Computer Methods of Analysis of Offshore Structures
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Module – 01
Lecture – 12
Planar, Non-Orthogonal Structures 1 (Part – 1)

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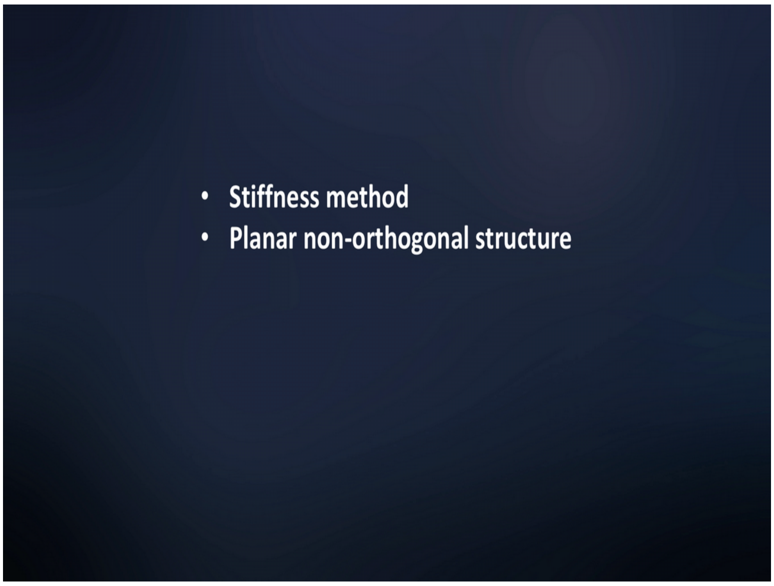

Friends, let us continue the lecture on module, 1 this lecture is lecture 12 where we are going to discuss about planar non orthogonal structure analysis.

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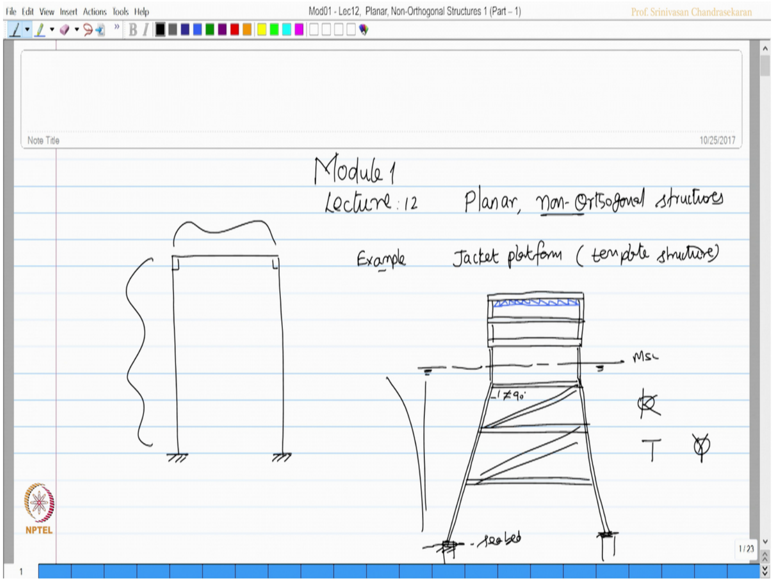

Let us try to understand the application of this kind of problem in reality. We all have agreed and understood that if we have a single frame of a simple type whatever maybe the end support conditions, whatever maybe the kind of loading. As long as the members are orthogonal to each other we could do a very comfortable analysis by writing the stiffness matrices of all these members finding the unrestrained stiffness sub matrix then find the end moments and shears of each member and we can solve the problem.

To do this we have to identify unrestrained degrees of freedom and then the restrained degrees of freedom of a given problem these degrees of freedom can be displacements which are translational and rotational at every node. So, the methods become more complicated when the structural members of the system are not at 90 degrees to each other. Let us see an example. Let us take for example, the jacket structure or a jacket platform which is also called as template structure which is one of the offshore platforms which are meant for shallow waters a typical view of this platform schematically looks like this, these are all different levels of deck let us say multi tier deck, they will be supported by some structural system.

The structural system can even be a truss type it can be a beam column type. There are now tubular members which are then extended to the sea bed which are then founded in the piles. So, this becomes my sea bed possibly, this becomes my water level, mean sea level and then they will also be braced to resist the lateral forces arising from the wave and then the super structure will have forces which are encountered by the wind. So, therefore, look at the structural system which is supporting the top side, the members here are actually not orthogonal to each other. So, this angle is not 90 degrees. So, there is a possibility that the members are interconnected to each other not at 90 degree, but at discrete angles like a K joint like a T joint like a Y joint where the members may not have all the time 90 degrees between them. So, such systems are called non orthogonal structural systems. What is the difficulty with non orthogonal structural structures systems?

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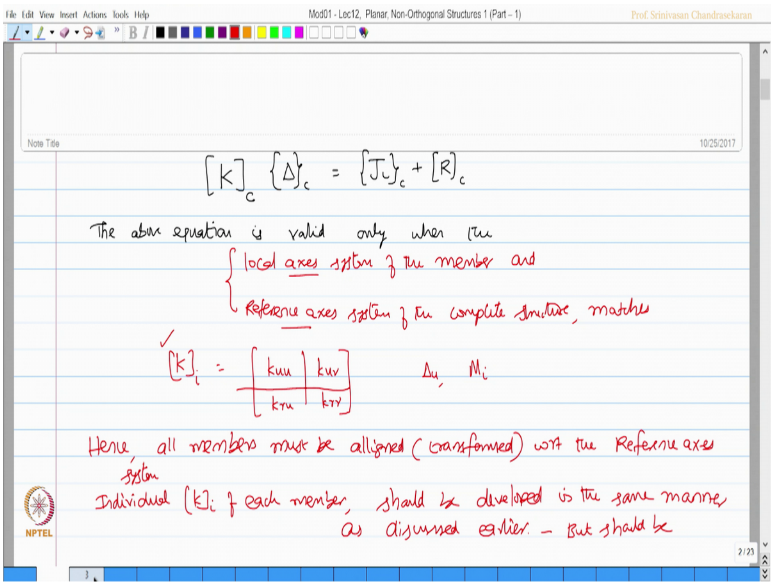

So, now we have a conventional equation of K the stiffness matrix of the entire structure I call this as K c where c stands for the complete structure multiplied by the displacement of the complete structure is actually equal to the joint load vector of the complete structure plus end restraints generated for the complete structure. This above equation is valid only when the local axes system of the member and reference axes system of the complete structure matches.

If this matching happens then one can establish K in terms of sub matrix by dividing them and partition them, then solving them for delta u then Mi as we have discussed in the previous examples. When the reference axes of the system and the local axes of the members of the system are not same, they are not mapped, they are not aligned then the stiffness matrix written for the member for each member may not be same as that of stiffness matrix written for the members which are not aligned with the reference axes of the structural system. So, we need actually do some transformation of the local stiffness matrix to the reference axes system matrix and try to solve the problem.

Let us see the complication starts only when the members are non orthogonal to each other. So, we can make a statement that all members must be aligned if not aligned transformed with respect to the reference axes. Individual stiffness matrices of each member should be developed in the same manner as we discussed earlier. So, there is no confusion in that.

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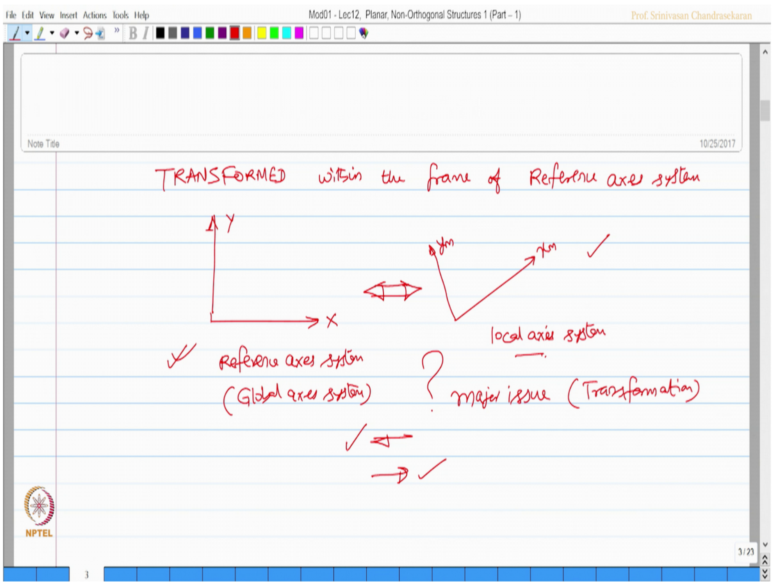

There is no confusion in that, but should be transformed within the frame of reference axes, some literature call the two axes systems as X and Y, xm and ym they call this as local axes system and this is called as reference axes system some literature address this as global axes system the meaning is going to be same.

So, there has got to be a connectivity established between the local axes and the reference axes system to solve the problem. Whatever derivation we so far had for a member aligned along xm ym axes, that is a local axes system of the member is all completely valid, but they need to be transformed when the local axes system is not mapped exactly to the reference axes system. If the local axes system and the reference axes system are one and the same then the issue will not be there that is possible only when the members are orthogonal to each other, when the members are non orthogonal to each other then the mapping of local axes system to the reference system is a major issue.

We need to do this transformation not only one way, but it is vice versa from local to reference axes we may have to do. Sometimes in reference to local axes also we may have to do because it is required for the design of the members. Both way we should have an idea how this can be done.

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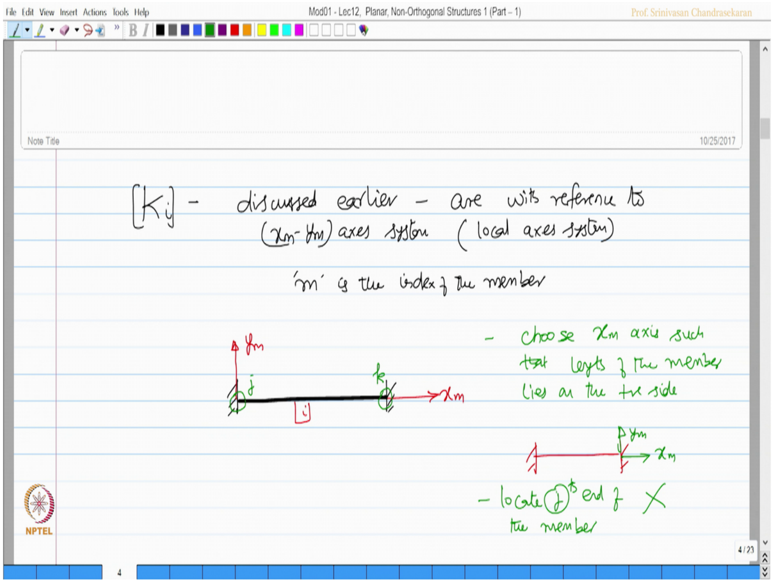

So, now, the stiffness matrix Ki what we have discussed so far are with reference to xm ym axes system, we can otherwise call this for our understanding as local axes system where m is the index of the member. Now each member if you look at the standard notation we had if this is the member. If these are the end supports of the fixed beam if this becomes my xm and this is accepted to be my ym, and if this is my ith member the member has got two ends this end is called the jth end and this node is called the kth node.

So, it is very interesting one must choose the xm axes such that the length of the member lies on the positive side. What do you mean by this? Let us say I have a member which is fixed at both the ends. If I choose my xm here and ym here the length of the member lies on the negative side of xm. So, this is a wrong notation.

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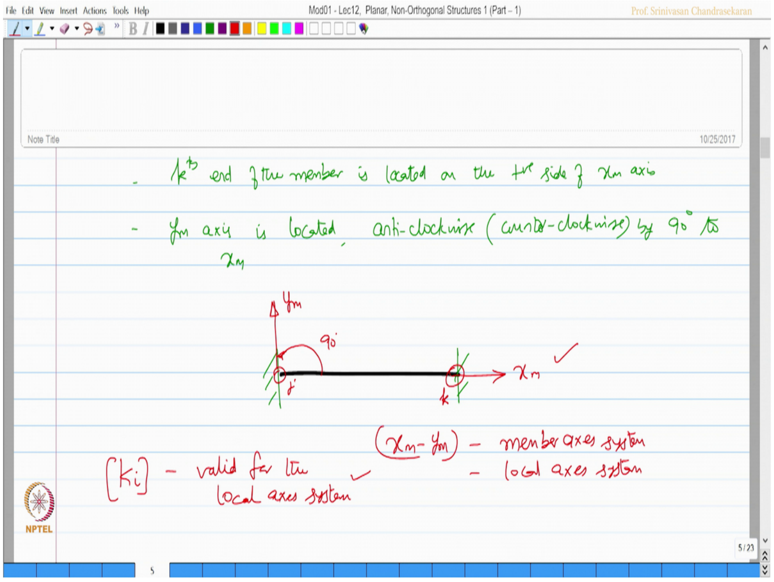

So, it all depends upon where do you locate your jth end of the member. Subsequently the kth end of the member is located on the positive side of xm axis, ym axis is located anti clockwise some literature address this as counter clockwise it is one and the same anti clockwise by 90 degrees to xm. So, let us again draw a member, this is my member these are the fixed supports of the member I am marking xm and ym here which is ninety degree anti clockwise with respect to xm.

So, this becomes my jth end this becomes my kth end. So, all conditions are satisfied like the length of the member is on the positive side of xm j is chosen such that the length of the member lies on xm positive - ym is anti clockwise 90 degree from xm and xm ym now becomes the member axes system or otherwise also called local axes system. So, whatever derivation we have done for the ith member the stiffness matrix derivation all are valid for the local axes system.

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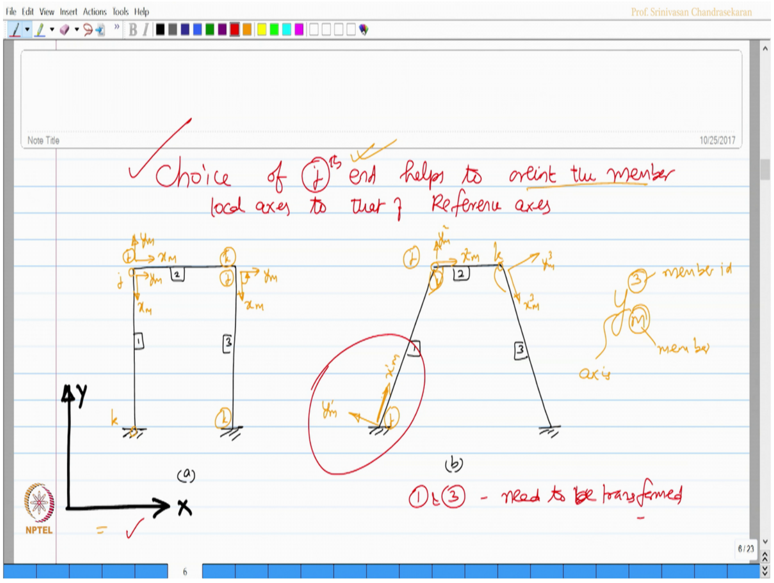

So, it is very important to note that choice of jth end helps to orient the member local axes to that of reference axes. So, it is all depending upon where do you choose your jth end. Again give some example, let us take two examples. An orthogonal system and members with non orthogonal to each other, let us a b let us mark the reference axes for both of them as same. So, this is X and Y for both of them it is same x and y, but the local axes are going to be different let us mark the member indices this is the first member the second member and the third member, similarly here the first member, second member and third member.

Now, I want to mark the J and K ends of the first member. So, we know that I have to mark xm and ym this way because the length of the member should be on the positive side. So, this becomes my jth end and this becomes my kth end of the member 1. Similarly, if you want to do it for member 2 this becomes xm of the member 2 and ym of the member 2 therefore, this end becomes the jth end of member 2 and the kth end of the member 2. Similarly, for member 3 I have to choose the length of the member to be on the positive side of xm and ym is anti clockwise 90 degree, so this becomes my jth end this becomes my kth end.

So, choice of jth end actually helps up to orient the member with reference to the reference axes let us do this for this problem which is shown in picture b so obviously, I am going to plan member 1. So, I can say this is my xm and this becomes my ym and this is my jth end this is my kth end. And for the member 2 this is my xm this is my ym and therefore, this becomes my jth end, this becomes my kth end. And for the member 3 I can either do it this way or the earlier way like we have done for member 1. So, this is xm ym. So, let me put a suffix this is 1 indicating for the member 1 this is 2 indicating for the member 2 and this is 3 indicating for the member 3. It is not xm q and ym q ym three indicates this is for the member, this is the axes and this is the member id that is how it is done.

So, orienting the member with reference to the global axes will happen by choosing the jth and kth end of each member. When the members are non orthogonal when the members are non orthogonal obviously, you will see the local axes of the members are not aligned with the reference axes of the structural system except of the member 2 it is possible for member 1 and member 3 they are not aligned. So, member 1 and member 3 need to be transformed either not because their axes are not getting mapped or aligned having said this.