturers in the market whose strategy consists in copying everything and trying to persuade the market that their copies at lower prices offer the same standards of quality and safety. We would like to point out that there are differences between countries in calculation methods and construction specifications. Moreover, differing interpretations of the basic principles or lack of knowledge of the normal application of trusses can lead to very different results for calculations. Hence at first glance it may appear that there are differences in the bearing capacity of the same truss systems but from different manufacturers. Only if internationally accepted standards are used for construction and calculations can the bearing capacity be compared.

Like a chain, a truss is only as strong as its weakest link. The load capacity of a truss is determined by numerous factors. Only one factor limits the load capacity at a time. Which factor this is depends on how the truss is being used at that point in time. For example, construction characteristics (overall height, wall thickness...) or technical characteristics of the material, e.g. tensile strength, can limit the bearing capacity in a particular case.

The usual standards (e.g. ANSI, BS, NEN, Euro Code and DIN) use different calculation methods for calculating constructions of aluminium and steel. However, these methods generally lead to the same practical results.

7.2 EUROPEAN STANDARDS

In the last 10 years a number of European standards/directives have been developed relating to trusses, truss constructions and stages. In the case of temporary constructions one can refer to EN 13814, the EU equivalent of DIN 4112 and the English publication 'Temporary Demountable Structures'. If trusses are used to lift loads, they fall under the EU legislation referred to in the Machine Directive.

Recently, a European code of practice has been drawn up in relation to stage machinery and load-bearing structures within the entertainment industry. Prolyte considers safety and transparency to be very important when it comes to providing information to users. For that reason, Prolyte played a key role, as chair of the 'truss constructions' working group, in defining the content of this document. There are a number of parts to CWA 25. One part relates to the manufacture of trusses and one part to their use.

The directive stipulates, among other things, that a manufacturer has to indicate the following:

- Values including a safety coefficient for trusses because these alone say something about the actual truss situation.
- The orientation of the truss with regard to the stated values.
- Values including a safety coefficient for truss lengths and for more than 2 suspension points.

The user will also have to find out about a number of matters in order to guarantee safe, namely:

- The forces which the construction is subject to.
- Whether I can use the 'standard' load tables or have a calculation done.

7.3 MATERIAL SPECIFICATION

EN AW6082 T6 is the most commonly used alloy for manufacturing trusses.

Other less rigid alloys are used in individual cases. As is the case for all aluminium alloys that are hardened, the technological specifications of a specific alloy are modified by the action of heat. The application of heat during welding reduces the tensile strength of the basic material in a certain zone around the weld.

This zone is called the heat affected zone (HAZ). The size of the HAZ and the remaining residual strength as well as workpiece geometry and many other parameters are also determined by the welding process itself (e.g. MIG and WIG). The corresponding DIN standards do not differentiate between the various welding processes in relation to calculation of the bearing capacity.

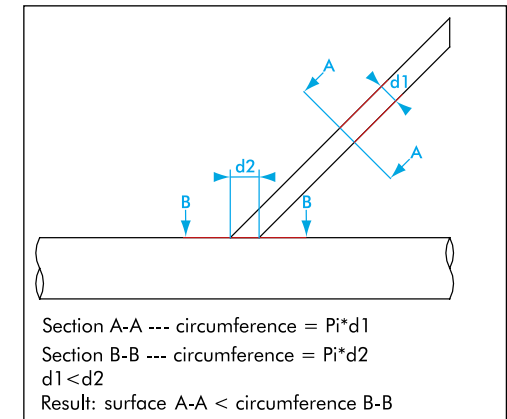
Other standards include this differentiation, although this is not yet generally accepted.

7.4 DIAGONAL BRACES

Since aluminium is very flexible because of its low coefficient of elasticity, the diagonal braces are assumed to be flexibly mounted on both sides for calculation purposes.

If they were assumed to be clamped on both sides, this would reduce the buckling length. Modern engineering methods prescribe that, for spatial structures where the main chord has a decisive larger diameter than the diagonals, a situation occurs whereby the restraint is a combination of both and therefore a reduction factor for the buckling length.

As shown in the picture below, mitring the braces on the chord tube allows for a larger circumference at the intersection (d_2) and hence a larger circumference for the welding seam compared with the circumference of the brace (d_1). This difference means the welding seam can be taken to around 9/10 of the circumference without reducing the overall bearing capacity of the connection.



8. DETERMINING SAFETY FACTORS

8.1 TRUSSES AS A CONSTRUCTION ELEMENT

General

Regulations or standards for calculating aluminium constructions are available in almost every country in the world. Similar regulations apply in most countries in Europe and North America so it could be expected that calculations would deliver similar results. Unfortunately this remains wishful thinking. It would be ideal if the calculation methods for trusses were determined in a blue print. However, this process of global harmonisation has only just begun.

Trusses should be tested by an independent body as part of a design test, and the design values and calculation methods should be disclosed. All calculations should be brought into line so that they can be compared

Construction Element

Spatial structures can be made from straight truss lengths in combination with corner elements. These structures can be free-standing and can withstand a certain load. If a truss is used as part of such a structure, it can be compared with a steel span in a normal building. Nevertheless, the safety factors cannot be compared with the safety factors usual in steel constructions because:

- Trusses are mainly used for mobile or temporary structures.
- Trusses are transported regularly.
- A truss is used in many different structures during its useful life.
- Trusses are made of aluminium, a relatively soft material.

For these reasons trusses are subject to wear and tear. The British standard BS 7905/7906, CWA 25 A/B and American standard ANSI E1.2-2000 prescribe multiplying the values in the loading tables with the factor 0.85 to compensate for wear and tear.

Unfortunately these standards do not regulate when trusses should be discarded.

Such data should be provided by manufacturers as a safety measure for working with trusses. We provide the corresponding criteria when trusses should be rejected and also offer an inspection service for truss elements.

The German standard VPLT SR1.0 states that the truss manufacturer is not responsible for the wear on the truss. However, clear guidelines are not available for this area, and according to the CE standards the responsibility should lie with the owner/user of the truss.

8.2 TRUSSES USED AS LOAD BEARING LIFTING EQUIPMENT

General

If a truss is used as a medium with a load bearing capacity supported by hoisting devices, e.g. chain hoists, the truss can be regarded as part of a crane construction or as a lifting beam (according to EN 13155:A1- Cranes – nonfixed load lifting attachments (2005)).

Such structures are calculated as normal steel spans, but additional safety is included by limiting the allowable deflection under load and increasing its safety factor with 1.2.

Deflection as limiting factor?

Limits for the absolute value of deflection are given in the Dutch NEN 6702 standard and depend on the use of the building structure and the type of construction. Trusses should be treated similarly. The limitation of allowable deflection should primarily be regarded as a functional value and not as an additional safety factor.

Here it should be emphasised that the allowable deflection for trusses is generally larger than that tolerated for uses in other technical areas. Sagging trusses do not give the impression of being a solid rigging structure, even if the trusses have not reached their maximum loading capacity.

8.3 SAFETY FACTORS FOR PROLYTE TRUSSES

All design-tested Prolyte trusses are calculated by experienced engineers.

Since Prolyte cannot foresee the different uses of trusses, the calculation of the allowable loads includes the same safety factors used in engineering as, e.g. when calculating steel supporting structures.

These safety factors are 1.7 for plastic deformation and 2.5 for a failure of the trusses, in relation to the maximum allowable values given in the loading tables.

WARNING: PROLYTE would like to advise customers expressly that it is ILLEGAL to exceed the allowable loads for the trusses.

Many times customers are unsure or confused about the need to use higher safety factors (10 or 12) for events technology. These higher safety factors, which are required by accident insurers, for example, come into effect when technical equipment is used to transport persons or for holding and moving loads over persons.

The origin for this is the EC Machinery Directive; however, this “only” requires doubling the safety factor by the manufacturer.

However, if this technical equipment has been officially tested (e.g. design test) for the purpose

of the application (e.g. for holding loads over persons) the tested loading values can be applied. Further details can be found in the test reports of the test centres.

If national or regional regulations, guidelines or laws place higher demands on technical equipment, these should always be followed.

Users/technicians are called on to remain up to date with the current versions of all regulations, guidelines, laws and standards.

9. LOADING TABLES

The load values apply for a single span without cantilevers when subject to a UDL (uniformly distributed load), a CPL (centre point load) or several equal point loads at regular distances from each other and to the supports.

The loading tables apply for spans which are composed of any lengths of truss types.

1. Length of the truss span in metres.
2. Length of the truss span in feet.
3. Allowable uniformly distributed load (UDL) in kg/m.
4. Allowable uniformly distributed load (UDL) in lbs/ft.
5. Deflection in millimetres under UDL.
6. Deflection in inches under UDL.
7. Allowable centre point load in kg (a point load that divides the span in 2 equal sections).
8. Allowable centre point load in lb (a point load that divides the span in 2 equal sections).
9. Deflection in millimetres under CPL.
10. Deflection in inches under CPL.
11. Allowable third point loads (TPL) in kg (two equal point loads that divide the span in 3 equal sections).
12. Allowable third point loads (TPL) in lbs (two equal point loads that divide the span in 3 equal sections).
13. Allowable quarter point loads (QPL) in kg (three equal point loads that divide the span in 4 equal sections).
14. Allowable quarter point loads (QPL) in lbs (three equal point loads that divide the span in 4 equal sections).
15. Allowable fifth point loads (FPL) in kg (four equal point loads that divide the span in 5 equal sections).
16. Allowable fifth point loads (FPL) in lbs (four equal point loads that divide the span in 5 equal sections).

PROLYTE H30V - ALLOWABLE LOADING															
SPAN		UNIFORMLY DISTRIBUTED LOAD		DEFLECTION		MAXIMUM ALLOWABLE POINT LOADS									
						CENTRE POINT LOAD		DEFLECTION		SINGLE LOAD THIRD POINTS		SINGLE LOAD FOURTH POINTS		SINGLE LOAD FIFTH POINTS	
m	ft	kg/m	lbs/ft	mm	inch	kg	lbs	mm	inch	kg	lbs	kg	lbs	kg	lbs
1	3,3	1984,1	1335,0	1	0,04	1984,1	4378,9	1	0,04	992,1	2189,5	660,3	1457,3	496,0	1094,7
2	6,6	988,9	665,4	4	0,16	1977,8	4365,0	3	0,12	988,9	2182,5	657,2	1450,4	494,5	1091,3
3	9,8	657,2	442,2	9	0,35	1936,7	4274,4	7	0,28	985,8	2175,6	654,0	1443,4	492,9	1087,8
4	13,1	491,3	330,6	17	0,67	1447,0	3193,6	13	0,51	982,6	2168,6	650,9	1436,5	491,3	1084,3
5	16,4	391,8	263,6	26	1,02	1152,0	2542,4	21	0,83	864,0	1906,8	576,0	1271,2	478,1	1055,1
6	19,7	318,1	214,0	37	1,46	954,2	2105,9	30	1,18	715,6	1579,4	477,1	1052,9	396,0	873,9
8	26,2	176,2	118,5	66	2,60	704,6	1553,1	53	2,09	526,5	1166,3	352,3	773,5	272,4	603,4
9	29,5	137,9	92,8	84	3,31	620,4	1369,2	67	2,64	465,3	1026,9	310,2	684,6	257,5	568,2
10	32,8	110,5	74,3	104	4,09	552,4	1219,0	83	3,27	414,3	914,3	276,2	609,5	229,2	505,9
11	36,1	90,2	60,7	125	4,92	496,1	1095,0	100	3,94	372,1	821,2	248,1	547,5	205,9	454,4
12	39,4	74,8	50,3	149	5,87	448,7	990,4	119	4,69	336,6	742,8	224,4	495,2	186,2	411,0
13	42,6	62,8	42,3	175	6,89	408,2	900,8	140	5,51	306,1	675,6	204,1	450,4	169,4	373,8
14	45,9	53,3	35,8	203	7,99	372,9	823,1	163	6,42	297,7	617,3	186,5	411,5	154,8	341,6
15	49,2	45,6	30,7	233	9,17	342,0	754,8	187	7,36	256,5	566,1	171,0	377,4	141,9	313,2
16	52,5	39,3	26,5	265	10,43	314,5	694,1	212	8,35	235,9	520,6	157,3	347,1	130,5	288,1

1 inch = 25.4 mm | 1m = 3.28 ft | 1 lbs = 0.453 kg



Photo: Impact Event, UK

10. STANDARDS

10.1 FOR TRUSSES AND HOISTING DEVICES

From national standards to Euro codes

One of the positive effects of the European Union is the gradual transfer of national regulations into the European system of an “integrated regulatory code/legislature”.

We can see the start of harmonised European standards (EN) and Euro Codes that will supersede the various national standards in the near future. This is the only means of avoiding differences when using machines as elements in event technology. Hoisting devices and accessories will be given technical specifications and will be classified by law. Unfortunately this process is only just beginning and will take some years to complete.

Trusses have a strange position from a regulatory perspective, although they are a basic component for many different applications.

For permanent installations such as shop installations attached to the ceiling or discotheque installations, normal design specifications should be used to determine the bearing capability and safety. Trusses must comply with the Directive on Construction Products (89/396/EWG) for such uses.

For temporary structures such as ground support or roof systems as used for concerts or in exhibition stand construction, other stricter regulations apply.

It should be evident that structures for hoisting guided loads (e.g. tower ground support) or free suspended loads (e.g. rigging tower) must be used in accordance with the directives and regulations for hoisting gear or load bearing installations.

European Directives that describe the use of lifting equipment.

- 1) The Machinery Directive (98/37/EG, formerly 89/392/EG, in future 2006/42/EG) has been transformed into national law in many countries. Describes the minimum safety requirements which apply to the design and production of machinery, including machinery lifting equipment.
- 2) The Health & Safety Directives for Employees in the Workplace (89/391/EEC) regulates the duties of employers as the parties responsible for the health and safety of employees at work.
- 3) The Directive on Work Equipment (89/655/EEC) defines the minimum requirements for health and safety when work equipment is used by employees at work. The employer must ensure that work equipment (including machinery) does not represent a danger for health and safety for employees in the workplace when it is used. This includes hoisting equipment which was not originally planned to be used for lifting loads over persons.

Future developments

Legislation and standardisation for event technology are in the process of development. This special segment can now be regarded as an independent field of work. Similar to the integration of the safety of machinery into legislation, the legislation for lifting loads over persons is slowly being harmonised.

The Machinery Directive forbids persons being under loads as a matter of principle and merely deals with lifting persons.

In many EU Member States, lifting loads over persons was equated with lifting persons.

This in order to be able to, at least, tolerate so-called stage depictions from a legal point of view.

Trends in regulations and directives for theatre and events technology agree on one point: If loads are lifted over persons using conventional hoisting gear (consistent with the Machinery Directive), the safety factor must be doubled at the very least. This tendency can be found in the directives and industrial standards of many EU Member States and in some drafts in the USA. In future this trend – at least within the EU – will lead to a series of “European Event Directives” with comparable standards for all EU Member States. A first step in this direction is the “CEN Workshop Agreement 25” or “CWA 25”. An association of manufacturers, bodies and interested users acting under the aegis of the European Committee for Standardisation (CEN) that elaborates guidelines which enjoy the status of recognised written cross-border technical regulations.

A similar development is expected worldwide, although not all countries are interested in participating in these principles.

It should be emphasised that users should familiarise themselves with local, regional or national regulations, directives, ordinances or laws that deal with safety when operating hoisting devices. If no such regulations exist in a particular country, Prolyte strongly advises to apply the principle of the “double safety factor” since this is now regarded as the most important part of “best practice”.

Each hoisting device, lifting accessory or load bearing element should only be loaded with half of the load bearing capacity given if persons have to be under the lifted load “for operational reasons”.

For trusses – insofar as they are a component part of a load hoisting installation – this means that they should only be loaded with half of the allowable loads given in the loading tables. Only work equipment which is intended for lifting loads over persons and has been tested for this purpose can be subjected to the full load according to the values given by the manufacturer (identification/operating instructions). In this case the manufacturer shares the responsibility if the equipment fails under normal operating conditions.

Even if the 50% reduction in normal load bearing installations seems drastic, this can often be achieved easily by increasing the number of supports for large truss spans or the selection of a truss with a greater load bearing capacity.

Responsible technicians that show awareness of safety and quality standards will find no difficulty in complying with these standards.

Safety first

It is time to realise that economic arguments can never outweigh the safety of employees or the public. There are various institutions and organisations for quality control and certification. They all base their work on the standards of their respective countries. In Europe the German TÜV is generally recognised as the leading certification authority; other well-known institutes include Lloyds (Great Britain), DNV (Norway) and Bureau Veritas (France). In Europe there is a number of “Recognised Institutions” that are legally recognised and can certify work equipment covered by the European Directive. Even if trusses for event technology are not dealt with in any European Directive, trusses used above persons must comply with the Directive for Work Equipment (89/655/EEC) and therefore require a risk analysis for this specific use.

10.2 REGULATIONS FOR MANUFACTURING TRUSSES

Manufacturing of trusses made of aluminium is subject to the following standards and norms:

- Aluminium alloys, DIN EN 573, designation, chemical composition, physical properties such as tensile strength, hardening properties.
- Welding aluminium, DIN EN 288-4.
- Aluminium structures, DIN 4113, BS 7906, BS 8118.

Prolyte manufactures aluminium trusses for event technology according to the following aspects:

Materials

The materials processed by Prolyte undergo a rigorous quality assurance by the suppliers. In particular aluminium materials are alike in appearance, but may have serious quality differences. Users should always ask what materials were used by a manufacturer; good product information documents should contain this information. Prolyte uses aluminium tubes made of the material EN AW-6082 T6 (AlMgSi1 F31). The significant properties of this alloy used for trusses are around 10% above those for the material EN AW-6061 which is used primarily in the USA. The materials used by Prolyte always have factory certification 3.1b in accordance with EN 10204. This certificate confirms that the chemical composition and mechanical properties lie within the prescribed tolerances.

Welding procedure

It is not easy to judge a welding seam by its appearance. Prolyte guarantees that welding is performed in strict compliance with the provisions of ISO 3834 and DIN 4113-3. This requires employing a qualified welding technician or a welding engineer.

Furthermore all welders are qualified pursuant to ISO 9606-2. The welding procedure used conforms to ISO 15614-2.

Quality assurance

Prolyte guarantees the quality of its products with a quality assurance procedure that was developed in accordance with ISO 3834. This standard describes all steps for the manufacturing process that have an impact on the end product.

Product certification

All mass produced Prolyte trusses are “design-tested” by RWTÜV. Prolyte tower systems are CE labelled and all Prolyte constructions can be delivered with verifiable static calculations.

10.3 REGULATIONS FOR ASSEMBLING TRUSSES

Assembling trusses in events technology is differentiated according to the location where they are used:

1. Assembling trusses outdoors

If structures made of trusses are assembled outdoors, they are considered to be structural works and hence are subject to building laws and the corresponding building regulations. General building regulations assume such structures are permanent as a matter of principle – and hence general environmental influences such as, e.g., storms, snows and frost – but as truss structures for event technology are generally temporary structures, special standards and regulations exist to cover this. Structures with the same design which are intended to be assembled and dismantled in different locations are considered to be “temporary demountable structures”.

Their design and construction are regulated in DIN 4112 – „Temporary demountable structures“. The building laws have regulations that contain a paragraph on “Approving temporary demountable structures” where the requirement for approval of a construction (Structural Specifications) is defined. Finally the “Sample directives for the construction and operation of temporary demountable structures” define the requirements for a moveable structure such as marking emergency exits, construction material classes of the materials used and compliance with safety regulations. A particularly complicated field with regard to trusses in temporary demountable structures is the almost universal interchangeability of individual truss elements of one construction. Classic temporary demountable structures are fairground rides where individual structure elements have a specified position in the structure and therefore have to be tested regularly by assessors; however, for trusses there is currently no such requirement to have them checked by assessors. Manufacturers, users and insurers in the events industry should answer openly and honestly all questions about responsibility, reliability and safety.

2. Assembling trusses in buildings

If truss structures are erected in buildings, they are not considered to be structural works – as long as they are not connected permanently with the building – but as installations; they are therefore not directly subject to the requirements of building laws. However, they do require proof of load-bearing capacity and stability and are subject to the requirements of compulsory accident insurance companies. The proof of load-bearing capacity for suspended truss installations can be provided by experienced assessors using recognised loading values for simple static systems.

Complex suspended structures or temporary demountable structures, structures generally require inspection by an assessor who can demonstrate that they are able to carry out a verifiable static calculation. However, complex structures or particularly high, slender supports must be inspected by a structural engineer.

Further current standards and directives of other EU Member States are “Temporary demountable structures” and BS 7906 – “Code of practise for use of aluminium and steel trusses and towers” from Great Britain.

10.4 STAGE PLATFORMS

EN 13814 is the EU standard for platforms. Still most other countries have to apply the local building codes.

In most cases the uniform loading capacity and a deflection limit of L/200 are prescribed as material design criteria for platforms, while possible point loads on the platforms are completely ignored. Existing building codes require a point load of 7 kN (around 700 kg) on an area 5cm x 5cm. If this requirement is compared with the technical data of birch plywood, the minimum board size is 35mm. The span or size of the board is not the deciding factor, but the point load pressing in on the board material.

German, EU and British standards give guidelines for horizontal forces. These are caused by movements on platforms (e.g. by dancers or stage machines) and additional loads created by railings.

EN 13814 requires a horizontal load bearing capacity for stages of 10% of the allowable

vertical loads; the British standards classify horizontal load-bearing capacity in three classes between 5% and 10%. For synchronous (rhythmic) movements the requirement is also 10%.

From that follows the requirements for legs, where, for a standard platform of 2 m x 1 m with an allowable vertical load of 750 kg/m² (that is 1500 kg uniformly distributed load) each of the four legs must be able to bear a horizontal load of 37.5 kg (10% of 1500 kg = 150 kg / 4 = 37.5 kg).

When using circular tubes as legs with 100 cm length, tubes with at least 48.3 mm x 4 mm of the alloy EN AW-6082 T6 should be used.

If platforms are connected to each other to create a stage area, the allowable load bearing capacity could be reduced if the full number of legs is not used.

Prolyte would like to explain this clearly and therefore has published tables with loading data depending on the length and material of the legs.

With regard to the requirements for railings, Germany differentiates between: Railings in public places (DIN 1055-3 and DIN 4112): This includes railings for freely accessible stages and stands that must be able to withstand a load of 100 kg/m at 100 cm height.

Stage railings (DIN 15920-11): These are used to prevent falls on areas that may only be used by authorised persons and must be able to withstand a load of 30 kg/m at 100 cm height.

10.5 STAGES

Principles relating to the use of legs for stages

As in the case of trusses, Prolyte also provides information on the load a stage element can support, based on the fact that a stage must be able to withstand 10% lateral force (F_h).

The 10% lateral force is derived from European regulations relating to grand stands and stages which have general public access.

The horizontal force which a stage element can absorb depends on the following points:

- Diameter and wall thickness of the leg.
- The leg alloy.
- The leg length.
- The leg connection.

The values stated by Prolyte for load of the Dex versus the height and the leg used are limited by the leg connection. This directly implies that the use of fewer legs means either that the load is less or that the permissible horizontal force F_h of 10% has to be adjusted downwards.

Load reduction example:

If a 100m² stage normally has 200 legs, (4 per 2m² (picture B)), this will change to 77 in the case of a 'hang-on' system (picture A).

The load can then be multiplied by a factor of 77/200 = 0.35.

If the load used to be 750kg/m², this will then become 262.5kg/m².



Photo: PERINIC SISTEMI D.O.O., Croatia

Picture A

4	2	2	2	2	2	2	2	2	2
2	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1

"stage 10x10 m. based on hang-on leg system"

Respectively 4, 2 or 1 leg per stage element

Picture B

4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4

"stage 10x10 m. based on 4 legs per stage"

Railing for Stages

Whether a railing has to be fitted or not to stages is the subject of much discussion. The load that a stage railing has to be able to withstand depends on the use. A distinction has to be made as to whether or not the stage is open to the public. In the case of most pop music stages, a railing that can withstand 30kg/m¹ ought to be sufficient. A railing such as this is a clear indication of where the stage ends.

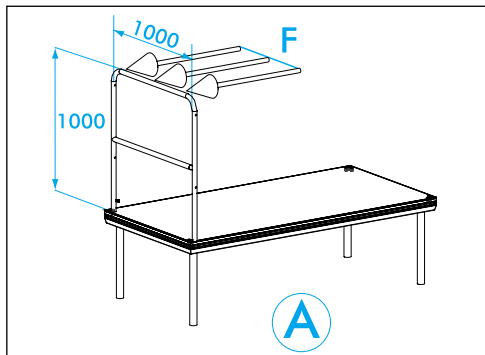
By contrast, very different requirements apply as regards the load to a stage or stand on which large numbers of people can congregate. The load requirement may be as much as 300kg/m¹.

Such loads cannot be accommodated by existing stage floors, or only with considerable trouble and effort. In particular, the dispersal of the forces is a worry. The connection between railing, stage and sub-construction has to fulfil stringent requirements. This is almost impossible to achieve in the daily practice of stage building. The German regulations, as referred to in DIN 4112, are more practical and realistic. Here, too, it would be sensible to make a distinction between temporary and permanent constructions.

The table below is based on existing EN /DIN standards and shows the values and dimensions to which the vertical railing posts have to comply. These values apply to Steel S235JR.

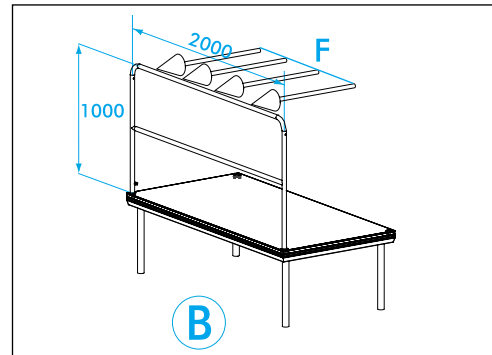
NECESSARY RAILING MATERIAL					
RAILING TYPE A					
Load F	Necessary Moment of resistance	Tube	Moment of resistance chosen profile	square tube	Moment of resistance chosen profile
kN/m	cm ³	mm	cm ³	mm	cm ³
0,15	0,52	33,7x2,5	1,78	30x2,5	2,1
0,30	1,03	33,7x2,5	1,78	30x2,5	2,1
1,00	3,45	48,3x3	4,55	40x3	4,66
1,50	5,17	48,3x4	5,7	40x4	5,54
2,00	6,90	48,3x4	7,87*	50x3	7,79
3,00	10,34	60,3x4	12,7*	50x5	13,7*

Material Steel S235 JR
items marked * = plastic def. Zone
Connection of railing should be able to bear restraint moment



RAILING HEIGHT 1 METER					
RAILING TYPE B					
Load F	Necessary Moment of resistance	Tube	Moment of resistance chosen profile	square tube	Moment of resistance chosen profile
kN/m	cm ³	mm	cm ³	mm	cm ³
0,15	1,03	33,7x2,5	1,78	30x2,5	2,1
0,30	2,07	33,7x3,2	2,14	30x3	2,34
1,00	6,90	48,3x4	7,87*	50x3	7,79
1,50	10,34	60,3x4	12,7*	50x5	13,7*
2,00	13,79	60,3x5	15,3*	60x4	17,6*
3,00	20,69	76,1x4	20,8*	70x4	24,8*

Material Steel S235 JR
items marked * = plastic def. Zone
Connection of railing should be able to bear restraint moment



10.6 STANDARDS AND REGULATIONS FOR ELECTRICAL HOISTS

Industry versus Entertainment application

Hoists as used in the entertainment industry are almost identical to the original industrial versions. The major difference is the use and the position of the hoist vis-à-vis the load. In an industrial environment, a hoist tends to be permanently suspended in what is referred to as a motor-up position, with the hoist being attached to the roof construction. In an entertainment situation, hoists are generally used in a motor-down position, whereby not the hoist but the lift chain is attached to the roof construction while the hoist stays in the proximity of the load. The advantage of this is that the cabling can be fitted at operating height and that, instead of the heavy motor housing, the relatively lighter chain need to be lifted.

People located under a live load

Another major difference is that, in the entertainment industry, loads are suspended or moved above people's heads. In a lot of countries this is only permitted if additional safety measures have been taken. The Machine Directive 98/37/EG (future 2006/42EG (European legislation)) refers to a doubling of the working coefficient when people are lifted. Within the meaning of this directive it can also be asserted that the same applies to lifting above people's heads. However, the same directive excludes theatre elevators.

It is unclear whether this directive also applies to immobile suspended loads above people's heads, a situation that is a regular occurrence in the entertainment industry. The New European Code of Practice CWA 25, as well as existing directives such as EN 14492 / FEM 9756 leave open the possibility of using a 'standard' hoist provided a risk analysis shows this to be justifiable.

The Dutch NPR 8020-10 states that the use of a standard hoist is permitted in this situation provided the working coefficient is doubled, such in accordance with the machine directive. In such cases, a 1,000-kg hoist can only be used for 500 kg. In Germany, a hoist known as a BGV D8+ has to be used in such situations. Besides having a double working coefficient, this hoist also has a double braking system but has no slip clutch between the brake and cable wheel.

Lifting loads above people

As regards moving loads above people's heads it may be necessary to use special hoists. In addition to having overload and underload protection, these hoists may have an operating system that checks the mutual position of the hoists and monitors the loads. In the event of any deviation from the set parameters, the system switches off, thereby guaranteeing safe usage. Such a system is often referred to as a BGV-C1. In Germany such systems are governed by the regulations of the BGV [German prevention & insurance association].

The equipment and operating technology used depends very much on the situation during hoisting:

- A load on a single hoist makes different demands on hoisting and controlling than a load lifted by four hoists, certainly if more than one of these loads is controlled by one and the same system.
- If the operator has a clear overview of the load and the immediate environment in which hoisting is to take place, it will always be possible to take action in the event of danger.
- What is the chance of failure and what are the risks for all the components used and their combinations.

Currently, a whole series of standards apply to the operation of machines and systems with a safety function. IEC 62061 applies specifically to machine building. This standard is derived from IEC 61508 and deals with the issue of how a safety system can be produced using combinations of 'simple' software, electronics and electrical components. IEC 62061 (previously EN 954) relates to the specification of the safety level of the specific part of the machine's controls that has a safety function and also assesses the whole range of software, electronics and electrical components. This is expressed as a SIL level.

Simultaneously with IEC 62061, the ISO 13849 standard was created for the mechanical part and components. This standard applies from the mechanical point of view to the reliability of components at component level, instead of to the whole. This standard allows the category and the PL (performance level) of a component to be determined. On contrast to systems, components cannot be categorised into a SIL level.

Double brakes

The use of a double brake is a point that has become open to question. If a hoist generates a doubling in the working coefficient (MR,NPR 8020-10 and D8+), this means that all settings, including those pertaining to the slip clutch and the brake, are increased by a factor of 2 with respect to the operating load. Fitting 2 brakes to one and the same shaft would only be advantageous if one brake were to fail. The question is what would happen if the shaft broke and what would happen if one of the brakes no longer worked. You would not notice any change and yet you would still think you were working safely! The double brakes requirement is derived from the German regulations as drawn up by the BGV and from the theatre standard DIN 56950.

Secondary suspension

What if I do not have a hoist which complies with the above-mentioned standards? Am I obliged to dead hang my load, or do I have to attach a separate suspension device? The lack of specific regulations in the majority of countries means this point is unclear. However, one can state that a chain hoist used to hoist a roofing system must be relieved of the load at all times. In the context of suspending a truss construction, the fitting of a dead hang often entails major risks which are not justified by the increase of the overall safety. The bridging of a chain hoist using a chain clutch is a method which is strongly advised against.

Visual inspection and testing

As is the case with other equipment and machines, the suitability of a hoist must always be assessed before use. This assessment is normally a visual one. If a hoist is used for a long period of time in a hazardous environment, the hoist must be tested (inspected) by a competent person in accordance with the supplier's requirements. Examples of such situations are long-term use outside, use in the rain, use in the vicinity of salt water or use in a sandy environment. Inspections must take place as frequently as is necessary.

Each electrical hoist must be tested at least once a year. The tests and inspections must be performed by a competent person. The person who requests the test/inspection is responsible for making sure that the testing person or company is competent. Therefore in most countries, hoisting and lifting materials, such as those used in the entertainment industry, can be inspected and tested by a 'competent person'. Do not allow yourself to be confused by people who claim that this work has to be done by an 'accredited or notified body'. However, a notified body does generally have to be called in to test and inspect cranes and passenger lifts.

Duty factor

Chain hoists are classified using what is known as a duty factor. The operating time (indicated in percentages of an hour) indicates how long a hoist may be used at a full load.

A 2m classification indicates that a hoist has a 40% operating time with a minimum of 240 starts and stops per hour. This means that a hoist with a hoisting speed of 4 m/min can hoist a maximum distance, with a full load, of $4 \times (60 \times 40\%) = 96$ metres.

IP Explanation and Ratings

EN 60529 outlines an international classification system for the sealing effectiveness of enclosures of electrical equipment against the intrusion into the equipment of foreign bodies (i.e. tools, dust, fingers) and moisture. This classification system utilises the letters 'IP' ('Ingress Protection') followed by two or sometimes three digits. (An 'x' is used for one of the digits if there is only one class of protection; i.e. IPX4 which addresses moisture resistance only).

Degrees of Protection - First Digit

The first digit of the IP code indicates the degree to which equipment is protected against solid foreign bodies intruding into an enclosure.

- 0 No special protection.
- 1 Protection from a large part of the body such as a hand, from solid objects > 50mm in diameter.
- 2 Protection against fingers or other objects not greater than 80mm in length and 12mm in diameter.
- 3 Protection from entry by tools, wires, etc., with a diameter of thickness greater than 1.0mm.
- 4 Protection from entry by solid objects with a diameter or thickness greater than 1.0mm.

- 5 Protection from the amount of dust that would interfere with the operation of the equipment.
- 6 Dust tight.

Degrees of Protection - Second Digit

The second digit indicates the degree of protection of the equipment inside the enclosure against the harmful effects of various forms of moisture (e.g. dripping, spraying, submersion, etc.)

- 0 No special protection.
- 1 Protection from dripping water.
- 2 Protection from vertically dripping water.
- 3 Protection from sprayed water.
- 4 Protection from splashed water.
- 5 Protection from water projected from a nozzle

Hoists are also often used outside, for example at festivals or outdoor events. Prolift hoists comply with protection class IP54. Classification 4 means that a hoist made in accordance with IP54 is not suitable for use in torrential rain! The hoist always has to be protected with a cover when used outside.

WLL versus SWL

Working load limit is the capacity of hoisting equipment or hoisting tools. SWL is the operating load of a system of hoisting equipment and hoisting tools.

Example:

A H30V truss with a 4 metre span is suspended from two 500kg hoists. The WLL of the hoist is therefore 500kg. The H30V truss at a span of 4 metres has a WLL of 1,965kg. The SWL is in this case $2 \times$ the lifting capacity of the hoists = 1,000kg – own weight of the truss = +/- 975kg.

11. SLINGING TRUSSES

11.1 RELEVANCE OF THE METHOD OF SLINGING

A lot can be said about methods of slinging trusses. Prolyte encourages all users of trusses to use the best and safest method of slinging trusses. However, it should also be mentioned that our experience with known truss accidents has shown that the method of slinging plays a subordinate role only.

There are three main reasons for truss structures to fail or for accidents with trusses:

- A** Overloading a truss section; too high pay loads in a truss section, frequently in combination with dynamic load such as:
- B** frequent interruptions of the lifting processes, persons climbing, lifting devices or winches sling to suspended trusses (mother grid),
- C** moving trusses catching or hooked behind building sections, stage superstructures or other rigid obstacles that lead directly to extreme overloading and damage (the operator of hoisting devices must be able to supervise the whole lifting distance of a suspended structure at all times and should not be distracted), overloading of chords between two node points of a truss (large point loads should always be placed in the node points or in the immediate vicinity). See 11.6 and 11.7

The type of slinging is of importance when shear forces and/or in combination with bending moment are the limiting factor for the strength of a truss structure (see 11.6/2).

11.2 SLINGING METHODS

When slinging trusses at first a differentiation must be made between temporary and permanent installations.

For permanent installations mostly rigid attachment devices are used to hold the trusses in positions. Rigid slinging devices may only be used for straight vertical support, diagonal pull is not permissible for lifting brackets and truss clamps. Therefore the use of rigid slinging devices on a truss in a bridle is not permitted.

For temporary installations, such as used for concerts, mostly flexible devices are used, to allow the freely suspended truss to react to horizontal loads. Round slings with a steel wire core or wire rope with a protective sleeve are used in conjunction with shackles.

11.3 SLINGING DEVICES

Round slings

When handling aluminium tubes, soft and non-abrasive slinging devices are needed. Round slings would be the perfect choice. Unfortunately round slings are made of polyester that melts at ca. 250° C. The allowable temperature for round slings in use is 100° C. Most countries have fire protection regulations that prohibit the use of round slings near sources of heat.

Tests have shown at the position of the gel frame of a 1000W PAR 64 can reach a temperature of 260° C, the truss directly above can reach up to 140° C. This must be taken into consideration when slinging trusses with round slings. Accidents have occurred which were definitely caused by melted round slings. If round slings are used, a second non-flammable safety device made of a steel wire or chain must be added.

Round slings with steel wire core (Soft Steel®)

The flexible slinging device Soft Steel differs from conventional round slings with its non-flammable steel wire core. Soft Steel is almost flexible as polyester round slings, but does not require steel wire as a second safety due to its high resistance to heat. The polyester material of Soft Steel is black, the identification label is silver grey and an inspection window covered with a Velcro strap means the steel wire core can be inspected. Soft Steel complies with all CE requirements. For the chord of a truss Soft Steel should be the preferred device over a steel wire since it offers a considerably wider support area.

Steel wires

A further flexible slinging device is a steel wire rope compliant with EN 13414. Direct contact between the steel wire rope and the truss chord should be avoided because of the abrasive surface of the steel wire rope. In this case plastic steel wire should be used. Since this is prohibited in Germany, sliding protective sleeves on the steel wires are used. Since the sleeves can be slid along the steel wire rope, this enables the whole steel wire rope to be inspected.

Apart from protecting against wear, the sleeve also acts as heat insulation. Slinging wires of type N with fibre inlay and aluminium crimp sleeves lose load bearing capacity above a temperature of 100° C, with a steel inlay from 150° C. Slinging wires of type F (Flemish eye) always have a steel inlay and steel crimp sleeves. They lose their nominal bearing capacity above 250° C. Good resistance to heat is always a good thing in slinging devices. However, if they are considerably better than the temperature susceptibility of the truss, their effectiveness reaches a sensitive limit. Aluminium alloys lose tensile strength with increasing temperature.

Above 75° C this is only 95 % of the nominal tensile strength, above 100° C it is 85 %, above 150° C 70 % and at 200° C it is only 50 %. It should be emphasised that in tropical areas with a massive use of conventional flood lamps or in film and TV studios where lamps are used uninterruptedly over long periods, there is a certain potential danger of trusses overheating. Steel wires are difficult to use in view of the preferred slinging methods with slings and sleeves. This reduces the possibilities of finding an optimum slinging method.

Chains

Chains can withstand higher temperatures, but absolutely require a protective sleeve and can only be used with difficulty for the preferred types of slinging. Even if the requirement foresees working temperatures above 200° C, the user must be aware that trusses made of aluminium are no longer sufficiently stable. At such high working temperatures steel trusses should be used. If chains are preferred as slinging method for aluminium trusses, the user will have to provide the arguments in favour, particularly if other slinging devices are as good or even better for most applications.

Lifting Brackets

The final slinging device worthy of mention is a lifting bracket with lifting eyes. These bracket can be produced for most truss series and have a property in common, namely, that horizontal forces between the chords can be ignored and that heat resistance is not of significance. Lifting brackets are made of steel or aluminium, depending on the type of truss. A small disadvantage is that these adapters can not be placed directly in the node points of a truss, but only close by and that mounting them, particularly in the lower chords, is time-consuming.

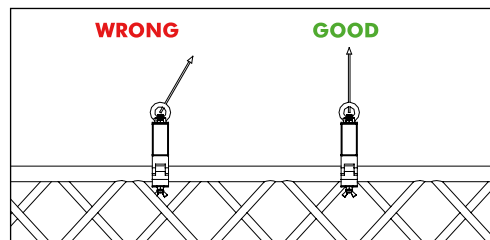
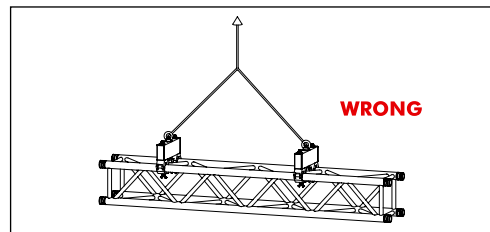
For permanent installations this limitation is irrelevant, therefore lifting brackets are very common. Since the lifting bracket is not fully comparable with standardised slinging methods, they will not be discussed further. Diagonal pull is not permitted when using lifting bracket or pipe clamps.



Lifting Bracket WLL 500kg



Lifting Bracket WLL 1000kg



11.4 SLINGING TRUSSES

All types of slinging worldwide are based on four basic types of slinging are:

1. Direct Hitch
2. Choke Hitch
3. Basket Hitch
4. Multiple legs

The various slinging variants for trusses are always composed of a combination of these four slinging types. The larger the contact area between a slinging device and the truss chord, the better loads can be directed into a truss. If the chord were to rest on a nail, the forces on the contact area would be multiples of the forces if a 50 mm clamp is used with an effective support area of approximately 1/3 of the circumference of the chord. Naturally no one would rest a truss on a nail, but steel wire and chains have a very small support area with direct contact and therefore can easily damage the chords. This should be considered particularly in the case of relatively thin-walled chords of only 2mm or even less.

Tests have shown that even fibre-reinforced nylon sleeves 3 mm thick used as a protective covering for steel wires with a diameter of 10 mm have a limit to their use. Support loads of around 1800kg (i.e. 900 kg per chord) lead to complete destruction of the nylon layer between steel wire and chord, only the reinforcing fibres remain. The protection from damaging the aluminium tube by the steel wire is lost. If steel wires with a protective sleeve are used to hitch trusses, they must be checked systematically.

A further possibility to protect the chords is to use slotted plastic pipes placed over the chords in the required pick-up point. This protection measure can be made quite easily with commercially available waste pipes with a section cut out. In this case "naked" steel wire can be used

because regular replacement of such a cheap means of protection cannot be problematic to anyone with a healthy respect for safety.

Chains are used fairly seldom to sling trusses since they are relatively expensive and using protective sleeves for chains to protect the chords makes slinging the truss very difficult. Basically the type of slinging should compensate primarily for the shear forces in the vertical of the truss. The method of slinging has considerably less influence, if any, on the safety of a free truss span in relation to the bending moment. Care must be taken with the type of slinging on the inner supports for multi-span trusses, where the tension and compression forces reverse in the chords. Here the truss must be attached in the nodes.

1. Direct hitch (DH)

This type of slinging is only used in conjunction with lifting brackets or when pick-up points are already present. Flexible slinging devices (round slings, steel wire or chain) are connected with a hook or a shackle.

2. Choke hitch (CH)

This type of slinging should only be used with two identical flexible slinging devices at one attachment point. One flexible slinging device holds one side of the truss cross-section. The slinging devices are tied around a lower chord and wrapped around an upper chord before they are connected to each other using a shackle or hook. Steel wires and chains are unsuitable for this method. It should be noted that this type of slinging reduces the load-bearing capacity of the individual slinging devices by the sling factor of 0.8 and the angle between the ends of the slinging devices means an additional reduction in the load-bearing capacity of 30% to 50%. This should be reflected in the loading tables provided by the manufacturers of flexible slinging devices.

3. Basket hitch (BH)

For this type of slinging the slinging device is fed underneath the truss and wrapped once around the lower chord or is passed upwards at each end of the truss and wrapped once around the upper chord before the ends are connected using a hook or shackle. The load-bearing capacity of the slinging devices is improved by the sling factor 1.4 – 2, depending on the angle between the sling ends.

The angle may not be greater than 120°.

Care should be taken that the slinging device is used close to a horizontal brace so that this can absorb the compression forces between the upper chords.

4. Multiple legs

As with basket hitches the top angle of a multiple leg (bridle) should not exceed a certain angle. The reasons for this is that load capacity of the sling will drop and horizontal forces in the construction lifted might increase to unwanted high levels. Reference to capacity should be taken from product labels on which reduction factors and allowable angles should be mentioned.

Slinging a truss – independent of the design – on only one chord is not advised, except when no load is exerted and the application is for purely decorative purposes.

Wrapping main chords

This method is basically used in connection with the choke or basket hitch and primarily to include the upper chord of a truss. Furthermore it is used for horizontal stabilisation of a truss. The load-bearing capacity of the slinging device is not reduced if the wraps are performed cleanly. Prolyte always advises using choked hitch with two identical flexible slinging devices. All truss chords should be included in the hitch.

11.5 COMMONLY USED SLINGING METHODS

Triangular truss apex up 1 sling wrap



Triangular truss apex up 2 sling choke



Prolyte points out that using 2 similar slinging devices for each suspension point is advised due to redundancy. All main chords should be supported.

Slings of truss may only be applied in - or close to - the node-points.

Triangular truss apex down 1 sling wrap



Triangular truss apex down 2 sling choke



Triangular truss apex down 1 sling wrap



Triangular truss apex down 1 sling basket



Rectangular truss 2 sling choke upper chords



Rectangular truss 2 sling choke lower chords



Rectangular truss 1 sling basket



Rectangular truss 1 sling wrap upper chords



Rectangular truss 1 sling wrap lower chords



Rectangular truss 1 sling open wrap lower chords/extra wrap upper chords



Rectangular truss 1 sling extra wrap upper and lower chords inside



Rectangular truss 1 sling extra wrap upper and lower chords outside



Rectangular truss 2 sling choke extra wrap upper chords inside



Rectangular truss 2 sling choke extra wrap upper chords outside



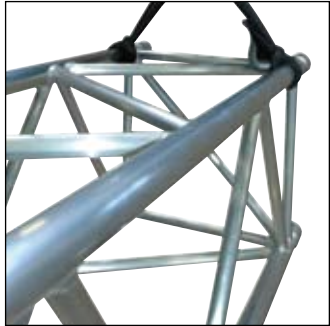
Folding truss 2 sling choke lower chords



Folding truss 1 sling basket on upper chords



Rectangular truss 2 sling choke upper chords



Rectangular truss 2 sling choke lower chords



Rectangular truss 1 sling wrap lower/upper chords



Folding truss 2 sling choke lower chords extra wrap upper chords



Folding truss 1 sling basket on upper chords



Rectangular truss 2 sling choke lower extra wrap upper chords



Rectangular truss 2 sling choke lower chords



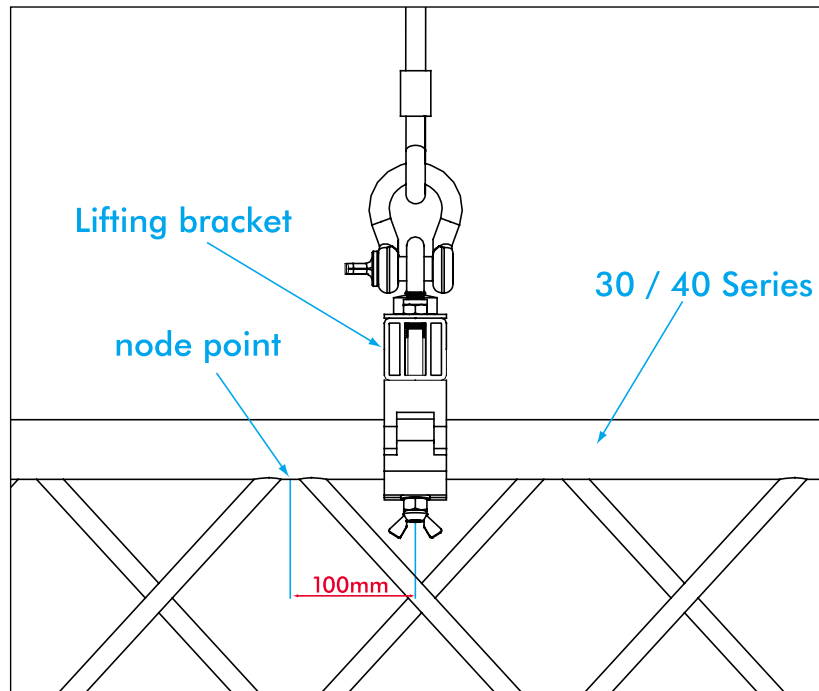
11.6 HANGING TRUSSES FROM LIFTING BRACKETS / GIZMOS

When using lifting brackets it is often not possible to attach these where the diagonals intersect. This can lead to a reduction in the load-bearing capacity of the truss, depending on the position of the suspension points and the number of suspension points per span.

If the truss is not supported in the node point but at the main chord, this chord will be subject to additional forces (bending moment).

1. Truss supported at each end of the span, max. 10cm outside the node point

At the end of the truss the bending moment is almost zero. This means that the main chord is not subject to normal forces. The only load is caused by the lifting bracket.



Resulting load-bearing capacity:

If the lifting bracket is attached 10cm from the node, trusses may be subjected to the following loads:

- Prolyte X30, H30, X40 and H40 series 100% of their load-bearing capacity.
- Prolyte S-series max. 2000 kg per support point.

2. Multiple supported trusses

If a truss is suspended at more than 2 points, the suspension points in between have to be attached into the node points. If this is not done, the truss may not be loaded to 100% of its load-bearing capacity. Slings to all main chords does nothing to change this. The correct load can only be determined by studying each load case individually.

Support points at multiple supported trusses, 2 forces need to be considered:

- a) Because of the own weight and payload on the both sides of the support, the truss is subject to bending moments. This results in compression of the bottom chord and tension in the top chords.
- b) An additional bending moment in the main chord occurs because of the miss nodding of the lifting bracket. An interaction of both forces means that the permissible load-bearing capacity of the support point can only be determined on a case-by-case basis. In general the load should be substantially reduced.

Loading the outer sections of the truss span to the maximum means there are hardly any reserves for the support points. In a worst case scenario, the support point can be loaded with only 100kg. (See max. allowable point load for free chords at the bottom of each truss loading table in the brochures).

11.7 LOADS AT FREE CHORDS IN BETWEEN TWO NODE POINTS

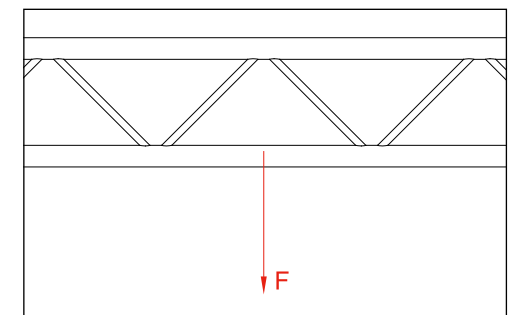
The load capacity of a free chord span is affected by :

- Length of span.
- Size of tube.
- Size of the HAZ at node points at both tube ends (For these reasons the CPL on a free tube in H30D truss is bigger as for H30V).

The loads given are calculated in such way that it does not matter whether;

- They apply to top or bottom chords.
- Loads are suspended at adjacent fields.
- The sum of all point loads may not exceed the maximum allowable bending moment of the truss. In case of having just one point load to be suspended at a free chord length, the load might be higher however this should be checked by a Engineer.

X30D	=	120 kg
X30V	=	90 kg
H30D	=	130 kg
H30V	=	100 kg
H40D	=	90 kg
H40V	=	60 kg
S36R/V	=	150 kg
S52 V/SV	=	80 kg
S66R/RV	=	70 kg
B100RV	=	140 kg



12. PRACTICAL TIPS FOR PROLYTE TRUSSES

12.1 DIMENSIONS FOR COMBINATIONS OF SLEEVE BLOCKS AND CORNER ELEMENTS

This diagram shows the length of a centre truss using standard T-corners (H40V-C017) in an MPT-tower system with CCS6-602 connections:

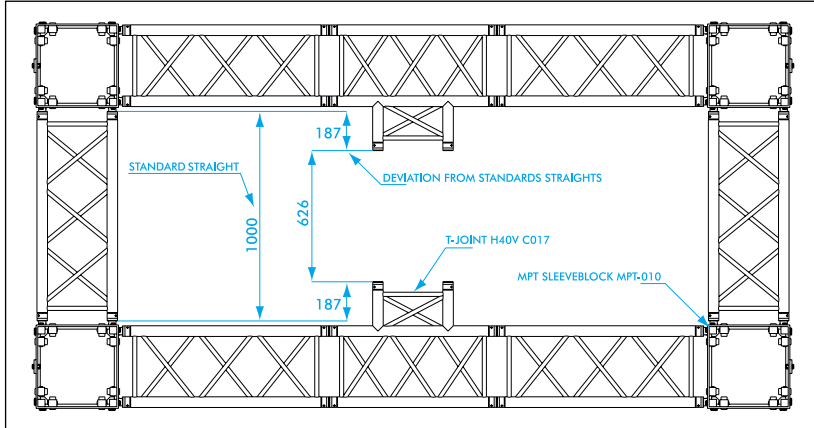


Image: H40V-C017 with MPT sleeve blocks

The length of the straight pieces between two T-corners H40V-C017 is $2 \times 187 \text{ mm} = 374 \text{ mm}$ less than the length used between the sleeve blocks.

This diagram shows the length of a centre truss using box corners (BOX40V + CCS6-651) in an MPT-tower system with CCS6-602 connections:

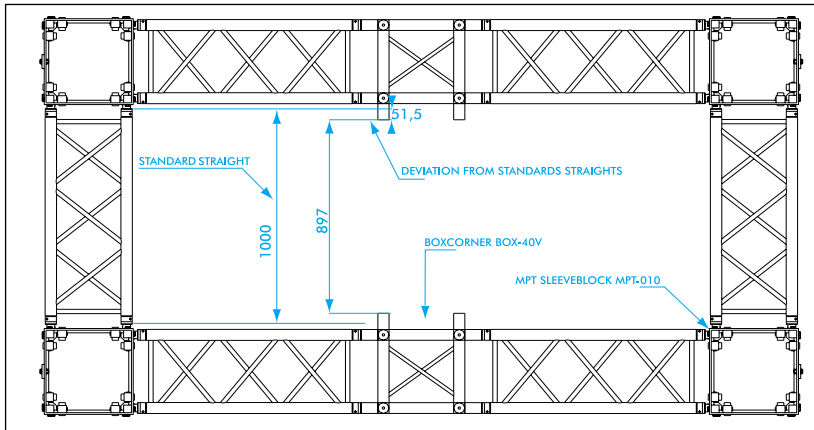


Image: BOX40V with MPT sleeve blocks

The length of the straight pieces between two T-boxcorners H40V-C017 is $2 \times 51.5 \text{ mm} = 103 \text{ mm}$ less than the length used between the sleeve blocks.

This diagram shows the length of a centre truss using standard T-corners (H40V-C017) in an MPT-tower system with CCS6-602 connections:

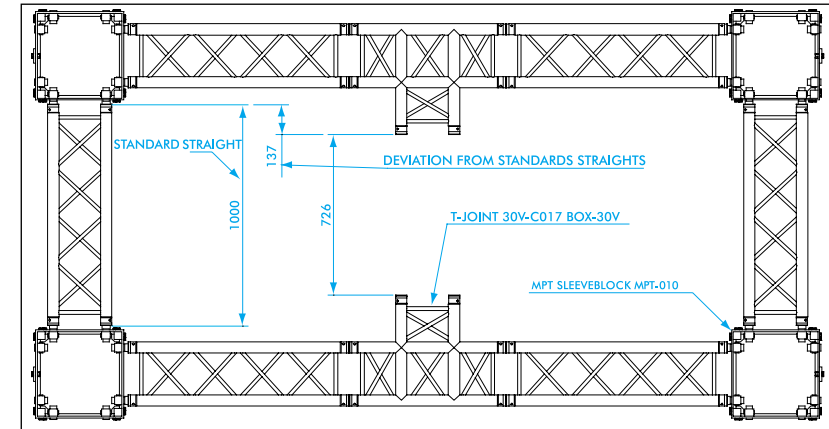


Image: H30VC017 with MPT sleeve blocks

The length of the straight pieces between two T-corners H40V-C017 is $2 \times 137 \text{ mm} = 274 \text{ mm}$ less than the length used between the sleeve blocks.

This image shows the length of a centre truss using box corners (BOX30V + CCS6-651) in an MPT-tower system with CCS6-602 connections:

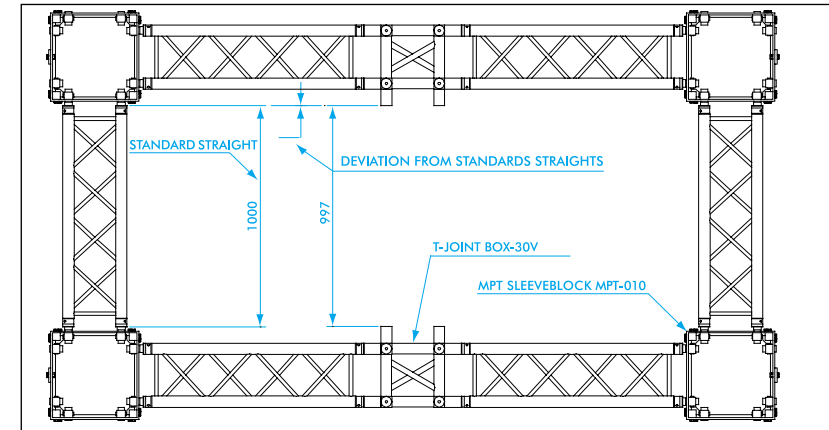


Image: BOX30V with MPT sleeve blocks

The length of the straight pieces between two T-boxcorners (BOX30V + CCS6-651) is $2 \times 1.5 \text{ mm} = 3 \text{ mm}$ less than the length used between the sleeve blocks. Prolyte can deliver special lengths or spacers.

12.2 HINGES OR HINGE ELEMENTS

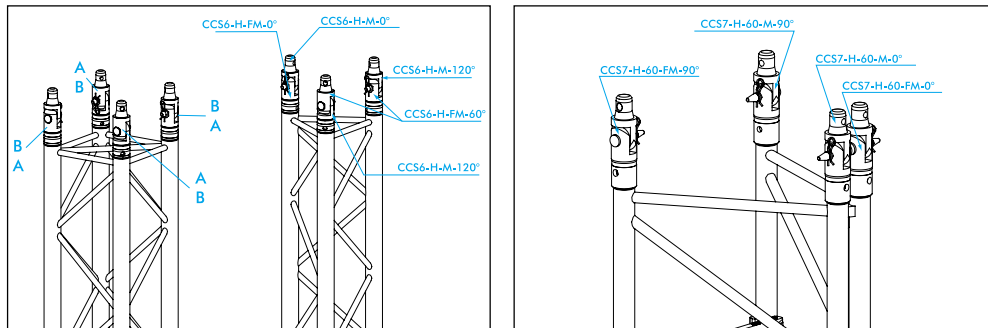
Hinges are primarily used in tower systems, but also and increasingly in special structures. Below we explain the hinge types for three and four chord trusses of the X/H series as well as for trusses of the S/B series.

The hinge most commonly used is CCS6-H. It is used in all MPT and ST tower systems as well as the rigging tower RT-H30V. CCS6-H is a single hinge set and is composed of a fork hinge CCS6-H-FM-45° (A) and a pin hinge CCS6-H-M-135° (B) together with a locking pin ACC-LP016 and safety pin CCS7-705.

The degrees show the angle of the conical drillhole in the direction of the hinge. The hinge always lies at right angles to the hinge axis. Older CCS6-H hinges are not identified, new CCS6-H hinges are engraved with their degree values.

Hinges for trusses of the S/B series are only given in individual pieces. A complete "set" for a four-chord truss of the S/B series consists of the hinge pin CCS7-H-60-M-0° and CCS7-H-60-M-90° and the hinge forks CCS7-H-60-FM-0° and CCS7-H-60-FM-90° as well as the locking pins ACC-LP20/60 and safety pin CCS7-705.

A = CCS6-H-FM-45°
B = CCS6-H-M-135°

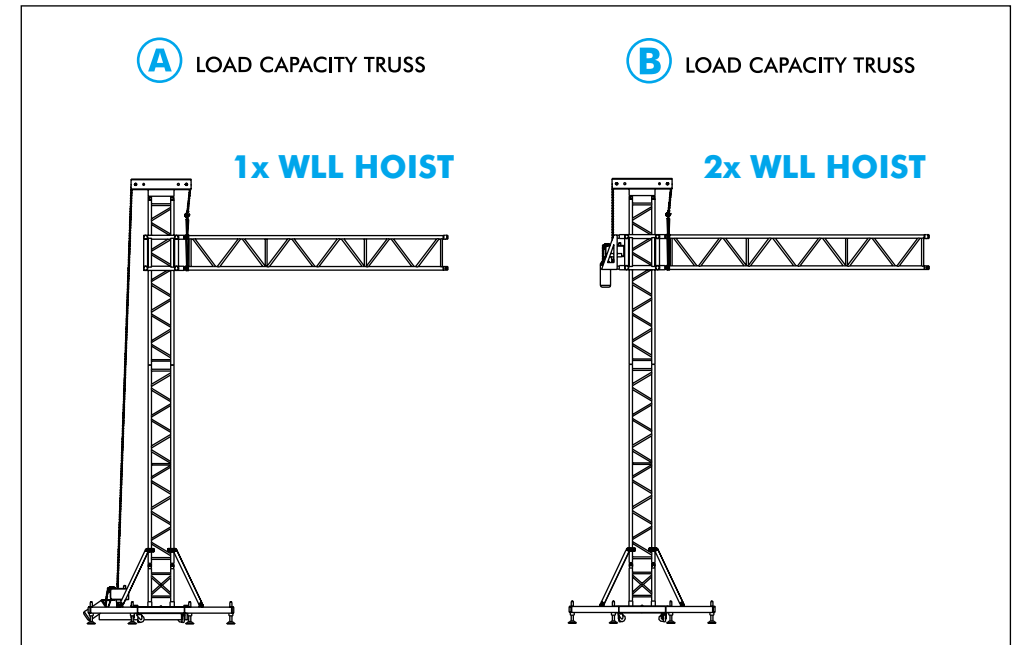


12.3 USING HOISTS IN A GROUND SUPPORT SYSTEM

A ground support is lifting device which can lift a guided load to a desired height using hoist. In a number of countries a distinction is made between lifting a free load and lifting guided loads. In the case of a guided load, and therefore also in the case of a ground support, one has to take account of the friction caused by the guide. This friction depends on the type of wheels and the sagging of the span between the sleeve blocks. A general rule of thumb is that, if a load is lifted using more than two hoists, the hoists may be used to a maximum of 75% of their capacity. Prolyte advises that this rule be observed in the case of ground support systems.

Attaching hoists in a ground-support system
Two methods can be used to attach hoists in a ground-support system:

- A** The hoist is fixed to the base and the hoist hook to the truss. The operating load of the truss will then be equal to the hoisting load of the hoist. However, part of the self weight of the trusses and sleeve blocks does have to be deducted.
- B** The hoist is attached to the truss and the hoist hook to the sleeve block. This doubles the lifting capacity but halves the lifting speed. Here too, the self weight of the truss construction has to be deducted from the lifting capacity in order to determine the SWL of the construction.



It is very important that the hoist hook and lift hook run in line with the direction of forces.

It is not permitted to have the lift chain run with a fleet angle into the chain hoist nor to attach the load hook at an angle, for example to the sleeve block, because this will exert a side load on the hoist housing.



12.4 ELECTRICAL POTENTIAL EQUALISATION FOR TRUSS SYSTEMS

The user needs to ensure that truss systems that might develop dangerous touch voltages in the event of an electrical fault are incorporated into a common potential equalisation system.

This applies to all elements made of electro-conductive material which have equipment placed on, or attached to, them or across which wires and cables run that, in the event of damage, could make electrical contact with metal parts. The connections can be made with clips, pipe clamps, screw joints or special single-pole locking connectors.

The common potential equalisation system must be connected to the earth wire of the electrical power supply system. For cable lengths of up to 50 metres, 16 mm² Cu is considered the standard value for an adequate cross-section. For cable lengths of up to 100 metres, the standard value is 25 mm² Cu.

In truss-tower systems, the potential equalisation connection can be made by means of a potential equalisation connection point provided by the manufacturer at the tower base. Since the wheels or rollers used in tower systems with 'sleeve blocks' insulate the movable part of the truss construction, the latter must be provided with a separate potential equalisation connection.

Protection against lightning strike Electrical installations in temporary structures should be adequately earthed in accordance with normal standards. Consideration should be given to the degree of exposure and likely risk of strike by lightning and, where appropriate, the structure itself should be adequately bonded or earthed. Advice on earthing and lightning protection should be sought from an electrical engineer. In ground-supported constructions the main grid is quite often isolated from the towers because of the use of plastic or rubber castors in sleeve blocks. Thus the main grid needs to be earthed separately.

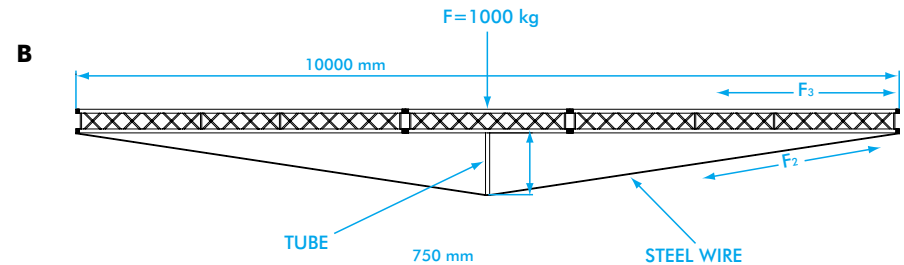
12.5 PRE-TENSIONING OF TRUSSES

In the case of some applications it is not desirable for a truss to sag. Examples are a projection screen that has to hang perfectly flat. There are various ways of minimising truss span sagging or even reducing it to nil.

- A** Select a truss with a larger construction height. If a truss is constructed using the same materials but with a larger construction height, the moment of inertia will be greater and the same load will cause the truss to sag less.
- B** Support the truss, for example, by attaching a steel cable to the end of the truss span and passing it via a turnbuckle attached underneath the truss in the middle. The steel cable will then absorb all tension forces.

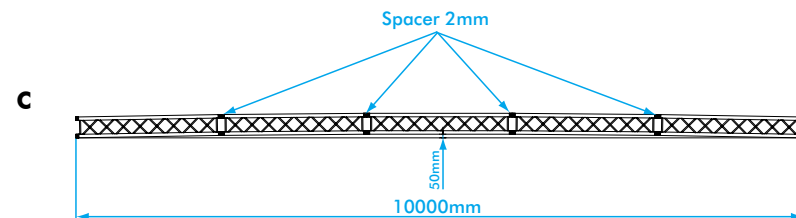
The truss is loaded to pressure. This method can be used to increase the load limit of the span. However, the steel cable attachment points will generate such a high force that special attachment points will have to be created.

- C** Place extended spacers in the upper edge of the truss. The lower edge is linked using ordinary couplers. Doing this at a number of different places will cause the truss to bend in what could be referred to as a positive sag. There will be no increase in strength and neither will the sag be any smaller, but the positive sag will compensate.



$$F_2 = \text{steel wire rope} = +/- 2823\text{kg}$$

$$F_3 = \text{truss} = +/- 2780\text{kg}$$



13. FLYING PERSONS

Moving people vertically is generally done with lifts, escalators, work lifts and hoisting platforms. The first two transport facilities are oriented towards the requirements for large machines that are open for general public access.

The last two facilities can be classified as working tools for a select group of persons who have been instructed. Both types are regulated by a series of safety requirements and regulations which are clearly defined by law.

However, if the creative use of the flying movement of a person is in question, there is scarcely a country on earth that has a legally correct and clearly defined regulation.

For such special effects (used in film, TV and theatre) special people flying systems were developed for events technology.

Despite this fact, this manner of transporting persons is excluded from the Machinery Directive (98/37/EC and also 2006/42/EG).

In the case of persons being lifted by devices that were not originally intended for this purpose, the requirements of the Machinery Directive are quite clear: double the safety factor. Generally this means raising the safety factor from 5 to 10. The compulsory insurers in Germany define a truss as a load-absorbing device whose loading values must be multiplied by the factor 0.5 if the trusses have not been tested for the particular purpose.

This proof can be provided by a manufacturer, for example, by a sort of design test by the TÜV and the subsequent identification of the trusses. Prolyte has design tests for all truss types.

Very detailed and specialised knowledge is required for flying persons.

We urgently recommend engaging only companies which specialise in these sorts of projects.

Furthermore a technician should test thoroughly all components of a people flying system and document the results of these tests. Before taking such a system into operation, an overload test and acceptance test should be performed.

A risk evaluation (formerly risk analysis) must be performed and the risks for persons documented and measures to prevent this given.

Furthermore, a practicable emergency plan must be drawn up, e.g. in case of a power cut.

We strongly recommend the Dutch code of practice MPR 8020-11 "Manual Driven Person" Fly"systems"

Safety factor	Static load. No persons under load.	Static load. Persons under load.	Dynamic load. Persons under load.	Static load. Persons on or attached to load (a)	Dynamic load. Persons on or attached to load (c)
Nominal load	✓				
0,5 x nominal load or equivalent secondary suspension		✓	✓	✓ (b)	✓

a) Examples: Focussing lights from the truss, the use of follow spot chairs or platforms for technical equipment.

b) Persons on the load need to take precautions against the risks of falls from height.

NB: The consequences for the static loading, as a result of climbing the construction or the absorption of forces resulting from fall arrest equipment need to be taken into account (EN 795)

c) Examples are; ballet, presentation on a lifting platform, instalations for flying of persons, work platforms



Photo: ZFX flying effects, USA

14. PERSONAL SAFETY EQUIPMENT IN THE ENTERTAINMENT INDUSTRY

In a working environment employees are obligated to wear Personal Safety Equipment (PSE).

It's a misunderstanding that only the persons who are working at height or working in a riskful environment must use PSE.

All personal entering a working site must use PSE. This could consist of shoes with rubber soles and steel noses or hard heads. In many building sites it's obligated to wear a yellow jacket, which is supposed to attract more attention to the other people who are working on the building site. Recommended PSE items are gloves, shoes with steel noses, a yellow jacket and a heard head.

The responsibility of the employer is to make sure all PSE items are available on site for every employee, and to check whether the employees wear and use this PSE.

It is the responsibility of the employee to take as little risk as possible during his work.

For example, never stand underneath a roofing system or a load while these are lifted.

All the PSE are regulated according to the European Health and Safety Directive.

Beside this European Health and safety directive there are a lot of other regulations on Personal Safety Equipment, and each different regulation has its own role in the total working environment. Many of these regulations are locally imposed, which makes it quite impossible to mention all regulations. The most common regulations are listed below.

Working at height

Working at heights (over 2,5 m.) is very common in the entertainment industry, for example to focus luminaires or replacing a broken bulb. In the case of working on height always try to get

the work done without climbing, and try to get access to the working area by the use of working platforms to decrease the risk this work involves.

Sometimes it is inevitable to use climbing to get access to a certain point in the roof or building structure. In that case always make your own risk assessment and try to find a solution with as little risk as possible involved.

Climbing gear

General regulations state that from a working height of 2,5 meter, the employee has to wear proper PSE, including a full body harness.

Employers are obligated to provide appropriate PSE for her employees. Freelance personnel should provide their own PSE.

For riggers and climbing technicians, the most important items of their PSE are; a full body harness in combination with a shock absorber and a fall arrest system.



There are many types of harnesses on the market. For riggers and climbing technicians a full body harness, consisting of a chess harness and a seat harness, is recommended.

The two parts of the harness are attached and thus designed to spread the forces of the fall over your entire body. Suspension position after a fall is calculated to maximise the chance of surviving.

In combination with a full body harness riggers should also use a fall arrest system.

The fall arrest system should be attached either to your front (chest) or back (shoulder blades) suspension point. The additional shock absorber should always be attached above the waist.

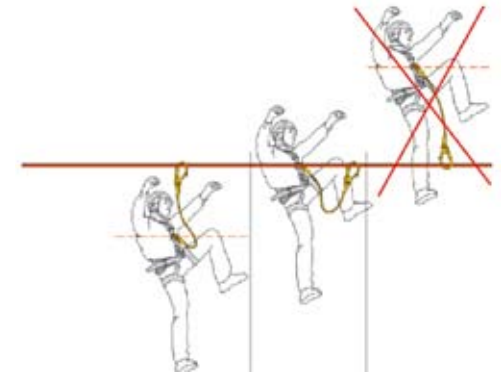
We recommend that the fall arrest system be attached to a lifeline system, which is attached to a building or roof structure at any time. Attaching your fall arrest system to the truss can be a dangerous option, as most trusses are not designed to withstand the additional forces of a free fall.

Fall arrest system with shock absorber

An essential part of the fall arrest system is the shock absorber.

This shock absorber is designed to reduce the force of a fall to a maximum of 600 kg. Without the use of a shock absorber, the force caused by a free fall can easily increase to 25 times the self-weight of the person who is falling, depending on the length of the fall and the attachment to the structure. (fall speed = 9,8 m/s²)

Any elastic movement in the suspension rope or the construction might reduce these rates, but only very limited compared to a shock absorber. The possibility of surviving a fall without a full body harness and a fall arrest system is very low. Any full body harness must comply with the EN 361 "personal safety equipment against falling ". The shock absorber should comply with Standard EN 355.



Fall arrest system with shock absorber



Shock absorbing Lanyard

Positioning equipment

Next to the fall arrest system the use of positioning equipment is also recommended. Positioning equipment normally consists of a rope or sling together combined with special climbing gear like karabiners or saflock (scaffold) hooks. The positioning equipment should always be attached to the ring on the seat harness and is mainly used to place yourself in a working position, without using your hands. When the positioning equipment leaves room for a fall of over 0.5 meter you are obliged to attach the fall arrest system/shock absorber.

We recommend leaving the fall arrest system always attached to the live line or roof system, this will reduce the risk of failing positioning equipment.

The anchor point should never be below the waste of the person who is climbing, in order to keep the falling distance as short as possible. When this anchor point is attached to the truss this anchor point should always be on the main chord and in a node point. The use of two separate anchor points leaves you always attached to the structure, even when you are changing the position of one of the scaffolding hooks.



Workman Adjustable Double-Leg Lanyard

Hardhat policy

For most building sites wearing a hardhat is obligatory, also for climbing personnel. Hardhats should comply with EN 397 standards. Hardhats will protect the head in case of bumping your head to any object or obstacle during climbing or in case of a fall. The hardhat will require a restrained strap cradle that will prevent the helmet to be displaced during a fall.



Climbing a truss construction

One of the most heard misunderstandings about climbing a Prolyte trusses is that the MPT truss series are not to be used for climbing and the heavy-duty series are. To be very clear in this respect in most cases neither truss are capable of withstanding the forces of a free fall.

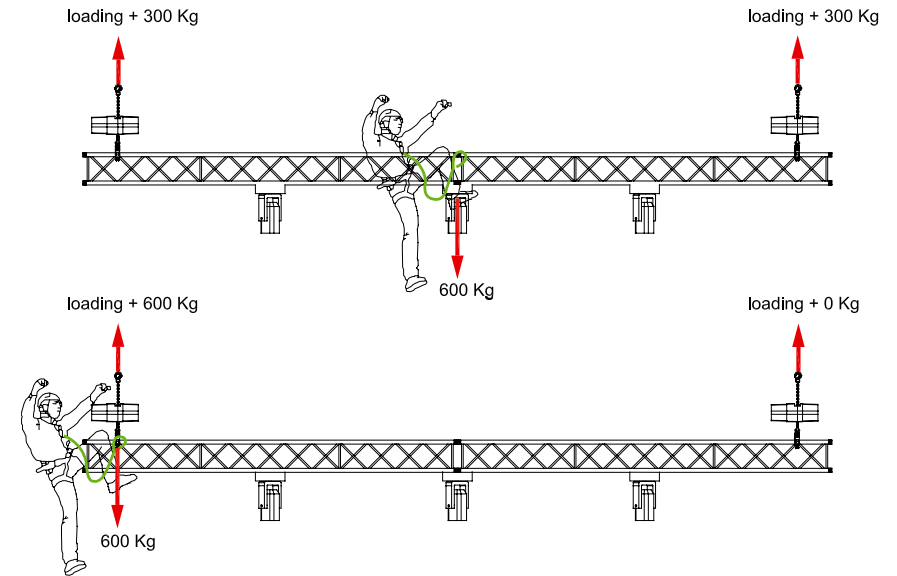
Where possible we would advice to suspend your lifeline system from the roof or additional structure and never from the truss grid itself.

Whenever you are intending to climb the truss rig, the weight of the technician must be included in the calculation of the system. This is not only the weight of the person itself, but the reaction forces of an eventual fall must be calculated, being 600 kg. on the worst possible position, mostly the middle of a free span.

Example:

For a single span supported on two hoists you need to determine if the truss span is capable of withstanding the reaction forces from either the equipment suspended from the truss, plus the additional 600kg, resulting from a free fall (calculated as point load).

Also the hoists should be able to take the resulting 600kg extra loading. Which is the case if you fall directly underneath a suspension point.



Regulations

Most common regulations are listed here.

NEN-EN 361: 2002	Personal protective equipment against falls from a height - Full body harnesses.
NEN- EN 358: 2000	Personal protective equipment for work positioning and prevention of falls from a height - Belts for work positioning and restraint and work positioning lanyards.
NEN-EN 354:2008 2nd draft en	Personal protective equipment against falls from a height - Lanyards.
NEN-EN 355:2002 en	Personal protective equipment against falls from a height - Energy absorbers.
NEN-EN 813:2005 2nd draft en	Personal fall protection equipment - Sit harnesses.
NEN-EN 360:2002 en	Personal protective equipment against falls from a height - Retractable type fall arresters.
NEN-EN 363:2008 en	Personal fall protection equipment - Personal fall protection systems.
NEN-EN 795:2003 draft en	Protection against falls from a height - Anchor devices - Requirements and testing.
NEN-EN 1868:2003 draft en	Personal fall protection equipment - Definitions and list of equivalent terms.

- Draft versions are replacing earlier standards.

15. APPROVAL AND INSPECTION

15.1 TRUSS APPROVAL

The use of trusses in the entertainment sector can be divided into two main applications:

- Truss used as a construction element.
- Truss used as lifting equipment.

Truss used as construction element, e.g. supporting structure for an exhibition stand or wall-mounted billboard frame, is, in most European countries, subject to local building codes and is calculated in accordance with the applicable standards, such as DIN 4113, BS 8118 and Euro code 9.

Prolyte trusses are calculated in accordance with DIN 4113 and the Euro code 9 standards.

In accordance with building regulations, as compiled by the DiBt (German institution for construction technology), trusses should carry a U sign. The U sign is a forerunner of the European CE mark and is restricted to building materials only. It means that trusses and the materials from which they are manufactured are in compliance with the requirements. A truss can also be used as a load-bearing element in combination with a lifting device. This application differs from the first because, in most cases, loads will be suspended above people or groups of people and this requires compliance with more stringent safety criteria. Moreover, trusses like those used in the entertainment sector are subject to wear and tear through repetitive use and handling. Compliance with CWA 25 A/B can be ensured by multiplying the safety factor with 1.2.

Prolyte has TÜV approval for most of its trusses. This approval can be acquired by checking calculations against German construction standards and by a live test being carried out to assess whether the values are achieved.

The test is not a value judgement. If the manufacturer decides to lower its values for whatever reason, the TÜV will assess those values. This fact makes it difficult to compare load tables from different manufacturers.

Prolyte's policy has always been to be clear and transparent as regards the information it provides. That is why, a number of years ago, we urgently requested that the TÜV state values including a safety coefficient for trusses on its certificates. Different brands of trusses can only be compared if these values are provided.

The details which a manufacturer has to be able to submit are:

- Material specs.
- Dimensions.
- Max. allowable bending moment.
- Max. allowable shear force.
- Max. allowable normal force in main chord.
- Max. allowable normal force in diagonal.

As regards constructions, local building regulations have to be complied with in the majority of countries. The temporary nature of constructions in the entertainment industry means that it is often impossible to comply with the rules applying to applications for a 'licence to build'. Supplementary regulations are therefore required.

In Germany, temporary building constructions for outside use have to be checked by an independent test engineer, after which a 'construction book' is issued. All Prolyte roof systems have been calculated and compiled in such a way that these constructions are immediately suitable obtaining a construction book. Standard construction books are already available for a number of systems.

15.2. INSPECTION LEVELS

Initial inspections

When first acquired, whether they are new or used, truss modules should be inspected in accordance with Table 1, and a record of the inspection maintained.

Regular inspections

Regular visual inspections should be carried out in accordance with Table 1. Regular inspections should be performed by a competent person and should be carried out prior to each incident of use.

Periodic inspections

Periodic visual inspections should be carried out in accordance with Table 1 and a record of the inspections maintained. Periodic inspections should be performed by a competent person and should be conducted at least once each year or in accordance with an inspection routine established by a qualified person.

Trusses which are subject to any accident must be inspected according to the requirements per periodic inspection and in accordance with Table 1.

TABLE 1

Part	Inspection level			Items to be inspected						
	Initial Chapter	Regular Chapter	Periodic Chapter	Chords	Diagonals	Connectors	Welds	Fasteners	Geometry	ID-TAG
Missing parts										√
Dents	√	√	√	√	√					
Bends	√	√	√	√	√					
Holes (1)	√	√	√	√	√	√	√	√		
Incorrect repair	√	√	√	√	√	√	√	√		
Abrasion	√	√	√	√	√		√			
Corrosion			√		√		√			
Missing members	√	√	√	√	√	√		√		
Flatness (2)	√	√	√			√				
Deformation	√	√	√			√		√		
Excessive wear	√	√	√			√	√	√		
Cracks	√	√	√				√			
Correct grading (3)	√	√	√					√		
Twisting	√	√	√						√	
Squareness	√	√	√						√	
Bending	√	√	√						√	
Sweep			√						√	
Camber			√						√	

(1) not to be part of the construction

(2) particular for trusses with connecting plates

(3) Minimum 8.8 grade

16. MAINTENANCE AND DISCARD CRITERIA FOR TRUSSES

15.3 INSPECTION FREQUENCY

Truss in regular service

Truss modules in regular service should be subjected to regular and periodic inspections.

Permanent installations, stationary

Periodic inspections should be carried out on all truss modules that are permanently installed in a stationary (not moving) configuration. The frequency of inspections should be determined on the basis of the prevalent conditions.

Permanent installations, moving

Periodic inspections should be carried out every three months, or in accordance with an inspection routine established by a qualified person, on all truss modules that are installed in a permanent configuration where movement of the truss system is an integral part of use.

15.4 RECORDS

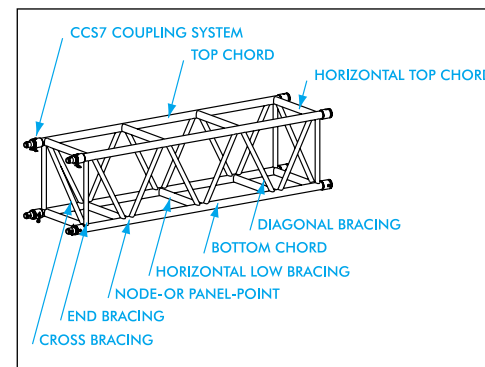
Records of initial inspections and periodic inspections should be kept by the owner for each truss module and should be signed and dated by the person carrying out the inspections.

15.5 REPAIRS AND REMOVAL FROM SERVICE

- If any part of a truss shows significant visible damage or is suspected of containing a damaged element (visible or not), the truss should be taken out of service and marked accordingly. A qualified person should carry out an assessment of the truss.
- Any module that contains damage which is deemed to be unrepairable should be permanently taken out of service.
- Damaged modules should be clearly and permanently marked accordingly.
- Repairs should be carried out and warranted by either the manufacturer or a suitably qualified person.

Introduction

Apart from the normal requirements with regard to due care in utilisation, professional assembly, dismantling, transport and storage of trusses, regular inspections are vital. A careful visual check of the individual elements before each use, independent of the respective field of utilisation, should go without saying. Regular tests of the trusses should be carried out at least once a year by an expert and documented in written form. If the trusses are used intensively, regular inspections should be performed at shorter intervals. If deficiencies are noted during an inspection of trusses that preclude further safe use, the truss must then be scrapped. This means: render the product (here the truss) unusable for further use. Identification of the deficiency cannot be considered sufficient in most cases. Disposal via the manufacturer/supplier or a metal recycling company is the only safe way of protecting others from risks generated by defective material. The criteria given here by PROLYTE for scrapping trusses should be incorporated fully into the inspection, since to date no official regulations exist within the EU.



Elements of a truss.

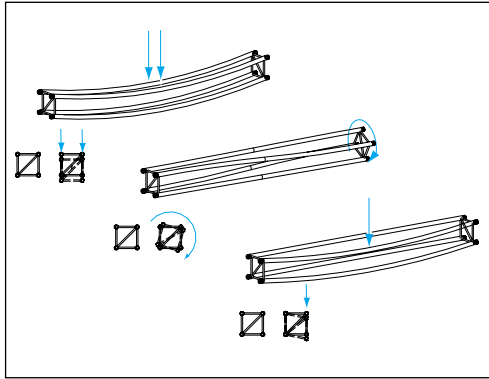
Scrapping criteria

Trusses are considered scrappable if they display one or more of the following criteria. In case of doubt the manufacturer/supplier or an expert should be asked for their opinion.

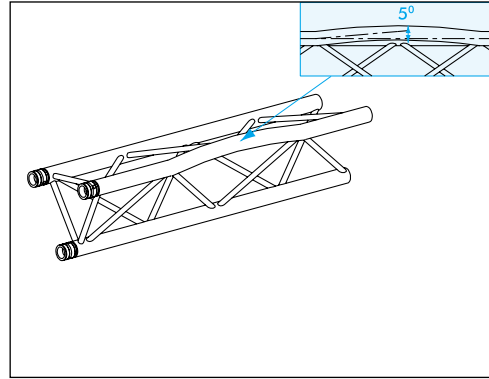
General

- Missing identification (name of the manufacturer, truss type and date of production).
- Lasting (3D) deformation of the truss elements by rotation, bending or torsion or other deformation with resultant deviation from the original shape.
- Welds which have cracks or other irregularities. The incomplete welding seams around the diagonal braces are production-related and their adequate stability has been proved (TÜV design-tested).
- Incomplete welds (apart from the welds mentioned above in the chamfer area of the diagonal braces).
- Reduction of the raised level of the welding seam by mechanical wear by more than 10%.
- Excessive corrosion whereby the total cross-sectional area of the truss is reduced by more than 10%.

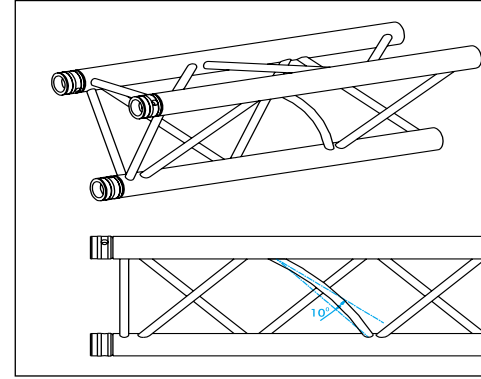
Although aluminium may not develop corrosion the way many steel alloys do, nevertheless ambient influences can impact on aluminium corrosively. Particular care should be taken with structures that are placed outdoors for a long time, in particular in areas with a high level of industrial pollution. Near the coast and in covered swimming pools and generally near swimming pools the trusses should be checked individually before each use as to whether the expected pollution has had a corrosive effect.



Types of deformation: deflection, torsion, rotation.



Bending of the main chords.



Bending of the diagonal braces.

Main chords

If one or more of the main chords breaks or shows cracks, or if one or more of the main chords is rolled by more than 5° from the original centre line then the truss is unfit for further use. The same applies if the ends of the main chord of a truss are rolled in the area around the conical coupler, connecting the truss to another element only possible by exerting considerable force.

Further signs of a discard condition are:

- Scratches, cuts or signs of attrition on the surface of the main chords that reduce the cross-sectional area of the tube by more than 10%.
- Scratches, cuts or indentations in the main tube to a depth of more than 1 mm and a length of more than 10 mm, irrespective in which direction.
- Holes which appear after the truss is brought into use.
- The remaining (plastic) deformation of the main chord to an oval shape or indentation of the tube by more than 10%.

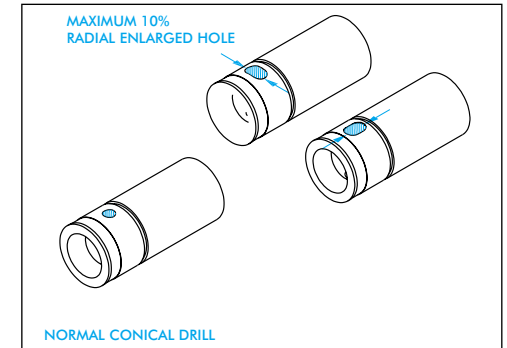
Braces

If one or more diagonal braces, end braces or cross braces is broken or no longer exists, the truss is not usable. The same applies for braces rolled by more than 10° of their diameter from the centre line.

Further signs of a discard condition are:

- Scratches, cuts or signs of wear on the surface of the braces that reduce the cross-sectional area of the braces by more than 10%.
- Scratches, cuts or indentations in the braces to a depth of more than 0.5 mm and a length of more than 10 mm, irrespective in which direction.
- Holes which appear after the truss is brought into use.
- The remaining (plastic) deformation of a brace to an oval shape or indentation of the brace tube by more than 10%.

- Excessive corrosion in the connection. For systems that have remained assembled for more than one year indoors or for one summer outdoors, new, galvanised bolts should be used or stainless steel in order to prevent possible dangers by galvanic corrosion.



Deformation of the spigot holes.

The conical connection system

Signs of a discard condition are:

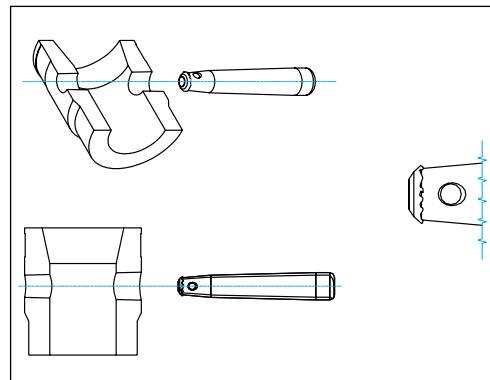
- Cracked or partially broken welding seams between the main tube and the conical coupler.
- Oval signs of wear in the drillholes greater than 10%.
- Rotational displacement for the drillholes for the bolt holes in a CCS connector or between two adjoining connectors by more than 2°.
- Deflection of the main chord ends with conical couplers by more than 5° which makes connecting two truss elements during assembly more difficult.
- Signs of wear on the conical connector or the conical coupler that reduce the cross-sectional area by more than 10%.
- Deformation or distortion in the main chord area next to the welds of the conical coupler.
- Overloading by excessive force causes buckling.
- Overloading through excessive tensile force can cause diminution of the main tube next to the welds.
- Each scratch, cut or hammer stroke indentation on the conical coupler to a depth of more than 2 mm and that is longer than 10 mm, independent of the direction.

Conical bolts

The conical bolts undergo wear when inserted and removed frequently, in particular by hammer strokes. They can be regarded as consumer goods. Pressure areas and deformations in the bolts are indications of a massive overload. If a bolt shows such a change, it may not be used any longer.

Further signs of a discard condition:

- Increase of the diameter by more than 10%.
- Cuts, indentations, scratches and other damages on the smooth surface of the pin.
- Burrs, mushroom heads and other protruding, sharp or pointed edges at the narrower end of the pin.
- Deformation through hammering which causes wear on the cross-hole or damage to a screw thread.
- Attrition of the zinc coating on any part of the bolt, causing this to corrode.
- No self-locking nuts may be used if the nylon safety mechanism is clearly damaged by wear.



Deformation of the conical pins.

Documentation

The stipulation to inspect all trusses or tower elements every day is unrealistic. All truss and tower elements should be inspected carefully by a qualified person at least once a year (if used intensively, this interval should be shortened correspondingly) in order to ensure the functionality and safety of the trusses. These inspections should be documented in an inspection protocol containing the test criteria and results. Ideally every element should be given a distinct mark so that the maintenance history of each element can be followed. Discarded trusses must be removed from use immediately and marked so that they cannot be used mistakenly by other persons. If there is any doubt about the usability of a truss it should not be used under any circumstances. In such a situation contact your supplier.

Maintenance and servicing

During these regular checks some defects can be remedied by professional inspectors. Aluminium can build up on the inner side of the drillholes of the conical couplers, which should be removed from time to time with medium grained sandpaper. Remains of spray paint, dirt, dust and fibres frequently collect on the conical couplers of the trusses or the tower and make assembling the elements more difficult. Some companies use spray paint to mark their trusses. Care should be taken that no paint gets on the fitting surface (inner side and abutting face of the conical coupler, outer sides of the conical connector and inner sides of the drillholes for the conical bolts), since the connecting elements are manufactured very exactly. Drops of paint can be five times thicker than the manufacturing tolerances. They can cause connecting elements to stick or interfere with assembly when they are dry.

PROLYTE recommends users to use a copper hammer when mounting the conical bolt. This will preserve truss pins since copper is softer than steel, also soft copper prevents excessive damage if the incorrect place is struck on the conical coupler or the tube. "Mealy" residues on conical connectors and couplers are normal and can be removed with water and lint-free cleaning cloths. Aggressive cleaning agents should not be used under any circumstances, and certainly not acids. Exterior soiling of the trusses, e.g. with glue residues, can be removed with soap or pressure water guns. Cleaning cloths offered by adhesive tape manufacturers can be used if the manufacturer declares their harmlessness to aluminium alloys.

WARNING:
If trusses and towers are not inspected regularly this can impair the safety of the products, risking damage to objects and injury or even fatal accidents to people.

Truss elements that are impaired in any way from a safety perspective must be removed from use immediately so that they cannot be used by mistake. A strip of adhesive tape as identification is not sufficient because its meaning can be misunderstood and it can be overlooked or removed. Understanding of the safety aspects for trusses and truss structures is of course heavily dependent on adequate information and training being provided for the user. Prolyte and all Prolyte dealers offer regular workshops and training courses on the safe handling of Prolyte products. For more information see www.prolyte.com.

Repairs

Repairs should be carried out and warranted by either the manufacturer or a qualified person.



Documentation

It is the liability of the installer or supplier to provide sufficient information with the equipment you buy. Each piece of equipment should be delivered with a proper manual. If your supplier does not include manuals with their delivery, you should ask for them.

If the delivery includes installation of the (rigging) materials, the installer should also provide the following documents:

- A complete manual for the installed system.
- Working and maintenance instructions.
- Structural calculations.
- Risk analyses.

Please be aware that these are not necessarily the same as equipment manuals from the supplier. An installation is regarded differently than the individual components within the installation.

All rigging and trussing equipment must be inspected and maintained on a regular basis. Knowing where the equipment was made, when it was installed and its history will help you make informed decisions regarding frequency of service. It is the responsibility of venue managers and owners to have access to this information and to keep the documentation up to date. All inspection and maintenance services should be documented in a log.

17. RULES FOR APPLICATION

We would like to provide some tips for using trusses in daily operation:

Data acquisition

Loads to be applied:

- Number of the different single and span loads such as: floodlamps, moving lights, power supply units, follow spots (including seat and operator), cables, adapters, loudspeakers, loudspeaker cradles, projection screens, projectors, flying frames, curtains, backdrops, etc.).
- Mass/weight of the individual loads.
- Determination of the overall load.
- Number and type of supports.
- Number and distance of the flying points and their load-bearing capacity.
- Number and distance of columns and/or rigging points.

Local circumstances:

- Access to the site.
- Potential equalisation.
- Communication paths with event organisers and authorities.
- Special local regulations (e.g. prohibition of special working materials).

Selection of suitable trusses

Firstly the load for every individual truss span must be calculated. If a combination of uniformly distributed load and point loads occurs on a truss, the corresponding formulae should be used. The values for uniformly distributed loads and point loads should not simply be added together. The bending moments are highly dependent on the positioning of the loads.

NB: uniformly distributed lighting fixtures on trusses can be regarded more or less as uniform loads with the exception of follow spots lamps which have to be treated as point loads.

The loads are compared with the allowable values according to the load tables for the corresponding truss types (the allowable structural data like bending moments can be found in the catalogues). As the next step the self weight of the truss type for this application is determined.

The overall weight can be calculated from the length of the truss (including all connecting parts). The overall weight is needed later to determine the reaction forces at the supports.

Multiple supports

Firstly it should be determined how many supports will be needed to ensure adequate safety of the truss span if either the load is so high that the allowable bending moment is exceeded or a span with two supports exceeds the values in the table. The reaction forces are calculated from the self weight of the truss and the loads imposed. The corresponding formulae for trusses on two supports or for trusses on more than two supports (multi-span trusses) should be used.

Next the required bearing capacity of the lifting equipment based on the reaction forces is calculated. If loads are suspended over persons, suitable methods must be found to ensure that the failure of an overhead suspension does not place that person at risk (single failure tolerance). This shall be documented by a risk assessment.

The reaction forces

The loads on the main structure are calculated as follows:

For "flying" trusses: Add the self weight of the lifting equipment to the calculated reaction force, calculate the length of the steels (and from that the mass which is also added to the reaction force) as well as the horizontal forces in the rigging points caused by possible bridles. For free-standing truss structures (ground support): Add the self weight of the vertical columns to the calculated reaction force and check the allowable effective length of the vertical supports. In addition the whole truss structure should be checked with regard to overall safety and stability. If needed, the appropriate braces or guy wires must be added. Checking the point loads of the rigging points in buildings:

For "flying" trusses: Check truss joints, spans and corresponding rigging points for their bearing capacity. The data regarding the allowable joist and node point loads must be supplied by the operator of the event site.

For free-standing structures (ground support): allow for the bearing capacity of the floor area. The base of a truss is generally much less than a square metre, despite the base plate. The information on the allowable floor loading must be provided by the operator of the site. The rigger will perform the necessary corrections to prevent potential overload situations by modifying the position and number of the hoist devices or placing bridles.

Diagrams and tables

All collated information and calculations must be recorded in written form so that they can be checked by structural engineers or authorities. Diagrams should show the position and identification of the suspension points and hoisting gear with the corresponding point load including the weight of the hoisting gear in kg or kN. Furthermore the diagrams must be to scale which must be given in the diagram.

The diagrams must also contain the allowable loads for the slinging points and the vertical slinging wires and bridles. Tables must contain all hoisting devices, all point loads, all slinging points and all vertical loads at the individual slinging points. The numerical values can be rounded up to the nearest 5 or 10 kg in order to allow for the weight of the slinging devices, shackles, rings, span clamps etc. that are not specified with all their details in the original weight lists.

Training and publications

Prolyte offers product training on request.

Apart from this there is the possibility to participate in seminars on rigging and trusses offered by Prolyte Worldwide. We believe that the safety of our products in use is heightened by the technical knowledge of our users and that a manufacturer should not rest on his laurels once a product is sold.

In the last few years various books on trusses and rigging have been published. Since the contents are oriented in some cases very strongly to the manufacturer and expound their philosophy, we do not wish to recommend any particular publication. We simply recommend the relevant journals and books, which can easily be found via an Internet search.

18. TECHNICAL QUESTIONNAIRE

- PROJECT NAME:
- What is the construction used for? (describe briefly)
- Is there a drawing available?
 - yes, see enclosure
 - no (If not make a sketch!)
- Please give all measurements (height, width, length, circle-radius)
- In which environment/under what conditions will the truss be used?
 - indoor outdoor
 - public area private area
- Is the construction a permanent or temporary installation?
- Is there any specific type of truss you want to use? If yes Why ?
- What types of loading does the construction have to bear?
 - Minimal load to support _____ kg
 - Point load (spots, speakers etc.) _____ amount
 - Uniformly distributed load (like drapes, floors, snow, etc.) kg/m²
 - Concentrated loads amount
 - Horizontal loading (guy-wires, steps, ladders) _____ amount
 - Dynamic loading (wind, moving loads) _____ kg
 - Special (like: people, set pieces)
- How will the truss (construction) be suspended or supported?
 - Hoists hand electrical amount _____
 - Legs (portal) amount _____
 - Ground support amount _____
- What are the distances between the supporting or suspension points?
- Do you need a structural report?
- What is the requested delivery time?

19. PROLYTE TRUSS STRUCTURAL DATA

TYP	Material	Cross-section single tubes				Conical coupler system		Permissible normal force in the single tubes		Truss length	Truss wide	Cross-section complete truss			Permissible internal force complete truss						Decd weight			
		chord tubes		diagonals		chord tubes		diagonals				A	ly	lz	My	Mz	N	Qx/Vz	Qy/Vy					
		D	t	A	D	t	A	N	N	h	b	A	cm ²	cm ⁴	cm ⁴	cm ⁴	cm ⁴	kNm	kNm	kN	kN	kN	kN	g
E15V	EN AW 6060 T6	32	1,5	1,437	8	4	0,503	CC54	6,90	2,41	11,80	11,80	5,75	175,8	175,8	175,8	1,63	1,63	27,60	3,41	3,41	2,5		
E20D	EN AW 6060 T6	32	1,5	1,437	10	1	0,283	CC54	6,90	1,36	16,45	19,00	4,31	224,7	223,4	224,7	1,14	1,31	20,70	1,67	0,96	1,6		
E20V	EN AW 6060 T6	32	1,5	1,437	10	1	0,283	CC54	6,90	1,36	19,00	19,00	5,75	446,7	446,7	446,7	2,62	2,62	27,60	1,92	1,92	2,1		
X30D	EN AW 6082 T6	51	2	3,079	16	2	0,880	CC56	22,17	7,04	20,70	23,90	9,24	771,2	763,1	771,2	4,59	5,30	66,50	8,62	4,98	3,8		
X30V	EN AW 6082 T6	51	2	3,079	16	2	0,880	CC56	22,17	7,04	23,90	23,90	12,32	1526,3	1526,3	1526,3	10,60	10,60	88,67	9,95	9,95	5,1		
H30D	EN AW 6082 T6	48	3	4,241	16	2	0,880	CC56	30,54	7,04	20,70	23,90	12,72	1057,3	1047,9	1057,3	6,32	7,30	91,61	8,62	4,98	5		
H30V	EN AW 6082 T6	48	3	4,241	16	2	0,880	CC56	30,54	7,04	23,90	23,90	16,96	2095,9	2095,9	2095,9	14,60	14,60	122,15	9,95	9,95	6,3		
S36V	EN AW 6082 T6	50	4	5,781	25	3	2,073	CC57	41,62	16,59	29,90	29,90	23,12	4445,1	4445,1	4445,1	24,89	24,89	166,48	23,46	23,46	12		
S36R	EN AW 6082 T6	50	4	5,781	25	3	2,073	CC57	41,62	16,59	29,90	29,90	23,12	4445,1	4445,1	4445,1	24,89	24,89	166,48	23,46	23,46	12		
X40D	EN AW 6082 T6	51	2	3,079	20	2	1,131	CC56	22,17	9,05	29,40	33,90	9,24	1531,6	1519,4	1531,6	6,52	7,51	66,50	11,08	6,40	4,1		
X40V	EN AW 6082 T6	51	2	3,079	20	2	1,131	CC56	22,17	9,05	33,90	33,90	12,32	3038,9	3038,9	3038,9	15,03	15,03	88,67	12,80	12,80	5,6		
H40D	EN AW 6082 T6	48	3	4,241	20	2	1,131	CC56	30,54	9,05	29,40	33,90	12,72	2104,8	2089,8	2104,8	8,98	10,35	91,61	11,08	6,40	5		
H40V	EN AW 6082 T6	48	3	4,241	20	2	1,131	CC56	30,54	9,05	33,90	33,90	16,96	4179,5	4179,5	4179,5	20,70	20,70	122,15	12,80	12,80	6,9		
H52V	EN AW 6082 T6	48	3	4,241	25	2	1,445	CC56	30,54	11,56	47,00	47,00	16,96	8000,1	8000,1	8000,1	28,70	28,70	122,15	16,35	16,35	12		
S40T	EN AW 6082 T6	50	4	5,781	25	3	2,073	CC56	31,86	16,59	33,90	33,90	23,12	5699,0	2800,0	2800,0	21,60	21,60	127,44	23,46	23,46	12		
S52F	EN AW 6082 T6	50	4	5,781	25	3	2,073	CC57	41,62	16,59	47,00	52,00	23,12	10906,2	10906,2	10906,2	39,12	39,12	166,48	24,11	24,11	12		
S52V	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	47,00	47,00	23,12	10906,2	3650,0	3650,0	39,12	39,12	166,48	28,79	28,79	15		
S52SV	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	47,00	47,00	23,12	10906,2	10906,2	10906,2	39,12	39,12	166,48	28,79	28,79	15		
S52D	EN AW 6082 T6	50	4	5,781	25	3	2,073	CC57	41,62	13,92	45,00	52,00	17,34	6672,4	6669,2	6672,4	18,73	21,64	124,86	17,05	9,84	12		
S66R	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	61,00	42,00	23,12	18335,3	3550,0	3550,0	50,78	50,78	166,48	31,24	31,24	17		
S66V	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	61,00	71,20	23,12	18335,3	3400,0	3400,0	50,78	50,78	166,48	31,24	31,24	17		
S66RV	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	61,00	42,00	23,12	18335,3	8719,7	18335,3	50,78	50,78	166,48	31,24	28,79	17		
S76RV	EN AW 6082 T6	50	4	5,781	30	3	2,545	CC57	41,62	20,36	71,20	61,00	23,12	24960,8	18335,3	18335,3	59,27	50,78	166,48	30,20	31,24	18		
B100RV	EN AW 6082 T6	60	6	10,179	48	3	4,241	CC57	63,90	33,93	95,00	52,00	40,72	78211,5	23522,6	78211,5	121,41	66,46	255,60	61,57	31,08	20		
S100F	EN AW 6082 T6	50	4	5,781	48	3	4,241	CC57	41,62	33,93	95,00	52,00	23,12	44396,3	44396,3	44396,3	79,08	79,08	166,48	47,98	47,98	18		

M = Bending moment
N = Normal force
Q / V = Shear force

I = Moment of inertia

D = Diameter
t = Thickness
A = Surface area

NOTES

Lined area for notes on page 84, consisting of 30 horizontal lines.

Lined area for notes on page 85, consisting of 30 horizontal lines.



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