Design of Offshore Structures
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Module - 02
Lecture - 04
Concepts of Fixed Offshore Platform Deck and Jacket 4

So, today we are going to just summarize what are the preparatory activities for in service analysis of a jacket structure which includes.

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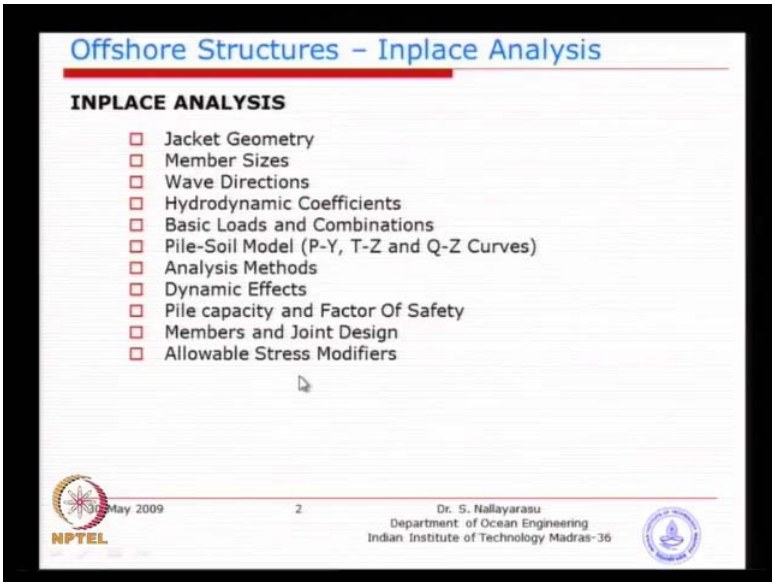

Several of them listed down basically from jacket geometry member size selection direction of waves and environmental loading hydro dynamic coefficients basic loads and the combination of them. The coexistence of various loads at any point of the service life of the structure and then the interaction of the structure with the soil, the foundation systems then selection of analysis method. Whether you will select a suitable linear method or non-linear method dynamic analysis time history analysis, or frequency domain depends on class of structure for example fixture structure mostly either you will go for static or dynamic analysis.

You may not actually perform most of the time dynamic analysis except if the structure is very slender, but for floating structures you may actually require dynamic analysis for almost all cases because the response is going to be slightly different. So, that is where the class of structure will determine what type of analysis you will require to perform

and then when you are trying to do this analysis how you incorporate the dynamic effects. Basically, the interaction between the dynamic load and the structure response then finally we come to design of foundation ultimately the structure has to transfer the loads into the ground.

If it is a fixture structure, if it is a floating structure it has to respond by sufficient buoyancy and also anchor to the sea bed by means of mooring lines. So, these components needs to be sufficiently designed with adequate factor of safety, which I think we will discuss about this in one of the class, what is factory safety why do we need it. In fact we will go into elaborate discussion on that and then finally once you complete the system analysis break down the system into several sub components like you will see some pictures.

Later on you can design each element of the system and then the assembly of those elements become a complete system for that structure which needs to behave safely during its life time. Then we will see also in what respect we will allow the stresses to be slightly increased or decreased depending on the situation for example if it is a regular occurring event on a daily basis or a yearly basis. Then it is going to be like a you cannot take high risk that means you will allow lower allowable stresses, but if then activity for example a 100 year storm is going to occur every 100 years later or every 100 years return period.

Then what you see here you can take a slightly increased risk instead of designing for conventional process, so this basically the allowable stress modifier is to incorporate the risk levels that you want to take. Higher the risk that you will increase allowable stresses that normally allowed, so in the design process you will make a decision whether to allow for increased stresses, or reduced stresses depending on whether the activity or the load effects is going to be the return period is smaller or higher. So, this whole process is called in service because the structure has to be designed for the full period of the design life during which the structure is subjected to several cases of loads, it can exist in different forms combination of them and make sure that we design for it.

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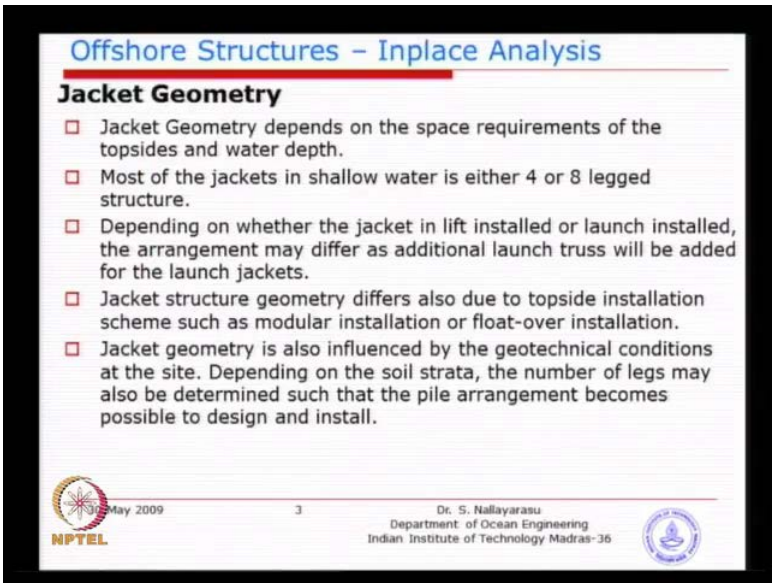

So, the first activity is that decision making on the geometry I think over the last 6 to 8 classes, 6 classes at least we have seen various pictures various arrangements. For a typical picture structure which you could have seen that it varies depending on various parameters. Just not one or two quite a number of parameters I have just listed down few of them here which may not be exhaustive, but at least will give you an idea that this are some of the important points that will decide how the jacket will look like. The jacket geometry depends on the phase requirements for the top sides and the water depth I think it is very easy to now understand the larger the foot print of the top sides. You will definitely require a bigger jacket very easy to understand and the water depth the deeper is the depth of water you could see that the base requires to be larger.

So, I think that that is exactly the idea these two parameters as a priority you just need to just look at these two first before going anywhere else. But, as for a 100 meter water depth you may actually have a base of fifty meter by 50 meter which gives you a stability during installation as well as during service. But, if it is 1000 meter water depth imagine what king of base is required, so we need to decide whether jacket is suitable even if it is suitable it could be possibly difficult to imagine the size and installation. So, far I think I mentioned about 675 meter water depth, I think if you look at the net or in the literature 675 meter water depth jackets have been installed.

So, imagine what could be the size of the base its very large almost 160 meter, so you could see that water depth plays a major role irrespective of the top sides. Even the top side is quite small does not matter because ultimately the jacket needs to perform during its service life due to environmental loading. But, of course they go in tandem top sides layout foot print requirement and the water depth play a major role in deciding what size of jacket. The next item is basically the method of installation in fact this the point number two most of the jackets.

We will see either 6 leg, 4 leg or 8 leg, 6 legs very rarely we use in fact one of the jacket just now they are doing it is a 6 leg jacket specifically to optimize because it neither fits into 4 leg nor fits into 8 leg. So, you go for a 6 leg, but of course there are some complications, but conventionally people use 4 leg or 8 leg which is the very easy to manipulate the installation.

The next item in the whole process of geometry selection is method of installation there are four cases in fact I have just listed down either the jacket is lift installed. I think by this time you should have understood what is lift install and launch installed lift installed is the jacket is lifted off from the bars and then placed into water. Just a transfer or launch installed is basically slided into sea water by some means externally giving push or by tilting the bars I think that terminology you should understanding. So, by doing this we have got 2 activities in a slightly different way which require the geometry to be adapted according to it.

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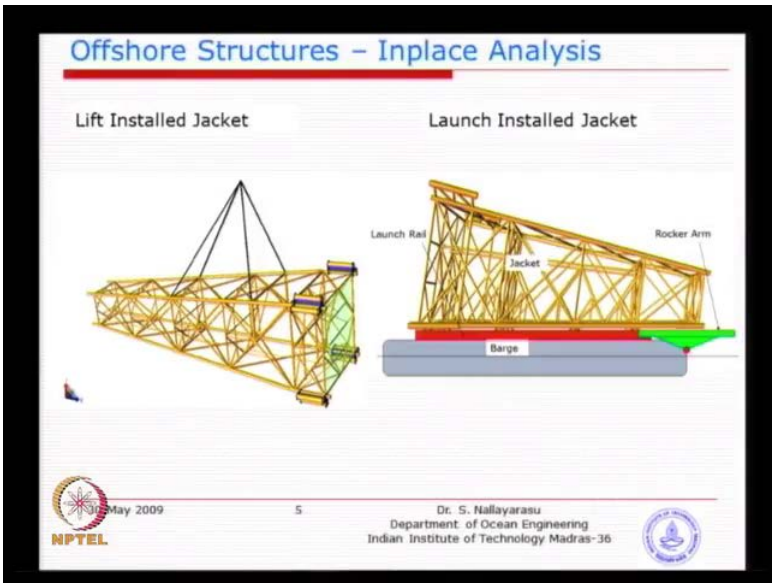

So, if you look at this picture you see this picture the jacket lift installed have a configuration does not require any special arrangement for skidding or for sliding where as the right side picture you see. Here, it has got a special arrangement basically some extra stiffening or so called extra members or brasses are added in such a way that during sliding jacket is safe.

Whereas, when you come to the left side you see the legs are strengthened according to the load transfer because this is being lifted at 4 points. So, your thinking must go in that direction that whichever the method of installation the structure geometry changes you could see that these extra members are not this, whatever you see. Here, like a small bridge which is no their which is actually supporting the jacket during skidding process, now if you go back also the geometry of the jacket can change depending on how the top side is installed if the top side is installed in modular fashion.

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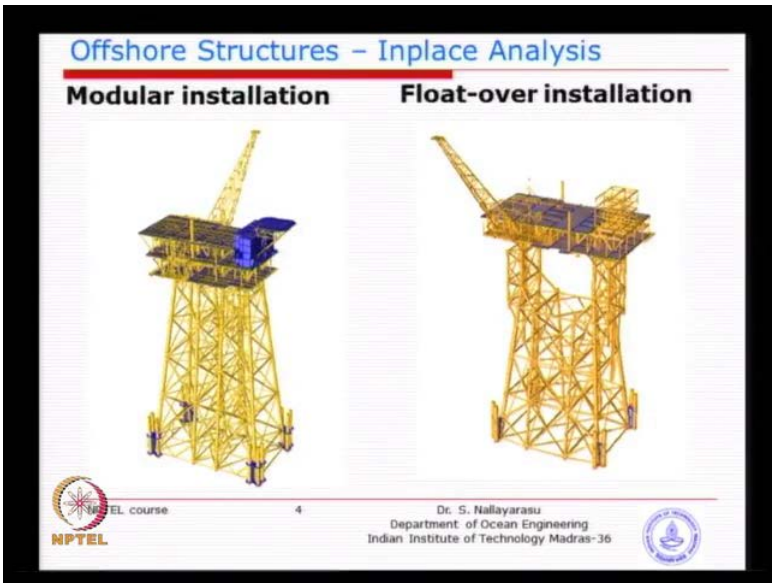

Means you split the top side into several sub modules and install in top it could look like this, but if you then you know the topsides using float over you see on the right side the complete top side is one piece. So, the jacket geometry completely changed, so that gives you an idea how is the methodology of installation could manipulate the jacket to a very great extent.

So, there is 4 cases lift installed jacket, launch installed jacket and then you have lift installed modular topsides and float over installed single piece top sides. So, this 4 could manipulate the jacket into a any configuration that what you have seen of four of them which means that you have to pay great attention to what the contractor is proposing irrespective of what you need out of this.

You may need of a jacket from topsides foot print point of view or the layout point of view and the water depth point of view. But, you should consult the contractor who is installing that installation method can just simply change whatever you have come up, so it influences so much the last one basically the soil conditions I think this is very important to understand in fact this is true for any structure on the earth as long as the soil condition does not permit. You may have to change the foundation system once you change the foundation system your configuration of the structure also have to be adapted accordingly.

For example, you have decided that only mine pile main pile will be adapted for you jacket I think you should know. Now, by this time what is main pile what is skirt pile, so if you have only main pile what will happen the pile has to go as deep as required by the design if the soil conditions are very weak you may end up taking the pile to few 100 meters which may not be possible to install. So, what will happen is you may put more legs instead of 4 legs you may actually make it eight legs to distribute the loads to many points because you decide that you will only keep main pile. So, main pile means more number of legs or if you allow for a skirt pile you can keep the 4 legs, but add additional skirt piles to the leg locations.

So, you could see that soil conditions is going to influence greatly the type of structure, in other words if you go back one step back ward you know if you look at a soil condition for a piled jacket type of structure it is definitely not the hard rock. For example, in some occasions you may find that if you go to villages or even sea bed you will see that some places the rock is at the surface level I think you might have seen in many places. So, in such type of locations if you imagine if you have to install a jacket it is impossible you cannot drive a pile.

So, you may to look for alternative foundation system, so which will work for sure work with the gravity based type of structures which you simply place a structure on top. You do not need a pile foundation the stability of the system is arrived by its own weight vice versa, if you the soft soil do not imagine of or think of putting of a gravity based foundation because the whole thing will settle. So, you could see that the soil conditions can change completely the idea structure the thinking has to change depending on what is the that is why you should have a very clear understanding of soil mechanics.

If you would like to design a suitable of shore structure you should through rigorous understanding of what is this layers what soil condition exist at the site. So, that the selected concept will definitely work because after all ultimate purpose is to make sure the structure does not deform outside the permissible limits, and the foundation does not fail because both of them is as critical as what we think.

So, the jacket geometry in think I have listed just down 4 of them, but you have to keep thinking what other parameters will influence and summarize for you specific project. So, I think these pictures you have seen already two times before, but the purpose of this

I have just placed it here to just give you an understanding that it could have the impact on the geometry similarly this picture you have seen already.

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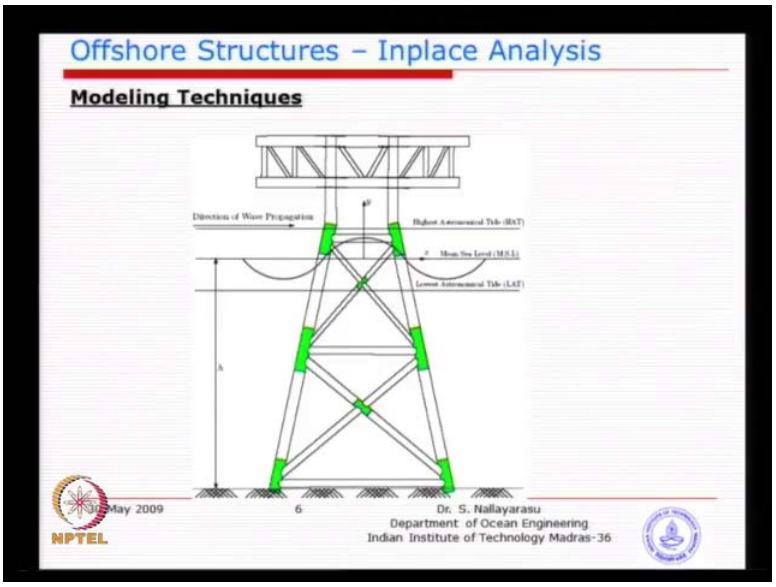

Now, what we just need to make sure that seeing those jacket framing or jacket model what exactly we are looking at what is the meaning of model I think most of you might have already done, I think we have discussed in the last class. Also regarding computation of internal forces on the member typically take a beam what you have is the bending movement I think most of might have studied in applied mechanics sheer forces.

What else actual force may not be there in a beam bending unless you have freshet in the apply a horizontal load, but for a column you have an actual force may be bending moment depending on whether the load is acting externally. But, if you have beam and a column combined you may have all components of forces actual force bending moments in both directions tarsal moment sheer in both directions.

So, you could see that if you see this picture or this picture in fact you could classify them either beam or column very difficult because this is subjected to three dimensional forces. So, it could be a potential beam column element member what I mean the meaning of the element number is one component of the structure you should get an idea you have so many of them. No, hopefully are of you are able to the terminology because in off shore we use element member represent one part of the structure for example this from here to here is a single member which is nothing but a part of the structure.

Now, each one of them will be subjected to different magnitude of loads due to external forces form environment and gravitational loads. So, we need to evaluate this and then take back and design it the primary purpose of the course for that we have a system analysis and then from system analysis each of the element is supplied with specific internal loads. Then the internal loads need to be treated appropriately to arrive at the applied stresses and then apply the code and permissions or provisions to find out what is the allowable stresses I think that is a simple technique. So, in the modeling what exactly we supposed to model should we moral everything or should we model only something.

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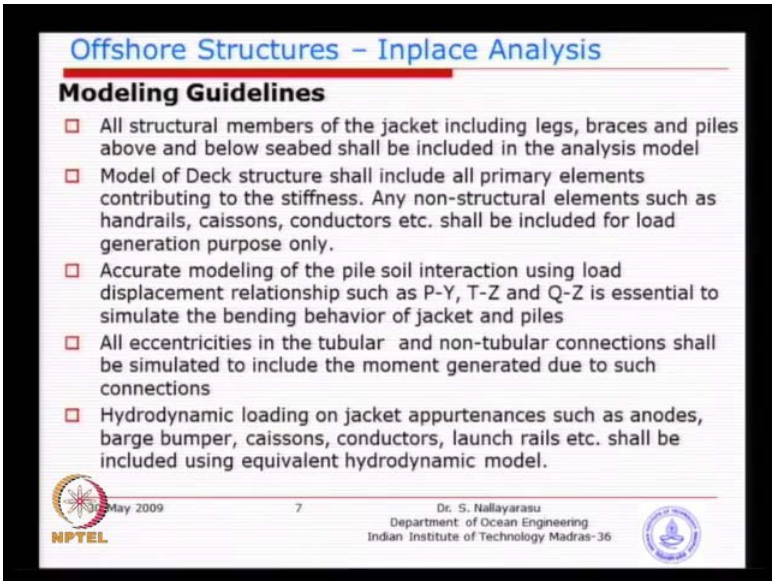

But, we need to just understand all structural members what is the meaning of structural members the meaning of structural member is to make sure you get a clear understanding because every part of the structure is a structural element. But, whether they actually contribute to the structural stiffness or its reduction or increase in the response when you ally loading needs to be understood. Some of them may only attract loads some of them may contribute to stiffness, so other may not contribute to stiffness.

So, what we need to decide is whichever the part in this structure contribute to stiffness reduction or increase in the response characteristics of the structure needs to be modeled. For example we have a photo frame you may have 2 columns, 1 beam imagine if you do not model the beam and only just model the column what will happen it will not become a photo frame. It will become 2 cantilevers column, so that is exactly we need to see

when you look at such a big structure. We need to model and simulate the behavior together to include every aspect of stiffness of the structure, so that is what I ment, here basically all structural member of the jacket including legs brasses.

What is a brace brass is all those members what you see and the piles above a below sea bed because the pile is above inside the legs and also below and the deck structure. The super structure should include everything which ever contribute to stiffness non structural elements like for example you may have a hand rail I think you every building will have a hand rail. I do not think anybody needs to simulate the hand rail because the hand rail is a functional requirement rather than structural strength purpose is only a protection for other purpose.

Accurate modeling of pile soil interaction is required because after all the structure is going to de form due to applied loads and de formation characteristics depends on how firm the structure is fixed to that ground. The stronger the soil the deflection will be less lesser the deflection for sure it will have lesser deflection means the bending moment will be less and associated stresses will be less so that means the foundation conditions have to be simulated accurately. That means understanding of the soil condition is very vital to the whole system analysis all the eccentricities in the connections needs to be modeled which you will come to know when we go into the tubular joint design.

At that time we will go more details basically the eccentric connections could introduce additional moments you know. Then the hydro dynamic loading on all the secondary requirements for the system for example you may have a cathode protection for the jacket you may install few anodes you will learn about what is anode in the later part of this course. So, you attach this additional, so called which only protect the structure they do not actually perform or as structural stiffer element that means they will attract loads as long as you put this element inside water the wave loads will come.

But, they would not actually give you any additional strength, so this needs to be taken little carefully that you attract the loads but, then the stiffness will not be contributed by them. So, like this there are so many items in this jacket that you may actually consider weight you may consider the buoyancy you may consider the hydrodynamic loading. But, not part of the structural simulation there will only be burden for us but, not as a

support, so this just only few of them I have listed down to give an example what is the meaning of modeling technique.

I think this is a very common sense even in any process simulation, you use to only look at what is contributing to the primary purpose of the process and what are considered as the secondary requirements. They only contribute to the load effects where as the strength effect is not there, so you should differentiate between these two and then simulate accordingly.

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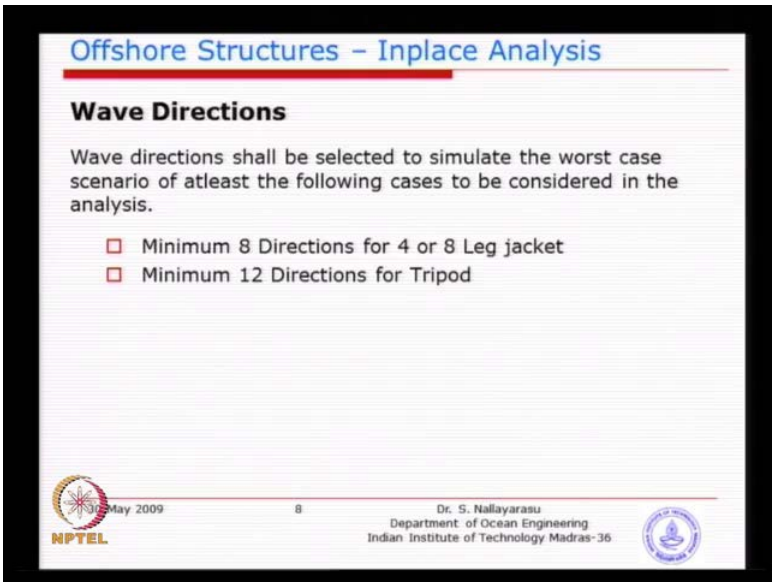

When it comes to design of off shore structures against environmental loading I think we have already discussed enough by this time you should have in your mind the uncertainty prevails a lot in the decision making of loading and its directions. Especially, when you are looking at off shore structure in a open sea condition prediction of sea state itself is a high uncertainty several techniques. In fact we actually do a measurement at site for a 2 years, 3 years, 5 years, you may get a better understanding, but nobody has the time to go and sit down and put the instruments and measure it for 5 years. Then come back and do the project nobody has the time once you find an oil at a particular location need to develop as soon as possible to make money immediately.

That is the exactly idea you may get only a year or less than a year to do any environmental study at the site you may actually do a 3 months survey, 3 months measurement data. Using that 3 months data imaging you need to design the structure for

25 years design life, so you need to predict what may happen for this particular location for the next 25 years what could be the possible maximum wave height possible. Maximum current possible, maximum wave period and the directions of those parameters whether the wave is going to come always from south may be yes.

If you ask the fisher man they will tell you most of the session the wave is only this direction, so what we normally do is we go and ask and study the historical data collect the recent information. Then correlate them and try to come up with a mathematical model which could predict possibly the next 100 years what could be the potential wave direction wave heights. All the parameters associated with it and this is how every where the design of off shore structure is done nobody is going to measure for one hundred years and then come back and then install the structure after one hundred years that will be the best way.

But, then that also gone because the 100 years data what you have measured becomes past, what you need is for future, so always this uncertainty cannot be removed with respect to off shore system performance analysis. So, always you will relay on computational model simulations and then the predictions based on probability theory, so there could be potential failure of your theory fail to predict correctly some cases may happen. You know if it is even 1 percent of your assumptions are wrong you may actually fail the structure, so that is where we need to play a critical role in decision making of this parameters according to the location.

Now, in this process some of the guides actually like a pi I think I have to introduce you a pi is a code which you will go into detail one of the classes is an American code. American petroleum institute devised the code for design of fixed off shore platforms very similar to you might have seen codes I S codes, I think most of you are familiar, no Indian codes bureau of Indian standards similar. So, they give a suggestions as a minimum consider this many wave directions based on experience actually you do not need a technical justification for that if you go through it is a leman exercise.

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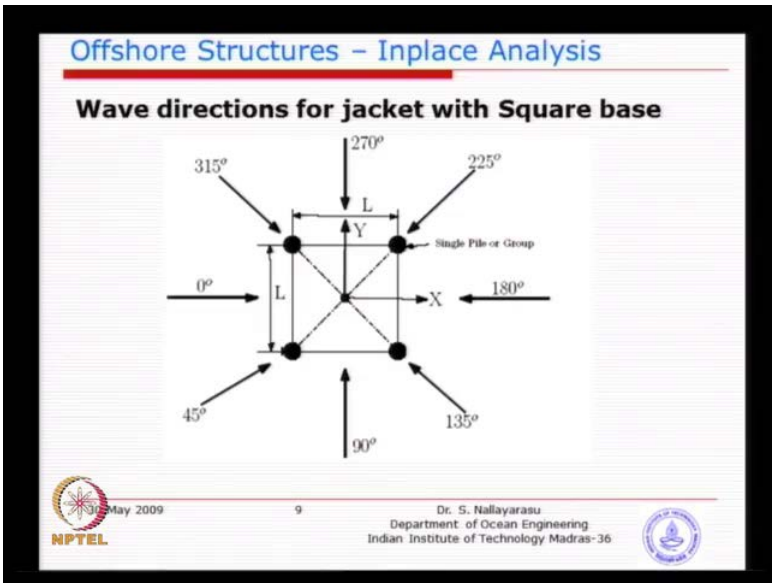

So, basically if you see this picture go to the picture, here it s a square base frame simply installed on top of sea bed you could easily see that 4 legs, 4 orthogonal directions, 4 diagonal directions orthogonal is 0, 180, 90 and 270. The orthogonal directions give you some type of response you will say see that what exactly is the idea behind why are we doing this you know.

After all, every element in the structure has to be subjected to the loads from environment also load from the gravity and the that super structure so if you imagine. If you have 0 degree load the pile number 1 it me just say 1, 2, 3, 4 I think hope I explained the other day, did I explain about this wave direction of forces, we will try to do that today basically if you see four piles, let me just draw as picture.

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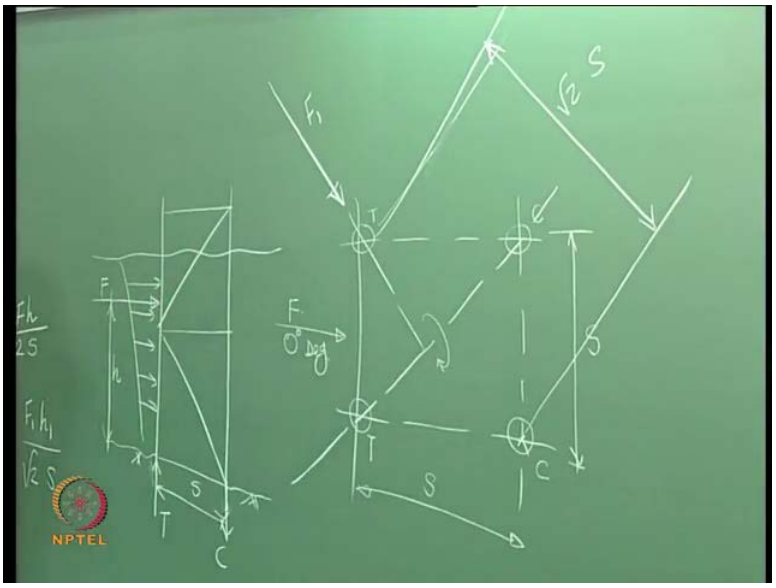

If I have 4 columns something like this and may be the spacing between the columns is typically S, you can have because it is a square base on the tower in terms of may be something like this which is your sea bed. The wave load on the structure is going to act something like this, so 0 degree is going to produce something like this at a height of say H. So, if you look at this picture you could easily find one simple conclusion due to force we have acting in this direction can produce compressive force on these legs and tensile force on these legs depending on the magnitude of this force.

The height at which it is and the spacing of the more the spacing tension may not come and also the magnitude of reaction is going to be very simple. So, this de coupling can be easily found out depending on sop if I want to find out what is the force on this 2 legs, you can find out F, F times H will be the over turning moment divided by 2 legs in compression, 2 legs in tension divided by spacing hope all of you can understand simple mechanics.

Now, if you look at the diagonal direction, so what happens the moment its acting with respect to the diagonal joining the opposite to corners and when you look at the compression force C 1 on this leg is going to be how you will calculate. Basically, F 1 times corresponding height where ever it is acting divided by only one pile is going to be, but the distance between this and this about 1.4.

But, not 2 piles are active, only 1 pile is in tension and the other pile is in, now you could imagine just simply changing the direction of the wave could be same magnitude of wave height wave forces. But, just changing from one direction to other influences the forces on the legs which is most important because the foundation design depends on the low transfer because you are going to design the foundation here.

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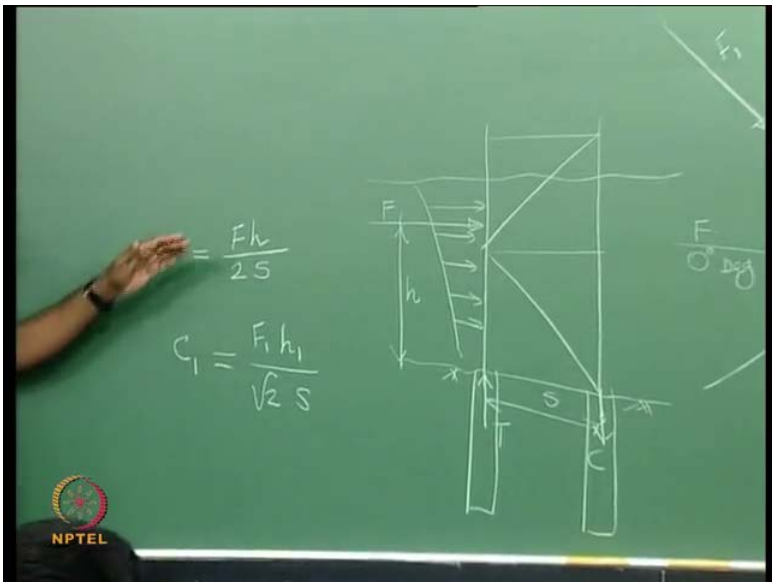

So, that means the direction by which the wave is applied is as crucial as the structure design because if it did not include this direction. For example you might have been happy that the pile loads are only this much this may produce lesser loads than this.

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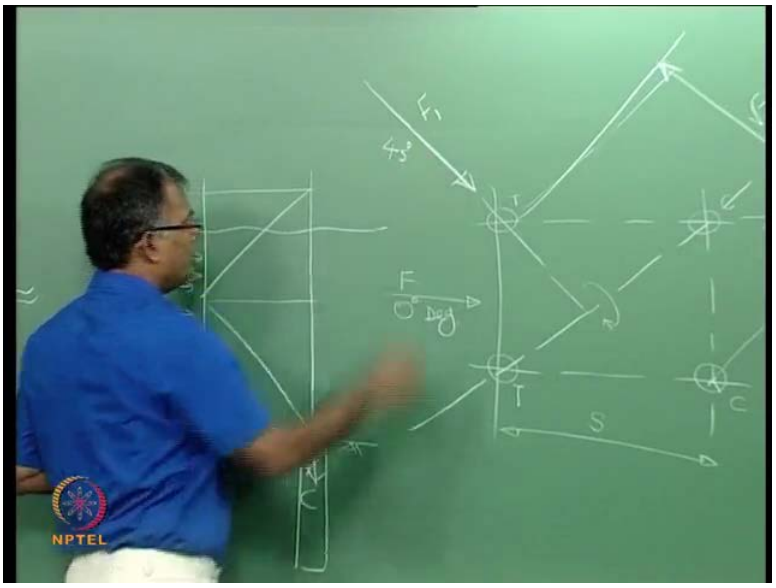

That means between 0 degree and this 45 degree whatever we were thinking there may be other way directions, which may influence this or higher pile load might be there depending on geometry of the system. Just now I have given you an example that just for a square base it is in this way, so depending on the type of structure if it is a rectangular base not necessary that only 45 degree is going to give you maximum forces.

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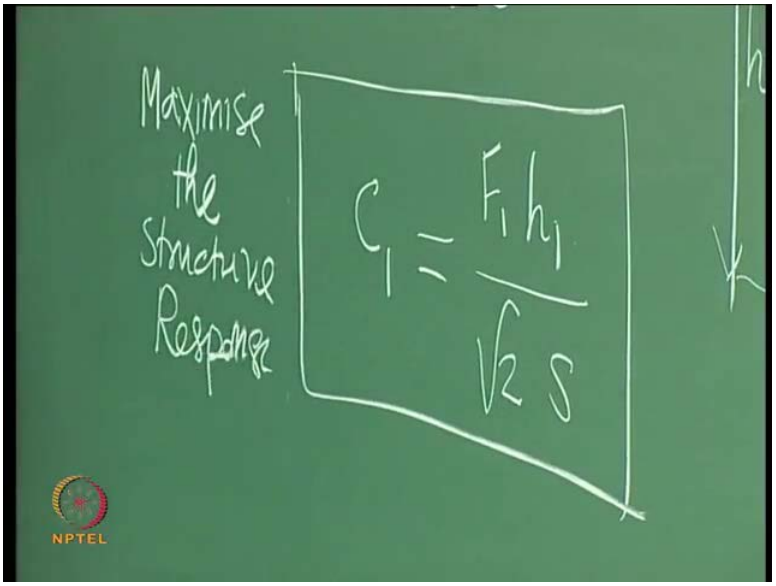

So, this is what we have done here is the message is maximize the structure response it is not that we want to purposely increase the response we would like to find out what will

be the maximum response. If wave direction changes from 0 degree to 45 degree which you have to ask yourself whether the direction will change yes or no, if it is yes then you do this if it is a perfect no. For example, 45 degree will never ever come when it will happen for example you have a east coast you have a jacket installed in east cost say few kilometers say 10 kilometers away can you expect a wave from west definitely no west direction is yielded by the land.

So, such question you should ask whether the waves can come yes waves may not come what is the probability of that may be but, perfectly yes it will never come then. So, you should ask and you should study the location of the place where the structure is installed then you get the... So, wave direction is just a common man understanding of structure design response hope you get the point.

So, basically I think you should you should spend some time thinking about why are we doing this the only reason, why we do this is basically the uncertainty involved in evaluation of directions. But, what happen over the last so many years every field where ever oil is found mostly number of measurement data simulation data including the recorded storms give a reasonable estimate of directions over a period of time. So, we normally use that because you are not finding oil suddenly from some where most of the oil fields in the recent say at least twenty years has been an expansion of existing oil fields, you find one and then drill another one in the same vicinity.

So, in that sense may be not a big deal because we got enough data to decide, nowadays what could be potential wave directions, now this simple question is the jackets are either 4 leg, 8 leg or 6 leg or 3 legs. But, we never have a jacket of a circular base at least I have not seen it, but maybe there is an occasion where you may have a circular base or an octagonal base or a hexagonal base. Then these recommendations given by a P I are not valid, so you keep in your mind that not every time I will apply this eight directions or 45 degree cases.

This is specifically for a geometry which is rectangular in base whatever may be the number of legs it could be four leg or eight leg does not matter. But, the structural configuration is this base suppose if you have a floating structure not necessary that it is always rectangular it can be a circular then do not apply that principle. Here, you could

actually have a different type of mooring configuration, so you have to find out what could be the potential wave direction that will actually maximize the response.

So, you have to think not simply apply somebody have told me 8 directions, I will simply for everything and apply this principle you have to think about how the response could be become maximum. Because that is more critical for us because the structure will fail if you forgot to or not considered in the evaluation.

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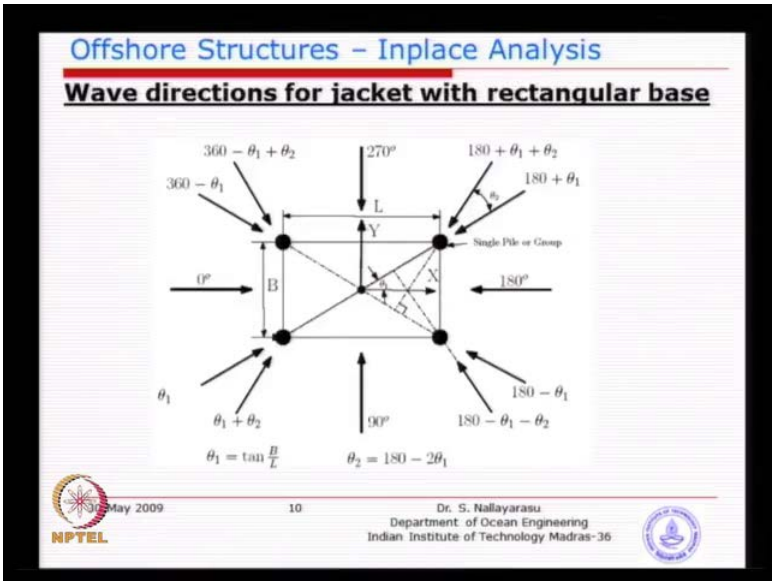

So, I think that gives you the trust of thinking required for decision making on the wave directions this is atypical sketch for a rectangular jacket where we in fact even consider a deviation from the diagonal. So, the diagonal could produce maximum, but also a deviation of plus minus theta 1 degrees which gives you simple idea that if that varies the sensitivity of the system could be evaluated.

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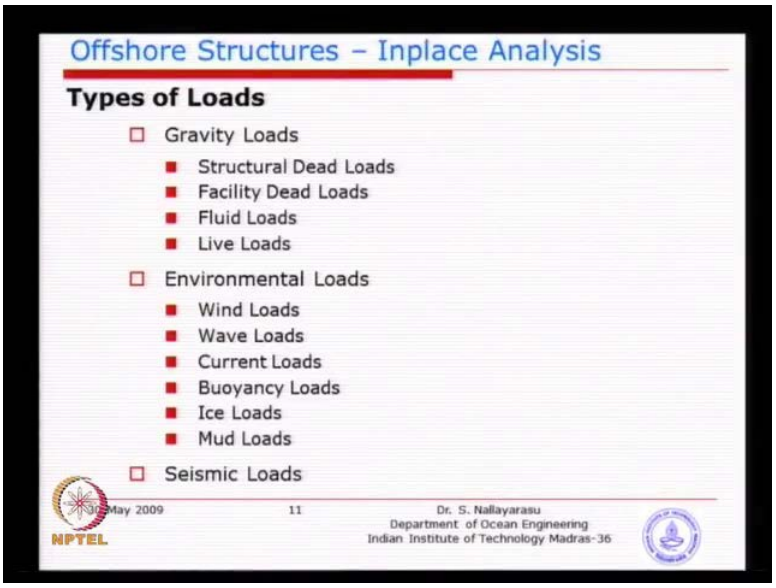

I think we have spent enough time on the loading do not have to spend any time just listed down all the loads that we already have discussed structural loads, facility loads fluid loads, live loads and all the environmental loads. The last one is the seismic load due to its own weight and the ground acceleration generates the inertia loads.

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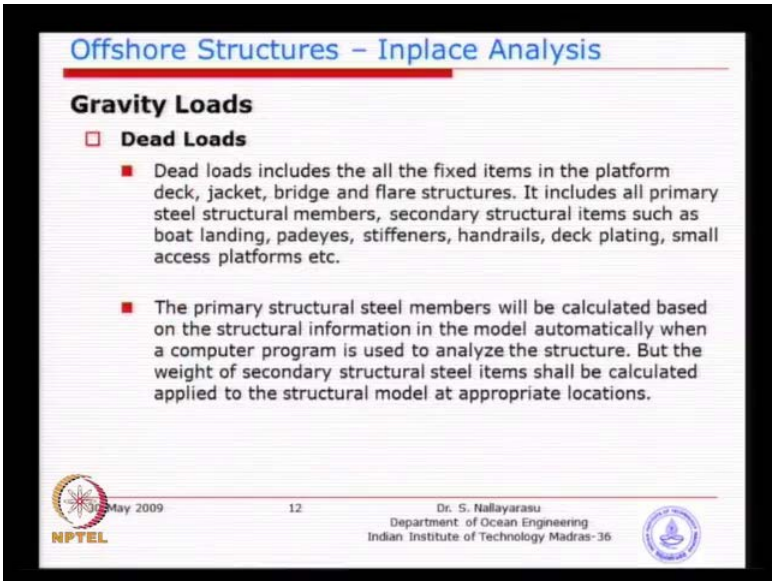

So, in the model when you are making a 3 dimensional model of the structure, you should have the sufficient information to generate the loads. Basically its density and its geometry should be modeled according to what is there the actual geometry or the cross

section. Then any additional weights that is not contributing to stiffness for example the floor slab you may have a structural slab or also have a non structural portion where is just a topping.

It is like it is a burden over burden or we sometimes call it super imposed loads in civil engineering terminology the loads due to various furniture, floor finishes wall finishes they are all just only a burden to the structure needs to be simulated. Appropriate density to be taken appropriate variations to be taken you know very important that you assume a 50 millimeter floor finish, but how sure is only 50 millimeter. So, you may consider a increased percentage sometime go higher facility.

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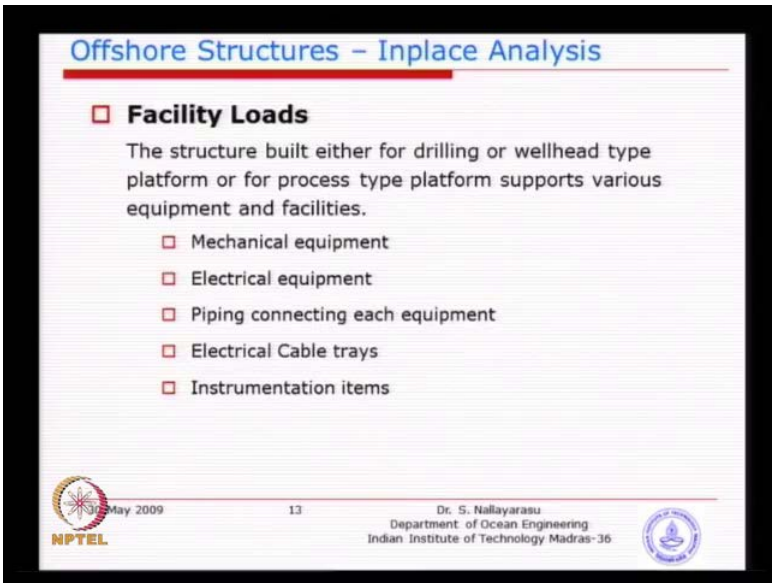

So, it is I think we have discussed earlier mechanical electrical all discipline, which involve in the island gas production you will have a many types of equipments involved there needs to be of course they do not contribute to the stiffness of the structure. They are all the weights contribute to the load and nothing else we cannot take any of the functional equipment as the part of the stiffness.

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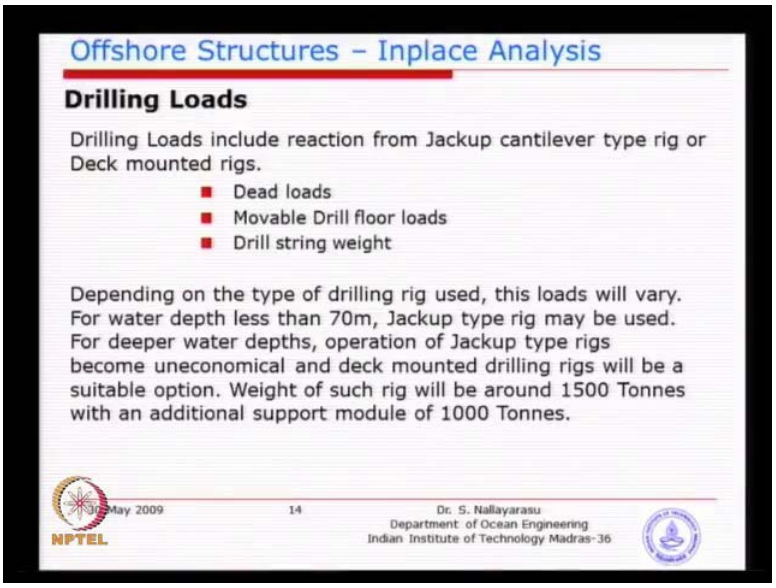

Drilling loads basically during the drilling work is going on what really happens is the weight of the drilling rig itself will be supported on the structure, if it is a self supporting jacket. That means the drilling rig is on top instead if you have a jack up rig drilling. Then there is no question of drilling loads coming here because all the drilling loads will be taken by jack up itself.

What else will come the continuous supply of drill material you know the drilling strings going into the ground, I think I have mentioned about the depth of drilling. What is the depth of drilling typically of island gas about 3 to 6 kilometer, so that much depth it has to reach so you have a drill string going down. So, the supply of those material will come, so that will also be added load into the structure during only time of drilling.

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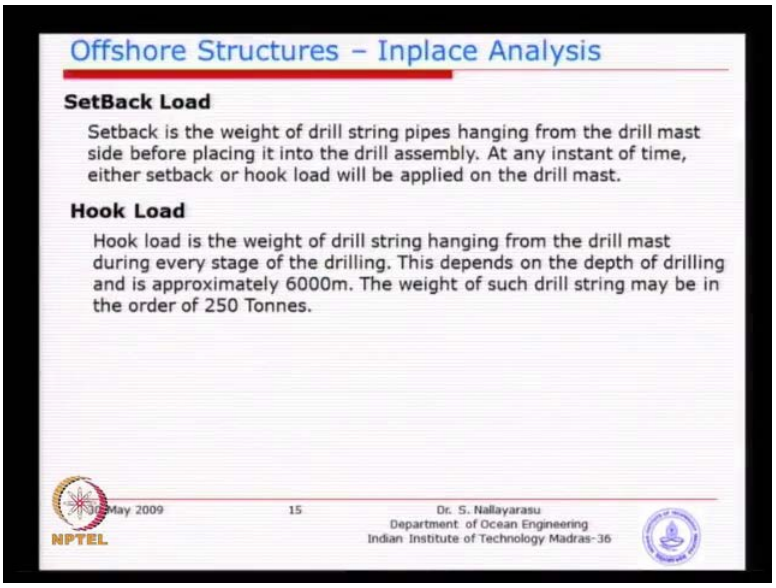

How it is done it is basically setback and the hook load is nothing but the hanging on the drill rig itself set back is the storage.

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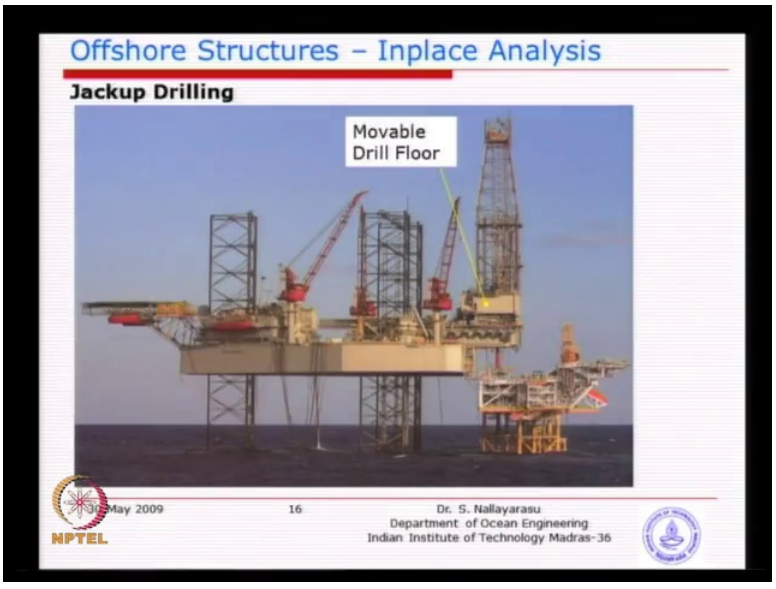

So, you see here a typical jack up its drilling in the vicinity where already a jacket is installed, so from this picture you could see the sea size of the drilling jack up with respect to a small well platform. So, much of facilities are required for example if you want to put all these facilities on this platform, itself this platform will become very large and the drilling is normally done for a few months in the starting of the project.

So, why to over burden this whole thing on to the permanent structure which is not required, so that is why this jack has become very useful, the jack ups go do the drilling and then relocate to another place. So, that is why you see here this jack up rig carry so much of equipment during drilling the details of which, we will be talking about jack ups in the last session this course we have a included a new topic only for this batch, jack up drilling previous batch it was not there. So, we will talk about this jack up in very detail how the operation and how the drilling is done. So, basically the jack ups are used for shallow water about less than 120 it use to be 50, 60 meters, but now the latest generation jack ups could even drill at meters water depth.

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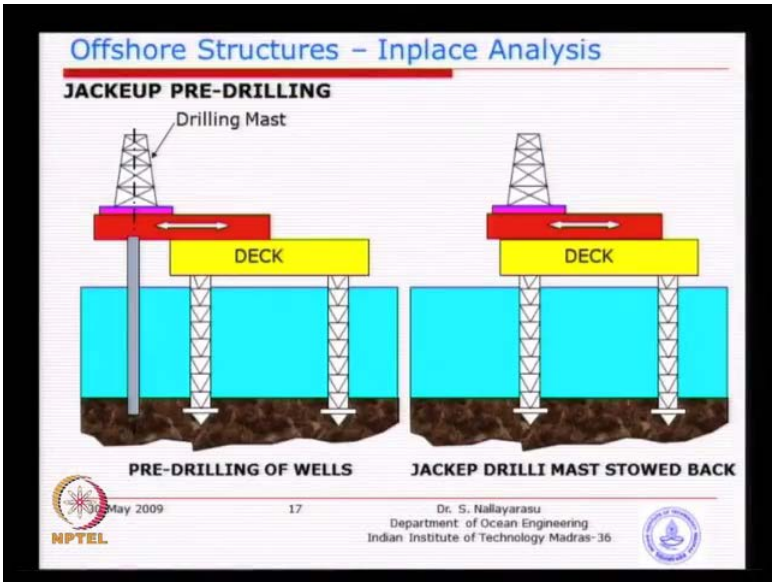

So, what is normally done is when you have a pre drilling of the wells you have jack ups arriving at site without any structure at site it does the drilling and go away and capping is cone at the sea bed. So, that means this is only used for operation purpose or the exploration planning purpose when the structure is not there.

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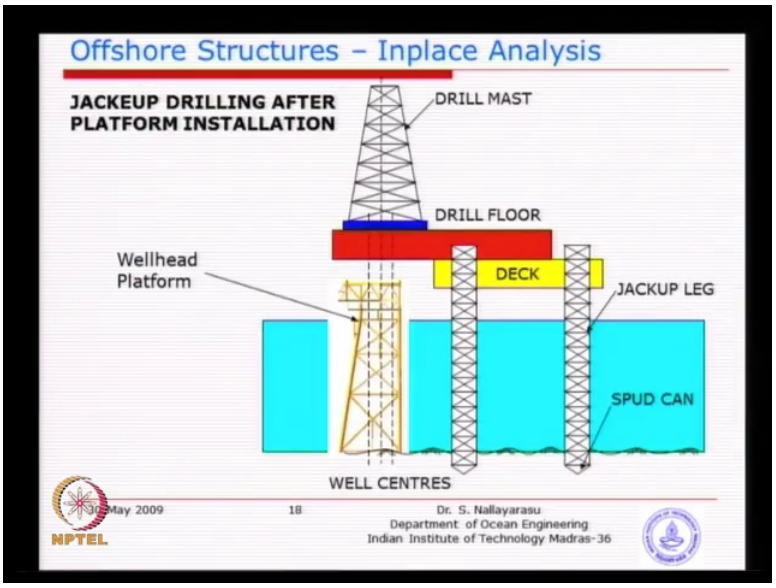

But, when the structure is there then you do the drilling after installation of the jacket. And basically both, sometimes we use jack ups sometimes use floating systems for pre drilling. But, post drilling you cannot use because you have to drill at the site at the jacket location, so you have to use the jack up well see tomorrow.