Elements of Ocean Engineering
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Lecture - 1
Introduction

So, welcome to the introductory course on elements of ocean engineering. This is suitable for both under graduates and professionals, who do not have a scientific knowledge of the ocean environment.

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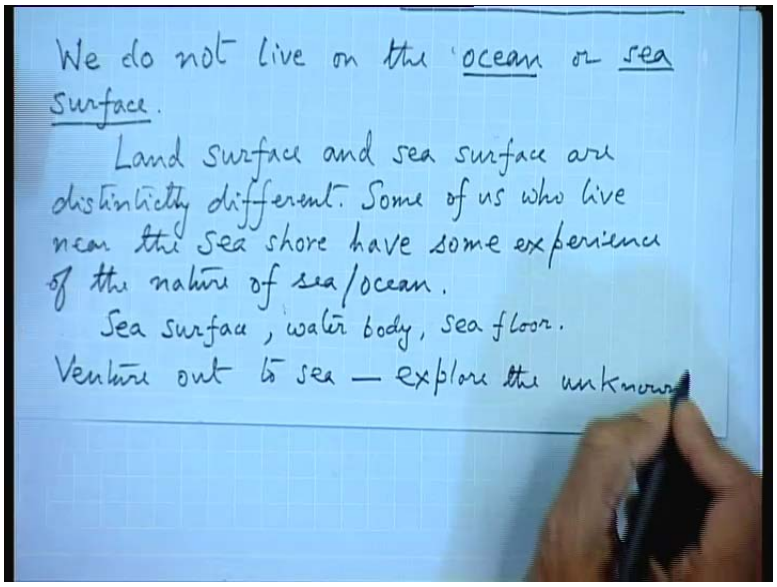

So, the course actually familiarizes with the ocean environment. So, this is the single most important aspect. First, the knowledge of the ocean environment is imparted in a sequential manner and scientifically. So, the problem with most of us is that, we do not live near on the ocean. So, the beginning of the course familiarizes one with the ocean environment. The reason is that, most of us do not live on the ocean or sea surface.

Now, this ocean or sea surface has certain characteristics, which are different from those on the land; the land surface and the sea surface are distinctly different. So, land surface and sea surface are distinct, are distinctly different. So, this is why most of us are not familiar with the nature of the ocean or what the sea has in store for us, except of course very few of us, who live near the sea shore. So, some of us, who live near the sea shore –

they have some experience of the nature of the ocean. So, these people have only some experience, but not all, experience of the nature of the sea or the ocean. So, this is the problem.

So, the ocean engineer, he has to deal with the sea or the ocean – both on the surface as well as below the surface or sometimes he may have to build a structure, which has the foundation on the sea floor. So, in this lecture, actually we will deal with these three aspects, that is, the sea surface and the water in the sea; the water, which constitutes the largest body in the ocean. So, water body. And to some extent, we will cover the sea floor. So, these are the three important parts of the ocean. So, Mankind over the ages for thousands of years, he was curious about the sea. So, he tried to venture out into the sea by making a very crude boat hollowed out of. So, first venture out to sea in order to explode the unknown. So, exploration was done.

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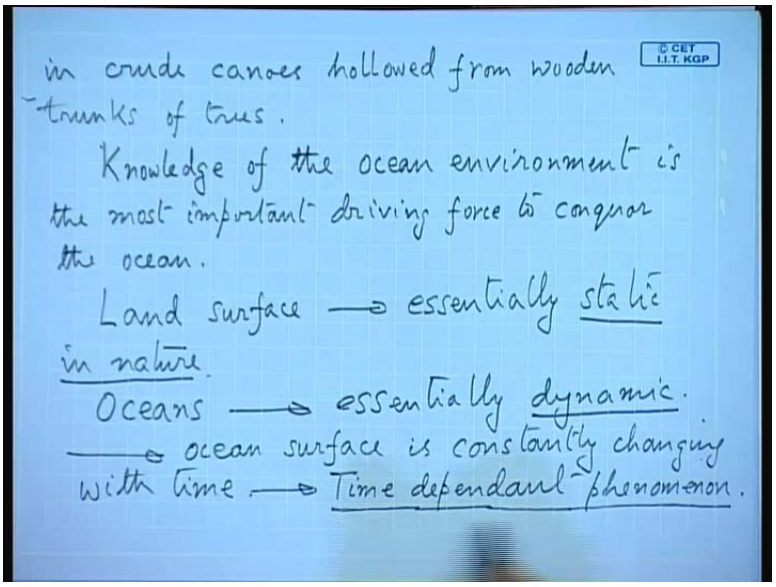

Explore the unknown of the sea in crude boats or in crude canoes hollowed out of the wooden trunks. So, this was his first venture into the ocean. So, hollowed from wooden trunks of trees. So, write till the beginning of Mankind. So, this was the development, which took place because of his curiosity of the ocean waves. So, now, of course lot of scientific study has progressed over the ages; and the knowledge is more and more developed. So, knowledge of the ocean environment is the most important driving force driving force to conquer the ocean. So, this was from the prehistoric times. This was

Mankind's first goal. It was how to conquer the ocean. But, it was not a very easy task; and still also it is not easy, because the nature is all supreme. So, this behavior of the ocean constantly perplexed Mankind.

And, in the beginning, I have told you that, it is very very different from the land surface. So, land surface is basically static. So, land surface is essentially static in nature. Whereas, the oceans – these are essentially dynamic in its form; essentially dynamic; so that means the oceans are constantly changing with time. Ocean surface is constantly changing with time. So, it is very much a time-dependent phenomenon. So, this is to be noted that, one has to encounter a time-dependent phenomenon in order to analyze anything or to come out with any scientific knowledge from the ocean. So, this is essentially a time-dependent phenomenon. Of course, time-dependent phenomenon – also there happens to.

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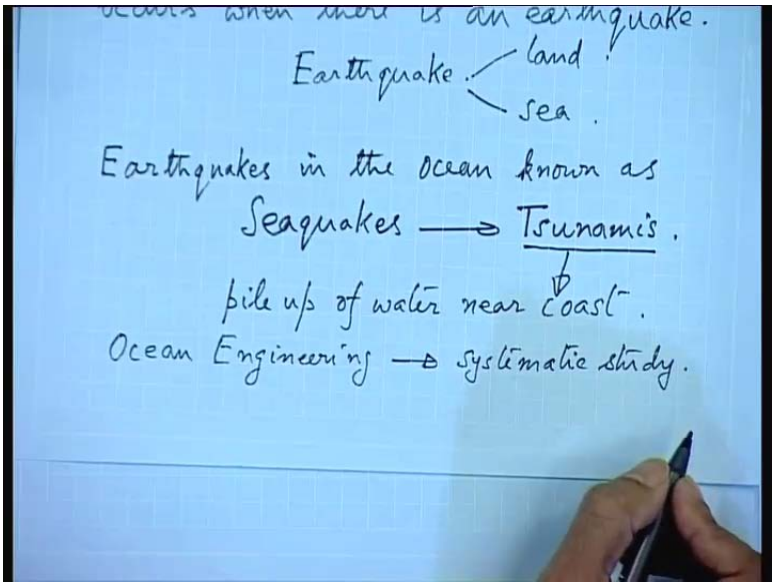

Sometimes it is experienced on land also, which is the land time-dependent phenomenon is experienced when an earthquake occurs. So, land time-dependent phenomenon occurs when there is an earthquake. So, earthquake is a time-dependent phenomenon, which occurs not only on land; earthquake can also occur in the sea. So, earthquake – the occurrence of earthquakes is basically on land as well as in sea. So, these. Now, when earthquake occurs in sea, of course the waters are also disturbed, and this gives rise to tsunamis or waves, which are emanated from sea quakes.

So, earthquakes in the ocean – they are known as seaquakes. And this gives rise to the waves on the surface – Tsunamis. So, this is all of us know what is tsunami; that is a wave, which travels very fast and hits the coast; the pile up of water takes place on the coast. In the tsunami, a pile up of water takes place near the coast. So, this actually causes havoc on the human habitations near the coast. So, this is what I wanted to point it out is that, one has to compare between a rather static phenomenon with a dynamic phenomenon. So, sea is essentially a dynamic phenomenon and one has to be. Whatever want does, it is time dependent.

So, when we analyze the structures, which we will come in the later part of the course, you will find that, the loadings from the waves have to be done in the time history; that is, in the time-based phenomenon. Now, so far, this is the nature of the ocean. Now, if one has to start a systematic study of the ocean; so the ocean engineering starts with the systematic study of the ocean waters. So, ocean engineering – you have to start a systematic study. Now, before one goes into the study of offshore structures – systematic study. So, one has to familiarize with the ocean environment.

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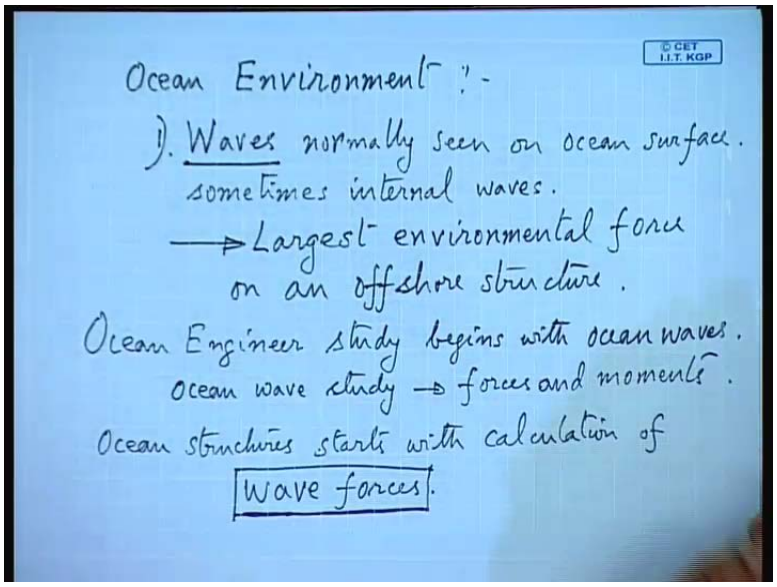

Now, ocean environment consists. Ocean environment – the major components of the ocean environment are waves. Now, waves – they normally occur on the sea surface; but waves can also occur below this surface. So, waves are normally seen on ocean surface. Now, waves occur wherever there is a change in the density. So, waves are normally to

be found wherever there is a change in density like density of water, density of air. Similarly, waves also occur inside the sea surface. Sometimes they are called internal waves. Now, these are normally unnoticed to the human eye, but these also occur below the ocean surface. They are called internal waves. So, here of course internal waves are very complex phenomena, which are not discussed in this eliminatory course. But, what is discussed is the surface waves, which are occurring on the ocean surface. So, waves constitute the largest environmental force – force on an offshore structure.

So, an ocean engineer – his study actually begins with the study of waves. So, an ocean engineer's study normally begins – study begins with ocean waves. Now, from his analysis of the ocean waves, that is, the wave height, wave period, frequency, etcetera, he calculates the forces on the offshore structures. So, from ocean wave study, the ocean engineer actually finds the forces and moments. So, these are the two most important loads, which come into any offshore structure. Forces and moments have to be found out. So, any structural analysis problem starts with the calculation of the environmental forces.

So, ocean structures start with calculation of wave forces and moments – calculation of wave forces. So, this – of course the study of the wave forces alone consumes the number of lessons, which of course be cannot be covered in this eliminatory course. But, what I have to try to discuss here is the some of these nature of these waves. So, wave forces can only be studied if one is exposed to the nature of the waves. Waves can be linear or nonlinear; what are the shapes of the waves; and how the forces are calculated, etcetera. So, this is a pretty vast area of study.

But, unless one is completely satisfied with the calculation of the wave forces, the structure calculation is not perfect. So, structure – the response of the structure or the thickness of the plating of the structures and the members of the structure very much depends on the accurate calculation of the wave forces. So, this is the primary most important aspect of any study on ocean engineering – calculation of these wave forces. So, the first – the ocean environment – the ocean engineer has to deal with is the waves. Now, waves are of course the most dominant forces in the ocean; no doubt. But, still we have other forces, which come into the ocean structure. What are these other forces? So, waves constitute the largest environment of the force. But, other forces also play an important role in the structure definition.

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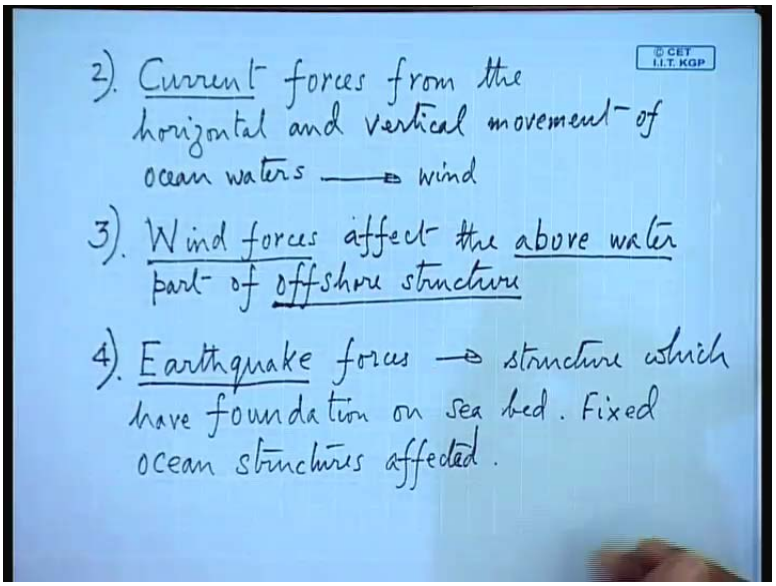

So, one of the forces, which are next in importance to the waves are the current forces – current forces from the horizontal and vertical movement of the ocean waters. Now, how this. In the study of ocean engineering, if we keep on discussing about waves and currents; that will take lot of time; say two or three more sessions will go simply on discussing how the forces and moments are calculated. But, current forces also have to be found out. So, an ocean engineer to some extent – he should have some knowledge of the current forces, which are coming from the horizontal and vertical movement of the ocean waters.

So, ocean waters as I have talked in the beginning, is never a static phenomenon; it is always a dynamic phenomenon; it is constantly changing with time. It is a time-dependent phenomenon. And we have the vertical movement of the ocean waters. So, this is caused by a number of factors. So, primary factor, which causes movement of these ocean waters are wind. So, we have wind-driven waves, wind-driven current and also thermal radiation, etcetera. So, all these are very complex physical phenomena. So, waves and current constitute the two most important forces.

And, of course the second last category is we should not forget the wind forces. Now, these offshore structures – one which we will be studying in our later lessons or in our later classes; the large part of the offshore structure is below the ocean surface. But, still a significant part of the offshore structure is above the waters. Now, what happens? How

We have to calculate the forces on the above water part? So, wind forces affect the above water part of the ocean structure. So, the wind also affects the land-based structure. So, with which of course the civil engineer is more familiar with the calculation of the wind forces. So, in a similar manner, we have to find out the wind forces, which will affect the above water portion of the offshore structure, because the structure calculation that we will be doing – we have to analyze all the forces, which are coming on the structure, because before we calculate the physical properties, that is, the plating thickness; then, the size of the structure. So, these are the three forces, that is, the waves. Then, we have current forces; then, we have wind forces, which act on the above water portion of the structure.

And the last, but of course not least, is the earthquake forces. So, earthquake forces mostly affect structures, which have foundation on the sea bed. So, these earthquakes affect… So, here actually, the earthquakes normally affect the fixed category of structures. So, fixed ocean structures are normally affected by earthquake forces. So, fixed structures – they get affected. So, here we have rather four types of forces, which have to be calculated before one actually goes into the structures part.

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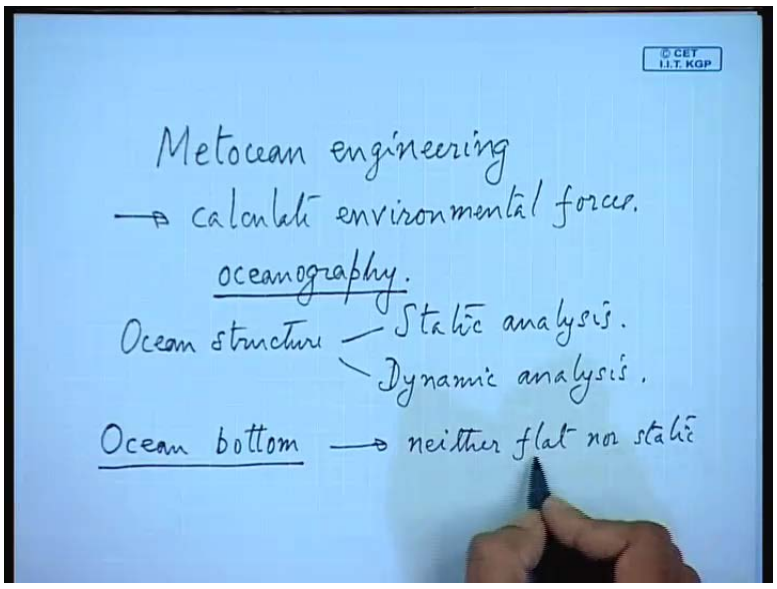

Now, these ocean environmental forces – normally a separate branch study has evolved over these years. So, that study is called metocean engineering. So, a metocean engineer – he can calculate all these forces. This is actually. Purpose of the metocean engineer is

calculate environmental forces. So, this is essentially a study of oceanography. So, any ocean engineering professional has to have some knowledge of oceanography. So, oceanography – actually no. Later classes we will see that, there are various branches of oceanography and this has developed. So, we are not going to all the aspects of oceanography. But, only that part of oceanography or metocean engineering, which you can call; which helps us to calculate the dynamic environmental forces. So, as you can see, all these forces of waves, current, wind and earthquakes – they are not static forces; they are always dynamic forces.

So, that means all these are time-dependent forces Of course, in our calculation of these structures, first we make a static analysis. So, any ocean structure calculation, you have to find out the. First, you make a static analysis; and then, you have to make a dynamic analysis. Static forces are normally found out; that is, the equilibrium forces; and then, the dynamic analysis has to be done. So, these are quite rigorous calculation and these are not simple. But, if one has to do all the dynamic force calculations, then he has to find out the nature of these forces; that is, the waves, current, wind and force, and how they are changing with the time.

So, the lecture will give you. But, the force calculation is normally I have introduce the after the physical oceanography part; I have tried to familiarize you the audience with the physical properties of the sea water, the nature of the ocean bottom. So, ocean bottom actually is another perplexing phenomenon, because the ocean bottom is also not static like the land surface. So, the ocean bottom is also constantly changing with time. So, this ocean bottom is also a very tricky phenomenon unlike the land, where one can see the surface – it is static. And these structures are resting on the land, that is, without any disturbance. So, ocean bottom – it is neither flat nor static. So, this is actually very troublesome for the ocean engineer, because if he has to build any structure on the ocean floor or sea floor. So, he is confronted with neither a flat surface nor a static surface. So why this, he will find.

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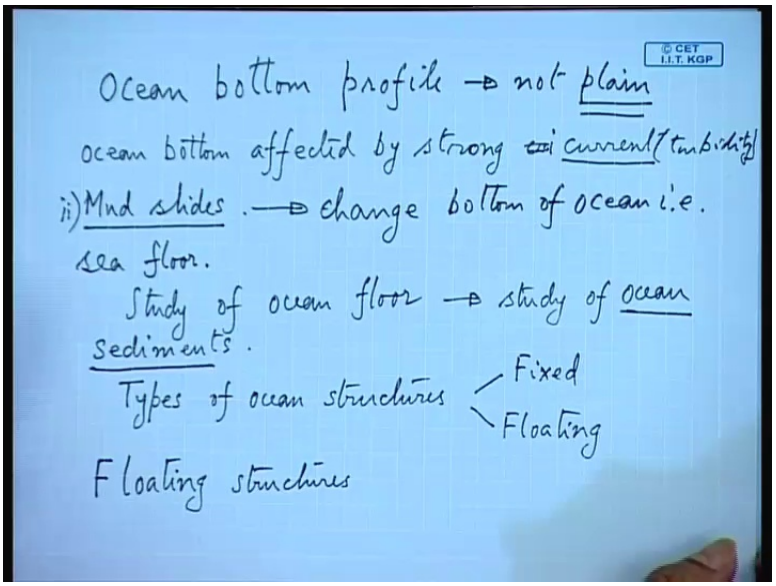

In the next, I think after the first few lectures on oceanography, one will see that, the ocean bottom profile. So, I have given the ocean bottom profile and which is not plain. So, this is discussed. What are the features of this plain – the ocean plain. And static phenomenon – of course, the ocean bottom has lot of currents; ocean bottom affected by strong currents. And because of these strong currents, that is, the soil beneath on the ocean bottom is wasted. And sometimes because of disturbance on the other parts of the ocean, there are all mud slides, which bring mud on to the particular location of the ocean bottom, where the structure is to be fixed.

So, these currents and mud slides – they are contently occurring on the ocean bottom and they are changing the bottom topography. So, these two things, that is, currents and mud slides change the bottom topography of the ocean floor or rather one – we can write – change the bottom of ocean, that is, the floor or rather sea floor. So, this is another interesting phenomenon with which Mankind has to face.

So, previously, the structures – they were not founded on the ocean floor. Mankind used to builds ships or boats, which normally sail form one part of the continent to another on the ocean surface; nothing to do of the contact with the sea floor. But one from 1970 - when Mankind started drilling for oil. So most of these ocean structures were found at the bottom. So, this created lot of study of the ocean floor characteristics and all these things. So, this is another study of the ocean floor. And study of ocean floor – one cannot

escape the study of the ocean sediments. So, these are actually very essential if one has to build a fixed structure on the ocean floor. So, study of ocean sediments have been incorporated after the physical part of the ocean floor is discussed.

Now, after this, I have discussed about the nature of the waves. So, waves are not only linear; there can be nonlinear waves and waves superimposed on one another. So, that is also a very complex phenomenon. So, after this, we have discussed the types of ocean structures. So, ocean structures – you will find that, basically two categories: one is the fixed type and the other is the floating type. So, this is discussed. Now, the fixed type more or less have to be found near the coast, that is, towards the land. And when one goes into deeper waters, then of course, the floating varieties are to be found. Now, because of these floating structures.

Now, all these study of ocean engineering actually came into focus after the 1970 oil embargo. So, in the oil crisis of the 1970, when the Arabs – they imposed the oil embargo. So, then people started thinking of drilling for oil from the ocean floor. So, that resulted in these two types of structures, that is, the fixed structure and the floating structures. Now, fixed structures – one is it is – they have the foundation of the ocean floor. So, I just now mentioned that, the characteristics of the ocean floor, that is, mud slides and then turbidity currents. So, ocean bottom afterwards… There are currents; these are called turbidity currents. So, ocean bottom waters are turbid; they are not clear. So, did you have large content of mud on the ocean bottom waters? So, that study is also important if one has to make any foundation on the ocean floor. So, this is the marine foundations – they are somewhat different from land-based foundation studies.

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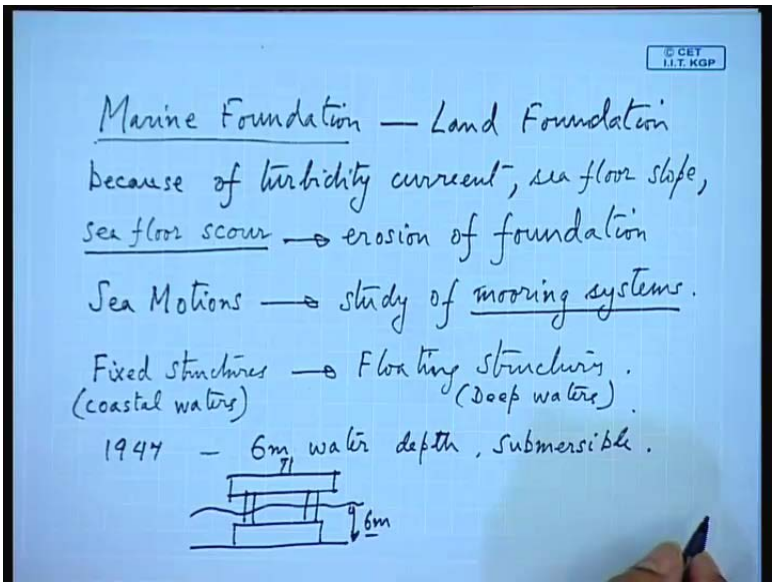

So, marine foundation studies are somewhat different from land foundations, because of this turbidity current and this is. Main is because of turbidity current, then sea floor slope. So, the sea floor may not be flat in all aspects or in everywhere. So, there may be some inclination on the sea floor. There will be turbidity currents. And the other aspect is sea floor scouring. So, this actually sweeps away the mud below the ocean structures. So, that is called sea floor scour. So, these erodes - this causes erosion of foundation. So, this erosion has to be taken care of if one builds a fixed type of structure on the ocean. There the foundation will become loose because of this turbidity current and sea floor scour. So, this marine foundation is somewhat different from land-based foundation.

But, what are these foundation types – that also has been discussed – the types of foundation and how to counter the sea floor scour or the erosion of the foundation by the current. So, these are the things, which normally affect the fixed structure and floating structures. The floating structures actually – they do not have the connection with the sea floor in so much; that is, mostly they have their foundation on the water.

But, the main problem of these floating structures in ocean engineering. In ocean engineering, our main purpose is we are drilling for oil. So, floating structures – they are affected by because the structure has to float. So, that means the structures should have sufficient buoyancy to support the weight of the structure. So, this is the primary requirement for any floating structure. The buoyancy requirement has to be done.

The other aspect that, if one has to study floating structure, is the motion aspect. Why? Because if the structure has very large amount of motions – there are rigid body motions; or, it is displaced from one place to another – displaced from where it is drilling to another place; then of course, the process of lifting oil from the deep water oil wells will be stopped or hampered. So, these floating structures are centered around the philosophy of motion minimization; the motion has to be minimum.

So, with this, the structure has to be designed or the size of the structure has to fix that, motions, which is related to especially the horizontal and the vertical movements are very much restricted. So, with this, the mooring systems from the sea motions for floating structure, one has to design the mooring systems of that form. So, sea motions give rise to study of mooring systems, which I have discussed. So, this is another area of study for the ocean engineer. The mooring systems – efficient mooring systems are to be designed for the holding down of the floating structures on to the sea floor. So, these are some of the aspects, which are required.

Now, I have gone from this study of the fixed structures to the floating structures. Here actually, there is a small diagram, which actually. First – fixed to floating – this occurs. So, fixed structures normally is to be found in coastal waters. So, coastal waters – one counters fixed structures; and these floating structures are normally in deep waters. Now, the ocean engineering actually started in the year 1947. So, this was in Luciana – 6 meters water depth. So, the structure that was conceived was what was called a submersible. Submersible – that means it had two sort of pontoons: one rested on the sea bed; and the other actually were from the top part of the pontoon or the top haul, the drilling actually took place. And the water surface is somewhere here; and this is only 6 meters. So, this was started in the Luciana – certain lake.

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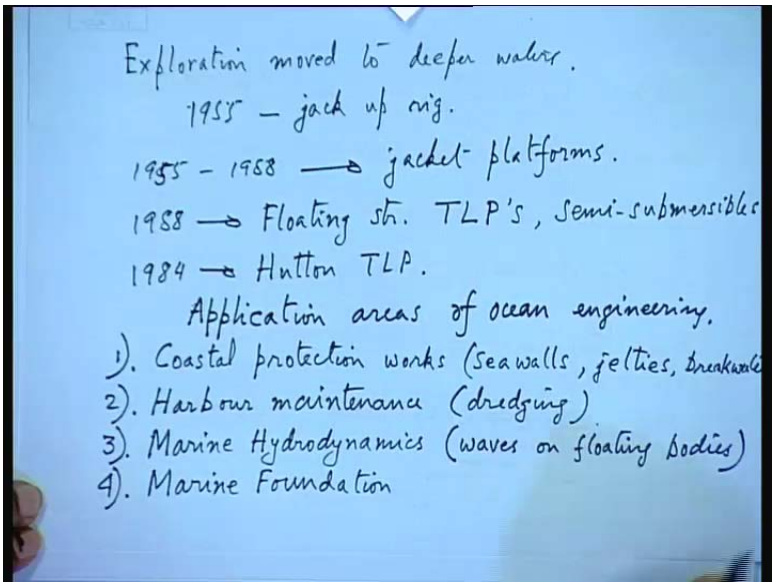

Now, with this, of course gradually, the deeper water explosion took place. So, exploration started going into deeper waters – moved to deeper waters. Now, deeper waters movement took place from 1955. 1955 – actually, the first jack up or jack up rig was designed. Then, of course onwards right up to 1988 – 1955 to 1908 gave rise to what is called the jacket structures or jacket platforms. So, these are fixed structures, which are piled – driven by piles on to the sea bed. And after 1988, people started or engineers started thinking about floating structures. So, floating structures for lifting oil or drilling for oil. Normally, they are tension-like platforms. In short, they are called TLP's or semi-submersibles.

So, these came into being after 1988. And in 1984 actually, it was Hutton TLP was the first platform, which was commissioned. There is a Hutton TLP in the north… This is the famous TLP. And after the Hutton TLP, other TLP's came to be… So, this is how the progress of ocean engineering started. And of course with the primary requirement, was the oil industry. That is our requirement for energy from the ocean. That was the primary requirement.

Now, the application areas of ocean engineering; there are lot of application areas. Now, number 1 is the coastal protection works. Now, these actually I have not discussed in this ocean engineering course, because they are mainly covered in any course on civil engineering or coastal engineering. So, coastal engineering is also a part of ocean

engineering. So, coastal protection works. And these are normally sea walls. So, these structures normally protect the coast. Then, you have jetties; then break waters. So, these are primarily the civil engineering structures, but essentially land based near the sea shore. Another ocean engineering application, which is called harbor maintenance; so this involves dredging. This is the concept of dredging and the dredgers. They will come under harbor maintenance.

Now, of course these will be their study. And number 3 – it is hydrodynamics; or, rather one should write marine hydrodynamics. So, without the knowledge of marine hydrodynamics, which normally is the study of the waves – waves on floating bodies. So, this is normally covered in this chapter and course on the application of marine hydrodynamics. Then, I have just now talked about marine foundations. So, what are the specific problems, which occur for marine foundation design? So, like the problem of turbidity currents, scouring, etcetera, those have to be taken care of.

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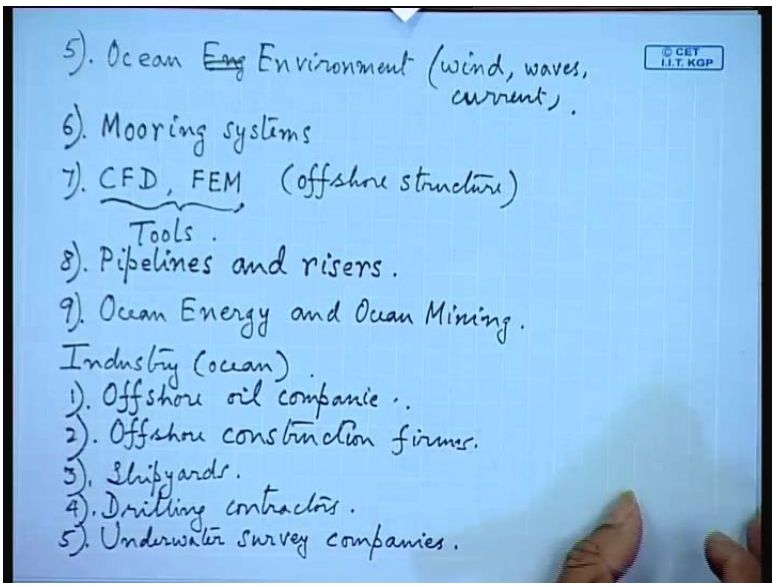

Now, other is the ocean environment; this is the ocean environmental studies. So, mainly wind, waves, current. So, this I have told you. So, this comes under the aspect of metocean engineering. So, this is wind, waves, current; then is mooring systems – very very important for floating structure design. So, unless this structure is secured to the ocean floor, then there will be lot of motions and then drilling is stopped. Then, of course, 7 deals with CFD or computational fluid dynamics and finite element methods to

find the structure analysis. So, this offshore structure analysis is centered around this. So, these are basically tools for structure design. So, these of course there are number of courses and books on CFD and FEMs. So, there are nothing specific about the ocean engineering. So, only these tools you required to find out the structures.

Then, the other things are pipe lines and risers. So, not only we have platforms. But, if one has to lift oil from the ocean floor, then it has to be lead through pipe lines – the pipelines, which will be resting on the ocean floor; and risers, which take this up to the platform. So, that is another aspect. Now, what has not been discussed in this elementary course is ocean energy and ocean mining. So, these are completely new topic. But, of course in one course, we cannot discuss this.

And, the industries, which are mainly concerned with the ocean, are the offshore oil companies; then, offshore construction firms. Then, of course we have ship yards; then, drilling – drilling contractors. And last, we have these surveyors – underwater survey companies; so these some of the ocean industries, which are engaged basically in the oil production or search for oil. Of course, this is not the end of the list; there are other companies, which also do for other – their own requirements.

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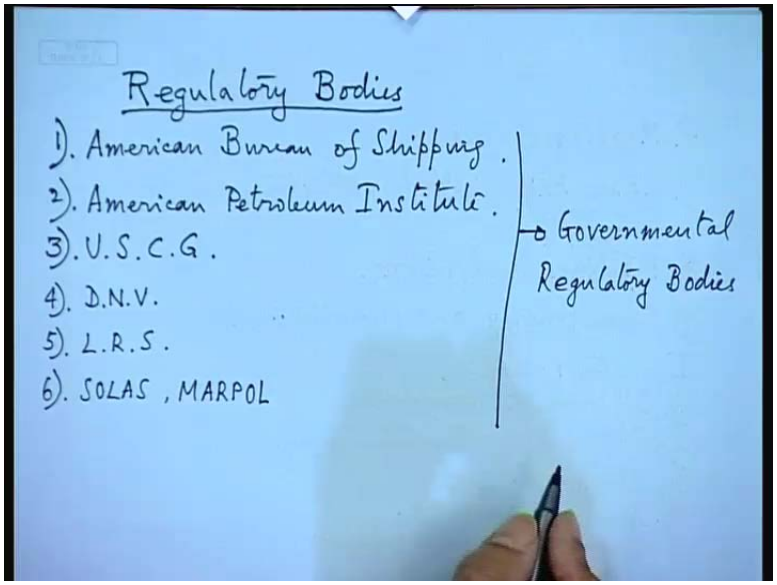

And, the last is one has to know what are the regulatory bodies. This is actually very important if one is exploring oil especially in the ocean waters, because if there is a disaster, then there will be lot of oil pollution. So, one of the bodies is the American

Bureau of Shipping. Then, we have American Petroleum Institute. Then, United States; in short, I am writing. So, this is U.S.C.G. – United States Coast Guard. Then, we have the D.N.V. or Det Norske Veritas. Then, we have Lloyd's Register of Shipping; and of course SOLAS, MARPOL rules. So, any offshore structure that is to be designed – it has to confirm to the regulation stipulated by these governing bodies.

So, mostly, these are governmental regulatory bodies. So, these are the rules, which are propounded by these regulatory bodies, have to be compliant. So, that is the primary requirement of any offshore structure. So, whatever structure one does, at the end, he has to see that, the rules from the regulatory bodies are compliant with. So, with this, I finish my introductory lecture in the area of ocean engineering. Of course, in one session or one semester, all the aspects that cannot be covered; but this is just to give you inkling or an insight into what is happening in the ocean and how one has to engineer the ocean in order to have his for Mankind's own advantage. Primarily, what we have discussed is the exploration of oil.

Thank you very much.