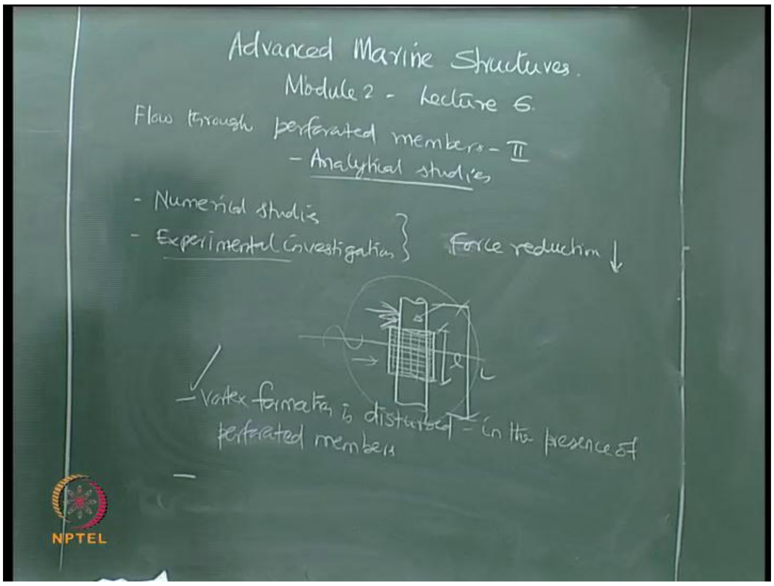
Advance Marine structures
Prof. Dr. SrinivasanChandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Lecture - 6
Flow through perforated
members-numerical studies – II

(Refer Slide Time: 00:16)



So, we have been discussing about the flow induced vibration in the last lecture. So, we discussed about the numerical studies, and experimental investigations carried out on cylinders and application of this problem on tlp's, where we said that where has been phenomenal force reduction in the members when a cylinder which is solid is covered by a perforated layer or a perforated outer cover which as perforations or along the periphery when this covers in a cylinder is expected that under the action of waves, the forces on the inner cylinder is reduce tremendously. So, one can easily look at perforations are perforated covers as an effective method of reducing forces are retrofitting or rehabilitating, the existing structural members ,which are already weak because of many reasons like material deteriorations, stress concentration factors, etc.

So, we have shown you how experimental investigations can be conducted in a scaled module of a tlp as well as group of cylinders of different perforate an outer covers, and we evaluated this results with that of the numerical studies from using software by names star ccm plus. But, we already told you yesterday that there are some difficulties of not able to trace the velocity potential variation along the depth of water, when you look at application of numerical studies in this case. Primarily, our interest is though it is force reduction, but we wanted to really understand and we have understood that whenever in outer cover which is poor us or perforated, the vortex formation is disturbed; the vortex formation is disturbed in the presence of perforated covers or perforated members.

So, this is one of the great advantages of application what we looking at which is recommended by researchers in the recent studies, that this can be one of the effective methods of reducing the vortex formation in a given member. In the present lecture, we will talk about how this problem can be handled using analytical formulation or mathematical modeling. For example, I want to write a program on my own or coding on the own to find out auto trace the velocity potential variation or water botanical kinematics essentially the velocity and acceleration variations along the depth, on the inner cylinder because the presents of outer cylinder. So, always we are focusing on what is happening to the inner cylinder when it is in compressed by an perforated cover, in the earlier example also we saw the same thing and in the present example also we will see the same thing.

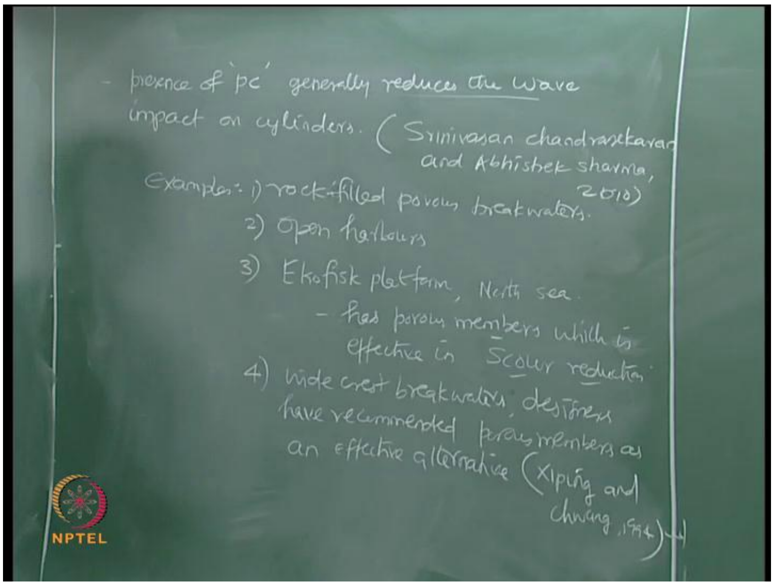
So, it is very simple to understand basically why this kind of disturbance happen, when a solid cylinder is encountering waves, it results in flow separation and that results in vortex formation. When you have a cover which is having pours or holes the fluid is made to flow through the holes, therefore vortex formation is disturbed is a very simple physical phenomena.

So, this is effective in two forms; one vortex formation is reduced and secondary vibrations cost by the fluid flow in the vicinity of the member or the structure is reduced significantly. The second advantage is when the member cannot take the intended load, because of it is material detraction age factor, stress concentration in the joints etc, can still provide strength in the member by providing an outer cover not over an entire link of the member, but on the regions where the stress concentration is maximum. It is expected that near that flash zone, you will always have the maximum forces accepted by the waves.

So, we can always try or attempt to put an preferred cover for a specific link which is going to be a function of the entire link of the member as parametric study, where I can move this position of the perforation above, below, etc, and see which is going to be the optimum location of the perforated cover which can reduce by forces on the member. Now, let us look at this example again revisit this case analytically, and see can he do a mathematical formation on this problem, and can I derive the velocity potentials for this problem mathematically, that is what you have got you look at today's study. Do you have any questions on the previous lectures, where we have been talking about flow through perforated cylinders?

So, we discussed experimental investigation, we also discussed numerical studies, we have understood that per porosity or perforated cover can be one of the effective method andmean to reduce vortex formation is a designer prospective. Now, we look in to a hydrodynamic prospective of this using a mathematical model.

(Refer Slide Time: 06:32)



It has been seen in the literature thatI am using pc for perforated covers,where need not have to write total you can easily understand this,presents of perforated covers generally reduces the waves impact on cylinder.There are studies reported on this, which can bemy poppa and Abishek Sharma2010.You can add many example of this application in reality,if u have attempted this idea in reality.For example,There are rock filled porous break waters of a very large dimensions where the break waters remains porous, and it has been estimated and seen that there is tremendous reduction in the wave impact on this break waters.

The second example can be, construction of what we understand as open harbors.These are very famous application examples where one can look at the presence of perforated cover or a poor structure as a mechanical mean ofreducing wave impact on members.We have another classical example of a gravity based structure which is an ecofisk platform,it is gravity platform constructed in North Sea.This gravity platform has porous members, which has been essentially used the movement.I say members they are structural members,porous memberswhich is effectivein cover reduction, because you understand in gravity based structure, because of the mask this cover on the see bed is a major problem.

So, that is essentially cost, because of the impact by the waves and current on the structure, and the providing porous members this effect was reduced significantly and people have shown that there has been reduction in the cover.For wide crest brake waters, designer have recommendedporous membersas an effective alternative,this can be seen in studies conducted by xiping and chuang 1994.

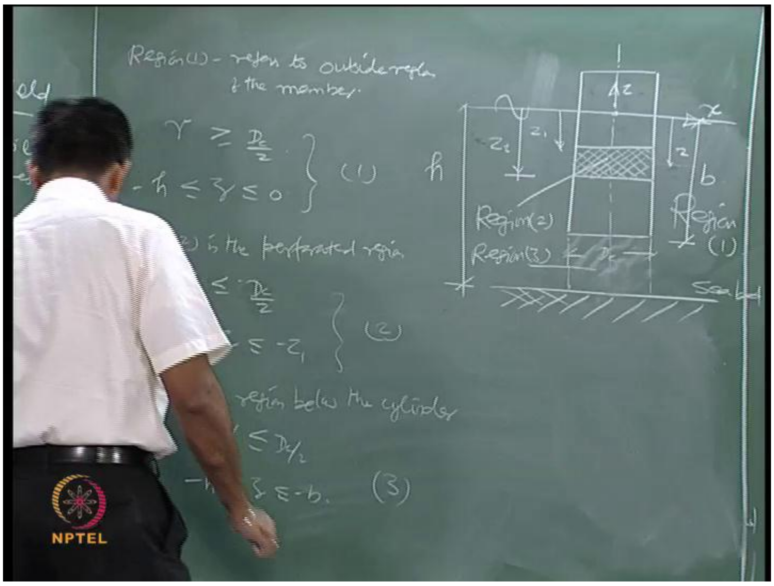
So, there are many references available in the literature where people you have used effectively the presents of porous members are perforated cylinder or structures to reduce the wave impact on the members.But,they have been essentially applied on coaster structures; the coaster structure also part of marine structures not on any deep water large floating systems,that is not been applied, but people have used it for brake waters, coaster protection structure people have applied, and they have seen that and there has been reduced impact.

(Refer Slide Time: 12:04)

Now, let us talk about the presentsof floating structuresin the flow field,because this was any who attempt which is not available in the literature,very (( )) mention about this applications available in this literature will discuss in this detail, because about the fix at platform like gravity based structures, people have conducted studies and you can fine lot of references on this and for brake waters people have conducted studies, and you will find lot of experimental as well as analytical studies available on this.From floating structures, this has been very scars, so let us look at that and revisit this area, the movement the floating structures or interfering with the flow field.

It causesalteration in the wave fieldby diffractionand radiationof wavesfrom the structure.Now, interestinglythis problem of equation formulation will have two solutions; one is the solution of the diffraction problemyields tothe excitation forceson the structure,where hassolution of radiation potentialresults in motion caused by the structurewhich produces acceleration, and velocity proportional forces.So, this problem has to two kinds of solution;one is the diffraction potential solution, other is radiation potential solution.One yields me the excitation force, other yields me the acceleration in velocity proportional forces.Now, in these two components the acceleration proportionalnon dimensional amplitude gives added massvalues, and velocity proportionalnon-dimensional amplitude gives radiation damping.

(Refer Slide Time: 17:08)

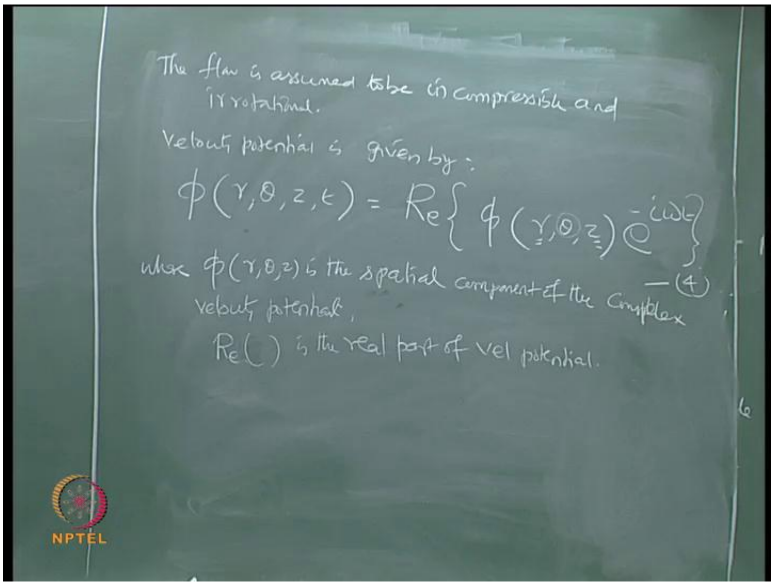


Now, let us take a system,this is my sea bed, this my cylinder, this is my perforated region,this my mean sea leveland startz from here, and of course x is in the forward direction of the wave propagation.I call this distance water tape as h,I call the diameter of the member as D suffix e and I call this asz 1, and this says z 2, and any value hereas a variable z.I divide this formathematical modeling into three regions; there are three (( )) I say region one,I say this is region two,and I say this is region three.

Let us explain these regions. Region onerefers to the outside region of the member,so in this case r radius is greater than D c by 2, D c is the diameter of the member of the cylinders, c stands for the cylinder and z varying between minus h is an 0,is it not minus h to 0, this is the region I call this equation number 1.Region two is my perforated region, where ris less than equal to D c by 2and z variesbetween minus z 2 to minus z 1, is it ok,this equation number two.Region three is aregionbelow this cylinder that is this region where in this region alsor is less than D c by 2,r is a radius.Letscall this value as b, depth of emotional the cylinder.

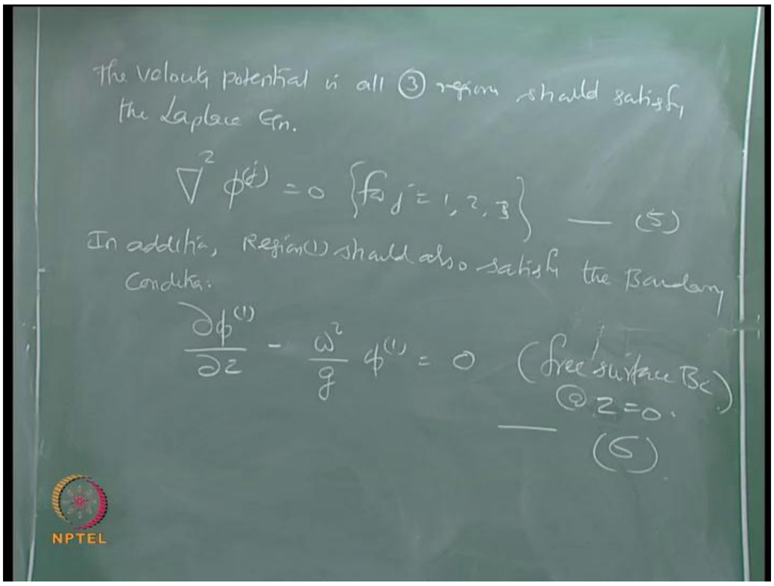
So, z variesbetween minus h to minus b is that ok,equation number three.So, we have divided this into three regions,and I am now I am going to derive the diffraction potential on the radiation potential in all this three regions independently.

(Refer Slide Time: 21:58)



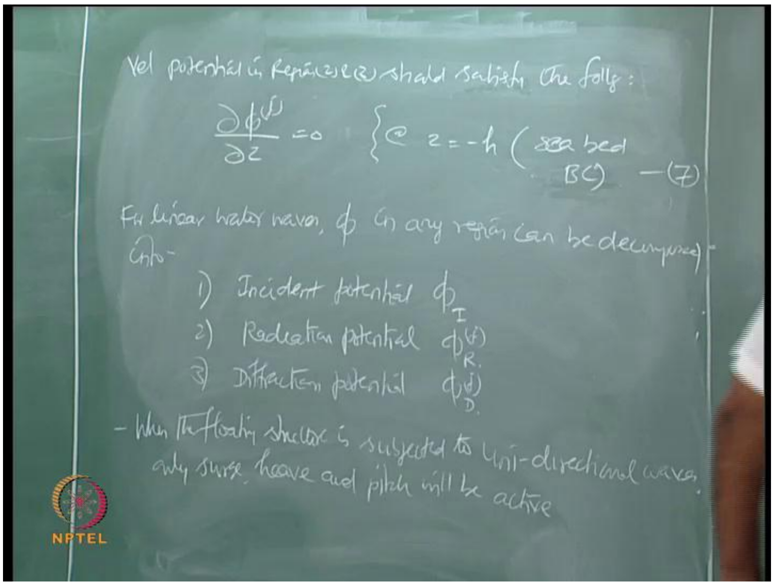
Now for this analysis,the flow is assumed to be in compressible and irrotational.Therefore, the velocity potentialis given bycall this equation number 4, wherephi, r, theta, zis the spatial component,you can see here r is a radius, z is a position along the depth of water, and theta is the displacement deductionand face black is a special componentof the complex velocity potential, because it is i omega tand R e of the argument is the real part of thevelocity potential.

(Refer Slide Time: 25:00)



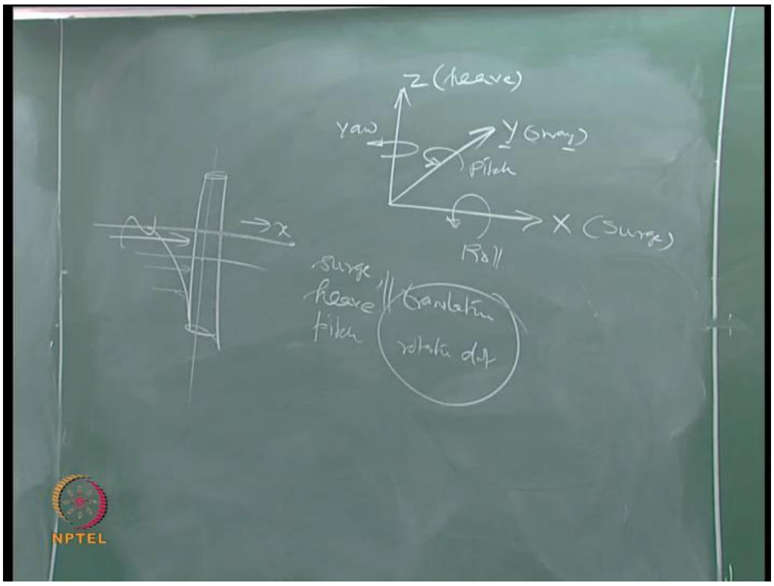
Now, the velocity potentialin all the three regionsshould satisfythe Laplace equation.Call this as equation number 5.We will do one thing,we will usethis different notation we will say del square i g.In addition,region oneshould also satisfythe boundary condition,region is the outer region,this is a free surface boundary condition. Therefore, I should say this should be satisfied and at z equals0, z is measured from the m s l,call this equation number 6.

(Refer Slide Time: 27:40)



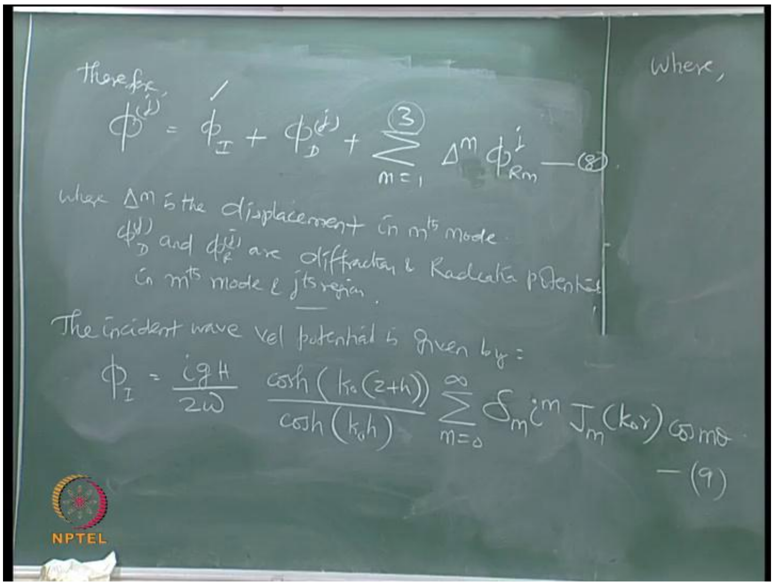
Now, velocity potentialin regions 2, 1, 3should satisfy also the following condition that is sea bed boundary condition,because z is minus h.I will call equation number 7,so for linear water wavesphi, in any regioncan be decomposed intoone - the incident potentialwhich i call as phi capital I,there radiation potential which I call as phi R, and the diffraction potential which I call as pi D.The radiation and depression potential will be validfor a count of J,I will explain this; there are three regions – 1, 2and 3.Now, interestinglywhen the floating structureis subjected to unidirectional wavesonly surge heave and pitchwill be active.

(Refer Slide Time: 30:54)



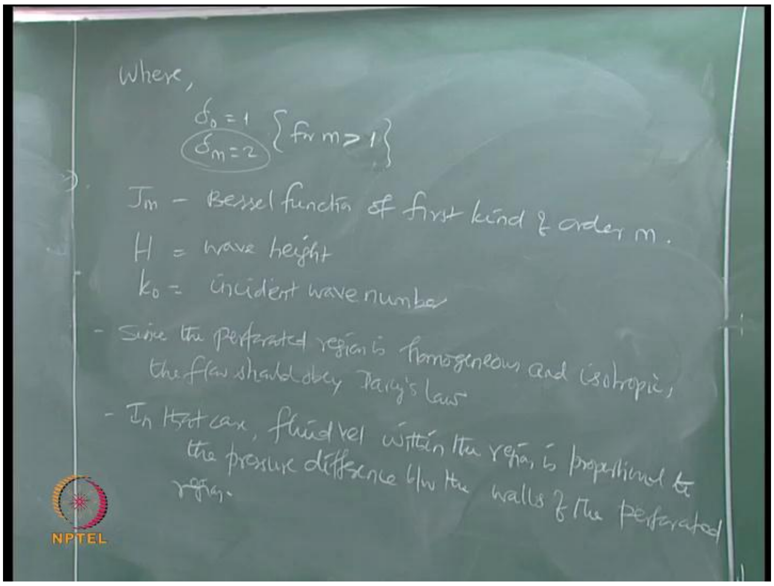
We all know that, and put you if comes towards this this four fingers will give me the direction of rotation, this wayyeah.Now,I have a cylinderacted upon some force velocity variation, so the force just becomes x direction, so I will have surge and we all known a floating system the setdown or the heavein the surge motion of strongly coupled setdown offset or coupled.Therefore, I will have heave andthe differential forces at the any point will cause a movement and that movement will be a about normal to this axis nothing but pitch.So,we will havetwo translationaland one rotationaldegree of freedomactive, when the wave in unidirectional.So, only three modes will be active, surge heavea pitch; though it is got six degrees of freedom, but we will active only three, that is what I am writing here only surge heave and pitch will be active.

(Refer Slide Time: 32:57)



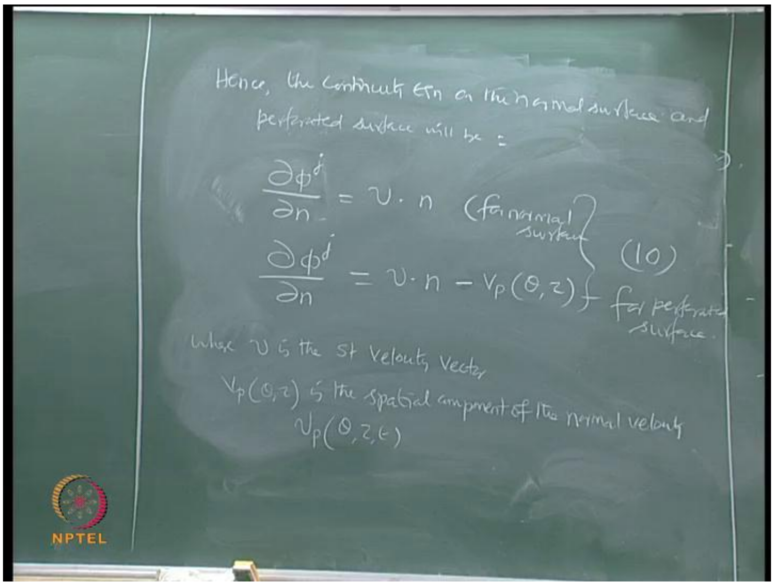
Therefore,phi can be expressed asincidental plus diffraction, sum ofso you can see here the summation done only for three modes.What is the equation number here?Where del mis a displacementin mth mode,phi D and phi Rarediffractionand radiationpotentialsin mth mode, and jthregion;j stands for the region.How many regions do we have in this problem?.Three-region one is the outer periphery, region two is a porous periphery or the pours region, and regionthree is a region below region two, where defined the boundary condition for this regions,in equation 2, 3, and 4.Now, theincident wave velocity potentialis given byphi I, which isigh by 2omega equation nine.

(Refer Slide Time: 37:30)



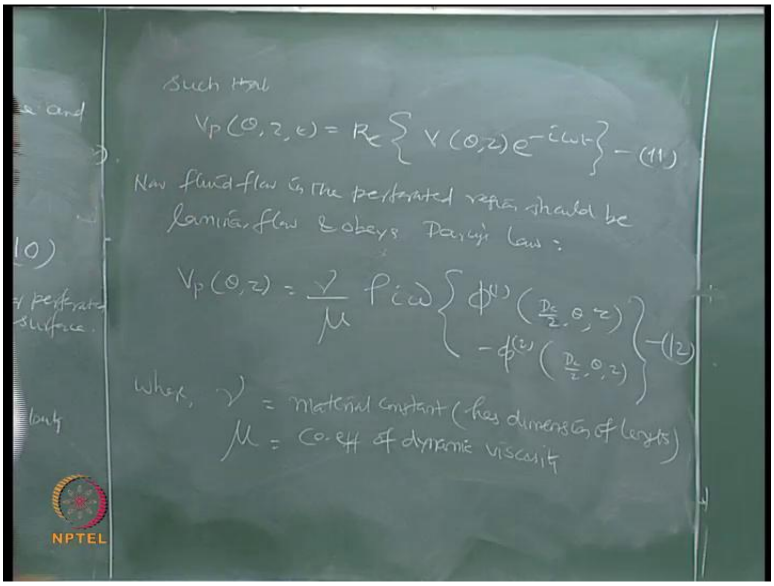
Where let me check this equation first. This is i, this is ii m, J m del 0 is equal to 1, and del m is equal to 2for mequal to 1greater than for any value m greater then1can say these values 2, when it is 0when it is taken as unity in this expression.J m is a bessel function of first kind of order m.H is the wave height of course,and k naught is the incident wave number.Know he now example since the perforated region is homogeneous.Let say an isotropic the flow should obey Darcy’s law.In that case, fluid velocity within the regionis proportional to the pressure differencebetween the walls of the perforatedregion.

(Refer Slide Time: 41:40)



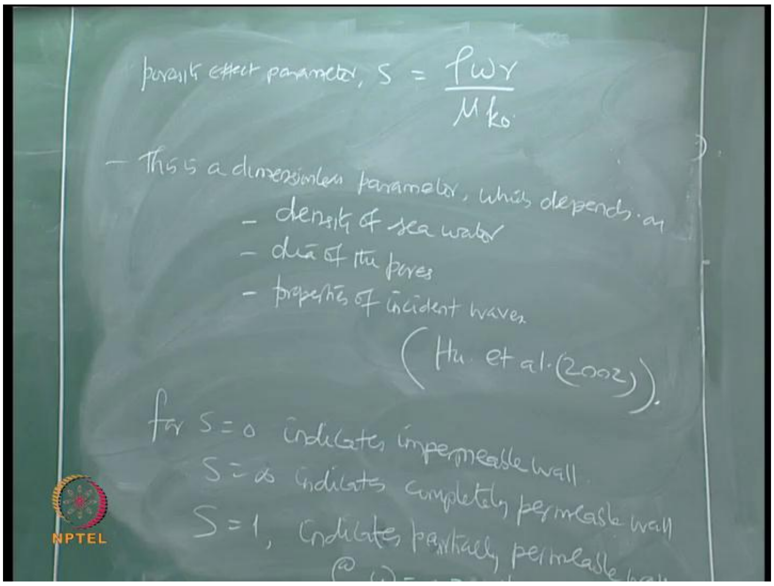
Hence,the continuity equation on the normal surface;normal surface means non perforated and the perforated region will be given by…Let me call this equation number 10, is it.So, this is fornormal surface and this equation for perforated surface, where vis the structural velocity vector, and vp of theta, z; is a specialcomponent of the normal velocity, the normal velocity is vp of theta z of twhich is valid applicable to the perforated region only.

(Refer Slide Time: 44:49)



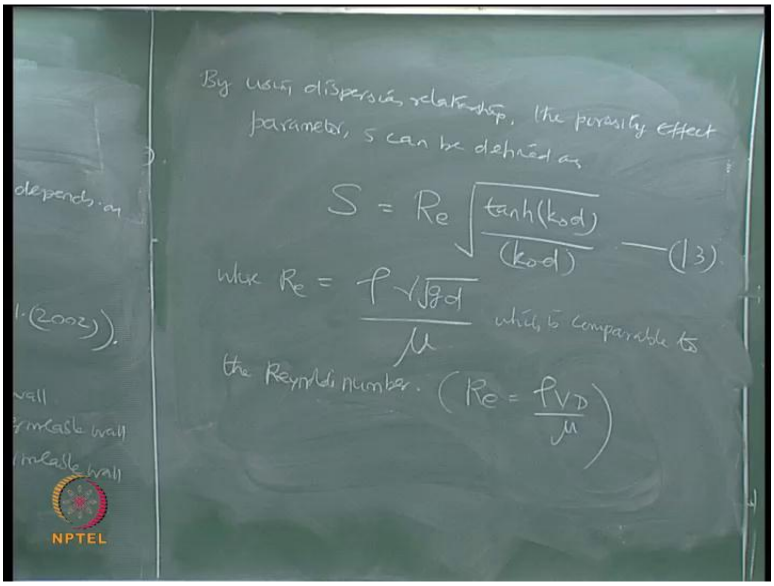
Such thatthere is the condition which is satisfy vp of theta z of t is real component of v thetaof z e minus i omega, call this equation number 11.Now, the fluid flow in the perforatedregionshould be a laminar flow, and obeysDarcy'slaw.In that case ,vptheta z is given by nu by murhoi omegaiphi one of D c by 2D c by 2theta z minus phi 2 of D c by 2 theta z.Let me check this equation,I call this equation number12,where nu is a material constant,which hasdimension of link in case of units,mu is the coefficient ofdynamic viscosity.

(Refer Slide Time: 48:01)



Let us now define in parameter call porosity effect parameter,which is define by S which is given byrho omega r by mu k naught, this is the dimension less parameter which depends ondensity of sea waterdiameter of the force, and properties ofincident waves.This parameter was first suggested and dependency of this factors,where establishedby huetal in 2002,then the porosity effect parameter Sfor S become 0, indicatesimpermeable walland S equals infinityindicates completely permeable wall,that is wall does not exist.In the present study, we have assumed Sis equal to unity, which indicatespartially permissible wallat a specific frequency of0.3 radiance per second.Now, one can compare thisporosity effect parameter with the well-known established relationship Reynolds number by using dispersion relation.

(Refer Slide Time: 51:24)

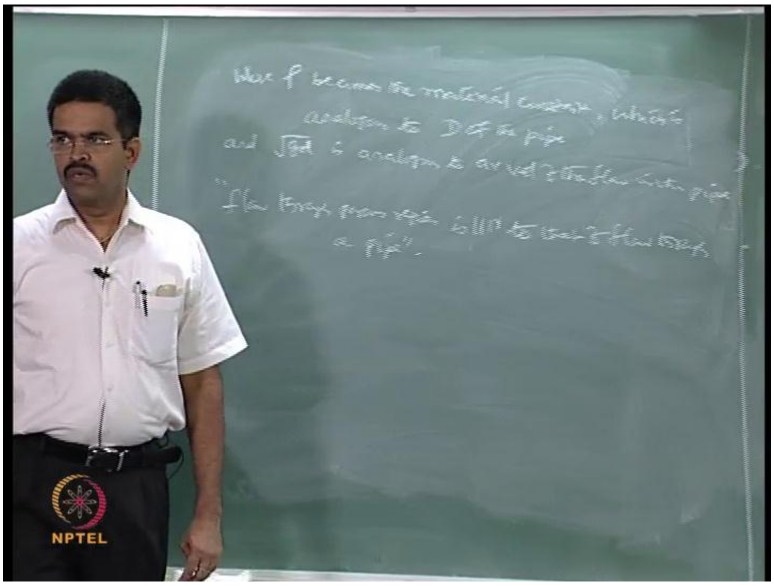


Now by using dispersion relation,the porosity effect parameter s can be defined as, call this equation number, what the equation number?

Student:13.

WhereR e, this R e is equal to rho mu gd by mu, which iscomparable to the Reynolds number,because Reynolds numberis rhoV D by mu.

(Refer Slide Time: 53:50)



Where rho becomes a material constant, which isanalogous toD of the pipeand root gdis analogous to average velocity of flowin the pipe, so what does it mean is, ones we can established the porosity effect parameter as similar to that of Reynolds number which indicates that the fluid flow is similar to that of pipe.So,I can say now the flowthrough porousregion is similar tothat of flowthrough a pipe,so we stop here we continue this lecture in the next one, where you will continue to derive the other velocity potential components.And then, you will apply this on a floating platform mc.how I can compute the influence of these parameters on the force reduction in a floating system, which is having porous members?

Thank you.