Engineering Mechanics

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Statics – 2.1

Hai, today we will look at structural systems that are made out of rigid bodies. In order to understand it better, we will just assume that the bodies are rigid that make up a particular structural system. Usually there are sets of rigid bodies that are connected to each other either in a rigid way or through a hinge or through a slot. There are many ways in which you can connect the rigid bodies to form a system. If the system is going to take certain loads we will call them as structural systems.

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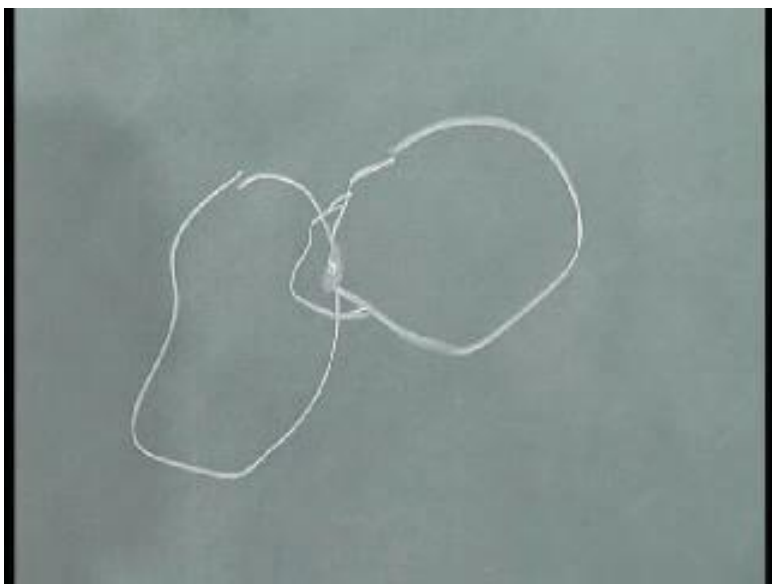

There are different kinds of rigid bodies that you can classify them into by the very nature of these rigid bodies. For example this particular piece of chalk, this has length dimension far exceeding the other two dimensions. In the practical sense this is like a one dimensional body. Another example could be this one where the dimensions of the thickness as well as the breadth are very small compared to the length of this. We call these as one dimensional member. This can be called as two dimensional member because it has finite dimensions of these and this dimension, the thickness dimension is very small. So we can call this as two dimensional body. Even if it is curved, you notice that there is one dimension in this direction, one dimension in other direction and the thickness is small compared to it. Such systems or such rigid bodies we call as two dimensional rigid bodies. A typical three dimensional rigid body is like this, solid like. The length, breadth and height are comparable to each other so this is the three dimensional. For our understanding we will first focus mainly in this particular exercise on bodies that are one dimensional.

This will be very useful for us to built structural systems and understand before we go in for systems that are two dimensional or three dimensional. To start with let's look at a single dimensional member. Again in single dimensional it can be a straight member like this, it can be curved in which way you want either in a plane or out of plane.

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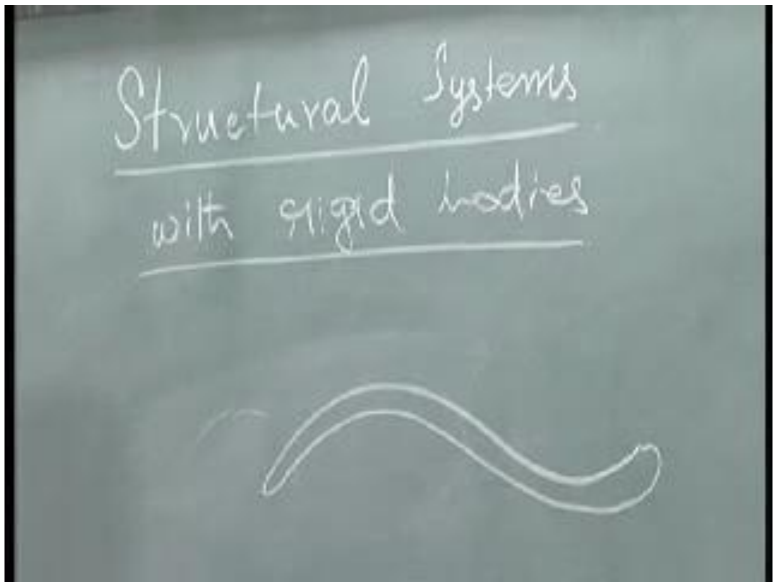

You can see that this is an out of plane member but still it is a one dimensional rigid body. For now we will again limit ourselves to just planar bodies which means whether it is straight or curved, it is on the one single plane that we are looking at. Let's say if this board is in the planar side of it, typical one dimensional rigid body can be something like this or it could be straight and so on. The very fact that it is one dimensional, instead of this we can as well draw the axis of this and say this is a one dimensional member. This is a one dimensional rigid body and we can build different structures out of this kind of one dimensional member. We will look at some of the examples at a later stage but let's examine.

How do we analyze for forces within this rigid body. The reason why you would want to have analysis of the forces within the rigid body is to understand whether the rigid body can take or the body can take the load or not. For example if this is a body and if I am pressing it hard on the board, how much hard can I go before this breaks and if I know the internal forces that will give me an idea of whether it will break or not for the particular situation that I am talking about. Such an analysis is called analysis of internal forces in a structural system. What are internal forces? Supposing I take this particular rigid body, from now on I am going to use only line diagrams and let's say this is subjected to moments or forces in different directions and so on.

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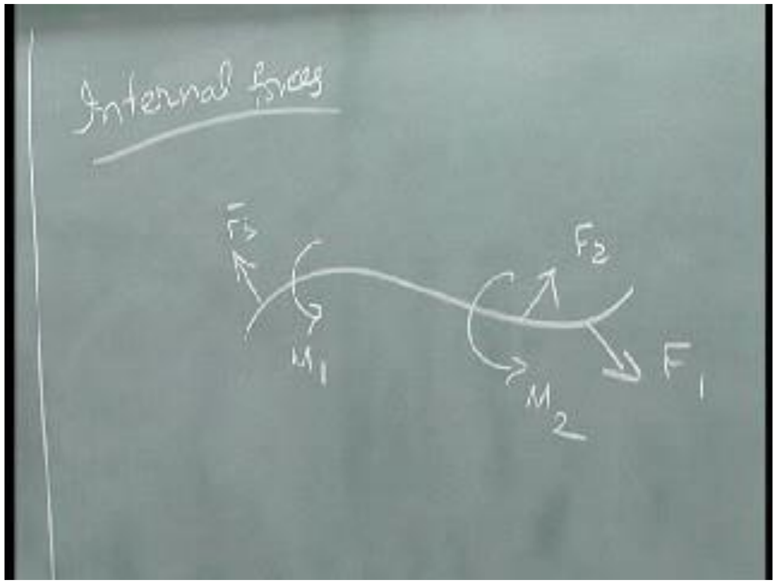

If I have to examine the internal forces, the first thing that I have to do is I have to separate this body into two or several bodies with the point at which I wish to know, what are the internal forces in the rigid body. If I have to do for example, examine the forces at this particular point x. So let's say x is like this. I need to find out the particular internal forces within this particular rigid body. First thing I have to do is separate this rigid body into two pieces and examine one of the two pieces.

Let's say if we are looking at this particular rigid body and I separate it. I am just showing the separated part. Let's say A, this is x, this is B. So I have A_x here, B there. The separation has occurred at x. We can examine the free body A_x or x B. First I am just drawing all the external forces acting on this particular part of the rigid body A_x. If I come to this particular point, this point because of pull, there may be an axial force or the force along the curve of this particular rigid body. I am going to call that as an axial force so we are going to use A, that could be a force that is acting perpendicular to it. Let's just call that force as what is called shear force equal and opposite. It could also be resisting for example this is resisting, bending so that could be a resistance and bending and that could form a moment, all at x. So I am going to use a suffix x in all this. Equal and opposite moments occur because there are reactions here that will cancel each other. Now I can insert all the other, rest of the forces that act on this particular body B. As you can see here, there are three internal force resultants that appear upon sectioning at x.

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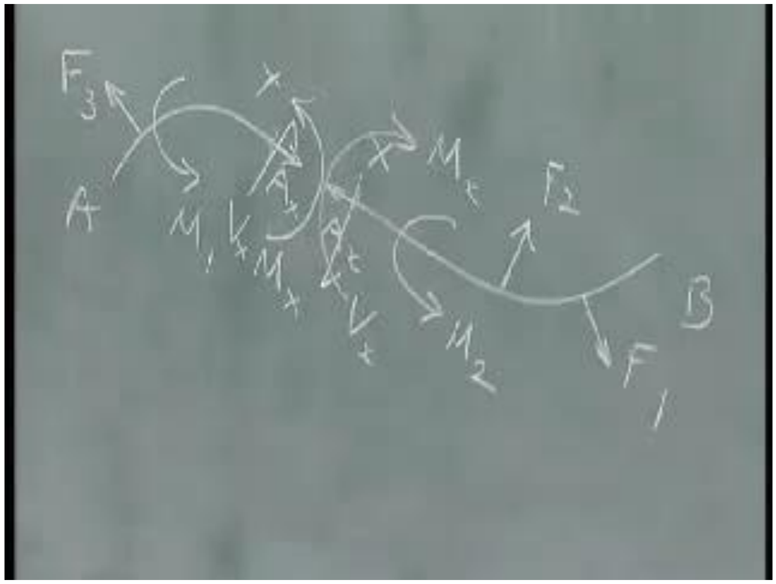

Let me just draw this. It looks like little cumbersome. So I will go and draw only A_x. This is A, this is x. Force F_3 is acting like this, moment is acting. At this particular point where I have section, there is an axial force, there is a shear force V_x and there is a moment all these appear because of sectioning. We are just using a suffix x where x is the point at which we are looking at. This essentially shows the free body diagram of A_x, given that F_3 and m_1 are known I have three unknowns A_x, V_x and M_x to be found out. Since this is a planar rigid body, there are three equations that we can form which are sigma F_x is equal to m A_x and so on. Let me ask not to use F_x here, sigma F alone in x direction. I am just going to denote a direction over here. This is x direction, this is y direction. Let's use a capital x here just to avoid confusion. If we are looking at only static's then we make this equal to zero.

Similarly F in the vertical direction is equal to zero and moment lets take this as positive, equal to zero. Three equations can be formed, this can be about any point on this. So if I take A as the point or x as the point, in question then I will have three equations, three unknowns that I can solve for. So equilibrium is enough to solve for forces in the member. How do we quantify this?

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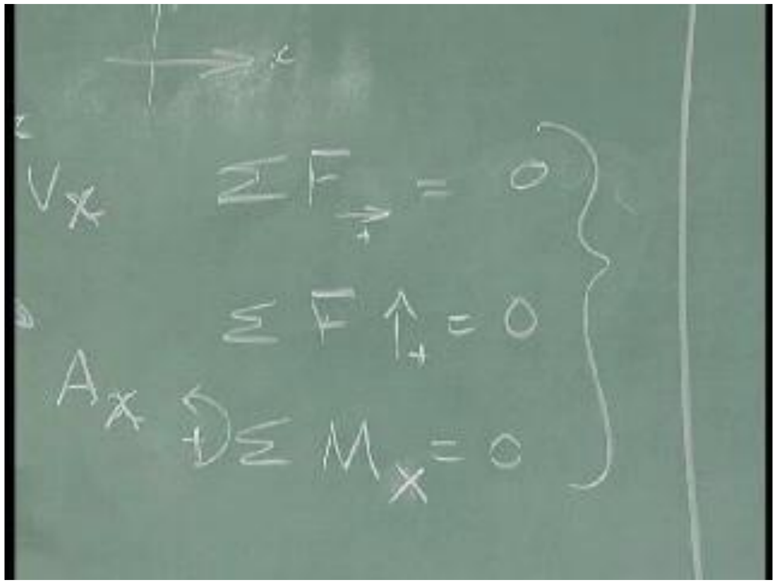

If I have to write let's say, we examine this particular body AB, I can probably run a coordinate s along this. So any cut here tells me what is the s value. I can start from s equal to 0 to s equal to either 1 or something. If I take s equal to 1, I can always find out what will be the value of the axial force in the member. Similarly at same point s away from A, the shear force is this. If you look at it, all the three vary with respect to the coordinate s. Or in other words I can also do a plotting starting from s equal to 0 to s equal to 1.

Let's say if axial force is changing like this. It could be positive or negative, I am just going to talk about sign convention in a moment. I will adopt this to be the axial force. Similarly I can show the distribution of shear along s equal to 0 to 1 and similarly m. This is an axial force diagram. In short it is called A F D and you can have shear force diagram S F D and you can have bending moment diagram. So B M D for bending moment diagram, so these are three diagrams that you can draw. Depending on the nature of these, we can classify the one dimensional structures or one dimensional rigid bodies. So far we have just examined the internal forces acting in a one dimensional member.

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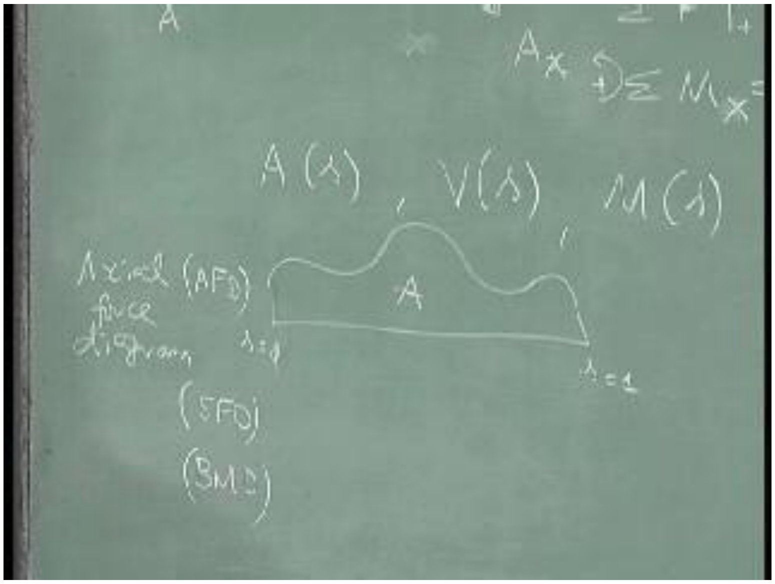

When I say member here, single one dimensional body. As structural system consisting of one dimensional bodies is basically many of them connected together to form a structural system. Typical structural systems could be for example let me just use the same kind of member. Let me take some s type of member. I could join many s type of members. Let's say I could have something like this. This could be a structural system that I have and there may be forces acting on it everywhere around and so on.

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I could have, perhaps this s integrally joining like this. If you look at this, it is different from this. I will show you in a moment, a few of those examples. Here it is integrally joining, here you have a pin type of joining or in other words in this particular case if I have a joining way of having a single pin that means this member and this member can rotate freely with respect to each other at this particular point. But then if I integrally connect them like this, they cannot rotate between each other and therefore there will be a moment reaction between them. This is another possibility. We will look at other possibilities. I could have a straight member.

For example I could have a straight set of members connected like this. I could have just a single member but vertically placed and forces that are acting are only vertical forces. If you look at this, this is like a column system. There are forces acting only in the vertical direction. Typically we name them differently depending on the shape of that particular rigid body and the internal forces that they carry. The internal forces that they carry could be either, all the three of them together or only one of them or two of them, any particular combination that we worked out in a structural system. Supposing I take small state elements and then join them like pins and then form some structure like this. This is like a chain.

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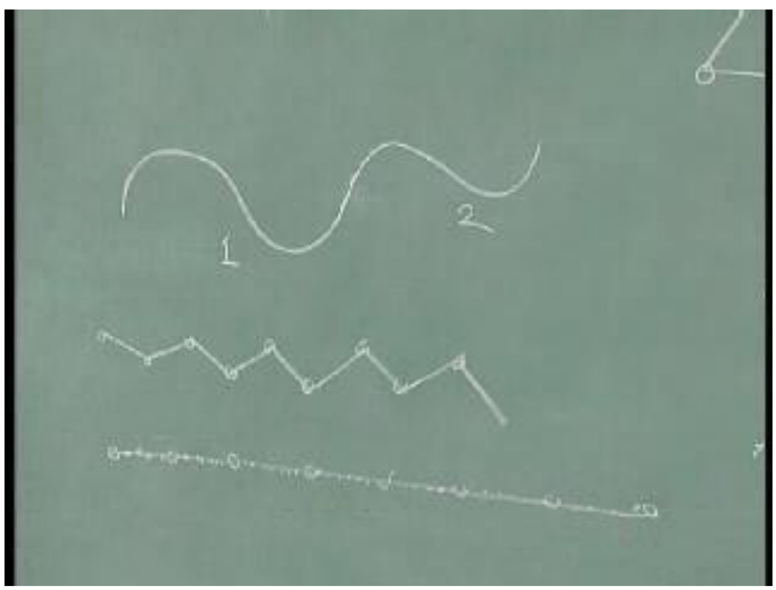

I can straighten it and I will have something like this. What is unique about this is these particular points where they are pined, they are free to rotate, there is no resistance offered. Supposing I think of these elements to be smaller and smaller and smaller. What do you get? You get so many pins attached to that or in another words it cannot resist any moment at any particular point. Such a member, such a structural system is called a cable.

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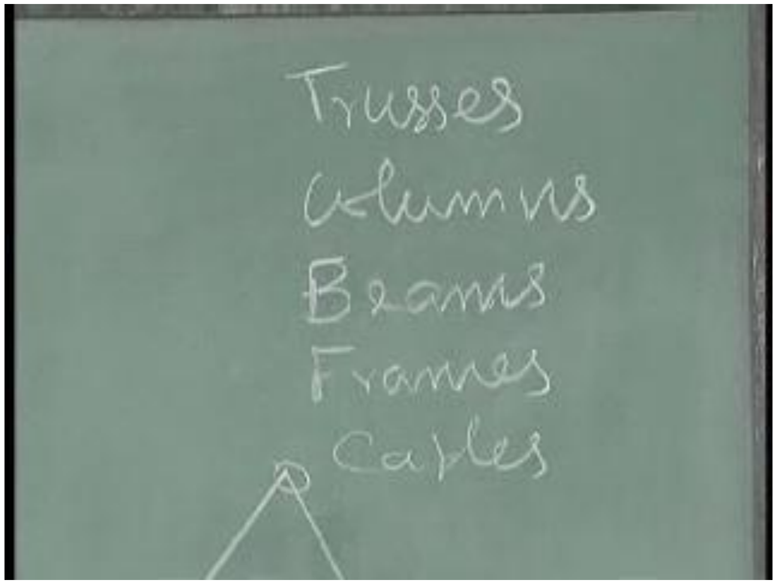

We name different structural systems that form out of this as different structures such as trusses, beams, frames, shafts, you have columns, you have cables and so on. If you have only tortional action on it, you call them as shafts. Depending on the action, we have different names to it. We will see what is unique about each of these systems in the next clipping.

Thank you.