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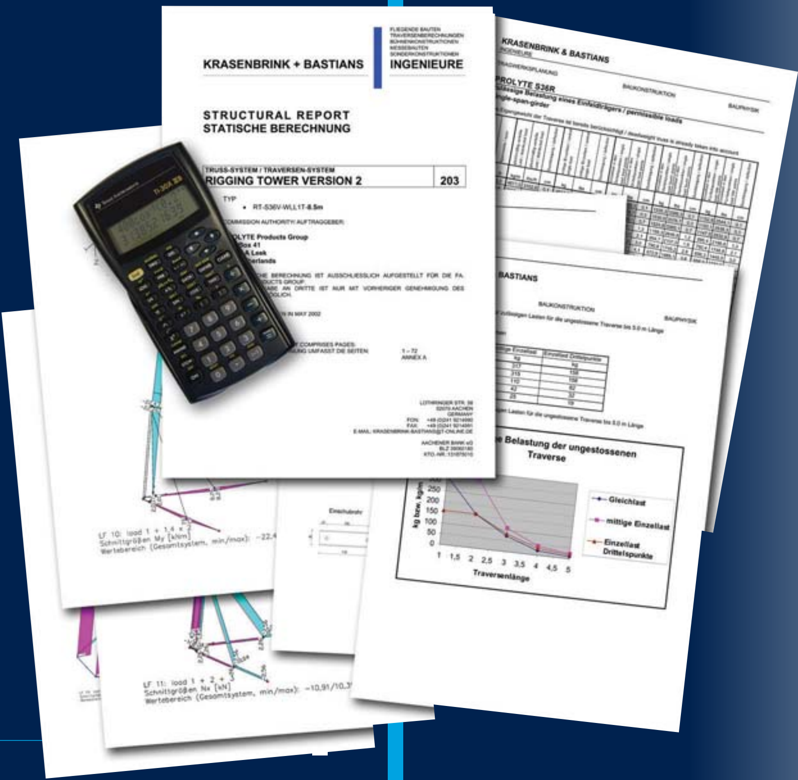


TECHNICAL **MATTERS**

INTRODUCTION

IN THIS SECTION, WE HIGHLIGHT A NUMBER OF TECHNICAL TOPICS. WE WILL STUDY THE TRUSS PHENOMENON AND IT'S TECHNICAL IMPLI-CATIONS, POSSIBILITIES AND PRACTICAL RESTRICTIONS.

WE ARE AWARE THAT THIS INFORMATION IS BASIC AND DOES NOT COVER FULLY ALL AREAS. HOWEVER, ALTHOUGH IT IS NOT COMPLETE, WE HOPE THAT THE INFORMATION GIVEN WILL PROVIDE A GOOD GROUNDING. IT IS UPDATED TO THE LATEST INSIGHTS AND STANDARDS.

EXPLANATIONS ARE GIVEN ON THE NATURE AND DESIGN OF TRUSS,DIFFERENT TYPES OF CONNECTION SYSTEM, FORCES ACTING WITHIN TRUSS AND TYPES OF LOADING.

IN ADDITION, WE WILL TOUCH ON THE STANDARDISATION AND LEGIS-LATION MATTERS THAT RELATE TO TRUSS.

AFTER THIS OUR CALCULATION METHODS AND LOADING TABLES ARE EXPLAINED.

ADDITIONALLY, WE WILL ALSO GIVE YOU TECHNICAL INFORMATION ON THE SLINGING OF TRUSS, LIFTING PEOPLE, TRUSS MAINTENANCE AND A FEW OTHER SUBJECTS.

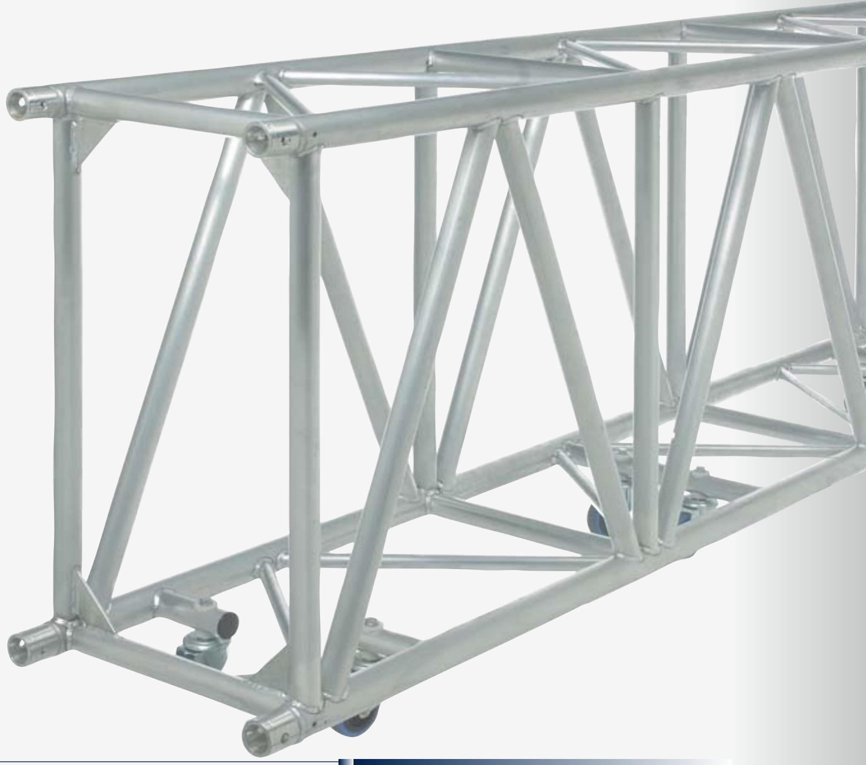
IT IS PROLYTE'S BELIEF THAT, CUSTOMER SERVICE IS IMPROVED THE MORE WE TEACH OUR USERS ABOUT TRUSS.

HE/SHE WILL BE BETTER ABLE TO CHOOSE AND USE THE TYPES OF TRUSS, IN ACCORDANCE WITH THE DESIGN CRITERIA OF THE PRODUCTS.

A BETTER, MORE APPROPRIATE, USE OF THE TRUSS IS VALUABLE FOR BOTH THE CUSTOMER AND US. IN THE LONG RUN, IT WILL RESULT IN A SATISFIED USER, IMPROVED SAFETY, INCREASED SALES, LESS TECHNICAL SUPPORT ETC.

OUR GREATEST CONCERN IS QUALITY. NOT ONLY IN TERMS OF OUR PRODUCTS, BUT ALSO IN THE AREA OF INFORMATION, BOTH ARE ESSENTIAL TO A SUCCESSFUL AND SAFE PRODUCT RANGE. THIS IS WHY WE OFFER THIS IN-DEPTH INFORMATION TO OUR USERS.

TECHNICAL MATTERS



WHAT IS TRUSS

TECHNICAL MATTERS

A. WHAT DOES TRUSS LOOK LIKE AND WHY

A short history

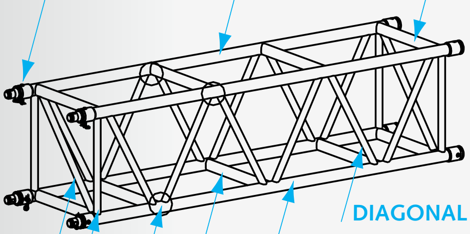
The first thing that might strike you when asking what can actually be defined as truss is the word 'truss' itself.
When the structural phenomenon 'truss' was introduced into the entertainment business (about 40 years ago), hardly anybody would have defined truss like this:
'A modular structural unit, made of welded aluminium round tubes. Used for assembling temporary overhead structures in the entertainment business, to suspend or support lighting instruments, sound cabinets and the like'. At that time, just about everything was used for the purpose, varying from round steel bars to antenna-masts.
Truss was solely a word for wooden structural frames, used to build roof parts for houses, barns, medieval cathedrals etc.
Truss, as we now know it, started to develop at the end of the 1970's.
The entertainment industry was looking for a solution to the easy and efficient building of safe but lightweight temporary structural spans.
Familiar with the spatial lattice structures (found in buildings like bridges, factories etc.), engineers used this as the basis for truss design. Apart from loading capacity, other more practical factors were just as important in the development of the truss systems we know today.

Truss now can be defined as:

A structural spatial lattice beam
- made from welded round-tubes
- composed of modular coupled parts
- manufactured in several standardised lengths
- used to support equipment in the entertainment industry
- supported or suspended at almost any desired point

Truss is made from aluminium, because:

- Aluminium has a low self weight, about 1/3 of the weight of steel
- Aluminium is corrosion resistant: less maintenance: no corrosion protection needed
- Aluminium has a relatively high tensile strength
- Aluminium has an attractive finish: bright polished in its standard form
- Aluminium is fully recyclable



The basic elements in each truss.

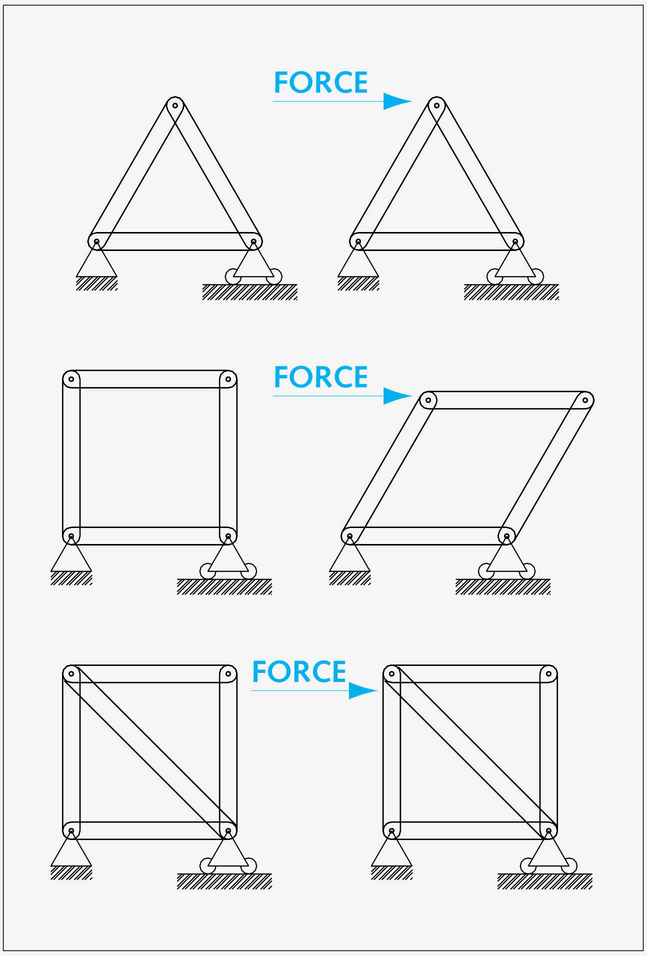
PART THREE TECHNICAL MATTERS

Basic elements in each truss are:
- Chords or main tubes (mostly 48-51 mm in Outer Diameter)
- Braces or diagonals (the web or lattice structure)
- Connection parts (to connect the individual structural modules)

All trusses should have these main characteristics:
- Exceptional strength and stability
- Easy, quick and reliable connection system
- Easy to handle with light compact modules
- Efficient to use, transport and store
- Versatile in its application possibilities
- Basic and for the customer clear information on allowable loading and resulting deflection in tables and/or graphs

There are several different cross sections: ladders, triangular, square, rectangular and various types of folding truss. There are large differences between these cross-sections, which all affect one or more of the following:
- Safety - structural strength and stability
- Economy - purchase price, efficiency in connection, storage and transportation
- Versatility - the widest possible range for different structural configurations and applications with one specific type of truss.

There are a number of advantages and disadvantages with each type of truss. The customer needs to carefully consider all possible applications he might be doing, from the next coming production to those in maybe three or five years time from now, before deciding on what to buy. ,



The hinged triangle retains its shape when loaded at the joints, the rectangle does not.

Prolyte produces trusses for almost every application in the entertainment industry. From decorative E-type elements for shop-fitting and displays, via Multi Purpose Trusses for the exhibition and lighting rental industry, through to Heavy Duty rigid and folding S-series trusses for continued high capacity repetitive use in the touring industry and as main component of temporary outdoor stage-roofs.
Although a comparatively new development, (under thirty years since its inception), truss has developed into a product that the entertainment industry can hardly do without.

The triangular layout of the lattice-members
Why is the triangular pattern one of the dominant features of truss?
The triangle is the only geometric shape that retains its form when being loaded at the joints or nodal points, even when these joints are comprised from hinges. Only when one element is distorted (stretched or ruptured, compressed or buckled) does the triangle looses its shape.

The hinged triangle retains its shape when loaded at the joints, the rectangle does not
It is relatively easy to calculate and predict the behaviour of a triangular structure under load, provided that loading is active in the nodes only. Structural engineers like, and need, to predict the outcome of their work within very narrow parameters, so that the user and insurer alike have 'peace of mind'.
There are some basic assumptions that must be made in calculations. Each composing element in the triangle must only be loaded through its axis: in tension or compression, with no side loading. Therefore, loads can only be applied to the nodes (or panel points).
This being said its effect on the 30-series range of truss is not that problematic, as this truss-size has relatively large sized chords in comparison to the total height of the truss, and a relatively dense web-bracing. However in the E-series as well as from the 40-series and up this characteristic is less pronounced and it must be once more stressed that loading (and definitely supporting) in the nodes is a prime demand.

It is important to note that if the triangular structural configuration is missing, the loading on the structure cannot be made as if the diagonals were present. This is, for instance, the case with side loading of the S36R, S52V and S66R and V types.

B. TYPES OF CONNECTIONS SYSTEMS

Truss generally is manufactured in modules of standard lengths, which thencan be assembled to spans of any desired length. It is seldom, that complete spans as they are used 'in the field', are produced as one single module; this would make the product almost impossible to handle and transport, and limit its application possibillities elsewhere.

The four main connection types

The vast majority of modules have standardised lengths around 2,5 - 3m (~8 to 10 ft); however, longer spans are often needed. Therefore, a fast, efficient and easy way of assembly or connection of the separate truss modules is necessary. Although there are numerous types of truss connections,
only a few have proved to be practical in actual use. Connection systems that do have a serious market share fall in to four basic types:

End- (or gusset-) plate connection

Using bolts (sometimes the infamous 'cam-locks') loaded in tension, and loading the endplates, way out of line from the chord centers, with high bending forces. Many loading tables possible for one and the same truss type, depending on bolt-type and number applied.
- Bad to line-up; many components; slow assembly; easy mix-up mistakes of tops and sides in square versions; special tools needed; low loading capacity; danger from use of incorrect grade bolts; special hinge sections needed in towers.
+ Genderless system; working length = unit length; connections relatively difficult to damage; simple use of corners.

Internal tube connection

Using bolts loaded in shear and loading the internal-tube and chord-walls
with high compressive, bearing and shear forces. Predominantly light duty versions only.
- Difficult to line-up; many components; slow assembly; any play in tolerance - even from new - is lasting; special tools needed; connections easily overloaded in bearing stress; connection-area's easily damaged (leading to the discard of entire truss module).
+ Genderless system; working length = unit length.

Fork-plate (or spigots) and cup-cone connection

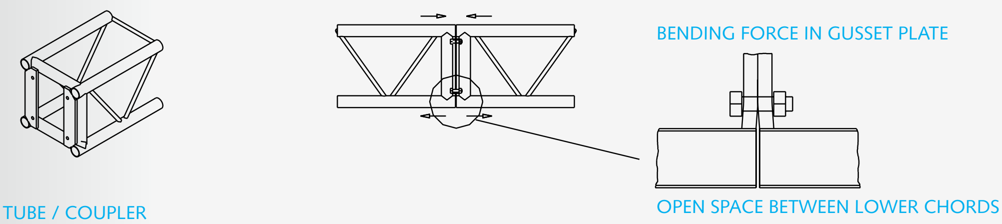
Using truss pins (spigots) loaded in double shear, with axial loading in line with the chord centres.
- Gendered truss; imprecise line-up of modules; elaborate orientation; many different complementary corners required; working length NOT = unit length, any play in tolerance through wear is lasting; connection-parts relatively easy to damage (leading to discard of truss-module).
+ Few parts; very quick & easy assembly. No special hinges required in towers.

Conical coupler connection

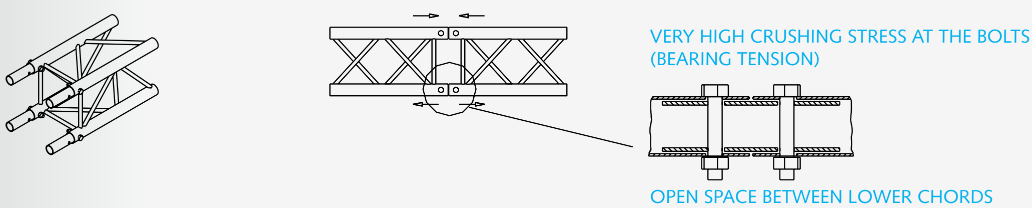
The best features of all the other connection systems combined. Using truss pins (spigots) loaded in double shear, with in-line axial loading of the chords.
- Special hinge parts needed.
+ Genderless system; easy and precise line-up of modules; very quick & easy assembly; rigid fixed-moment connection; working length = unit length; some play in tolerance through wear is compensated by conical spigot truss-pins; connection-parts difficult to damage and easy to replace.

CONNECTION TYPES

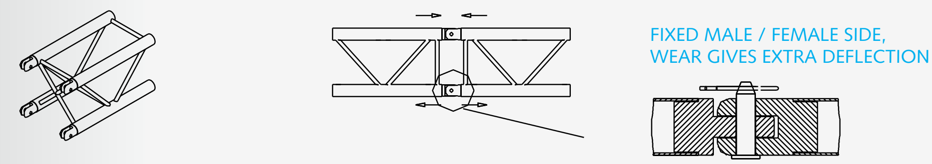
1: GUSSET / ENDPLATE



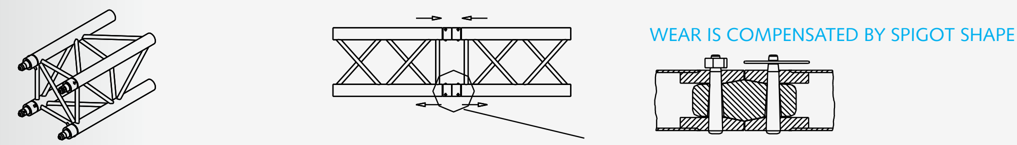
2: TUBE / COUPLER



3: MALE / FEMALE COUPLER



4: CONICAL COUPLER



C. FORCES WITHIN TRUSS

Bending

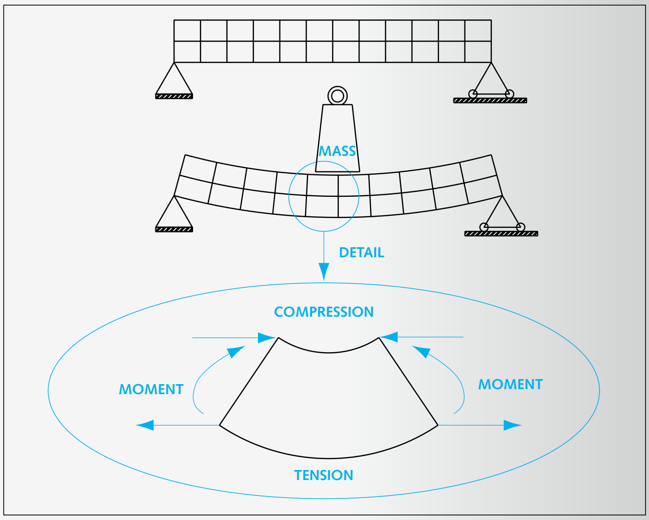
Gravity is at work at almost every spot in the universe; accordingly, loading takes place on all structures. The self-weight of a truss – or any other type of beam for that matter - will give it the tendency to sag or 'deflect' in the unsupported area of the span; this is a result of loading forces.
We call this effect 'bending', and the same word is used in many branches of engineering. 'Bending' means: to constrain, or strain to tension, causing a straight-line structure to turn into a curve-shape.
The force that is active inside a truss structure is the bending force, leading to compression in the upper chords of the free span and tension in the lower chords of that span, and to either tension or compression inside the bracing elements. The bending force can be quantified as the bending moment: the effect resulting from the principle of a force multiplied by a distance (F x a) that leads to the bending of a beam, girder, truss etc, around the neutral axis, at any section along the span.
The bending moment is expressed as M, and can be either indicated positive (sagging) or negative (hogging). The bending moment has specific formulas for typical loading situations such as UDL (Uniformly Distributed Load), CPL (Central point Load) on simple supports, cantileversand continuous beams. Units are expressed in the metric system as Nm or kNm (or in the imperial equivalent as 'lbsft'). If the specific characteristics of the truss are given i.e., section surface area and height of the truss, (known as the 'moment of Inertia'), the amount of stress in the chords canbe calculated: the bending stress. Every alloy is only capable of taking a limited amount of stress in tension or compression before failure occurs, seen as a rupture or tensile break in tension and squeezed or aggregated material in compression. Compared to steel, aluminium has a low ductility, and 'warning' of the metal before showing these failures is definitely less. However in welded or roll-pin connected area's, a deformation pattern visible at the surface of the chords, could surely indicate a (previous) overload, and must be checked with extra care and certainly marked for detailed analisys if not taken out of service right away.

Buckling of a span

The bending forces at a certain point will have a tendency to lead to another instability phenomenon known as buckling. This is the tendency for compressed members to get out of line and bend or tilt sideways. On longer spans the whole truss might show this characteristic, and as a result may become unsafe and fail through this instability. Therefore the standard allowable loading tables have an upper limit in the given length. Again there is a relation with the length of the span and the amount of weight applied to it, which is also the case with the vertical bending known as deflection. When deflection is respected and checked the risk for buckling is also taken away.

Deflection

The bending force is made visible by deflection. Deflection can be defined as: the elastic movement of a structure under load. Deflection in itself poses no direct strength -thus safety- hazard; how-ever, a point will be reached when deflection has become so extreme that it will cause instability within the structure, or its connection tot other structural elements. No indications as to the amount of permissible deflection in a structure will lead to false feelings of security. Instability in a structure can be life threatening.



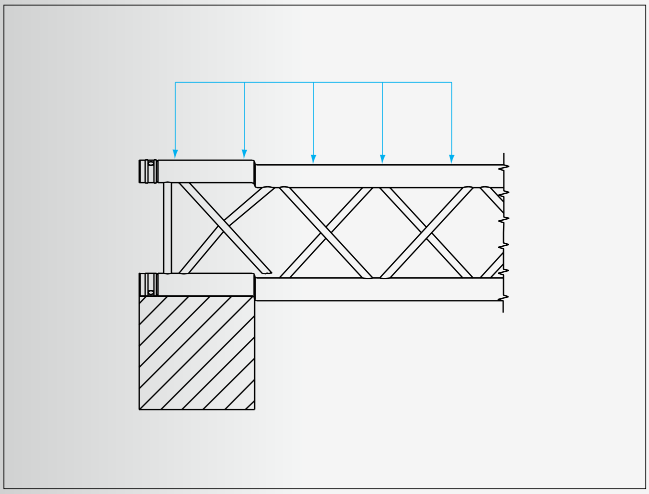
A span under loading and the resulting forces

Prolyte adheres to a maximum deflection limit of 1/100 of the span: 1cm in 1m or 15cm in 15m. If you want to use the TüV approved loading data in combination with an estimated level of 1/100 for the deflection you need thissimple linear calculation.
A 12m (=1200cm) span with 800 kg UDL and 12cm deflection will be
12m span with 6cm deflection when loaded with 400 kg UDL
(1/100 of 12m = 12 cm = allowable deflection)

Other manufacturers might use different deflection limits, but if deflection limits of a truss-type are not given by a manufacturer, all loading values must be treated with extreme caution. It leaves the user no tool for checking any possible ways of warning that might dangerous levels of loading are reached. It might take only a little more (mistake in operating a motorcontrol, a cable getting caught, a lighting-tech holding tight while setting a digital adress , etc) to lead to collapse of the whole span caused by failure of one of the modules in it.
Deflection can also be caused by bad connections where truss-pins are not engaged to the full extend or worn connecting pieces. Prolyte's CCS are designed to adjust for some wear, as a widened spigot-hole will be filled by the conical pin intruding a bit further into the connection. Other connection types don't and allow for this principle and some 'free sagging' is introduced from day one of use.

Shear

At the position of the supports another force is active, the shear force.
Shear (shear force) can be defined as: the load acting across a beam or truss, at its supports or at the position off a point load, in such a way as to "cut" the truss vertically at the supports. Allowable shear force in a truss is limited by the braces in the sides. The shear-force tries to push the chords towards each other.
In the standard structural engineering calculations the supporting position is taken at the lower side of the bottom chords. When the first diagonal brace faces downward from this supported area to the free-span side, this results in an effort to 'pull' the free span down in between these supports, and the diagonal brace shall thus be in tension, with the allowable stress in Heat Affected Zone of the welds as limiting factor.
Visa versa when the webbing brace faces upward from the supported area, this results in an effort to 'push' the free span



Shear force acting on a truss.

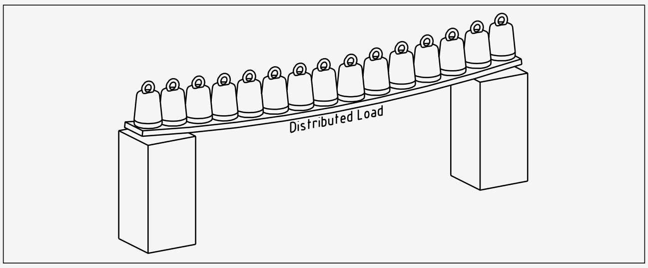
down in between these supports, and the braces shall thus be in compression, with either the allowable stress in Heat Affected Zone of the welds acts as limiting factor compressing the diagonal itself, or the length of the diagonal brace itself makes it susceptible to buckling. Another failure possibility could be the diag pushing hard into the thinwalled tube eventually resulting in a dented area around the diagonal brace. One of these mechanisms can be limiting at one time and the worst possible one is taken. In the MPT series there is always a combination of a brace in tension with a brace in compression. In the S-series the webbracing pattern is parallel thus only one of these mechanisms is present as limiting factor.

When the truss is supported from the upper chords it is almost exclusively only in the suspended situation. Furthermore the load will be predominantly on the lower chords, and when lifting is done there is a certain degree of dynamic loading added to what is found in the loading tables given as a static load. Care is to be taken when lifting speeds increase, chainmotors cause dynamic "wobbling" effects, trusses or structures will be raked and so on. In general terms it is best to support the trusses from the bottom chords and keep the welding of the closest braces diagonal - or vertical - in compression.
The shear-force then tries to rip apart the chords from the web, where failure in tension has a much higher hazard concerning the total disintegration of the structure, that could run along the span in a chain reaction. Regular truss corners should therefore be used only as a spatial fixation element and not as a structural unit. Supporting the truss structures shall be on the straight modules only and cantilevered structures across corners should be avoided. Box corners are equipped with relatively dense bracing to allow for more shear absorbing capacity, just as in steel structures the corner joints are always clearly reinforced when compared with the regular beam-spans.

D. TYPES OF LOADING

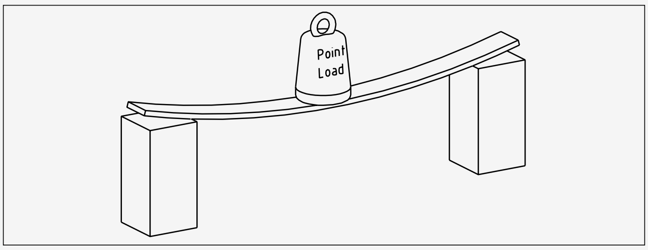
Load can be defined as:
The amount of force as a result of mass, weight or strain, that is imposed on a length of truss including the self weight. The types of loading that are considered can be put into two categories: Uniformly Distributed Load and Point Loading.

Uniformly Distributed Load (UDL)
- A load that is identical in weight along the whole length of the truss
- A load that is evenly spread over the (node points of) the lower chord(s) of the truss



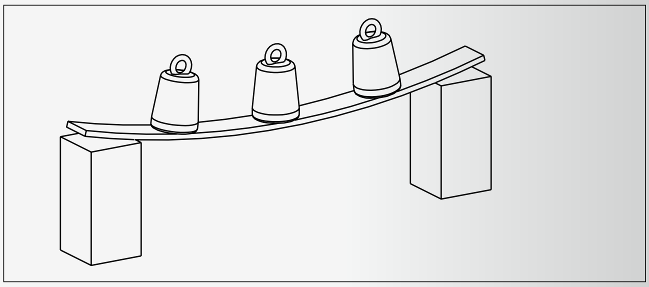
Examples of UDL are curtains and scrims as well as a series of identical spotlights at identical distances along the complete span. The total UDL is indicated with Q and expressed in kg, tonnes, kN, lbs. etc. When the load per unit length is meant, this is indicated as ‘q’ (kg/m; N/mm; lbs/ft).

Point Load
A load that acts at one specific point only. The worst place to apply this load is right at the middle of a span.



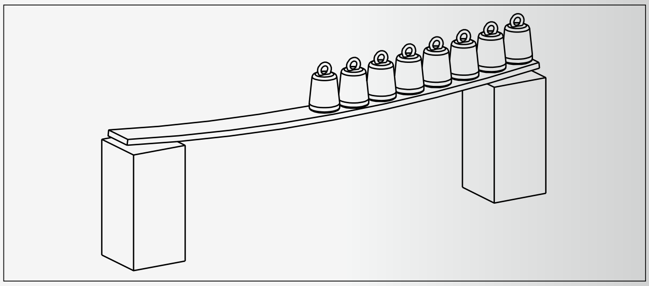
This type of load is generally indicated as **Center Point Load (CPL)**. Placed anywhere else along the panel points of the span, this amount of point load results in less bending stress, although the amount of shear stress at its load point remains. Examples of point loads are: inverted chain hoists, (large) speaker cabinets, followspot-seats, and technicians. At Prolyte, we consider anything with the weight of a person or above to be a point load, and recommend our customers to do the same. A technician sitting on the truss will initially result in, at least, a PL of 1kN.

Multiple Point loads
A situation that is frequently encountered is not just a single point load at the middle of the span, but several identical point loads at regular and identical distances along the span.



In the load-tables we give allowable loads for 2 identical point loads, dividing the span in 3 equal sections (‘thirdpoints’); for 3 identical point loads, dividing the span in 4 equal sections (‘fourth points’) and 4 identical point loads, dividing the span into 5 equal sections (‘fifth points’). Above this num-ber of points, the allowable loads for UDL can be used.

Concentrated loads
This can occur where only a part of the span is loaded with a UDL, or where several point loads are applied in limited area, and the remainder of the span is not loaded.



Depending upon the amount of loaded and unloaded parts of the span; generally the easiest, (and safest), thing to do is to consider the total weight acting as a point load in the middle of the concentrated loaded area.

It is clear that these different types of loads have dramatically different effects on the strength of the truss and accordingly should be clearly distinguished when questions arise.
Two basic questions always crop up when choosing a type of truss:

1. “How long can we make the truss span?” Meaning: “How long can the free span be?”
   The free span being the distance between two suspensions or supporting points, thus the unsupported part of the truss.
2. “How much weight can we put to the truss?” Meaning: “What is the loading capacity of the truss?”
   Free span and loading capacity however are two inseparable factors.

The larger the span the lesser the loading capacity and the larger the load the smaller the span can be. Except in those (rare) cases where not deflection but shear is the limiting force within the truss, where in very short spans an large amount of load can lead to failure in the actual support position. This can be by denting the chord-tubes or by buckling of webbraces in compression, or breaking of welded area’s of the braces in tension. Any particular type of truss, no matter which manufacturer, has its specific failure charactersitics. Every manufacturer has to make sure to that in the calculations for the loading tables these charactersitics may never be a remaining hazard.

STANDARDISATION AND LEGISLATION

Standards as well as legislation and regulations are found for numerous aspects that have to do with the general principles of design, manufacture and use of aluminium structures. Many of these deal with several industrial applications. Special standards and or safety regulations for the entertainment industry have, so far, been developed only on national scale with respect to general safety conditions (Germany in 1974: VBG-70, recently renamed into BGV-C1). Only recently an effort is made to accomplish more international standards in the entertainment industry. The first initiative was taken by the ESTA and has resulted in the publishing of the ANSI E1.1-2000 standard (Design,Manufacture and Use of Aluminium Trusses and Towers in the Entertainment Industry).

There are several kinds of standards and sometimes they are quite different from one country to another.

- Labour legislation is often national and sometimes even regionally different.
- Standards (for instance the names of different alloys) and Codes of Practice can differ between nations.
- International standards (such as ISO, CEE or IEE) are not always internationally acknowledged. Even the basic standards in the economic centers as the US, Europe or Japan differ in more than just the units of measurement and calculation.
- Standards within the European community (EU) are converging into European standards (EN ~ :European Normalization).
  A dominant legally limiting 'standard' is the European Machine Directive regarding safety of machines and as such also concerned with lifting equipment. Truss however is not specifically men-tioned in this, nor is there any specification of entertainment lifting appliances. For lifting of people at least a doubled coefficient of use is specified. Again the emphasis is made to the directly loadbearing parts that are susceptible to wear such as chains, shackles roundslings and wire-ropes.
  So far trusses have been engineered to the same principles as fixed and predominatly fixed.
  A new draft standard for lifting beams (prEN-13155: 1998: Non-fixed loadlifting attachments) however does request a raised level of safety in lifting or suspension over people.
- There are also a several Quality Control and Inspection Institutes and Organisations that all tend to stick to the standards in the country of origin. Within Europe the German TüV is generally acknowledged as a leading certification body, but also Lloyds (UK), DNV (Norway) and Bureau Veritas (France) are well known in this respect. In Europe there is a transnational series of 'Certified Bodies' that are legally set to certify specific items that also are subject to European Directives and Euro Codes.

Truss manufacturing and truss assembly need to conform to:

1. Aluminium alloy use (name, chemical contents and phy-sical aspects as tensile strength)
2. Aluminium welding (methods, Heat Affected Zone weakening)
3. Aluminium Structural Standards. These standards deal with the structural strength and safety in design of aluminium structures. This means the modular units of a truss-type are subject to standardization and certification.
4. The practical and daily use of truss in simple spans or large and complex structures is the prime responsibility of the user (rental-company, exhibition company or trussing-rigging designer).
   This is clearly indicated in the ANSI E.1.1-2000 Truss standard.
   As most Building Standards & Codes are predominantly concerned with permanent structures it is very helpful that these are complemented with Standards for Temporary Structures. The majority of applications in the Entertainment industry is temporary and moves from one location to another. In Germany this is covered by DIN 4112: Temporary Structures (originally published in 1960) and in the UK by "Temporary Demountable Structures", (first published by the IstructE in 1995).

A last complicating thing is that certainly for trusses in the rental industry a considerable part may be used in different structural position from one production to the next, where as e.g. fairground attractions do travel, but the structural set-up and forces are identical in all places.

Quality control

Prolyte protects the quality of its products through a quality control protocol developed following EN 729-3: Quality requirements for welding. Fusion Welding of metallic materials; Standard quality requirements. This standard describes all steps in the manufacturing process that can be influential to the material, the welders or the final product.

Welding

Judging a weld by its look is difficult. Prolyte ensures that all welding complies not only to the EN 729-3 standard, but also with DIN 4113-3. The standard requires that we appoint a competent in-house welding technician or welding engineer. Furthermore all our welders are qualified following the EN 287-2. Our welding methods comply with EN 288-4.

Materials

We use only the best materials. On the outside, materials appear much the same, but they are not because they differ in quality. You should always check which materials are used in the manufacture of structural products. Good product information should contain this data.
Prolyte uses aluminium tubes with alloy EN AW-6082 T6 F28/F32 (AlMgSi 1). The properties of this alloy are about 7% superior to the often-used EN AW-6061. Prolyte also demands a 3.1 b certificate (EN 10204) with each delivery. This certificate states that the chemical composition
and mechanical properties are kept within the required tolerances. Furthermore, adhering strictly to a required protocol, regular checks are performed on all incoming goods.

Product hallmarks

In close co-operation with the RWTüV (Germany's notified test and certification body), Prolyte has obtained a 'Bauart Prüfung' for all the truss series.
Our tower systems have the CE hallmark and all our constructions and roof systems can be supplied with a stability certificate, the so-called 'Baubuch'.

PROLYTE PRODUCTS ARE MADE IN COMPLIANCE TO THE FOLLOWING STANDARDS:

EN 573	Wrought aluminium and aluminium extruded sections; Properties
DIN 18000-1	Modular co-ordination in building
DIN 4112	Temporary structures; code of practice for design and construction
DIN 4113-1	Aluminium constructions under predominantly static loading; static analysis and structural design
DIN 4113-2	Aluminium constructions under predominantly static loading
DIN 931	Hexagon socket set screws with cone point, ISO 4026 modified
EN 10002-1	Tensile testing of metallic materials. Method of test at ambient temperature
EN 287-2	Approval testing of welders- Fusion Welding. Part 2: Aluminium and aluminium alloys
EN 288-3	Specification and approval of welding procedures for metallic materials- Part 3:Welding procedures tests for the arc welding of steels
EN 288-4	Specification and approval of welding procedures for metallic materials- Part 3:Welding procedures tests for the arc welding of Aluminium and aluminium alloys
EN 292-1	Safety of machinery. Basic concepts, general principles for design. Part 1: Basic terminology, methodology
EN 292-2	Safety of machinery. Basic concepts, general principles for design. Part 2: Technical principles and specifications
EN 729-3	Quality requirements for welding. Fusion welding of metallic materials. Part 3: Standard quality requirements
ISO 10042	Arc-welded joints in aluminium and its weldable alloys. Guidance on quality levels for imperfections
NEN 2063	Arc welding. Fatigue loaded structures. Calculation of welded joints in unalloyed and low-alloy steel up to and including Fe 510 (Fe52)
NEN 6710	Regulations for the calculation of building structures
TGB 1990	Design of aluminium structures
ANSI	E1.2-2000: Entertainment Technology: Design, Manufacture and Use of Aluminium Trusses and Towers
BS 7906	2:2000: Code of practise for use of aluminium and steel trusses and towers
BS 7906	2:2000: Specifications for design and manufacturing of aluminium steel trusses and towers

TRUSS & LOADING

Practice & Theory

Even the most accepted theoretical models for strength and stability calculations will not be able to cover all the various situations that clients have to deal with on a day-to-day basis. As a manufacturer, an awareness of this situation is essential, so that we are able to offer solutions that work and prove valuable in the long term.

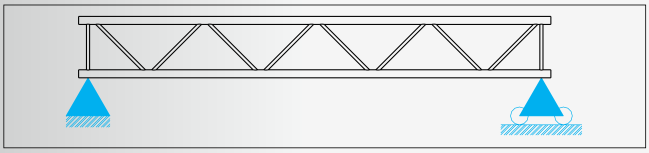
At our engineering and sales departments, we employ people that have 'hands on' experience in the field of rigging and trussing. Their invaluable knowledge and experience combined with the pool of knowledge that Prolyte already has, as a major manufacturer of truss, is a major asset.

Our awareness of the lack of theoretical knowledge of truss users makes us mind ful of our responsibility to educate the end user. This ensures that the end user gets safe long lasting use of our products.

A. TYPES OF SPANS

Simply supported span

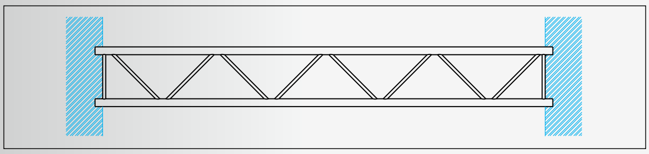
The tables represented show the values for simply supported spans, which are the most commonly found types of span in the industry.



This type of span is supported at both ends of the truss, permitting movement of the truss in between the supports, caused by deflection because of loading.

Fixed span

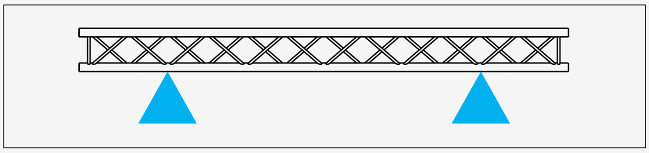
Data that show values for fixed spans are almost completely hypothetical, because in our industry this type of support is rarely used.



Manufacturers that use this type of data only want to show high figures ('hyping' their pro-ducts), but, essentially, are misleading the customers.

Cantilever span

Cantilevers are the best example of a lever arm. All the weight of the load as well as the self-weight is acting in shear at the connection.



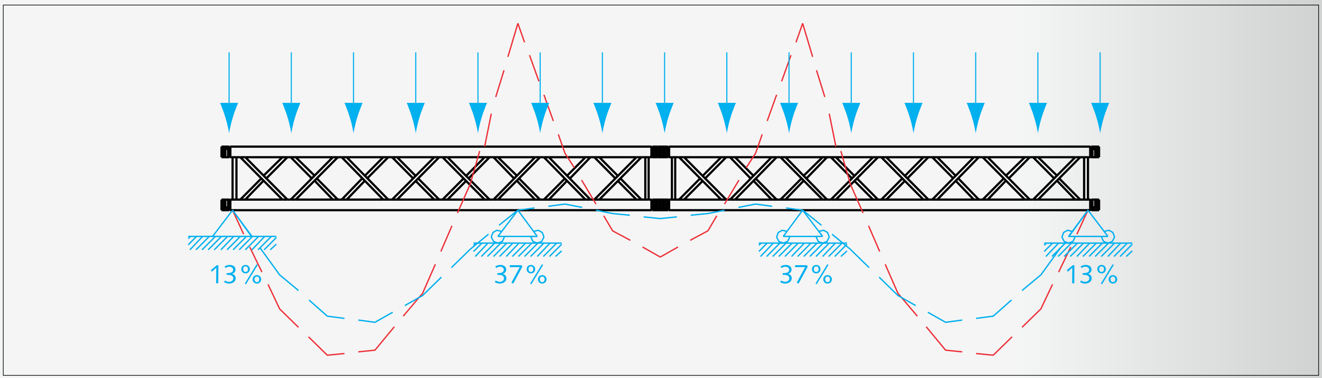
And the longer the arm the larger the bending moment will be at the connection. Cantilevers also are only restrained at one point against any torsion force and therefore extra susceptible to uneven loading of both chords.

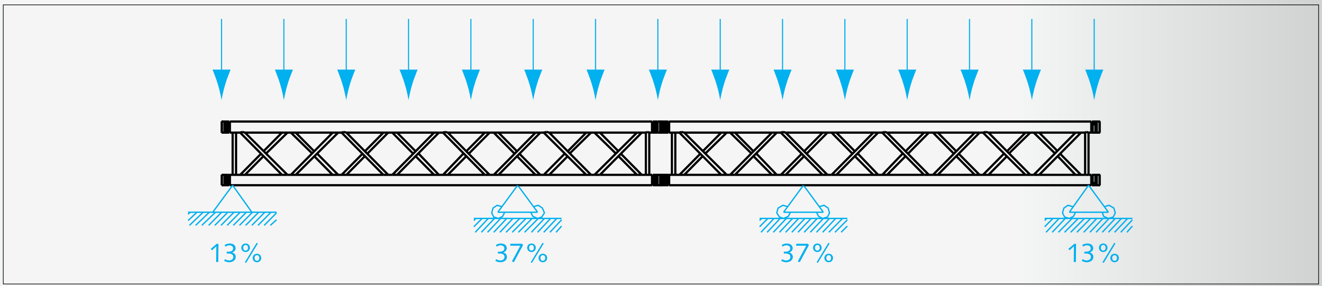
Continuous span

Beams that are on more than 2 support point but have continuous sections (no hinges) are known as "statically undetermined" spans. A load in any field – the area in between two support points – will influence the behavior in the next field. The possible loading combinations are almost infinite.

Because the consequences for the allowable loading are complex, no separate tables are given for all these loading combinations. To have an indication of what the support reactions will be is important because the shear force is present in the support position. Furthermore the character of the bending moment at the inner supports will be opposite to that of the fields. In the fields the bending force will lead to tension in the lower chords and compression in the upper chords. Over the support point the bending force will lead to tension in the upper chords and compression in the lower chords. In triangle cross-section truss this needs careful consideration when choosing apex up or down for a particular reason.

In this instance we follow the requirements of the DIN standards, also the recent developments in the ESTA-ANSI, PLASA-BSI and VPLT (German) and VPT (Dutch) draft standardization's for the





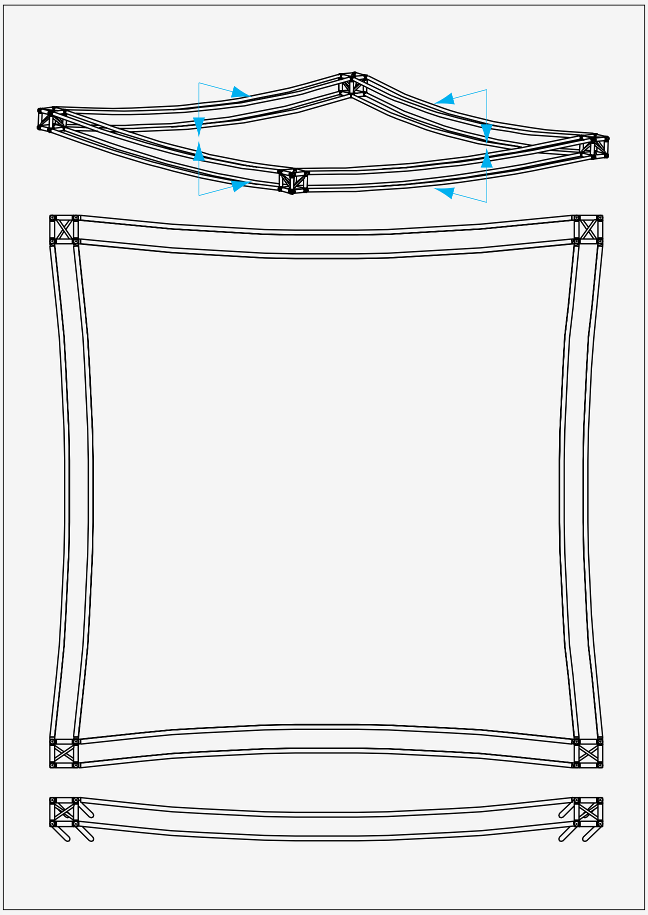
design, manufacture and use of trusses in the entertainment industry.

Load application

In all cases, loads are presumed to be applied vertically and equally distributed along the lower chords. Trusses are calculated according to this principle, and any deviation from this assumption will essentially reduce the safety. As a rule of thumb a load applied to only one of the two lower chords shall mean that the allowable loading is to be reduced to 50% only.

Double bending

Either any kind of side loading or horizontal loading should be entirely avoided. Truss that has webbing only in the vertical planes is not able to absorb any horizontal load. (e.g. S36R, S52F, S52V, S66R, S66V). Truss that has identical braces in all directions can absorb horizontal loads only when the vertical load is reduced (e.g. H30V, S36V, S52SV).
Combinations of vertical and horizontal loading are referred to as "double bending", a process that can easily result in exceeding the allowable stresses in the truss. Apart from this data, we would like to remind the user that the support or slinging method itself is very important, as can be seen in the chapter on rigging and slinging.

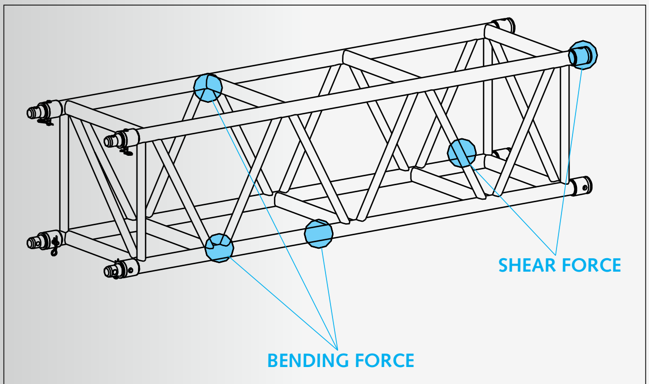


B. CALCULATION METHODS

Determining factors for load calculation

Each truss-type has a set of components, that are built together in a specific module of determined size and shape. These modules are to be put together into spans of certain lengths and certain loads.
For any given span the maximum allowable load is determined. The allowable load is determined by the allowable stress in the components of the truss. The stress of each component is depending on the type of loading and on the position of the component in the span.
Stress will be expressed in bending force (tension or compression) or shear force:

- Shear force acts on the truss in the bracing-members at the position of supports and pointloads. Shear force also occurs in the steel conical truss-pins that connect the conical couplers.
- Bending forces occur in the top-chords of a span as compression and in the lower chords of the span as tension.



Other determining factors:

- For any component used there is a certain amount of surface area. Each alloy has a certain amount of stress in can absorb before it fails. In the Standards DIN 4113 part 1 & 2 an allowable amount of stress is given for a series of alloys.
- All welding causes a Heat Affected Zone in the welded material, this means the alloy is locally reduced in strength and lowered allowable stresses have to be included in the calculations.
- At a certain length any member that is in compression will be subject to another principle: it will become unstable and is going to fail as a result of buckling. DIN4113 part 2 and the AA (US) Aluminum Design Manual, both give allowable stresses. In the German approach as a absolute value, in the American as a statistical value for permanent structures.
- In Europe a top-quality alloy used for trusses is EN AW6082 T6 (=DIN: AlMgSi1-F31). Always make sure the manufacturer is consistent in the use of specific alloy's. The 6082-alloy is not produced in the USA. There the AA 6061T6 is the main alloy for the production trusses. When these dominant US and European alloys are compared the EN AW 6082 T6 alloy has a 7% better performance in tension and compression compared to the AA 6061T6. This means that either self weight can be reduced or higher loading is possible when the European alloy will be used in a US-design.
- The ANSI standard ANS E1.2 – 2000 and BS standard 7905-2 do take into account the occurence of repetitive use, and the wear and tear that might result from it. Therefore there is a proposed additional factor of safety of 0,85 x the standard structure calculation results. This factor is not yet taken into account here, as the TÜV – the Certification Institution that Prolyte is sub-mitting it's products to - so far has not acknowledged the ANSI and BS standard as a certification reference.

The loading tables are based on the allowable stress for each component, when loaded on the lower chord(s) and in a simply supported span, with supports at the lower chords at the outer node of the outer truss modules.

All calculations are based on the self-weight equivalent of 2,5m sections. It is obvious that in the hypothetical case where a 12m span will be assembled of 0,5m sections, the selfweight of that span is clearly higher. Compared to the allowable loadings this is not of very significant within the range of the loading tables. When in doubt make sure the deflections do not exceed the values as given in the loading tables for the given spans.

Stress limits inside the components of the truss-module

All data is based upon allowable stresses that are given in the German standards for the alloys used, referring to the standardised structural calculation methods for single truss-modules. Prolyte's choice of the German (DIN) standards is for several reasons. A major consideration being the severe and conservative approach of DIN on the one hand, and the ready recognition of TÜV (German certification body) approvals by a number of other certification authorities in other European countries and overseas. The allowable stress calculation methods may be conservative, but it is wise to stay on the side of caution, and it can be checked independently. We will gladly leave 'creative' calculation and testing to our competitors.

Deflection

The permissible amount of deflection is not usually discussed. Varieties of standards for structural calculations allow for very different amounts of deflection. No exact deflection limit for the entertainment industry has been formulated in any of the general standards for aluminium structures. Manufacturers either show the amounts of deflection in the tables without stating to what limit the allowable deflection is taken, or do not mention any deflection what so ever, and save some money by not even calculating it and checking these values. Thereby leaving it up to the customer to find out what is acceptable (or applicable!) to the particular situation. Low levels of knowlegde combined with low levels of information leads to lower levels of safety as well. Prolyte adheres to an allowable deflection of 1/100 of the length of the span:
A 12m span shall deflect no more than 0,12m = 12cm at the given maximum load; this includes the self-weight of the truss. Specific applications might even require a lowering of the deflection level, for instance when curtains are used. We have verified the deflection on a number of occasions at our test facility. The values given in the tables prove that our products do meet the deflection data consistently, even on trusses that were in use for a couple of years.

Secondary failure processes

When extending the spans the selfweight of the truss becomes predominantly important, at a certain point even limiting: the truss would collapse under its own weight if the span is increased enough.
A slightly conservative approach in this respect is certainly not overdone. When allowable stresses are taken in consideration this could open up the possibility for failure from structural

instability, as a result of deformations of the truss as a whole. Even with the internal diagonal cross-braces that are a standard feature in the square and rectangular trusses produced by Prolyte, slight mistakes made by the rigger can have serious effects on the structural stability of the truss. The effects of this are increasing by square root of the length extension.

Some simple formula's to remember and use

About 95% of all the loading of trusses is Uniformly Distributed and these loads are applied to trusses that are in a horizontally position. The first thing that can be given is the approximate resultant support reaction per point as percentage of the total load, when we take in consideration that supports are never completely at the far end of a truss, but often allow for a short cantilevered section.

But what about pointloads somewhere randomly placed in between two supports?
We still would like to know whether out chainhoists or wind-ups or exhibition-booth walls are safely loaded.
The first thing is common sense once more. With the load applied straight underneath a chainhoist, it is obvious that the other hoist is "feeling" nothing at all except for half of the weight of the truss of course.
In a formula this would be expressed as:

Sr1 = 1* Lw + 0,5*Tw **and** Sr2 = 0*Lw + 0,5* Tw

Where:
Sr = resultant load at the Support
Lw = weight of the pointload
Tw = weight of the total span of the Truss

Put that same amount of load right in the middle and it is again outspoken obvious that both hoists will be as follows:

Sr1 = 0,5*Lw + 0,5*Tw **and** Sr2 = 0,5*Lw + 0,5*Tw

Slide this load to the right, ending at two/thirds of the length of the span and now we find:

Sr1 = 0,33*Lw + 0,5*Tw **and** Sr2 = 0,67*Lw + 0,5*Tw

And we find that the closer the load is towards the support, the higher the amount is that needs to be supported.
Again nothing like rocket science, but pure common sense. And it is also clear right away that the specific amount is related to the relative distance: the further away that load is the lesser the amount is of what is to be supported.

Repositioning that same load to three/quarter of the length of the span and now we find:

Sr1 = 0,25*Lw + 0,5*Tw **and** Sr2 = 0,75*Lw + 0,5*Tw

Similarly we could put two, three, four or many pointloads in between the supports and than check these one by on for their resultant supportload. In general one has to start knowing the weight of the luminaires that are to be applied, and when 10 or so identical luminaires are put at more or less equal distances between supports this is almost the same as an UDL situation and no one would bother to start a one-by-one calculation.
However when serious weights come into consideration checking the supportload is mandatory with regard to shearforces in the truss, the slinging factor and the hoist capacity.
Never guess that its gonna be allright, the amount of people that always guess the right thing is extremely limited, and a wrong guess might easily lead to a falling load!
When in doubt: don't do it! There is no sorry for unsafe practice!

C. READING OF THE TABLES

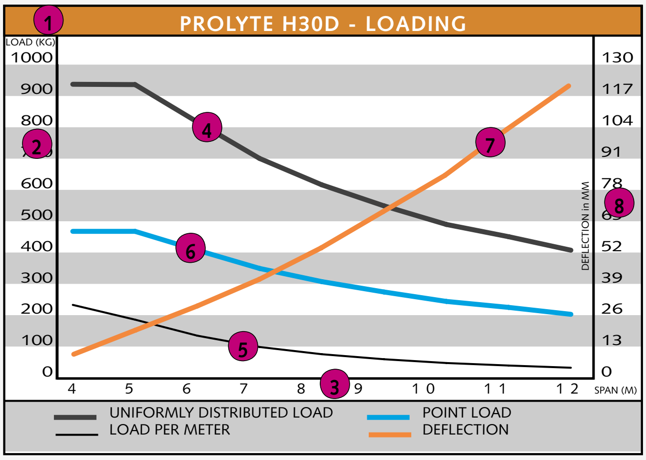
How to read the loading tables

Length	column 1-2
UDL	column 3-5
Deflection	column 6-7
CPL	column 8-15
Weight	column 17

Values in metric units: black on white printing
- Metres and millimeters for the dimensions of spans and deflections
- Kilograms and kilograms/metre for the allowable loads

Values in imperial units: black on grey printing
- Feet and inches for dimensions of spans and deflection
- Pounds and pounds/foot for the allowable loads

1 The first column shows the length of the span in metres.
2 The second gives the length of the span in feet.
3 The third column shows the allowable Uniformly Distributed Load: as the total load in kilograms.
4 The UDL in kg/m
5 The UDL in lbs./ft.
The columns showing the deflection represent the values of the deflection in the spans with the maximum value for the UDL.
6 Deflection in mm
7 Deflection in inches
The deflection values include the self-weight of the truss.
8 The allowable single load in kg's and pounds applied to the
9 centre of the truss-span (CPL)
10 The amount in kg's and pounds of the allowable two points
11 loads, dividing the span in to three.
12 The amount in kg's and pounds of the allowable three points
13 loads, dividing the span in to four.
14 The amount in kg's and pounds of the allowable four points
15 loads, dividing the span in to five.
16 Shows the actual weight of the truss-span itself.
This additional information saves time for people working at the rigging pre-production and is the riggers' quick 'on the spot' check to see how much weight is actually formed by the truss itself.



D. READING THE GRAPHS

The graphs are "summary's" of the data given in the loading tables.

1 Each graph represents a specific type of truss in a simply supported span.
2 In the vertical left hand axis the allowable load is shown in kilograms.
3 On the horizontal axis the length of the span is shown in meters.
4 The black fat line shows the total allowable load on the whole
1 span in UDL ("Q").
5 The black thin line shows the total allowable load UDL per
1 meter ("q").
6 The blue line shows the allowable Central Point Load.
7 The line equivalent to the serie color (orange in this case) shows the relative curve of deflection in UDL. This is not to scale in the graphs, but indicates at what point deflection gets to be limiting in allowable loading.
8 In the vertical right hand axis the deflection in mm is shown.

PROLYTE X30D - ALLOWABLE LOADING

		UNIFORMLY DISTRIBUTED LOAD			DEFLECTION		MAXIMUM ALLOWABLE POINT LOADS								
m	ft	total	kg/m	lbs/ft	mm	inch	kg	lbs	kg	lbs	kg	lbs	kg	lbs	weight
4	13,1	888,0	222,0	149,4	13,0	0,5	444,0	980,1	333,0	735,1	222,0	490,1	184,7	407,7	18,3
5	16,4	710,0	142,0	95,5	21,0	0,8	355,0	783,7	266,3	587,7	177,5	391,8	147,7	326,0	21,9
6	19,7	594,0	99,0	66,6	30,0	1,2	297,0	655,6	222,8	491,7	148,5	327,8	123,6	272,7	25,2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	26,2	440,0	55,0	37,0	53,0	2,1	220,0	485,7	165,0	364,2	110,0	242,8	91,5	202,0	32,1
9	29,5	387,0	43,0	28,9	67,0	2,6	194,0	428,3	145,5	321,2	97,0	214,1	80,7	178,2	35,7
10	32,8	350,0	35,0	23,5	83,0	3,3	175,0	386,3	131,3	289,7	87,5	193,2	72,8	160,7	39,3
11	36,1	319,0	29,0	19,5	100,0	3,9	160,0	353,2	120,0	264,9	80,0	176,6	66,6	146,9	43,0
12	39,4	288,0	24,0	16,1	118,0	4,6	144,0	317,9	108,0	238,4	72,0	158,9	59,9	132,2	46,4

1 inch = 25.4 mm | 1m = 3.28 ft | 1 lbs = 0.453 kg | 1 daN = 10 N ~ 1 kg

PROLYTE LADDER TRUSS - ALLOWABLE LOADING

TYPE	X30L		H30L		X40L		H40L		S36L		S52L		S66L	
m	POINTLOAD	UDL/m	POINTLOAD	UDL/m	POINTLOAD	UDL/m	POINTLOAD	UDL/m	POINTLOAD	UDL/m	POINTLOAD	UDL/m	POINTLOAD	UDL/m
2	176,0	176,0	206,2	206,2	250,0	250,0	292,4	292,4	369,4	369,4	580,6	580,6	735,6	753,6
3	52,0	34,0	60,6	40,4	74,0	49,3	86,1	57,4	108,1	72,1	170,1	113,4	220,8	147,2
4	22,0	11,0	25,8	12,9	31,0	15,5	36,5	18,3	45,7	22,8	71,9	36,0	93,4	46,7
5	11,0	4,5	13,8	5,5	16,1	6,5	19,6	7,8	25,2	10	39,6	15,8	51,4	20,5
6	6,6	2,2	7,7	2,5	9,2	3,1	11	3,6	13,6	4,5	21,4	7,1	27,7	9,2
7	4,2	1,2	4,9	1,4	5,9	1,7	6,9	1,9	8,7	2,5	13,7	3,9	17,7	5,1
8	x	x	x	x	3,9	1,0	4,8	1,1	5,7	1,4	9,3	2,3	12,1	3,0

X = NOT ALLOWED I APPLY LOADS TO BOTTOM CHORD I SUPPORT POINTS MUST BE HORIZONTALLY STABILIZED

ALL LOADS IN KG

E. LOADING OF LADDERS

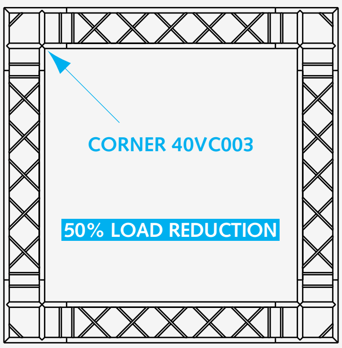
A vast number of questions continue to arrive at our engineering department regarding the loading capacity of ladders. We often have to disappoint our users because ladders are a poor choice when loading is the main parameter, even for small loads like projection screens or banners.
Ladders do not posses the physical capability to prevent the sideways deflection caused as a result of compressive forces in the top chord. Sideways ladders are no better than a single tube! Sideways deflection leads to buckling. Buckling is an instability phenomenon that causes failure of a structure. Structure failure is exactly what we do not want to happen, at least, not outside our testing facilities. The loading capacity of vertically (upright) used ladders, as a free span, is given here. It is obvious that a stabilizing system will improve the capacity of a free span, but this often requires more effort and cost than using a spatial cross section truss. No data is given for ladders in a flat position. When used in a horizontal (flat) plane, a ladder is no better than the two tubes with which it is built.

Rule of thumb

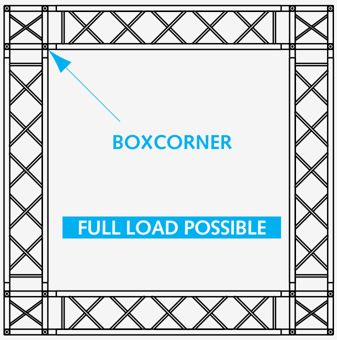
When a ladder is supported of the top chord at approx. every 2.00 meters, the loading capacity is approx. 40% of the loading of a similair box truss.

F. LOADING OF CORNERS

Where grid-structures are built of more combinations of truss-runs, the resultant loading on the supports also gets more complex. With the limited capacity of standard truss-corners, like the T- & X-shape corners the loading of the straight runs should be done with extra care.
A simple example makes clear that the same complications do not arise when BOX corners are used. Box corners are designed to withstand complex loading situations apparent in truss grids or structures. Standard corners should be used with more care and insight in the loading situation within your truss grid. When standard corners are used within a more complex set up they are easily overloaded, without having reached the allowed full load of the straight truss run.



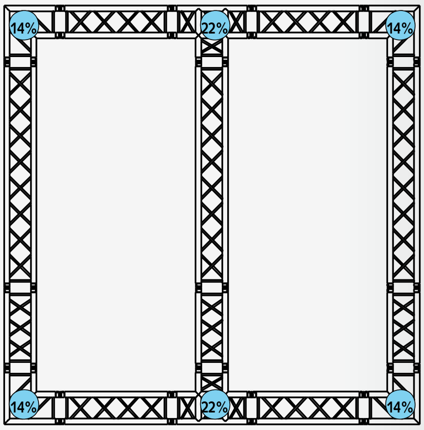
In a grid with standard corners, the maximum permitted load of a single span should be reduced to 50%.
Each corner is loaded with the resulting forces from two spans (one on each side of the corner). Standard corners are not designed to be able to withstand this double loading.



In a grid with box corners the maximum permitted load of a single span does not have to be reduced. Each corner can be loaded with the resulting forces from two spans (one on each side of the corner).
Box corners are designed to be able to withstand this double loading.

Calculating your loads within a truss grid however is a complex matter. We give some simple examples just to illustrate the hazard of overloading. For more background knowledge we refer to the standard mechanical engineering workbooks, or contact your structural engineer.

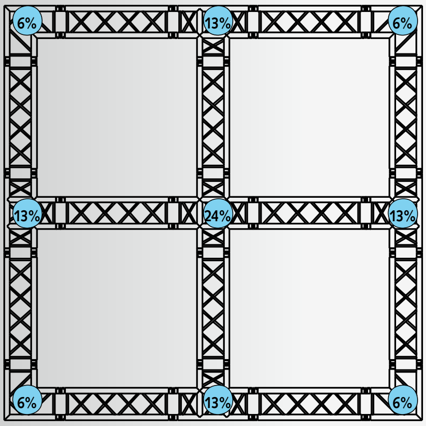
Providing each corner is supported a schematic representation of the support reactions as a percentage of the total UDL in the set up of a square grid with one middle beam is approximately as follows:



When the loading tables are checked for the maximum allowable point load in the shortest given span (e.g in X30D = 378 kg) 50% of this amount should be used (~187,5).
The highest support load percentage found shall never be more than that, meaning that the loading on such an X30D grid must never be more than a total of 860 kg UDL resulting in:

120kg 190kg 120kg
120kg 190kg 120kg

Providing each corner is supported a schematic representation of the support reactions as a percentage of the total UDL in the set up of a square grid with an internal cross-trusses in two directions is approximately as follows:



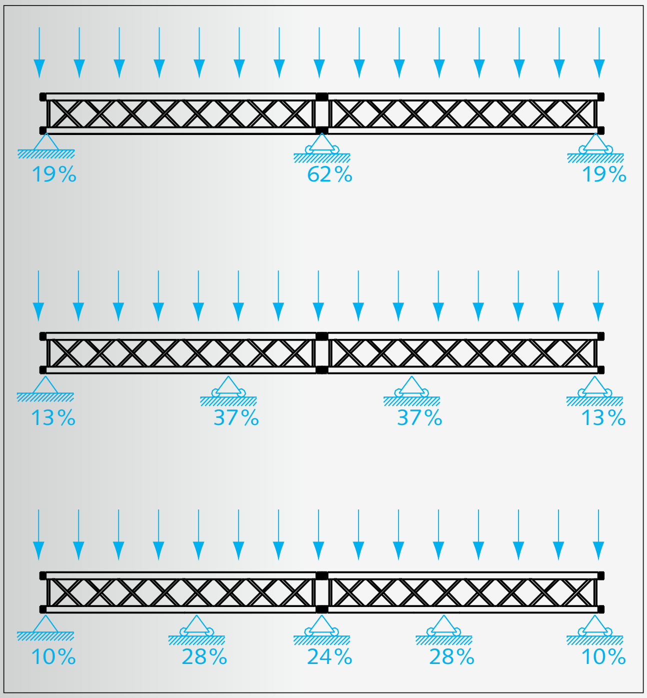
When the loading tables are checked for the maximum allowable pointload in the shortest given span (e.g in X30D = 378 kg) 50% of this amount should be used (~187,5), to find the allowable load for that C-016 corner. The highest support load percentage found shall never be more than that, meaning that the loading on such an X30D grid must never be more than a total of approx. 760 kg UDL resulting in:

48kg	95kg	48kg
95kg	190kg	95kg
48kg	95kg	48kg

It is again stressed that this particular grid-configuration has about a quarter of the total UDL concentrated into this one X-corner.

G. LOADING OF SPANS

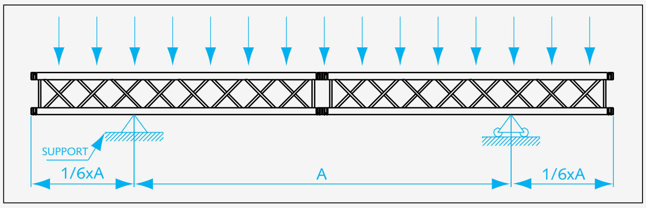
Continuous spans, on more than two supports are known as statically undetermined spans. The calculations for the allowable loading are complex.



Continuous spans, on more than two supports are known as statically undetermined spans. The calculations for the allowable loading are complex. The figures show the approximate resulting load at the suspension or supporting points. As it is apparent, a hoist can be easily overloaded if these forces are not taken into account. The figures show the approximate resulting load at the suspension or supporting points when loading is Uniformly Distributed. As it is apparent, a hoist or other type of support position can be easily overloaded if these forces are not taken into account, and the extra attention for the correct slinging is most important at the central supports, while the end-support loads are considerable less.

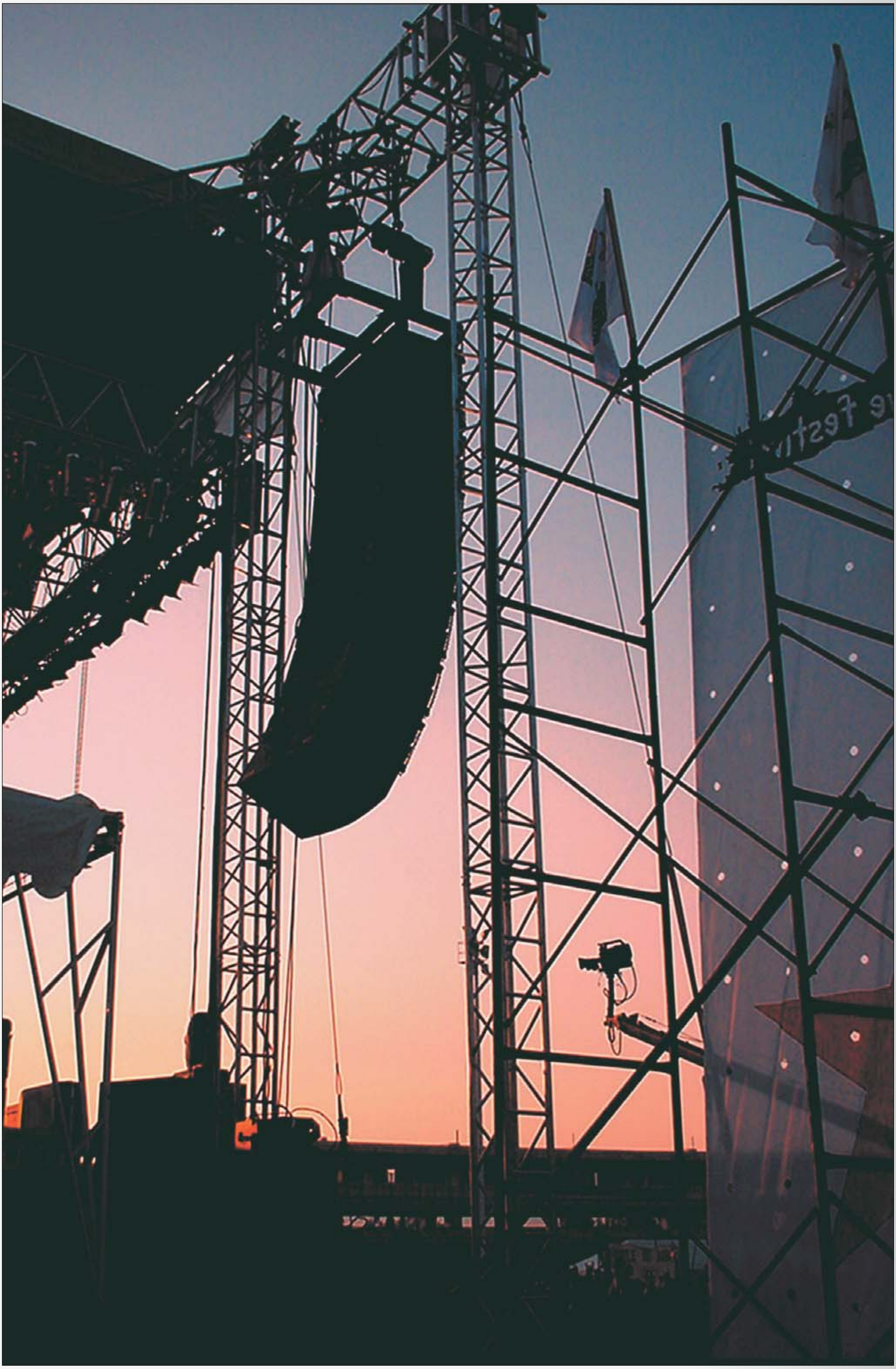
H. LOADING OF CANTILEVERS

When truss-spans are limited, it is a possibility to extend the truss on each side of the support or suspension point. The truss, loaded in a UDL, can be extended to each side by 1/6th of the length of the span inside the supports.



When truss-spans are limited, it is a possibility to extend the truss on each side of the support or suspension point.
The truss, loaded in a UDL, can be extended to each side by 1/6th of the length of the span inside the supports. However, this is only permissible if the total load per support point does not exceed the allowable shear force.
Thus ensuring that the 'bending moment' at the supports, remains less than the one in the centre of the span.
Cantilevers on other objects (walls, sleeve blocks, side of a truss-span) must always be checked separately against the capacity of the connection parts, wall mounting bracket or plate, the torsion effect, etcetera.

However, this is only permissible for the larger spans, and only if the total load per support point does not exceed the allowable shear force, which can be read from the highest allowable pointload given for the shortest span of that particular truss. Thus ensuring that the 'bending moment' at the supports, remains less than the one in the centre of the span. Cantilevers on other objects (walls, sleeve blocks, side of a truss-span) must always be checked separately against the capacity of the connection parts, wall mounting bracket or plate, the torsion effect, etc.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SLINGING OF TRUSS

TECHNICAL MATTERS

A. HOW TO SLING THE TRUSSES

Our truss series have a variety of different cross sections, but for every truss type there are three basic slinging methods. Almost all standards about slinging anywhere in the world do only recognize these three essential methods, with some variation in defining the additional wrapping.

When 'thinking' as an aluminium round-tube would do in its position as one of the chords of the truss, there is always a preference for a nicely spread area of suspended load pressing against the tube.

It's not hard to understand that contact – and thus: bearing - stresses on the surface and in the tube's wall, will be much greater when resting on the tip of a nail, covering e.g. 1 mm^2, than when resting in a 50mm wide clamp like CLP-535, that allows for an area of appr. 1/3 of the tube to be supported, giving about 250 mm^2 of aluminium area to support the same amount of load. When a load of 500kg UDL is supported by the whole truss, resting on the four lower members, this would mean a load of 125 kg (= appr. 1250 N) to be supported per lower chord –forgetting for a moment the self-weight of the span.

Thus the bearing stress in the case of the nail would be ~ 1250 N/mm^2, while in the clamp area this would reduce to only 1250/250 = 5 N/mm^2. As the latter will be no problem at all, the nail-point situation exceeds the allowable bearing stress by far, resulting in a punch effect, and effectively puncturing the round-tube.

Nobody will be using a nail, but certainly wire-ropes and chains have much less surface contact-area with the aluminium tubing, and therefore could much more easily damage the chords surface or even roundness. This is certainly a point of attention for the D- and X-series, where thin-walled round-tubes are used for the chords. Not just for reasons of wear or the sawing and grinding effect of wire-ropes it is advise do always use 'sleeved steels' when trusses are supported. And even then care must be taken. From experimental research at Prolyte it is shown that even the best types of 3mm thick fiber-reinforced nylon hoses, used as protective jackets around the 10mm diameter wire-ropes have a limit to their use. Supportloads of appr. 1800kg (t.i. 900kg/chord) made the nylon layer fully disintegrate in between wire-rope and truss-chord, only leaving the armour fibers in place. The protective effect towards the aluminium of the tube, not being 'eaten' by the steel of the wire-rope, however was lost. Thus using 1 ton motors to the full extend leaves a factor of safety for nylon sleeve survival of only about 2:1, while the wire-rope itself remains at appr. 10:1 depending on the angle of the basket's legs with the vertical of course.

When using sleeved wire-ropes for slinging of truss this is certainly a matter of systematic inspection, and the carefull rounding of a truss-tube does not allow for considerable weights, even though these forces are fairly well spread.

It must be stressed that these type of sleeves do not provide very adequate protection to the wire-ropes themselves, when being used on structural steel beams where the same load (+motorweight) is concentrated into the very narrow area of the beam-flange edges.

When wire-ropes are used for slinging another possible method for aluminium chord protection is the use of plastic C-shaped tubes of about 100mm long that are 'clicked' over the truss-chords at the required suspension point. These can be made from regular type of rainwater pipes of with a section is removed to fit across the chord-tubes. In that case any regular wire-rope steel can be used to sling-support the truss, and discard of such inexpensive pieces of equipment can not be a serious topic when safety comes to mind.

Chain slings ar much less likely to be used because of pricing and weight, but truss-chord protection is again an issue to keep into consideration.

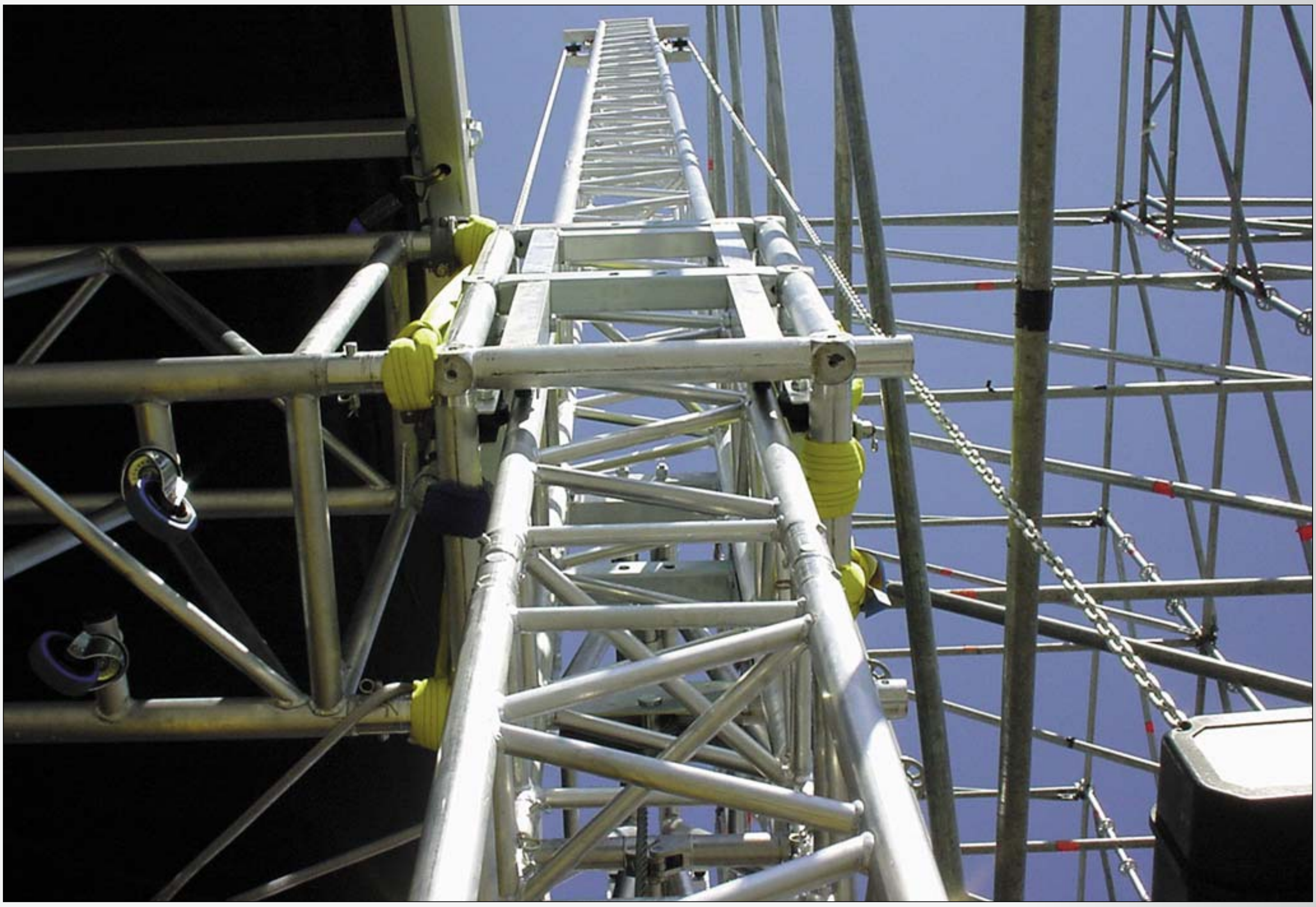
In general the slinging of truss shall first and foremost have effect on the lateral shear-force in the truss cross-section.

There is much less to almost no influence on the safety of the free spans of the truss with respect to the bending moment. But in the continuous beam type support of trusses, the inversion of the bending stress character at the centre supports leads to tension in the top chord and compression in the lower ones. This again needs the care of slinging / supporting the truss in the lower nodes.

Direct hitch ('straight vertical pull' hitch)
This method is only found where an extra piece of suspension equipment is used, such as a bracket with an eyebolt or lifting ring fitted onto the truss-module. The sling (round sling, wire rope or chain) can then be attached to this by means of a hook or shackle.
When all safety aspects are considered it is obvious that use of only one single suspension sling is less favourable.

Choke hitch
This method should only be undertaken using pairs of round-slings or 'steel-flexes' in each support-point. Each one of this pair supports one side of the truss beam-cross-section. These slings can be choked to the bottom chords, then wrapped once around the top chords before attaching the hook or a shackle. Wire rope or chain slings are impossible to use with this method.
Furthermore, this method degrades the slinging factor to 0.8 times the WLL (workload limit) of the sling. Even when using two slings, the net result will only remain at 1.6 times a single sling WLL. When all safety aspects are considered it is obvious that use of only one single suspension sling is less favourable.

Basket hitch
This is the most used method for suspending truss-beams. The slings, no matter what type, are placed underneath the bottom chords and wrapped, or are run straight up on each side of the truss and wrapped around the top chords before attaching the hook or shackle.
This method improves the slinging factor by 1.4 to 2 times the WLL of the sling, dependent on its outer angle with the vertical. Angles over 45Þ are not allowed under the new European Standards, thus the inclined angle of a basket-truss-wrap is never more than 90Þ. Please ensure that the sling is attached next to a horizontal cross brace, so that it is able to absorb the compressive force between the chords.
In general, a truss could be slung from just the top chords, but this could reduce the 'shearing' capacity by 50%. If, for some reason, this needs to be done, make sure that the total loading of the truss is not in excess of 50% of the relevant figure given in the loading tables (see part 2).
Suspension of any type of truss from just one chord is never acceptable, unless this would be for decorative purposes only, and no load is attached to the truss.
When all safety aspects are considered it is obvious that use of only one single suspension sling is less favourable.



B. SLINGING WITH WHAT

For support of trusses a series of fixed shaped or flexible lifting equipment tools can be applied.
In the entertainment industry flexible slings are predominantly used as lifting tool.
Wire-rope (steels), chain (clutch-chains) and round-slings (spansets) are very common pieces of lifting equipment.

Round slings

When looking at a lifting sling from an aluminium tube's point of view, it has a preference for supple, soft and non-abrasive slings. A roundsling will be the prefect choice.
But round slings are made of polyester, which melts at appr. 250ÞC (~480ÞF). and the allowable temperature for this material to be used at is limited to 100ÞC (~212ÞF). Many countries have fire-regulations that don't allow this kind of suspension equipment in situations were hazards from heat sources are present. Think of a light source as a heat generator at the housing, and a heat radiator in the beam are present. Research has shown that 2kW luminaire-housings can reach tempeartures of about 190ÞC (~370ÞF), with the truss-chord straight over it being almost 140ÞC (~280ÞF). Not adding a safety is a situation like this will be pure neglicence.
Accidents have been reported of round slings being melted by spots or the heat of the rays, and as a result trusses have fallen. When round slings are used, a safety backup must be applied by a wire-rope or chain sling.

Wire-rope slings

The next best flexible type of thing to use for suspension of trusses will be a wire rope, but only one with a good cover or sleeve to protect the aluminium truss-chords from abrasion by the hard and rough wire-rope surface.
Wire-ropes do resist higher temperatures, but when used as slings this depends partly of the type of termination. Wire-ropes with 'return eye' type of termination with an aluminium swage sleeve ('Talurit') are allowed up to 100ÞC only. But when used with the protective nylon-hose jacket around the steel, this also does insulate the direct heat transfer from lower chord to wire-rope, as would any other type of insulating material in between both items. Furthermore heat-dessipation along the wire-rope steel itself reduces the temperature before being transferred into the ferrule, and all of this makes it more acceptable in a risk-analysis, when compared to polyester roundlsings.
A next step will be using wire-ropes with steel compression sleeves or wire-ropes with 'flemish eye's' type of spliced and swaged terminations. However improvements on the temperature resistance of the slings might surely be a good thing to aim for, when they get much better than the temperature hazard of the truss itself the effectiveness has reached a sensible limit. At one point the aluminium of the truss itself starts loosing strength and at 75ÞC (167ÞF) about 95% of the original tensile strength remains, at 100ÞC (212ÞF), this is already reduced to 85%, and at 150ÞC (302ÞF) only 70% and finally at 200ÞC (392ÞF) only 50% of the original strength remains.
It must be stressed that in tropical area's with lots of generic lights, or in Film or TV-studio's when the lights can be used in a specific setting for a considerable length of time, the actor might still pretend - in take 56 - that he is very happy with the heat of the moment in that particular scene, the truss might very well be not! Wire-ropes are more difficult to apply in the preferred slinging methods of chokes and wraps, thus leave less possibilities for best support action.

Chain-slings

Chain slings do allow for use at high temperatures but also need protective cover and are difficult to apply in the preferred slinging methods. When the temperature limit demand is set at a level of more than 200ÞC, one must realize that the complete truss out of aluminium itself is not sufficient anymore.
At these types of tempartures the reduction of allowable loads are about 50% of the original truss capacity and in all honesty we might consider to advise a truss in steel.
So when chain-slings are preferred as truss slinging equipment the specific arguments must come from the users themselves as other types of slinging material are just as good or even better in most applications.

Wire-rope filled round-slings ('steel-flex')

In the last four years research in the USA and in the Netherlands has given the (next but) best flexible suspension item for trusses. The idea was to replace the heat-vulnerable polyester core of a roundling jacket by a great number of thin wire-rope 'yarns' in an almost identical 'endless' way.
Although no official standard has been set so far, in any of the countries involved, a number of rental companies already is happy to use these as a replacement for the polyester ones, and take part in the research efforts. Before standards can come into play it is needed that the experience from both manufacturer and user are well documented and added to the risk analysis that has to come with this type of product anyway.
When looking at this product from the point of view of an aluminium tube, this type of sling is surely to be preferred over the single 10mm diameter "sleeved wire-rope slings". The supported area is at least 4 or 5 times that of a regular wire-rope and when choked even better.
The heat resistance of the jacket may be still at polyester levels, but the hazard of failing suspension and falling trusses is reduced in great extend. The wire-rope core has better heat resistance than the truss itself. Prolyte Products endorses all innovations that add to greater safety in the entertainment industry and this is definitely on of them.
Prolyte is involved in experimenting and testing prototypes on it's truss-products and is in contact with manufacturers and consultants on setting standardization criteria that are to meet the strictest of safety requirements. Therefore Prolyte is proud to be contributing to the realisation of future standards. Check out our web-site on a regular basis and you might be the first to know.

Fixed shape support brackets

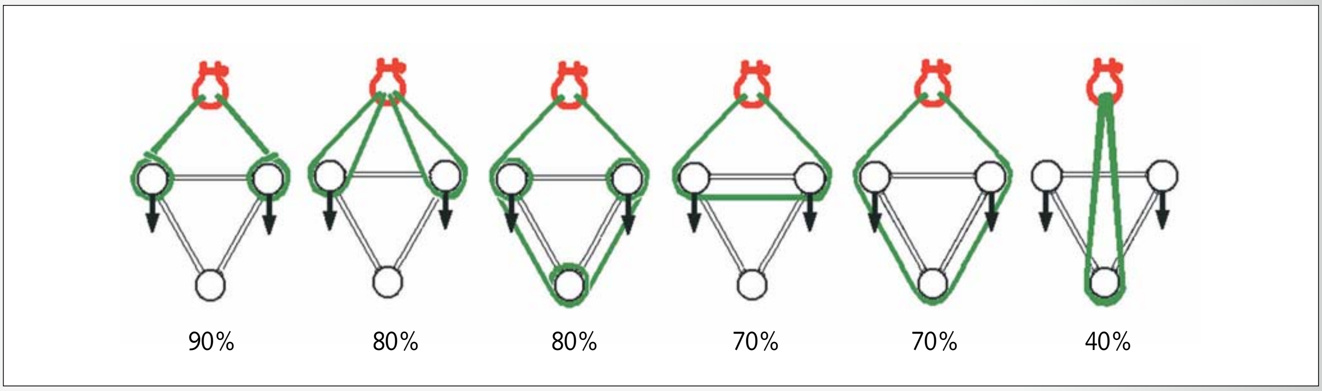
A last item to consider are the fixed-shape lifting brackets, generally using clamps of the types CLP-535 or CLP-587. These are produced for most truss-series and have in common that horizontal forces between the chords ar absent, and that fire-proofing is never a problem. Depending on the type of truss there are steel or aluminium versions (or both).
A small disadvantage is the fact that they can never be placed right at the node-point, but must always be as close to it as possible, and they definitely do take more time to put into place, certainly when to be fitted tot the lower chords. For permanent (or semi-permanent, like a TV-show running a couple of years) installations, these type of considerations are less important and thus fixed brackets more often found there. As far as the standadized slinging methods are involved these do not compare fully and are not take into further consideration.
Please contact Prolyte for possiblities, types and specs.

Lifting eyes

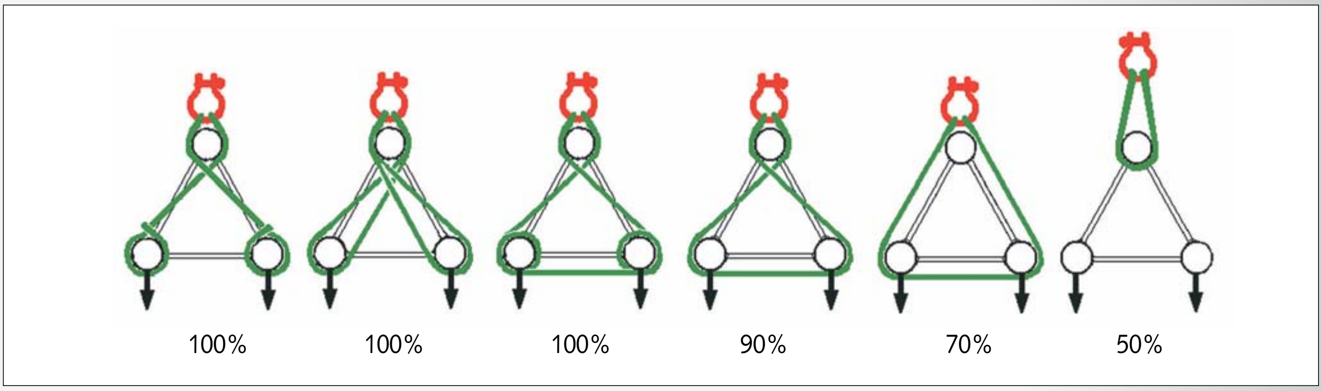
The last lifting feature that might be discussed is the special lifting eye that can be fitted onto the triangular boxcorners, leaving you not to wonder about which method and why, but do a straight vertical hitch.

Preferred slinging methods

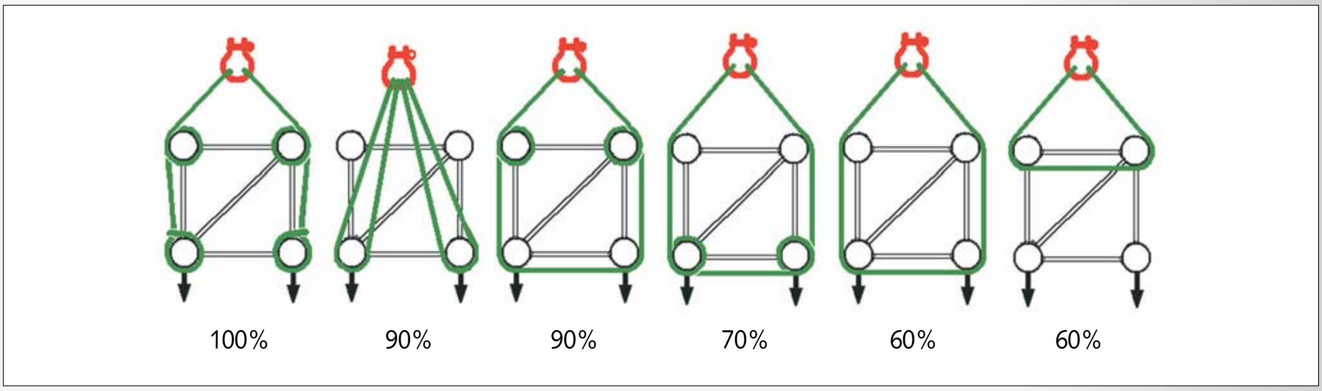
Based on shear forces in support points and added safety by using multiple slings.
All examples are based on roundslings. Slinging should be undertaken at, or as close as possible to, the node point. Please take note of the fact that if roundslings are used to sling the trusses an additional safety wire should be applied.



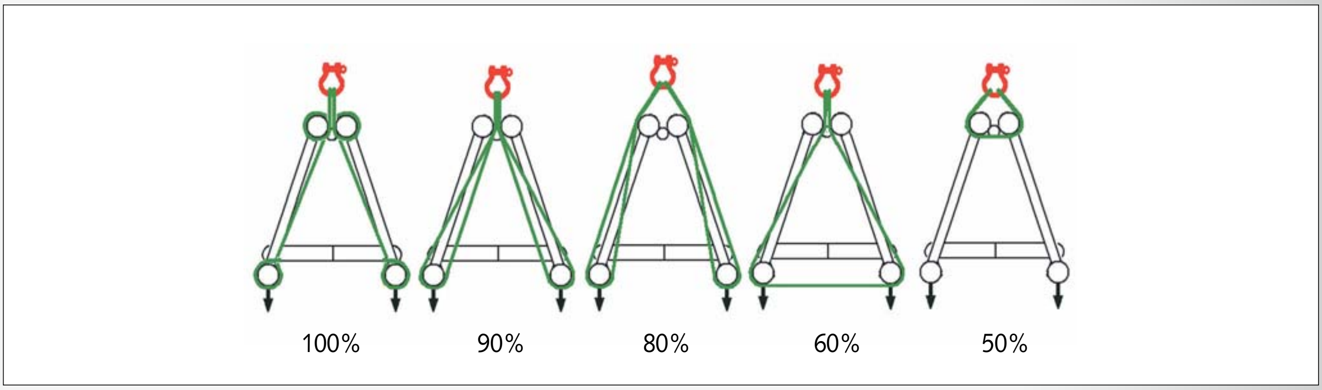
Decreasing safety in slinging from left to right. E20D, X•H 30D, X•H 40D. Apex down.



Decreasing safety in slinging from left to right. E20D, X•H 30D, X•H 40D. Apex up.



Decreasing safety in slinging from left to right. E20V, X•H 30/40V, S36R, S36V, S52V, S52SV, S66R, S66V.



Decreasing safety in slinging from left to right. S52F, S100F.

PART THREE TECHNICAL MATTERS

CIRCULAR TRUSS

TECHNICAL MATTERS

Prolyte is well known for their complete range of truss series. In addition to these series Prolyte manufactures circular trusses, curved trusses and arcs.
Prolyte is able to manufacture these curved trusses to a high degree of accuracy ensuring a perfect fit with no distortion.
All circular trusses are manufactured by a specialist department within the company; this department is equipped with state of the art welding jigs, most of which have been designed by our own R&D department.
These jigs produce circular sections ranging from the elegant E20 truss to the exceptionally robust S66 as standard items. This ensures that every segment of a circle can be mounted at any position, without affecting the integrity or overall shape of the completed circle.
Circular and curved trusses are available for every type of trussing, with the exception of the folding trusses (S52F, S100F and E15V). For further technical details on our circular truss systems, please refer to part three of this booklet.

Ordering a circular truss

When used for rental purposes we usually recommend ordering whole circles with 4, 8,12,16 segments. Constructed like this, the circles can be used in various structures as shown in the drawing. The number of segments that a circle will contain depends on the radius of the circle. The maximum tube length we can bend is 5 metres; therefore, no segment can be longer than this. On average lengths between 3 – 4 metres are the easiest to handle, transport and store; accordingly, we would advise our clients to keep this in mind when ordering. Additionally, for circles constructed from triangular truss please do not forget to indicate whether the apex should be inside, outside or on top.

Circle production

Although Prolyte has recently brought the production of circular trusses to the same level of machine aided manufacturing as the straight trusses, the production of circular and arched trusses will always differ.
The production of curved truss-components takes relatively more time. Each individual tube has to be bent to the specific radius that it will have once it will function as one of the chords in the truss cross-section. This means that in one curved truss at least two different tube-radii are present: the inner and the outer radius.
Each tube will be bent only over the arc-area that fits in between the 3 rolls; the loss on each bent curve will be around 20-25cm on each end.
Therefore a standard extrusion length of 6m will leave a curved length of app. 5,5m. This is limiting for the length of the individual arc's that constitute standard circles.

Another factor affecting the circle and arc production is the placing of the diagonals. Where this is easy done in preset diagonal positioning jigs for the straight trusses, there is (still) no such thing for the circles, and all the upright diagonals have to be positioned manually.

There is a limit in radius for each type of tube. If the radius is made smaller the truss will:

- Become deformed oval (10% change of dimension is take as the limiting state),
- Loose the shiny surface aspect, starting to show a 'crumbling' effect as a result of compressive forces on the inside of the curve.

The level to which bending can be done satisfactory is mainly depending on 3 properties:

- Outer diameter of the tube – this is directly influencing the moment of inertia and the resistance against bending
- Wall thickness of the tube - this is also influencing the moment of inertia and thus resistance against bending, where thicker walls tend to be less susceptible to surface-crumbling, they need a lot more time and energy to actually be rolled curve-shaped
- Alloy of the tube – the lesser quality alloys are cold deformed more easily.

We refer to circle diameters of outside dimensions of the outer tube. In bending the tubes, the inner side of the inner tube is limiting.

This gives the following absolute minimal circle diameters that we can produce without too much deterioration of the tube surface and loss of strength:

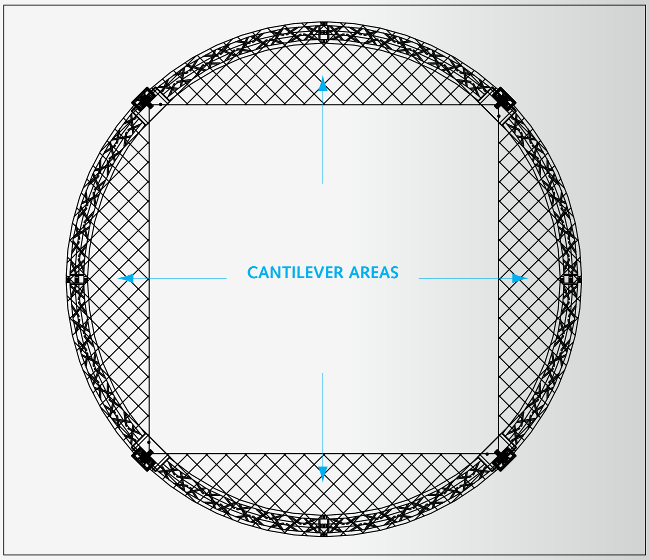
E type (32 x 1,5 mm)	minimum tube bending radius	400 mm
	minimum circle diameter	1,3 m
X type (51 x 2 mm)	minimum tube bending radius	1000 mm
X30 D&V	minimum circle diameter	2,2 m
X40 D&V	minimum circle diameter	2,4 m
H type (48 x 3 mm)	minimum tube bending radius	800 mm
H30 D&V	minimum circle diameter	2,2 m
H40 D&V	minimum circle diameter	2,4 m
S type (50 x 4 mm)	minimum tube bending radius	1300 mm
S36R	minimum circle diameter	3,2m
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

Loading of circles

Circular trusses in a horizontal plane and, to some extent, arc-sections are characterised by phenomena that definitely have a negative effect on the circle loading capacity.

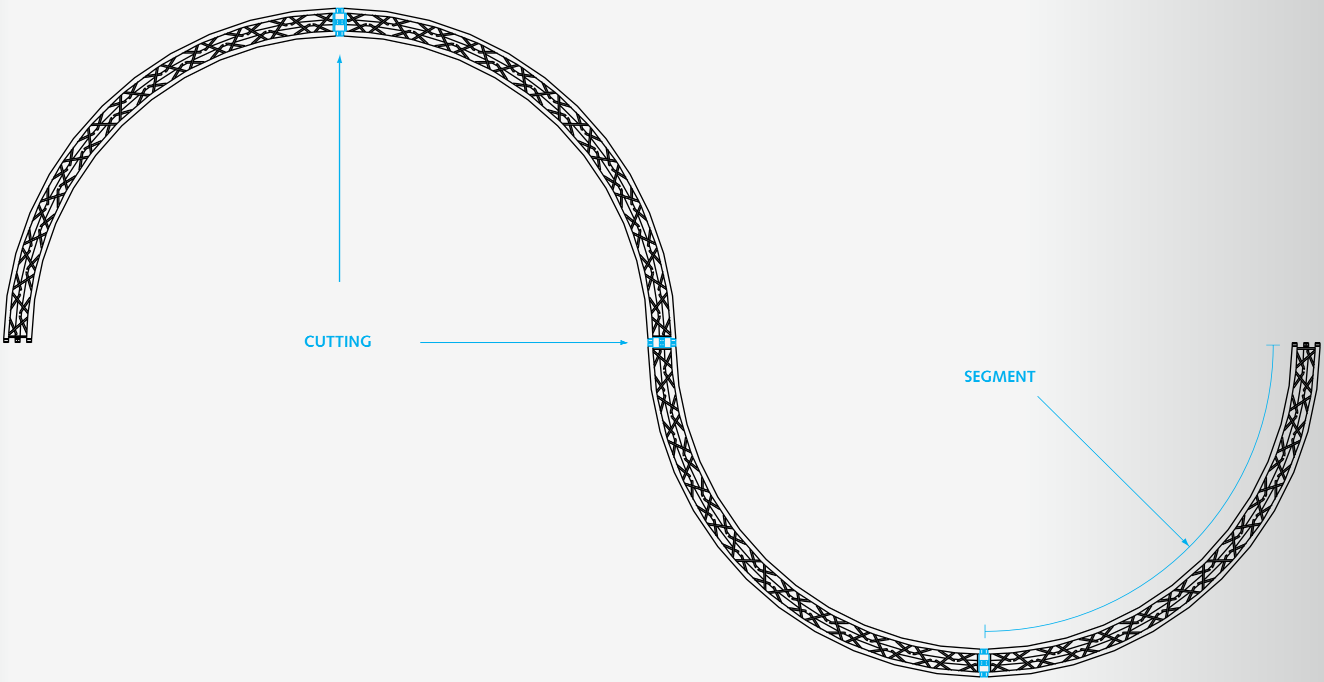
As the number of supports is, generally, as limited as possible in circles or arcs, this causes overhang in the bow, thus resulting in a cantilever area.
In a curve, the lattice bracing of the inner and outer 'faces' is always different. Accordingly, the buckling lengths of the diagonals in the outer face are always bigger; thus, an asymmetric force is being built into the truss.

The result of this is not only that the bending and shear forces are affecting the truss chords, braces and connections, but also that a rotation or torsion force has a distinct effect on the strength of the truss.



This torsion force influences the buckling load in the arc-spans. All these phenomena have powerful effects in the different types of trussing whether ladder, triangular, rectangular or square.
The minimum number of supports that is workable without any stability or balance problems is three.
This is the minimum that Prolyte use in the calculations of the standard loading data. Circles supported by only two points are fundamentally unstable and therefore considered unsafe.

Sometimes, a circle is angled, or moves during an event. Calculation of the allowable load in such circumstances is very difficult, as it is not always possible to predict accurately the resulting forces. Please consult our engineering department if this situation occurs.



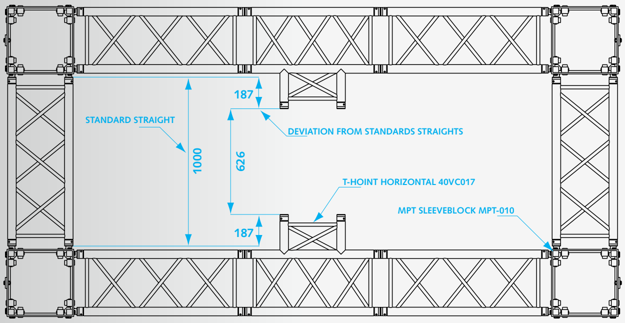
PART THREE TECHNICAL MATTERS

MISCELLANEOUS

TECHNICAL MATTERS

A. MEASUREMENTS OF COMBINED GRIDS WITH SLEEVE BLOCKS AND CORNERS

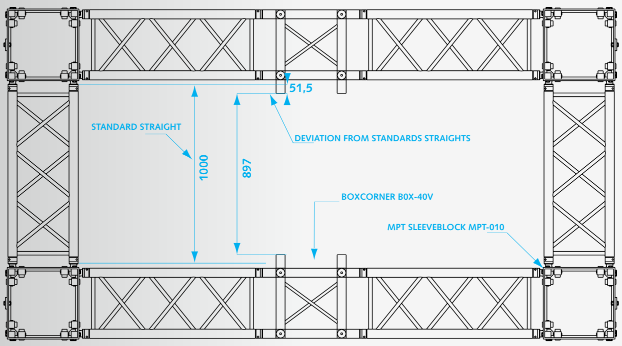
This figure shows the additional length of a standard corner, when used within an MPT system.



The use of standard X or H 40 corners within a MPT system.

The straight run of truss should be 2 x 187 mm = 374 mm shorter between the boxcorners to be able to combine it with the lengths between the sleeve blocks. Prolyte can supply special lengths or spacers.

This figure shows the additional length of a box corner, when used within an MPT system.



The use of 40 series box corners within a MPT system.

The straight run of truss should be 2 x 51,5 mm = 103 mm shorter between the boxcorners to be able to combine it with the lengths between the sleeve blocks. Prolyte can supply special lengths or spacers.

B. LOADING CAPACITY OF TOWERS

To what height can a single tower, a goalpost or a multi tower ground support system be built?
This question is mainly depending on these factors:

- Indoor or outdoor situation
- Stability
- Strength
- Horizontal loads
- Bending capacity of towers

Indoor or Outdoor

The difference between the two is as obvious as it is important. The direct influence of climate conditions on any building structure can be of great effect on the safety.

Wind:

- Can damage the skins of canopy and walls
- Can result in overloading of trusses and towers where skins of walls or scrims are attached to these as a result of 'double bending'
- Can lift a part or even the complete structure and subsequently even blow the complete structure down

Rain:

- Will cause towers and trusses to get slippery, thus reducing the safety when climbing these
- Can cause overloading of rooftops due to accumulation of water
- Can cause short-circuits in control systems or electrical hoists that have to bring the grid down
- Can cause saturated soils to weaken considerably and give way to the pressure from the load transferred by the towers

Lightning strike:

- Can hit the towers, causing severe personal safety risk as well as disablement of all electric and electronical systems in or on the structure

Temperature:

- Solar heat will cause towers and trusses to get very hot, thus reducing the safety when climbing these. Gloves are needed to protect the skin from contact heat. In combination with generic lighting instruments burning for longer periods (> 1 hour) truss chords can reach temperatures in excess of 120ÞC. This is in excess of the guaranteed safe temperature of polyester roundslings!

Each of these factors can represent great safety risk to eithermaterials or persons. Subjection to climatic conditions in outdoor environmentsneeds to be accompanied by a wide range of safety precautions to be taken by the project coordinator.

Stability

Stability is the capability of a structure to retain its structural shape and position and not collapse, buckle, slide or topple over. Apart form the amount of the load the position of the load, in regard to the centre of gravity, within the structure is important. A lot of loading combinations are possible. We just give a few rules of thumb:

- Vertical loads shall be over the centre of gravity of the tower and its base. No horizontal loads are to be present.

Single tower & goalpost height in outdoor use shall not exceed 3 times the width of the base:

- MPT-011 outriggers cover a surface of 0,9 x 0,9m, height is limited to 2,7 m.
- MPT-012 outriggers cover a surface of 1,9 x 1,9m, height is limited to 5,7 m.
- ST-011 outriggers cover a surface of 1 x 1m, height is limited to 3 m.
- ST-012 outriggers cover a surface of 2,1 x 2,1m, height is limited to 6,3 m.

Single tower & goalpost height in indoor use shall not exceed 4 times the width of the base:

- MPT-011 outriggers cover a surface of 0,9 x 0,9m, height is limited to 3,6 m.
- MPT-012 outriggers cover a surface of 1,9 x 1,9m, height is limited to 7,6 m.
- ST-011 outriggers cover a surface of 1 x 1m, height is limited to 4 m.
- ST-012 outriggers cover a surface of 2,1 x 2,1m, height is limited to 8,4 m.

Multiple tower systems used indoor with no side loading ensure a sufficient stability from the sleeve block guiding wheels along the towers. The overall distance of the base-ments should be more than 1/4 of the total height of the system.
Multiple tower systems used outdoor, have to have all the guy-wires, base distance units (compression bracers), and possible ballast as indicated in manuals or structural reports.
Roof systems with covered canopy are not to be build without guy-wires, base distance frames, and ballast.

Strength

This is the capability of a structure to retain its structural shape and not break or deform permanently when under load. Strength is determined by the size of the truss as well as of the area of the cross-section of the members.
As each truss and tower is different, is it necessary to check each structure on these main factors:

- Type of loading (UDL, CPL, multiple point loads etc.)
- Amount of load(s) applied
- Allowable bending moment, highest in the centre of a span or at the support point of a cantilever or tower. The chords and the connection parts are the limiting factor for the bending moment.
- Allowable shear force, highest at the position of the supports or at the position of point loads. The dimensioning and positioning of the diagonal bracing is the limiting factor for the shear force.

Horizontal loads

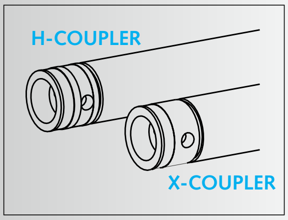
This is often an under-estimated type of loading. It can be present in many forms: wind, projection screens, canopy skins, guy-wires and ropes, etc.
In the loading tables the allowable load in a vertical direction is given. A simultaneous loading in any other direction to a truss results in additional bending forces. These can easily lead to overloading the truss due to bending stresses in one or more chords.
For a number of truss types only vertical loading is allowed: S36R, S52F&V, S66R&V and S100F.
When these trusses are side loaded, adequate measures need to be taken to ensure that these loads are absorbed in compression (e.g. additional truss) or tension (e.g. wire ropes) bracing elements.

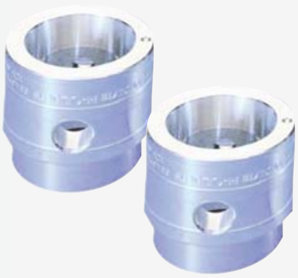
Bending Capacity of towers

If a tower is only vertically loaded there is a downward force along the chords setting these in compression. Forces along the axis of the tower or truss are called axial loads or normal
forces. When side loads are present as well these will try to make the tower fall over. A bending force is present acting sideways to the axis of the truss or tower.
At the base or the position where the side force is applied to the tower or truss there is a shear force, trying to 'slide' the truss away from it's fixation point or flattening the cross-section at the specific position. The bending moment is depending on the amount of force combined with the length of the arm. It is important to keepcareful watch over both. The allowable bending moment is given for each type of truss and tower.

Rigging towers

Originally designed to allow for easy and safe flying of PA-delay-clusters in large-scale concerts or festivals, these towers now find a variety of applications. Where standard stand-alone towers (or even wind-ups like Genie towers) could very easlily turn out to be a pain to work with and be unstable and unsafe, this system shows to be much more versatile. Its main importance being an angled tower and thus leaving a free suspension and working area underneath and in front of the hanging point.
With V-shaped groundtruss-setup no obstacles are met when moving the load(s) to the tower, and because of this set-up additional ballasts with respect to wind-loading can be greatly reduced. The effect of the wind however even in this type of tower does require a tying down of any load that might otherwise start swaying.
As always Prolyte uses as much standard truss-modules in these towers to allow for efficiency of use of the product outside of the outdoor season.





C. DISTINCTION X AND H TRUSS

Distinction X & H

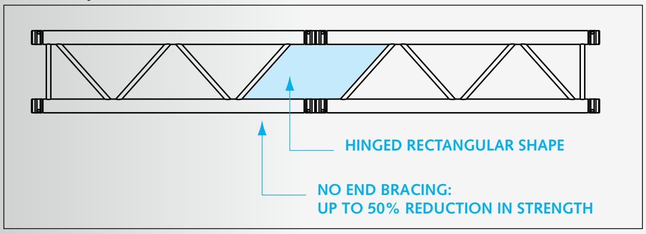
1. The outer diameter of the X-chords are 51mm (~ 2 inch) and of the H-chords 48 mm (1,889 inch)
2. H truss has a 25-30% higher self weight than X truss.
3. H truss has an added second recessed ring in the coupler receiver next to the Prolyte-embossed ring.

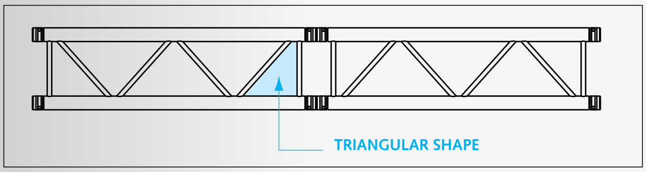
Because of the differential in their loading capacities, you should never combine X and H trusses.

D. TRIANGULAR SETUP ANS END-BRACES

Prolyte manufactures all its trusses with end braces

This is to prevent any loss of loading capacity if the trusses are incorrectly mounted.





The triangulated shape remains, no matter which way the truss is mounted, due to the end bracing.

E MOTOR-POSITIONING ON GROUND SUPPORTS IN 1 TONNE AND 2 TONNE LIFTING CONFIGURATION

Reeving the chain of a one tonne hoist through a chain-block, and replacing the one tonne components as hooks etc for two tonne parts, results in: half of the lifting speed, half of the lifting height, but a doubled lifting capacity. A one-tonne chain reeved in two falls can lift two times this one tonne!

When a one ton hoist is reeved over the top section of a tower a similar situation is created, however the attachment of the chain hoist itself makes the big difference.

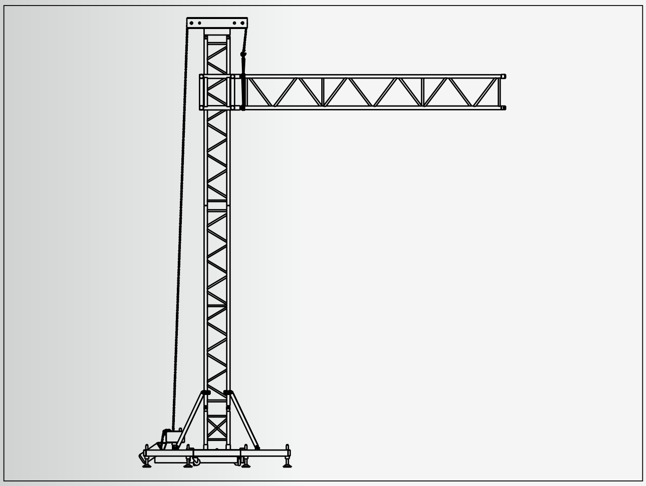
The first figure shows a tower with the hoist attached to the tower-base, and the chain is reeved across the top section to the truss or sleeve block that are to be lifted. Anywhere along the chain, the lifting capacity is one tonne, and as the chain is fixed to the horizontal and moving trusses of the ground support, this can be lifted with a maximum allowable load of 1 tonne.

In the tower itself however both sides of the chain have a one tonne resulting force, thus the tower must withstand a down force of 2 tonnes.

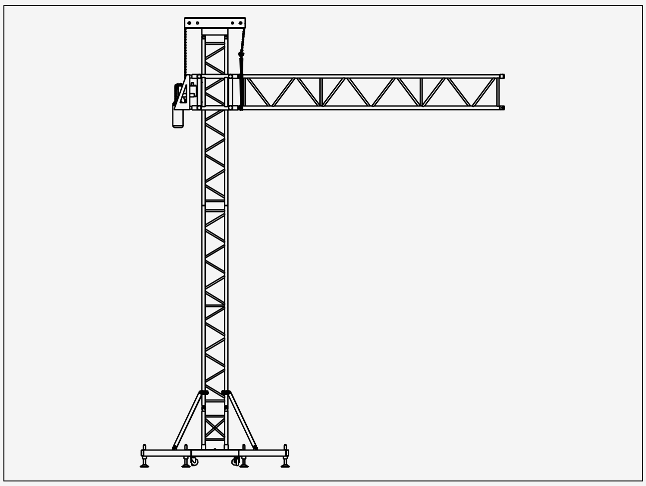
In the second figure an identical 1 tonne chain hoist is fixed to the sleeve block, reeved across the top section and then fixed to the truss or opposite side of the sleeve block. This means that the chain motor now lifts the load with two times a one tonne capacity, thus with a two tonne capacity, while the lifting speed and lifting height are reduced by 50%. As standard chain-lengths of entertainment chain-hoists often are about 20m (~65 ft), this results in the highest possible lifting height of the towers as 10 meters, obviously more than enough for the vast majority of shows!

The tower itself still "sees" two chains with a one tonne load on each side, and is still loaded by 2 two tonnes max.

If these ground support-towers are used within a system of two towers or more to lift the same load, several European countries demand a reduction of the load to each hoist to 75% of the lifting capacity. Other countries do require a well-documented "lifting-plan" or "rigging-plot" that shows the calculated load to each hoist, accompanied by a thorough Risk Analysis.



How to lift 1000 kg.



How to lift 2000 kg.

LIFTING PEOPLE & CLIMBING TRUSS

TECHNICAL MATTERS

The European Machine Directive states that; a doubling ofsafety (design) factors is mandatory when persons are lifted by, (read: suspended from, placed upon, climbing in), machinery structures. It is therefore the complete responsibility of the user to establish the actually required level of safety,
when persons are to be lifted by, suspended from, or placed upon truss structures.

This can be done in two ways:

- Double the amount of weight applied by each person. Generally, a person's weight is standardised to 1 kN (app. 100 kg = taken as a worker with his tools) in static load; thus the calculation factor for a person moving around will be 2 kN in static (resting) load.
  Any forcefull or harmonic movement of that person or even a group of persons (i.e., dancers or a complete rockband) is not included in this factor, but needs careful consideration. Movements can easily lead to dynamic effects that exceed the assumed static loads. As a rule of thumb, assume a factor of two for dynamic loads. This will lead to a calculation factor of 4 kN load per person.
- Reduce all allowable loaddata given in the tables by 50% whenever persons are to be on the truss. This also results in a doubled design factor, the minimum requirement in de European Machine Directive.

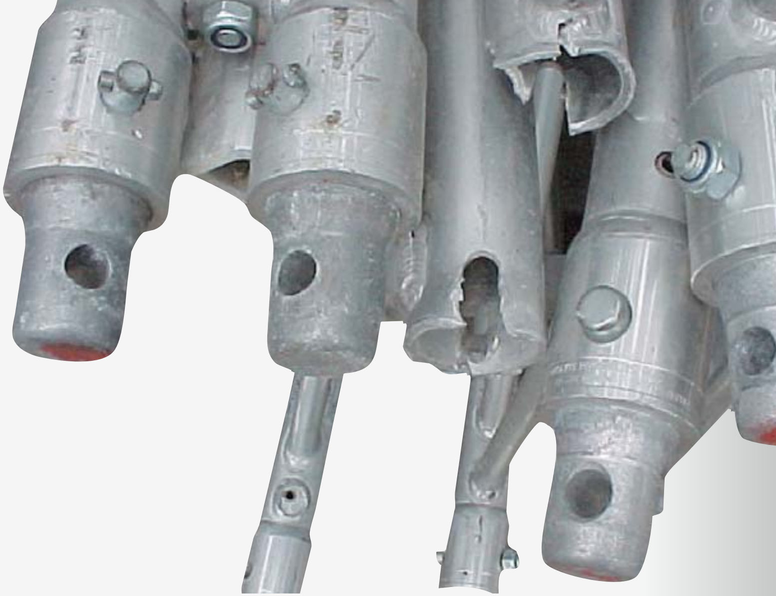
Apart from this, be sure to take sufficient safety precautions. Thus when a platform is built using truss as structural components, and handrails and so on are fixed to it, make sure both the handrails and the trusses can absorb the horizontal forces resulting from the design loads on these handrails!
And when just the truss is used and needs to be climbed for focussing or luminaire replacement, make sure proper horizontal and vertical fall protection and safety lines are installed. When in place, the effect of the possible forces caused by the safety systems on the truss structure, also needs to be calculated and checked. We do certainly not encourage people to climb any type of truss smaller than 35 cm, thus 40 and 36-series being the Prolyte climbing lower-limit. Just the fact that the 30-series trusses are so small that climbing becomes difficult, could be convincing enough. But most trusses of these dimensions are not strong enough to absorb the forces caused just by a climbing person - when calculated by the above method(s) - let alone resist forces resulting from arrest of a falling person, as applied to it through the safety lines and fall arrest equipment.

This however can also be the case in the larger truss-series, when the spans or loads are often considerable to start with, even though the allowable loads are halved because of the expected climbing. A strong warning must be given to the occasionally observed practice of fixing safety lines to diagonals or verticals inside a truss-module.
Shockloads of falling persons can excede the design load of a carefully moving person by far. If in doubt please always consult your dealer or Prolyte on this. At Prolyte value our customers and users beyond buying our product.

When climbing rigging is necessary to reach panel points in structural steel beams or any other position where falling hazards are apparent, the venue shall provide a fall protection system in accordance with intentional, national or local safety requirements. This is to be inspected and
certified by an independent and recognised authority. The climbing riggers themselves shall take care in adequate precautions by wearing the appropriate type of fall-protection harness, in compliance with international (eg. EU or ISO), national (ANSI) and/or local laws, standards and regulations.

APPLICABLE STANDARDS:

NEN-EN 353-2	Personal protective equipment against falls from a height. Guided type fall arresters on a flexible anchorage system.
NEN-EN 360	Personal protective equipment against falls from a height. Retractable type fall arresters.
NEN-EN 361	Personal protective equipment against falls from a height. Full body harnesses.
NEN-EN 363	Personal protective equipment against falls from a height. Fall arrest systems.
NEN-EN 364	Personal protective equipment against falls from a height. Test methods.
ANSI	E1.1 1999: Entertainment Technology. Construction and use of wire-rope ladders.
ANSI	Applicable standards



MAINTENANCE & REJECTION CRITERIA FOR TRUSS

TECHNICAL MATTERS

A. PREFACE

Next to the normal requirements for careful treatment, assembly, disassembly, transportation and warehousing of truss; inspection, such as visual checks of each module prior to every time and type of use is mandatory.
A periodic and elaborate inspection of each module shall be documented to ensure the safety of use of the modules. The list given can serve as guidance for evaluation of the safety and quality of each truss module, and give criteria for the discard and taking out of service of modules.

Prolyte encourages careful documented inspection by a competent person at least once a year and possibly more often if the circumstances or itensity of use require so.
Prolyte's criteria are more detailed and stringent than those mentioned in the first ever published standard for truss in the entertainment: ANS E1.2-2000, Entertainment Technology: Design, Manufacture and Use of Aluminum Trusses and Towers, and the highly similar BSI standard.
Prolyte truss modules have to be checked and inspected visually for damage or any other aspect that might negatively affect the safety of the truss, prior to each time of use.
All trussing is to be inspected at regular intervals, on its general technical condition with emphasis on the strength and safety, with complete documentation of the results.

B. CRITERIA FOR DISCARD

All truss is to be discarded and taken out of service when any of the criteria, mentioned below, are found to be present:

General

Absence of any indentification showing: manufacturer, trusstype and date of production Permanent (plastic) distortion of the module by rotation, bending, torsion or any other deformation from the original design. Welds showing cracks or sudden discontinuities. The open heel in the bracing welds is normal and accepted in the Tuv approval and certification. Any incomplete welds – apart from those in the heel area of the diagonal bracings. Reductions of welded areas through wear or tear by more than 10%. Excessive corrosion, reducing the total truss-cross-section area by more than 10%.

Although corrosion of alluminium is very much less than any compared non-coated steel tubing there are still environments that have corrosive effects even on the EN AW 6082T6 alloy that Prolyte is using. With this in mind extra attention needs to be given to long-standing or (semi-) permanent installed truss-structures in the vicinty of chemical plants, or industrial polluted areas in general. Also salt-water coastal area's and indoor as well as outdoor swimming pools are to be considered as area's where truss-structures can only be built with extra careful consideration about the corrosive hazards.

Chords

Any of the chords being broken, torn or partially absent.
Any of the chords being bent out of the centre line by more than 5 degree.
Any bending of the chords-ends next to the coupler, resulting in the use of force when connectiong two modules.
Scratches, cuts or wear on the chords surface reducing the chords section area by more than 10%.
Any scratch, cut or local dent on the chord deeper than 1 mm and longer than 10 mm no matter in what direction.
Any smooth round hole reducing the chord's section area by more than 5%.
Permanent (plastic) deformation by ovalness or dents of the round tube diameter by more than 10%.

Braces

(diagonals, end-braces, internal cross-braces)
Any of the diagonals, end-braces or cross braces being broken or partially absent. Any of the braces being bent out of the centre line by more than 10Þ. Scratches, cuts or wear on the braces reducing the braces section area by more than 10%.
Any scratchor cut on the braces deeper than 0,5 mm and longer than 10 mm no matter in what direction. Any round hole reducing the brace's section area by more than 5%.
Permanent (plastic) deformation by ovalness or dents of the round tube diameter by more than 10%.

Conical coupling system

Cracked or partly broken welds between chord and receiver fitting. Any oval-shaped wear on teh holes by more than 10% (see fig 3). Out of line rotation of teh spigot-pin holes withib a CCS coupler or between to adjoining couplers by more than 2 degrees.Bending of teh chord ends with the coupler receiver parts by more than 5 degree, resulting in difficulties in joining two truss-modules during assembly.
Wear on the coupler or reveiver parts resulting in cross section area loss of more than 10 %.
Deformation or distortion in the chord area next to the weld of the receiver part .Overload in compression leads to outward buckling effects, overload in tension parts leads to constriction in the chord tube next to the welds. Any scratch, cut or hammer blow on the receiver deeper than 2 mm and longer than 10 mm no mater in what direction. Excessive corrosion in the connection. In systems having stayed assembled of longer periods it is advised to use only new and freshly galvinised spigot pins, to prevent hazard from galvanic corrosion.

Conical spigot pins

These steel pins are, effectively, "consumables", this means these parts are the most susceptible to wear by the use of hammer etc. Also they are indicators of ecessive overload showing compression-surfaces and bending.

Reduction in diameter by more than 10%. Cuts, dents, scratches and other damage to the smooth sur-face of the pin.
Burrs, 'mushrooms' and other extending sharp edges on the narrow end of the pin. Deformation by hammering, leading to closure of the safety-clip hole, or screw thread.
Loss of zinc coating on any part of the spigot pin, causing it to corrode. No self-locking nuts shall be used which show clear loss of the nylon-locking mechanism by wear.

C. DOCUMENTATION

A complete inspection of each truss- or tower module cannot be executed on a daily basis. However, at least once a year, each truss or tower module should be carefully inspected by a qualified person, (or more often if needed, with respect to the intensity of use), in order to guarantee the technical quality and safety of the truss-modules. A documentation record of this inspection should be kept, registering all details and crite-ria. Each module should be marked with an inspection sticker or other identification mark, being traceable in the files, such as to comply with local safety regulations concerning lifting applications. When in doubt on technical details or safety aspects always contact the dealer or Prolyte Products.

Manufacturers providing only 'rudimentary' product related information, mostly are doing so because of a lack of serious knowledge of these products, and often this is caused by just copying trusses of other brands, without understanding many of the details.

Spigot pin deformed due to shear force.

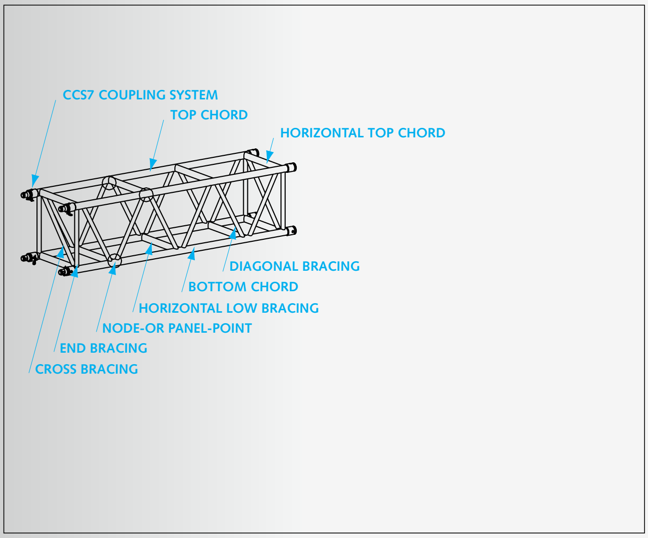
D. MAINTENANCE

Like any other item being used in situations where wear and tear are normal, truss also needs maintenance. Do not trust manufacturers or salesmen who claim that trusses or truss-components are free of maintenance. Responsibility and liability for the safe use of truss, is for a great deal with the user itself. Special attention must be given to the coupler components. Damage to these components will result in increased deterioration of the technical quality and thus reduce the safety of the trusses or towers. These components are to be considered 'consumables' (ref. ANS 1.2.2000 - truss standard), in the sense that these parts will show more wear in use, and might from time to time have to be replaced with new ones. It is strongly advised to maintain these components by regularly smoothing the surface with fine sandpaper, and keeping them slightly lubricated with silicone oil, spray or similar lubrication. However, any lubricant used should not be 'sticky', thus preventing the gathering of dirt, dust or small parts of debris from paper or cloth.
Similarly, the inside of the spigot-holes in the receivers might build up aluminium, which from time to time should be removed with medium sandpaper.
In addition, the 'sticky' remains of spray-paint, dirt, dust and debris might tend to tighten the receiver ends of the trusses or towers, thus causing assembly that is more difficult.
When companies for reasons of easy recognition, are spraypainting the outside of the male and/or the inside of the female coupler-parts, it is advised that no droplets of spraypaint are left to dry in position.
This does have a negative effect on the precise fit of the coupler parts resulting from highy accuracy-low tolerance of the CNC-machining. A drop of remaining paint can be five times as thick as the CNC-tolerance setting, and could act as a glue when pressed in between the two coupler surfaces, and is left to dry.
To prevent excessive damage to tubes and coupling components, Prolyte encourage their customers to use a red-copper hammer of 500gr (app. 1 lbs.) to connect spigot-pins, thus avoiding damage to coupler-receivers and the truss chords.
In case of the occasional jammed spigot-pin a counter-positioned spigot might just do the trick with a firm blow of the hammer. Only when this is not working a direct hit with a steel hammer could be the answer, but the spigot should immediately be inspected for wear or pointed head deformation, and if so, kept separate for maintenance.

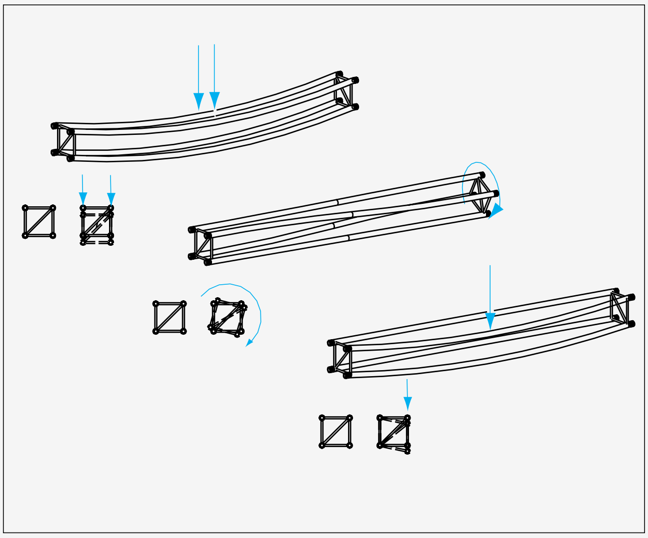
WARNING

Neglect of maintenance and/or inspection at regular intervals of the truss, might eventually lead to the use of unsafe products, resulting in risk of property damage, personal injuries or even death.

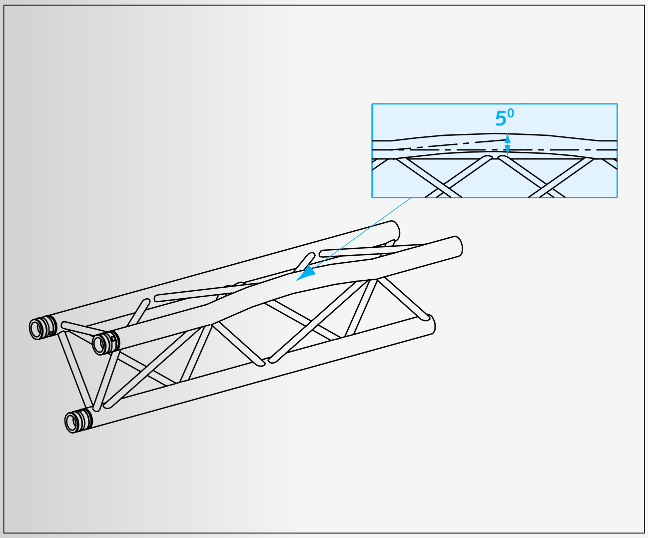
When modules are found with any aspects that negatively influence the safety, these should be taken out of service and clearly marked in such a way that it prevents the possibility of use by mistake. To ensure this respect for safety, is however greatly depending on company procedures and/or the dry-hire client's proper information and education. Just a piece of duck-tape on a damaged part is not sufficient as this is too easily removed.



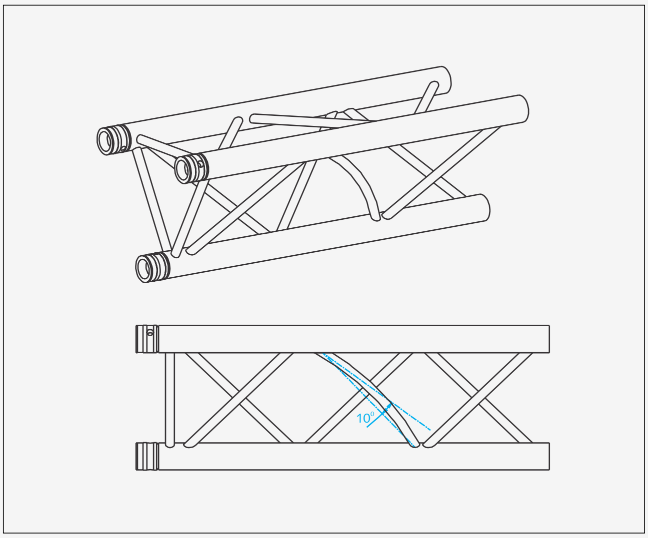
1) Orientation and indication of the various components and parts



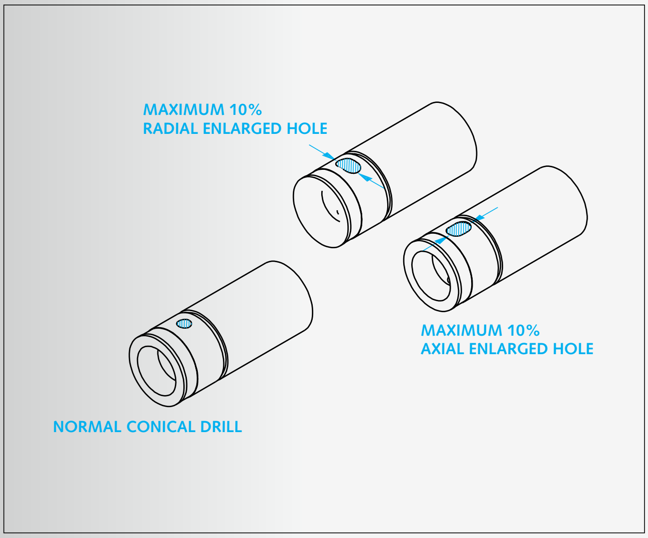
2) Deformation in truss: bending, torsion and rotation



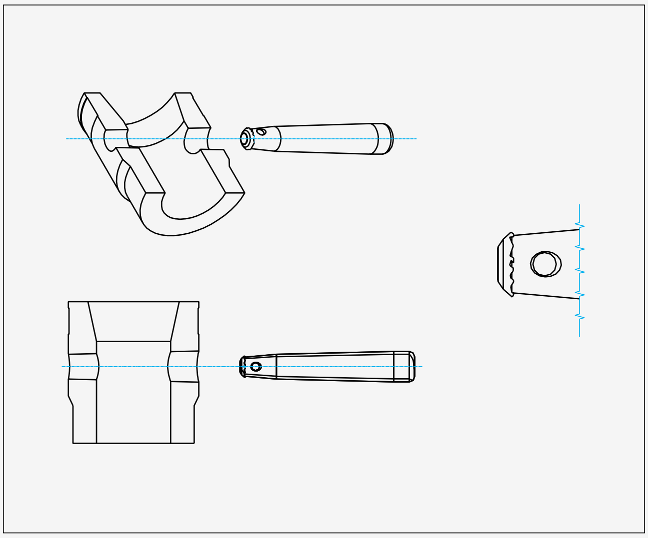
3) Bending of the main chords



4) Bending of the diagonals



5) Deformation of the spigot holes.



6) Deformation of the spigot.

CODE OF PRACTISE FOR RIGGERS

TECHNICAL MATTERS

A. GATHERING DATA

Lighting Loads

- numbers of the various types of luminaires, ballast's, follow-spots (including seats & operators), cables, adaptors etc
- weight of each fixture or device
- required height of the luminaires, deciding upon the height of truss or in the case of gantries or ground supports: length of upright columns

Sound Loads

- numbers of cabinets, flying frames, cables, cabinet suspension equipment, adaptors etc
- weight of each item.
- required height of the speakers, deciding upon the height of the flying frame

Scenery / Set Loads

- numbers and types of screens, projectors, flying frames, trolley's and beams, cables, adaptors etc

Projection equipment

- id.

Choose truss

Calculate the load for each individual truss-run. Use the appropriate calculation formulas when combinations of uniformly distributed loads and point loads are found on one truss. Just adding totals of UDL and concentrated and point-loads are not allowed: bending moments in the span can be seriously affected by the placement of the loads.
Note: lighting loads on trusses can roughly be taken as UDL, except for followspot seats, which are to be considered as point loads.

- Check truss loading with the allowable loading tables of the truss-types. (bending moment and aluminium alloy allowable stresses to be derived from the truss-manufacturer) Include in this, the possibility for a point load of at least 100 kg + 2 times 50kg at any given point along the truss-run: a lighting technician should be able to do maintenance from the truss, or replace even the heaviest luminaire.
- Establish the self-weight of the truss-type to be used for the purpose
- length of the truss provides the total weight (include all parts needed for connections)
- self-weight of truss-slings or any similar equipment is not to be considered

Multiple supports

- Establish the number of supports needed to give the truss spans adequate safety when the amount of weight exceeds either, the allowable weight or span on simple supports of the available truss types.
- Calculate the reaction forces from the total of truss + load, by using
- Formulas for simply supported beams
- Formulas for continuous beams on more than two sup-ports
- Establish the lifting capacity of the chain hoist by the foundreaction forces
- When lifting people or when technicians climb the grid, choose hoist types that have at least double the capacity of the amount of the reaction forces found.
- When two or more hoists are lifting the same load, the allowable loading capacity of each hoist shall be no more than 75% of the capability of the lightest capacity hoist.
- When loads are suspended in overhead situations, an additional safety device of adequate strength is to be applied.

Resultant force

Calculate the resultant point loads onto the supporting main structure:

- In rigging: add the self weight of chain hoist to the reaction force found, calculate bridle length and wire rope loading, also calculate vertical and horizontal loading on structural steel framework.
- In 'ground building': add the self weight of the column to the reaction force found. Check column length against buckling stability; also check overall truss gantry on total safety and stability. Add bracing, guy wires or struts where necessary.

PART THREE TECHNICAL MATTERS

Check point loads with supporting main structures

- In rigging: roof beams, girders and panel point loading capacities. The data on allowable beam and node point loading are to be provided by the venue.
- In 'ground building': loading capacity on the floor area's, a truss footprint can be much less than one square metre. The data on allowable floor loading is to be provided by the venue.
- Corrections for possible overloading situations are to be made by the rigger in bridling the chain hoists (differently) or by the 'trusser' by adding more supports.

Drawings and tables

- All information gathered by the rigger and all calculations should be put on paper. This data has to be checked by any building or safety inspector, structural engineer or compe-tent person in this respect.
- Drawings shall include position and identification code of support or hoist, with the point load including hoist weight in kgs. Drawings shall indicate the scale and or a reference-size.
- Drawings shall also indicate the direction and attachment position of the bridles and the beam-wraps.
- Tables shall include all hoists, all point loads, all attachment points and all vertical loads on each attachment point.
- Figures shall be rounded up to the nearest 5 or 10 kg to allow for the weight of slings, shackles, rings, beam-clamps etc which are not specified in detail in the original weight lists.

TRAINING AND LITERATURE:

Prolyte is providing product-trainings to it's customers upon request. But apart from that there is also the possibility to take part in the rigging and truss seminars that are held at Prolyte in the Netherlands. We strongly believe that manufacturers should not sit back after selling the product, but that the safety of using it is greatly increased by the amount of technical knowledge that the actual user has. No point of putting our catalogs on the sales-counters: the contents must be stored in the user's minds.

Next to the Prolyte classes however various fully independent companies provide rigging courses that all have acquired a good and serious reputation in their own right over the last decade or so. Of these we are happy to mention the rigging training, seminars or masterclasses provided by:
- Harry Donovan of Riggingseminars Inc.
- Rocky Paulsen of Stage Rigging Inc.
- Steve Kendall of Rig-Star Inc.
- Bill Sapsis of Sapsis Rigging Inc., all based in the USA,
- PCM Motorschool, based in the UK
- Klaus Köberle in Germany
- Rinus Bakker of Rhino Rigs BV in the Netherlands.

All of these have shown to understand their job to great extend, and provide independent, accurate and skillfull knowlegde on all topics where rigging is involved. We at Prolyte certainly encourage everyone that uses our product to keep extending their technical knowlegde and acquire insight in a broad perspective from these people even though they might not be using Prolyte at all.
For us the quality of our product will remain undisputed at all times, it can only be copied, but never seriously improved.

Further reading:

Peter Hind. Aluminium structures in the entertainment industry. ISBN 190-4031-064
Chris Higgs. An introduction to rigging in the Entertaimnent Industry. ISBN 190-4031-129
Harry Donovan. Arena Rigging; A pratical guide for riggers, desingers and managers. ISBN 0-972-3381-0-1

CONVERSION TABLE

Temperature:

To convert C to F multiply by 1.8 and add 32

To convert F to C subtract 32 and multiply by 5/9

Length, Distance and Area	Multiply by:
Inches → Centimetres	2.54
Centimetres → inches	0.39
Feet → metres	0.304
Metres → feet	3.28
Yards → metres	0.91
Metres → yards	1.09
Miles → kilometres	1.61
Kilometres → miles	0.62
Acres → hectares	0.40
Hectares → acres	2.47
Square miles → square kilometres	2.59
Square kilometres → square miles	0.39

Weight	Multiply by:
Ounces → grams	28.35
Grams → ounces	0.035
Pounds → kilograms	0.45
Kilograms → pounds	2.20
British tons → kilograms*	1016
US tons → kilograms*	907

*) A British ton is 2240 lbs, a US ton is 2000 lbs.

Volume	
Imperial gallons → litres	4.55
Litres → imperial gallons	0.22
US gallons → litres	3.79
Litres → US gallons	0.26

MORE INFORMATION?

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PROLYTE PRODUCTS
STAGING - RIGGING - TRUSSING

NOTES

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