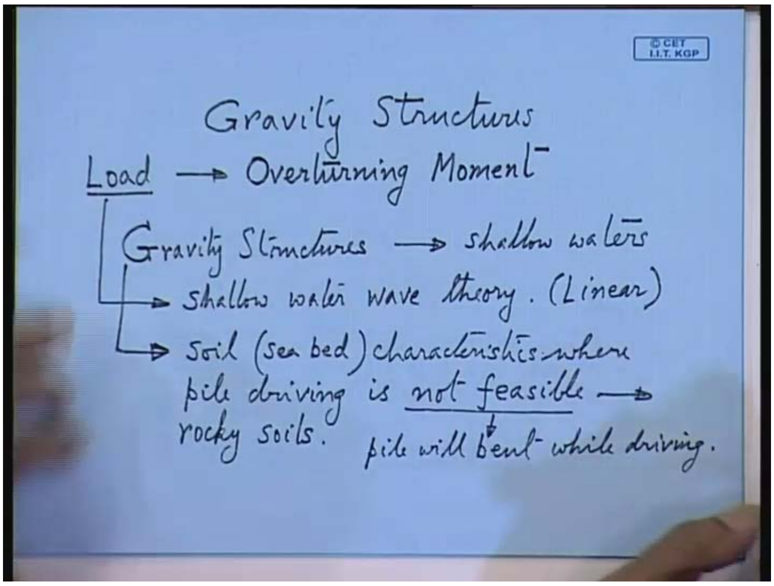
Elements of Ocean Engineering
Prof. Ashoke Bhar
Department of Ocean Engineering and Naval Architecture
Indian Institute of Technology, Kharagpur

Lecture - 20
Offshore Structures – II

(Refer Slide Time: 01:00)



So, next part of the lecture will be on gravity structures, now the basic thing that we have done in your structure, and this is why you are going for these two types of structures. So, the first structure that I have described you, that is basically your pile foundation, so this was what we were resisting, that was the overturning moment, so stability against overturning is a prime ((Refer Time: 01:38)) for the stability of the structure.

So, in any case in offshore foundation you have to resist the overturning moment, so this is very crucial, now how you resist that, that is no problem, is it not? So that you have to decide, so that decides on the tight of structure, that is tight of fixed structures, that you that is normally design, so basic load that is coming is what is your load is your overturning moment, and the structure actually normally resist this load.

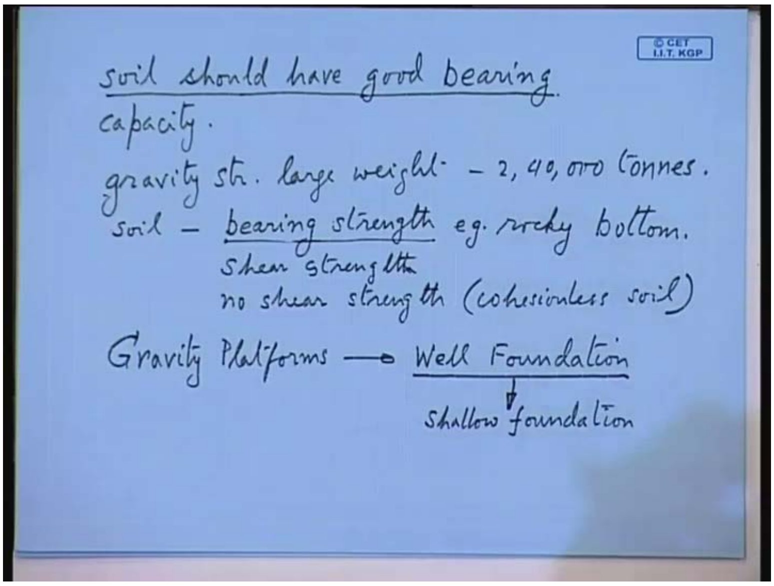
So, this is the external load that is coming on to be structure, now jackets the pile actually is resisting the moment, and that is why I have told you in the jacket the pile there is a tendency to bend. The pile there is a horizontal load coming right at the sea level, the pile will no more we straight like this, but it is starting bending of flexing, so that is why our problems that we should have laterally loaded piles. So, laterally loaded piles will have inherent capacity of resisting this is called pile flexure, so bending is the analysis, which we take records to when you were designing offshore piles.

Now, what about this gravity structures now this type of structures, again the same overturning moment is coming here, the one thing you should note that the gravity structures and the jackets. They are normally in shallow water see gravity structures, now here I am not tracking pile because I have written that, so these are all normally look at it in shallow water.

So, shallow water you first calculate the load now this load, you calculate from what from shallow water wave theory, so this is where your hydrodynamic is going to come. So, shallow water wave theory imply all those shallow water formulas normally in shallow water they imply what is the linear wave theory linear wave theory, you can use what for shallow water.

Now, this gravity structures are normally look it in shallow water, and here you find now why you go for gravity structures, gravity structures are more costlier than pile structures, but because of soil characteristics soil or sea bed characteristics. Now, what is that sea bed characteristics, soil sea bed characteristics where pile driving is not feasible, where in what region in rocky soils stator, your soil is made up of rocks. There the pile is going to not feasible means pile will bent while driving, so this is phenomenon that is going to occur, so here you cannot drive piles, but for gravity structure one thing you should note.

(Refer Slide Time: 07:31)



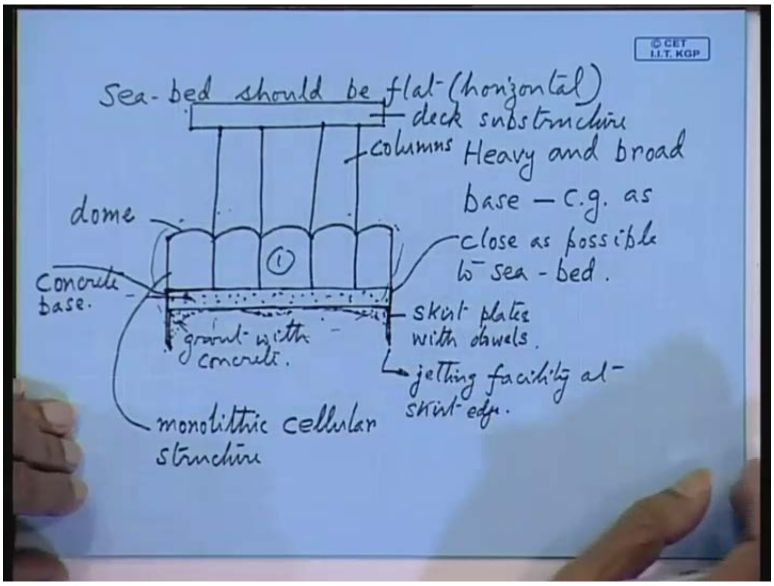
That the soil should have good bearing capacity, because your gravity structure is having large weight, see gravity structure weight will be of the order of gravity structure large weight see 2 lakh 40,000 tones, so this is a typical weight of gravity platforms. So, in order to resist this slow, such that your structure does not go down in to the soil, that is the soil should have the bearing capacity of the soil should be go.

Now, soil basically you will find, there is a bearing strength and there is a shear strength, soil actually is marked by two characteristics, one is called the bearing strength. This in soil mechanics you come across this is called a bearing strength, and the other is called a shear strength. These your two types of soil that will come across, bearing strength and shear strength, if there is no shear strength than that is called a no shear strength, I think this particular type of soil is called cohesion less soil, example is sand.

Sand is not cohesive, you cannot take it in your hand and just a lump of clay is a cohesive soil, there are two distinct categories of soil. So, any way what is talking about the gravity structures should be locating on soil, which has good bearing capacity, especially say if example is rocky bottom. Now, these type of structures normally come under the category of gravity platforms, they fall under this category of foundation, they are called well foundations.

So, in civil engineering they called this as a well foundation, the other one that have talk about is the pile foundation, so those are called deep foundations, so pile foundation is normally called a deep foundation. So, well foundation are normally come under the category of shallow foundations, another type of foundation that you come across is called a raft foundations, which of course, we are not discussing, because you are discussing gravity platforms. You corner under this category of well foundations, and here actually they have to be located on a particularly a rock status, which is good bearing strength.

(Refer Slide Time: 12:07)



Another characteristics is that sea bed should be flat, there is a horizontal, because you are locating so much of weight you cannot do this on an inclined flat and horizontal, good bearing capacity. So, that is what you have to do now these structures are normally I will give you the diagrams, they have large amount of weight located at the base of the platform, so your base is made particularly white and heavy. So, these type of platforms are characterized by heavy and broad base so; that means, c g you bring down, this c g as close as possible to sea bed, that is why these structure you will find the base to be of say 2 to 5 meters deep and this is grout to do with concrete.

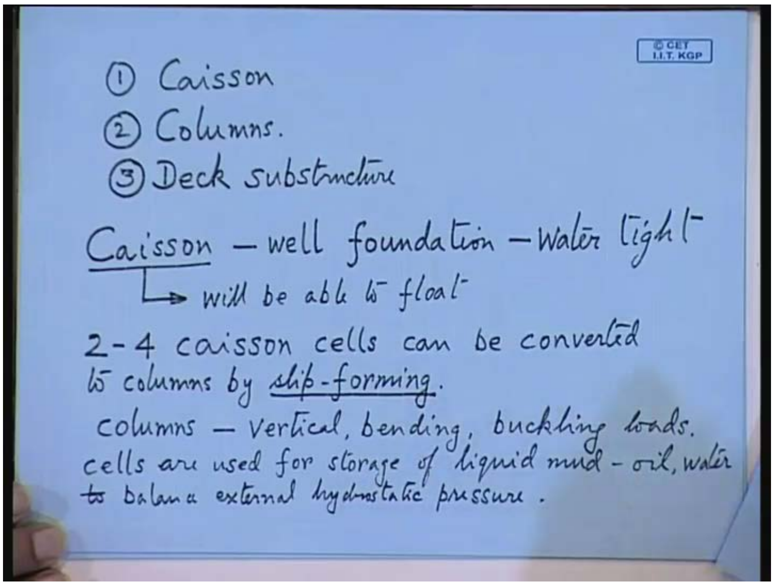
So, this is concrete base now on the periphery of this base, there is steam plates are attached, so you have large steel plates, so these are called skirt plates with dowels, so like your piles that I have drawn that having teeth. So, here you have also sharp pages these are called dowels, so these actually go below your soil, there are able to pears the rock. Now, here after the gravity structure is able to sit on the sea bed located on the sea bed, a portion of the structure goes below by means of it is weight below the sea bed, and this skirt plates actually.

They are instrumental in cutting the rocks and taking this structure down, now here you find lot of soil, but there will be gaps, so these part are wide spaces, and these parts you grout with concrete after you locate this structure. The reason is you have to distribute this load even the on the base, otherwise what is happened you get point loads coming from this valuation in the soil. They are likely to rupture your base, so you grout the whole dam this thing base with concrete especially feeling of rides.

Now, sometimes this is not possible feel to remove this soil by what is called a jetting facility at skirt edge, so these are normally done anyway. So, this is part of this structure the other part that is important is that you make your columns or this is cells, they call it cells, so this is actually a monolithic cellular structure, then this is call dome.

So, this is the first thing that is to be built in the ship yard, now next you start building your columns from the cells, and then you put your deck or this is called a deck sub structure the same as in your jacket platform. So, this is your columns, and this is called your deck sub structure sub structure means below the actual deck, this is how it is built.

(Refer Slide Time: 19:11)



So, there are three main parts of the structure is number 1 is this portion, this portion is called caisson, number 1 portion they called as caisson, the number 2 portion is called columns, the third one is your deck. So, the structure actually consist mainly of these three part, caisson, column and decks or you can write this a deck sub structure, the main structure consist of these 3 components.

So, this is one the other part is two, this is the third one and this one is 3, now after this what you do is this caisson is that is built this is called a well foundation, caisson is the well foundation. Now, this is made water tight, there are various types of well foundation you come across, you may have a open well foundation, but that is not used in gravity structures. So, these are the water tight categories; that means, caisson by itself will be able to float, this is why you are making a crudes caisson, so this is the well foundation water tight will be able to float.

Now, say 2 to 4 caissons depending on the size of the platform, 2 to 4 caissons cells or rather you write caissons cells can be converted to columns. So, this columns you can you are able to see this, that is these columns are nothing but the extension of the cells of the caisson. This is called you do not have the dome, just continue your construction all this done a float construction columns are not built in the ship yard, you have to do what is called a float construction, ship yard construction will just part of the base that is all.

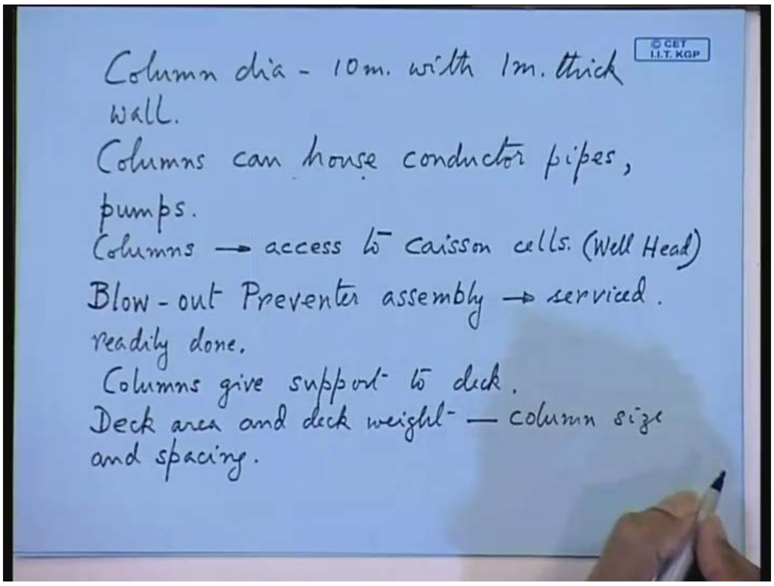
So, can we converted to columns and this by a process what is called slip forming, so columns are actually slip formed over the caisson cells, just keep on adding the walls of the column. So, this is done normally this takes place the point that is to be noted is this is your waves, so wave load is coming somewhere here, now here you can see that is your main wave load is actually taken up by the columns not by the caisson.

So, the bending load that is coming will be taken up by this columns, and not only this and down below you have hydrostatic pressure will be quite large, because of that row g h form which is quite large at the base of the caisson. So, here these factors at to be noted and columns at to take large amount of vertical loads, vertical bending and buckling loads, so these type loads are going comment columns.

Now, here actually the cells you can store oil cells normally used, now here what is what have to do is at the outside at down you got the sea bed level you have large amount of hydrostatic pressure coming on to the walls of the caisson. Now, unless you balance the hydrostatic pressure; that means, the sides of the column is going to Kevin, so you have to do lot of pressure balancing. Now, pressure balance only you can do either if this caisson with sand or you can fill this with mud or with oil, that is the oil that you are taking out from the there will be the conducted pipes, which are going.

This is called the well head will be going down on to the well down below, so cells normally are used for storage of liquid mud used in grieving. So, when I talk about grieving you come across this liquid mud, oil or even water, basically to balance external hydrostatic pressure. So, this type of platforms normally you will find in the north sea, but the whole point is the hydrostatic pressure balance, what do you going to do in the columns, if you want to resist then you have to make walls very thick.

(Refer Slide Time: 26:52)



So, column diameter can be as large as say 10 meter, with 1 meter thick wall, where is the wall thickness column wall thickness, now here coming back the columns you do not store oil. This not stood in columns, but this columns and when we used for columns can take conductor pipes, columns can house conductor pipes, that is why you do not store anything out here, this is one function of the column.

So, are you conductor pipes are actually protected from the sea, because they are led through this columns on to the top of the platforms, this one advantage you are getting who were the jacket platform, jacket platform the conductor pipes are expose. So, columns can house conductor pipes, then you can house pumps, so there are number of columns serving different purposes one columns can house your pipes and pumps, other columns can have access.

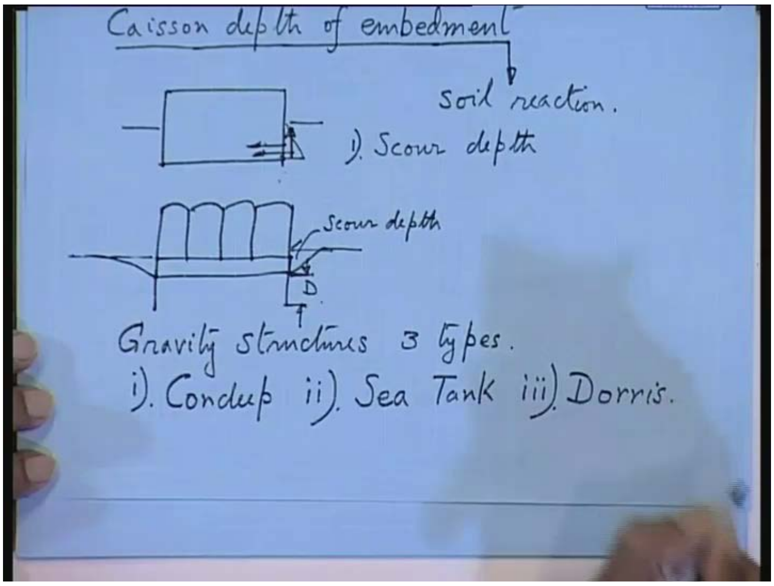
So, this serve as access to caisson cells, access has to be provided in this region; that means, persons should be able to go down from the deck of the column. So, this one advantage you are getting over the jacket structure, so person can literally go down right to the bottom of the structure through ladders, through these columns, so he is able to access what access your caisson cells or sometime this is called well head.

Now, those of you who are not interested you can go, you give your attendance and do not disturb me these all do not like, if you are not interested you give your attendance, you can quite, so access to caisson cells sometime this is called a well head. So, this is one part the other part is well head assembly can be your blow out preventer, now this blow out preventer assembly has to be serviced.

So, this blow out preventer assembly this has to be serviced, so this is readily done, so because this is the main advantage over your floating platform, the BOP stack you can locate on deck, but BOP stack also you can locate down below. Since, you can access BOP from this columns BOP access is critical, because for safe operation of the platform, so one it is serving for the conduct or a conduit for your pipes, your access and housing the pumps.

So, the other I think, these are the two columns other columns are basically for support, so columns actually basically provides supports to deck. And this deck area actually determines columns spacing, and this you have to decide deck area and deck weight, so these are the two governing factors you decide on column size and spacing caisson depth of embedment.

(Refer Slide Time: 32:52)



So, this is again what you have to calculate, what is going to be your depth of embedment of caisson, so this is calculated from the well foundation mechanics, so this is your say caissons and this is your sea bed. So, you find out how much is going to be your friction force that is coming from the soil, and soil will also give you a lateral pressure like this.

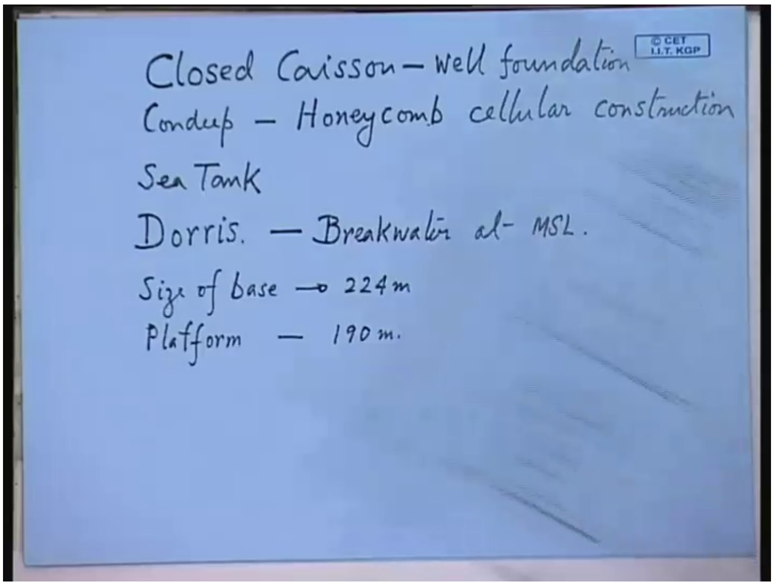
So, the larger the amount of embedment the larger will be the reaction from the soil, so caisson depth embedment you calculate from soil reaction. Now, this has to be done, otherwise there will be the whole structure is going to poplar and slide, the other part that you should remember is what is called scour depth. Now, in case of jacket platforms this is not a major cause of body, because your foundation is a pile foundation.

So, you have larger depth of penetration, but in this case of shallow foundations, scouring of the plat formed or scouring of the soil is very crucial for stability of the structure, so what happens is that the soil gets eroded there is erosion of the soil at the foundation. Now, this depth of course, if you calculate that is the depth of the embedment, this is always down below scour level, so that means, your structure has to go down below scour level.

So, this is this depth is called scour depth, so depth of embedment is always below scour depth, so this you have to find from the local soil erosion, how much is going to be your scouring. So, this is one particular thing that is to be remember now the other thing that is other part of the structure, which is normally important actually we will find there are three types of gravity platforms, you can see in the diagram. I will show you, gravity structures three types first one is called the con deep, then you have the sea tank, the last one is called Dorris, they are three types of the gravity structures Dorris design.

So, these the con deep and the sea tanker more or less the same value you can see from this the picture is bit hazy, this is your con deep variety, now here actually you will find number of circular cells. Now, all these cells are attached one with the other, so this is one cell and they are locked in by means of this kind of locking mechanism, all these cells are tight down, so this is actually called a honey comb construction.

(Refer Slide Time: 37:35)



So, this cellular construction or caisson is in the con deep category, con deep basically has honey comb cellular construction, now this type of construction actually. Where, it is more convenient you go for that, honey comb cellular construction; that means, here the individual cells can be formed in the ship yard and then they are linked. There also you can see in this structure the base, you can see the double line, so that is the base of the platform, and this the dome is given, so this is the cap of the dome on the caisson.

So, each individual cells are built and they are connected by means of a locking mechanism, so this is the essential of a con deep type of structure, now here the other variety is called the sea tank design. Now, in the sea tank you do not have this honey comb type of base, so the other type is called a sea tank, now sea tank is normally constructed as a rectangular or a square base. Now, in this diagram you can see the base is square. So, we have 3 4 5 cells 3 or 5 cells across 5 cells on the other side so; obviously, you have 5 5 25 cells.

Now, here this can be either square or rectangular as the case may be, but you can see the construction of the cells, the cells are not cylindrical; that means, only the outer portion is having the cylindrical curvature, but inside they are all built in one monolithic design. That means, they are not individual cells, these are the walls which are common to the next cell, so this is called a con deep or a this is a sea tank design and the dome instead of having a curve dome, you can see that it is given here some kind of a flattish nature.

So, this sort of structure is easier to built and the same columns you can slip from and take the deck on top, all the cells, normally we have to be closed, the top of the cells have to be closed, because they will give bouncy, I will tell you why it is done.

Student: No sir, is it necessary to get a dome, because sir there is there is square in shape and it will become secularly from.

No, that the top has to be closed, so this is the top of the cells you can see in this diagram, but this is not curve let your cell, so these have a some kind of a flattish top, but they essentially all the cells have to be closed because this whole thing is a caisson. And caisson is used primarily from the numeral architect, point of view it has to give bouncy and number 2 is used as storage for oil and water.

So, this is a what is called a closed caisson, where you have wells which you have also having open caisson, but that is not used in gravity structure. So, this is a closed caisson well foundation, you can see well foundation of IIT, if you can go to this Kaizan viewer, where they take the water you will find that at the bank of the river. You go down there will be a big kind of structure have you seen, this are all the pipes are going down over there.

So, that is called a well foundation, but unfortunately that well foundation on the top there is no roof, so that is a called a open caisson, so basically this is called a closed caisson. Now, so this is your seat and design now, so here actually in the hand of design, you can see the conductor pipes, you can see some pipes, host of pipes going through this columns, but also he has taken pipes outside your columns, but emanating from the caisson any way.

So, that last is you are the after the sea tank, you come to the dorris design, so these are actually the dorrision designs you come to the dorrision term dorris. Now, the dorris design, now dorris design marked by two break waters, you can see one break water at the sea surface, you can see lot of holes over there. So, this break water there are used for damping your waves, so break water is actually protecting your conductor pipes which are coming out from this central shaft.

So, this break water this is Dorris design essentially has break water at ((Refer Time: 44:04)) MSL, there is another break water, if you notice at the sea bed, you can see another type of wall with lot of holes at the base of this structure. So, there are two break waters one at the sea level, and the other is at the sea bed, but at the sea bed why they have given, there is no there is no waves, this type of break water is used for countering your wave action, but what about this.

Now, here actually there we flow due to current, so it is going to damping the speed of the current, what lot of malt water is going to flow in this region, because of malt circulation and with the current. So, that has to be resisted you can see smaller deafen walls, you can see the stepped walls, so one stepped wall is out here, the another stepped wall is in the dashed line, and in between the crevice they are taking here pipes. So, these pipes are coming from the well head.

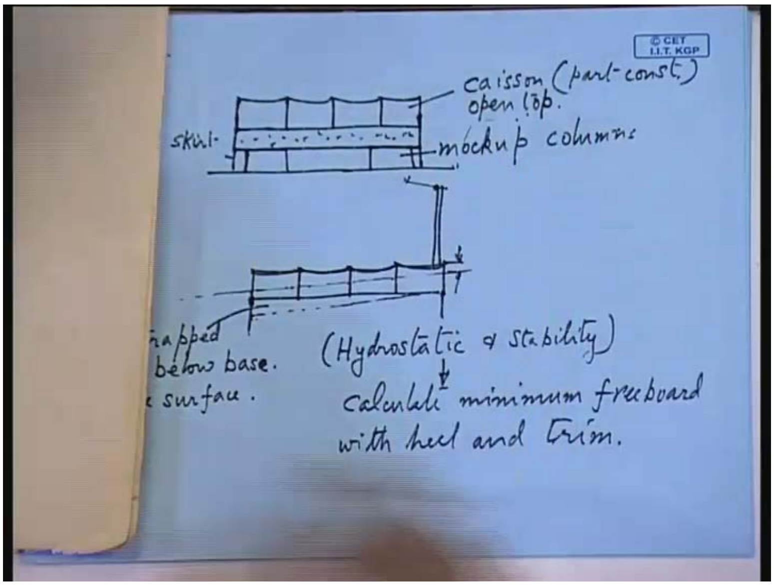
So, well head pipes that is your made riser or conductor pipes are taken up north inside these huge base, so you can see this base is actually caped on top, but on the sides they are taking all the pipes. And this is actually piercing your break water wall going through a central shaft, which is not shown here and then they are taking this up to the deck.

So, this Dorris design is used also for storage you have oil storage out here, but essentially this design is used, where you have large wave impact loads here, wave impact loads will be that. That design is such; that means, these columns are taking in the majority of your wave impact, but wave impact give our some out mitigating or somehow reducing by means of these break waters.

So, the gravity platforms are used primarily, these three types normally used the con deep and the sea tank is used, in less waves Dorris design, you can use for more extensive waves. And the here two basic things, but all these designs are remarkable from one point of you view from the size of base. So this can be as large as 224 meters, now platform height can be as high as 190 meters, so base dimensions I told you bases are to be made particularly heavy and wide, so base with this of the order of few hundred meters.

So, that is why the mass of the platform or weight of the platform is few lakh tones, which is taking care of your weight. Now, these platforms, now when you make this in a ship yard, now ship yard you cannot normally these gravity structure the whole structure never built your ship yard, because of the large size. So, in shipyard what they do in the this figure, I have one diagram out here you can see the ship yard construction, now ship yard construction is limited to the caisson only ship yard construction. So, ship yard construction you can see their keeping out the water and this is your dried up, but they have made only the bottom part, so bottom part consist of only the base slab along with part of the caisson you never built the whole caisson and the ship yard.

(Refer Slide Time: 49:03)



So, what is done is in the ship yard construction is say this is a bed of the deck, and you built some mock up columns, these are column mock ups in a ship yard training, I do not know, whether you have seen any these kind of mock ups, these are called mock up columns. Now on this you build your structure, so the caisson part is going to come like this along with your skirt plate, first you make your base slab, now base slab can be as high as say 2 to 5 meters. So, it will come a solid base we have to construct on mock ups, so this is grouted with concrete.

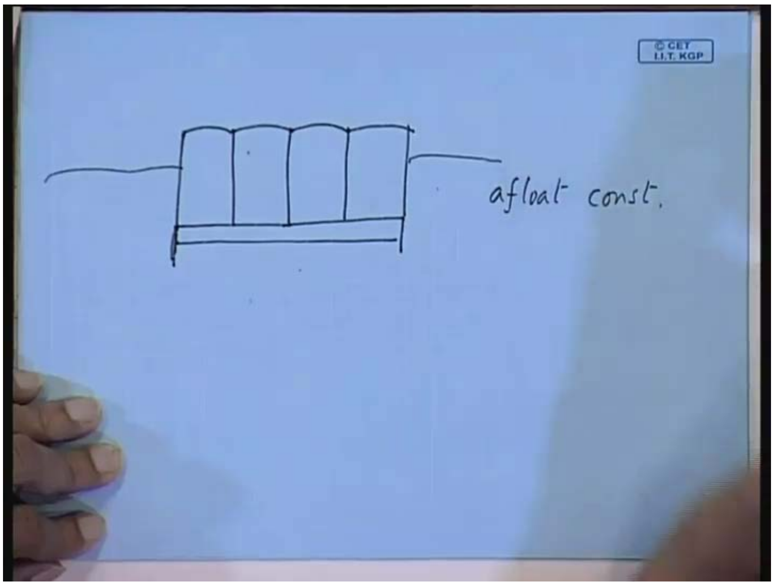
Now, what is the you built part of the caisson out here, now this caisson at the top you find this is open not closed, you built like this in your ship yard, so caisson part construction part construction open top why it is like this. So, you can see in the ship yard they are not building the whole structure only this part is made in the ship yard, now after you after this is made, then you remove your embankment and the whole structure is floated out as you can see here.

So, this is this part of the structure that is shown here; that means, in a smaller diagram, you can see this base slab part of the pontoons, but in steam has this open caisson, now here actually to be pretty careful, why because on the one hand you are having a travelling crane. So, here you have to do your hydrostatic and stability calculations, and you will find that the whole structure is tilted, if you have a crane like this at one side as you shown in the picture.

Then that will cause a hiding moment, now here you have to calculate the minimum free board, and there is also going to be entrapped air, this is going to be another cause of concern entrapped air below base, this will cause free surface. So, brawler no, so this you do hydrostatics and stability calculation at this juncture, so this is the naval architects job, this has to be found out.

Now, remember this just like a ship without a deck that the stability is given by what, stability is always given by enclosed volume here not having any enclosed volume, but still this portion that is going to contribute to bouncy. So, you calculate the minimum free board requirement with heel and trim, so that this is your job followed, now after this is done you start building the structure, now here what is the first thing that you do is that you are not having substance free board.

(Refer Slide Time: 54:30)



So, that is you start, you the sides of the caisson is made more longer, this is and then you cap it the first thing that you do in a float construction, so this is a float construction, and now caisson will be floating like this, so this is a float. Now, the next stages you can see out here so; that means, here is already completed the caisson part, and the not only on the top of the caisson 2 or 4 cells are here, already built the columns have already been built.

Now, after this you have built this, now the columns at this and this opened, so you ballast in the whole structure in goes down, you take the deck on 3 barges. The barges you cannot see out here, deck is taken on 3 barges on top of this columns, and then it is de ballast then it is comes on to this mode. Now, here you can do anchoring also now, but in the transit mode, now you are your this is your towing mode, now towing mode you should not tow this structure in this mode, because you may have insufficient stability.

Why, because you are not having water plane area, your water plane area contribution is only coming from the columns, but here you have a larger water plane area, but have a problem with this is your g, your g has gone up. So, this stage and this stage you always calculate stability hydrostatics this is your towing mode, and the final when it comes to again de ballast the whole structure, this is your caisson on the important. So, this is how your gravity platform is built, so thank you next class we will start about hybrid platforms.