, Advanced Marine Sructures
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Lecture - 11
Ultimate load design principles - I

In the last lectureseries of lectures the previous cases, we discussed about different kinds of marine structures, varieties of marine structures; bottom founded or bottom supported flexible systems. New generation structures where form governs the functional design of the marine structures. Subsequently, we discussed about the environmental loads acting on marine structures. We discussed in detail about the hydrodynamic loadingcoming on the marine structure,we also discussed about wind loads, we also discussed about seismic loads,earthquake loads which is acting on the marine structures. So, in this lecture briefly we will again cover the remaining other loads on current, dead load, live load and impact loads which act on marine structures, once we understand this we will move on to the ultimate load design principles in this lecture.

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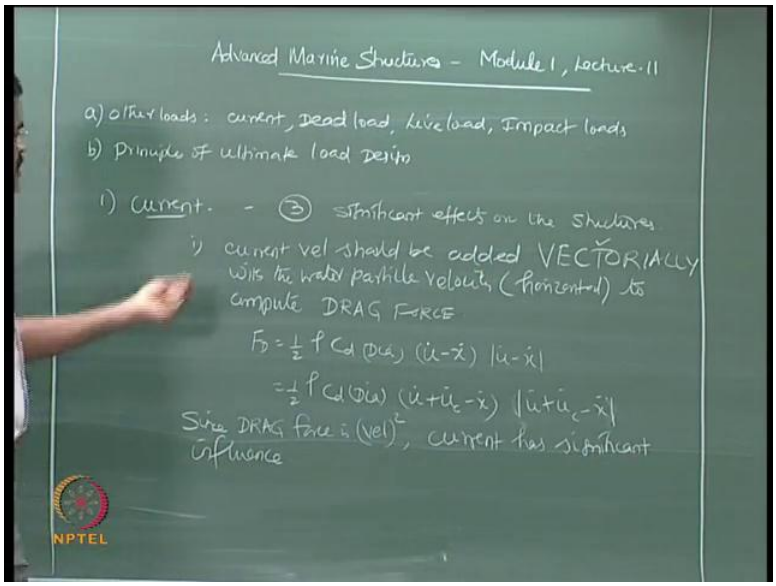

So, let us talk aboutthe effect of current or the influence of current as a loadon marine structures.Current has a actuallythree significant effectson the structures.Let sayfor example, the first could be current velocity should be added vectorially with the water

particle velocity,to be very specific I should sayhorizontal.To compute,can you tell me where this horizontal water particle velocity plays a role in computing ports on structures? You can compute the drag force.

If you look at the Morison'sequation which is applicable for cylinder structures, the drag force can be given byhalf rho C ddiameter uminus x dotand u dot minus x dot that is a drag component in the horizontalin the Morisonequation. Now, where u dot is the water particle velocity horizontal, x dot of course the structural velocity horizontal. If you have the current value to be also included in my study then I should sayhalf rho C ddia,u dotplus u c dotminus x dot of u dotplus u c dot minus x dot.

So, I should add the current vectorially of course, I say plus here it is vectorially to be added depending upon the value. So, you can see from this equation, sincethe drag forceis velocity squareyou can see itsvelocity square, so current hassignificant influence. So,that is the first part how do we handle current as a force.

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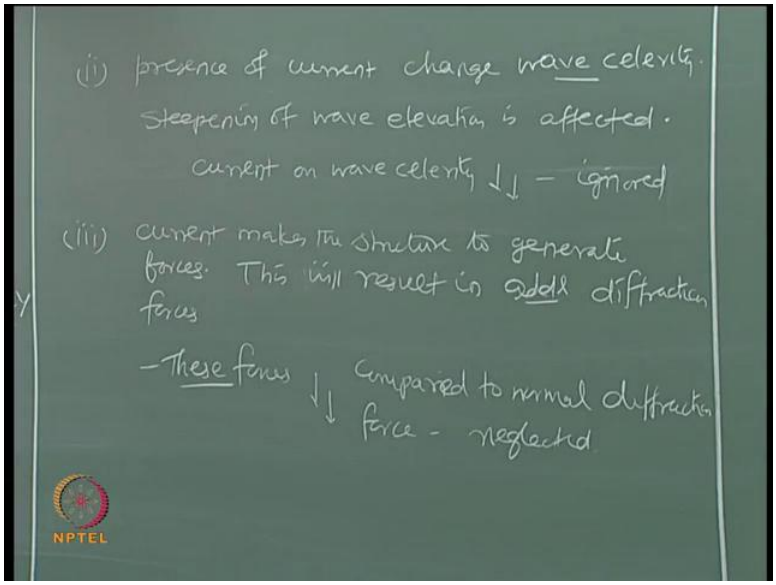

The second could bepresence of currentchangeswave celeritytherefore,the steepening of the waveelevationis affected, but studies of shown in the literature that effect of currenton the wave celerityis very less so generally it can be ignore.The third effectwhat the current has as a force on marine structure is,current makes the structureto generate forcesso this will cause, what we callI should say additionaldiffraction forces, because it will make the structure to generate forces. Howeverthese forces,these forces in sense the

diffraction forces caused by the structure because of action of current on the structure, these forces are very less compared tothe normal diffraction forcesand generallythis is neglected.So, these are the three consequences of current as you see as a force on marine structure, out of which the case two and case three generally ignore in the literatureit is not important.

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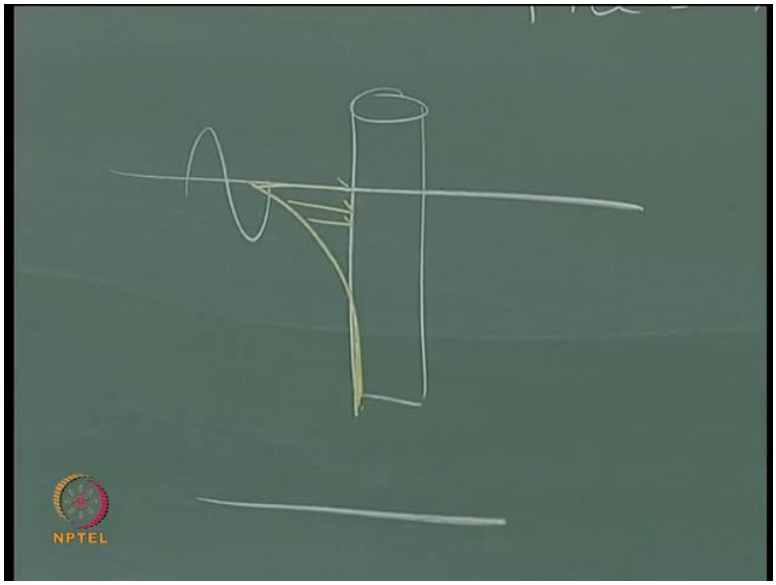

The first one why it is important?Because interestingly ifyou look at any structural memberwhich may be floating or bottom supported,this becomes mystill water level or mean c level. You will see that the velocity variation horizontal velocity variation is practically 0as he increase the depth whereas, it is maximum near the mean c levelis maximum.

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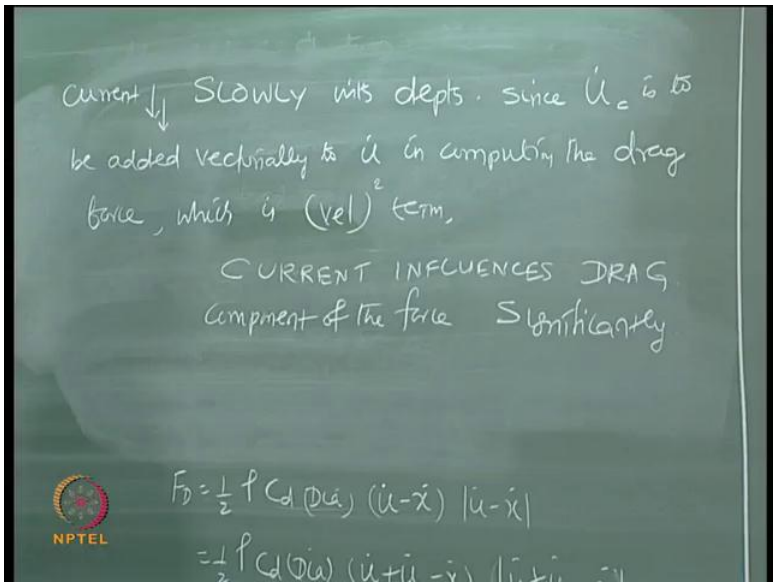

So, I should say that currentdecreasesslowlywithdepth,with depth current decreases very slowly, since u dot c is to be added vectorially to u dot in computingthe drag force,which isvelocity square term,thereforecurrentinfluencesdragcomponentof the forcesignificantly that is the summery what we have as per as the current forces concerned. So, let us quickly see what we have seen so farunder the environmental loads acting on Marine structures, we discussed about hydrodynamic loading.

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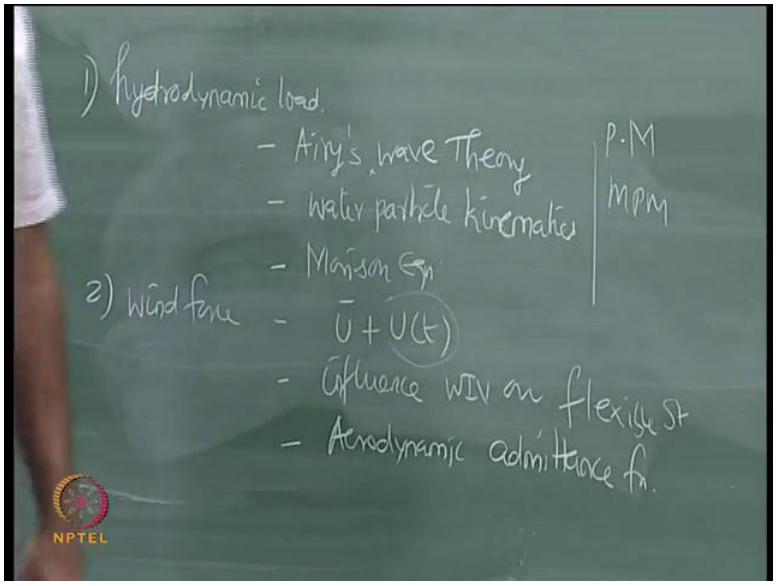

We started with the simpleC surface elevationgiven byclassicallinear wave theory given by Airy's,we all agree that why the wave theory is called linear, already said this in the previous lecture.So, based on this we compute water particlekinematics,if the structure is fixed or the structure is large diameter or the structure is lender or compliant I use appropriate equation to compute the wave forces, let us say for a compliant structure the wave force is computed usingthe Morison equationand now we know how to compute wave force.

We discussed aboutthe wind forcethere is an aerodynamic clouding.Wind force has two component, one is the mean componentother is the gust component which is fluctuating; one will give you the static effect other is giving you the variation spectro time. So, wind generally caused wind induced vibration on structures, this will significantly influencewind induced vibrations are flexible structures.So, how the dynamic component are how the gust component can be handled? Because one is random process how to handle this in a close form solution? We have got aerodynamicadmittance functionwhich helps us to handle this issue easily in computing the wave forces.

Now, the question comes, what spectrum should I use for finding out the wave forces? Because for wind load sorry, for wave forces we already haveP S and mosque at spectrum modified P S and Mosque at spectrum Johns Swab etcetera. Whereas, when you come for wind forces people said,I will used one seventh power law, butthat is generally used for fixed type structures.

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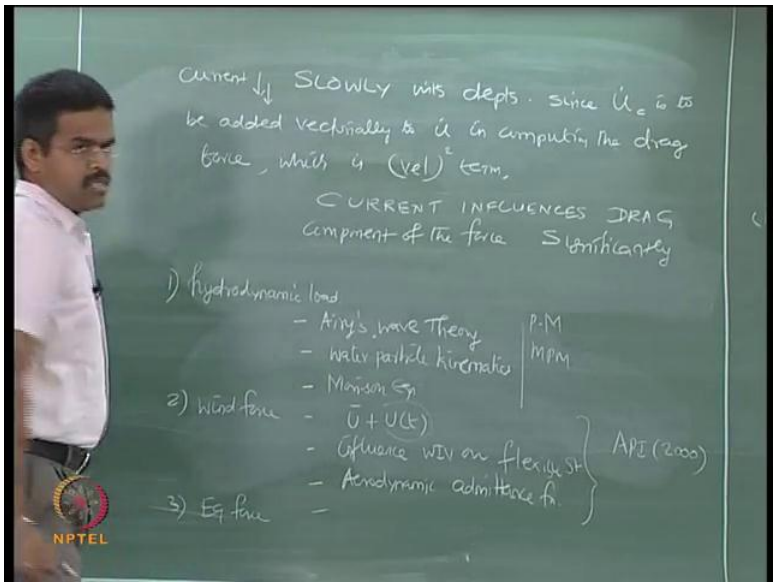

For flexible type structures there are different spectragiven in the literature, one classical example which is commonly accepted for flexible type structures is thespectra suggested byAPIand so on which we saw in the last. What are the factors on which these spectrum is depending etcetera we have seen them.

Thirdly, we also discussed aboutsite quick load,earth quick forces.The earth quick forces is predominantly effecting bottom supported structure, because it can transfer the force from the c bite to the structure directly, this induces initial component it does not induce or initiate drag component in the structure. Whereas, wind end wave both induces drag component, in addition wave induces initial component also. Whereas, earth quick force induces only the initial components or the mass of the structure is very important and we all understand offshore structures a very large in size and very heavy in mass or weight therefore initial forces become predominant. When they are bottom supported it is directly super in post, but does not mean that earth quick forces cannot influence structures is are taught mode,we picked up an example in the last lecture.

We showed you how your top moved system like a TLP can also be influenced when earthquake force significantly by an indirect mechanism, which is suggested by the various session in the literature. In this lecture we have started with introducing current forces,what is the effect of current force on Marine structures?What are those three

domains of contribution out of which is important and why?Now, we look into the conventional forces which otherwise common to other kind of structures.

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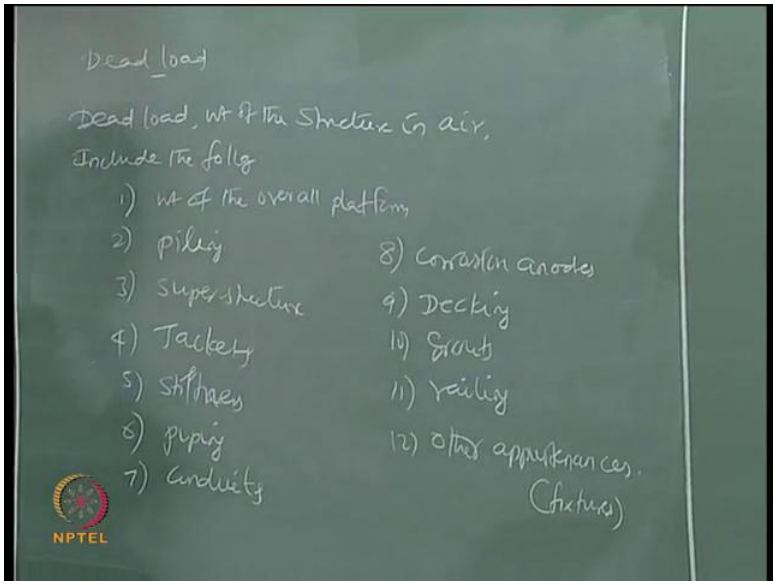

For example, thatwhat could be the dead load, in terms of its intensity and what you understand by dead load? A very clear explicit interesting and intelligent definitions are given for the dead load, live load, impact load and EPIRP. You must read these codes reference are available in the NPTEL website of this course, butstill I willreproduce them as a very brief summary here for our understanding.Dead loadis essentially the weight of the of the structure in air,this will includethe following,include the following means includes the weight of the following.

Weight of the overall plat form,you know how to compute this because you know the member dimensional,you know the material and you know the density, you know the volume and you therefore, you can find out the overall weight of the plat form in air. Remember, we all understand thatis the difference between the weight of the plat form in air and water, toweight comes from piling,weight comes from the super structure,weight comes from the drillingsorry, this is excluded this is excluded,jackets, stiffness,piping,conduits,corrosion anodes, deckinggrouts,railingand other upper appurtenances, appurtenances means fittings,fictions or fittings.

Now, interestingly we must understand which are excluded in the dead weight that is very important included is all these, butthere are very classical exclusion of the dead

weight, which you should not consider as a dead weight. What are they? Are very important to understand?Why are they excluded and where are they included? We must know this.See, interestingly Marine structures are form driven system they keep on changing the geometry the profile arrangement of members as the water depths keeps on increasing. As the function for deep water generation is keep on changing every day or may be every season.

Now, we have moved from shallow watersof 20 meters of oil exploration to 230 meters of oil exploration the presence standard. If you have picked up any one specific case of an offshore structure, which is meant for 1500 meters like a spar platform or a triceratops or a TBLP tension boy and leg platforms, where we can go for deeper depths unless are where is we understand very clearly the design mechanisms. What are the loads contribute in to these members?

We will not be able to proceed further for ultimate load design and plastic design, because they all will look for you as a mathematically equation and getting the solution from solving the problems, butwhere are the source of loads coming from? You will never know. If you do not know the variety of lodes coming on the structureyou will not appreciate. What are the deficiencies in calculating these loads accurately?Therefore, the question of how your design mechanism is reliable is not understood. So, reliability part of advanced marine structures will not be understood by you.If you do not know where the loads coming are concentrated on the members, you cannot understand the stress concentration development in the third module, you will not agree or you will not realize how do you do the fatigue design.

So, it is very important fundamentally, first let us understand what are different kinds of structures?What are the different kinds of loads? Probably you would have understood all these things in some other courses parallel, but it is my responsibility for you to make it clear before you proceed further for ultimate load design. Because I must understand where are the contributions coming in the format of load, in the format of string on the members, because these are the two parameters where I will keep on handling for ultimate load design in the next few lectures.

So, if you have not clear about the sources of the loads where they coming from, which are included, which are excluded and what are the intensity values? Approximate

ideahow much live load or dead load I must consider on a deck plat form of 90meter by 90 meter.I must have an idea; otherwise you will never really understand the problem in a physical meaning.

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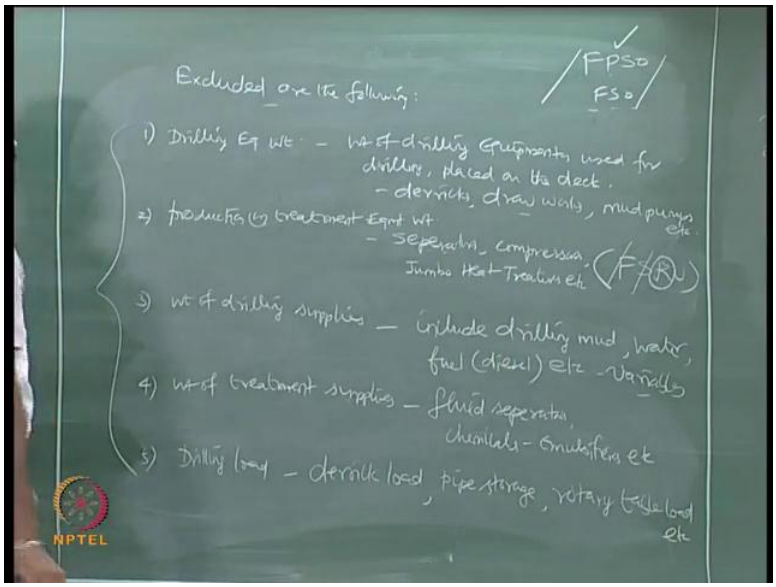

So, there are some classical exclusionin dead loads. One drilling equipment weight,two productionor treatment equipmentweight,three weight of drilling supplies,weight of treatment supplies,drilling load.Now, there are reasons why they are excluded?First let us see what are excluded? What you mean by drilling equipment weight? Let us see this;this is nothing but weight of drilling equipmentsused for drilling, which are placed on the derricks,placed on the deckwhich are placed on the deck, examplederricksdraw works. You understand what is the draw works?

Draw works are those mechanically equivalents, which are used for drawing or you know sucking oil from the sea bed these are called draw works in general.Mud pumps,we all know why mud pumps are required?Drilling mud is a very important component in drilling operation and we need to pump this mud, because these are a very high specific gravity, they do not flow automatically you are got to pump them so mud pumps etcetera I should say etceterathey are excluded.

Production treatment equipmentincludes,let say separators,compresses,jumbo heat treaties,these are all equipments which are require to process the oil what you gate from the sea. Now, one by wonder why should he process it,I am talking about the marine

structures somewhere offshore, which is about let say 100 200 kilometers away from the cost somewhere in the middle of the sea, where the water depths is about 500 meters,I am looking for an oil exploration at a depth of about 1000 meters may platform cost is very very high, the service like us only 10 to 15 years, why should I invest on treatment plants on the offshore system itself?

Why cannot I simply explore the oil and keep on transporting it to the off onshore and do all these treatments onshore. There are two main reasons for this; one is the cost,because what they producex volume of oil, all what you explore is not oil. You have got a process it to extrude oil from that the majority will be become a crude. So, if you are transporting the x volume completely from offshore to onshore your cost of transportation for transporting the slug or the rubbish will be unnecessarily high.

So, what people are thought in reason times is let us process it in the plant itself in offshore and only transport the net worth of financial asset to onshore. Now, the concept ofFSRUcame in to play floating, storage, re gasification units. So, its floating system it is having a normal storage, it does not do drilling remember very importantly it is not an FPSOor FSOit is floating storage offloading, this is floating production storage an off loading, but these platforms or at least these for sure that is drilling, where as this only floats off course is got a non of storage an off load it to the tanker.

Whereas in this case, they do floating storage they do re gasification there is process happening here. So, this is a reason investment which is come now, may be very recently within couple of years. So, people have looking for a very large investment on FSRU in the current standard, because treatment becomes expensive only transport the slug to onshore.

So, these are some equipments which are used for etcetera,for treating the oil water explore. So, these are all excluded from the classical dead load of a marine structure. We look at the drilling suppliers, they includethey includeweight which comes from the drilling mud,water,fuel,essentially it is dieseletcetera,I should call them asvariables.You do not know how much mud you will be stocking. How much water do you required? How much water you will deeper etcetera, these are all drilling supplies.

If you talk about treatment supplies, fluidseparatorschemicalslike emulsifier'setcetera. What does it mean? These are all used in the treatment process in the units here

like,drilling mud is used for drilling equipment.Similarly, these are all nothing but they variables used for treatment process in the plant, these are all excluded from the classical dead load of Marine structures, we do not include them. Drilling load includes the derrick load,pipe storage, rotary table load,I should say etcetera alwaysand there are many things which we are not mentioning here.So, these are all excludedin the classical dead load, which we other way consider like including this. So, essentially if you we look at in summary,dead loads are related toweight of the structural system variables are excluded,process equipments are excludedfrom the classical dead loads.Now, where do we consider them? Where do we include them in our load capacity?Will talk about that.

So,I have a smallhomework for you, you try to look in to the literature not necessarily API RP not the code, look at the literature try to find out approximately weight of each component in air.So, there are very many kind of platforms already installed, look into the Wikipedia Perry plat form there are certain books, which has been advised to you in the literature read them, you will find a table of column in giving weight of each component approximately in terms of the percentage of the overall weight.In the overall weight is of course, given in the literaturetry to give an idea get, an idea that how they are contributing to the overall weight.

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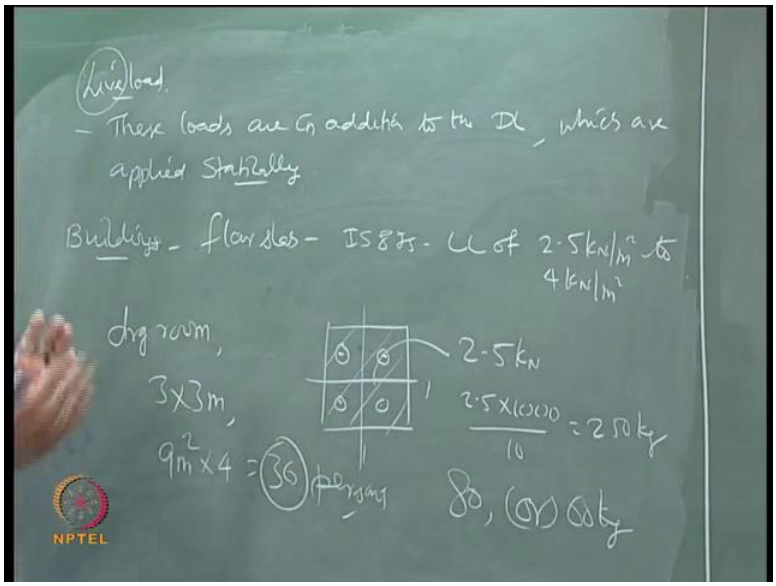

Next of course, will be the Live load,these loads are in addition totothe dead load,which are appliedstatically, remember this.So, static component you may say sir live load will

very big time for example, for buildings just for understanding of the viewers for example, for buildings when you design a building let us take a component of a building,let say a floor slabI S875 the loading code advises, a live load of 2.5 kilo Newton per square meterto 4 kilo Newton per square meter depending upon the choice of the designer.

What does it mean? In 1 square meter area,you can use2.5 kilo Newton that is 2.5 into 1000by 10,which comes to 250KG, it means if you apply or if you use a Live load of250KGin 1 square meter taking an average human weight as 80or let us say60KG, your approximately allowing four people to standin one flow. On the other hand, if your drawing room is approximately a size of 3 meter by 3 meter,9 square meter into 4 people,you have 36 percents living in your house only in the drawing room, okay.

Imagine the other rooms and imagine the total area.So, one can clearly understand there is a very highly conservative number, but in a building in a floor slab in a drawing room like this, all the load will not be acting continuously throughout the day. Because a load will pattern will shift from drawing room to, kitchen to, dining to, bedroom to service areas etcetera.For example, in institution, in a school class room to, library to, rest rooms to, corridors to, play areas etcetera there will be shift depending upon the timing of operation.

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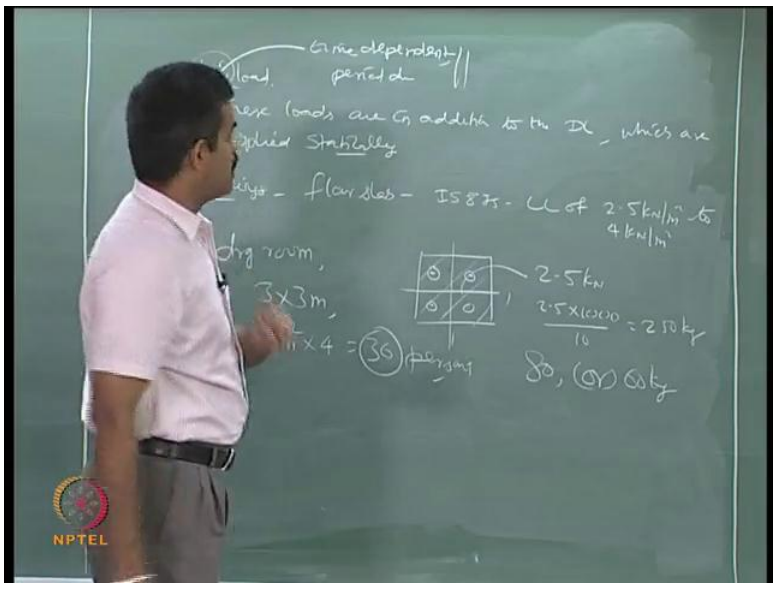

So, in real séance if you see live load should be time dependenton Saturday Sundayis 0, Live load it should beperiod dependent alsoetcetera is it not, butremember importantly these factors are ignore, they are considered as independent of they are statically applied. So, we obviously cannot handle the Live load suggested by building codes on to offshore structures, because we have a different concept it is also a structure, but our operational loads in terms of live load are different.

Say now, a case where to the Live load come from for example, in house like this example, you have seen Live load come from human being etcetera, buthere we have only limited number of people operating on the depth is it not we have got maximum 50 to 705 people on boat which will work, because the area is 100 meters square,100 meter by 100 meter theTLP. Typically has a side of the square platform about75 to 90 meters. So,10000 square meters only 50 people live. So, live load cannot be simply based upon the load what you have from the human being? So, what are the sources of the live load coming on the structure in offshore or in Marine structures?

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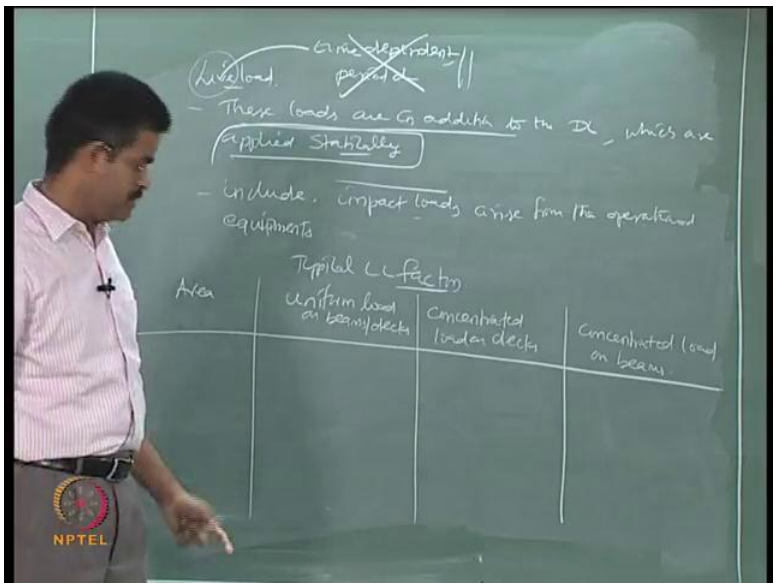

So, they includetheimpact loads arisefrom the operational equipments.So, what is a guide line? How do we know? Because I have said simply operational equipments I would also these equipments have a Rotary mechanism, because they are not static, they are running, they are working like a generator like a heat exchange, they have compresses, compressive routers and they will keep on operating. So, the operations speed will impose certain dynamic effects on the platform where they are installed. So, we have travel impact load.

What is the guidance advice by the course? Interestingly,I must now look at the designer instead of the studying in the concept let me look at the numbers.The typical live load,I should say factorsof the following, let say area,let us say uniform load on beams.Make a column,let us say concentrated load on beams,so that is, this is on decksthis is concentrated loadon beams.First let us try to understand the difference between these three, before we write on the numbers on the area of descriptionthought you may be knowing it, butstill, since this course does not have any pre reprised the audience can be even from any source of mechanical electrical etcetera.Let us try to understand what you understand mean uniform load concentrated load beam deck etcetera.

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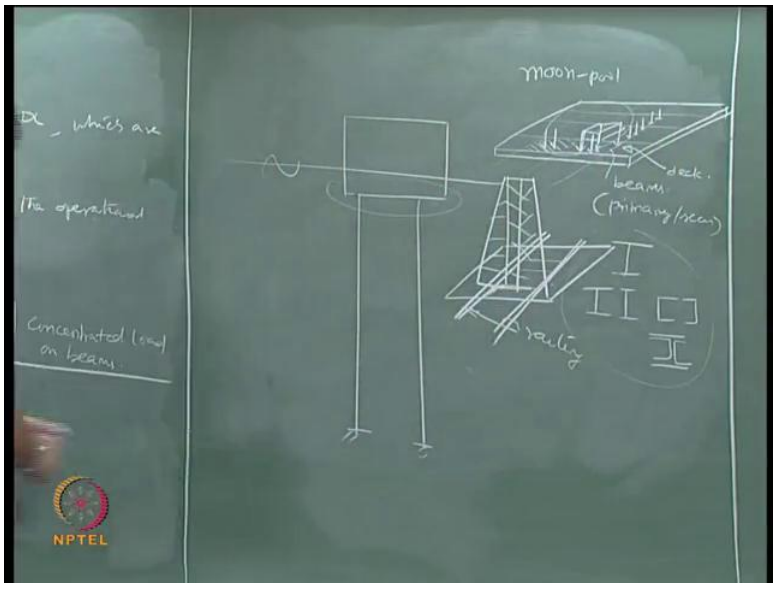

Let us say I have an offshore platform may be a TLP;may be a jacket top more. Now, I pick up only thisand try to draw, I call this as a deck supporting system. So, the deck comprises ofessentially, a plate. I am just drawing only a line diagram. Essentially a plate

of x thickness, butobviously asthe plate is very, very large may be 90 meter, you put any thickness here as the plate will start buckling is it not it will not bend now, take any load. So,I have got the push stiffness,these stiffness can be called as beams, they can be called as primary and secondary beams depending upon on what direction you are running and they can be generally an I section,they can be a composite I section, they can be a face to face channel, they can be a back to back channel, they can be a back to back channel with the plate all these have what we call built up sections, we call them as beams,we call thisas deck. So, what we are saying here is uniform load on the beam syntax, that is, load on this area.

So, the intexity of this column should be so many loadper square meter that is called uniform load, is uniformly applied. Concentrated load on decks,these decks sometimes will have concentrated loadalso times you do not know, in equipment can be standing for example, I R an equipment here, which can be a compressor, which can be a compressor it is got four columns on which adjusting. So, all these four columns will impose a concentrated load at the point where it has been jousting on the deck that is what we says concentrated load.

Sometimes unfortunately or fortunately these loads can also at exactly onthe beam line also we do not know, can you give me the example where the beam line load can be developed? You are heard about moon pool?Moon pool is an opening given in the deck to perform drilling operation, the drilling derrick is a single standing equipment or the stack which can not regret ofevery time,because that takes lot of time, what they do is interestingly if you look at the view hereI am drawing only one segment of this, they put a railing this is a railingbothand these are all slotsthey are removableslots,you can remove them if you wantyou can remove the plate it becomes the moon pool.

So, the Derrickwhich will make to move on this where are you want to operate the drilling you can do that.So, this becomes a rolling load which is also a concentrated load on these beams that is what we looking at here,so let us look at the areas here can be walkways, staircase, etcetera.

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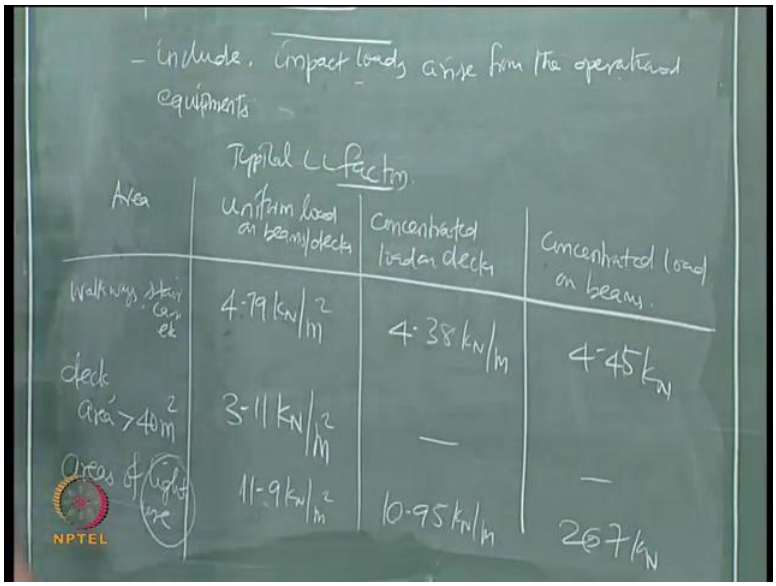

4.79 kilo Newton as expected it is load intensity per area, this is 4.38 kilo Newton per meter.This is 4.45kilo Newton. Now, if you have a deckwhose area is larger than40 square meters whose deck area is large than 40 square meter, then the load will be3.11 kilo Newton per square meter of course, since it is a deck we are not talking about concentrated loads, if you are got areas of light usednot use for process may be living quarters for example, living quarters then in that case, this becomes11.9 kilo nekton per square meter is a wonder interestingly.

Student: Sir, we say area of light used, butintensity is much more than we have got areas of operational use. Why it is so?

I will explain that is 10.95kilo Newtonper meter, it is 267 kilo Newtonand so on.We have a reference for this I wish to state the reference, so that if you had made any mistake you can correct it.

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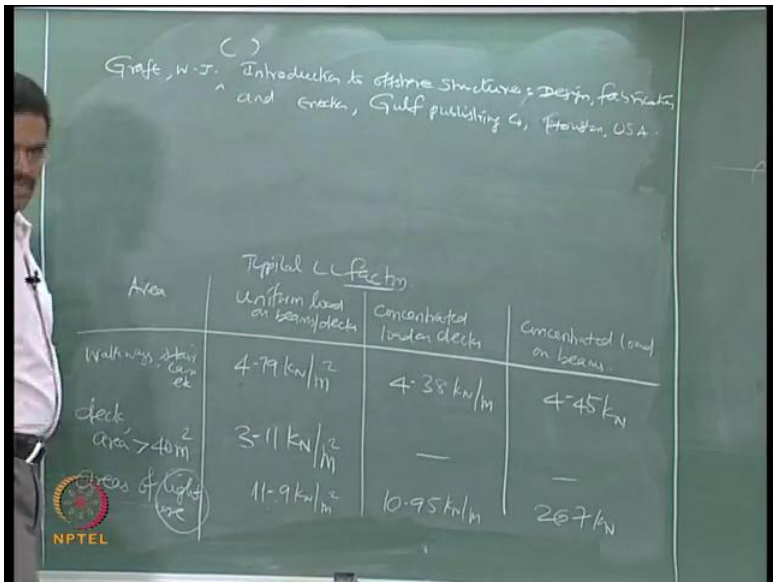

GraphW Jintroduction to offshore structures.Design,fabricationand erection, gulf publishing companyHouston, unfortunately you will remember the...I will give you the year next class I forgotten to note down here I will give you this.So, let us come back to this question of argument that why area of light used which will have large intensity compare to that of areas where you got operational area of 40 square meters. Coming back to the functional use of any platform as we saw here areas of light use will be limited, the areas usedfor light use are meant for light use will be highly restricted.

So, eventhough the intensity is larger, when you multiply with the area the total load of system, because of this will becomes lowerwhereas, operational areas are very, very high. So, if you multiply this intensity with this area unnecessarily the load on structure will becomes very large, example building, live load, two point fix load of the square meter, approximately saying four persons on 1 square meter area which is un imaginable load highly conservative.

So,you must appreciate that when live loadswhere prepared for offshore platforms there has been very intelligent thought of identifying the magnitude and intensity very carefully. So, there is no conservatism hereis that clear of course, this change is the designers options changes with of course, water kind of equipment you are using, but it is only a idea just to know what is the value and comparisonto the buildingsand you will know note very clearly, all the values stated here or much higher than meant for

buildingswhere that I said 2.8 to 4, butthis is 4.79, this is 3.11 9, this is 11.9very, very high.

So,that is what we are talking about the live load here. Now,interesting factor these live loads are considered static, butthey essentially come from movement of equipments or vehicles ordrilling Derik etcetera.So, there should be some impact on this, why impact will be there? Because when any vehicle or any equipment operates or moves and applies a break or changes it is speed or alters it is acceleration velocity will cause an additional impact to the restrained offered by the support, example car is moving on a road at a velocity of let say 60 kilo meter per hour apply a break the vehicle stops. Now, the reaction force which makes a vehicle to stop essentially comes from the friction between the tire and the surface which is running.

So, the reaction force is offered by the restrain boundary which is given to the car. Similarway,here when a vehicleequipment is operating when you want to change the operation speed because of the requirements from the operational mechanism those changes will all affect or get affected by the boundary on which is restrain is nothing but the platform deck.So, they all will be impact load. Now, the question is very difficult to find out what could be this impact load or average operational when equipment on a floating system like this.

So, people have said let him multiply this Live loads with the factor to create an impact load. So, I now looking how for impact load factors, so impact load is not essentially arrive directly on from any equipment, we simply picked up the live loads and multiplying them with a specific number what we call as I l factors impact load factors, if you want to is it the practice commonly available in structures in buildings yes answer is bridges.

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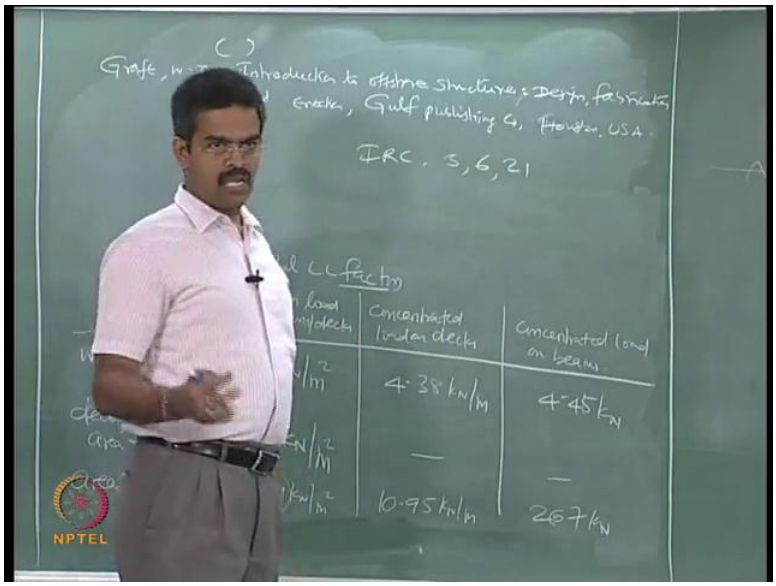

If you look at IRCIndian rope congress 5, 6, 21 these are the numbers of IRC code for example, they are all meant for design of railway and road bridges, where moving loads are there vehicles are travelling, where cranes are also operated for example, all in these codes they say, that the impact load caused by the vehicle movement will be enhanced by a multiplying factor on factor on the Live load.

So, this practice has been common in almost all codes which speak about impact loadssimilar concept is adopted in marine structures design also. Now, I am talking about impact loads, butas he said I am not talking about impact load directly I am handling this indirectly.

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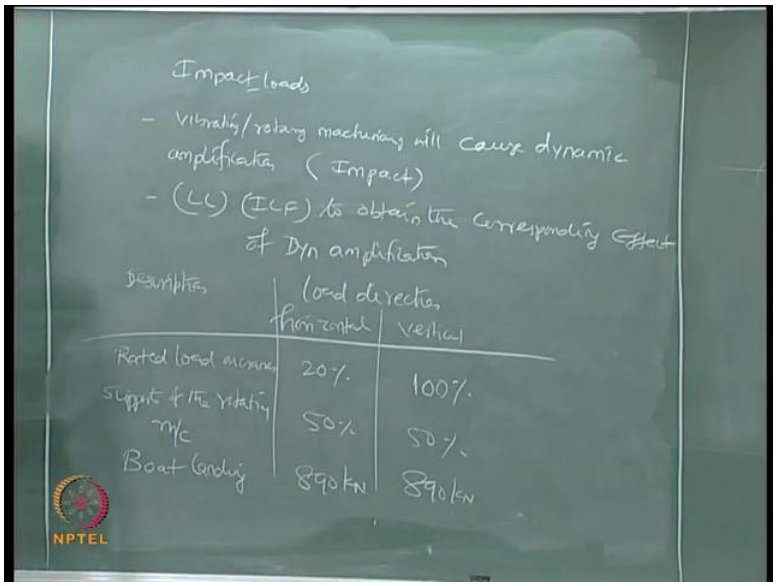

Say Impact loadswe all understand that any Vibratingor Rotary machinerywillcaused dynamic amplification,which I caused as impact.Therefore, Live loads are multiplied byImpact loads factor to getthe correspondingeffect of dynamic amplification,you understand this. Just to get the amplification of the dynamic effect on the members, we multiply the live loads which some impact factors that is why we call this Impact factors on the Live loadsImpact load factors, so again a table.

So,description loads direction. The impact load cannot remain same for horizontal and verticalcannot remain same. So, I should say horizontaland vertical,if you have a rated load on cranesfor horizontal the impact is 20 percent for vertical it is 100 percentthis for the crane loads, cranes. If you look for supportsof the rotary or rotating machinery equipments, then the horizontal impact and vertical impact factors are equal.If you look at impact because of boat landingthen here it is a specific value given.

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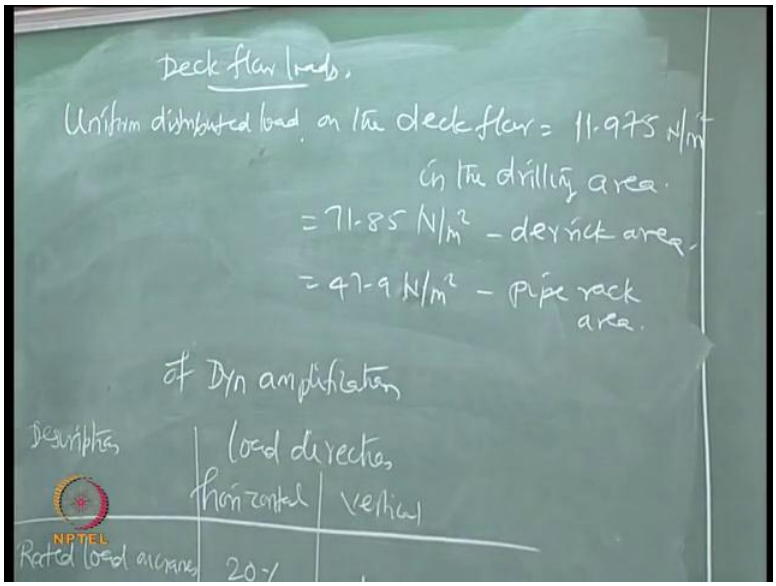

In addition to this, what would be the common uniform distributed load which is advised on the decks,this is 11.975Newtonper square meter in the drilling areathese are all original Live loads,71.85Newton per square meter in the Derrick area47.9Newton per square meter in the pipe rack area,these are what we called asdeck flow loads, these are all the loads which comes on the decks flow.

So, with this lecture ladies and gentleman you competed the comprehendsummery of all the loads acting on marine structures, we have understood now what are the different kinds of loads verities of loads coming on marine structures. How are they handled in the analysis? Which factors influencing what? How much? Why? How are they? A designated in the literature which are the different spectrum stepping appropriately used? What is the effect of these forces in combine nature on the marine structures? Which is dynamic? Which is static? Which is deterministic?

Which is probabilistic? Why? How are they handled? What are the different parallel functions? Which can map the probabilistic on a deterministic issue? Which load can combine with what? Why? What would be the effect all we have seen in this six seven lectures along with the different verities of marine structures. We have studied with this bases will move on to the next lecture, will talk about ultimate load design principlesand factors which will affect, then will slowly move on to the plastic design of marine structures.