Mechanics Of Solids

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Lecture - 17
Tutorial on Force Displacement Relationship and Geometric Compatibility – 2

Welcome back to the course Mechanics of Solids. So, in the last lecture, we were talking about the geometric compatibility; and based on that we were solving the actual problem like we studied we generally study the force system and then we study the deformation system and then finally, we try to bridge between these two. So, we will take couple of numerical problems today to understand this chapter or this topic in a better way.

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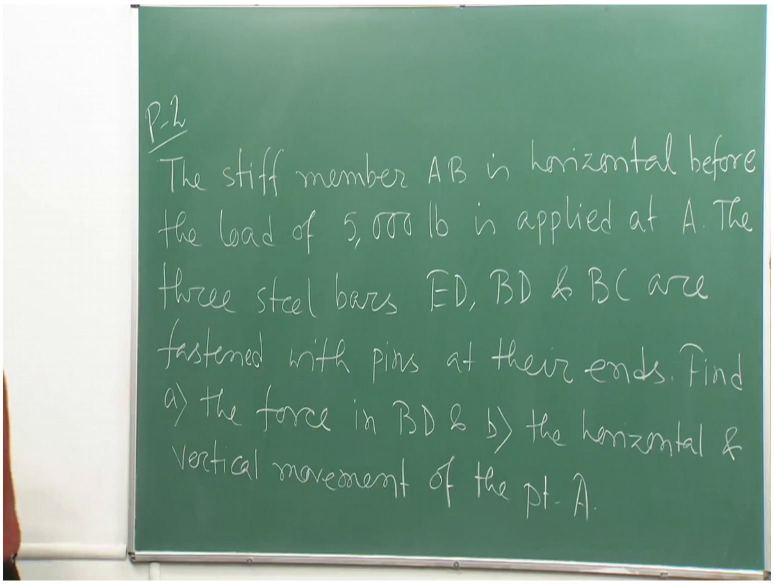

So, next problem the stiff member AB is horizontal before the load of 5000 pound is applied at A. So, I will show the figures later on. The three steel bars ED, BD and BC are fastened with pins at their ends. Find first the force in BD; and second is the horizontal and vertical movement of the point A.

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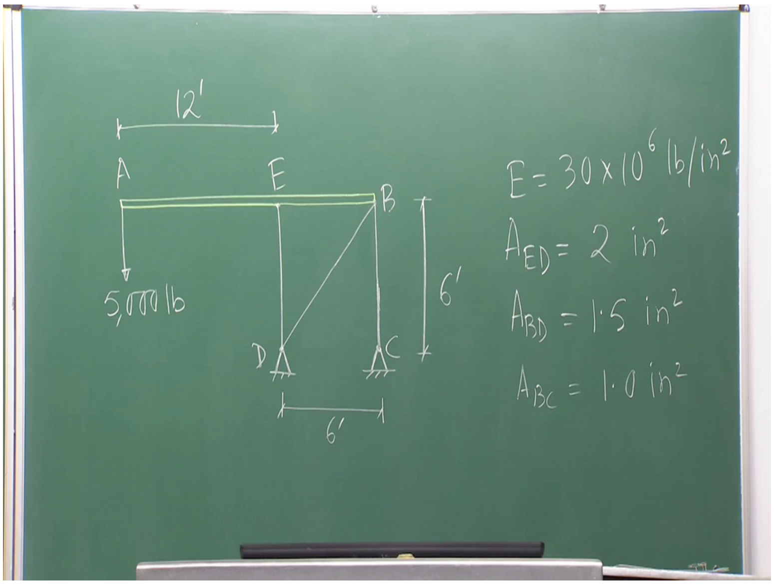

Now, let me draw the figure. So, this is the problem. So, the problem says the stiff member AB, so AB is a stiff member; that means, we are considering this member as a rigid member without any deformation. So, this member is not experiencing any deformation. So, it will be behaving as a rigid member. So, the stiff member AB is horizontal before the load of 5,000 pound is applied say before the application of this load at point A, this member AB remains horizontal. The three steel bars ED as shown in the figure ED, BD and BC. So, they are all two force member, so are fastened with pins at their ends.

Find first the force in member BD, and the second the horizontal and vertical movement of the point A after the application of load 5,000 pound. Now, what will happen if you apply the load here, so it will try to rotate with respect to these points, with because AB will not be deforming at all. So, if you if you try to draw the deformed shape, so it how it will look like.

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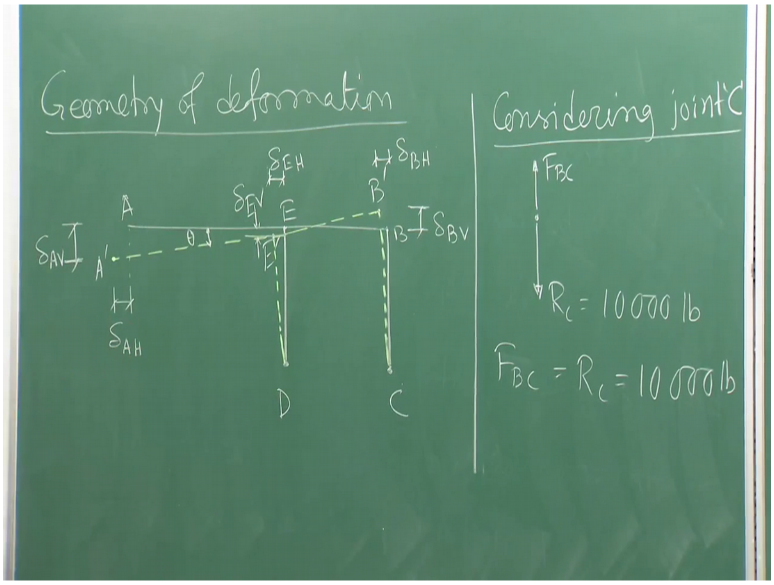

So, let us draw that first: so geometry of deformation. So, let me draw it. So, the probable deformed shape will be like this because you are applying some 5,000 pound load here. So, now, if you look at this figure, so how I mean if you want to find out the deformation or the movement, so AB, AEB rather that was the stiff member. Now, that is taking the position like A prime E prime, this is your E prime, this point is E prime, so A prime, E prime, B prime. So, you are just observing some rotation here right you are observing just rotation here and of course, some deformation in the steel member will be there based on the member force. So, if it is compressive then it will be compressed; if it is tension, then it will be elongated. So, based on the member forces, so these members will be deformed

Now, this B point basically goes to B prime point. So, this is the point. So, therefore, you have the vertical movement of B point is given by delta BV which is the vertical distance between B and B prime. Similarly, the horizontal distance between B and B prime is your delta BH that is your horizontal movement of point B. Similar delta EV is your vertical movement of point E and delta EH is a horizontal movement of point E. Likewise delta AV is your vertical displacement or the movement of point A, and delta h is the horizontal movement of point A. So, this is your probable deformed geometry.

Now, if you try to find out the free body diagram of the system, so if I want to draw the free body diagram if I want to draw the free diagram what should I do, I should remove these supports whose is the reaction forces.

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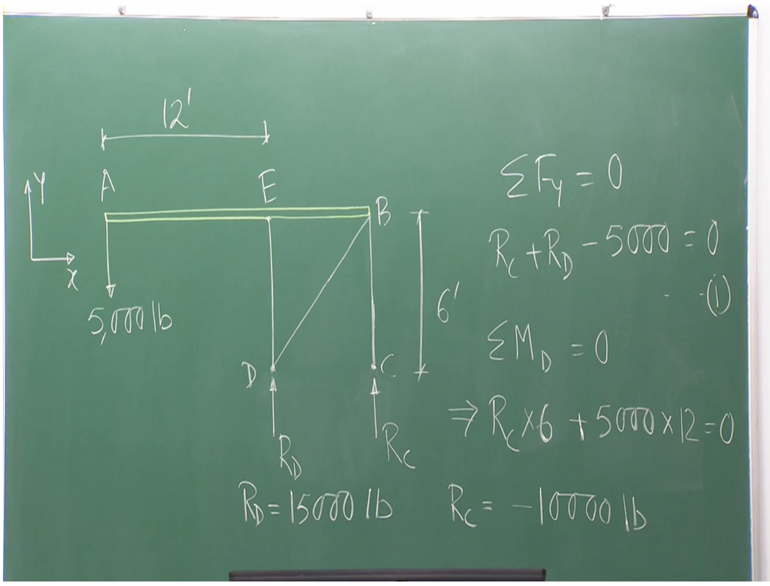

So, now as I told you this BC is the two force member. So, therefore, the reaction which will be developed at point C that will be simply vertical. So, we are not going to discuss much about this because already we have discussed in detail regarding this I mean why you will be getting only the vertical reaction so that I am saying say R C. Similarly, at point d you will be getting R D though you are having two different members ED as well as BD which are connected at point or the joint D, still you will be getting only the vertical force. Because you do not have suppose if you apply some horizontal reaction here, suppose if you can have some horizontal reaction, now which force will take care of that horizontal reaction, because there is no horizontal reaction at C to take care of that. And there is no externally applied horizontal force also. So, if there is no horizontal force in the system then you do not expect some horizontal reaction which will be developed. So, therefore, at D also you will be having only the vertical reaction fine.

So, with this system, we can solve for the unknown reactions if you solve the unknown reaction, then basically if you consider summation of all the forces in y direction, so if it is my y and x direction, this is my x and this is my y and if it is not mentioned every time i am not going to mention this if it is not mention, so it will be taking the same direction like x and y. So, summations of F y equal to 0 see if I do so what are the forces are acting. So, R C plus R D minus 5,000 equal to 0, this is my equation 1.

Similarly, I can take moment equilibrium with respect to point D, summation of all moments with respect to point D equal to 0 that gives me R C into 6, because this distance is 6 feet plus 5,000 into, so R C will be giving me the anticlockwise moment. So, R C into 6, and 5,000 pound also will give me the anticlockwise moment 5,000 into 12 feet. So, from this I will be getting R C equal to minus 10,000 pound and R D equal to and R D equal to 15,000 pound. So, these are your support reactions.

Now, if you look at the magnitude of support reactions. So, R C is coming minus 10,000 pound. So, 10,000 is a magnitude now what is the minus sign as I told you because I was not knowing what should be the proper direction of the actual direction of R C and R D. So, I considered R C as well as R D both are in the positive wise direction; that means, upward direction. But now after calculation it comes that R C is negative 10,000 pound that means the actual direction of R C is downward. I need not to consider need not to assume anything or I should not have any preconceived notion that what should be the direction of R C and R D; automatically it will be coming from the calculations. Well, so R C is actually acting in vertically downward direction whereas, R D the direction of R D is perfectly fine.

Now with this, so I will keep this figure because I need this. Now, if you consider considering joint C, if you consider join C, R C is acting. Now, R C, I can show vertically downward; so R C which is equal to 10,000 pound. And what is acting the member force in BC is also acting. So, I am showing F BC which is coming away from the joint so that means, we are considering tension. Still I do not know what should be the direction of F BC or what should be the sign I mean tension or compression that I do not know anyway. So, that will be coming from the calculation. So, from this, I can simply write F BC is equal to R C equal to 10,000 pound.

If you consider summation of F y equal to 0, if you satisfy that the condition at joint C will be getting that. So, from this, what we have got, we have got whatever direction of F BC we considered before the analysis that was perfect. So, we have got F BC equal to 10,000 pound.

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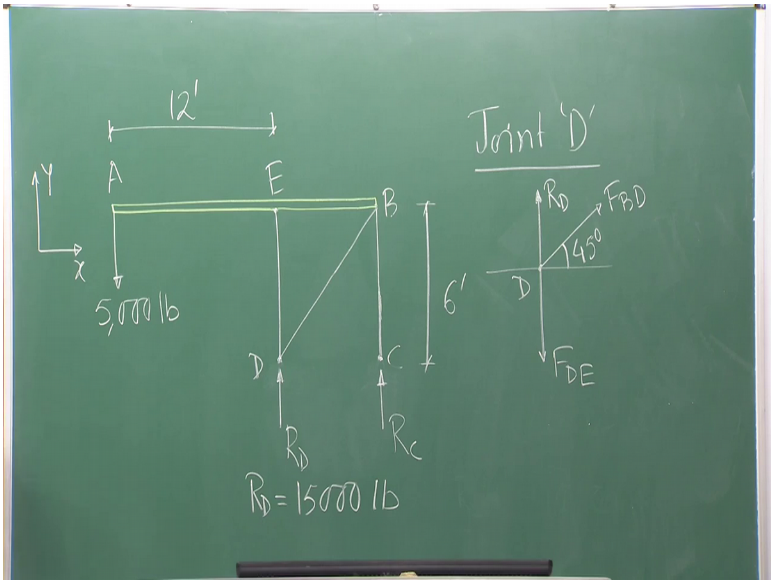

Now, if you considered joint D, if you consider, so at joint D, if you draw the force vectors this is your R D, which will be in the upward direction. Now, I am considering this is my F DE, which is towards the joint. So, I am considering F DE as compression, and then F BD fine. So, these are the forces are acting at joint D and this angle is 45 degree whatever. So, now if you try to find out the forces from this force vector or force diagram, so what you will get, you will get simply F BD equal to 0, and F DE equal to R D equal to 15,000 pound.

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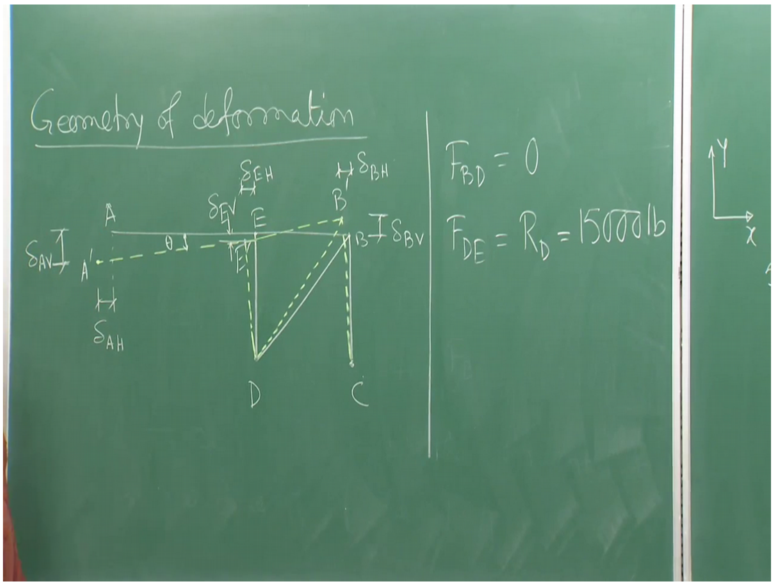

Now, you have got all the member forces. Now, in the first part of the problem it was asked that what is the force in member BD, so that you have got what is the value of the force in member BD simply 0. So, member BD, so I forgot to draw here, so upwards this is connected by this, and this will be connected like this. So, anyway, so that is not a problem.

So, it is quite understood that to those members are there. So, member BD is not carrying any force. If it is not carrying any force then what you can conclude, there is no deformation in that member. The deformation will be happening only if the system is carrying some force. If member BD is not carrying any force, then there is no deformation in member BD. If there is no deformation in member BD then BD must be equal to B prime D. If member BD is not carry any force then member BD the length of member BD must be equal to the length of member B prime B.

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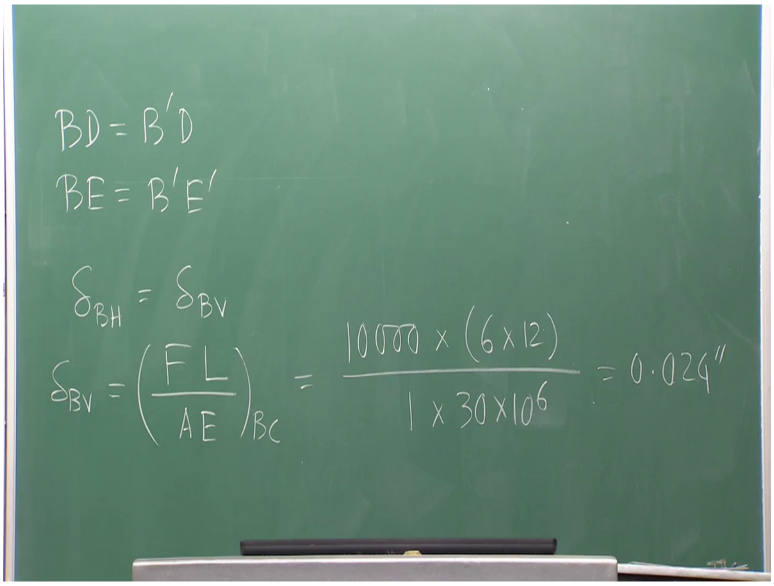

Now, if it is so, then what we can write as because member BD is not carrying any force. So, member length of member BD must be equal to length of member B prime D. And similarly BE must be equal to B prime E prime. Why it is so, because we considered this AEB this member as a stiff member; so, if that is a stiff member then there is no deformation. So, length of B E before deformation must be equal to length of B prime E prime even after deformation because there is no deformation happening in that member, but that is the stiff member. So, form the deformed geometry if you look at this deformed geometry. So, this BD and this B prime d both are equal.

And if I consider a small deformation problem, so basically what is happening this member AB, this stiff member AB is just rotating with respect to point D try to understand, member AB that stiff member is just rotating with respect to point D. So, basically from B to B prime, you can consider a circular arc that rotation is happening. And BD or B prime D that is nothing but the radius, because they are equal. So, from that we can simply established this geometry compatibility or the feet delta BH must be equal to delta BV. So, something like, so this circular rotation is happening. So, whatever amount of vertical movement is happening at point B, the same amount of horizontal movement is happening at point V. So, delta BV is equal to delta BH.

So, now, what is the value of delta BV. So, delta BV we need to calculate. Now, if we want to find out delta BV, basically delta BV is nothing but the elongation of member BC because delta BV is in the vertical direction, member BC is also vertical member. So, the amount of elongation happening at member BC is equal to the vertical movement of point B. So, delta BV can be calculated as a F L by A E of member BC. F is a force in member BC, L is a length of member BC, A is a cross sectional area everything is given in the problem of member BC, and E is the elastic modulus. So, you know all those things.

So, if you put all the values, so 10,000 pound is a force carried by member BC into length of member BC is 6 feet, so 6 into 12 is nothing but the inch, so 72 inch. So, I am doing this problem in APS unit that does not matter whether you do in APS or SI, you have to consistent with you have be consistent with your unit system. And then area is given 1 inch square into 30 into 10 to the power 6 that is the E value, so that comes around 0.24 inch.

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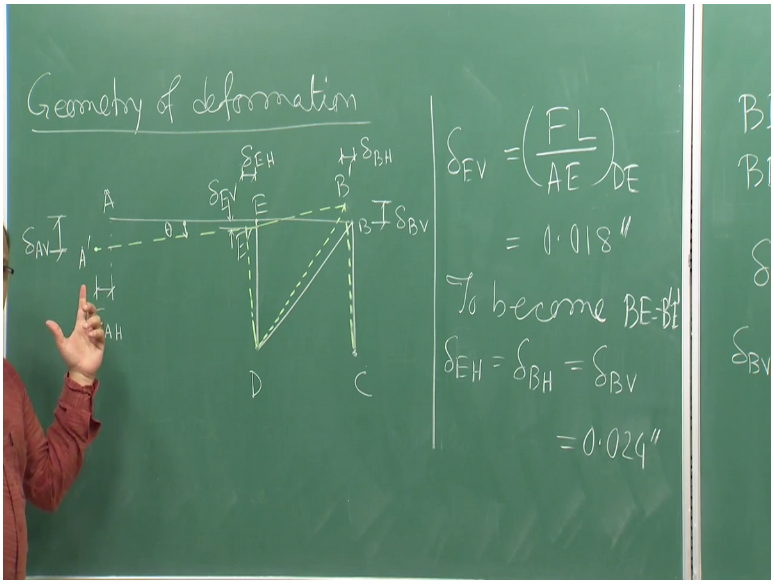

So, now similarly I can calculate delta EV. So, I can calculate delta EV because ED or DE whatever you say. So, DE member is a vertical member. So, and DE member is under compression already we have seen. So, the amount of compression happening in member DE is nothing but equal to the vertical movement of point E. So, delta EV can be calculated as F L by AE of member DE. So, if you put all the values you know; what is the magnitude of force carried by DE that is 15,000 pound; and if you put all the numerical values, you will be getting 0.018 inch. So, this sign is for inch, I hope you know that, so double dash. So, I have got delta BV and delta EV.

Now, to become B E equal to B prime E prime, I have delta EH is equal to delta BH is equal to delta BV is equal to 0.024 inch already calculated. Delta EH, what is delta EH that is the horizontal movement of point E; what is delta BH that is the horizontal movement of point B. So, they must be equal otherwise you will not be getting B equal to B prime E prime. So, once I say B is equal to B prime E prime, so same amount of horizontal movement should happen in the member AB. So, the amount of horizontal displacement, the B point experiences a same amount of horizontal displacement E point experience should experience and A point also. And of course, delta BH must be equal to delta BV already we have established from the geometry compatibility.

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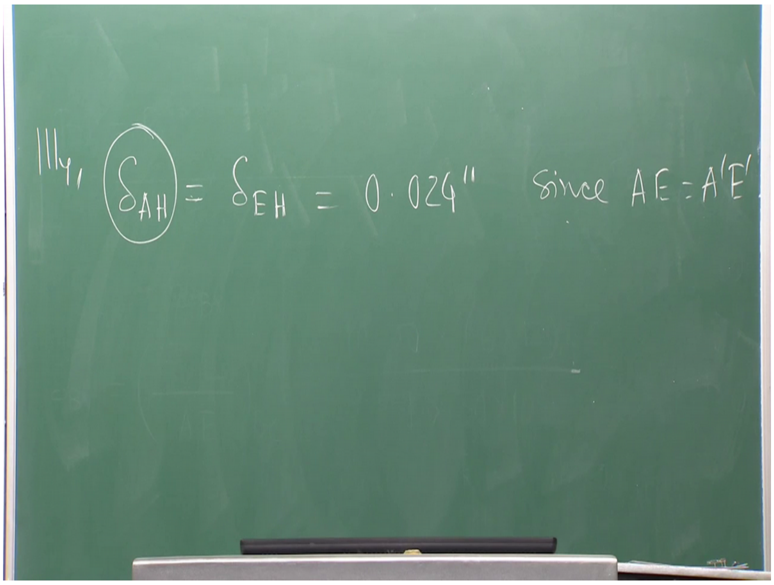

So, now if we can write that then of course we can write similarly delta AH that is the horizontal movement of or horizontal displacement of point A must be equal to delta EH because AE is equal to A prime E prime is equal to since AE is equal to A prime E prime. So, what we have got we have got the horizontal displacement or horizontal movement of point A which is nothing but 0.24 inch. Now, we need to find out the vertical movement of point A.

So, in the next lecture, we will talk about or will try to derive the vertical displacement of point or vertical movement of point A.

Thank you very much.