Ocean Structures and Materials
Prof. Dr. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module - 2
Lecture - 11
Foundation and sea bed anchors

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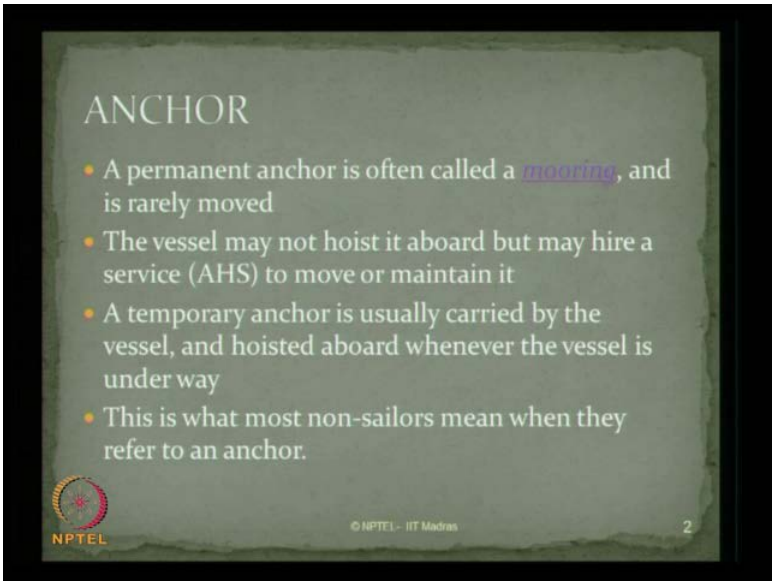

In this lecture, we will talk about foundation and different types of sea bed anchors. First fundamental question, which we would like to answer is, what is an anchor? A permanent anchor is often called as a mooring and is rarely moved. It is more or less fixed to a specific position. The vessel may not hoist it aboard, but may hire a service to move it or to maintain it. A temporary anchor is usually carried by the vessel and hoisted aboard whenever the vessel is under way. This is what most sailors mean when they refer to an anchor.

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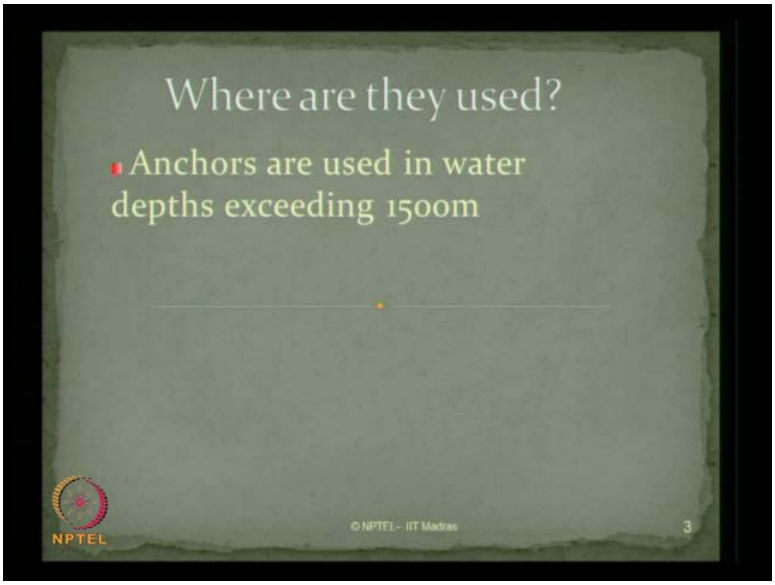

Where are these anchors used? Anchors are used in water depths exceeding, 1500 meters. It is a typical photograph of an anchor; this photograph shows a proportionate size in terms of its dimension, length, thickness and material compared with that of human figure.

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You can see an anchor is a very large structural component which holds down the vessel in position restrain.

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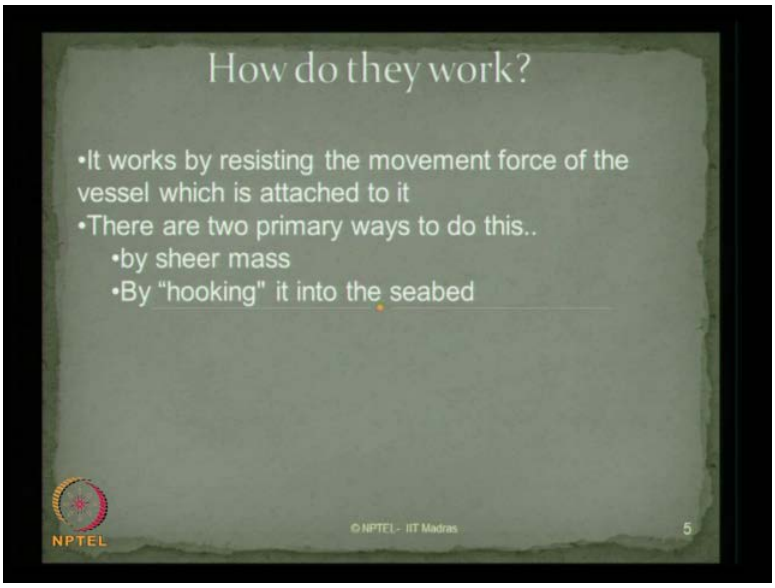

How does it work? It works by resisting the movement forces of the vessel to which it is attached. There are two primary ways to do this. One is by having a sheer mass, you have a massive element which can hold down the vessel in position, so by improving the mass or we increase in the mass of an anchor it may not allow the vessel to move or the second option is hook it down to the seabed by some arrangement. Either hold it down to the seabed by hooking it up or create a massive attachment to the bottom of the vessel such that the vessel does not move.

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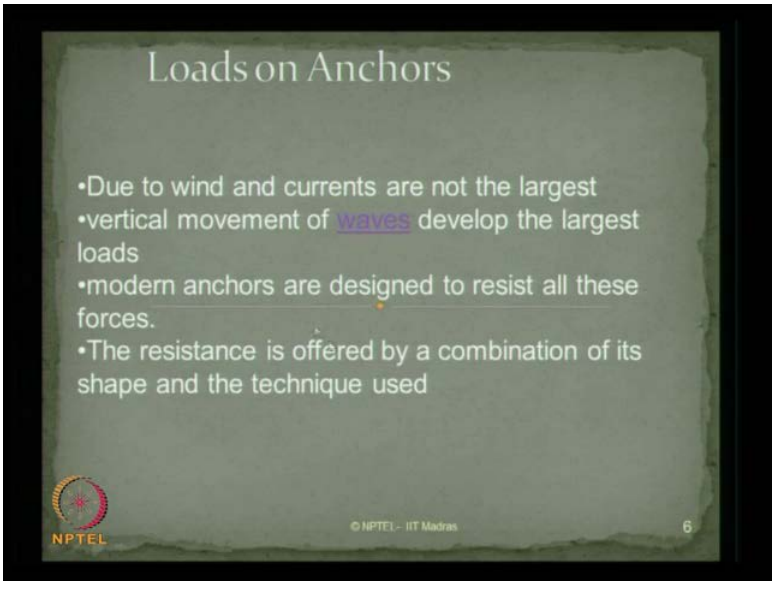

What are the different kinds of loads which are coming on anchors? Due to the winds and currents the forces coming on anchors are not the largest. The vertical movements of waves develop the largest loads possible on anchors. Modern anchors are of course, designed to resist all these forces. The resistance offered by an anchor is essentially a combination of the shape and the technique used to anchor it to the seabed. There are different terminologies when we talk about seabed anchors. Aweigh is a one of the important term, which is commonly referred in seabed anchors. Aweigh describes the anchor, when it is hanging on the rope and not on this bottom.

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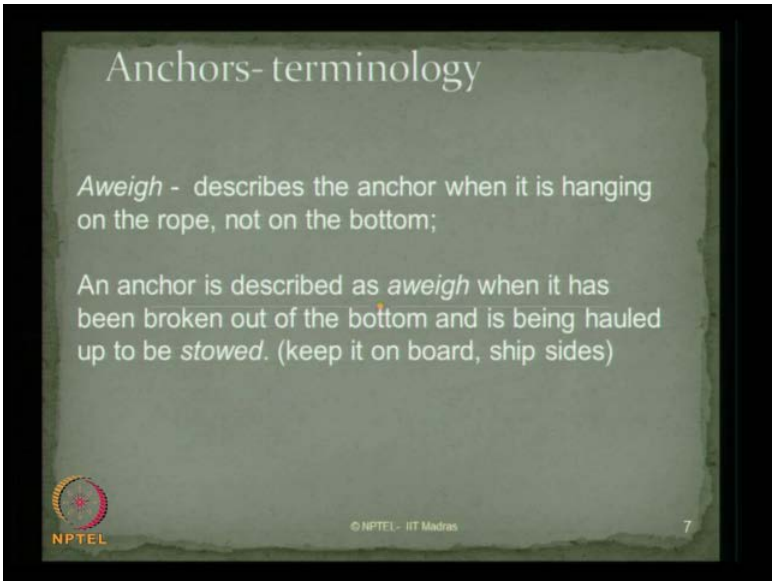

An anchor is described as aweigh when it has been broken out of the bottom and is being hauled up to the stowed area, so it can be kept on boat and on the ships on the sides of it. Two photograph show different views of an anchor, which are essentially temporary anchors. These are called Fluke style anchors. This one of the temporary type of anchor which generally used a central bar is called as a shank.

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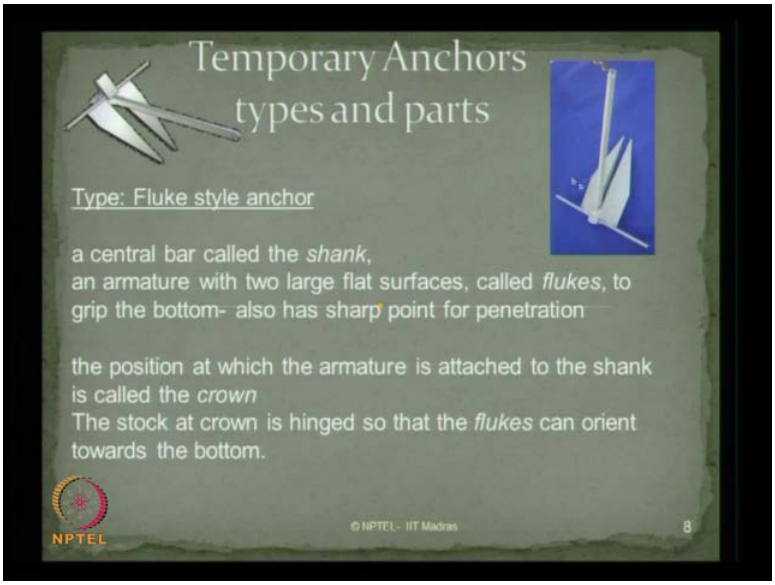

You can see hear, this is what we called as a shank. An armature with two large flat surfaces, which are called as flukes. These are two large flat surfaces which we called them as a fluke.

So, this type of anchor is what we call Fluke style anchor. So these are the flukes. The flukes have the sharp tip at the end so that this can be penetrated down into the seabed for holding it down in position. Now, the shank is attached to the fluke by meant of an hinged arrangement and this point is what we call as the crown. So, crown is the point where, the shank and the armature are attached together. The stock of the crown is hinged so that the flukes can move or rotate, about the hinge and this can be position and can be used for anchoring the object to which it is been connected to and this shank is connected to the object by means of a steel chain or a wire.

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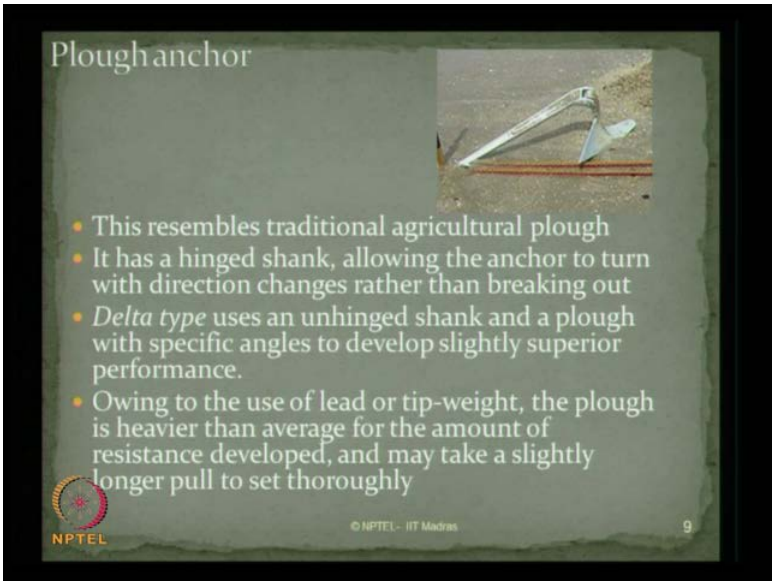

The other type of anchor which we call as a Plough anchor which we you a photograph here. Yes, ladies and gentlemen, it is typically same as we used for agricultural fields. This resembles traditional agricultural plough, which we used in the fields. It also has a hinged shank, this a hinged point. It also has a hinged shank, allowing the anchor to turn with direction changes rather than the anchor will break, when the direction is changed. The hinge enables the flow component of this to turn its direction in position, when the anchor is being use for holding it in position.

Delta type uses an unhinged shank sometimes there are unhinged shanks also available and plough with specific angle. So, the plough has a specific angle, to which it is manufactured and there is no hinge because there is always a probability of the anchor getting broken exactly at the hinged point because this is the point of weakest connection in a given anchor. Owing to the use of lead or tip weight, the Plough is heavier than average for an amount of resistance developed. So, we can see that the plough is having a very massive element which can hold down the shank, at the specific location and cannot be pulled down so easily when it is being placed in position.

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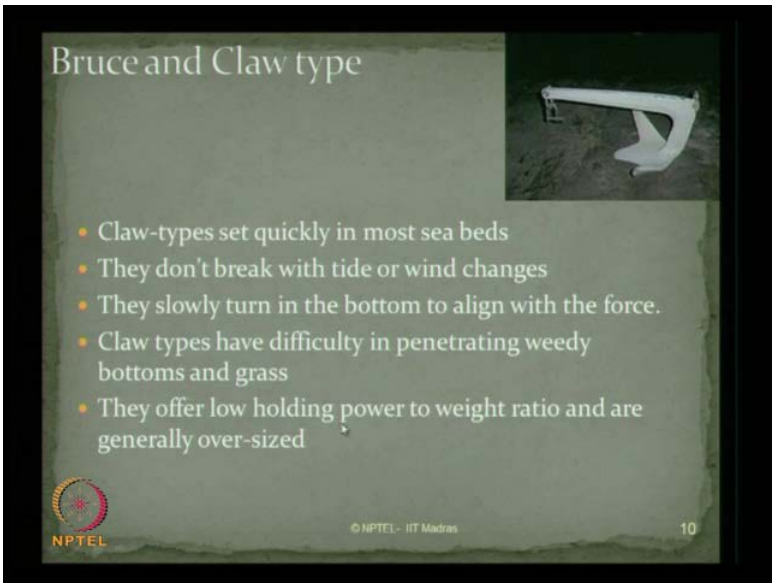

The next type of anchor what we see in the picture is Bruce and Claw type. We can see this is the claw and this is the Bruce;. that is Bruce and claw type. Claw types set quickly in most the sea beds because if its geometric arrangement, this is one of the convenient way of holding down the object in position. They do not break with tides or wind changes, they slowdown in the bottom to align with the forces. They slowly turn so that they get set at the sea bottom as the force gently acts upon these anchors.

Claw types have difficulty in penetrating because the sharp edge is not as same as that of a plough type and the claws type. So this is having certain difficulty in penetrating in the sea bed but of course, it holds rigidly in position and it can suitably be used for many types of sea bottoms. Essentially, when you got large vegetation intensive, vegetation in sea bottom, these kind of anchors are conveniently used. Bruce and claw type is that kind of anchor which we talk about. They offer of course, low holding power the holding power of the pulling capacity of this anchor compared to its weight is lower and therefore, they are generally oversized.

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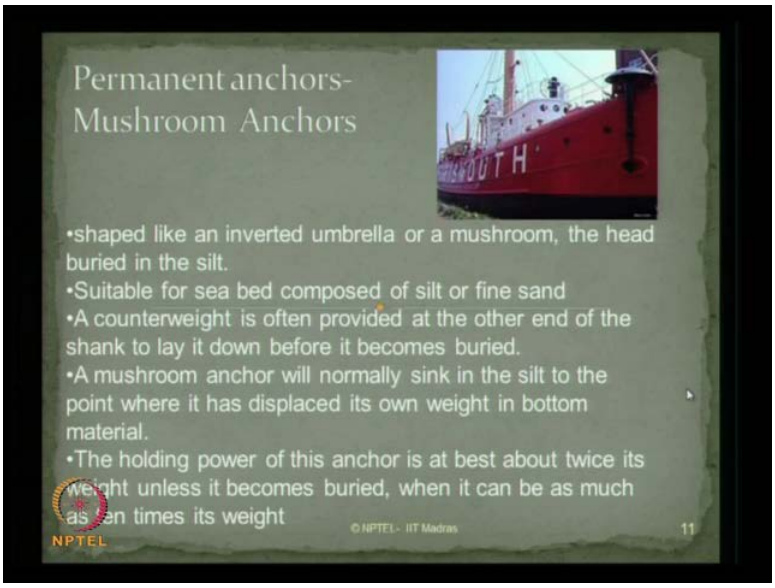

The other type what we see here is permanent anchors. What we saw in the previous slides are all temporary anchors. The one what you see now, are all permanent anchors. The first of its kind is what we called as mushroom anchors. It is shaped like an inverted umbrella or a mushroom. The head is buried in the silt to hold the vessel in a permanent position. It is suitable for sea bed, composed of silt or fine sand. A counterweight is of course, provided at the other end of the shank to lay it down, before it gets buried.

A mushroom anchor will normally sink in its silt, to the point where it has displaced its own weight in bottom material. The holding power of this anchor is best about twice its weight unless it becomes buried. So, if the weight of the anchor is about 2 then the holding power is above 4 times of its mass. So, that it can be used for permanently anchoring the vessel in a specific location.

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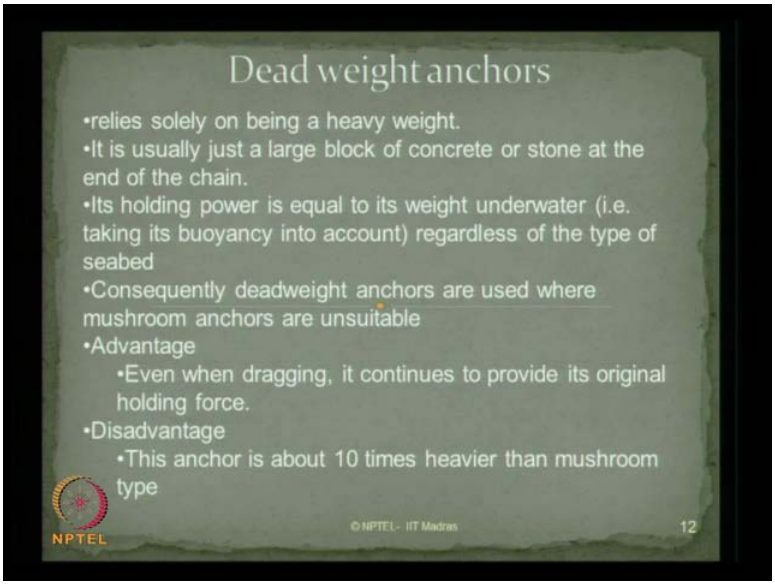

There are other kinds of anchors, what we called dead weight anchors. They rely solely on their heavy weight. It is usually just like a large block of concrete or a huge massive size of stone. It is holding power is equal to its weight under water that is taking it to buoyancy into account regardless the type of the sea bed. It can be used in any kind of sea bed surface which can be rough, vegetation etc.

Consequently, dead weight anchors are used where mushroom anchors are not suitable. There are several advantages of this kind of anchors. Even when dragging, it continues to provide its original holding force. That is an advantage whereas, one important demerit is the anchor is about ten times heavier than the mushroom type so you are unnecessarily increasing or carrying this kind of anchors, which about very heavily placed on boats whereas, mushroom type anchors can be alternate to this, but of course, mushroom type anchors cannot be suitable for all kind of surfaces sea bed.

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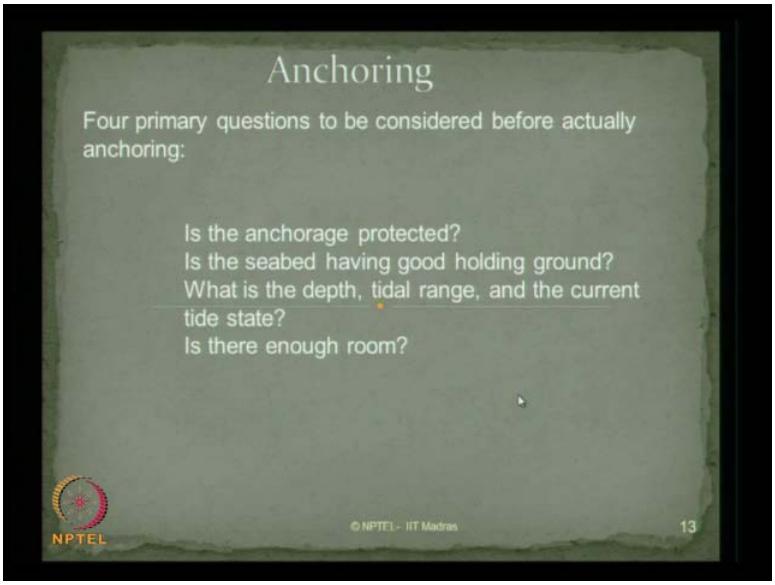

When we talk about anchoring, let us ask 4 primary questions, which we must consider before we select any specific type of anchoring. Is anchorage protected? You must check whether the anchorage system what are using is completely protected from the lateral forces. Is a sea bed having good holding ground? Do you have a sea bed which is made of silt or sand or enough vegetation or rocky etc? Because depending upon the surface of sea bed, you must select a specific type of anchor. Then of course, you should talk about what is the depth at which you are thinking of anchoring it? What is the tidal range? And what is the current tide state at that specific location? And of course, is there any enough room for variability, of all these values during anchoring process being carried out. So we must answer all these primary questions, first before we select any specific type of anchor.

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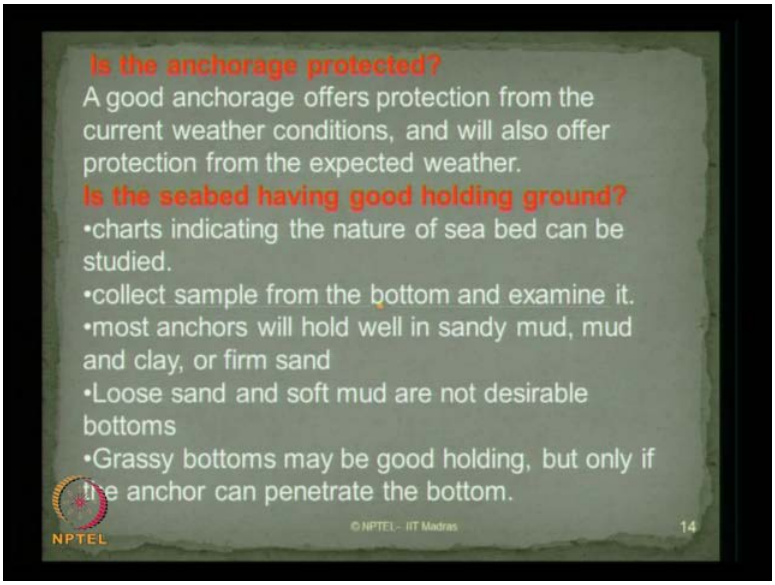

Now, let us elaborate the questions in detail. Is the anchorage protected? A good anchorage of course, offers good protection from the current weather locations and also offers good protection from the expected weather locations. Now, the second question which we elaborate is; isthe sea bed having good holding ground? It depends upon the nature of sea bed you are talking about. So, collect the sample from the sea bed bottom and examine it, what kind of material is that? Is at the rocky bottom?

So you must examine it physically as well us by taking samples out of the sea bed and try to see what kind of anchor can be made suitable for this kind of sea bed. Most anchors of course, will hold well in sandy mud clay or firm sand. Loose sand and soft mud is not desirable for many of that. Of course, if you have got strong vegetation in the bottom, some types of anchors may be found very good in holding capacity, but only when the anchor can penetrate for a grated at depth at the bottom.

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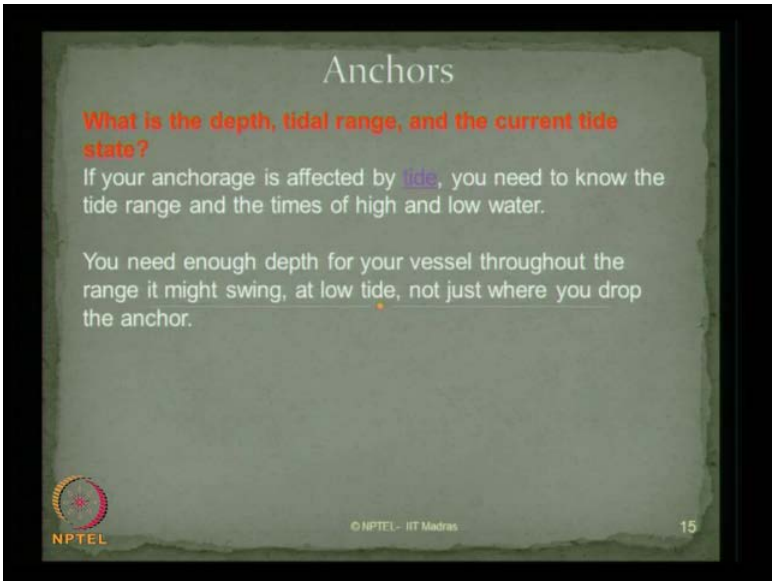

The next question as we discussed is, what is the depth at which you are planning to anchor? the depth, the tidal range, or the current state? If your anchorage is affected by the tidal variation then you must know the tidal range and the times of the high and low water tides, which can occur in a specific sites. Of course, you must have a good idea about what is the enough depth available of your vessel and what is the drop at which your vessel should float, throughout the range as long as it is being position restrain we using anchors.

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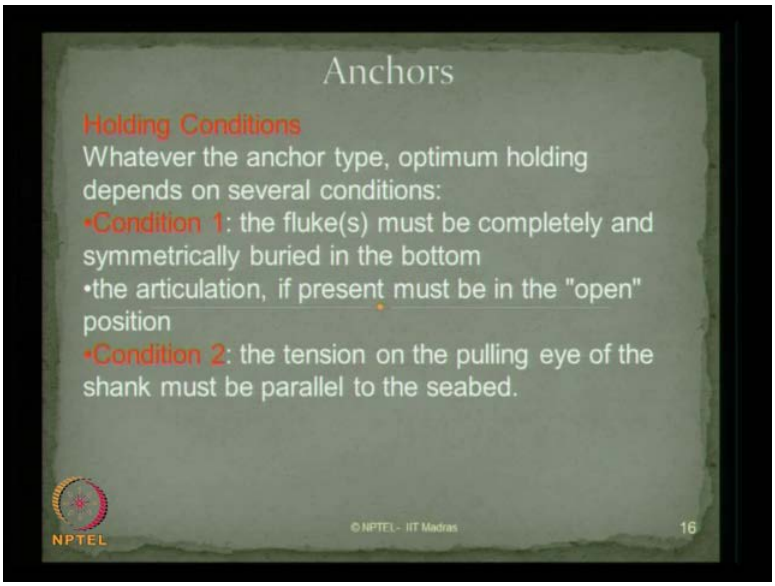

Now, we also talk about what are the different holding conditions at which anchorage is going to be done. Whatever the anchor type may be, optimum holding depends on

several conditions. The foremost condition what we see in the slide is that the flukes that is nothing but the point at edge blades must be completely and symmetrically buried in the bottom, that is very important. If we do not have a symmetric holding of the anchor, this may result in unnecessary lateral displacement of the vessel during high tide or low tide operations. Therefore, you must ensure that the flukes are held down symmetrically and completely penetrated in the sea bottom.

The second condition is that, if the fluke and the crank shafts are hinged together, what we say as articulation then the articulation must be kept in open position therefore; the angle of rotation of the fluke can be adjusted by itself depending upon the lateral forces, acting on the anchor. The second condition which you must examine, to select an anchor is that the tension on the pulling eye of the shank must be more or less parallel to the sea bed. So do not try to hold down the anchor or do not try to place the anchor in such a manner, that the shank remains almost perpendicular to the sea bed. This may result in a very less holding power and the anchor may get pulled off from the sea bed for even very less value of lateral forces. So one must ensure that, the shank is almost parallel or closed around ten to fifteen degrees to the horizontal of the sea bed so that the anchor generates enough holding capacity, when it is being penetrated in the sea bottom. So two conditions are essentially to be satisfied and examined to select what type of anchor is required for a specific sea bed.

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Now, let us see some pictures showing which are good settings and which are bad settings. As I told you, in the case of sand or silt clay etc. The shaft should be almost parallel to that of the sea bed to ensure good holding power but if the flukes are not completely embedded as we see here or even if the shank is completely covered as you see here there is no holding power available therefore, these are what we called as bad settings. These are what, what we called as good settings for an anchor.

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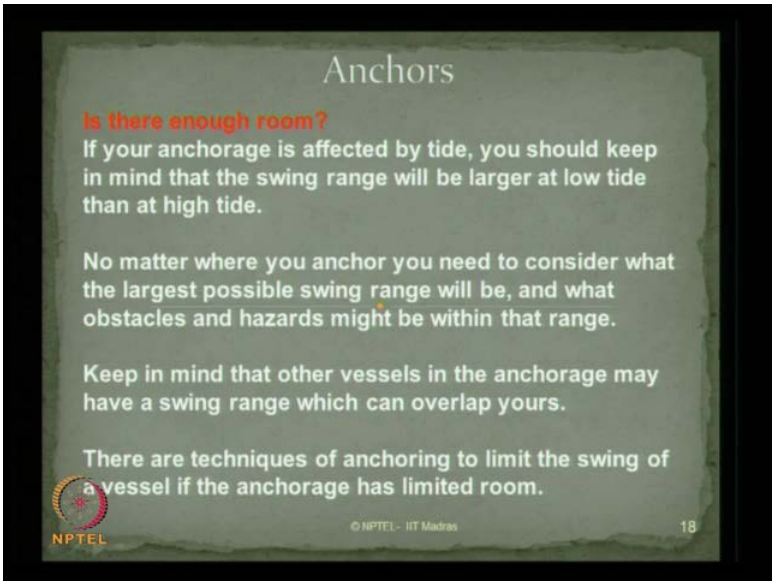

Now, the foremost question also comes to mind is do you have enough room to make any adjustment? Now, the answer is if your anchorage is affected by tides you should keep in mind the swing range of the tide which will be larger at the lower tide than that of the higher tide. No matter, where you anchor? You must consider what the largest possible swing range at the specific location Is. Keep in mind that other vessels in anchorage may also have a swinging range therefore, remember that your anchor should not overlap with other neighboring vessels nearby. There are many techniques of anchoring to limit the swinging of an anchor or that of our vessel that is what we say, as enough room available for swinging the anchor. First, one must ensure that these four conditions are satisfied, these questions are answered primarily, before you select the type of anchor, the method of anchoring for a specific site.

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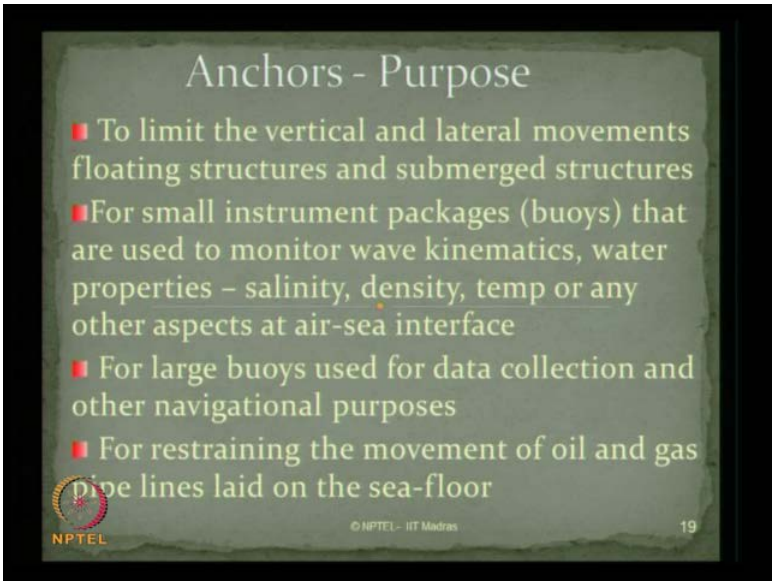

Now, let us quickly see what are the different purposes are or what is the main purpose why we anchor a vessel? The vessel is actually anchored, to limit of course, the vertical and lateral movements of the floating structures and of course, in case of submerged vessels as well. For small instrument packages for example, power buoys point buoys etc which are used for ocean environmental measurements that are used, to monitor the wave kinematics variations, the water particle velocities and properties like salinity, density, temperature etc then also holds this buoys down of course, the pulling power required to hold these buoys are not as high has that required, for holding the vessels in position. For large buoys which are used for data collection and other navigational purposes also, you may require to anchor them to the sea bed. So, there are varieties in the purposes why we use the sea bed anchors as we see in the specific slide. Essentially, for restraining the movement of oil and gas pipe lines on the sea floor we do anchor them to the sea bed.

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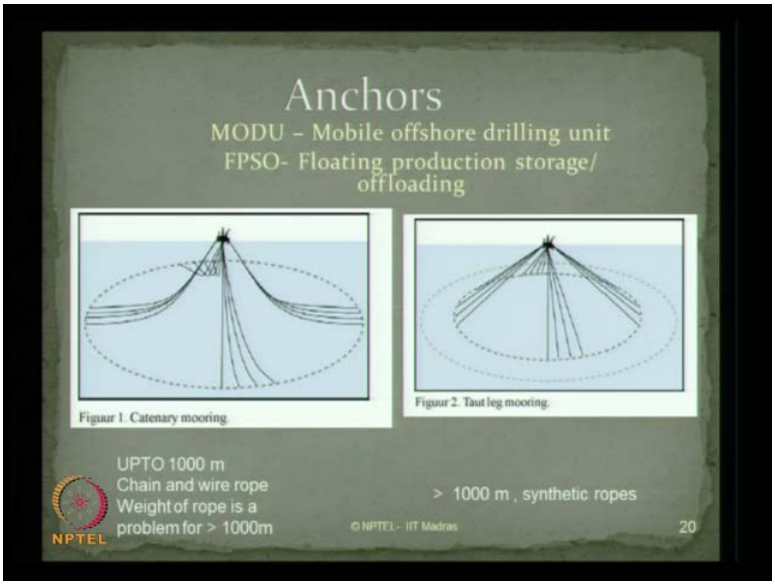

Now, the figure 1 shows Catenary mooring and figure 2 shows the taut leg mooring. So, these are different arrangements of anchoring and you will see in both the arrangements that the shaft is almost or the shank is almost parallel to the sea bed where the anchorage is being generated. So, the Catenary mooring is applied to the maximum depth about 1000 meters and the chain and wire rope is used. The weight of the rope is actually a major problem, when you go for deep anchorage more than 1000 meters. So, in case of more than 1000 meters one is recommending synthetic rope to be used instead of steel chains or steel wires. Essentially, it is the two arrangements of anchoring system which are used for mobile offshore building units and FPSO.

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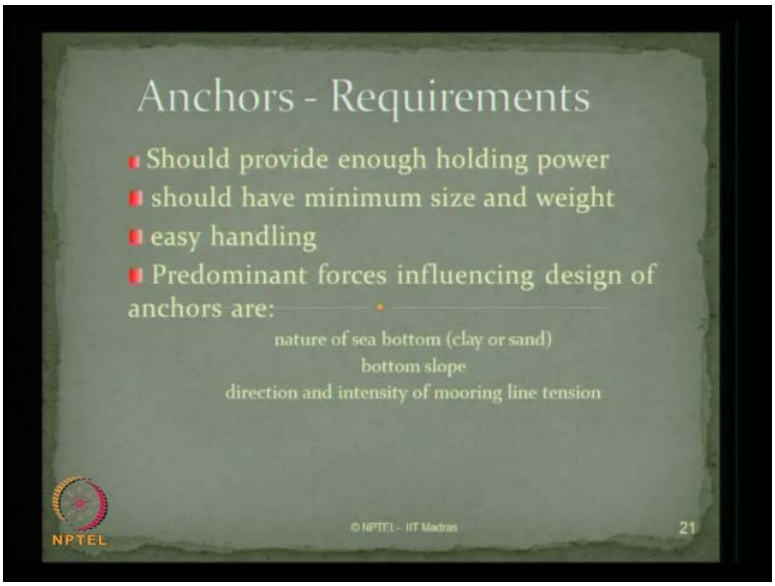

Let us see, what are the functional and design requirements of anchors? Anchors of course, should hold enough holding power. It should have a minimum size and weight. Now, it should be easy to handle so the predominant force influence the design of anchors are the nature of the sea bed, the bottom slope of the sea bed and the direction and intensity of the mooring line tension.

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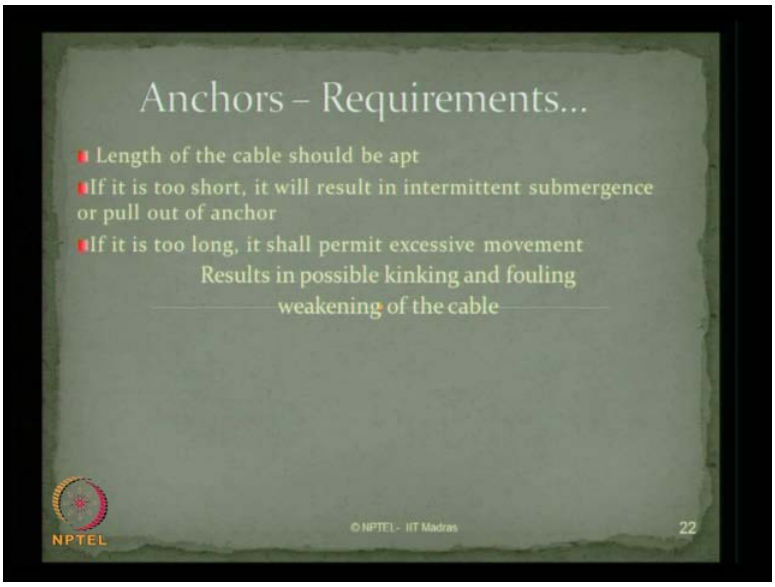

The length of the cable should be apt and optimum. It should not be longer or shorter, because shorter will result in the lifting up of the shank, the longer will result in unnecessary dragging of the anchor. If it is too short, it will also result in intermittent submergence or essentially land up in pull out of the anchors. If it is too long, it shall permit excessive movement that will be also a problem for maneuvering or sea keeping of the vessels.

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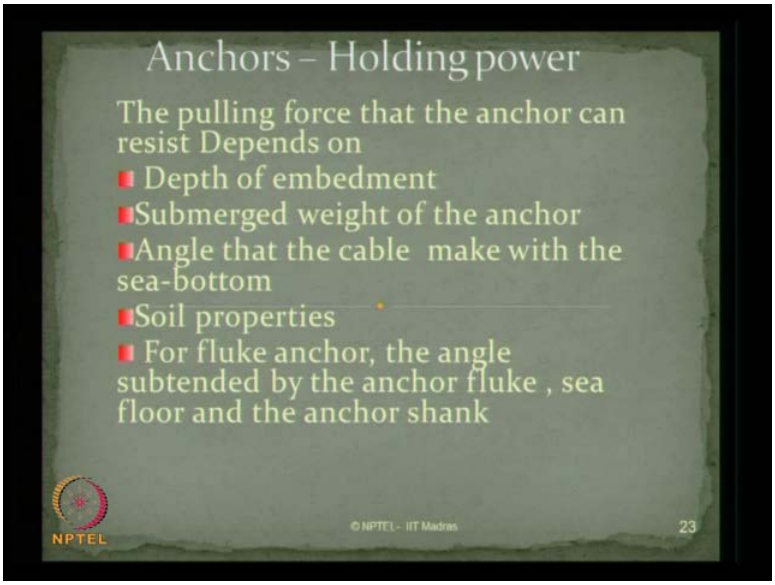

If you want to calculate the holding power of an anchor, essentially the holding power refers to the pulling force that the anchor should resist and it depends on; the depth of embedment, the submerged weight of the anchor and the angle at which the cable makes with that of the sea bottom and of course, soil properties also play in important role in case of fluke anchors, the angle subtended by the anchor respect to the sea bed and the anchor shank it is a very important value or a parameter which will decide the holding power of an anchor.

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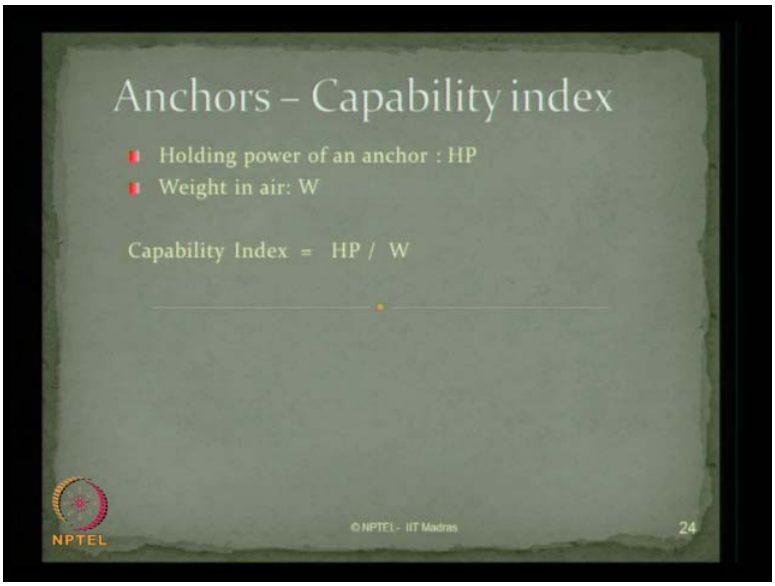

The anchors are also having something called capability index, which we called as holding power of an anchor. If weight of the anchor W be in air then the capability index

is nothing but H P by W what we call holding power to the weight of the anchor in air, this what we called as capability index.

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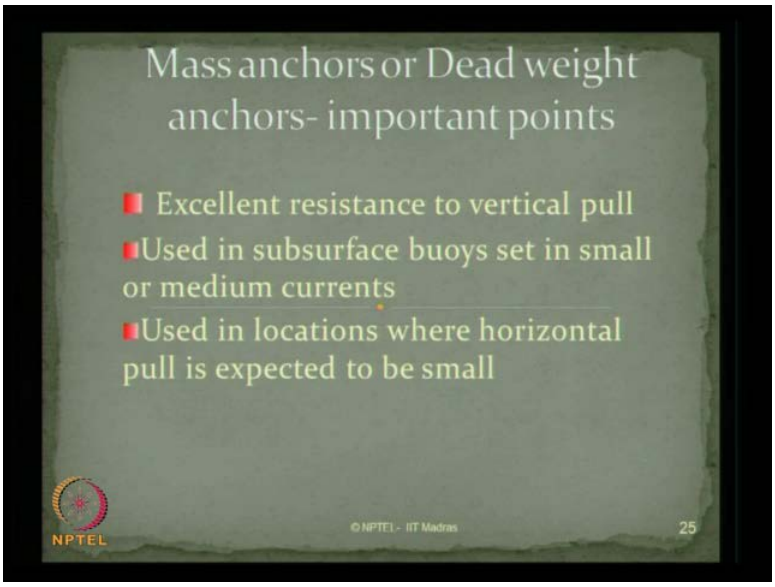

Let us speak about mass anchors or dead weight anchors. There are some salient points related to dead weight anchors. Dead weight anchors have excellent resistance to vertical pull. They are used in subsurface buoys that set in medium or small currents. They can be used in locations where the horizontal pull is expected to be small.

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The mass anchors holding power can be computed and it is depends on the cohesive nature of the soil, the adhesion between the contact of the anchor and that of the sea floor. If you got a Cohesionless soil for example, like sand then the fiction between the contact of the anchor and the sea floor plays a major role in determining the holding power of such anchors.

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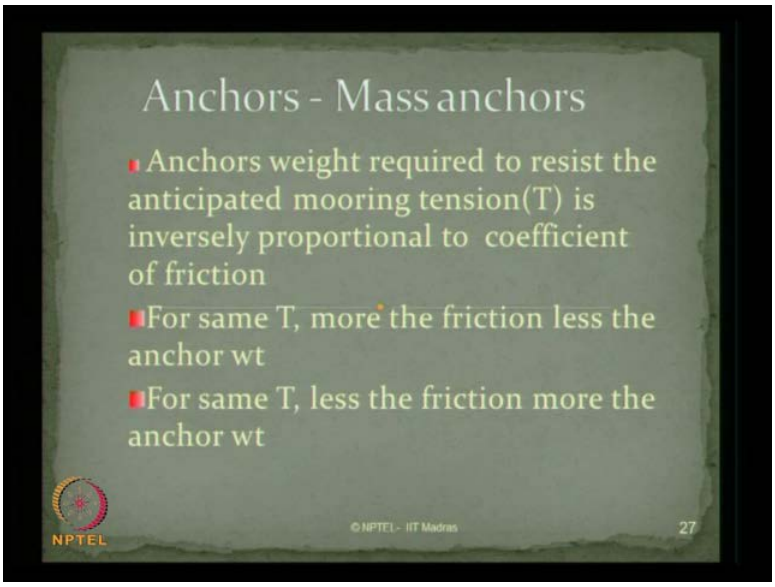

Talk about mass anchors. Anchors weight is required to resist the anticipated mooring tension and it is inversely proportional to coefficient of the friction. For the same T more friction less the anchor weight, for same T less the friction more the anchor weight.

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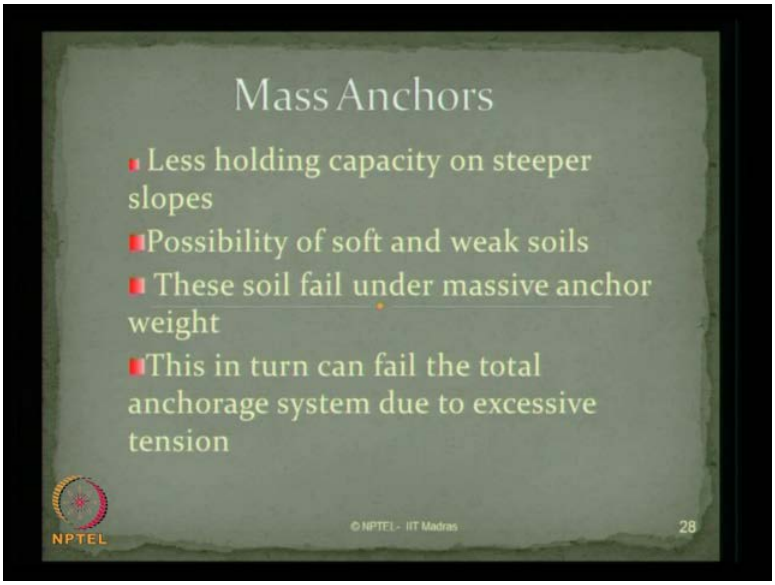

If we talk about mass anchors, less holding capacity on steeper slopes is a major problem that mass anchors. There is a possibility of using them in soft and weak soils. These soils of course, fail under massive anchor weight. This in turn can fail, the total anchorage system because due to excessive tension caused in the cable as the failure of the mass anchors occur in this type of soft and weak soil.

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If we look at the application of mass anchors in detail, soil which are not very weak and soft you can use mass anchors. Tension should be essentially vertical. So, your cable should not be very long. So, that tension applied at the point of contact to the anchor

shaft, should not be horizontal it should remain vertical. If we talk about mushroom anchors then we talk about some salient points of mushroom anchors.

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Mush room anchors get embedded completely by their own weight, sometimes jetted to the desired depth, depending upon the site operation. Mush room anchors are used for permanent mooring in muddy bottoms.

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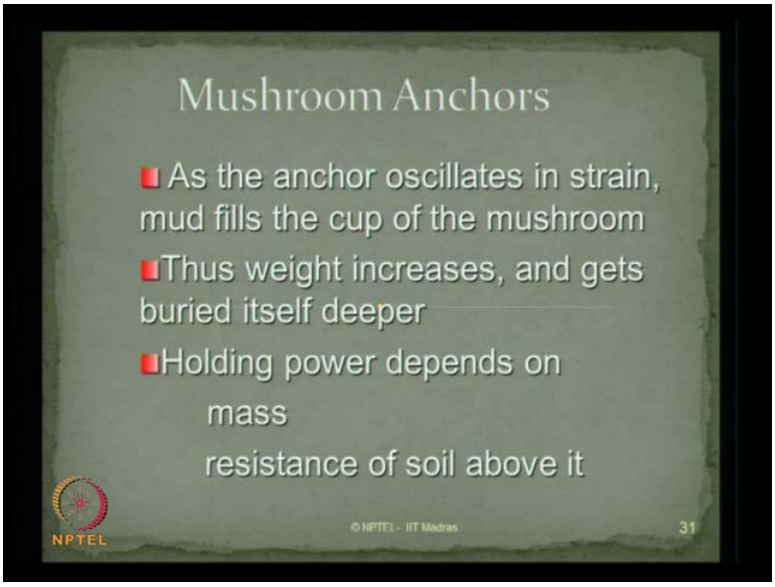

As the anchor oscillate in strain, mud fills the cup of the mushroom and thus the weight increases and it gets buried itself deeper and deeper. The holding power of this, depends

on the mass of the anchor and the resistance of the soil above it and the filled up on the cup.

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Drag anchors, ladies and gentlemen, are the other type of permanent anchors, which are primarily meant for large ships or vessels. They designed to dig into the sea floor, as they are dragged along by the horizontal force. In this way they get embedded deeply and firmly in the bottom soil.

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Look at the parts of the drag anchors.

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The drag anchor consists of fluke, Stock, crown, shank and a shackle. Drag anchors otherwise addressed as embedment anchors. There are important points which you must remember in selecting these kinds of anchors. These combine to give a light weight and the large resistance to lateral pull. There is an advantage of these kind of anchors, which can be used for large vessels.

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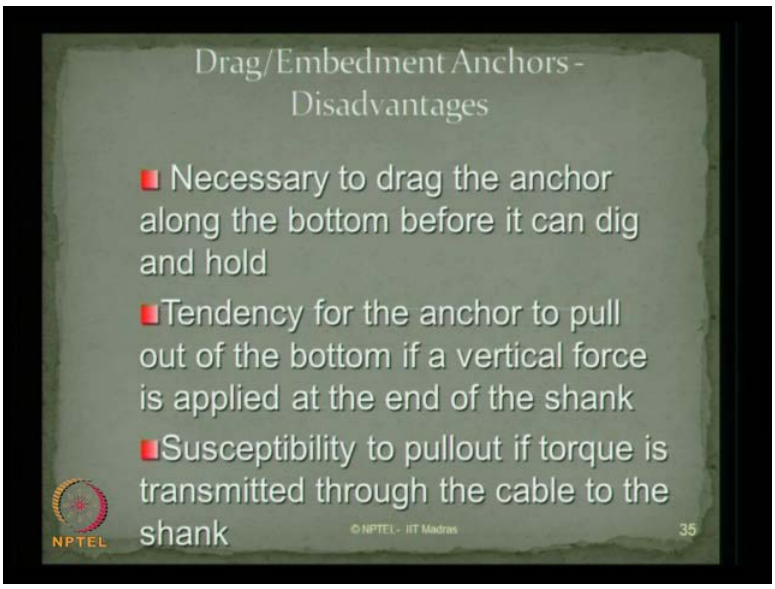

There are of course, couples of demerits related to the embedment anchors. They are necessary to drag the anchor along the bottom, before it can dig and hold. It is very

important that, the drag anchor should be dragged for certain distance so that it develops resistance to hold down or to generate holding power, before it actually being used as an anchor. It has a tendency to pull out of the bottom so a vertical force is applied at the end of the shank. Remember ladies and gentlemen, it is very important that they should not have a vertical force, which can be applied at the bottom. It is the susceptibility to pullout if the torque is transmitted through the cable to the shank.

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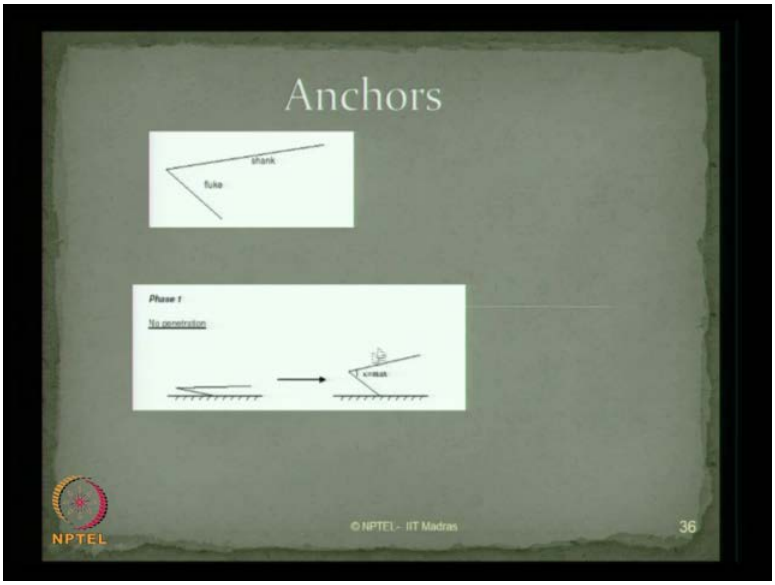

These are different layouts of pictures, which are shown for anchors for example, so the picture has the arrangement of different shapes which are connecting shank and the fluke. So in case of, let say, process of anchoring to the sea bed, in phase one, when there is no penetration, then you pull the shank and the fluke will get adjusted as they are connected by a hinged connection. So, there should always a maximum angle, beyond which this connection should not be stretched or open because this should enable, that the fluke should embedded in the soil for a proper anchoring to be applied and as I told you earlier, the shank should never become vertical or the opening angle of this should not be very large.

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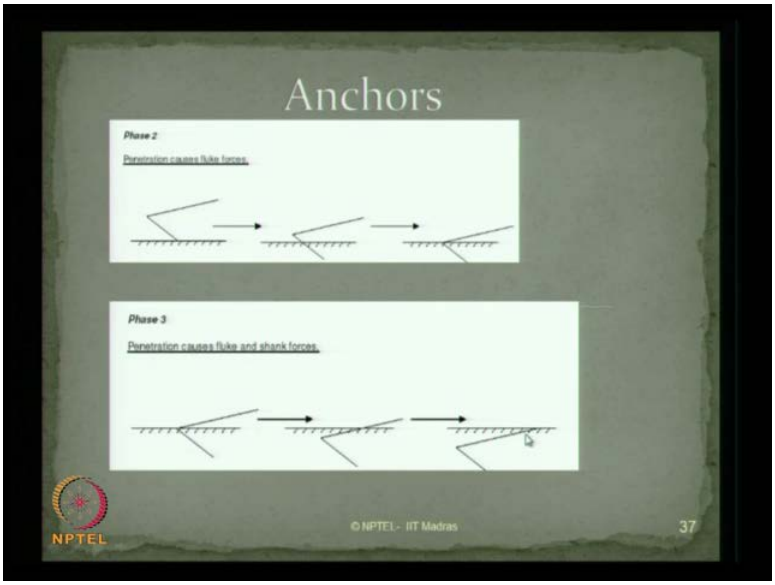

The second phase depends on the penetration causes, the fluke forces to resist. As we keep on dragging the anchor, you will see that the fluke gets embedded and there is an ideal condition where, the hinge goes and set on the sea bottom. So, that complete fluke is totally embedded and the shank is keep on applying or improving the holding power of the anchor. That is what we call as phase two. In phase three, as the shank is above and the fluke is completely embedded, you can further drag it and for further forces apply laterally you will see that, even the shank also get embedded completely and this will offer a maximum resistance for the holding power of the fluke or the anchor.

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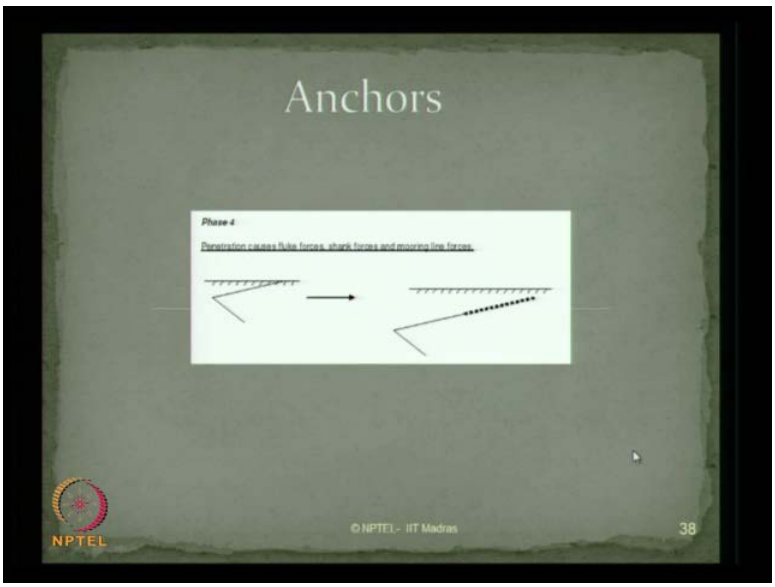

In the phase four, as this is completely embedded you will see that even the mooring lines will also offer standard offer resistance with that of the forces applied by the waves and wind.

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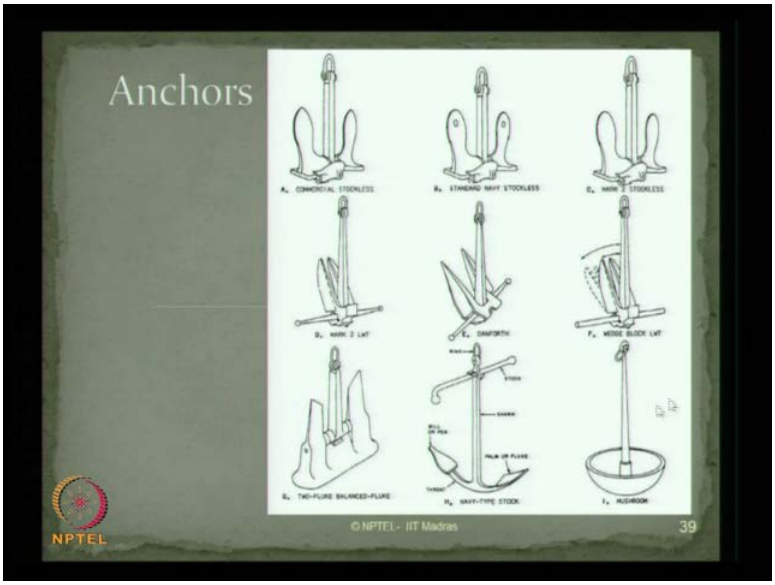

There are different kinds of commercial anchors available in different names. For example, the commercial stockless anchor looks like this, this of course, you can understand, these are all flukes to the shank. There is the hinged connection to which a chain or a wire can be connected. The second type of anchor is standard navy stockless type. The third one is mark 2 stockless types. The advantage or the difference between the standard navy stockless to that of the mark 2 stockless is that, there are holds possible on the flukes directly and the flukes can also be connected together along with the shank and it offers more resistance compared to that of the commercial stockless and the mark 2 stockless. Of course, these are different varieties of anchors. We just got the flukes with sharp edges. Of course, these anchors had flukes with blended edges. So, they can be suitable for different kind of soil, essentially for mud etcetera. This can be for different kind of soil where clay bottom is available.

So, the arrangement between the connection of a shank and that of the fluke at the hinged point or the crown is different for different kind. Mark two light weight system, dany fourth medium weight system and wedge block light weight system are different kinds of anchors, which has fluke with sharp edges. The other kind of anchor, which is commonly

used for holding larger vessels, is two fluke balanced fluke system and the navy type anchors. Ladies and gentlemen, you must have seen a very common type of anchor which is generally used for holding down larger vessels because this has a high holding power compared to this kind of anchors. You also have mushroom type anchor as I told you in the beginning, when the fluke is inserted this cup is filled with mud and depending upon the soil resistance which is being filled up this mud, this kind of anchors will offer resistance or will generate holding power.

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Youmust have also seen something called pile anchors. Pile anchors are used essentially to hold down the pre- cast concrete piles. They are drilled cast in situ 2 concrete piles. You can also have steel piles in position.

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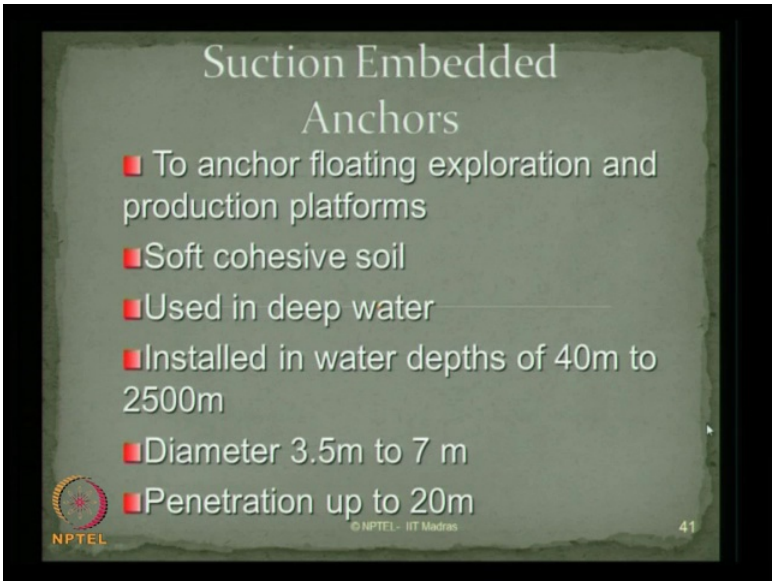

The suction embedded anchors, give another type of anchor, which is commonly used holding down the vessel, to anchor the floating exploration and production platforms this kind of anchors are used.

They are best suitable for soft, cohesive type soil. They are generally used in deep and ultra- deep waters. They are installed in water depth varying from 40 meter to 2500 meters. These kinds of anchors, have a diameter varying from 3.5 meters to 7 meter. They are really heavy in type and the penetration is up to maximum of 20 to 25 meters.

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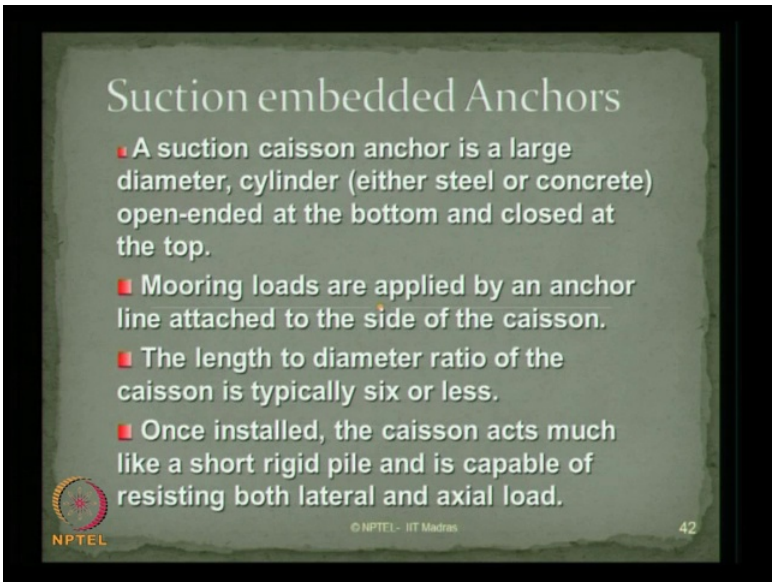

A suction caisson anchor, is having a very large diameter and cylindrical in shape can be either constructed with concrete or steel and it is got an open-endedness at the bottom and closeness at the top. The mooring loads are applied by an anchor attached to the side of the caisson, the length of the diameter ratio of this caisson is typically about 6 or lower than that. Once this kind of anchors are installed, the caisson acts much like a shorter rigid pile and is capable of resisting both lateral as well as axial forces acting on these anchors.

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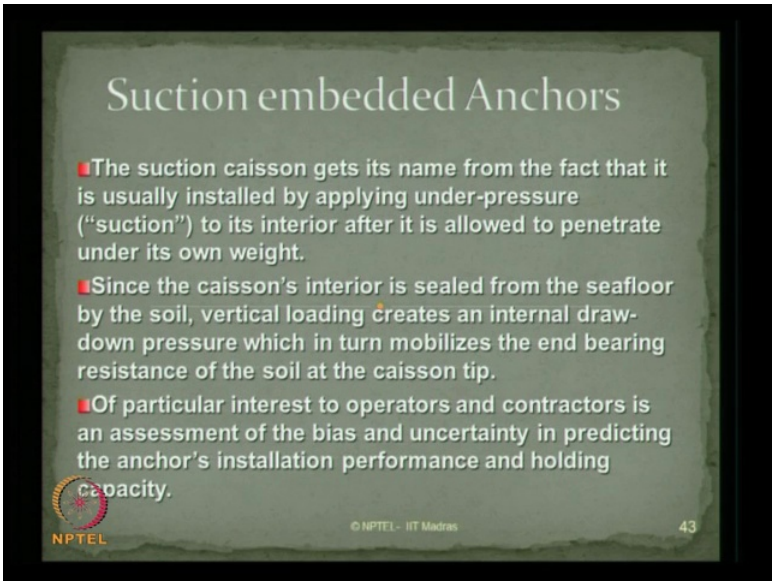

The suction caisson gets its name from the fact that is usually installed by applying under pressure. That is why it is called suction caisson. To its interior, after it is allowed to penetrate in its own weight, since the caisson's interior is sealed from the seafloor by the soil, the vertical loading creates an internal draw down pressure, which in turn mobilizes the end bearing resistance of the soil at the caisson tip. For particular interest to operate as a contractor, is an assessment on the bias and uncertainty in predicting the anchor's installation performance and holding capacity.

So, there is always an ambiguity of estimating, the reliability of this kind of anchors or holding power of this anchors on every kind of soil bed. Ladies gentlemen, in this lecture we discussed about different foundation system, different types of anchors varying from semi- permanent type, temporary type to permanent type. We have also seen the methodology of operation of an anchor and the method by which the anchor generates

holding power. We have also seen different classification of anchor and suitability for different type of soil. So, it all depends upon, many parameters; therefore, you got an answer for question which we discussed in this lecture that before you select any specific type of anchor, depending upon the sea bed, depending upon the water depth, depending upon the room for swinging and of course, depends on what kind of vessels you are holding down.

Thank you very much.