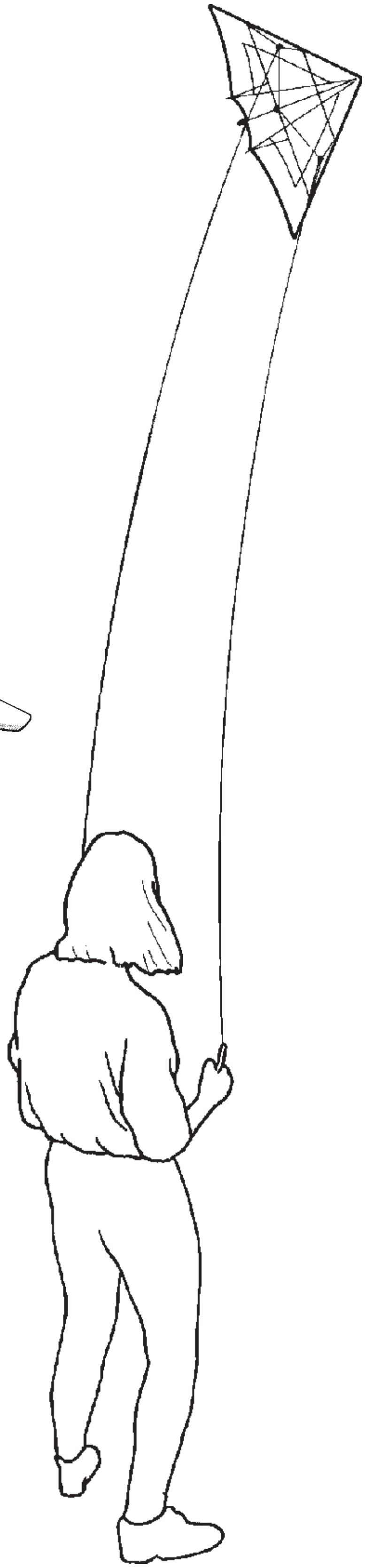
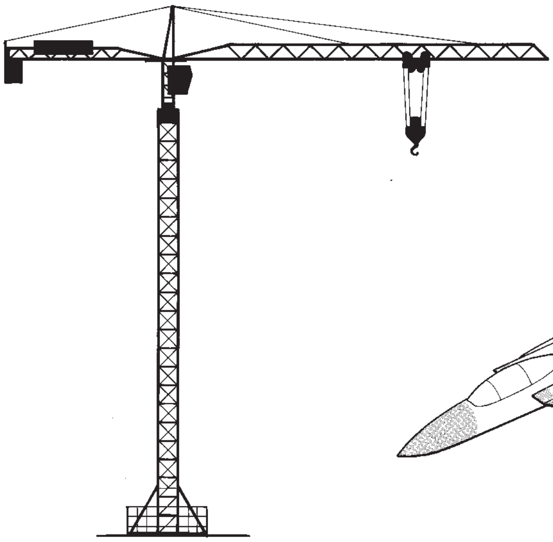
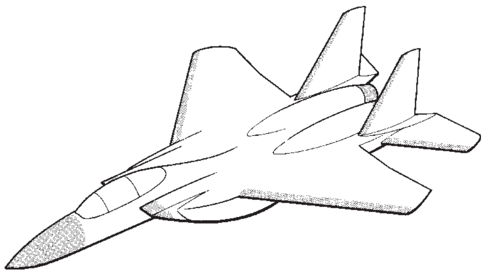
TYPES OF STRUCTURE

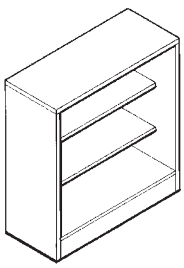
INTRODUCTION

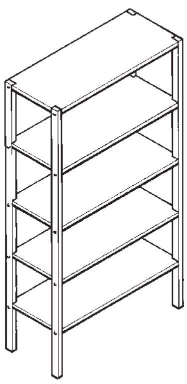
Many structures can be described as belonging to one of two types, shells or framed structures. Common examples of framed structures are electrical transmission towers and girder bridges. Examples of shell structures range from simple storage tanks to complex designs such as car bodies. Many other structures however are a mixture of both frame and shell. Examples of these mixed types are aircraft fuselages and ships hulls which consist of a framework covered by a skin of sheeting.

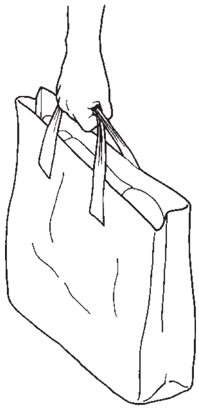








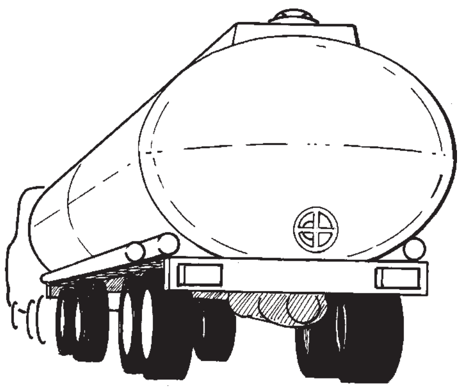




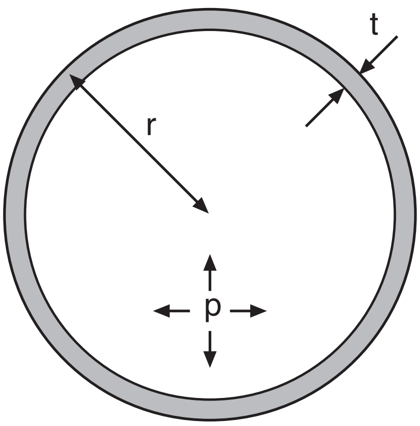
SHELLS

Some of the simplest types of structure are tanks and pressure vessels for containing gases and liquids. If the pressure is high or the gas or liquid toxic, serious hazards can result if the vessel fails, so careful design and testing is necessary. Nowadays there are few accidents due to failure of pressure vessels but in earlier times accidents were common. The explosion of steam boilers on ships and railway engines in particular caused heavy loss of life during the nineteenth century.

The most common shapes for pressure vessels or containers are **spherical** or **cylindrical** (often with hemispherical ends). The skin of the vessel has two jobs. Firstly to prevent leakage of the fluid and secondly to carry the stresses caused by the pressure in the fluid.



For a spherical vessel it is easy to work out what the stress will be for a given pressure. Just as for an inflated balloon, the tension (and the stress) in the shell is the same in all parts and in all directions parallel to the shell.



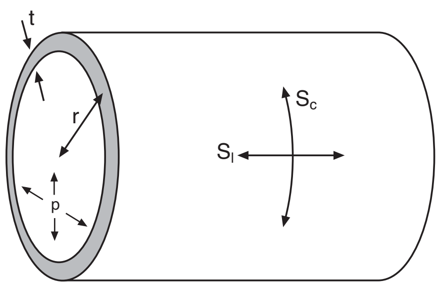
If the radius of the vessel is **r**, the thickness of the wall **t** and the pressure is **p**, then the stress in the shell wall is given by,

vertical internal force on half sphere $= \pi r^2 p$
area of metal resisting this force $= 2\pi rt$

$$\textbf{stress} = \frac{\pi r^2 p}{2\pi rt} = \frac{rp}{2t}$$

Using this formula you can calculate what thickness of shell is needed for a vessel of given radius, pressure and material.

Example
For many applications it is much more convenient to use a cylindrical pressure vessel or container rather than a spherical shape. These are often seen for example on road tankers. Tubes and pipes can also be regarded as very thin pressure vessels.



Unlike a sphere the stress caused by the pressure inside a cylindrical vessel is not the same in all directions. The stress along the cylinder (the **longitudinal** stress) is given by the formula,

$$s_l = \frac{rp}{2t}$$

The stress across the cylinder (the circumferential stress) is given by the formula

vertical internal force on half cylinder of length $L = 2rLp$
area of metal resisting this force $= 2tL$

$$s_c = \frac{2rLp}{2tL} = \frac{rp}{t}$$

This means that the stress around the wall of a cylindrical pressure vessel is twice the stress along the wall and explains why, when pipes burst, the fracture is usually along the length of the pipe rather than around it . When designing cylindrical pressure vessels, the thickness of the vessel must be chosen to be able to resist the larger circumferential stress.

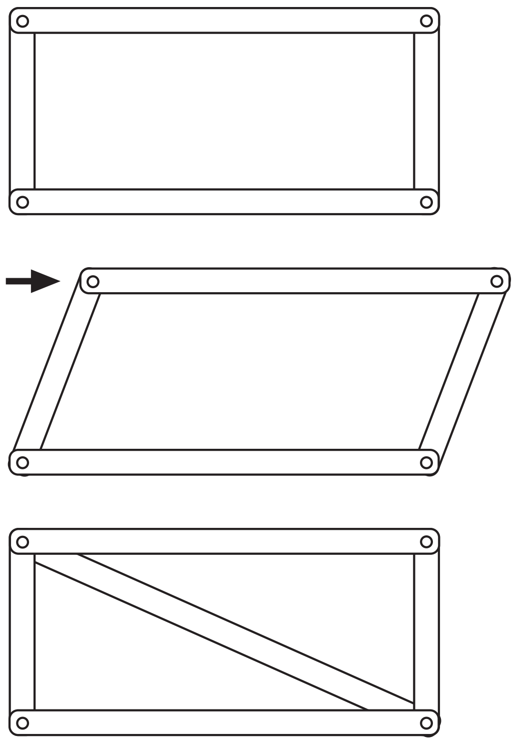
Tanks and pressure vessels are known as tension structures because they support internal loads by the tension in their shell. They are the most efficient way of containing internal forces but are not often used to carry external loads which cause compression.

There are a few examples of shell structures carrying compressive loads however. The fire and rescue services use inflatable bags to raise heavy and awkward loads such as crashed vehicles. The airbags fitted to many modern cars are also tension structures carrying compressive loads. A submarine hull carries an external load which causes compression.

FRAMED STRUCTURES

Many modern structures consist of slender parts joined together to form a framework. In this way large loads can be carried using small amounts of material. Even large framed structures can be manufactured and transported to the construction site in pieces.

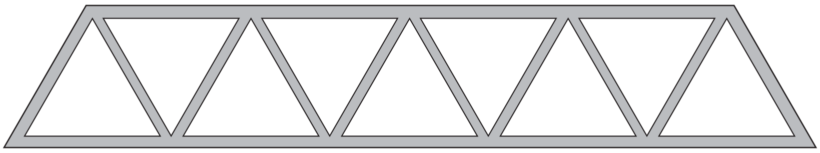
The most obvious simple framework is a rectangle.This will support a compressive load successfully but unless the corner joints are made very strong (and therefore heavy) a sideways (shear) force causes it to collapse.



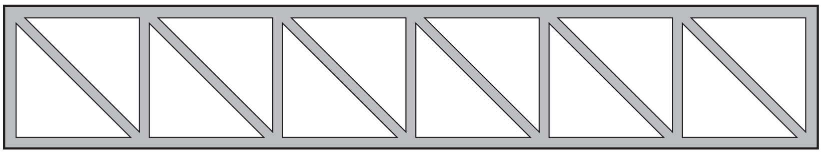
This can be avoided by adding a diagonal member to the frame as shown, so making a **triangulated** structure.

When a structure is needed to bridge a gap, support a roof or carry a load between columns a lattice girder or truss is often used. These are very useful in constructing long spans in which their small depth:span ratio, generally from about 1/10 to 1/14 gives them an advantage over roof trusses.

There are two most common types of lattice girder. One of these, the “Warren” type, is shown below. When the framework is loaded some of the parts will carry a tensile force (ties) and some a compressive force (struts). The elements acting as struts are shown shaded in the diagram. The diagonal elements carry the forces resulting from the shear stresses due to the bending of the girder.



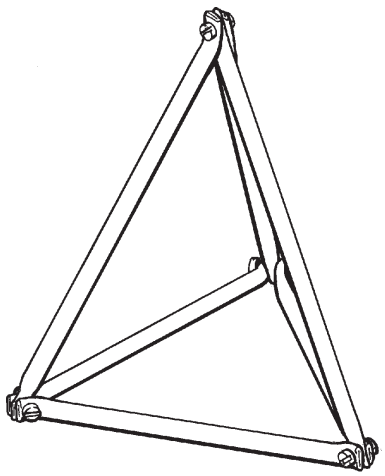
The other common lattice girder is the N-girder. In this the diagonal bracing members are arranged so that they all act as ties.



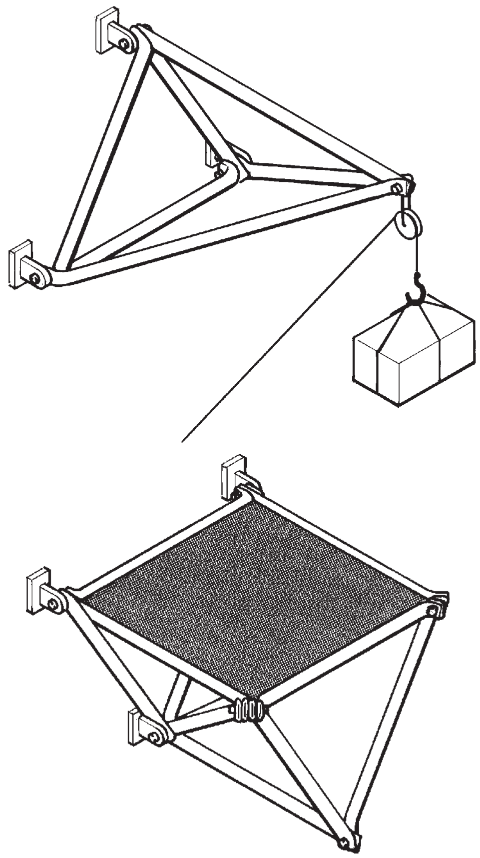
The weight of a girder can be kept low by using lightweight cross sections for the elements, such as angle or tubes. If very low weight is needed the tension elements can be made from cable or cord since these do not have to withstand compressive forces.

Three Dimensional Frames

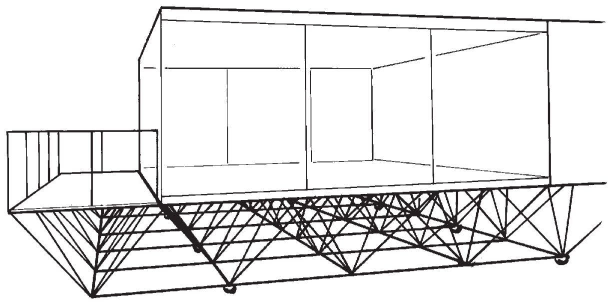
Three dimensional frames are also called space frames or space trusses. The least complex space frame is a tetrahedron made up of six components.



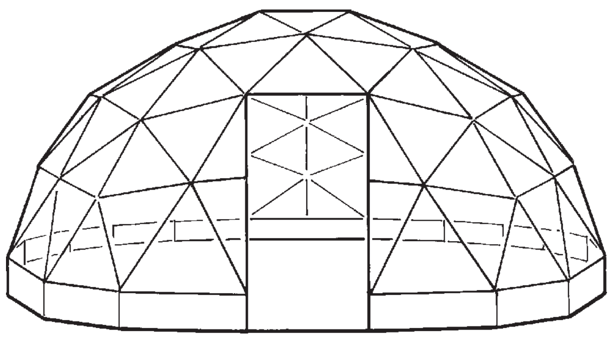
Simple space frames of this type may be used for supporting platforms or other loads on the sides of buildings. Some examples are given.



The tetrahedron can be repeated many times to provide a complex space frame; e.g., one that spans a wide gap without support at the centre. Modern buildings sometimes incorporate space frame structures to lift them off the ground or support roofs.

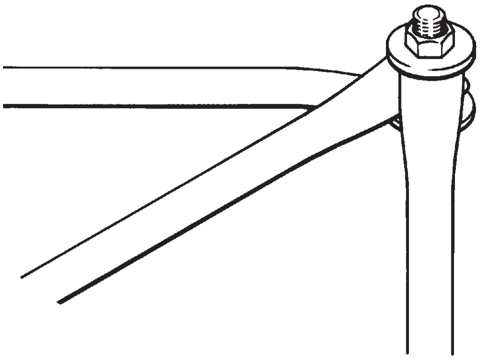


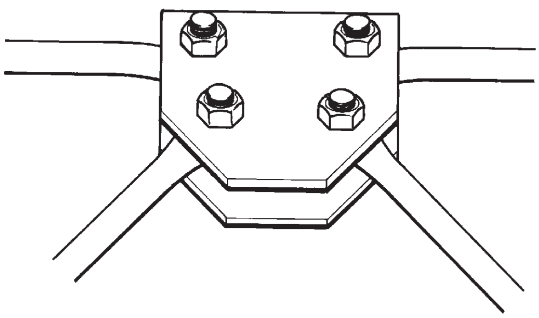
A designer called Buckminster-Fuller, became famous for his investigations into the use of *geodetic* space frames. A geodetic frame is a three dimensional structure whose parts fit together to enclose a space.



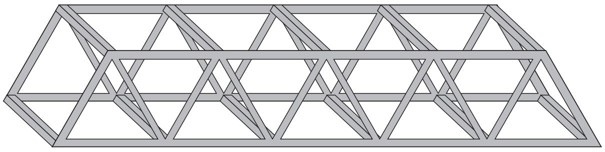
The example shown uses simple triangular frame elements repeated many times to create a dome. This kind of frame can be covered in a flexible material for use as a building.

The components of space frames can be joined in a variety of ways. The most common methods are pin joints or gusset plates. In a pin joint, the 'pin' is usually a steel pin (with high shear strength) or a bolt. The gusset plate method uses a metal plate to which components are either welded or bolted.



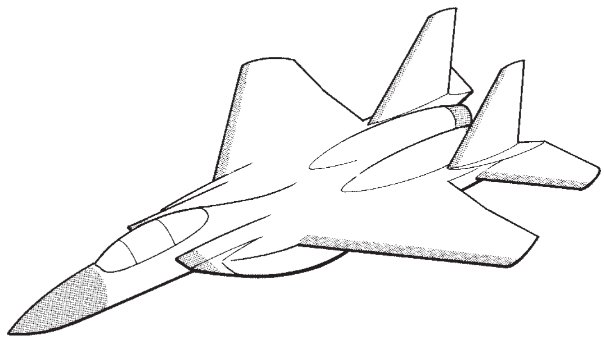


Three- dimensional girders can be made by joining together one ore more 2-D girders. Once again care has to be taken to include diagonal joining elements if shear forces must be resisted. Structures of this type are often seen as bridges.



Mixed Structures

Many structures are made up of a framework covered with a shell. In some, like steel framed buildings, the shell adds very little to the strength of the structure and is merely there to protect the users of the building from the weather. In other cases though, the shell forms a very important part of the strength of the whole structure. Examples of these are the hulls of ships and submarines and the fuselages and wings of aeroplanes.



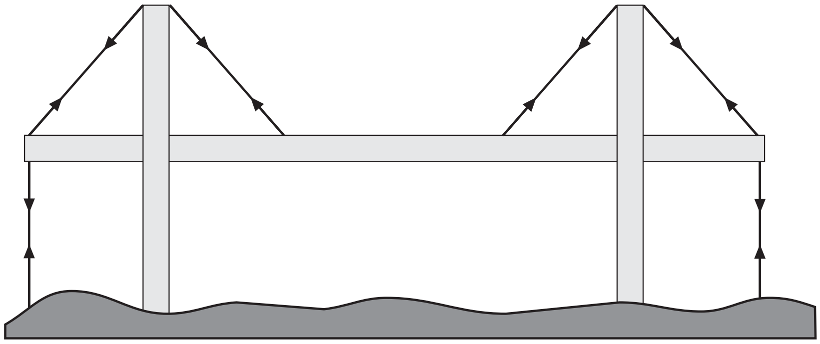
Designing these mixed structures for low weight is a very complex task usually needing the use of computer programmes to calculate the distribution of stresses in the structure when it is loaded.

TENSION STRUCTURES

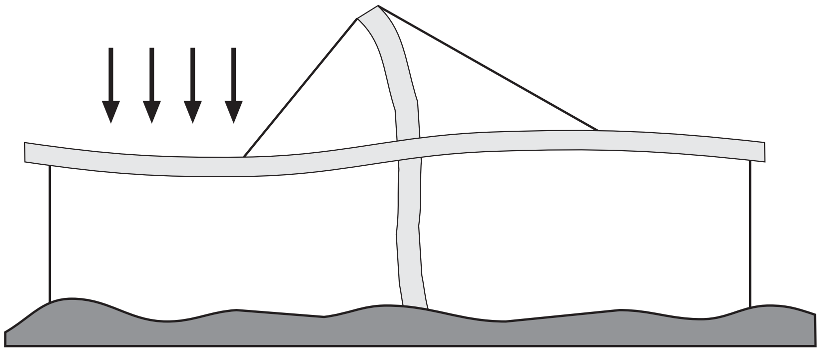
Many modern structures are made to be very light in weight by using designs in which ties, carrying only tension forces, are major elements in the overall structure. Such structures are often called **tension** structures.

Suspension bridges are an example of this type. On a much smaller scale, tents are also tension structures. The tent fabric and the guys are in tension and only the poles are in compression. Tension elements can be long and slim or made of thin sheet, yet still carry large loads safely. Only the struts in the structure have to be heavy and strong enough to carry compressive loads.

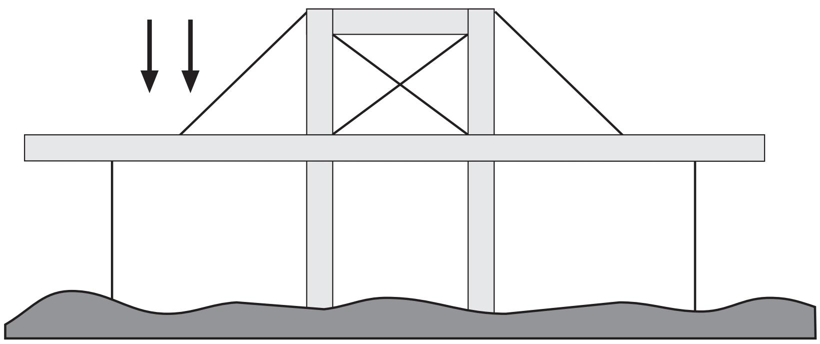
A simple example of a two dimensional tension structure is shown below. Here the weight of the beam and any loads on it are carried by the ties attached to the vertical struts. Notice also the ties to the ground at the ends of the horizontal beam.



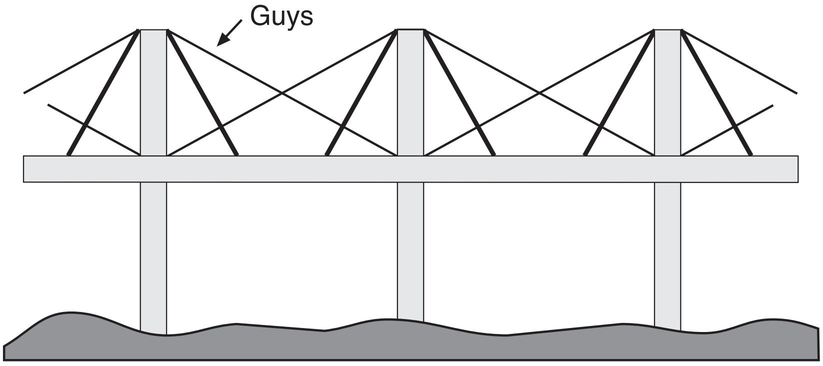
A problem can arise in the design of this type of structure if the loads on it are uneven. This can cause “uplift” on part of the structure.



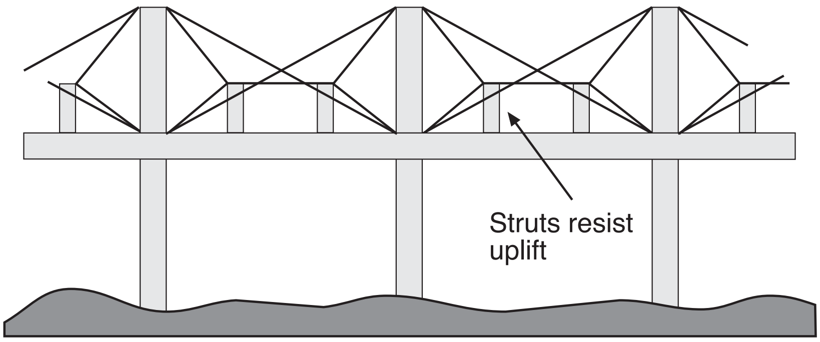
One solution to this problem is to make the columns (struts) much stiffer, for example by using a double, cross-braced arrangement.



Another way of making the structure more stable is to use guys between each column and its neighbouring columns as shown below.



An even more stable result can be obtained by adding extra struts between columns to further resist uplift of the beam.



These methods can be extended to three dimensions to create visually interesting 3-D lightweight structures.