Airframes – Instructor Training Manual

Chapter 1 – AIRFRAME DESIGN

Learning Objectives

1. The purpose of this chapter is to make you aware of the various influences that affect the shape and performance of an aircraft and to give you an understanding of the structure that make up the airframe itself.

2. So, by the end of this lesson you will be able to identify the main components of an aircraft, and understand how the underlying structure is made up.

Introduction

3. A typical aircraft is made of many thousands of individual part. Some parts could be made from larger pieces – why do you think manufacturers make the aircraft in so many separate parts?

- Through use, components will wear out, so we need to be able to replace them.
- Some components will inevitably become damaged, so again, they will need replacing.
- Some components are made out of several sub-assemblies in case one part fails, the other components will stop the aircraft from crashing.

4. An airframe is therefore made of a number of assemblies, which build up to form several *major* components, such as;

- Fuselage
- Engines
- Cockpit/Flight Deck
- Wings
- Flaps
- Fin
- Landing Gear
- Fuel Tanks
- Tailpane
- Rudder
- Elevators
- Ailerons

5. All the above a perfectly valid, but for the purposes of this lesson, only the four *major* airframe components (wing, fuselage, tailplane and undercarriage) will be discussed in detail in further lessons.

Engines & Cockpit

6. Now, you may think that this lesson is missing a couple of important components, such as Engines and Cockpit. Although valid, the Viking glider is an aircraft and it is fairly obvious that it does not have an engine. Likewise, an Unmanned Aerial Vehicles (UAVs) is also an aircraft, but they have no pilot and therefore do not need a cockpit for them to sit in.

7. Therefore as both gliders and UAVs utilise airframe structures, for the purposes of the airframe subject lessons, they will not be discussed further.

Structural Loads

8. Before continuing, it is useful to have an appreciation of the loads an airframe is likely to encounter and the methods, which an airframe designer utilises to deal with them. All the loads that the structure of the airframe carries have to be resisted by components that are shaped and formed to resist those forces.

9. For example, the types of forces present in the components of an aircraft wing include;

- Squashing
- Bending
- Tearing
- Pulling
- Twisting

10. In order to cope with these loads/forces, the airframe designer has four types of *Structural Element* available to be used within the airframe design. These are

- Ties – these resist tension ‘or pulling’ forces
- Struts – these resist compressive ‘or squashing’ forces
- Beams – these resist bending forces
- Webs – these resist twisting and tearing forces

Ties

11. Ties are members subject purely to tension (pulling). A tie can be a rigid member such as a tube, or simply a wire. An example commonly available that Cadets could relate to includes guy ropes on a tent – where the guy is used to stabalise the tent structure.

Struts

12. Struts are members in compression (squashing). It is much more difficult to design a strut than a tie, because a strut is liable to bend or buckle.

If a strut is put under compression until it fails, a long strut will always buckle, a short strut will always crack (crush) and a medium strut will either buckle or crack, or sometimes both. Generally, hollow tubes make the best struts.

Beams

13. Beams are members that carry loads at an angle (generally at right angles) to their length, and take loads in bending.

The beams in an airframe include most of the critical parts of the structure, such as the wing main spars and stringers. Even large structures in the aircraft are acting as a beam, for instance, the fuselage.

Webs

14. Webs (or shear webs) are members carrying loads in shear, like tearing a piece of paper. The ribs and the skin within the wing itself are shear webs.

Practical Examples of Structural Elements

15. Looking around you can you spot any of the members we have looked at in normal everyday things

16. So what examples could you see?

- Table Leg: Strut
- Table Top/Door: Shear Web
- Table Top Rail/Door Lintel: Beam

But did you spot any Ties? These are not so common in a normal room, but keep an eye out whilst in the rest of the building, and see if you spot anything.

Airframe Structures

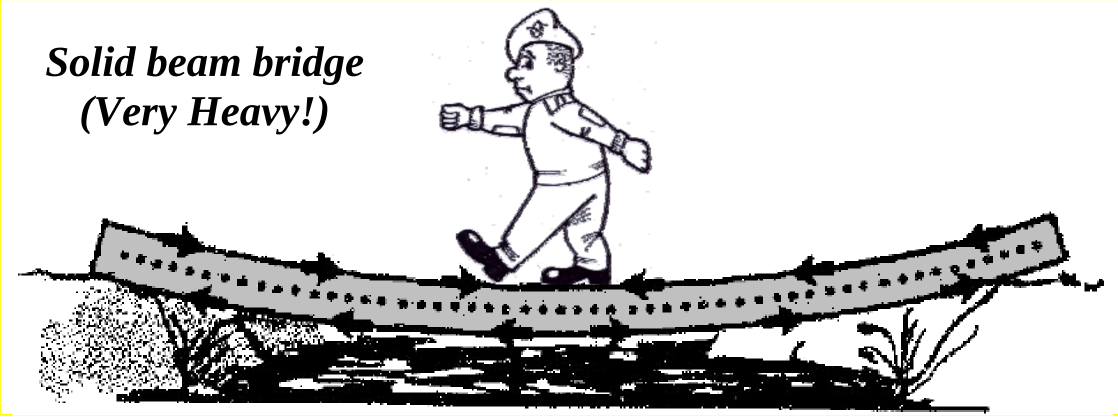
17. You may get the idea that each part of an airframe is either a Tie, a Strut, a Beam or a Web, but this is not always the case. Some items, such as wing spars, act almost entirely as one type of member, but others act as different members for different loads. For instance, the main spar near the fuselage will transmit load in bending and in shear.

18. By carefully mixing these members, and making sure that each part of each member is taking its share of the loads, the designer will achieve the greatest strength with minimum weight, and so get the best operating efficiency and maximum safety.

As an example, let us look at how we could reduce the weight of a solid metal beam being used as a bridge across a stream.

The 'Bridge' Example

19. When the cadet walks over the bridge made of a solid block, it bends under his weight.

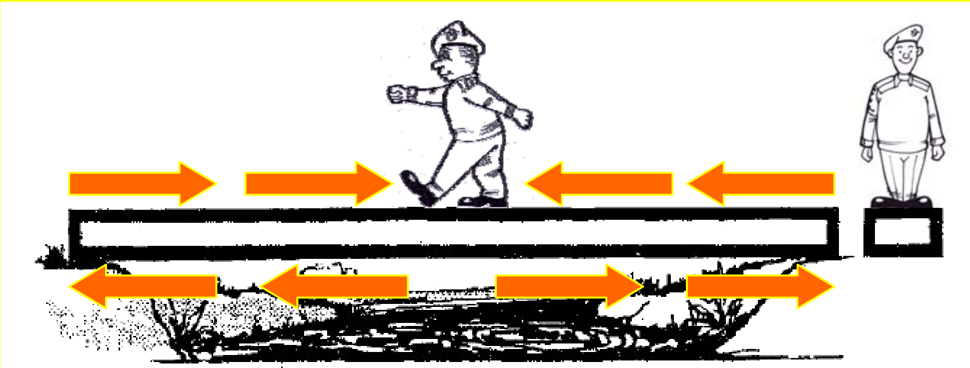


The effect of a weight on a solid beam bridge

The top surface is in compression (being squashed).

The bottom surface is in tension (being pulled). We can assume that the centre is least affected (neither pulled nor squashed) and therefore in an equilibrium state. However, by using a solid block to bridge the gap, the resultant structure is very heavy

20. As the centre portion of the beam is the least affected by these forces, the redundant material could be removed from the central portion to make the bridge lighter.



The bridge with the centre 'hollowed out'

21. Whilst the removal of this material would have very little effect on its strength, we. Still need to ensure that the top and bottom sections are structurally supported and therefore still strong enough to carry the load.

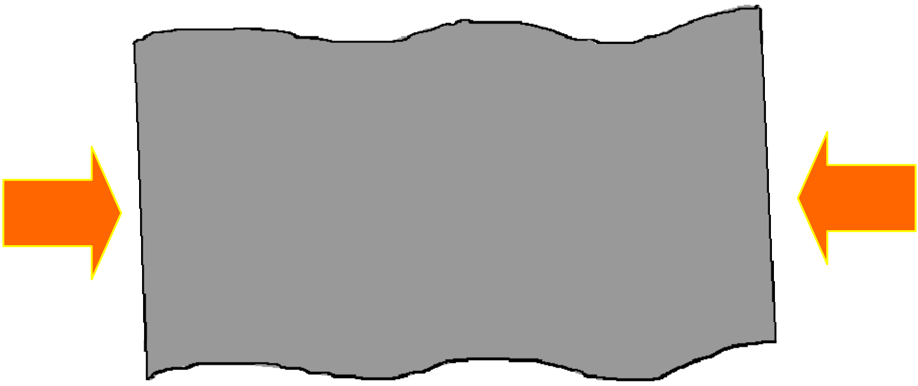
You can see from our earlier examples that the top section is effectively acting like a strut, whilst the bottom section acts like a tie.

A Practical Exercise

22. So we have the top and bottom of our bridge, but how about the supports at either end and along the sides? Well, if you take hold of a piece of paper and pull it from each end, you will see that it is quite strong in tension.

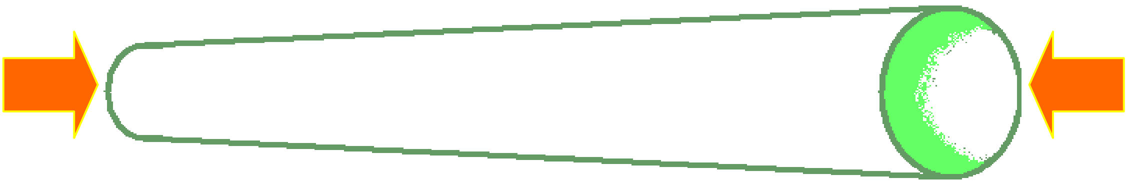
The paper is strong in tension

However, if you push the edges of the paper inwards, it distorts easily, because it has very little resistance to compression loads. Because the paper is so thin, it will crumple, or buckle easily.



The paper is weak in compression

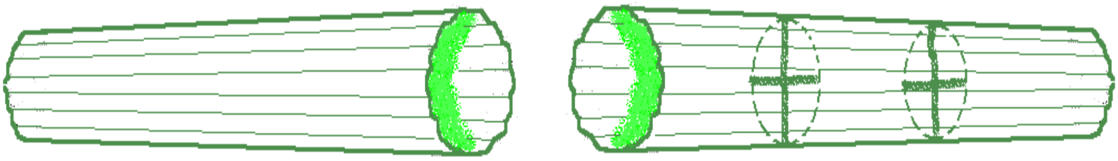
23. Now if we roll a same size piece of paper into a cylinder (along the long side), and then push the ends together. It is now much stronger, because of its shape.



So the sides of the bridge are important to support the top and bottom, preventing the bridge buckling and distorting out of shape. You can demonstrate this by trying to balance a weight on the top and see what happens.

24. When our paper tube does fail, it is because the walls buckle.

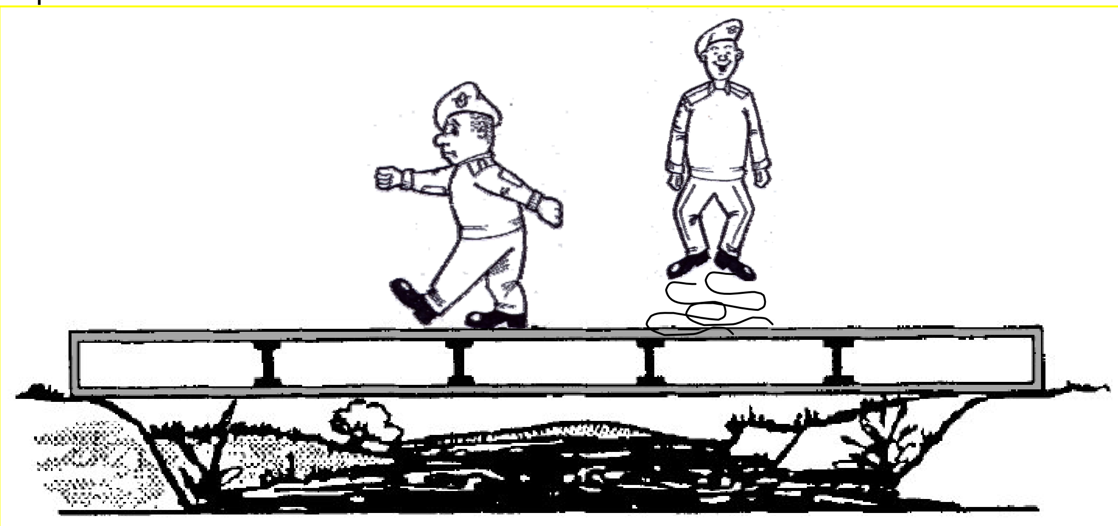
Try making a shorter tube, and see if it will support more weight. If we braced the inside or corrugated the walls, it would prevent them buckling, and make it even stronger.



We can do the same with the structure of the bridge, and use even thinner walls, provided they are properly braced to withstand the loads.

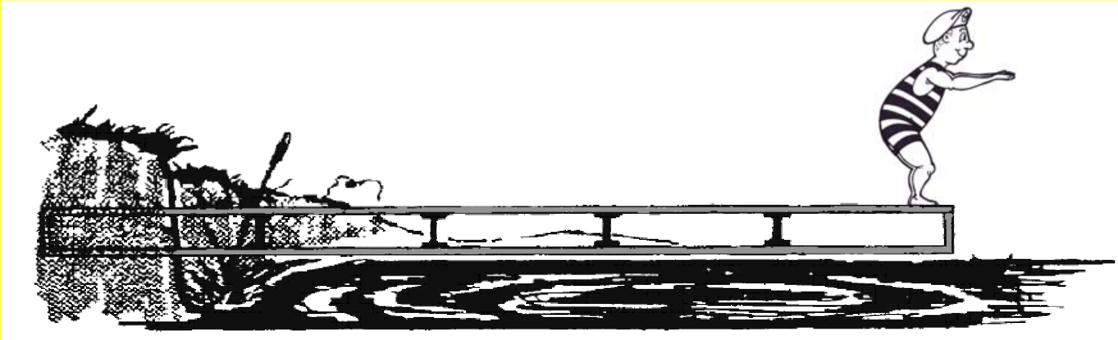
So Back to the Bridge Example

25. So now the bridge is much lighter, and looks something like a modern bridge or part of an airframe.



However, this is a beam supported at both ends. Let us now look at a beam only supported at one end

26. So what happens if the bridge can be supported at one end only?



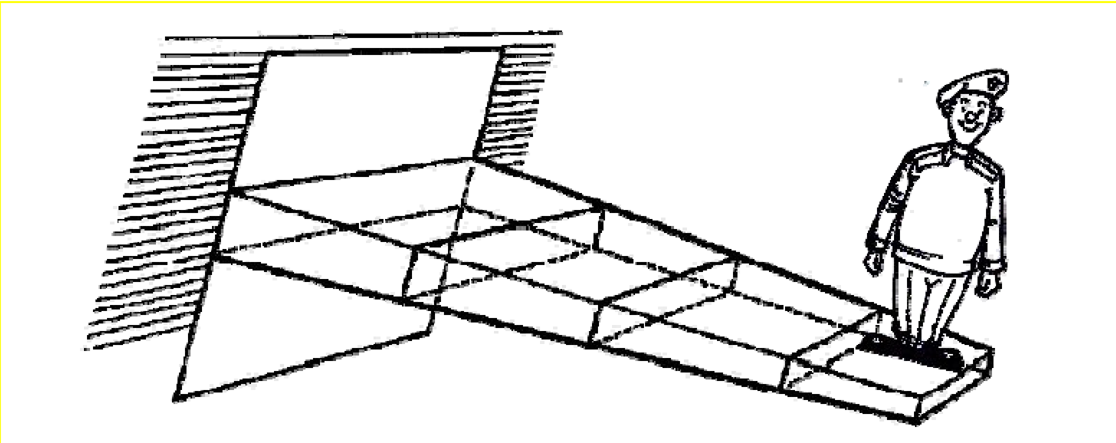
Wouldn't it look more like a diving board?! If our bridge is to be used as a diving board, it can still carry a load, but the whole of the force must be taken through the end that is supported.

27. Provided the outer, unsupported end is still strong enough to carry the cadet, we could make it smaller than the supported end. However, in doing this, we need to ensure that the supported end is still strong enough to carry the weight and bending force from the cadet being at the very end plus the weight of the whole of the structure.

28. Therefore we would want to make the supported end much bigger than that used on our previous bridge design. This results in the strongest, lightest structure to do the job – which in the case of our previous example was to provide the cadet with a diving board. This type of structure is referred to as a cantilever and is widely used in airframe design..

<u>The Cantilever</u>

29. Like the supported structure, the cantilever will still bend downwards, but this time the top will be in tension (like a tie) and the bottom in compression (like a strut).



The cantilever structure is widely used in aircraft, because airframe design contains many structures which are attached at one end. The wings are just one example of this.

30. Because the wings need to be much stronger and stiffer at the root (the attachment to the fuselage), they are therefore wider and deeper there than at the tip, where loads are much less.

31. There are many other examples of cantilever structure. For instance, the Forth Rail Bridge is a cantilever truss and so are balconies.

<u>Conclusions</u>

32. To build an airframe to cope with the ever-increasing demand for higher weights and speeds, and to do this with the lightest possible structure weight, the designer must solve many problems.

33. A thorough under-standing of the loads on an aircraft structure is needed. Of course, these structures must also be safe and reliable.

34. You should now have an understanding of the *'major components'* that make up an airframe, as well as what major parts make up an airframe, and the different types of structural elements used in the construction of the airframe itself.