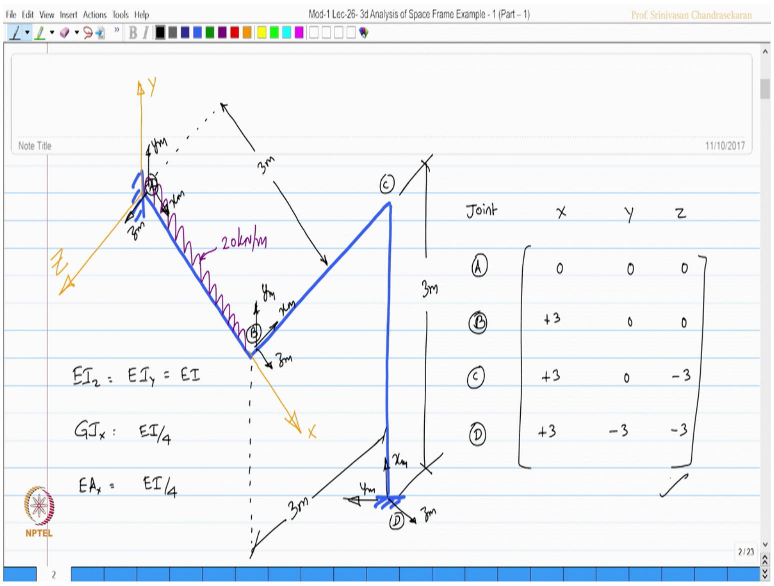
Computer Methods of Analysis of Offshore Structures
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 01
Lecture – 26
3d Analysis of Space Frame Example -1 (Part -1)

Friends, welcome to the 26h lecture in module 1. We are now going to apply the concepts what we studied for 3d analysis on to a 3 dimensional space frame problem. We will also discuss the computer program in parallel and then get the outputs by running this program; then finally, assigning the values at the end reactions and checking for its accuracy from the analysis. So, let us now watch how we do a 3d analysis by taking a simple example.

(Refer Slide Time: 00:04)



So, let us have a structural system as shown in the figure. Now, this is my structural system; let us mark the dimensions of this; this is 3 meters, let say this is also 3 meters and this height is also 3 meters; let us mark the nodes as A, B, C and D, let us say; it is subjected to some uniform distributed load as shown in the screen now the load intensity is 20 kilo Newton per meter.

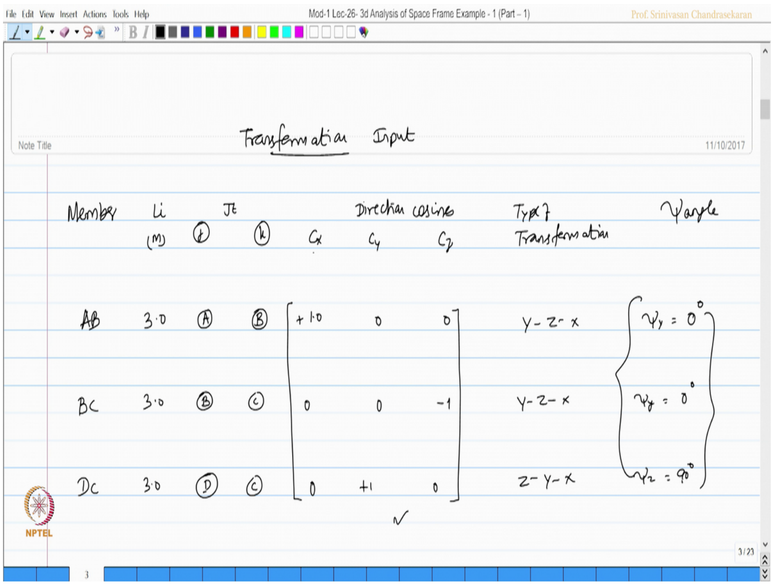
The problem has certain constants let us write down them EI z value is as same as EI y value which is simply EI, GI x that is the torsion constant is taken as one forth of EI and the axial rigidity constant is taken as again one forth of EI the first job is to mark the local axes and global 1axes of the system and the coordinates.

Let us mark the local axes and the global axes let us say the global axes is marked, now which is x, this as y and this as z. Let us now mark the local axes of each say this my xm ym; this 90 degree anticlockwise. So, ym and zm for the member A B for the member B C, let us mark this as xm 90 degree anticlockwise ym and 90 degree clockwise zm.

For the member D C; let say this is xm 90 degree anticlockwise ym and 90 degree clockwise zm, let us mark the values in simple terms; for these from the table let us say joint; let us mark the x-y-z coordinates of all the joints there are 4 joints 1, 2, 3, 4. Let us say a, b, C and d; if you look at a joint it is exactly at the origin of the reference axes. So, x-y-z is 0.

If you look at the b joint we have travelled 3 meters along x. So, plus 3 meters and y and z are exactly same if you look at the joint C we have travelled 3 meters along x and no travel along y, but minus 3 along z if you look at the joint d, we have travelled 3 meters along x and along y, we travelled minus 3 and minus 3 along z. So, this coordinate system which is going to be the input matrix for the analysis can be established easily no difficulty on that.

(Refer Slide Time: 05:55)



Having said this, let us now mark the members and make a table for the transformation input let say member the length of the member the joint designation of j and k and then the direction cosines which are Cx, Cy, Cz, then let us also decide the type of transformation then let us find the psi angle by simple inspection.

The members are A B, B C and I should say D C or C D; the length of all the 3 members in meters are 3, 3.0, 3.0 and 3.0; for the member A B the j and k joints are A and B respectively, this is B and C and as per this is concerned; this is D and C because the origin of the D C member is at D.

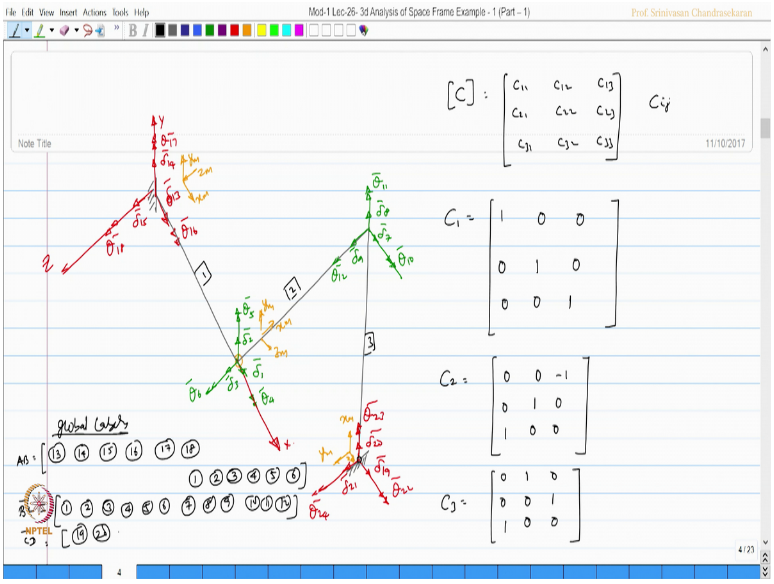
Now, let us talk about directional cosine what is directional cosine we already said that it is actually the angle between xm with x here let us look at this member with x; xm with y and xm with z; xm with x is 0. So, cos 0 is going to be 1.0 plus as far as Cy and C Z are concerned the angles are 90 therefore, they going to be 0 let us look at the member B C xm angle with x 90. So, the cos 90 going to be 0 ym sorry xm with y is again 90. So, that is again going to be 0. Xm and z are opposites, so minus 1. So, 0 0 and minus 1; let us talk about the member C D or let say rather D C xm with x global x 90 degrees xm with global y exactly same. So, it is going to be 0 degree and xm with global z 90 degrees therefore, I should say here 0 plus 1 and 0. So, there is no difficulty in establishing the direction cosine matrix for all the members this can be obtained.

Now, let us look at the member A B x is oriented along the x no problem we should say I am going to practice y-z-x transformation. So, we are going to get psi y angle and for the member B C xm is oriented along z therefore, I should do y-z-x transformations and again I will get psi y angle as for the member D C is concerned xm is oriented with y I cannot do y-z-x. So, I should do z-y-x transformation, I will get psi z by inspection.

Let us try to find out what is the angle of psi the angle of node psi, y will be angle between ym and y, let us say ym and y say it is 0. So, psi y is going to be ; so, psi y is going to be 0 degrees similarly the angle between ym and y of the member B C the member B C ym is here and y is here again the angle is going to be 0; let us mark 0 degrees.

For the member D C, I am looking for angle between ym and y ym is horizontal where as y is vertical. So, the angle is going to be 90 degrees. So, I can easily estimate the psi y values for input like this as a vector in my computer program you can also input the type of transformation because the psi angle actually depends on what transformation you are actually working at correct.

(Refer Slide Time: 10:35)



Now, let us mark unrestrained and restrained degrees of freedom for this given problem. So, what I do is I draw the frame; let us mark the degrees of freedom unrestrained. So, along x along y and along z, let us mark the reference axis system, this is actually my y axis, this is actually my x axis and this is my z axis, correct.

So, let us mark displacements along x-y-z first. So, I should say this as delta bar 1, then delta bar 2, then delta bar 3, then I should also mark rotations about this theta bar 4, theta bar 5 and theta bar 6 at the jth end, then let us mark here at this joint also unrestrained along x 7, along y 8 and along z 9, then rotation 10, then rotation 11, then rotation 12.

So, there are unrestrained degrees of freedom are 12 in number. Let us talk about restrained degrees which is again along x 13, 14, 15, 16, 17, 18, then here 19, 20, 21, 22, 23 and 24. So, totally it is the freedom are 24 out of which 12 are unrestrained degrees and remaining 12 are restrained degrees. I do not think there is any confusion in marking this which is exactly same as that of the 2 d analysis.

Now, let us try to see; how we can work out the direction cosine matrix and then how to get the transformation matrix. So, let us do that here itself; if I want to really do the C matrix, the C matrix; actually C 1 1, C 1 2, C 1 3, 2 1, 2 2, 2 3; similarly 3 1, 3 2, 3 3, what is it mean C ij is actually the direction cosine of the angle between xm and the reference axes.

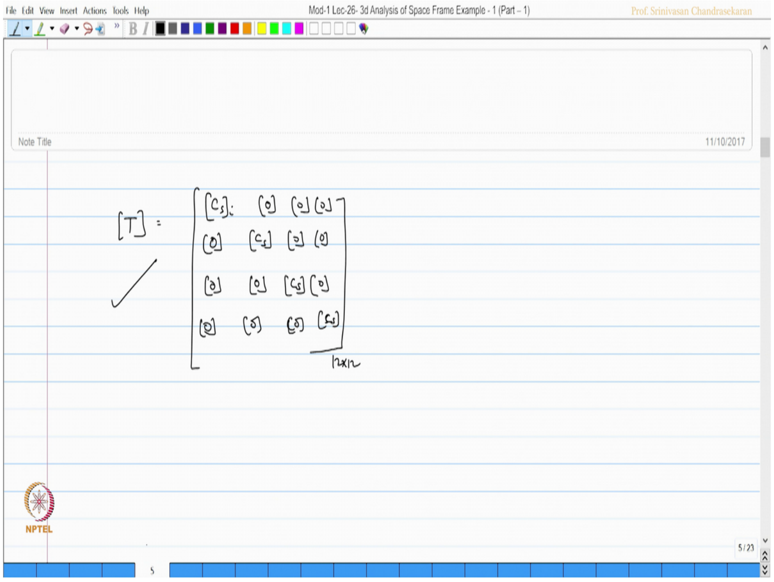
So, what is the angle this is the member 1, this is the member 2, this is the member 3. So, let us do it for C 1 only for translation let us say. So, the angle between xm; let us also mark the local degrees xm, ym and zm for all the 3 members mark xm, ym, zm, I am marking it here; xm, ym and let us say zm; I do not have space there, mark it here for this member xm, ym and zm origin, here for this member xm anticlockwise. So, ym and zm for this member.

Now, let us write down C 1 matrix for this the angle between xm of the member and x of the member 0. So, cos 0 is going to be 1, the angle between xm of the member and y which is 90 degree cos 90 is 0 angle between xm of the member and z which is 90 again 0; similarly angle between ym and x is 90 ym and y 0 thats cos 0 is 1 ym and z 90 become 0. Similarly zm and x 90 0 zm and y 90 0 zm and z 1, so that becomes my C 1 for translation; this is true at the jth end kth end for rotation also it is true.

Similarly, let us do it for C 2 angle between xm and x is 90 cos 90 is 0 xm and y is again 90. So, cos 90 is 0 xm and z is minus 1; similarly ym and x 90 0 ym and y is 0 1 ym and z 90 0 zm and x is one zm and y is 0 zm and z is again 0. So, that becomes my C 2.

Let us do for C 3 matrix xm of C 3 with x 90. So, 0 xm with y 1 xm with z 0 ym with x 90 ym with y 90 ym with z 1 zm with x 1 zm with y 90 zm with z 90. So, now, I have the direction cosine matrices for all the 3 members namely 1, 2, 3.

(Refer Slide Time: 18:05)



So, we all know that the transformation matrix t is simply given by cs of the member I, then 0 0 and 0. Similarly 0 cs 0 0 0 0 which we derived at is it not and 0 0 0 0 and cs which is 12 by 12.

So, one can easily find out this matrix; let us then write down the global labels for each member. So, let us write down the global labels for each member, I can do it here the global labels for the member 1, I will write down here for the member A B the global labels looking at the jth and kth end. I should start with x-y-z translation at the jth end rotation at x-y-z at the jth end, then translation x-y-z at kth end and rotation at x-y-z kth end.

So, let us talk about the; so, easily you know translation x 13, then translation y 14 translation z 15 at the jth end rotation, about x 16 rotation, about y 17 rotation m about z 18, that is along the jth end, then continuously I am writing it here if you look at this phase it is going to be 1; is it not; 2, 3, 4, 5 and 6 that is going to the label for member A B.

Similarly, one can do for member B C and C D simply; for example, if you fill up for B C for your convenience starting from jth end, one can see here along x. So, I should say 1, 2, 3, 4, 5, 6, then kth end along x. So, 7, 8, 9, 10, 11, 12; similarly for C D, we can write down jth end is here; therefore, it is going to be simply 19, 20, 21, 22, 23 and 24. Similarly for the kth end is going to be 7, 8, 9, 10, 11, 12; these are the labels. So, there is no problem at defining the labels for these degrees of freedom. Let us now look at the computer program to solve this.