FRAMES IN SPACE (2): DESIGNING AND MAKING LARGER STRUCTURES

WHAT YOU WILL LEARN

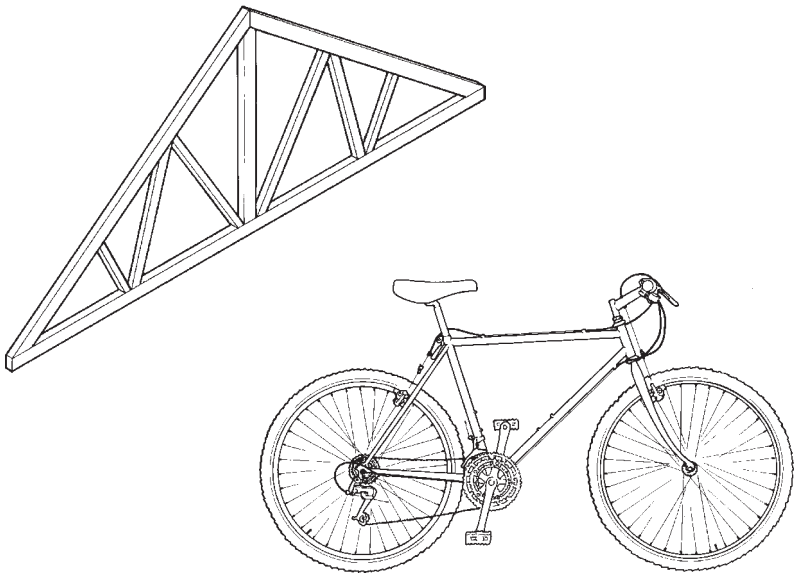
After completing this unit, you should understand:

- What a space frame is.
- The difference between weak and stronger space frame structures.
- How space frame parts can be joined together.
- The importance of modular systems.

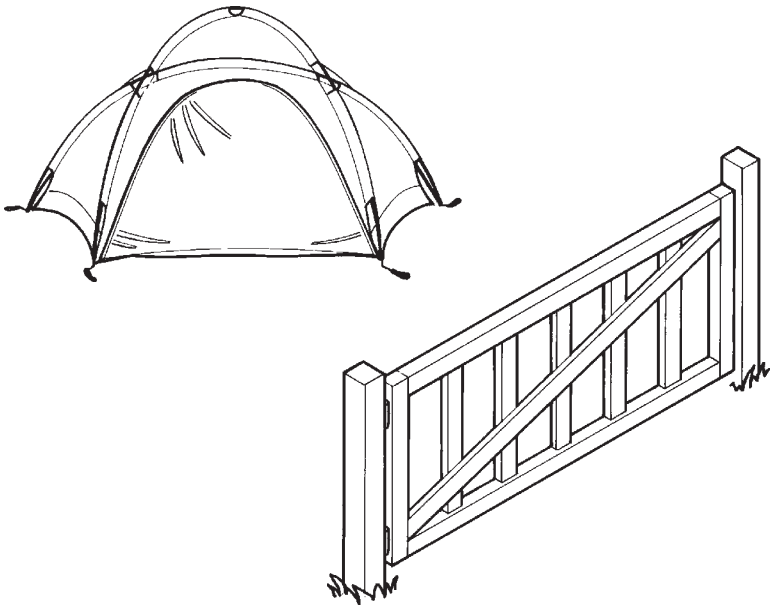
You should be able to:

- Recognise and name the parts of a structure - e.g. truss.
- Work to a design brief and write a specification.
- Recognise design constraints when designing.
- Design and make a larger scale space frame using roll-tubes in combination with other components.

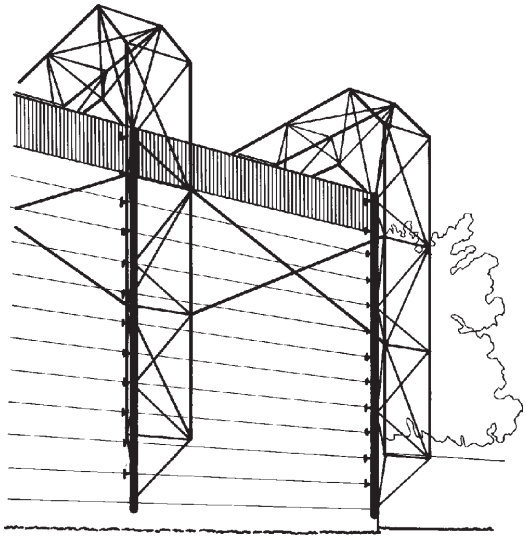
A frame structure consists of a number of parts or components joined together to support a load or resist forces. The type of frame used to support the tiles or slates in a house roof is an example of a two dimensional frame structure. Other examples include bicycle frames and gates.



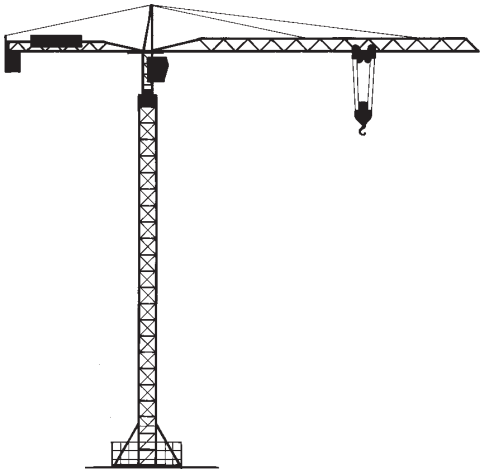
If you think for a moment about uses of the word 'frame' - e.g. 'door frame, 'tent frame' - you will realise how common frame structures are.



Many 'high technology' buildings use three dimensional frame structures - sometimes called space frames.



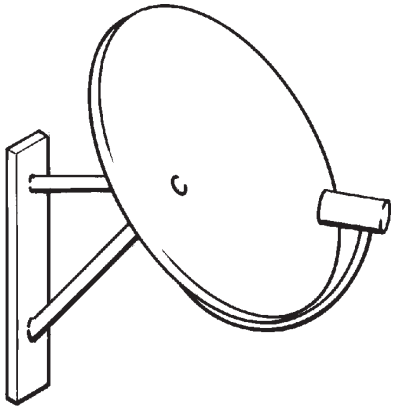
The example shows part of a building whose outer 'skin' is supported by an external framework. Tower cranes use a similar three dimensional structure.



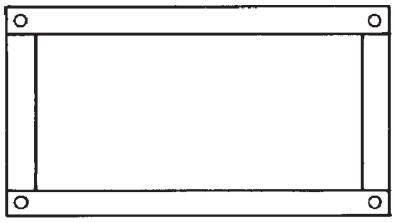
This unit teaches you about these examples and other structures by inviting you to make a prototype frame product for a firm of structural engineers. Before looking at this task, you need to know some basic terms and how to use them correctly.

TWO DIMENSIONAL FRAMES

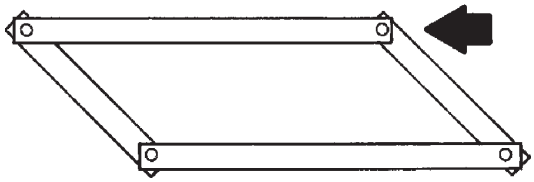
Two dimensional frames are often referred to as **trusses** and are flat or **planar**. They consist of slender struts and ties joined at their end points. The triangle formed by the three parts of a satellite TV aerial frame is an example of a simple truss.



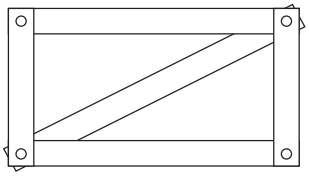
The example shown has a wall plate and a single strut and tie. Because it forms a complete triangle, it is rigid and stable. This means the frame will not change its shape when forces act on it unless there is a structural failure (i.e. components parts or joints break).



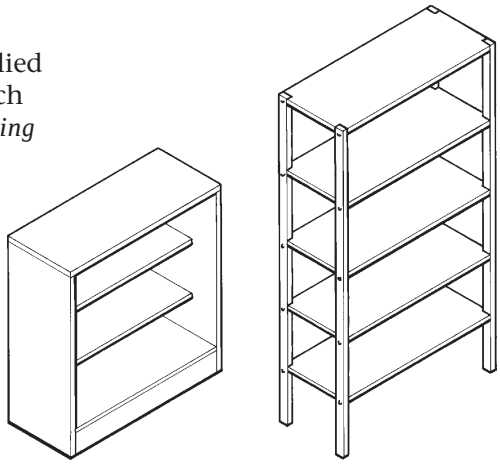
If a frame is made up from four parts bolted together as shown, it lacks rigidity. When subjected to forces, it tends to behave as a parallelogram.



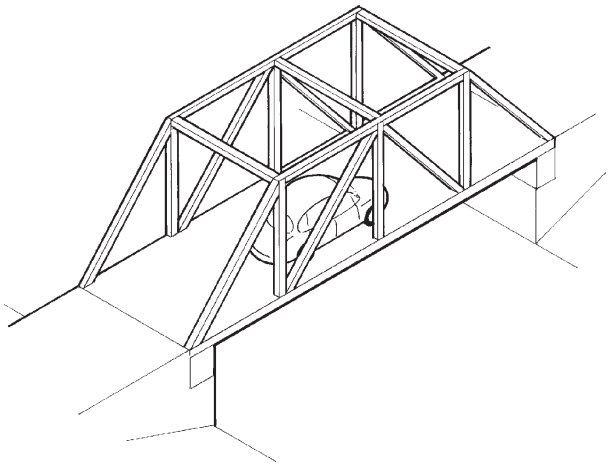
The addition of a fifth (diagonal) component, however, makes it rigid.



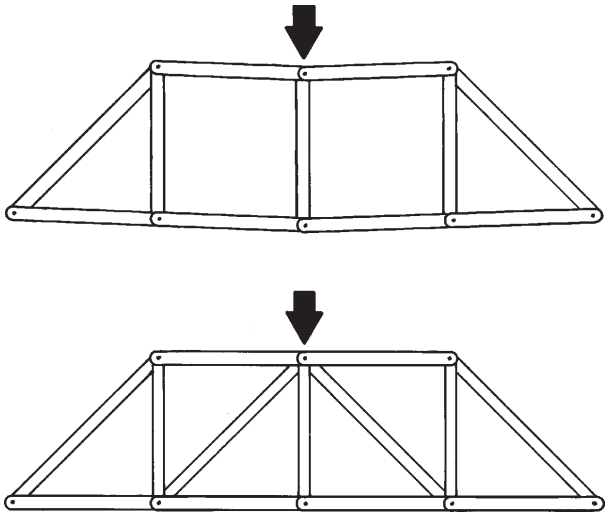
The same principle is applied to flat pack furniture which incorporates *diagonal bracing* to give it rigidity.



The more complex trusses used in bridge and building construction consist of a larger number of struts and ties - some of which are placed diagonally.



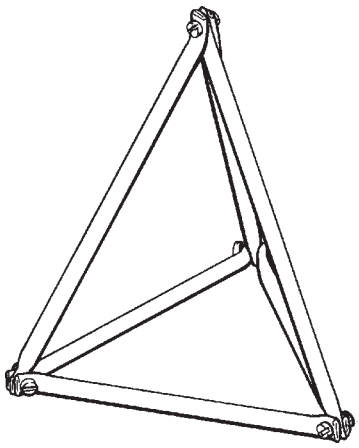
The simple bridge truss shown below is very weak until two diagonal struts are added.



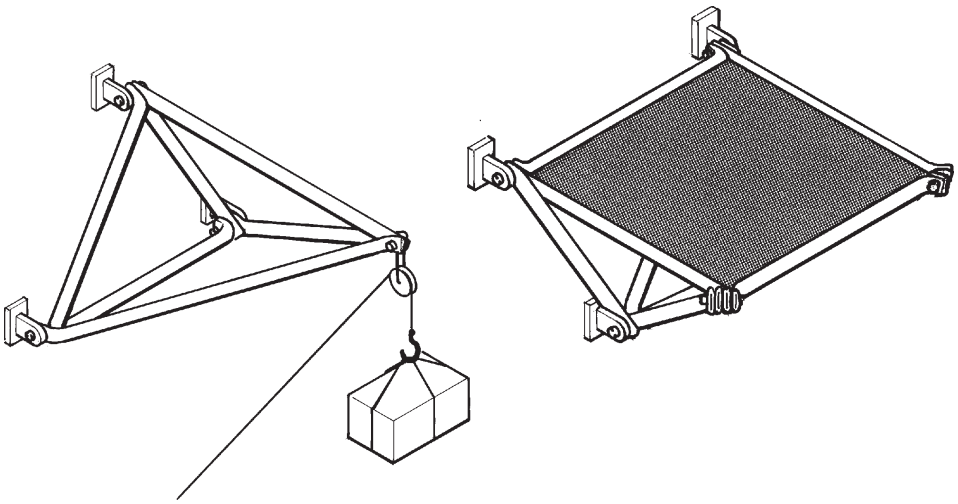
Each roof truss of a modern house contains several diagonal components. To support a given load, the amount of material used in a roof truss can be reduced by good design. Modern trusses use much thinner and less timber than those of 20 years ago and are said to be more 'efficient'.

THREE DIMENSIONAL FRAMES

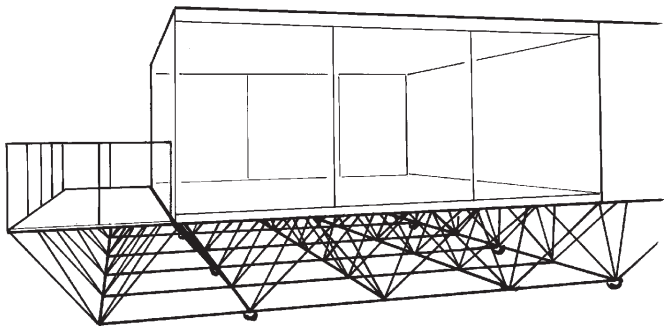
Three dimensional frames are also called space frames or space trusses. The least complex space frame is a tetrahedron made up of six components.



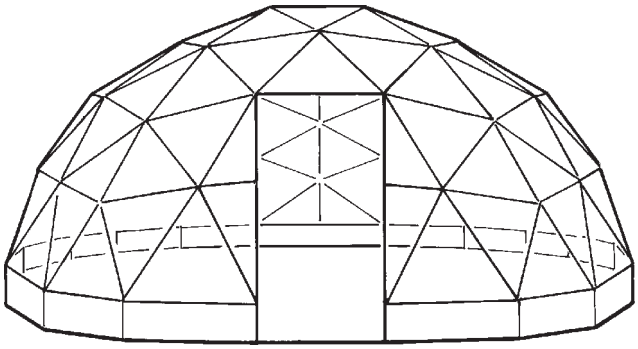
Simple space frames of this type may be used for supporting platforms or other loads on the sides of buildings. Some examples are given.



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 to support roofs.

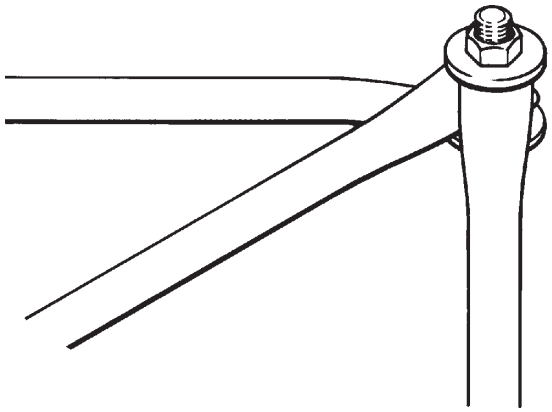


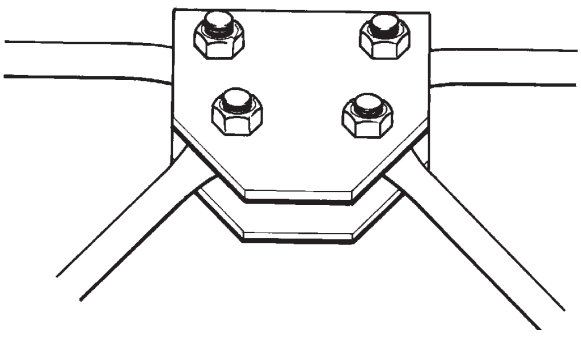
A designer called Buckminster-Fuller became famous for his investigations into the use of *geodetic* space frames. A geodetic frame is a three dimensional structure whose parts fit together to enclose a space.



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.



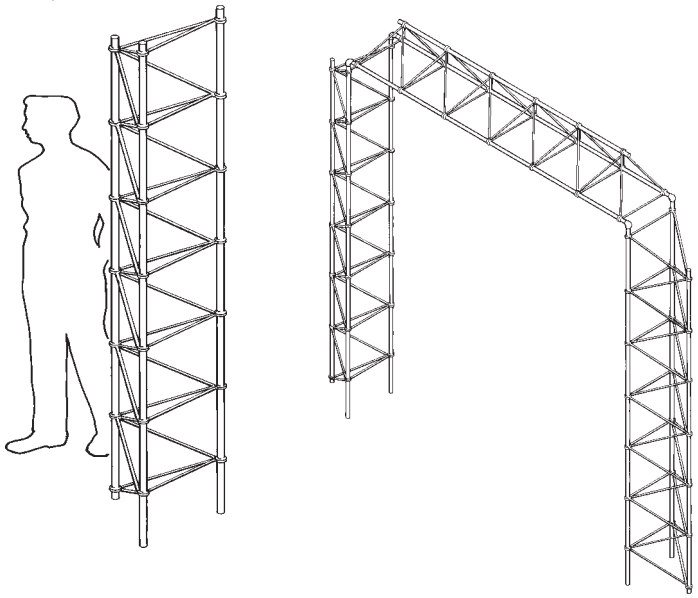


DESIGNING AND MAKING A LARGE SPACE FRAME

Space frames are often used in exhibition systems to:

- divide up spaces
- hold display panels
- support lights

Commercial systems can be very expensive and may be "over-engineered" for an exhibition display that is needed only once. Using roll-tubes connected to larger plastic diameter plastic tubes and you can create larger space frames for exhibition systems, room dividers and shop displays at a very low cost.



YOUR TASK

◀ DESIGN BRIEF

Design and make a space frame unit (or units) for an exhibition system, shop display or other purpose. The system or units should be as strong and stiff as possible, but use the minimum amount of material and fittings. Although the unit or system may be used only once, it should be possible to break it down into parts for storage and possible future use.

DESCRIBING YOUR TASK

◀ DESIGN SPECIFICATION

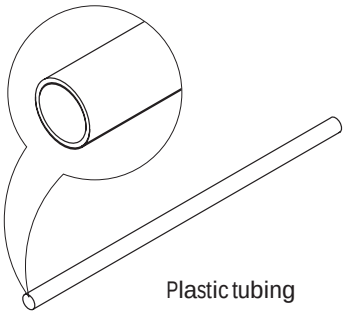
First, you need to draw up a design specification for your space frame. A specification is a more detailed description of what a product will be like, what it will do and who will use it.

Here are some questions to help you produce your product specification:

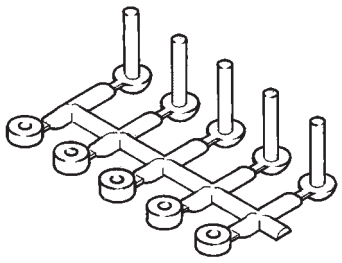
- What should the space frame do ?
- Is the space frame part of a modular system ?
- How much load will the space frame need to support ?
- What fittings are needed apart from those supplied ?

MATERIALS YOU HAVE TO WORK WITH

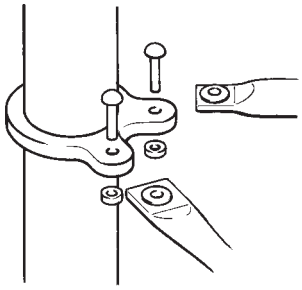
Before you get on with your design work, you need to know what materials and equipment are available. Your teacher will provide you with some of the materials shown. The plastic tubing is standard waste piping sold by most builders' suppliers. The connecting rings are designed to fit over this tube but are a tight fit and should be heated in water before slipping over. The rivets - each with a locking ring - locate in the lugs of the rings and will secure one or more roll-tubes. An alternative to the rivets is screws and nuts - or fittings which you design.

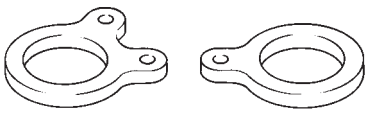


Plastic tubing



Plastic rivets





Connecting rings

Connecting ring on plastic tubing with roll tube connections

WORKING OUT YOUR DESIGN

◀ DESIGN PROPOSALS

Once you know what materials and components are available, you need to thing about some ideas for the space frame product.

- *Set your ideas down on paper.*
- *Play around with your ideas.*
- *Check your ideas against your specification.*
- *Decide which is the best design.*
- *Do a detailed drawing of the design.*

You will need to end up with a working drawing from which you or someone else can work to mark out, make and assemble the parts.

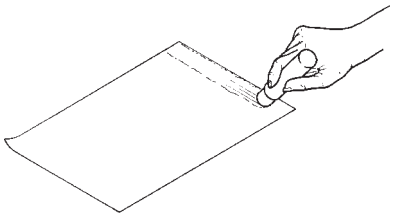
◀ NOTE

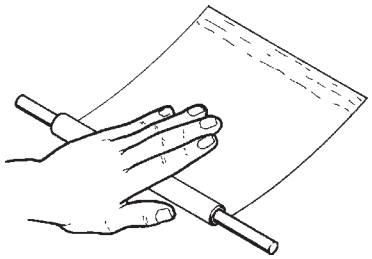
See Technology Study File 2.

Before you start, the following notes will give you some ideas about how the space frame can be designed and made. They do not give you the answers though. You must make the important decisions and put all the "ingredients" together so that you end up with an effective product.

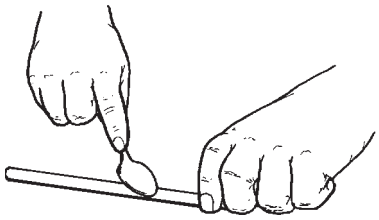
MAKING ROLL-TUBES

Method 1
Cut the paper to the correct length and width (allowing extra width for trimming after rolling). Apply adhesive (e.g. Pritt stick) to the paper edge to close the roll.



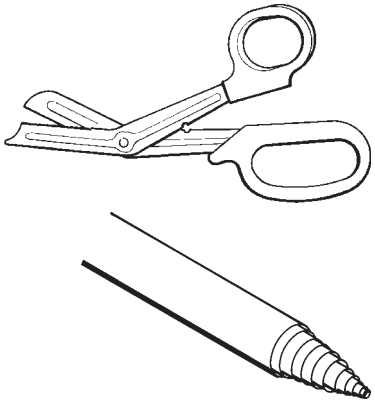


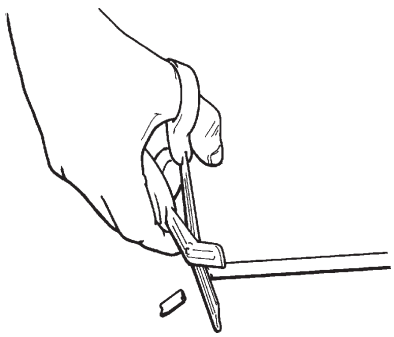
Carefully wrap the opposite edge of the paper round the mandrel and roll it up over a flat surface.



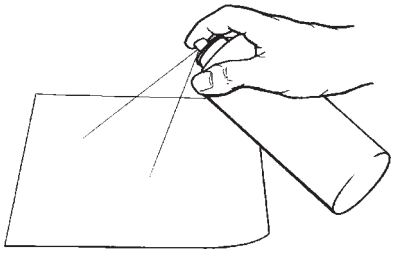
When rolling is complete, burnish the glued edge with the back of a spoon - keeping the mandrel inside. Slide the tube off the mandrel.

Unless the paper is wound perfectly parallel to the mandrel, one end will 'spiral' in slightly and the other end will 'spiral' out. Trim both ends with the type of scissors shown. Their high mechanical advantage enables the thick tubes to be cut easily and the serrations prevent the tube sliding between the blades.

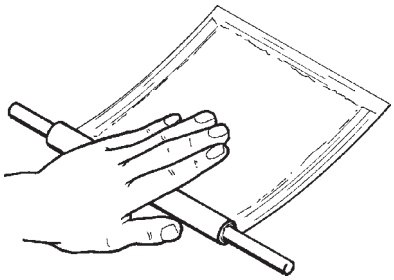




Method 2
For additional strength, adhesive can be applied to the whole paper surface before rolling. Spraymount or dilute PVA can be used.

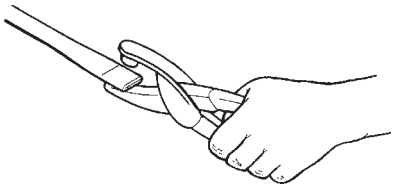


Method 3
If the end of a larger diameter tube is to be left open - for example, to contain another sliding tube - adhesive should be applied along the edges of the paper so the layers of paper at the ends are glued solidly together.

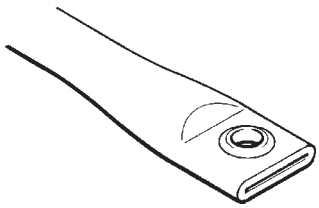


TERMINATING ROLL TUBES

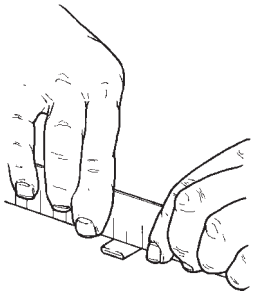
For most space frame structures, roll tubes can be joined using small nuts and bolts. The tube requires flattening and reinforcing where a bolt passes through.



The tube is pressed flat and then punched using a combined eyeletter and riveting tool. Reinforcing eyelets are then inserted and closed with the tool.

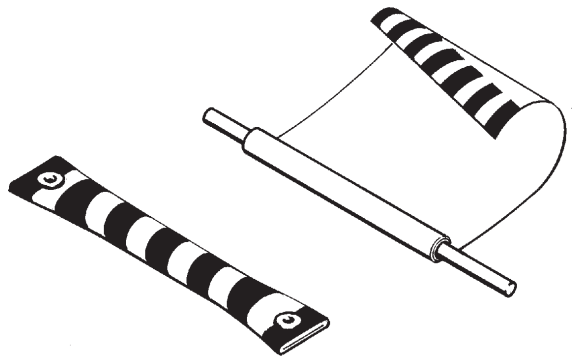


The flats on a tube may be parallel to each other or at any desired angle. The flats can be made to flex or 'hinge' by creasing with a ruler edge pressed down very firmly.



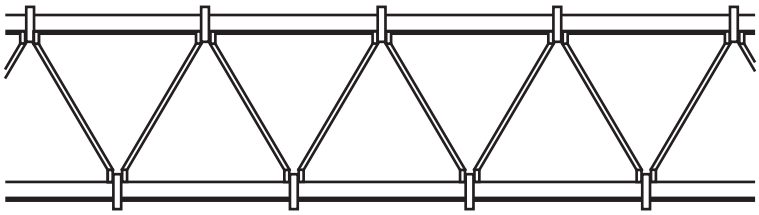
FINISHING ROLL TUBES

Roll tubes can be spray painted with cellulose or enamel paint. Alternatively, coloured paper can be used in their construction. Special papers available include those with 'day-glow' colour finishes. For other modelling effects or simple labelling, the paper can first be passed through a photocopier to print an image. (This only needs to be printed on the edge of the paper).

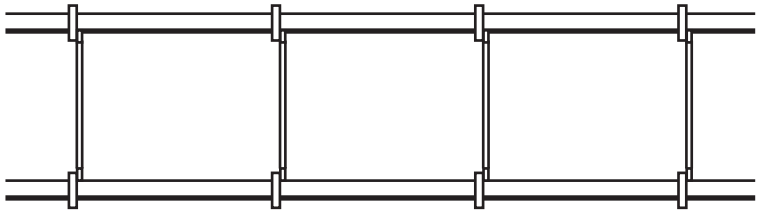


SPACE FRAME GEOMETRY

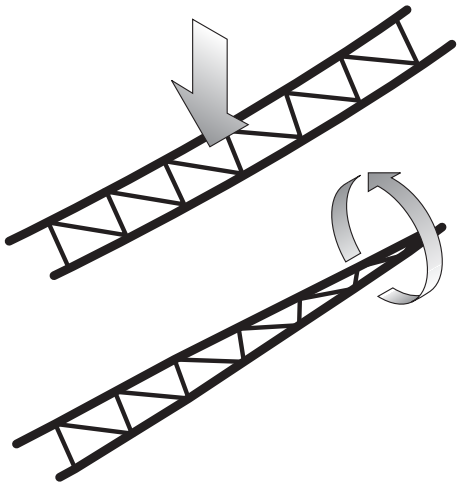
There are several proven methods of combining large and small tubes to make larger space frames. The simplest construction is a two dimensional frame structure This has roll-tubes connected across between two larger diameter plastic tubes.

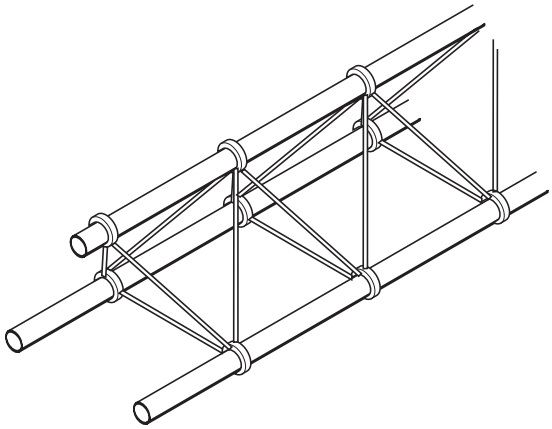


For strength and stiffness the roll-tubes are placed diagonally. If connected at 90°, the truss would be very weak.

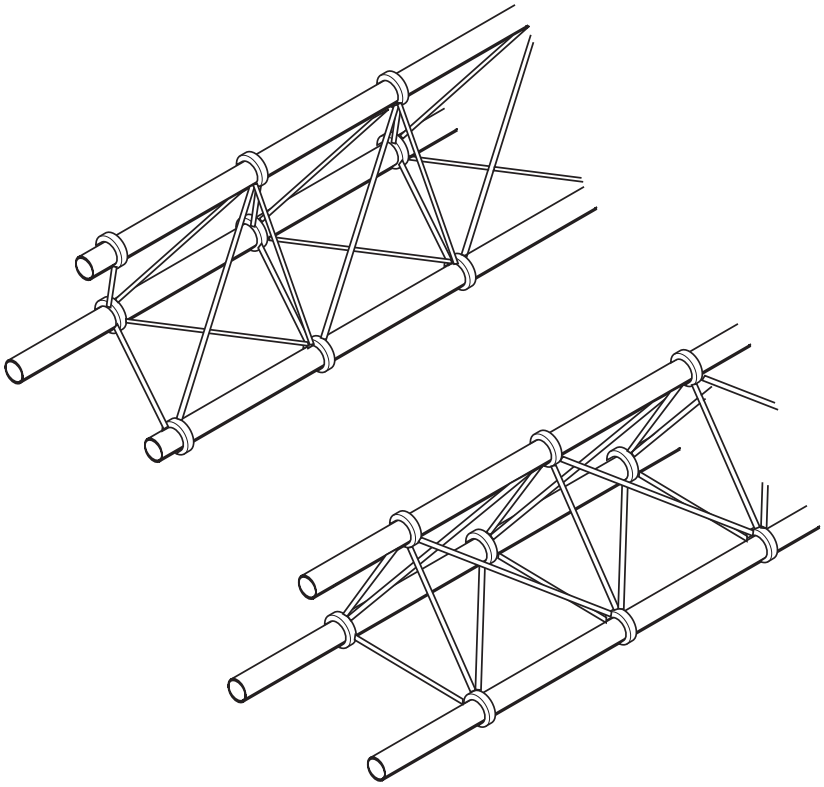


A two dimensional frame by itself has two big drawbacks: it bends easily in one direction, and it twists very easily. Both of these problems can be overcome by putting three frames together to form a triangular section but using only three of the larger tubes.

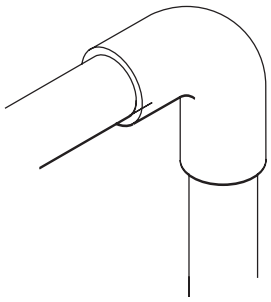




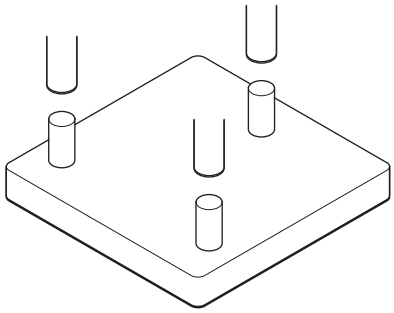
There are, however, several options for the positioning and layout of the roll-tubes. This can be quite difficult to imagine and may require some experiments with short lengths of the larger diameter tubing. Two possible options are illustrated.



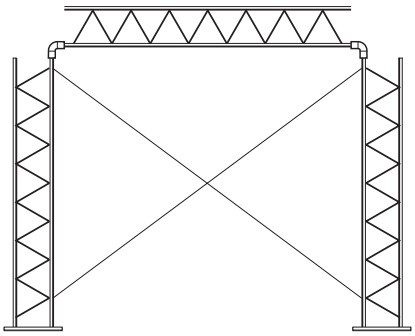
Two or three dimensional frames can be joined using standard fittings supplied for the waste pipe. It is not normally necessary to use the special adhesive because the fit is a tight one. Also, without adhesive, the structure can be taken apart easily.



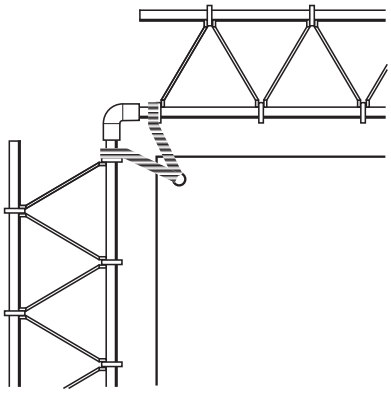
To make a single upright space frame stable, a base plate is needed. This might be a piece of MDF (medium density fibreboard) with dowel pegs over which the larger tubes can be slipped. The larger the area of the base, the greater the stability.



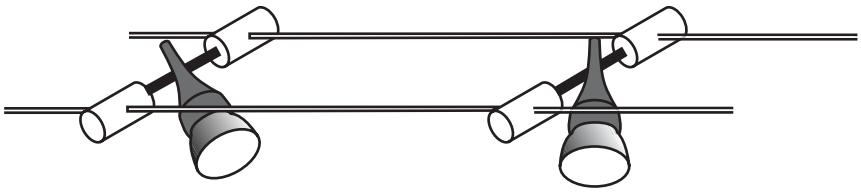
If a number of three-dimensional units are used together, the whole structure will offer more stability. With several units, it may be necessary, however, to use cross bracing. Thin nylon (fishing) line might be used to achieve this.



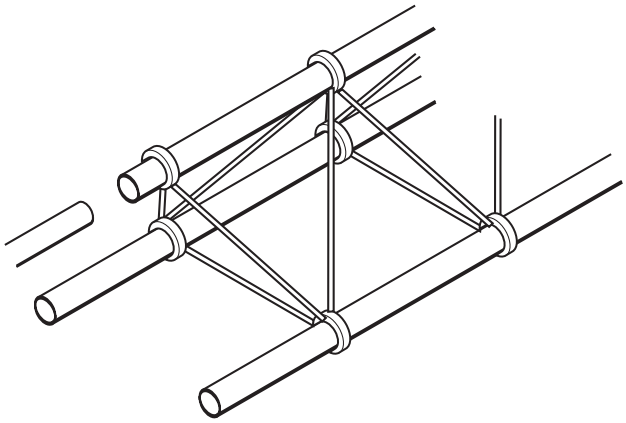
Display boards and lights can be fastened to the space frame units in several ways. One option is to suspend lightweight boards - e.g. foamcore boards - using nylon line. If this is thin enough the boards will appear to “float”.



The fitting of lights depends on the type and weight of what is used. Small low voltage high intensity lamps are very popular for display lighting and have the advantage that they weigh very little. They can also be clipped to current carrying rails or wires providing adequate safety precautions are taken.



Although a three dimensional space frame unit will be very strong in relation to its weight (and therefore very efficient), it can "sag" when horizontal. If heavier lamps are suspended, for example, from a complete gantry, it is necessary to add reinforcement. An easy solution is to place dowels within one of more of the larger diameter plastic tubes.



EVALUATING YOUR SPACE FRAME PRODUCT

There are a number of things to consider when evaluating the success of your design:

- Does it meet the specification ?
- Does it meet the requirements of a space frame; i.e. is it rigid and stable ?
- Can it be easily assembled ?