Strength and Vibration of Marine Structures
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Lecture - 1
Introduction to Ship Structures – I

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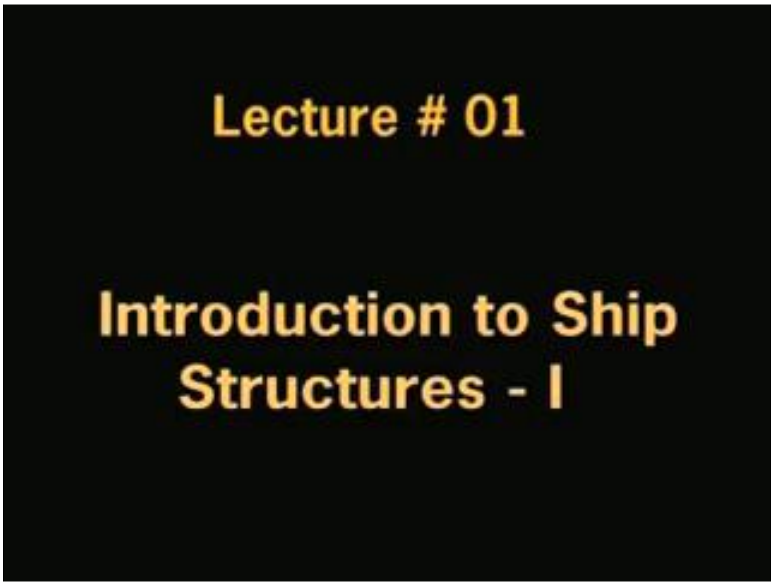

So, here we will be studying strength and vibration of marine structures. So, there are a number of courses, it is one of that; the primary object here is to basically assess the strength of the structure - strength of a marine structure or more specifically you can say strength of a ship. And the basic requirement of getting the idea of strength of a marine structure or a ship is to assess or to have some idea about the structural safety of the vehicle. Now, there are two important terms here: one is the strength and another is the stress. So stress and strength - they are two important terms.

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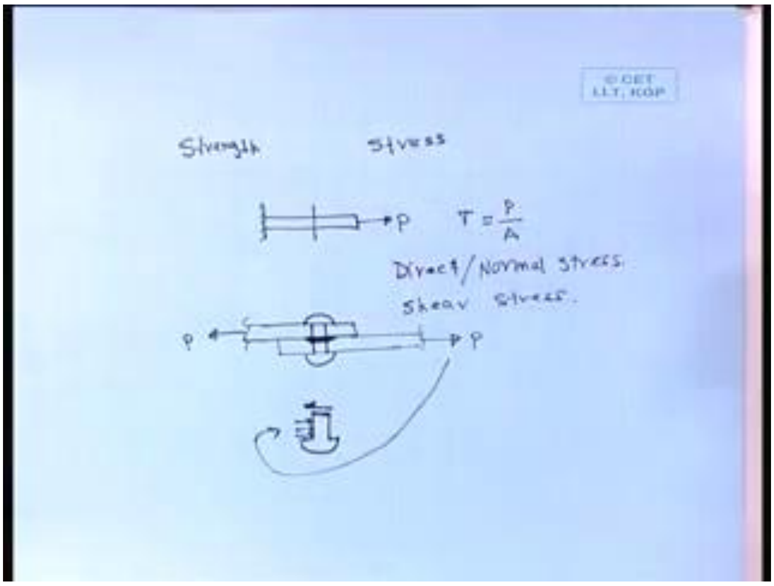

So you can write here - strength and stress. Now, I can give one example to have a feeling about strength and stress. So there is one lift; we want to go to some high level; on the lift, something will be written - maximum load it can carry 800 kilograms. So, it is basically its capacity; so capacity is analogous to strength. And stress is how much is the weight. So, you may want to carry one machine; you want to carry some object; so, that is something analogous to your stress.

So, if that weight is within the limit - say, weight is 800, or less than that - we can safely carry that weight by the lift; here also the stress we have to predict. If the stress is within our level of stress limit - what we are defining as the strength - then there is no problem; structure will be in a safe state or we can assess or we can define that it is more or less in a safe condition. But if it exceeds that, definitely, we will get the indication, safety will not be there; we have to take some measures.

Now, so the basic requirement is we have to determine the stresses and the stress will not be constant within the entire structure. So whole problem will be a state where the stress will vary from point to point; we have to get the idea regarding the distribution of the stress, and from there we will get the maximum value of the stress, and that stress should be within the allowable limit.

Now, let us define what stress is. We can take a very simple case; say there is a bar; sometimes we say it is a case of simple stress; there is a force P. So, this is a bar; there is a load P. So, what will happen? If you take any section, if you cut the member at any point, so that P, it will be distribute over the entire cross sectional area. So, we define a term sigma that is equal to P divided by A. Now A is the cross sectional area of that member. Here at the application of the point the load may be acting on a small area, but gradually that load will be distributed over the entire cross section. So, there might be a localized problem at the application of the load, but within a short time, it will be stable.

So, if the load will be distributed over the entire cross section; throughout the entire length of the member. So, anywhere if we try to get the stress, so stress we can get by P divided by area. Now, this is one of the very simple cases. In real structure, it may not be so. Stress - it may vary from point to point. So, our objective is to find out the distribution of the stress and its maximum value. Now, this type of stress has a typical name - we say it is a normal stress or direct stress. So, that type of stress we will say direct or normal stress.

Now, there is another type of stress; we say it is shear stress. Now, at this level, I am trying to take some example where problems are very, very simple; later on, we can combine all these individual parts to get a much more complete stress picture; definitely that will be much more complex or typical stress situation.

Now, if I want to define what shear stress is, we can take this type of example. Say there is a plate here; there is another plate here; these are just continuous; I am putting some break line; now here, say, take a rivet. So, it is a problem where two plates are connected by a single rivet. Now, there is a load P this side and there is a load P the other side. Now here, you try to fill about the failure of the rivet. Now, the plate, which is below, it will try to move in the right side; the plate on the top it will try to move in the left side

Now, along this plane, the rivet will try to fell. So, this is the plane where rivet will try to split into two parts. Now if I try to draw the forces on the rivet - say one part only - say left part, if you consider; so, that will be the rivet. Say if there is a failure of the rivet, it will be here, and the right side that plate, it will apply some force on that, because whatever P will apply, that will be transmitted here in a distributed form, and it will try to pull in the right side. And the upper part, it will try to give a force in that direction that will be distributed over the cross section of the rivet.

Now, the arrow, whatever I have shown, basically it will show the entire force, but that will be distributed over the circular cross section of the rivet. Now, here it is not in a direct mode, but it is in a plane, and that stress we say is a shear stress. So, any stress - we encounter in any structure problem - basically, there are two types: one is normal stress; another is a shear stress.

Now, I will come to the effect of the stress or what we will get when some force will be applied; some stress is there; we will get some deformation of the structure. And the deformation is measure in terms of strain. So, strain is one term, it is related to force; strain is a term it is related to deformation of the structure.

Now, stress, we can say if we want to define, it is basically measure of internal forces. We are putting a force here externally P, but at any point within the member, the stress will be transmitted; that is though it is applied at the end only one force. So, if you take the… it is acting on a particle; that particle will try to move in a right side; there will be a particle adjacent to that, it will try to pull it.

So, when it will pull, as a reaction it will get the force on the right side. So, next particle it will try to pull it. So, in that process there will be a interaction between the different particle. So, force will be transmitted within the body. And internal forces will be generated, and the measure of the internal force in the form of some intensity. Basically it is a distributed force; so, its distribution… that distributed force, if we try to measure the intensity of that, it is nothing but stress.

Similarly, due to the external load, the structure will undergo some deformation. So, deformation will take place all over the structure. So, all that particle will undergo some movement. So, that movement if we try to define, we define in the form of strain. Now, what is strain?

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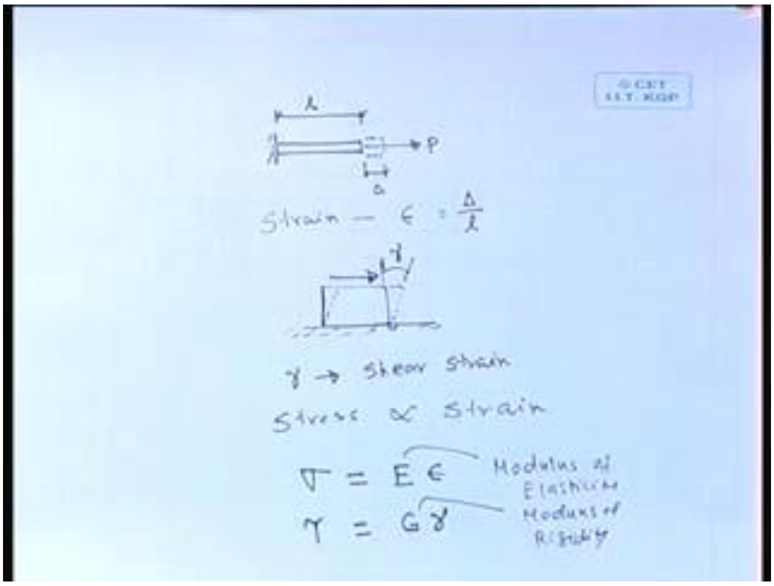

If you take the same problem, this bar, and there is a load; we will get some elongation of the member. So, there will be some change in length of that member. If the change in length is a delta, and if the initial length is your l; the strain we define as epsilon; it is basically whatever is the elongation divided by the original length. So, delta is the change in length; l is the original length. So, rate of change of length we are defining as epsilon or strain. Here also, it is a simple strain. And that strain is constant throughout the member. Because it is a uniform case; stress also it was a uniform case, but if you take a complex problem, definitely it will change. The shear stress it will produce some form of strain; that strain is called shear strain. So, normally that strain here it will be the direct strain or normal strain; just like stress was direct stress or normal stress; it is direct strain or normal strain.

Now, if I take a case like that, say a block, say it is resting on some support. If I put some force here, so there will be some distortion of the member. So, here it will not change its length, but it will change itself; initially it was a rectangle; now it is not rectangle; here the change is change in angle. So, initially that line was there normal to the horizontal line; now it is oriented in a different manner.

Now, this angle – gamma - this is basically your shear strain. So there will be some shear force here, and it will produce some shear strain. Shear force, intensity of that will be shear stress, and shear stress will produce some shear strain. Once we have the idea about stress and strain in the form of shear or normal, we have to find out the relationship between that; because they are closely associated with each other.

Now in general stress and strain, they are proportional to each other. So if stress is increased, strain will be also increased; if stress is decreased, strain will be also decreased. So, we can say stress is proportional to strain, and that was first proposed by Robert Hooke. So, we say it is Hooke's law. And if you try to equate both, there will be some constant. So, stress will be equal to strain into some constant. And that constant is dependent on the property of the material. And if you take a normal stress - so this sigma - it can be written as E into strain; if you take a shear stress – tau - that will be taken as G into gamma.

So, whether it is sigma or tau, and this side epsilon or gamma, here the constant will be E and G. So, E is what? E is the Young's modulus or modulus of elasticity of the material. So, E is basically your modulus of elasticity and G is your modulus of rigidity. So, they are basically the property of the material. If it is steel, it will have some value; if it is aluminum, it will have some other value. So, it is absolutely a inherent property of the material. Now, in direct mode we say this constant is E; in shear mode this quantity is defined as G - modulus of rigidity; and this E and G, it has some relationship.

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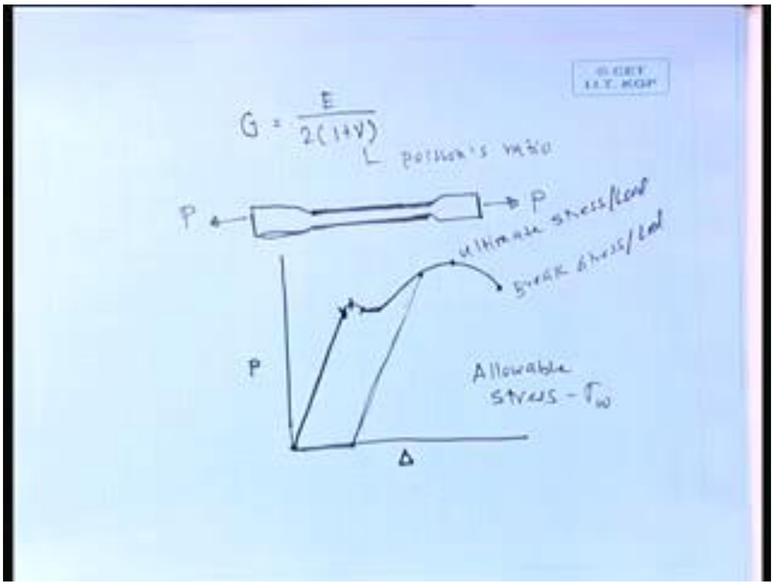

This G and E it can be related by G equal to E divided by 2 into 1 plus nu; now this nu is written as Poisson's ratio. So, normally for a material, definitely, it should be isotropic material. There are two constants: either it may be modulus of elasticity and Poisson's ratio, we can find out G; or it may be modulus of elasticity and modulus of rigidity, from there we can find out Poisson's ratio. So, all these three quantities are not independent; two quantities are independent; the third one we can determine from this expression. So, that is the very basic relationship between stress, strain in direct mode, in shear mode, and their relationship.

Now, here that proportionality we have taken - shear stress is proportional to strain or we have written stress equal to E into strain. So, there is a linearity between the relationship between stress and strain. Now, let us investigate what happens if we take some specimen try to put some load. Means it will undergo some deformation, and how much it is linear with the stress and the strain. We can take the example of mild steel. The tensile strength of some mild steel specimen, we can investigate in some laboratory test. So specimen will be more or less like this.

Say P here; it is P here. So, you can go to any laboratory or tensile strength can be accessed through some experimental measurement. So, there should be some instrument or specimen can be put there, and we can apply some tensile force. And there, we can measure force corresponding to the elongation of the member, or stress with the strain. And sometimes we can get a continuous plot of the load and elongation. And that elongation is… it looks like. So, the initial part will be a straight line, for that it will go like this, and here it will break.

Now, this side is P; this side is delta. If we apply load here, and this side if we plot the elongation of the member. So, on the plotter we may get a plot, which will show the load elongation of the specimen; that will be something like that. Now here, up to that limit the load elongation curve is linear or rather we have followed Hooke's law; Hooke's law will be valid up to this limit. Now, if you cross that limit, your curve will be a non-linear one; it will be not be a linear one;

Now, what will be happening here? Here there is a point; it is called yield stress, because here the material will start yielding. Sometimes we get two yield points; one may be upper yield point; another may be a lower yield point, but those points will be very, very close to each other. In the real experimental plot, it will be very difficult to distinguish both.

But if it is very precise and all those, we may get two different values. It will go up; again, it will come down; then more or less it will be a flat part. This flat will be a plastic flow. Again, it will gain some strength. So, some strain handling will be there. So, it will go up to certain extent; again it will come down, and here it will break up.

Now, in this part is quite interesting; this is called your ultimate stress; and this is called your breaking stress. Now, there might be one question - why load is suddenly decreasing? Because in the machine, we will try to pull the specimen. So, up to ultimate stress it will go on increasing; suddenly why because elongation will be more, but your load level will come down.

Now, what happens when it will reach to this ultimate stress? Somewhere within the specimen, we will find there is a sudden reduction; in the area, we say some neck is formed; it looks like a neck. So, area will be reduced suddenly, and the load carrying capacity will be reduced.

Now, we have put here P and delta, we are writing here ultimate stress, breaking stress, rather it is ultimate load and breaking load. So, it should be load and load instead of stress, but we loosely express that part in the form of stress also; because stress is load by the area, but if you cross beyond this ultimate level - ultimate load - your area will be significantly reducing. But we are not taking that actual area, how much it will be there after reduction.

Normally we will take whatever load we are getting, that divided by original area what we have measured at the beginning. Similarly, the delta part, if we try to express in the form of strain. So, delta by the original length, but length is also increasing. So, we are not actually trying to get the actual strain or actual stress, but we are trying to get the… basically we are trying to represent the force and elongation with some factor, and that factor is nothing, but 1 by original length; 1 by original area. So, that amount of scaling down or scaling up - whatever you can say - we are doing; basically it is a reflection of load and elongation of the member.

So, here what is happening? Your area is reducing, load carrying capacity is reducing, but actual stress if we measure, you will find actual stress will increase beyond that point. But the nominal stress - nominal stress means whatever load divided by the original area, that we have defined as nominal stress - that nominal stress, it will act like that, it is reducing. Now, anyway that will be the behavior of the stress-strain curve of a mild steel specimen.

Now, let us see what will happen if we unload the specimen or if we release the load, what will be the deformation of the structure. Normally, if it is within the straight part, at any instant you will release, it will come back to the original point. But say it is here, if you want to release normally, it follows a path parallel to the initial line. So, it comes like this. So, what will happen when the load will be 0, we will get some deformation. So, you get some permanent deformation there. So, if we go beyond our linear range, it will be here in the non-linear range; the problem is, if we release the load, still we will get some deformation within the structure.

Now, in actual design what is followed? In actual design, we do not go up to the breaking load or up to the ultimate load even after the yield stress. So, we take some load with some margin, and that stress is called your allowable stress. Or sometimes we write sigma working, and that sigma workings, sigma allowable that part will be much below compared to your ultimate stress or breaking stress or yield stress.

Just like that I was talking about the lift has some capacity 800, but normally we will not load up to 800, we will keep some little margin there I think. So, here also there will be some margin, and that margin is given in the form of something we call factor of safety.

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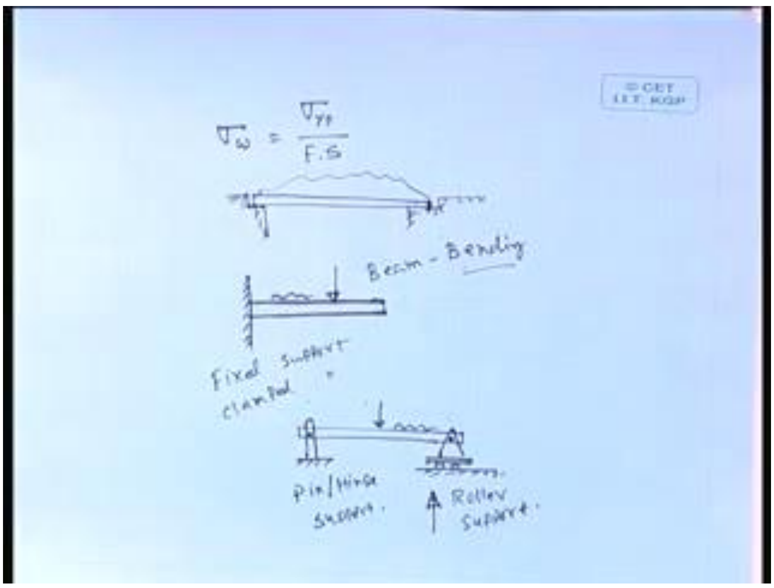

Now, the factor of safety is we say sigma working or sigma allowable; that is sigma. So, this FS is factor of safety, and sigma this may be yield point; it may be ultimate stress. Depending on the situation, if it is ultimate stress, definitely factor of safety will be little more on the higher side.

If it is yield stress it will be little bit on a lower side, but that will be the load or the limit of the stress we normally permit. So, if we come back here. So, this divided by some factor or this divided by some factor. So, normally it will be somewhere here I think. So, our design limit will be always within the linear range, keeping some safety factor in our hand; because any load we will calculate, it may not be ultimate; there might be some unseen forces; so, that part we have to keep in our hand, so that the risk of failure will be as much minimum as possible.

Now, these are related to say idea of stress, strain, allowable stress, stress-strain diagram, but normally I have tried to tell simply stress in a direct mode or shear mode, but all the time it will not be in a direct mode or a shear mode; another very important part is the bending mode. Say I am taking a member like this, and say it is resting on some support. Now, if I put something - some load on that; so, this member will undergo some deformation; say piece of member, it is supported at the two ends, say it is resting on two walls, some loading is applied on that; it will undergo some deformation. Now, that deformation is basically bending of the member. So, under the load it will undergo some bending. So, bending is one important type of deformation, and normally, it happens when a member is subjected to a load perpendicular to its axis, and it is properly supported.

Now, I will try to explain something on bending of a member, and normally, this member on the bending, we say it is beam. So, beam and bending - they are two associated terms. So, we say it is a beam bending. So, a member which is supported and subjected to transverse load, that is basically a beam, and the type of deformation is a bending.

Now, here I have tried to put some wall and some type of support. I should tell little bit about the type of support - a very common type of support, which we normally face in our actual structural problem. See there is a member like this, and there might be some loading on that. And it is connected to some wall or some strong vertical support.

Now, that type of support we say it is a fixed support or sometimes we say it is a clamped support. Now I shall take one case. See that member is like. Now that type of support, we say it is pin support or hinge support; and that type of support we say roller support. Now, what are the differences or why you are defining in that manner? One is a roller support; another is pin support or hinge support; another is fixed support. It basically depends on how it puts resistance or reactions. Now by roller support, this is the member, and the member end, under load it will try to move horizontally, vertically or it may rotate; all the possible movements are there.

Now, the roller support, it will only prevent the vertical movement and allow to move vertically upward or downward, and in that process, it will give one reaction. So, when there is a resistance, there is a reaction; when there is no resistance, there is no reaction. Say, if we try to move that end on the right horizontally, so there are some rollers; so, it will smoothly roll on the roller, there will be no resistance. So, it can freely move; it will not experience any reactive force of that side. So, it will get only one reactive force.

Now, if we talk about your pin or hinge. So there is one flit type; there is the beam; there is a hole, we have put a pin here. Now, the pin, it will not allow to move that end, either in horizontal direction nor in a vertical direction. So, both the movements are restrained. So, but if we try to rotate; rotation is absolutely free, because there is a pin here, and there is no resistance, but t can move this way or it can move this way. So, it has two resistance; it will not allow to move to this way; it will not allow to move along vertical direction. So, two components of resistance or reaction it will get, but rotational part it is allowed. The roller, it is only vertical movement; it will allow to move horizontally. So, it is just resting; it will allow the rotation also. So, rotation no problem; it can move also; only this way it cannot move.

Now, we come to the fixed end. So, it is basically absolutely blocked. It will neither allow to move horizontally nor vertically. It will not allow to rotate, because it is absolutely fixed there, through some strong welding or some arrangement. So, it has horizontal resistance, so horizontal reaction it will get; vertical resistance is there, vertical reaction it will get; plus some movement will be generated, because it will not allow to rotate. So, due to the load, it will try to rotate, but it will not allow to rotate. So, there is some resistance. Already I have mentioned, when there is a resistance, there will be reaction. So, when some restrictions are there, some restraints are there, some reactions will be generated.

Now I am talking about a two-dimensional problem. So, all are on a piece of paper. So, we will get more or less this three types of support: either roller or a hinge, or a fixed type of support. You can define a foot type; say this end there is no support. So, you can say, 0 means it is free supported. Now, we will try to handle some problem, where some calculations are involved for finding out the reactions at the supports.

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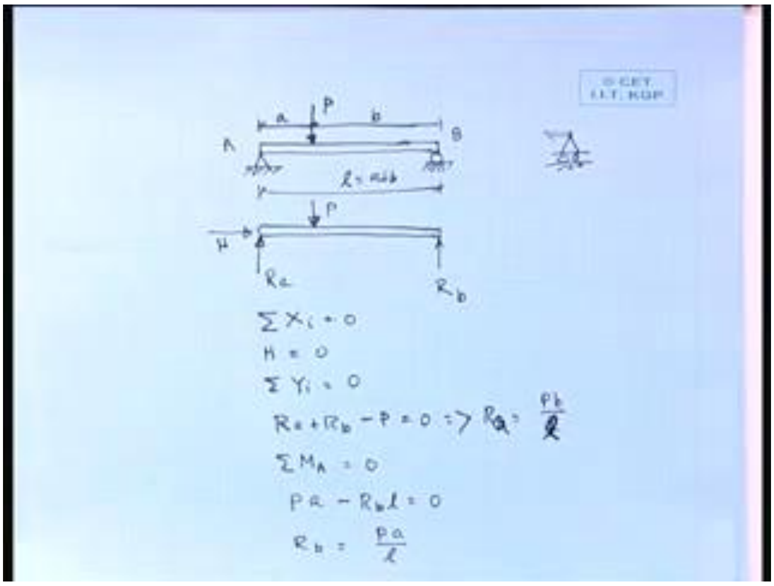

Say there is a beam here, and hinge normally we try to put in that manner; we will not show the pin, the plate, how this is connected with the support. So, in a convenient way just put a triangle, some line, something it will indicate it is a hinge. And the roller, sometimes we just put a circle and put it like that; or we can sometimes put like this some roller, like this, that is also another way.

Say there is a load here P; and the distance here to here it is a; the remaining part is say b; and total length we can say it is l. So, l is nothing, but a plus b. So, this is a beam, two supports at the two ends; there is a load P. So, our first interest or first job is to find out the reactions - how much it will be develop at the support?

Now, we can take the free body of that. Now, the problem can be plotted in that manner; there is a load here P, and here there will be a reactions say R; b, if we say this point is B, this point is A; then here there will be a reaction Ra; and here also there will be some force say, we say, there is some horizontal component H.

We have the idea of equation of statics. We know all the force in a particular direction P equal to 0. So, summation of all the forces along horizontal direction we can take 0; we can take summation of all the force in the vertical direction 0; or we take movement about that point of all the force it should be 0.

Now, only a plane problem, we have three equations of static. So, from our knowledge of statics, we have three equations. Normally, we utilize that - those equations - for finding out these reactions. So, here if we take, say, all that forces in X direction equal to 0. So, only one force, that is H, and that is equal to 0. And here there is no horizontal force. So, automatically the horizontal reaction, it will be 0.

Now, if we take the summation of all vertical forces along - vertical force means Y; then we will have Ra plus Rb minus P that will be equal to 0. Now, the next step we can take moment out any at point. So, you can take moment about A, moment about B, moment about the application of about anywhere we can take it. So, we can take say moment about A, that is equal to 0. So, if you take moment about A, it will be P into a; that will be the clockwise moment; and Rb into l it will give anticlockwise moment. So, minus Rb into l that will be equal to 0. As we are taking moment about A, your H and Ra will not come, because that force into distance is 0, automatically it will cancel. So, from here we will get Rb equal to Pa divided by l.

Now, we have already one equation Ra plus Rb minus P equal to 0. So, if we substitute there, we get the value of Rb. So, from here, I can directly write, I need not calculate here, it can be easily obtained. Rb is already there. So, it will be Ra; Ra will be your Pb by a. You will get because a plus b is equal to l. Automatically if we substitute there, we will get it. It will be not Pb by a; it will be l, not a. So, Rb will be Pa by l and Ra will be Pb by l.

So, if we get a beam type of problem, we will find some forces, some supports; those supports we will replace by some forces; we will use this equation of statics; from there we can determine the support reactions. So, ultimately it will be a beam problem, subjected to some forces, something this side, something other side. Now under the action of force, the member will undergo some bending. So, that bending part we want to study here, what we will have.

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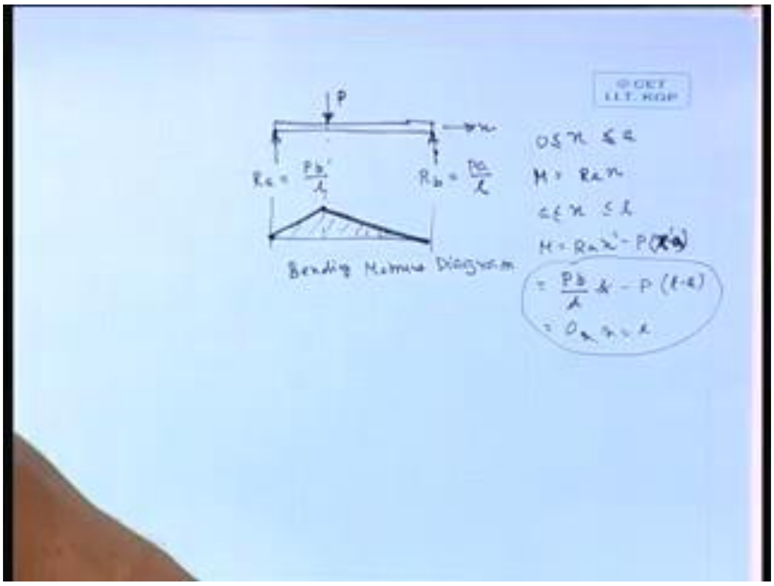

Now, if I take this problem. So, here we are getting, so Ra; we got Pb by l; and Rb Pa by l. Now under the action of this force system, try to visualize the deformation of the member. Say total summation of force it will be in equilibrium, and whole thing moment if you calculate, it will be in equilibrium. So, it will be a stable; it will not move.

But under the action of this load, because the loads are not acting at a single point - it is acting here; it is acting here; it is acting here - so, it will undergo some bending; so, there will be some deformation. Now, that bending is expressed in the form of bending moments. Say here, this side there is a load Rb. So, Rb into that distance that will give some moment, and that type of moment we say bending moment. And that moment it will vary from your point to point.

Now, if I take, say, from this point to this point, or rather if we put here x-axis. So, when x is less than equal to a. So, it is 0 to x minus a; means Ra to P - that range - your moment we can say it is Ra into x. If you cross that limit, say x, it is beyond P. So, m will be your Rax minus P L minus x, right? So, there will be one additional term. Now Ra already we have determined. So, if we put the value of Ra, and try to plot the curve here.

So, when x will be equal to 0, M will be equal to 0. Now under the load if we come, so it will be Ra into a; and Ra equal to Pb by l. So, it will be Pab by l. So, it will be up to this; and it will follow in a linear way, because it is multiplied with x. With the increase of x it will increase, and it is not x to the power 2, x to the power 3. So, it will follow a linear curve. Now, if you cross that path, so it will be Ra into x, it will further increase; for the second term, it will reduce, actually. So, that curve if we follow, say at x equal to your l, P, no this part will not be lyx, it will be x minus a. So, it will be x minus a. So, if I put x equal to l. So, Pl minus a, and this Ra part if we put, so l minus a will be basically b. And this part Ra if you put here, x equal to l, automatically it will cancel. So, rather I can put it Ra equal to your Pb divided by l, say x equal to l minus P. It is l minus a; l minus a is equal to b; and this l l cancels. So, it will be Pa, Pb; it will be Pb automatically it will cancel, and 0 in a special case.

So, at the right hand. So, if we if we put x equal to l, the whole quantity will lead to 0. And it will follow in a linear manner, because it is x to the power 1, x to the power 1. So, automatically it will come down to 0. So, this we will get a diagram. And this diagram is called your bending moment diagram.

So, we can keep up to that in next class. We can continue the remaining part.

Any reference book?

There is one book by Markel. Ships Strength by Markel. Normally that part, will come little later, when we will come in terms of ship bending and all those, but initially we want to cover the basic part. So, that is general for anything; you can follow any standard book of structures or strength of materials.

There is one book Strength of Material by Timoshenko. That book you can follow. Timoshenko is a thin book available in the market. You can use it, no problem; any book you can use it.

It is a white color book?

Color, it changes time to time. So, I will show you one; it has a color.

Preview of Next Lecture

So, we have talked about bending moment in the last class. We can continue with that and switch over to other thing like shear force. So, it is, basically, some component related to bending of beam. For the same problem if we draw here again. So, we took a beam like that; put a load at some intermediate point P; we got some reaction Rb Pa by l; and at a it was Ra Pb divided by l.

Now, one of the component, we have defined as bending moment. And we wrote some expression for bending moment. And we have seen that quantity is not fixed within the member; it is varying; and that was function of x; we have tried to plot that. In that case, it was varying in a linear manner.

Similarly, there is a quantity called shear force. Basically, at this force, if we try to take any section, so it will give some shearing type of stress. So, if you take any section in between and that shear stress will be that force divided by area, more or less, it is shear stress, and the total force is shear force.

Now, here also if we define the total beam segment into two regions: one a to this load point, and load point to the b. So, x, one part it is a 0; here another is x a. So, shear force sometimes we define in the form of b. It will be say Ra. So, here there is no other force. Any section if you pick up, the shear force is only Ra. If you cross that load, so b will be your Ra minus P or this Ra will be your Pb by l or here it is Pb by l minus P; Pb by l into P.

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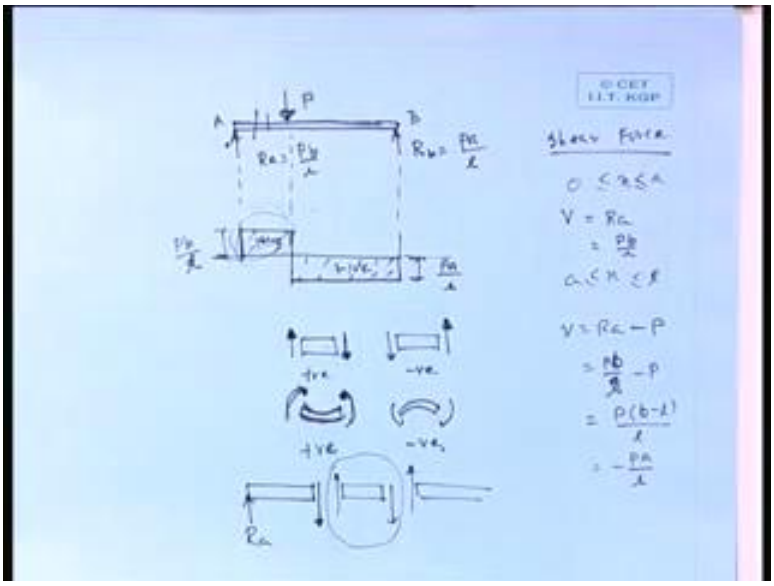

Or if you write P it will be b minus L by l or you can write P into a by l, because l minus b is basically a.