Computer Methods of Analysis of Offshore Structures
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Module - 01
Lecture - 14
Non-Orthogonal Structures 3 (Part – 1)

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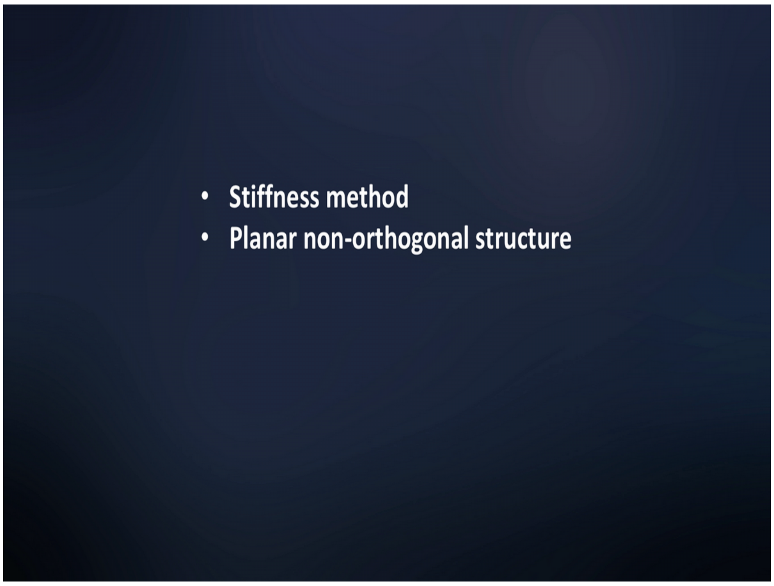

So, friends let us continue with the discussions on planar Non-orthogonal structural members, This is lecture fourteen and lecture one. Where we will explain and continue to discuss about solving non orthogonal structural members. We already said that K bar of the i-th member can be given by T transpose of the i-th member k local of the i-th member and t of the i-th member, where k bar is the stiffness matrix of i-th member in the reference axes system.

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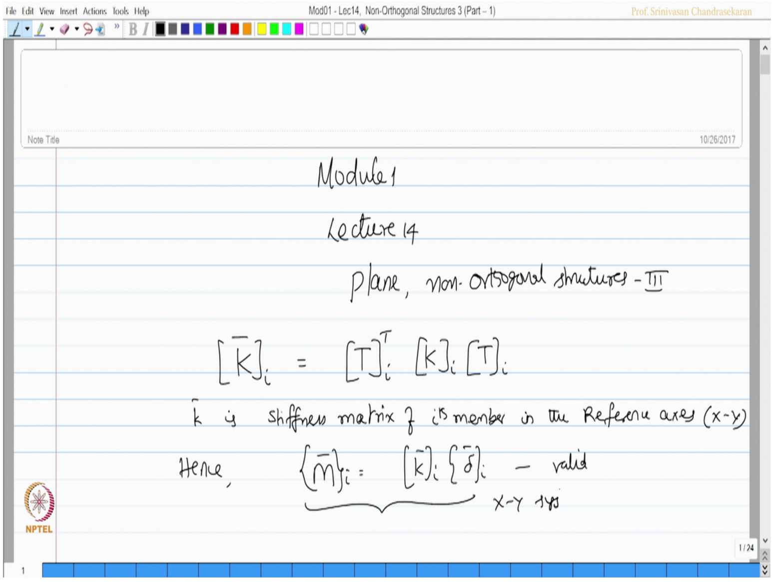

Hence the convectional expression m bar i will be equal to k bar i of delta bar i is also valid, where all of them are being expressed in the reference axes system.

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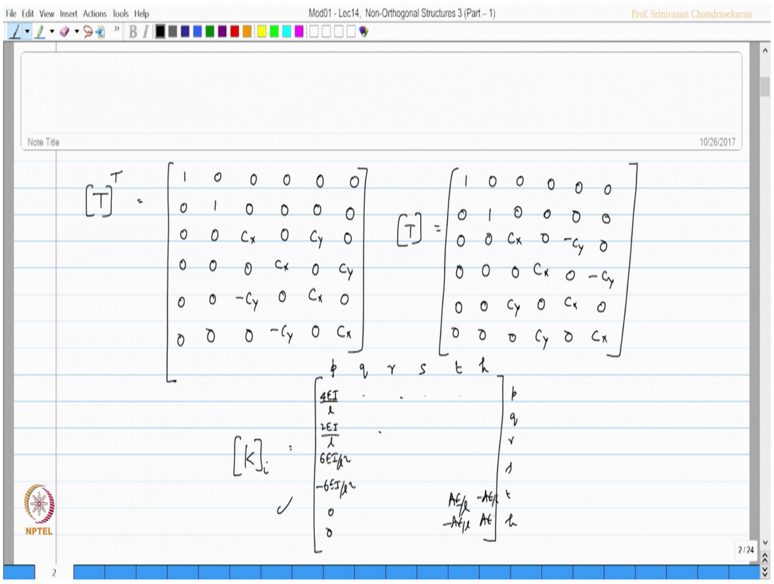

So, we already have this expression, where T transpose or T of arbitrarily oriented member for all the six degrees is given by this. And T matrix that is the transformation matrix is also known to us, which is interchange of this rows and columns, and the k matrix of local for six degrees of freedom namely p q r s t and h is also known to us is it not.

So, I hope you will be able to fill up the remaining values by looking at this except that in the last case is going to be AE by l minus AE by l, AE by l and AE by l. Now look at this expression, if you want to find k global I have to do T transpose pre multiplier to my k i, and then post multiply this at the transformation matrix, I have all the three here I think you can do a simple arithmetic and try to find k bar as an interesting exercise for any i-th matrix, there is no difficulty in getting this.

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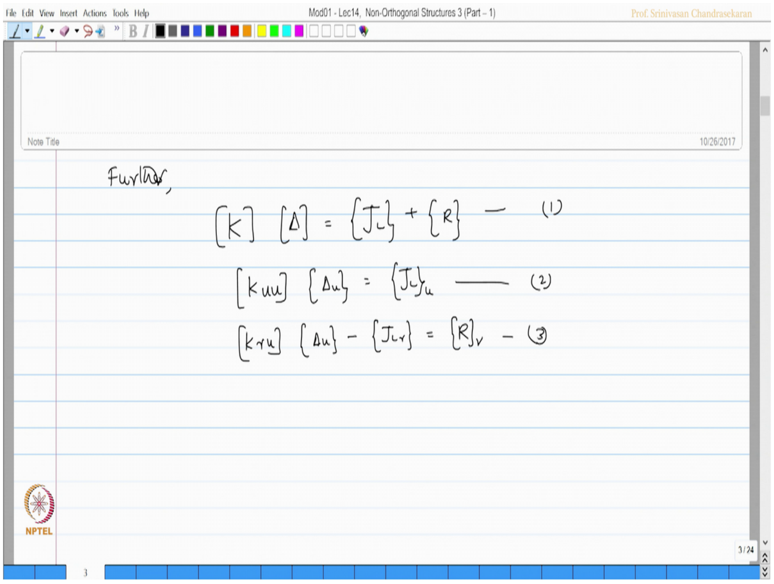

Once we get k bar then, we know the following equations are valid K of delta is joint load plus restraints call this is equation 1 k uu that is un restrain degree of delta u will be again valid with delta u J L u and k r u with delta u is again minus J L r will give you the end moments and shear of the given member.

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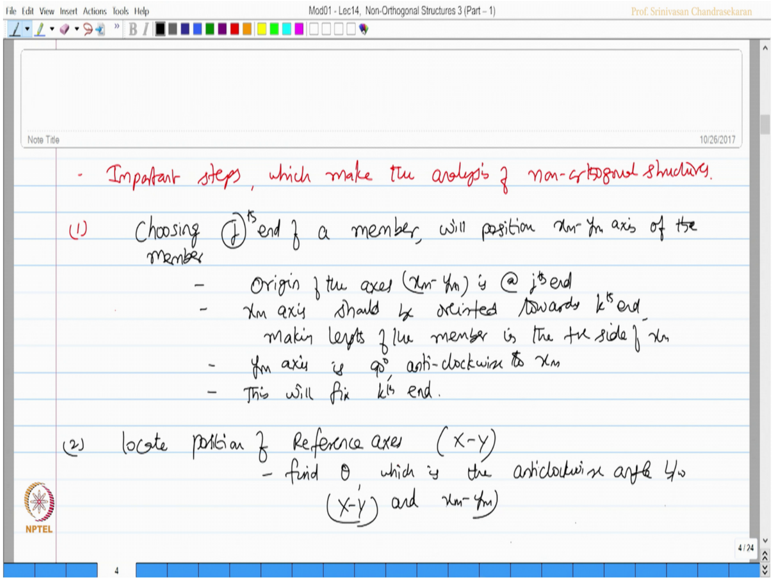

Let us now find out what are those important steps, which make the analysis of non orthogonal structures special let us see this.

First step could be choosing the j-th end member of a member, will position the x m, y m axes of the member, how to choose this we already have an idea, origin of the axes x m, y m is at j-th n, x m axes should be oriented towards k-th end making length of the member in the positive side of x m and y m axes is 90 degrees anticlockwise to x that is how you will choose this. So, now this will fix the k-th end. So, for a given member x m y m is fixed, now locate position of the reference axes that is x y, now find theta which is the anticlockwise angle between x y and x m y m.

Friends let us elaborate this; this is my x m, y m of a given member. Let us say this is my x m and y m of a given member.

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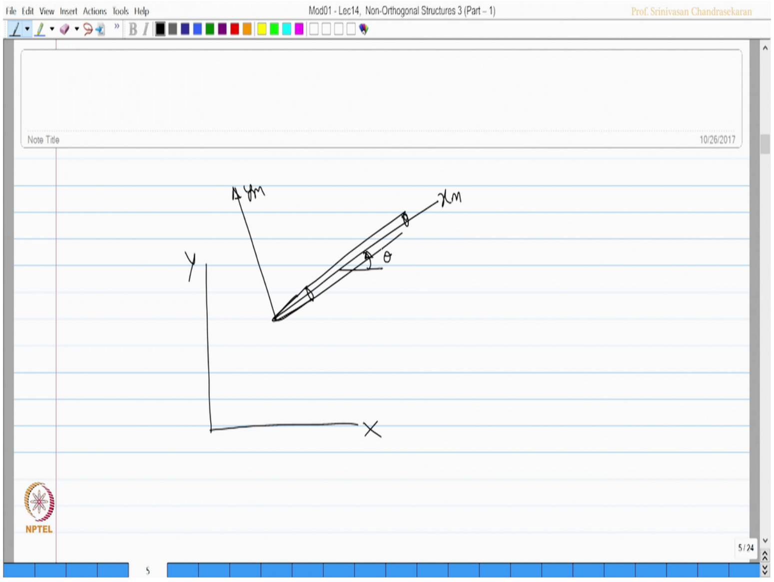

And let us say this is my x y axes of the whole structure, I am looking for the angle theta which is anticlockwise inclination of x m with respect to x.

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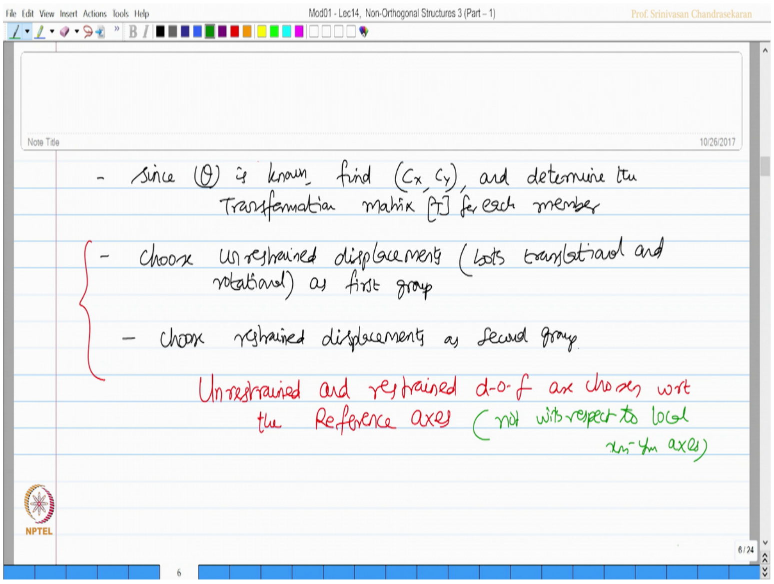

Then next step could be since theta is known, find c x and c y and determine the transformation matrix T for each member. After that choose unrestrained displacements both translational and rotational, as first group then choose restrained displacements as second group friends, when we do this we have to do an important step here, we have to take care that the unrestrained and restrained degrees of freedom are chosen with respect to the reference axes, I will explain this with the problem.

So, I should write here not with respect to local x m, y m axes its very important step. Lets explain this with an example, let us take a problem very quickly just explain this, I have got a frame which has non orthogonal members as you see here.

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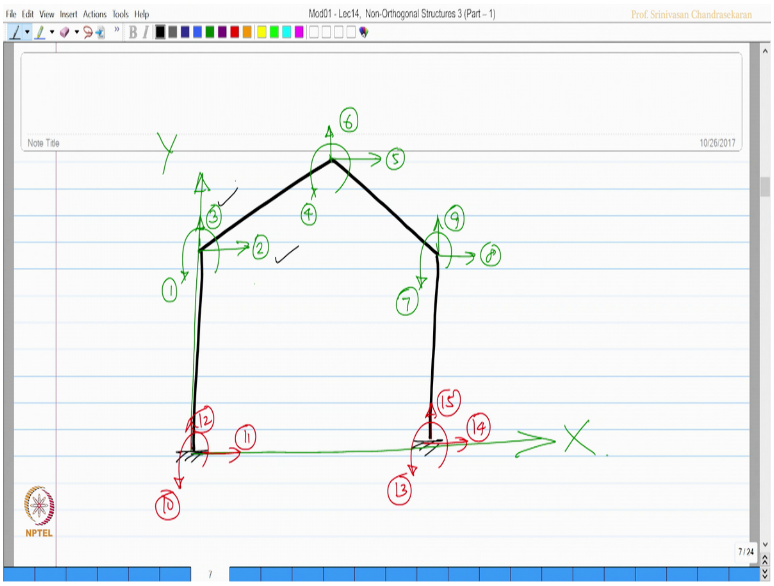

Now I want to mark the reference axes exactly here, x y axes. Now I want to mark the degrees of freedom right, so labelling is different but degrees of freedom alone let us discuss.

So, I am marking the understand degrees so, 1, 2 and let us say 3, 4, 5, 6, 7, 8 and 9 the restrained degrees could be, 10, 11, 12, 13, 14 and 15. So, we have got the group the unrestrained degrees first, and then the restrained degree levels while marking them please note my x and y displacements, which are unrestrained displacements, and restrained displacements are all oriented with reference to the reference axes, but not with reference to the local x m or y m axes, this is very important. You must choose the unrestrained and restrained degrees of freedom in such a manner that they are marked with respect to the reference axes that is how it is done.

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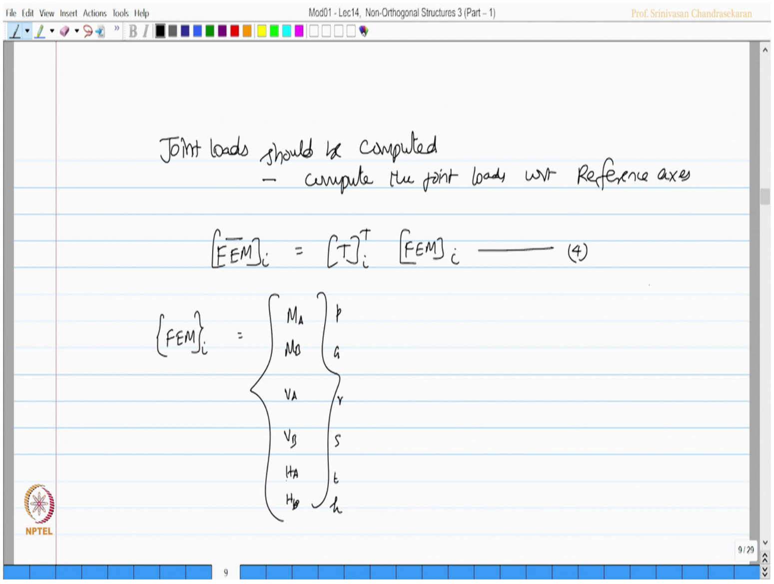

Joint load should be computed again, you should compute the joint loads, with respect to reference axes. So, you know joint loads are actually reversal of signs of the fixed end moments, so fixed end moments of any i-th member of bar that is global will be actually; T transpose, of the i-th member of the fixed end moment of the i-th member.

Let us call this equation number 4 now for our understanding let us recollect fixed end moments of the i-th member is simply for the values of p q r s t and h, so I should say this is going to be m maybe M A, M B, V A, V B, H A and H B.

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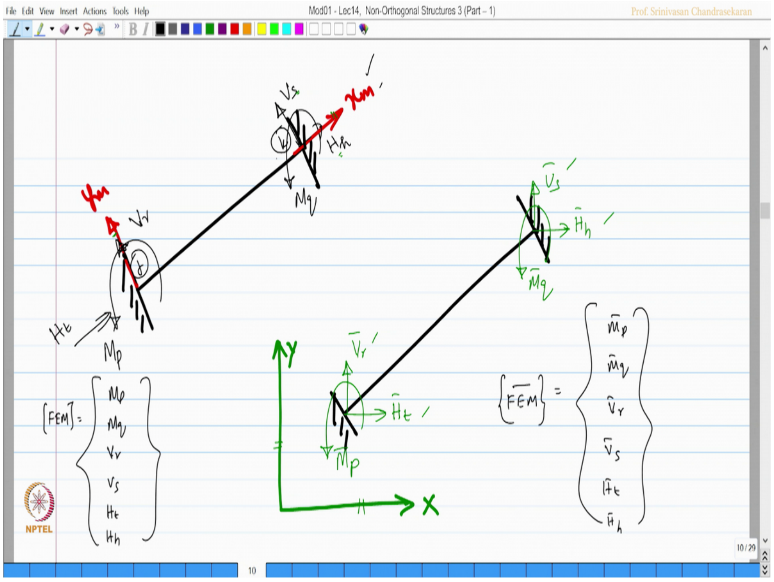

So, that is how we can compute for each member, let us try to explain this in a graphical form. Let us make two statements I am drawing them individually, they are parallel of the same length one is for the local axes, other is the reference axes. We know this is my j-th end; this is my k-th end, because the member should be oriented towards the positive side of x m and y m should be 90 degrees to x m ok.

So, I want to mark the degrees of freedom, let us say this is going to be my M p. This is my M q, that is the moments this is my V r this is my V s and this is going to be my H t and this is my H h, please note the degrees of freedom, in x m y m axes are marked parallel and normal to this axes. When you move this to the global axes system, then I mark in a different manner this is going to be my M bar p this is my M bar q, M bar refers to the reference axes, this is going to be my V bar r and V bar s, and this is going to be my H bar t and H bar h. Please note the sign conventions of these they are related to this axes, please note the sign conventional of these they are related to these two axes, so there is a difference ok.

Now, if I say FEM of the local which can be simply M p, M q, V r, V s, H t and H h. If I say FEM bar of the i-th member, then that should be equal to m bar p, m bar q, v bar r, v bar s, H bar t, and H bar h.

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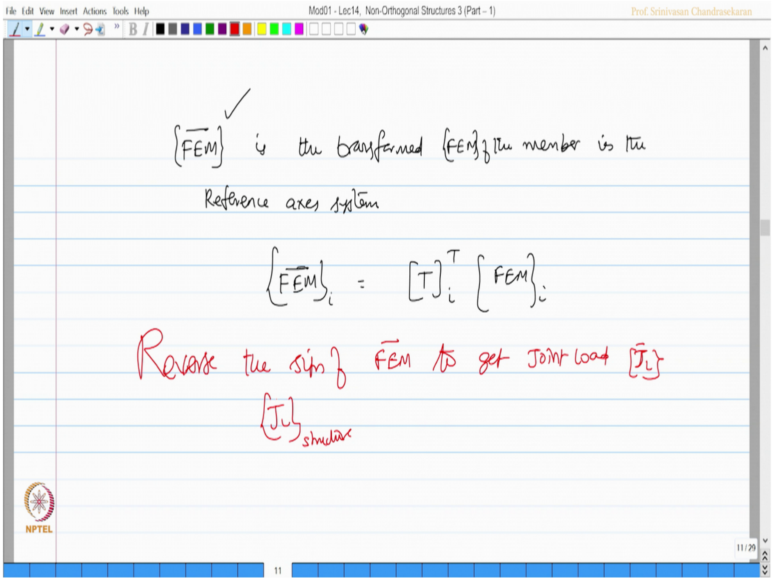

Now FEM bar actually is a transformed value of FEM so, therefore, the fixed end moments bar is the transformed FEM vector of the member in the reference axes, how to get this we already gave this equation, let us once again write the equation there is no problem. FEM in the global of the i-th member will be given by T transpose of the i-th member of FEM of local, so I can get FEM bar, now once I get FEM bar reverse the sign of FEM bar to get the joint load ok.

So, now I can get joint load bar of every member, but I want the joint load of the entire structure.

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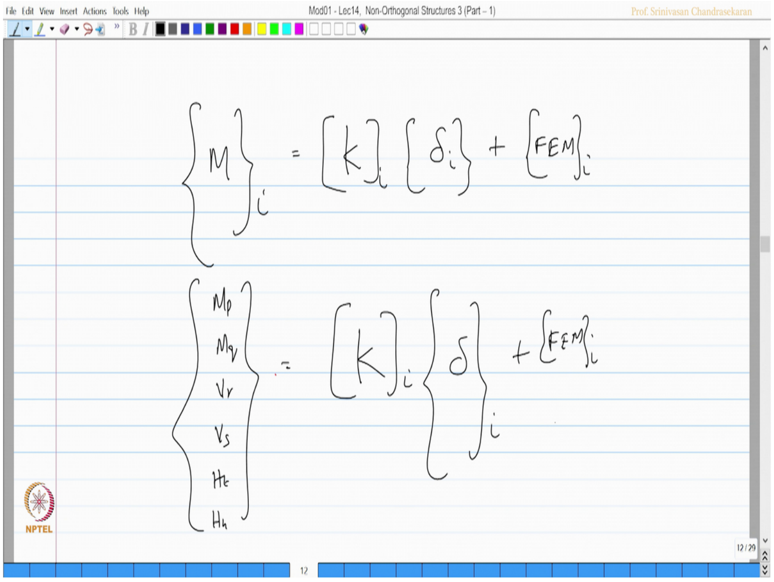

Once I get this then the end moments M i of the member will be equal to the k local of the member, multiplied by delta i of the member, plus fixed end moment vector of the i-th member whereas, I can expand this and write (Refer Time: 20:54) M p, M q, V r, V s, H t, H h will be actually equal to the K matrix of the i-th member in local multiply by delta of the i-th member plus fixed end moments of the i-th member, but I am not interested in knowing m, I want to know M bar.

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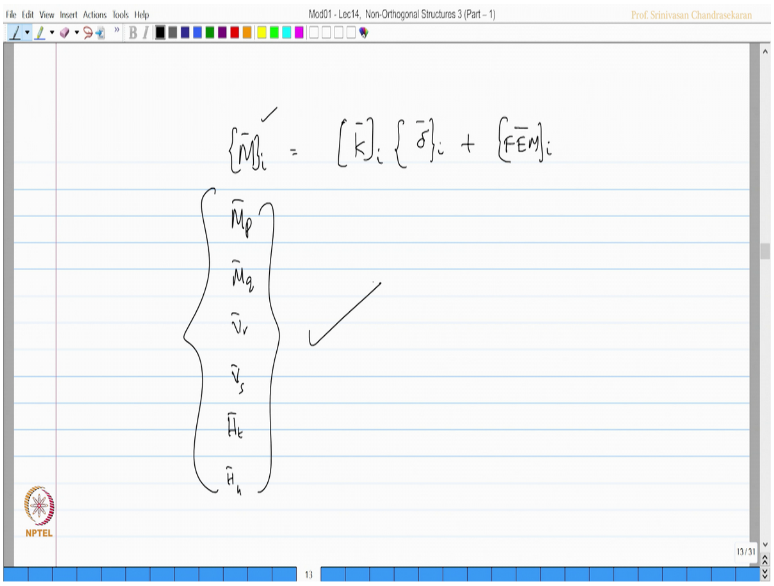

So, M bar vector of the i-th member is given by K bar vector sorry matrix of the i-th member, multiplied by delta bar of the i-th member plus fixed end moments of the i-th member. It is very easy to get the end reactions of the member as M bar p, M bar q, V bar r, V bar s, H bar t, and H bar h I can get this. So now, we have to apply this discussion to a specific problem, and solve the problem using non orthogonal matrix knowledge and try to find out this problem.