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Part 3: Technical Matters

In this section, we highlight a number of technical topics. We will study the truss phenomenon and all its technical implications, 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.

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 legislation 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 etcetera.

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 free of charge.
What is truss

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 word ‘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 building of 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 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
• Aluminium has a relatively high tensile strength
• Aluminium has an attractive finish: bright polished in its standard form
• Aluminium is fully recyclable

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

The basic elements in each truss

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

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 affect the following:
• Safety; structural strength and stability
• Economy; efficiency in connection, storage and transportation
• Versatility; the wide range of possibilities for different structural configurations with one specific type of truss

There are a number of advantages and disadvantages with each type of truss. Prolyte produces trusses for almost every application in the entertainment industry. From decorative elements for shop fitting and displays, via Multi purpose trusses for the exhibition and lighting rental industry, through to heavy duty folding trusses for continued high capacity repetitive use in the touring industry.

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 shape
Why is the triangle 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, compressed, bent) does the triangle lose 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. Structural engineers like, and need, to predict the outcome of their work within very narrow parameters, so that the user has ‘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 an axis: tension or compression, with no side loading. Therefore, loads can only be applied to the nodes (or panel points).

If any other geometric shape is being loaded at the nodes, one has to take into account several extra parameters, this renders the equations (much) more complex.

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 connection systems

Truss is manufactured in standard lengths, which can be assembled to 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.

<table>
<thead>
<tr>
<th>CONNECTION TYPES</th>
<th>FORCE</th>
<th>FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: GUSSET / ENDPLATE</td>
<td>OPEN SPACE BETWEEN LOWER CHORDS</td>
<td>OPEN SPACE BETWEEN LOWER CHORDS</td>
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<tr>
<td>2: TUBE / COUPLER</td>
<td>VERY HIGH CRUSHING STRESS AT THE BOLTS (BEARING TENSION)</td>
<td>FIXED MALE / FEMALE SIDE, WEAR GIVES EXTRA DEFLECTION</td>
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<tr>
<td>3: MALE / FEMALE COUPLER</td>
<td>WEAR IS COMPENSATED BY SPIGOT SHAPE</td>
<td></td>
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<td>4: CONICAL COUPLER</td>
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The four main connection types
The 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 with high bending forces, way out of line from the chord centers.
- Bad line-up; many components; slow assembly; special tools needed; low loading capacity; danger from use of incorrect bolts; special hinge sections needed
+ Genderless system; working length = unit length; connections difficult to damage; simple to use corners.

**Internal tube connection**
Using bolts loaded in shear and loading the chord-walls with high compressive and shear forces
- Difficult to line-up; many components; slow assembly; special tools needed; connections easy to damage (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 loading in line with the chord centres.
- Gendered truss; elaborate orientation; many corners required; working length NOT = unit length; connection-parts easy to damage (leading to discard of truss-module); imprecise line-up of modules.
+ Few parts; very quick & easy assembly.

**Conical coupler connection**
The best features of all the other connection systems combined. Using truss pins (spigots) loaded in double shear, with in-line loading of the chords.
- Special hinge parts needed
+ Genderless system; precise line-up of modules; very quick & easy assembly; rigid fixed-moment connection; working length = unit length; connection-parts difficult to damage and easy to replace.

**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 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 and tension in the lower chords of the 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, cantilevers and 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 can be calculated: the bending stress. Every alloy is only capable of taking a limited amount of stress in tension or compression before failure occurs.
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 hazard; however, a point will be reached when deflection has become so extreme that it will cause instability in the structure. 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.

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 this simple linear calculation.

12m. span with 1000 kg UDL and 24 cm deflection will be 12 m. span with 500 kg UDL with a deflection limit of 12 cm. (1/100 of 12 = 12 cm = allowable deflection)

(12 cm = 1/2x 24 cm > 1/2 x 1000 kg = 500 kg UDL)
Other manufacturers might use different deflection limits. If deflection limits are not given, all loading values must be treated with extreme caution.

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.
When the load is on top and the supports are from below, this sets the braces in compression. The shear-force can try to rip apart the chords from the web, when the truss is supported from the top-chords and the load is attached to the lower chords, setting the braces in tension.
Box corners are equipped with relatively dense bracing to allow for more shear absorbing capacity.

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 (‘third points’); 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 number 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.

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.
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 for the entertainment industry have, so far, been developed only on national scale with respect to general safety conditions (Germany in 1974: VBG-70). 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).

This standard will soon have a counterpart in the UK (PLASA-BSI), Germany (VLPT-DIN) and the Netherlands (VPT-NEN).

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 standard is the European Machine Directive regarding safety of machines and lifting equipment. Truss however is not specifically mentioned in this.
- 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 TuV is generally acknowledged as a leading certification body, also Lloyds (UK) 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 physical 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.

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).

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 F28/32 (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 ‘Bau-art Prüfung’ for all their 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:

| DIN 1748-1 | 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. |
| DIN 18000-1 | Modular co-ordination in building |
| EN 10002-1 | NEN 2063 | Arc welding. Fatigue loaded structures. Calculation of welded joints in unalloyed and low-alloy steel up to and including Fe 510 (Fe52). |
| EN 287-2 | NEN 6710 | Regulations for the calculation of building structures TGB 1990. Design of aluminium structures |
| EN 288-3 | ANSI E1-1-2000 | |
Truss and 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 mindful 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 products), 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 bending moment at the inner supports will be opposite to 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 (see page 99 for support reactions in continuous spans).
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. DIN 4113 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 AW 6082 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 would be used in a US-design.

- The ANSI standard ANSI E1.1 – 2000 and BS standard 7905-2 do take into account the occurrence 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 submitting its 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 chords(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 would 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 show any deflection whatsoever. Thereby leaving it up to the customer to find out what is acceptable (or applicable!) to the particular situation.

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.
c. Reading 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 centre of the truss-span (CPL)
9. The amount in kg’s and pounds of the allowable two points loads, dividing the span in to three.
10. The amount in kg’s and pounds of the allowable three points loads, dividing the span in to four.
11. The amount in kg’s and pounds of the allowable four points loads, dividing the span in to five.
12. 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.

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<tr>
<th>PROLYTE X30D - ALLOWABLE LOADING</th>
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<tbody>
<tr>
<td>UNIFORMLY DISTRIBUTED LOAD</td>
</tr>
<tr>
<td>DEFLECTION</td>
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<tr>
<td>m</td>
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</tbody>
</table>

1 inch = 25.4 mm  | 1 m = 3.28 ft  | 1 lbs = 0.453 kg  | 1 daN = 10 N = 1 kg
**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 span in UDL (“Q”)
5. the black thin line shows the total allowable load UDL per 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.

**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 possess 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 similar box truss.

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**NB! THE LOADING FIGURES MENTIONED BELOW ARE BASED ON A INTERMEDIATE UNSUPPORTED SPAN.**

<table>
<thead>
<tr>
<th>PROLYTE LADDER TRUSS - ALLOWABLE LOADING</th>
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<tr>
<td><strong>TYPE</strong></td>
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X = NOT ALLOWED | APPLY LOADS TO BOTTOM CHORD | SUPPORT POINTS MUST BE HORIZONTALLY STABILIZED

**ALL LOADS IN KG**
f. Loading of corners

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.

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. 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.

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. 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.
Slinging of truss

a. How to sling the trusses

Our truss series have a variety of different cross sections, for every truss type there are three basic slinging methods.

Direct straight 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.
The sling (round sling, wire rope or chain) can then be attached to this by means of a hook or shackle.

Choke hitch
This method should only be undertaken using pairs of (round-) slings, each of which supports one side of the truss beam. 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.

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. Wire rope or chain slings are impossible to use with this method.
This method improves the slinging factor by 1.4 to 2 times the WLL if the sling, dependent on its the outer angle with the vertical. Angles over 45° are not allowed under the new European Standards. Please ensure that the sling is attached next to a 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 would 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.

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 roundnsling would be the prefect choice.
But round slings are made of polyester and the allowable temperature for this material is limited to 100 °C. Many countries have fire-regulations that don't allow this kind of suspension equipment in situations were hazards from heat sources (think of a light source as a heat generator!) are present.
Accidents have been reported of round slings being melted by spots or the heat of the rays.
When round slings are a safety backup must be applied by a wire-rope or chain sling.

Wire-rope slings
The next best flexible thing to use for suspension of trusses would 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 this depends partly of the type of termination. Aluminium compression sleeve termination (talurit) are allowed up to 100 °C only, but the sleeve does insulate the direct heat transfer from lower chord to wire-rope.
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 200°C, one must realize that the complete truss itself does start to loose a considerable amount of it's structural strength.

Apart form several kinds of fixed shape support brackets a new and promising higher temperature resistant flexible “round sling-like” product is entering the market. Prolyte is involved in experimenting and testing prototypes on it’s truss-products and is consulting the manufacturers on standardization criteria to meet the strictest of safety requirements. Check out our web-site on a regular basis and you might be the first to know.
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.
Miscellaneous

**a. Measurements of combined grids with sleeve blocks and corners**

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

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

The straight run of truss should be $2 \times 187 \, \text{mm} = 374 \, \text{mm}$ shorter between the standard corners to be able to combine it with the lengths between the sleeve blocks. Prolyte can supply special lengths or spacers.

The use of 40 series box corners within a MPT system

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

The straight run of truss should be $2 \times 51.5 \, \text{mm} = 103 \, \text{mm}$ shorter between the standard corners 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 disablment 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 120°C.

Each of these factors can represent great safety risk to either materials or persons.
Subjection to climatic conditions in outdoor environments needs 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 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 sys-tem.
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, it is 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 its 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 keep careful watch over both. The allowable bending moment is given for each type of truss and tower.
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 and 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.
The European Machine Directive states that a doubling of safety (design) factors is mandatory when persons are lifted by, suspended from, placed upon, or climbing, machinery structures. It is therefore the complete responsibility of the user to establish the actual required level of safety, when people are 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) in static load; thus the calculation factor for a person will be 2 kN in static (resting) load. Any movement of the person or group of persons (i.e., dancers) is not included in this factor, but needs careful consideration. Movements can 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 data given in the loading tables by 50% whenever people are to be on the truss. This also results in a doubled design factor.

Apart from this, be sure to take sufficient safety precautions. For example: proper horizontal and vertical fall protection and safety lines. When in place, the effect of safety systems on the truss structure, also needs to be calculated and checked.

We do not endorse people to climb trusses smaller than 35 cm. Apart from the fact that these trusses are so small that climbing becomes difficult, most trusses of these dimensions are not strong enough to resist forces resulting from applied safety lines and fall arrest equipment.

When climbing is necessary to reach panel points in structural steel beams or any other position where risk of falling is apparent, the venue shall provide a fall protection system of adequate safety. The same 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 (CE or ANSI) and local regulations.

<table>
<thead>
<tr>
<th>Applicable standards</th>
<th>Description</th>
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<tbody>
<tr>
<td>NEN-EN 353-2</td>
<td>Personal protective equipment against falls from a height. Guided type fall arresters on a flexible anchorage system.</td>
</tr>
<tr>
<td>NEN-EN 360</td>
<td>Personal protective equipment against falls from a height. Retractable type fall arresters.</td>
</tr>
<tr>
<td>NEN-EN 361</td>
<td>Personal protective equipment against falls from a height. Full body harnesses.</td>
</tr>
<tr>
<td>NEN-EN 363</td>
<td>Personal protective equipment against falls from a height. Fall arrest systems.</td>
</tr>
<tr>
<td>NEN-EN 364</td>
<td>Personal protective equipment against falls from a height. Test methods.</td>
</tr>
</tbody>
</table>
Maintenance and rejection criteria for truss

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 intensity of use require so.

Prolyte’s criteria are more detailed and stringent than those of the upcoming international standard for truss in the entertainment: draft-standards ESTA/ANSI: E1.001: Standard for design, manufacture and use, of truss and towers (in the entertainment) and a similar PLASA/BSI-draft.

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 identification showing: manufacturer, truss-type 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 other sudden discontinuities. The open heel in the bracing welds is normal and accepted in the TÜV 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%.

Chord
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°. (see fig 2).
Any bending of the chord-ends next to the coupler, resulting in the use of force when connecting two modules.
Scratches, cuts or wear on the chord’s surface reducing the chord’s section area by more than 10%.
Any scratch, cut or local dent on the chord deeper than 1mm 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 10°.
Scratches, cuts or wear on the braces surface reducing the braces section area by more than 10%.
Any scratch or 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 coupler system
Cracked or partly broken welds between chord and receiver fitting. Any oval-shaped wear on the holes by more than 10%, see fig.3.
Out of line rotation of the spigot-pin holes within a CCS coupler or between two adjoining, by more than 2°.
Bending of the chord ends with the coupler-receiver parts by more than 5°, resulting in difficulties in joining two truss-modules during assembly.
Wear on the coupler or receiver part 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 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 matter in what direction.
Excessive corrosion in the connection. In systems staying assembled for periods longer than a year indoors or one summer season outdoors, it is advised to use only new and freshly galvanised spigot pins, to prevent any hazard that might arise from galvanic corrosion.

Conical spigot pins
These steel pins are, effectively, ‘consumables’, this means that these parts are the most susceptible to wear by the use of hammers etc. Also they are indicators of excessive overload,
showing compression-surfaces and bending. Reduction in diameter by more than 10%.
Cuts, dents, scratches and other damage to the smooth surface of the pin.
Burr, ‘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.

d. Maintenance

Like any other item being use in situations where wear and tear are normal, truss also needs maintenance. 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. ESTA-standard for truss), 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. 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.

**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.
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 practice for riggers

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
- 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 supports

- Establish the lifting capacity of the chain hoist by the found reaction 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.

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 competent 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.
## 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

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**More information?**
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