Marine Hydrodynamics
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Lecture - 32
Gravity Wave Transformation & Energy Relation (Contd.)

To this series of lecture submarine hydrodynamics in the NPTEL program, in the last class we are talking about wave energy relations and wave scattering. Today we will continue the same in there is a channel factor because, the end of the lecture I started this, but I will repeat this again.

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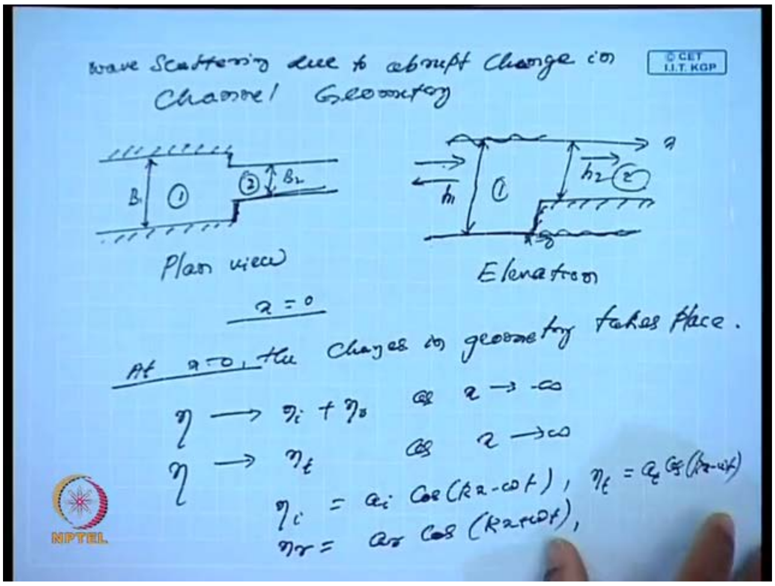

Suppose, I consider a channel of width the and suppose, there is a appropriation in the channel width this is and then, this occurs initially the width of the channel device B 1 and then the width of the channel weakness B 2, this is the basically the plan view. And then, if it look at the elevation suppose, the depth wise is initially the depth wise h 1 and after some time let me see the depth has become h 2 from depth h 1 to depth h 2 wave propagate. And so, there is just say wave scattering wave scattering due to abrupt change in due to arrow abrupt change in channel geometry change in channel geometry.

So, initially the width was given and I say that just let is possible, let all these set take place and x is equal to 0 in the axis, this is the plan b this is the surface elevation, this position is called x is equal to 0, here also this line is this is x is equal to 0 and this I call region 1, this is region 2. So, this is the same region 1, this is region 2, this is by x axis if this are the solution.

So, what will happen when we propagate from a that that are two things, when a wave propagate from this side. So, we get very abrupt change in the geometry here, at x is equal to 0. So, part of the wave will be reflected, part will be transmitted to the other side. So, in that case what will happen I will say that at the interface at x is equal to 0. So, I have two things here, if I just say that I have at x is equal to 0, if you look at for whether the changes occur in geometry takes place, if I just say than what will happen.

So, then my at the (( )) when because, at the here for away from the channel where the changes occurs, than what will happen to my eta this will be a combination, it is like eta e plus eta r as x tends to minus infinity and eta it is like a eta t as x tends to infinity. And what will happen to eta I, eta i would not be up this form, if I say eta is a, a i let it be anything cos k x minus omega t and my eta r is a r plus a x plus omega t. And then my eta, you can take this exponential format any form is a t cos a x minus omega t. So, this is the eta, eta r eta t now, if I look at the a n to analyze this problem, if I look at the energy relation.

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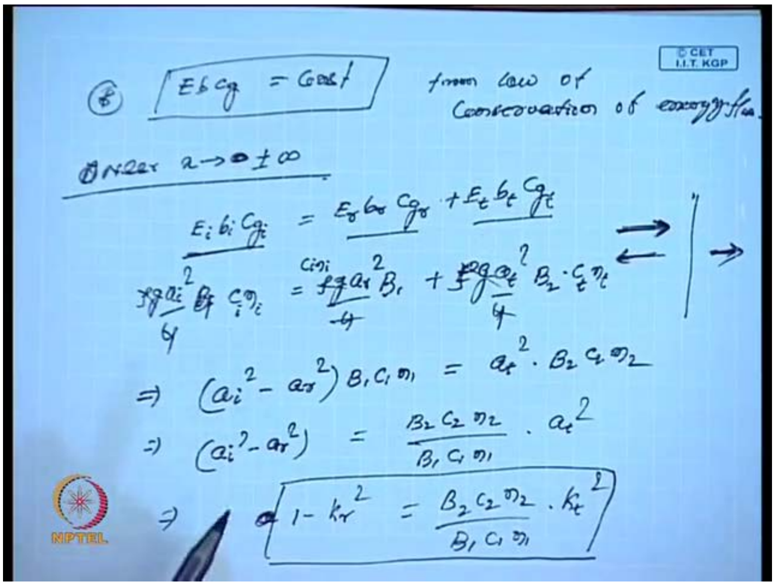

The energy what will happen, I have E b c g because, I have a here it is, this is equal to constant because, in this case this channel is up this is from, from low of conversation class and here I have. So, if I looked at the left hand as near near x tends to infinity plus minus infinity I can always say that I can always say that if I follow this principle is equal to star, than x tends to plus minus infinity I always can say E i b i c g I, E i b i c g i this is equal to same as E r b r c g r plus E t b t c g t.

So, basically this is a all this terms are associated with the wave incident way, this is a associated with the reflect wave, this is associated with the transmit wave. So, if I follow this approach and here, if I look at the incident wave, this incident wave is the incoming wave because, this is approaching towards the structure were as the reflected wave and the transmitted wave near the outgoing waves. So, whatever waves comes in, if this is the place where the waves the changes takes place.

So, whatever wave that is coming in the same amount of energy is also because, the energy that is entering approaching towards the towards the location were the changes are taking place, geometrical changes from the same place, same amount of energy will be radiated, but outgoing. So, because of that this is a must the incident wave energy is same as the reflected and transmitted wave energy, if this is the case than if I further simply e 0 g a i square by 4.

So, and that will give me than b i into c g i is c, c n is equal to c i n i equal to e r is rho g a r square by 4 into this side that that is b i and less b r. So, this is I am using the notation B 1. So, this will be B 1. So, this will be again b 1 plus this will be rho g again a t square by 4 into by 4 into c g t again into c i n i plus c g again into B 2 into c t n t and this by 4 will cancel, this term will get cancel, than you will get it a i square a i square minus a r square into B 1 c 1 n 1 is same as a t square B 2 c 2 n 2 this is what this is what happens and what is c, c is nothing, but omega by k.

So, if c is omega by k or if I a i square minus a r square equal to B 2 c 2 n 2 by B 1 c 1 n 1 into a t square this can be simplified further a i call it 1 minus k r square that could be B a 2 c 2 n 2 by B 1 c 1 n 1 into k t square. So, this will becomes the most general form of the energy relation and there is a change in the applets.

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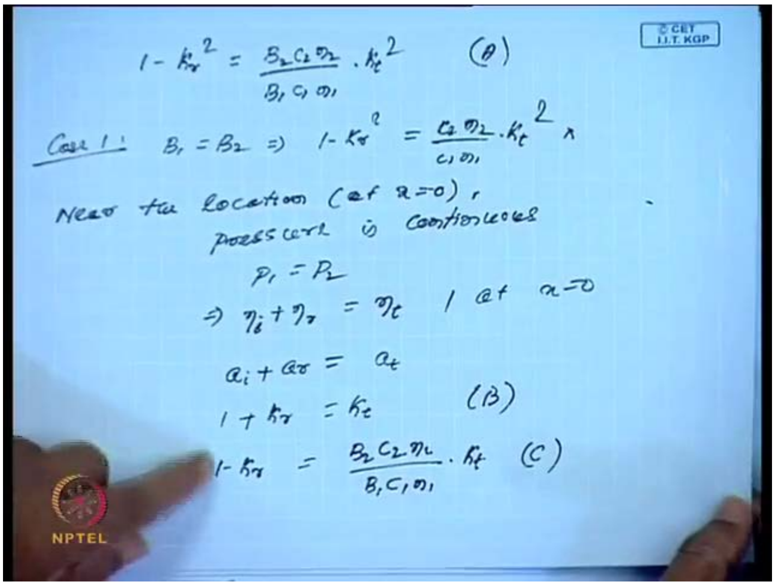

So, this also can be written in a another simplified manner particularly if the wave is a say of 1 minus k r square is equal to I can further simplify because, if I write it c is omega by k or in terms of lambda I will I can write it, this is B 2. So, B 2 c 2 n 2 by B 1 c 1 n 1 into k t square. So, two things happens, if I have in the wave case I will just consider case to case case 1, in the case of case 1, incase of case 1, if I just say that my B 1 is B 2 than what will happen, this is same as 1 minus k r square 1 minus k r square is equal to c 2 n 2 by c 1 n 1 into k t square.

And also, further again I will come this a little later whether this case, another thing I will discuss it here that what will happen happen near the free surface, near the location that is at x is equal to 0, at the near the the fluid the pressure continuity. Thus displacement the pressure is continuous the pressure continuous in the flow and because, that x is equal to 0 the any other location the pressure is continuous that will give me p 1 is p 2 because, the dynamic pressure will be continuous and once p 1 is p 2 that will give me that eta because, p is a that will give me eta 1 plus eta i plus eta r will give me eta t.

So, basically we have seen that as if the surface displacement is continuous at this particular space that is continuous that is the no changes in the pressure takes place there at the interpolation at the location. So, that will give me eta i plus eta r if eta i plus eta r if I look at the amplitude of this at x is equal to 0 in x is equal to 0, this is that x is equal to 0 and that gives me a i plus a r is a t and once this is; that means, 1 plus k r is k t.

So, we have already got another relation that is from A and this is B. So, from A and B you can always get 1 minus k r because, if I divided by 1 plus k r I will get it 1 minus k r is B 2 c 2 n 2 by B 1 c 1 n 1 into k t. Now, if I have k r and k t are two unknowns this is c if k r k t are two unknowns and I have two equations. So, this will give me, what will give me my k r and k t my k r will be.

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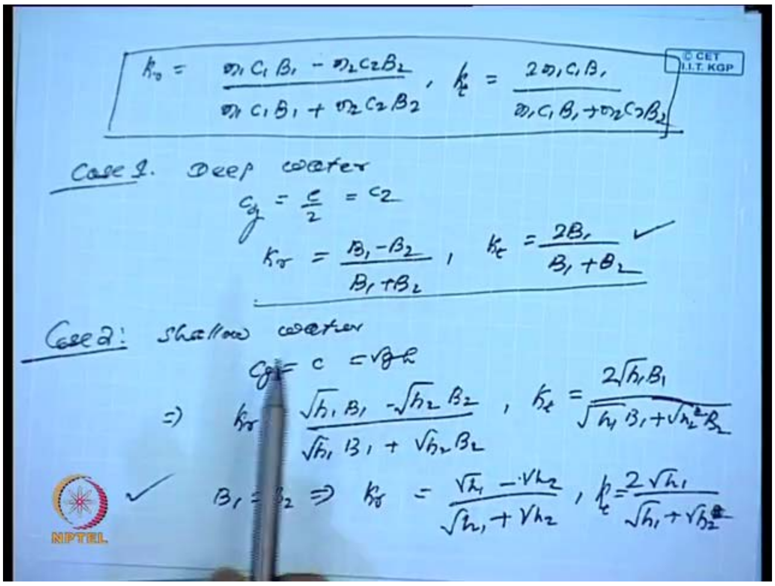

So, this will give me, if I just start this things r and subtract this two things I will get my k r is and usually you get k r is n 1 n 1 c 1 B 1 minus n 2 c 2 B 2 by n 1 c 1 B 1 plus into c 2 B 2 and similarly, will get k t if will do that, we will get k t is a two time two times n 1 c 1 B 1 by again n 1 c 1 B 1 plus n 2 c 2 B 2. In fact, this is the general regulation for the reflection and transmission (( )) and there is a abrupt change in the geometry.

We can consider several cases, like suppose the case 1, if I say if it is a deep water, let us say deep water, if it is deep water case then we have c 1 is a c by 2 and again is equal to same as c 2 and in that case, we will have what will happen. So, that will give me n 1 c one is c g is a rather c g is a c by 2 and that will be n 1 c 1 is same as n 2 c 2. And that case this will give me my k r is B 1 minus B 2, B 1 minus B 2 by B 1 plus B 2 and here, k t will be 2 B 1 by B 1 plus B 2 this is simple and that is the were.

So, it all depends on the width ocean width, because if the in the deep water, just abrupt change particularly this happen in a bay, suddenly if there is certain change in the width of the bay, than the reflection on the wave will be get reflected and this is the way the reflection and transmission coefficient can be obtained, another case let us see case 2.

Here, this side it is 2 B 1 because, what will happen, when the wave is reflected it is physically says that as if the because, one incident wave, one reflected wave in the superpose, for us say standing wave is generated that standing wave amplitude becomes this this becomes this. And as we have seen in my previous lecture that standing wave will be generated once the two wave superpose each other.

Now, if will go to case 2 that is shallow water, if I say shallow water than what will happen, by n n 1 c 1 is a c's c g is a c we have c g is a c that is root g h, and which gives my k r is h 1 B 1 root h 1 b 1 because, from here I will get minus h 2 B 2 divided by h 2 B 2. And this k t becomes twice h 1 B 1 root h 1 B 1 by h 1 root B 1 plus h 2 root B 2. So, than this will becomes (( )) and again if we say that B 1 is same as B 2, this is what we have earlier obtain that that will give us root h 1 minus root h 2 by root h 1 plus root h 2 and here is a 2 k 2 will be 2 root h 1 by h 1 root plus h 2 root sorry.

So, this is the way in case of deep water and shallow water in a similar manner, we can see that when it move comes shallow water, deep water to shallow water the similar situation will occur. Now, here what we have done in this relation, we have done that there is a change in the both in change in water depth, as well as width.

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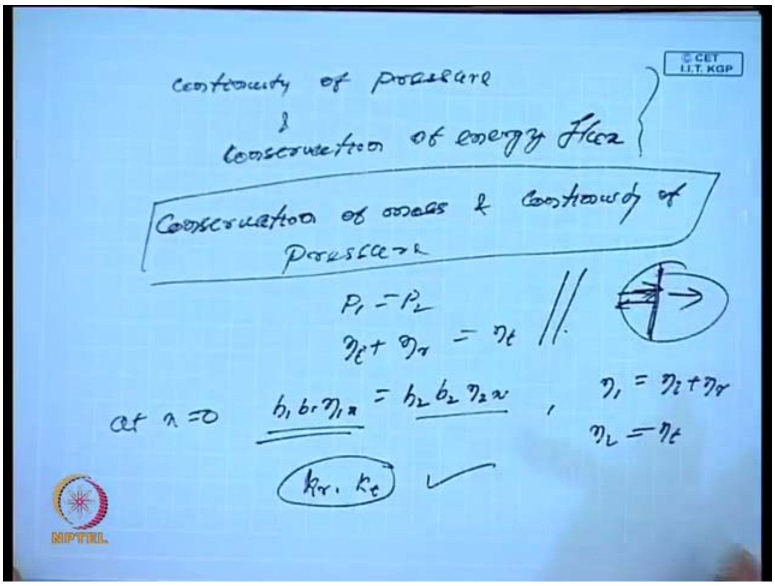

What will happen and here we have used two things, one is the continuity of pressure continuity of pressure, as well as the conversation of energy flux conservation of energy flux, this way we have written this case. On the other hand the same can be obtained, same love and reflection if I just say that, we can proceed in the same way by assuming that conservation of mass, as and continuity of pressure and the interface.

So, what will happen in case of conversation of mass, here we have p 1 is p 2 and that has leaving us eta 1 plus eta eta e plus eta r is eta t on the other hand, if you come this is from the pressure continuity. And if you look at conservation of mass that will give us h 1 that will give us h 1 b 1 eta 1 x is h 2 B 2 eta 2 x and this eta 1 x is the overall the depth of water in the left side, this is eta 1 is nothing, but my eta 1 will be eta i plus eta r and eta 2 will be eta t.

And basically here, will look into this will happen at x is equal to 0, there is the same mass will be mass of fluid because, that is a reflection. So, whatever amount of mass is on the left side, same amount of mass will also generates a. So, at this point amount of mass that will enter the side and same amount of mass, because the total mass at this interface will be the same whether the wave is reflected which is transmitted as it goes to this end look at this end, the total mass will be same where there is the change in the water depth.

And if you look at this also, then also we can easily see that will again arrive at the same set of k r and k t, I am not going to this part, but it can be easily derived, this I will leave rather with this part leave the wave transformation I will complete. And I will now, go to another thing what I call the equation of the wave load calculation on a structure.

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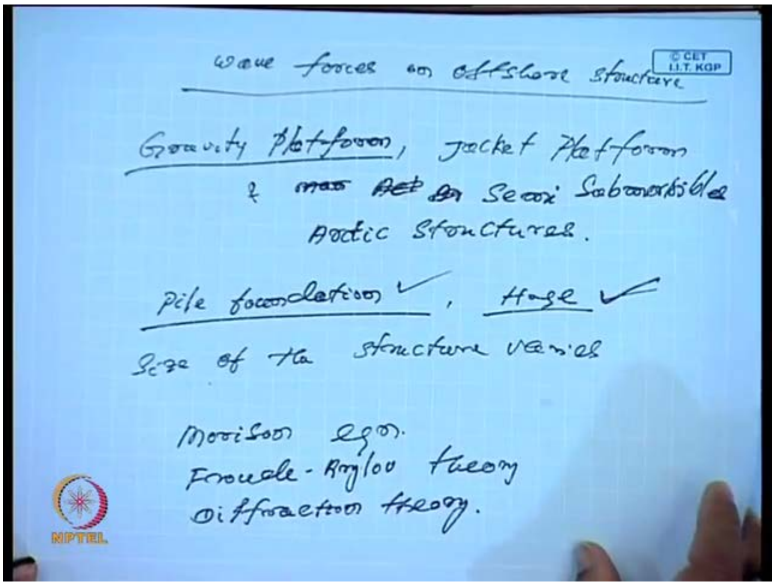

Particularly the second part of this lecture will be wave forces on offshore structure and when you look at offshore structure, particularly; these are large structures there are the means there are radiation type of offshore structure that is gravity platforms, (( )) exploration of a oil from the activities from the sea bed and others activities we have various, gravity platforms, jacket platform and many others. Even if arctic structures, sometimes call this semi submersibles semi submersibles arctic structures, these are some of the examples of offshore structures.

So, these offshore structures that are two kinds of things, there are sometimes there these some last structures there they have a pile foundation and particularly pile foundations. So, large number of piles, thin pipes are there and on which the structure is based on sometimes there are gravity incase of particularly gravity based structures, the structures are huge and they may be cylindrical, structures this piles can be cylindrical they can be rectangular, they can be triangular piles plies and then, but in case of a huge structures like a gravity platforms, the structural size is very large.

Particularly, if you look at circular, structure basically cylinder type structures which are extended from the sea surface, till the bottom there are huge in. So, there are three types of basically to calculate the on the structure because, as I say this is the size varies, size of the structure varies when I say look at the size, always look at the diameter because, the most of the size of the structure varies because, when I look at the diameter I always mean the.

When you look at the size of the structure I always mean the diameter here because, the radiation of this structure because, the structures all this structures I am taking up here today, is there all extended form this free surface from the till the bottom sea bed. So, there are two calculate normally, we apply three types of a depending on the size and the characteristics of the wave, we always concentrate on three types of three methods, for calculating one is Morison equation and is Froude krylov theory, other one is diffraction theory although I will not go to the details of this things, but I will just give a give a just a glimpse about about this equations at this theories, just that a glimpse I will not go to much details.

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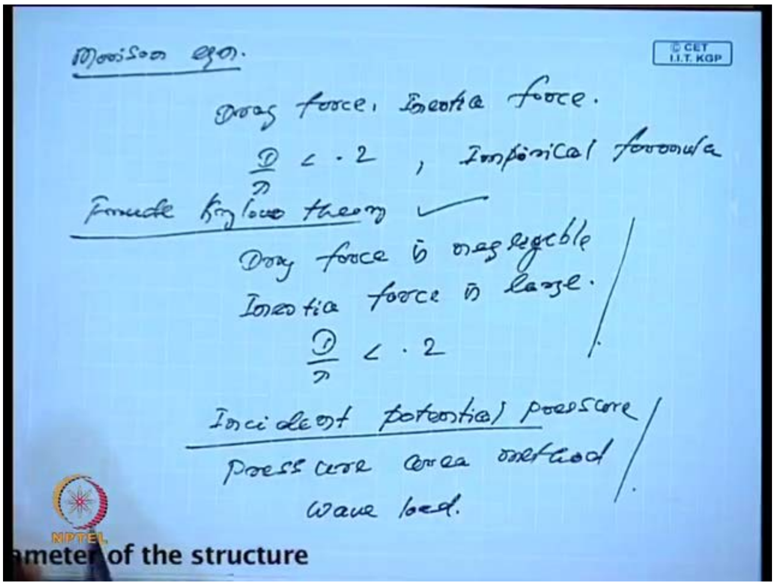

And then, what happened when you look at the Morison equation, this is based on a assumption that there are two components, one is the drag force one is the inertia term inertia force, there are two terms in this. And particularly this is most suitable when the structural size d by lambda is less than 0.2 here, the it is a super positional of the two components, one is the drag force part, one is the inertia force part and there.

In fact, this was this was this on the other hand if I look at the Froude krylov of theory Froude krylov of theory and this is the imperical formula which depends on the mass coefficient, energy at the energy at the drag coefficient and energy at mass coefficient with sometime we call it the added mass coefficient. On the other hand when it comes to the, in the drag force is negligible drag force is negligible where as the inertia force is dominating is large.

So, then and also the structural size D by lambda is a similar to less than 0.2 then in this case, what to do then in this case we apply the Froude krylov theory, one of the advantage of this this is. In fact, many simple problems can be handled like this, but here it utilizes the what it does, it utilizes the incident we put inside under corresponding incident potential, potential pressure.

Basically, in it consider a incident under the corresponding pressure based on the equation and take that, and use the pressure area method pressure area method on the surface of the structure to calculate the wave load. And the advantage of this method is that it, the most of the symmetry structures many times we get the explicit expression for the wave load, on the other hand this is came a Froude krylov.

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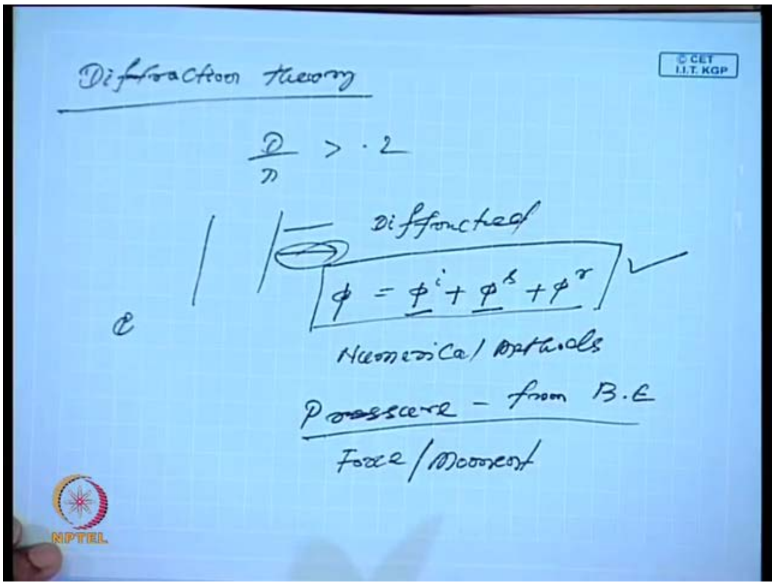

Theory on the other hand when the structural size D by lambda that I will go to diffraction theory, incase of diffraction theory what happen when D by lambda is greater than 0.2; that means. So, what happens here, the wave that is increase on the structure I have structure from the wave increase on the structure, what happens it gets diffracted basically, the structure that is a diffraction field is because, a part of the wave energy get reflected, to get diffracted, scattered, radiated out. So, the energy is diffracted.

And the diffraction field is developed under, in this case what happen one as to apply we apply the diffraction theory. And in the diffraction theory what we do, total potential pie we call it has a incident pie i plus a pie s that is this incident potential, is a scattered potential plus pie r is called the radiated potential. And this is as for very few problems, we can get a close point solution, and otherwise we always go for numerical methods to obtain the solution of this.

Once we know the diffracted potential, the total potential numerical methods we apply and once we get the total potential, then we always calculate the pressure by from bornoulis equation. And once we get the pressure from bornoulis equation, bornoulis equation and once we get the pressure then you calculate the force, in a usual way by integrating, again we can easily also the calculate the moment because, once we know the pressure we calculate the force and the moment on the structure (( )).

But, I will not go to details on this diffraction theory and (( )) theory, but I will just give in brief what happen to the Morison equation and just because, it is imperical formula I will just briefly mention the Morison equation, the diffraction theory. And the Froude krylov theory it can be taken up in some other course because, of the limitation of this because, this is a introductory course. So, I need not go to the details of this theory details there are other courses where it will be taken up.

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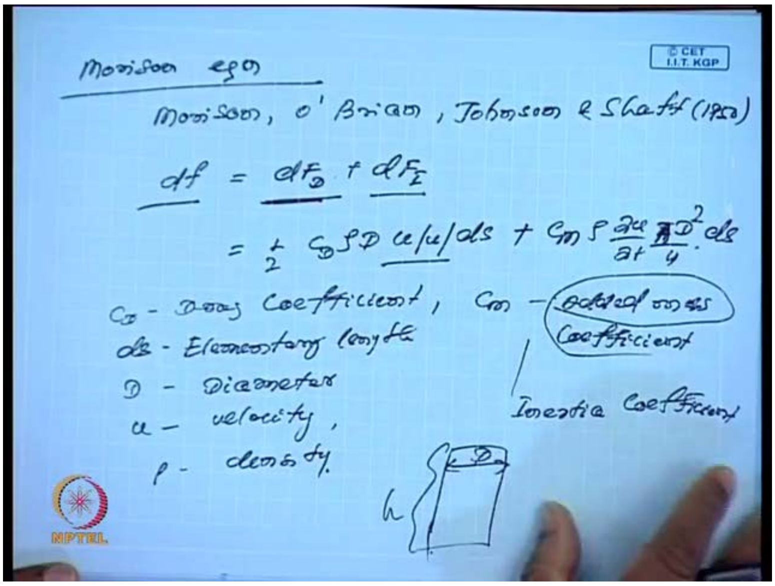

Now, if I go to the Morison equation and this Morison equation, it was developed by Morison, brian o brian, Johnson and shaff. In fact, it is developed in 1950 and to evaluate the presential wave forces acting on a cylinder vertical pile with basically and which is extended from the bottom, till the free surface, still water level on the free surface and as I mentioned that here the total force, if as look at d f is elemental force it has two components one is d F D plus d F I.

So, this is the elementary drag force and this is the elementary total force, this is the elementary drag force, this is the elementary inertia force and this is again given by the formula 1 by 2 c D row D, D is the diameter, row is the density of a fluid and it is u into mode of you d s plus c m into row del u del t 2 pie D square by 4 into d s, this is the formula. In fact, this is an imperical formula and what happens c D in the drag coefficient c d the drag coefficient, c m is the d s is the elementary length of the structure, elementary length (( )) elementary length of a cylinder I have basically this way applied to cylinders.

And then we have D the diameter of the cylinder, basically this is we told for pile type of structures because, d by lambda is less than 0.2, and u is the velocity, what are else rho is the density and d m is a c m is a added mass coefficient, mass coefficient a is the area of this is pie, pie D square by 4 it is can be called as area. Now, here we have a term modulus because, that will always because, the drag force and the directional wave propagation at direction the u is such that absolute value of u is taken and because, it is such that it is always in the direction of the propagation of the wave.

That is why u is taken positive because, the drag force will this whatever u will be this will be always in the positive direction it has to be taken. So, this, this is basically the Morison equation and say me the c m is sometimes called the inertia coefficient, call this inertia coefficient. Now, if I know the elementary force d f than what happen, if I have a cylinder if I have a cylinder I am pile type of structure, whose radius is D and its length is h then what happen now, what we do?

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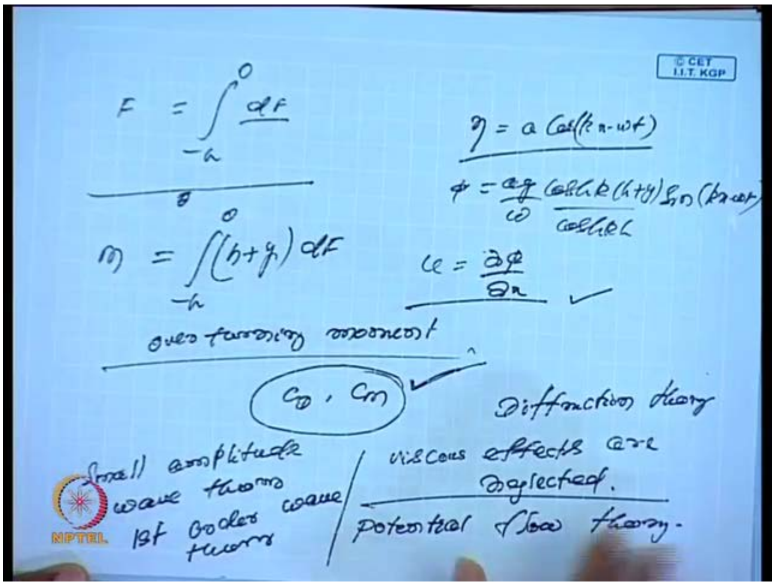

We calculate this total force f just by integrating over minus g to 0 d f and that will give us basically integrate over minus. And here, we have seen that only u and u is know because, for every eta, if I take is equal to a cos k x minus omega t and this is integrated over the depth, the elementary force because, d f is over the length, small elementary length and minus s 2 0 it is integrated.

And here, if I say that eta is a cos k x this is one of the wave elementary basically one of the progress one, than what is the corresponding pie always we know that this will be a g by omega cos hyperbolic k into h plus y by cross hyperbolic k h into sin k x minus omega t. And once we have this pie than we get u that to del pie by del x that is give us radiantial force, once we have u that is acting on a cylinder, once we have u you substitute it in the Morison equation, the elementary force d f, expression and integrate it and we get the force.

In a similar manner, we can get the moment again by using the definition minus h to 0 h plus y h is the length h plus y into d f and that gives the over turning moment that gives the over turning moment. In fact, a large number of a in large number of offshore offshore structures, as I say that the piles, piles have several piles are used. So, to calculate loads in a piles and to calculate the moment on the structures, (( )) moments on the structure, this Morison equation is used to since 1950.

And there are a several other like a one of the most a important result in the what we have make next particularly for the calculation of wave load on offshore structures and it is used to this equation, Morison equation is applied to a large class of problem for calculating the wave load on structures, even if moving ropes and when moving ropes and any structure which is always. So, we consider this as a thin structure.

Then wave load calculation and where, the structure is thin and where both inertia and viscous effects are very important and always we apply this Morison equation to calculate the wave load on the structure and it all depends because, once we have the imperical formula, we have to we have imperical formula which depends on two factors c D and c m. So, depending on the nature of the structure, this c D and c m are calculated sometimes competence value, sometimes by module tester physical module testing this c D and c m are calculated.

And once c D and c m are known, which is always as same that there it can be formed various law, good standard law good it has been mentioned for several structures and some other cases, it is obtained various model testing, from physical ambient and once this is known then, c D, c m once this is known than f and m are formed and that helps in calculating the wave load on the structure.

Particularly in the case of Morison equation, on the other hand in case of diffraction theory, particularly when the structures because, gravity platform when the structures becomes very large, we all depends on this diffraction theory, because here inertia force here, viscousing effect are neglected are neglected, particularly when we think about the diffraction theory.

The viscous effect is neglected are neglected and we all, we apply the potential flow theory, we apply the potential theory and in the diffraction theory, there are there are the small amplitude wave theory is the first order wave theory, but we have discussed in this course in the last several lectures, simple amplitudes we analysis basically in this small amplitude theory and which does not call the first order wave theory of strokes, first order wave theory.

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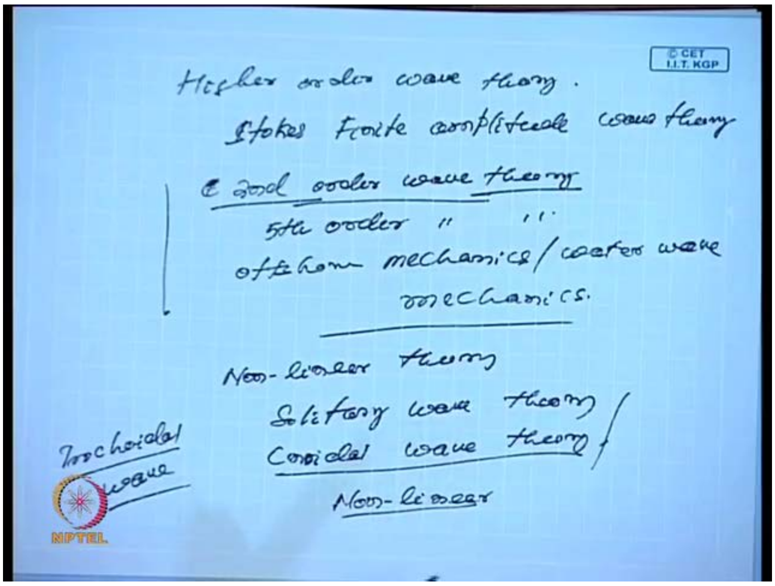

On the other hand there are higher order wave theories higher order wave theory and particularly for wave load calculation on flat structures and this higher order wave theory there, this is basically confirm the strokes in finite amplitude wave theory strokes in finite amplitude wave theory because, as a I have told, in the past lectures I have told that what we are considering, we are considering a wave theory and that is what the first first order wave theory of strokes are eligible theory, but the higher order theories are obtained just by (( )) free surface condition on the other boundary condition.

And then the in fact, in (( )) particularly for calculating wave structure, wave load structures often when you go to fifth order, second order is large in the last ten to two to three decades (( )) was given on the second order wave theory, for wave load calculation on structures, second order wave theory has been taken into account in the diffraction theory, for wave load calculation and even if the other cases, where people have gone up to (( )) arranging the sub column one up to fifth order, wave theory.

Some of the details can be formed this wave theory details can be formed in books and by offshore mechanics books are wave shore mechanics books mechanics or water wave mechanics, this details I did not go here because, this course is a an elementary course basically, I had try to give a brief over view about various waves, various things about basic sub waves and then basic of wave load calculation and the detail can be found in this, apart from the linear theory there are several non-linear theory.

Because, unlike solitary wave theory solitary wave theory, conidial wave theory, then I have solitary wave conidial wave and strokes finite amplitude wave theory, strokes finite amplitude wave theory, there we always go one by one and this solitary wave theory conidial wave these are all basically non-linear waves and even if there is a another wave which is called trochoidal wave in fact, but for a large class of problem this theories that are lot of results, but very few problems which are handle of now, based on this theory when it comes to problems of practical nature.

But, major analysis (( )) application most of the time we always depend on the potential flow theory and basically and the viscous effect in potential wave theory, basically particularly the diffraction theory the viscous effects are almost negligible there are neglected, where the structural size is always same to large, but this solitary wave theory or conidial wave theory, trochoidal wave theory, these are special types of waves and sometimes only the effects, not much several large number of (( )) are involved in developing solving trying to solve this class of problems.

But, because, of the non-linearity is very it has been difficult to handle the problem, the original problem. So, face to face problems are being analyzed and several problems are attack for solution as, I defined is required based on module test or physical arguments and by generalizing, by simplifying the theory to as per the need of the requirement, as per the need rather I will say.

So, this couple of lectures around I think, I have covered around 12 lectures and we make a list in this course and further details can be found in other courses, for traveling rather my emphasis her was to, teach the as the application of the basic potential flow theory, basic potential flow problems I tried to simulate, I tried to discuss the wave mechanics and, so that how one can get the wave energy, how I will go to calculate the surface elevation, wave load on the structure and how the energy effect that is one of the major thing how the energy is related.

In fact, here we have two things as a main sun that a our emphasis, apart from the waves because, we have a fluid which is flowing and we have a wave which is propagating. So, here our major emphasis in the is the wave energy propagation, rather then and then there are two things which as we have seen that, the particular motion.

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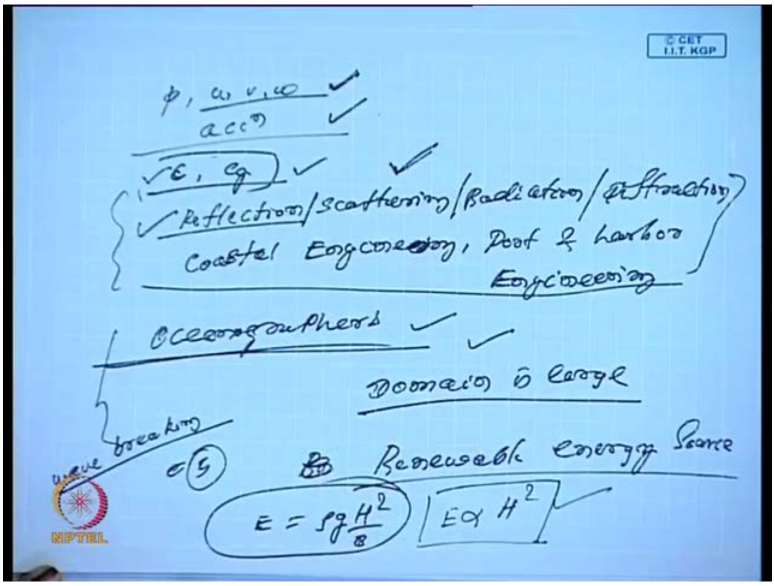

That is always related with the, the phi u, v, w this may be the components and then acceleration, on the other hand we have the face velocity c here, we do velocity c g this talks about the energy propagation and this things talks about the vertical motion, (( )) velocity this is very interesting that particularly, there are two things here, there are two types of energy, one is the speed one is the speed of the partial, one is the speed at which the wave energy propagates and speed at which the individual waves propagates.

Than we have seen how the phenomena of what we studied in physics, here is phenomena of reflection, scattering, transmittance, radiation all this things, is arising in this class of problems, diffraction more on this diffraction theory this radiation problems this will be found in books on various applications of this problems are there, in costal engineering application, costal engineering, optional engineering and port and harbor engineering.

So, here the emphasis is more. In fact, if you look at oceanographers, then may not be interested in waves of this wave, this type of, but when they because, they are way of looking at problems, is look at the whole the domain is large here, our domain for oceanographers the domain is large. So, in that do wave modeling, the consider the wave model from different perspective by assuming whole Indian ocean or the bay of Bengal as a single domain.

And the grid size is different, but for costal engineering are port and have original application, the grid size is see always concentrate yours the total area is very locally it is couple of kilometers or square kilometers area, but here they always there for them, may be (( )) refers may be the one grid itself is 5 to 10 kilometers, but in the other hand costal engineer or for any engineering activity, you always restricted to particular location, but here, they look at the whole ocean as a whole as a one domain.

So, because of that the analysis point of view because, of we are potential flow theories good enough to analyze the flow problems here, from most of the activities developed under activities related to engineering; however, many times the information study on oceanographic data that is required because, what exactly happen at various part of the ocean, how the wave nature changes, how the topographic effect the things, these information are collected from the soil and how the ocean circulation modeling, all these information is sometime required for any kind of activity.

And the proportional activity takes place, after getting the data from oceanographer and analyzing totally by a ocean engineer or a professional engineer who does lot of analyses and computers in this class of problems by doing physical modeling or numerical modeling. And then coming out with fruitful solution to for the designer, to design various structures or various developmental for which are used for various developmental activity.

And this few lectures are. In fact, it is a very deeply discussed about the basics of waves and however, more about waves one can find with the today there are several books and wave mechanics, water mechanics, and various aspect of costal engineering port. And harbor engineering are ocean engineering are date with in a different manner, so depending on the requirement (( )) earliest shows the problems and analyze this. And another aspect of today concern is the energy extraction from ocean waves, another way energy extraction renewable energy, renewable energy, and we also that ocean is a…And we have seen that incase of wave E is rho g H square by eight. And this gives us energy propositional to E values us H square. But one of the difficult problem is how to extract the waves, and made up of whether (( )) become progress, he has not it, a not it arrive to this significant progress does not done in this aspect. And it comes to extraction of the wave energy basically from tidal waves. And another aspect I think have particularly understanding are not clear and the breaking wave breaking.

And we have seen that like as a wave techniques. Wave techniques is a phenomena, this happens more on the here (( )) particularly in the coastal area, because cut, larger waves of in as I mentioned that larger waves of reduced it is smaller waves by breaking them. And what happens how to mechanisms of breaking take place. It is still a lot more the theoretical progress, this is not much, whereas model testing did not doing.

But, theoretically not possible, this end done on this aspect. And another few things in, so this is all goes beyond the (( )) of this course, I am not going to the details about this vibration or energy extraction, energy or various application of fluid mechanics basically in the area of coastal engineering, host and urban engineering to calculations. Particularly if you are interested in the state, particularly knowing how much (( )), it is required in the design process. And these are the details which is goes to the application side and the other hand for a subject theoretical subject like for a physics and mathematician, it is more challenging, because many thing (( )) potential floor because of the non-linearity of the program, lot of mathematical challenges are there in this study of fluid mechanics particularly marine hydrodynamics. The parts of marine hydrodynamics and on the other hand, today I will conclude this part of this lecture (( )) and then in a next couple of lectures will just introduce give about the viscous flow.

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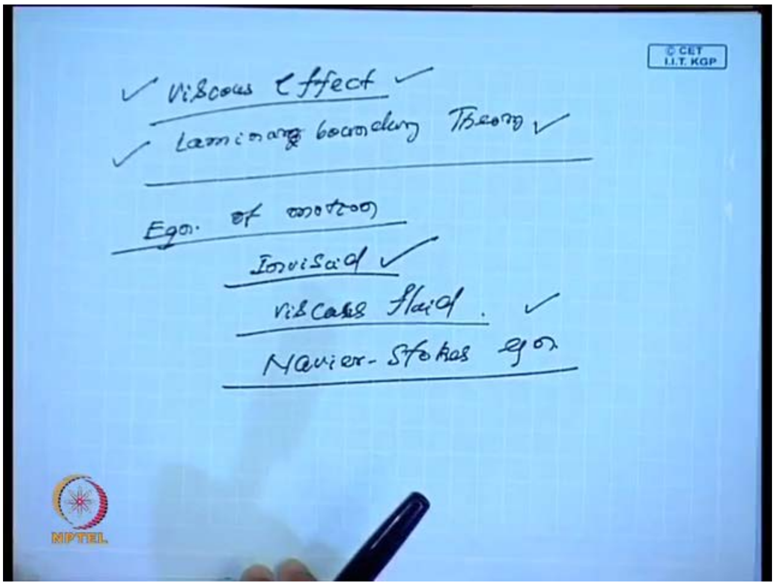

Viscous effect and brief about these things will talking about, this course (( )) application on fluid mechanics, and just glance will go to the boundary layer theory - laminar boundary layer theory. And we talk about viscous effect, basically we have talked equation of motion when we have talked about equation of motion, we have assumed that of ...

We have assume that viscosity intermediate some have neglected. And in the process we have assume that washing machine. A lot of challenges problems isolated, as we have seen lot of challenging mathematical (( )) are there, and isolated machine print. And we will still a briefly discuss let we discuss the contrast of this is series of lecture. Of course, fluid mechanics in general viscosity, they are different other courses. But here I am just give a brief introduction to (( )), and some of the brief characteristic, and simple problem basic understanding of the Navier stoke equation. Basically we concentrate on Navier stoke equation. I will just briefly mention the detail mention of the Navier stoke equation. And then I will worked out same problems after completing as it is lecture on this. Then we conclude this series of lecture is today that details will discuss later, and today will stop here.

Thank you.