No 2 TENSION and COMPRESSION

Gerald Foley Given at CTC 21 June 2010

1. Last time, we looked at the idea of a force. It is a push or a pull, in a particular direction, acting at a point, and having a certain size or magnitude that we can define in kgs or other units.
2. In particular, we looked at gravity. Advanced physics has a lot of pretty incomprehensible things to say about gravity. But in these talks we are sticking with the version we owe to Sir Isaac Newton.
3. In this version, gravity is the downwards force that acts on all objects on the earth, and around it, and tends to pull them towards the centre of the earth.
4. Gravity is acting all the time. If I drop something, I expect it to fall downwards because of the pull or force of gravity. If I release a ball at the top of a smooth slope, I expect it to roll down to the bottom – again because of the force of gravity.
5. This is an issue which is of particular interest to us as AT teachers. Every one of us, teachers, pupils, all of us are subjected to the constant downward pull of gravity.
6. You could say that a lot of our work as AT teachers has to do with helping people to manage their muscular use in order to deal less damagingly with the downward pull of gravity on our bodies.
7. Today I want to look at the concepts of **TENSION** and **COMPRESSION**.
8. First tension. Like a lot of technical terms, it has a variety of common meanings. I couldn't bear the tension at the end of the match or when I was waiting for the results of my examination. I might say I have a tension headache; or he's a person with an awful lot of tension in him.
9. Generally, we tend to think of tension as a bad thing and there are lots of popular health articles on how to deal with it or even get rid of it. "*Eliminate tension from your Life*" might even look like a good snappy slogan as you wrestle with what to put into your AT brochure.
10. But like force, the engineering or physics definition of tension is extremely precise and limited. Nor is there any suggestion in the technical definition that tension is a bad thing. An AT teacher who succeeded in completely eliminating muscular

tension in a pupil would be in pretty deep trouble and very glad of their professional indemnity insurance as the emergency paramedics arrived.

11. Compression is the opposite to tension but the word has few popular connotations. You don't hear people saying, I feel terrible, I've got so much compression in me nor do you have people offering to get rid of your excess compression. The fact is, however, that if you do have excess tension, you are almost certainly going to be suffering the effects of excess compression also.

12. So, what do these words tension and compression mean for the engineer or scientist?

13. Put at its simplest, tension is a pulling apart or stretching tendency and compression is a pushing together or squeezing tendency.

14. We create this tension or compression by applying forces to an object – outward forces for tension and inward forces for compression.

15. Let's take this piece of wood. If I pull the two ends apart, or stretch it, we say I am putting the piece of wood in a state of tension or under tension. When I push on its ends, we say I am putting it into a state of compression, or under compression.

16. Note there is nothing special about the forces themselves which bring about tension and compression even though you hear people referring to tension forces and compression forces.

17. Tension and compression refer to the state of the object on which the forces are acting.

18. Different materials behave differently when subject to compression and tension forces. The study of this behaviour is covered by branch of engineering called **Strength of Materials**. It was one of the major subjects when I was studying engineering and we spent several years on it but today we are going to deal with it in about ten minutes.

19. Various factors determine the strength, or ability, of different materials to resist tension and compression forces and I think the best way of getting into the subject is by showing you a couple of examples.

20. Let us look at tension first. Here is a piece of rolled up tissue. Rather like cooked spaghetti, it has a very low ability to

resist tension. If I subject it to even a small amount of tension, it immediately breaks. We say it has a very low tensile strength.

21. This piece of string clearly has a greater resistance to tension than the tissue. We say it has a greater tensile strength. I can use it to resist quite a strong force; I could probably lift three or four kilograms with it.

22. This piece of wood is even stronger and if it had a hook on the end, I could use it to lift a much heavier weight. My calculation is that it would be about 50 kg.

23. And if I used this piece of steel I could support an even bigger weight – I have calculated that it would support about 250 kg. Steel is obviously very strong in tension.

24. Another thing we notice is that the length of the piece of material does not have any noticeable bearing on the tensile force it can carry. A long piece of material, provided it doesn't have weak spots, can carry the same tensile force as a short piece.

25. So, in summary, the intrinsic quality or strength of the material determines the tensile load it can carry. The tissue has virtually no tensile strength, the piece of string has quite a reasonable tensile strength, the piece of wood has a higher strength, and the piece of steel has an even higher tensile strength. We can draw up a table of materials, listing them in their order of tensile strengths.

26. Now let's look at compression. The question is rather more complicated than with tension.

27. Just as in the case of tension, different materials have different compressive strengths. Some, like this plasticine are unable to resist much compression. We say they have a low compressive strength – or that they are soft.

28. If we look at a piece of wood, we find it can carry a much higher compressive load. It has a much higher compressive strength than plasticine.

29. And if we look at a piece of steel, and were able put a very strong squeeze on it, we would see that it is even stronger in compression.

30. But something else emerges when we start going further into the question of compression. This is the question of shape.

31. If we take a piece of steel which is long and thin, even though it can carry quite a heavy load in tension, it can carry hardly anything in compression. When I try to make it do so, by placing it in a vertical position and putting a downward load on top of it, it bends or buckles.

32. This takes us into an engineering area which is called the theory of buckling or sometimes the theory of struts – a strut is just another name for a column or pillar which carries a compressive load.

33. The big man in this area was Leonhard Euler a Swiss mathematician who lived from 1707 to 1783 and produced a series of quite complex mathematical formulae to do with buckling which have tormented engineering students ever since.

34. Without going into any detail, what Euler said was that in addition to its intrinsic strength, two things influence the load a strut can carry without buckling.

35. The first is its length. If we have a long spindly thing, we know it cannot carry as big a load as when it is shorter.

36. We saw our piece of steel and the way it buckled. But if it has only half the length, it is very much stronger in compression.

37. The second important thing is the cross-sectional shape of the strut. The way Euler put it was that a strut is only as strong in buckling as its least lateral dimension – its narrowest width – allows.

38. This means that if you have a certain amount of material and you can spread out its shape, it will carry a heavier weight than if it is tightly concentrated. For example if you are forming steel rods into different shapes in a rolling mills, you find that if you reshape a round bar into a cruciform one, one in the shape of a cross, it will carry a much higher compressive load than when it had a cylindrical shape.

39. Another way of spreading out the material is to make it hollow. We can illustrate this by taking this piece of card. If I try to use it this way when it has a flat shape, so that its least lateral dimension is just its thickness, it cannot even carry its own weight. But if I roll it up into a cylinder, even though it is hollow, it can carry quite a heavy compression force or load.

40. These fairly simple observations on how objects behave when they are subjected to tension and compression forces provide us with a considerable degree of understanding as to why various parts of the body are the way they are.

41. When the body, or belly, of a muscle contracts, the tendons pull on their anchor points and are put into tension. Because they are resisting tension forces, the tendons are generally thin and strong pieces of connective tissue.

42. But, of course, they are useless in compression. Muscle tendons only pull; they cannot push.

43. Now look at the bones. These carry compression loads.

44. Bone is quite a hard material which is good at carrying compression loads. But, as we saw, being hard is not enough. The material has to be arranged in a shape which prevents the bones from buckling. We also saw that the hollow tube is a very good use of material as far as a strut is concerned.

45. And when we look at bones, we can see that evolution has been at work since long before Leonhard Euler.

46. Most of the bones, especially the longer ones, are hollow or have highly porous interiors. Nature arranges the material in such a way that the tendency to buckle is reduced.

47. This had the additional advantage of reducing the amount of weight the body has to carry around in the form of bone. And clever old nature has made use of the space inside the bone and used it as a workshop for bone marrow to work on making red blood cells.

48. Finally, let us look at this diagrammatic person. The heavy weight of the head is carried down through the cervical vertebrae, on to the spine. The weight of the thorax and all the major organs is carried into the thoracic and lumbar spine and down into the pelvis.

49. From the pelvis, the weight goes down through the bones and joints of the legs into the feet and on to the ground where it is supported. Everything is in compression all the way down.

50. We also notice how the width of the vertebrae increases as the cumulative weight on them increases.

51. Suppose now I happen to be carrying a weight, or a pair of weights, in my hands. Now the arms are in tension and the weight is carried up into the shoulders by the arm muscles,

tendons, ligaments and joint capsules all of which are good at carrying tension.

52. The tops of the arms are connected into the shoulders which transfer the weight into the spine which, as before, carries it in compression down to the pelvis and into the legs and down to the ground. Once again, clever old nature has given us a very efficient use of compression and tension materials.

53. But the human body is extremely versatile and the arms can be used to carry compression loads. If the arms are raised up, we can see how they would use the bones to carry the loads in compressions down to the shoulders, through the spine and the pelvis and legs down to the ground.

54. I think that is enough for today. We have looked at the difference between compression and tension. We have conquered Strength of Materials and seen how different materials have different capacities to resist tension and compression forces. We have also seen that the shape of an object can affect its ability to carry compressive forces. And we have begun to see how all this relates to the working of the human body.