Lecture - 16
Geophysical Investigation in Offshore Environment

Welcome all to lecture 16. In todays lecture we are going to discuss about geophysical investigation in particularly related to the offshore environment. So, if you recall whatever topics

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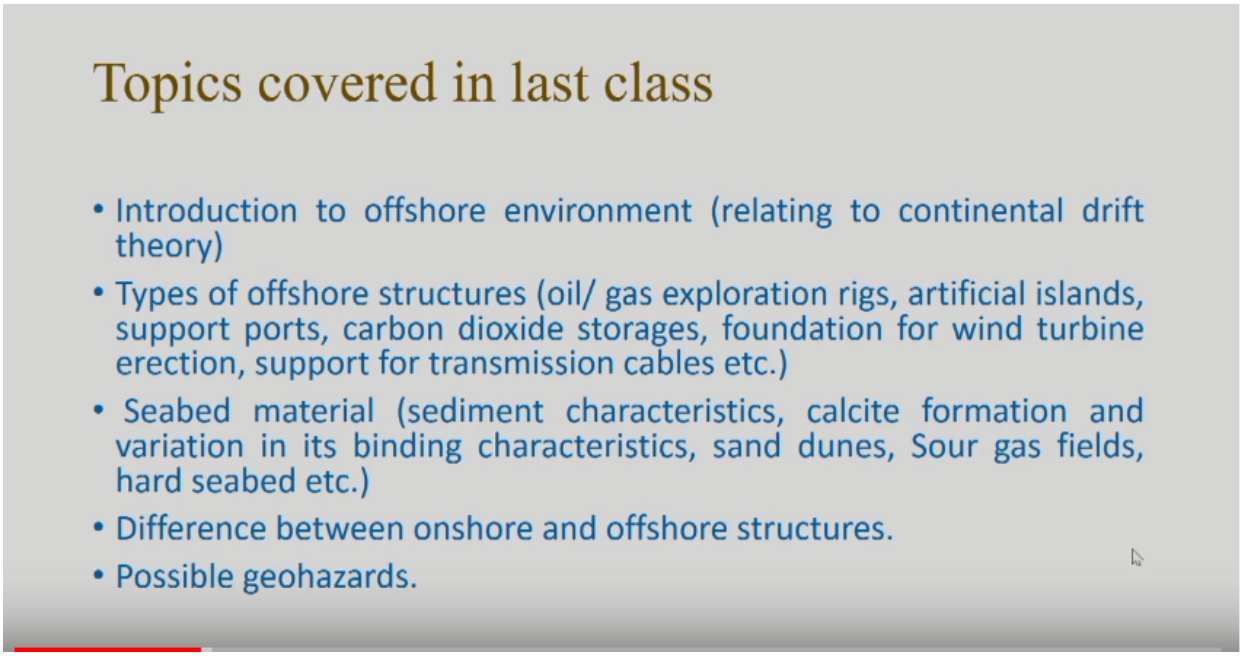

we had covered in the last class, we started with the introduction of offshore environment, because in the last class till lecture 14 we are precisely discussing about different classes of investigation, different phases of investigation, different methods whether it is geo technical or geo physical methods, interpretation wise we were discussing more precisely or related to onshore structures that that the the kind of structure we are constructing or targeting whether it is for new structure, whether it is for journeying structure, whether it is the suitability for construction material mostly related to land masses, in the last class we are also highlighted because of several reasons people are also moving offshore particularly related to as we see related to, whenever we see whenever we consider to very dynamic starting with magnetic poles, then reversal of magnetic field in the geological timing scale, then as we go on to the down surface and deeper than that we see the most of the process are getting governed by continental drift, that is we can say like that is overall governing the configuration of land masses, configuration of oceans and the process happening at the interface of the land masses as well as the oceans, more precisely to be, to be said like the continental margin, continental shell, ridges, continental rise, every self play an whatever we have discussed in last classes, as a result of which sometimes you have or having gradual variation between the adjacent continents as well as the ocean influence, sometimes it is too steep depending up on, what are the processes governing up on, governing at that interface than the relative thickness of continental plate as well as the oceanic plate so on and so far, in the last class we also discussed particularly the continental margin which has been understood as the possible locations for oil and gas depositions which particularly the agency which are responsible or interested in exploration, its its main target for detailed investigations. So, one is this thing like whenever we are interested go for oil and petroleum, we can go for detailed investigation which is classified under also the

structures of the investigation, in addition to oil and gas exploration in the last few decades, other useful other applications of offshore environment had also coming to the picture, whether it is related to transmission cables link on the sea floor or may be long term story for carbondioxide gases or similarly as as erection of wind turbines, off shore because the the there will be continuous supply of winds and relative fluctuations will also be less, in comparison to land mass, it will be far far easier as far as the maintenance goes, if you are constructing or erecting wind turbines offshore. Similarly, we also discussed like on shoo offshore, lot of time people are going into a in-order to setup some heavy industries whenever we are creating some artificial islands for tourism, for polonisation purposes, even as for also airports, even for the case of tunnels, bridges, lot of investigation of solar happening, and the support ports did I mentioned earlier, in-order to minimize the traffic moment near the actual costal line. So, the bigger container traffics can go to the support ports and from there to the actual costal line material can be imported to small vessels. So, accordingly the depth and the other things can be can be can be controlled or decided, you also discussed what are all the different materials starting with sediment characteristics depending up on the time required or given for the sediments to get deposited at a particular location, some might be normally consolidated, on the country you can have over consolidated sediments so on and so far. So, that will govern, how the sediments going to respond once you lay particular foundation, whether it is for exploration purpose, whether it is as communication cables, whether it is encode structure, how it is going to respond?

We also discussed once the calcium carbonate which is present in abundance particularly on merona, environment, once that gets receipted it acts as a binding material and and and binds the sediments which are available at the seafloor. So, depending up on the binding characteristics of the calcite, the binding characteristics of binding material or encoder may also vary, then we also discussed sour gas fields, which are particularly the deposits of nitrates whether in formula of small bubbles in pour fluid or between the layer which can cause two problems, one I like exploration, explosion, second thing may be because these are poisonous that can lead to even death. So, So, we have to be prepared for that then we also discussed about hard seabeds, how they can pose more prolonged in terms of resistance offered to pile driving. Similarly, when whenever you are trying to get more and more resistance as, as sharp resistance from hard drop or hard bed it will be difficult to in comparison to relatively tougher material, we also discussed what are sand dunes and how they can control or govern the serviceability or design type of the structure whether in-terms of settlement, whether in-terms of differential settlement or any other kinds of failure, we also discussed potential differences between onshore structure or an offshore structure and what are the possible geohazards? So, this why I am going to in this much detail, because offshore as we know like many of the basic courses this offshore structure is not covered. So, whatever I have discussed in last class, I have just given you the revision briefly which are now the topics which we have covered

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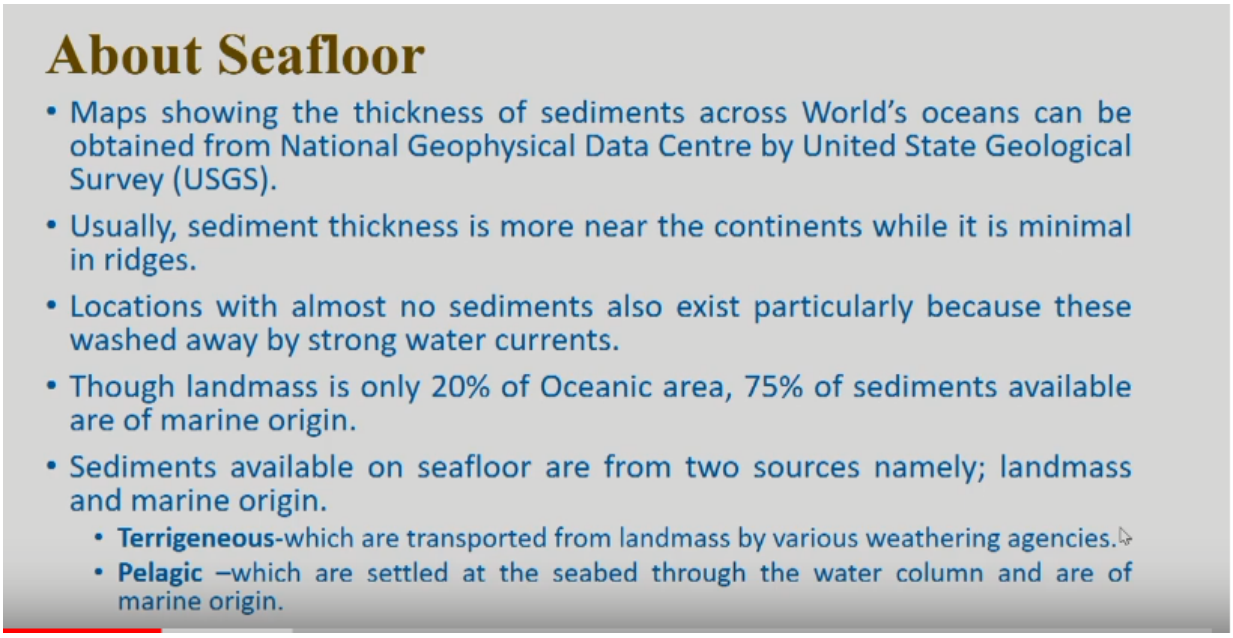

Now, in before going further into detail geophysical investigation, certain more points are there, we discussed about seashore material, we discussed what are all the problems it can cause. So, there are maps, particularly which are indicating the thickness of sediments across the globe, whether it is land mass, whether is ocean. So, those maps particularly referring to the national geophysical data center that is NGDC under united states geological survey. So, one can refers to those maps and that will give you idea about like your possible location that continental margin where you are going for detailed explanation, what is the overall depths of sediments as per those margins, one can go about this and depending on that depth of sediments you can get an idea what method is very suitable or the kind of material, the kind of depth and that will also give you an indication like what is the depth, you are interested to explore for based on detailed investigation, usually sediments are available in more thickness near the land mass in comparison to the ridges which are available within the sea, however there are other locations also, where you don't find almost any sediments because whatever sediments was deposited in a small tank get washed away by high water currents. So, they can be possibility within seashell where you can very thicked sediments, did I mentioned like continental margins which will be adjacent to your actual land mass see you can expect relatively larger thicknesses in comparison if you go to ridges , you have lesser thicknesses then were the water currents are higher particularly in intermediator, you can have relatively low sediment deposits at certain location, we know like land mass, the entire land mass which is globally available though it is only 20% of total oceanic surface, however the landmass containing the sediments 75% of sediments comes from the marine origin.

So, the sediments which is deposited which ever we see onshore, almost 75% of that sediments is coming based on the marine deposits or marine origin. Similarly, the sediments available on the sea floor itself can be categorized broadly into two categories, one is known as terrigeneous sediments which are more precisely called as those sediments which are transported from actual land mass to the ocean environment by means of different weathering agency whether it can be glacier, it can be because of river, it can be because of wind, it can be because of gravity. So, those are called as terrigeneous sediments, then you have pelagic, pelagic sediments which are particularly, the sediments which are of marine origin, but get deposited as it settled, as it is undergone the process of settlement through, through. Sorry! for that. So, precisely you terrigent, terrigeneous sediments or you can have pelagic sediments which are available on sea floor, then so we know like sediments, where the sediments are there, because either it has been settled, because of stresses offered by the water column and or by different weathering agency which brought the sediments into its in-situ condition

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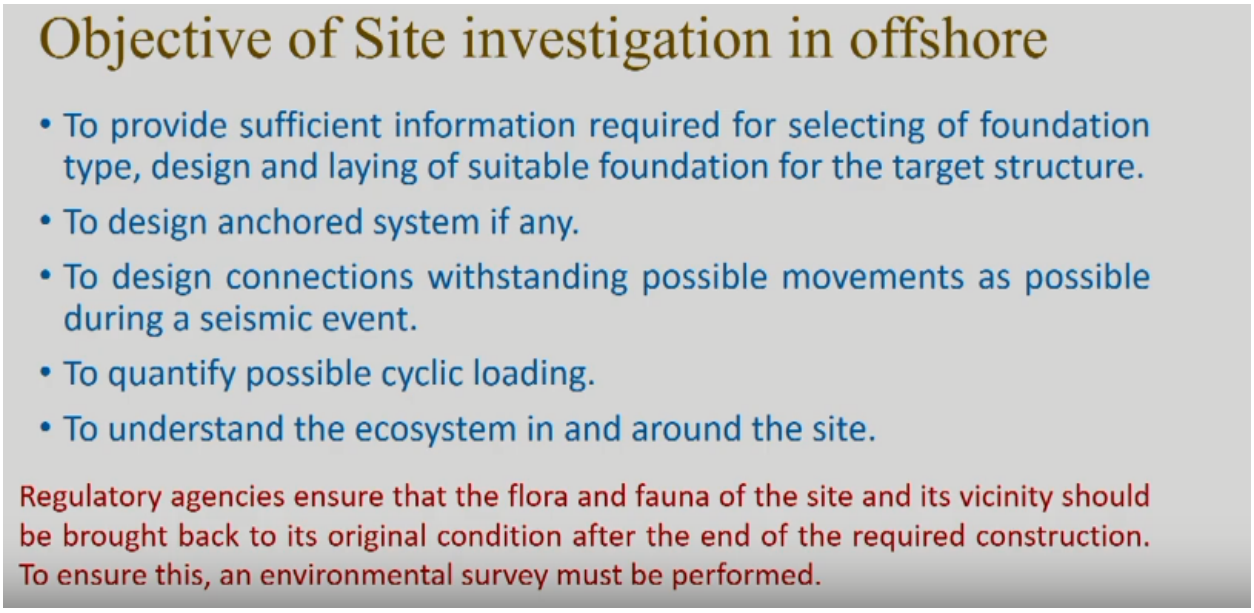

and where those get settled. Now, we know the sediments are there, we know below the sediments or sometimes even within the sediments there are possible locations where you can have a deposits of your interest, may be gas and oil deposits which you are interested to explore and so that you can bring out on to the surface for different purposes, secondly for to use at suitable construction material or in-order to create an artificial island or foundation for wind turbines, you have to go for detailed investigation. So, just like when we were going for detailed investigation also there are certain objectives when we go for site investigation also. So, these particularly the objectives, the first one is to provide sufficient

information which is required so that you can select particular kind of foundation, how the foundation design will be governed and once the designing is over, how the foundation is actually going to be light or how you are going to lay the foundation in it institute condition. So, everywhere the the information whatever you are gathering for your offshore investigation will play a role. Its related to selection of foundation, its related to design of foundation, its related to actual execution or laying of the foundation in its actual condition. Second thing, if you are going for anchor kind of structure, then what are the stresses which are going to control the design of the anchor, the behavior of the anchor, the strength of the anchor will also get input from your site investigation of offshore structure, third thing if you are, if you are designing some king phonation particularly for pipe lines or even for communication cables. So, So, the beside investigation is going to give some input like what are the expected level of moment the particular connection has to withstand, otherwise there will be a failure in the actual structure.

So, that is another objective particularly when are you going for offshore which was not there in onshore, repeatedly this anchor in, then to quantify possible cyclic loading as I mentioned last time in comparison to onshore structure, offshore structure are dominated via cyclic loading, whether it is because of ice, because of water current, whether or whether because of seasonal variation as well or may be due to the gravitational pull by maybe moon or sun that will again lead to change in your water column tab as well as result in cyclic loading. So, in-order to possibly understand or quantify the possible cyclic loading, you have to have detailed in site investigation, then to understand the overall ecosystem, the flora and fauna, the ecology of the system, the geographical features which are available in and around the study area, you have to have detailed site investigation for often. Now, in very important thing here like in in addition to go for understanding the soil and subsoil information which we generally do for in case of onshore structure also, what happens when we go for offshore investigation, there are very separate regulatory agencies authorities are there, the objectives of those agencies have to ensure that the flora and fauna of the, of your study area and its vicinity are should be maintained and it should be disturbed as minimum as possible. Further, you have to ensure that the end, once the project gets over, the ecological of the system should be brought to its original condition. So, this is though, its, you can consider it as a part of a object or you can consider it is equally important than the objective, but it is because of the constraints or guidelines provided by the regulatory agencies. So, that's why maintaining the ecology of the system is equally important in addition to know about the side. So, that you can get an idea about the foundation, you can get idea about learning condition, design parameters and so on and so far,

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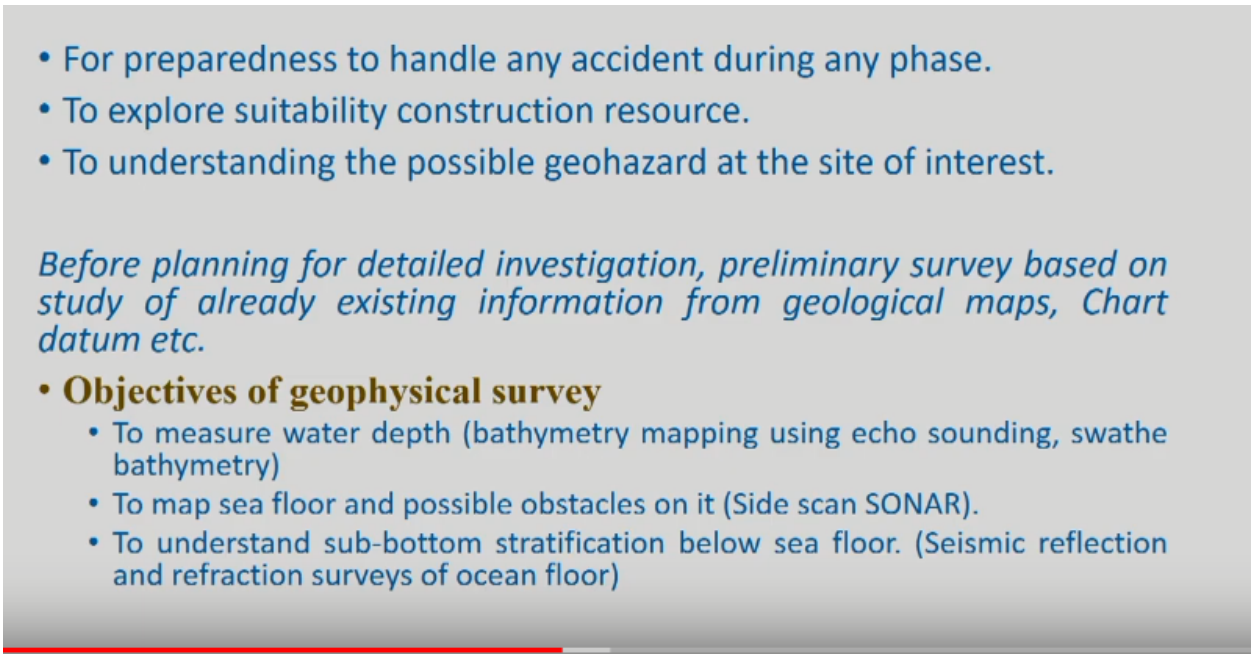

then, further preparedness that they mentioned like in later stage, during construction time, its its almost impossible to change your design parameters or a foundation choice. Secondly, you cannot go for ground improvement. Thirdly, in case of any accident. So, once you do proper investigation, you will get some idea like whatever the chances at later stage some kind of accident, possibility is there, or it is not there. So, accordingly you can prepare, the team you can be prepared at the side, once you are going for detailed investigation like geotechnical investigation, where we are actually going to drill or during laying of the foundation or may be during the operation part also. So, operates the accident can happen during geotechnical, it can happen due to laying of foundation, it can happen during actual exploration purpose, we are, we are, when we are actually exploring oil or gas at the sensitive condition, then as per in the suitability of construction resources, what are resources available to you and depending upon those resources whether those resources are suitable to provide, to lay the foundation which we are going to design, that design making will also help once you go for detailed site investigation, next one is to understand the possible of geohazard at the site of interest, whether it is related to geology, whether it is related to echo, whether it is related to tsunami, whether is related to seismicity and so on and so far. So, that once you go for detailed investigation like this, all, all possible geohazards will be identified and you will get an understanding like what are the design parameters which you will be resembling, each of these geohazards and you will take appropriately the condition in to your design of the foundation.

Now, before planning for any kind of detailed investigation, then if you remember, we also told particularly when we are going for onshore investigation, you have to go for reconnaissance survey, you have to collect experience, you have to collect the reasons of failure if any from the surrounding regions

or the other projects which have been concede, which have been concede, constructed in the vicinity of your propose side. So, is the case with your offshore investigation, before going for any detailed investigation, you have to collect already existing information which may be available in terms of geological map, it may be available in terms seismological map like seismic settlers map, it may be available in terms of chart data, it may be available in terms of the map just I referred from UAGS, which give me an idea of like what will be the depth of overburden or what is the depth of thickness tentatively available at your site of the interest, once you have those information that will give, that will give me an idea or some confidence which is required to decide what are the methods we have add of for a particular investigation and what are the challenges you may face, when you go for detailed investigation. So, with this those are the objectives of site investigation, in todays class, as they mention we will be discussing about geo physical survey. So, what are the objectives of geo physical survey in case of offshore investigation, if you remember in case of onshore investigation, give an interest to find out different stratigraphy, the soil type and sand characteristics of the soil in particularly, but in case of offshore investigation because the environment is different. So, you have some more objectives here, the first one is called as to measure the water depth, remember in onshore there was no such objectives because and also there will be water and beneath the water actually you will be having the sediments and below the sediments you will be having the rockies etc., So, So, you depending up on what kind of structure you are targeting for it may be possible based on the soil itself or may go to deeper medium depending up on what kind of structure is that? So, in order to I mean, the objective lies here is to measure the depth of the water on which you are going for detailed investigation. So, you can this is particularly called as bathymetry mapping, you can done it based on echo sounding method, you can done it using swathe bathymetry. Second objective is to measure the sea floor, the sea floor again it came into existence because of different processes which are still happening at the sea floor. So, you can have discontinuous channels, you can have some uniform depositions and even they can be later variation in the sediment depository in on the sea floor, in addition to this, you can have possible obstacles which have been deposited, which were not there in actual condition but have been deposited may be in different processes. So, for this you can go for site scan SONAR, it is sound navigation and ranging.

So, based on the vessel, you can have this kind of investigation, you put receiver on both the sides and then, get an idea about what are the, what is the characteristics of the sea floor and what are the kind end type of obstacles which are available on the sea floor even the broken vessels which, which were some else may be long back or may be some other objectives, which but are actually there at the side. So, that later on once you go for detailed investigation or exploration purpose, you will not encounter those obstacles to be there at the site of the interest and a foremo the last and the most important thing is to understand sub-bottom stratification. So, in onshore, we started exploding from the top itself, but offshore

investigation because the, the environment on which you are lay your foundation it is actually starting after certain depth of water column. So, certain method which can actually get you an idea about sub-bottom stratification below the sea floor, you can usually for seismic reflection survey, seismic reflection survey. Yes! we are practicing onshore structure. So, bathymetric as I mentioned here, the objective is to determine

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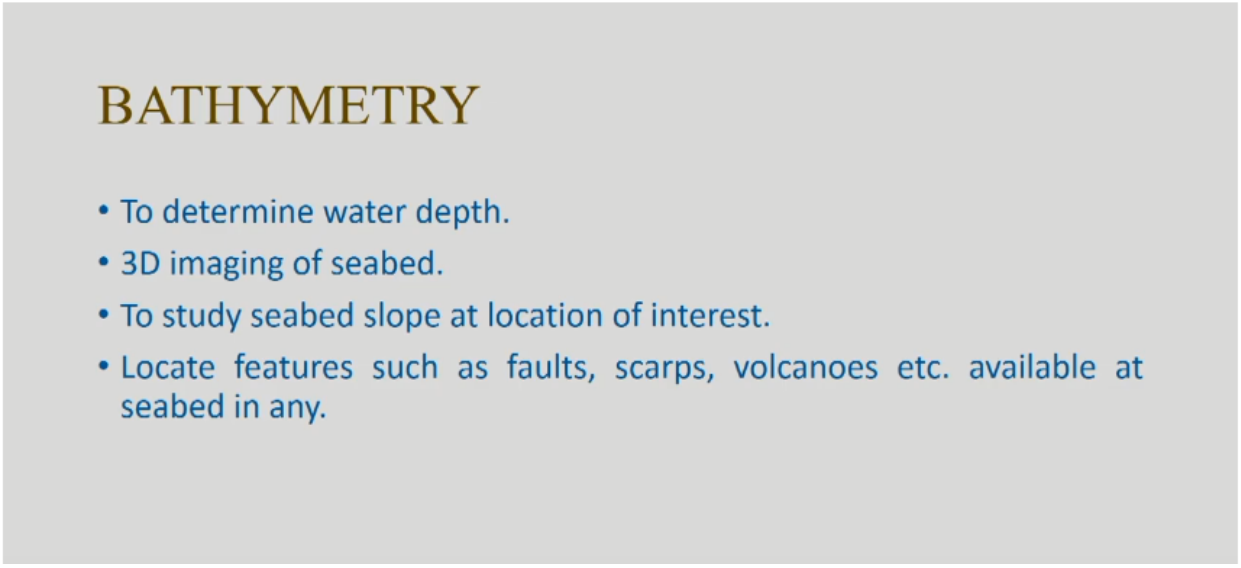

water depth at at at you're the point of observation, if you are interested to survey for larger area then bathymetry possibly kill you, give you an indication of variation in water depth along your study area or indirectly giving you an indication of about sea floor, then 3D imaging of sea bed, because there will be some obstacles also. So, there will be 2D imaging and if you are doing the survey for a larger area that will help you in getting a 3G, 3D image, how how the overall ecology of the the topography of the sea floor and possible obstacle is changing along the study area. Third one, to study seabed slope at the location of the interest, that will also possibly indicate you the possible variation or topography or if some slope is there, whether there is any chance of discontinuity is there or whether there is any ridge or any other characteristics which available there or may be see mount. So, that will also get, you may get some idea once you do bathymetry mapping, then another important objective of bathymetry mapping is to find out features such as faults, scraps, volcanoes etc., which are actually available, but unless you do the test, you will not be able to get those things. So, this is an objective of bathymetry.

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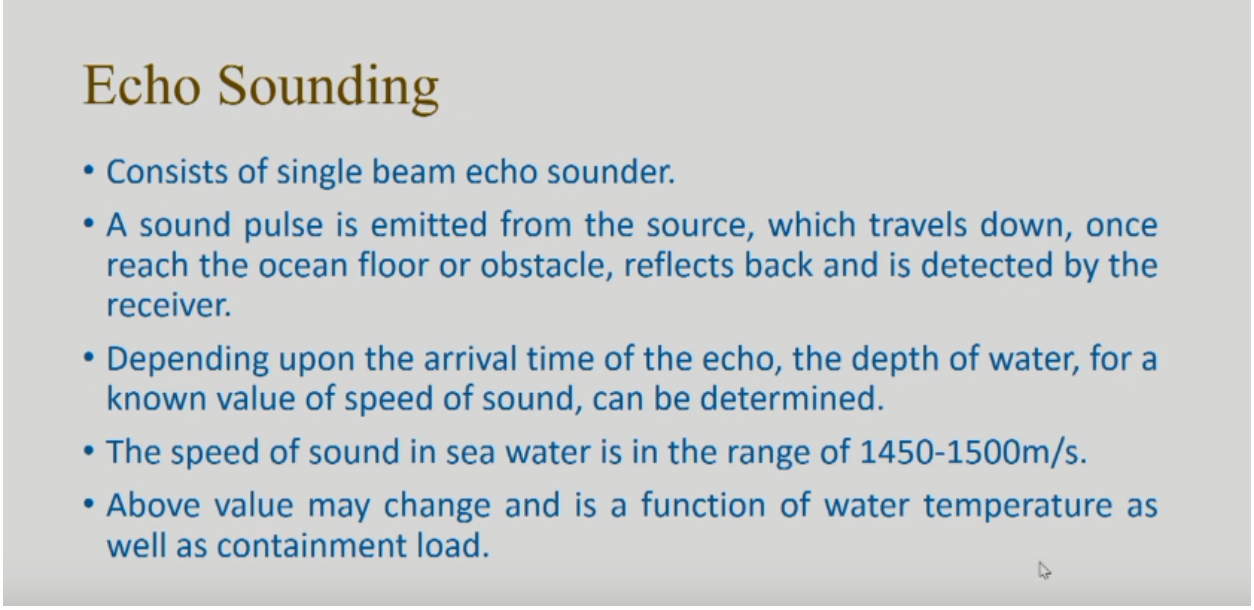

Now, as I mentioned here so the the broadenly if you say there are three objectives ones to know about water column, second once you pass the water column, what is the characteristics of seabed, third, once you go below the seabed, what are the stratification, what are the different layers and characteristics of those layers and depending on those layer characteristics, what kind of foundation, what will be the depth of the foundation, what is the mechanism based on which you can actually start up your foundation inin-situ condition, all those will be collectively consider as the broad three objectives of offshore investigation. So, first one, I mean in echo sounding, what you do, the test usually consist of single beam of echo sounder, what it does? It actually emits a sound pulse from the force, this is generally loaded on a vessel, vessel like like hips, which are particularly design for this kind of investigation in to the sea shore, those, those investigating vessels or onshore investigating systems will contain echo sounder which will emit a particular sound wave, what will happen, this sound wave will travel towards the sea floor, once you travel towards the sea floor either it is getting reflected from the sea floor or at the at the location where you have actually emitted the sound wave, if it find some obstacle again it will reflect back.

So, whether it is a sea floor, or it is an obstacle, in both the cases sound, whatever sound pulse you are generated, it will be reflected back, and it will be recorded by the receiver kept at the same vessel. So, depending up on the time required between emitting a sound wave and the time when the same sound, the echo of the sound is getting detected the receiver, that is going to give you an indication about how much will be the depth of the water at that particular location. So, depending up on the arrival time, depending up on the speed of the sound in air, in sea water of course we all know the speed of sound in air, the speed of the sound in sea water will be significantly higher. So, once you know these two parameters, you can get the idea about how much will be the depth of water at your observation time, the speed of the sound I

would like to highlight here, particularly in sea water within the range 1450 to 1500 meter pert seconds is the almost like 4 to 4.5 times higher than what is the speed on ground surface or in air, above values may change, the speed of the sound may change depending on the temperature of the water as there else, the containment load which the sea water is containing. So, those two parameters more more precisely can affect the speed by which the wave will be travelling and will be reflecting back, and this sequence will be recorded at the receiver. Now, there are two systems just like your any geophysical survey, two systems are there, active system

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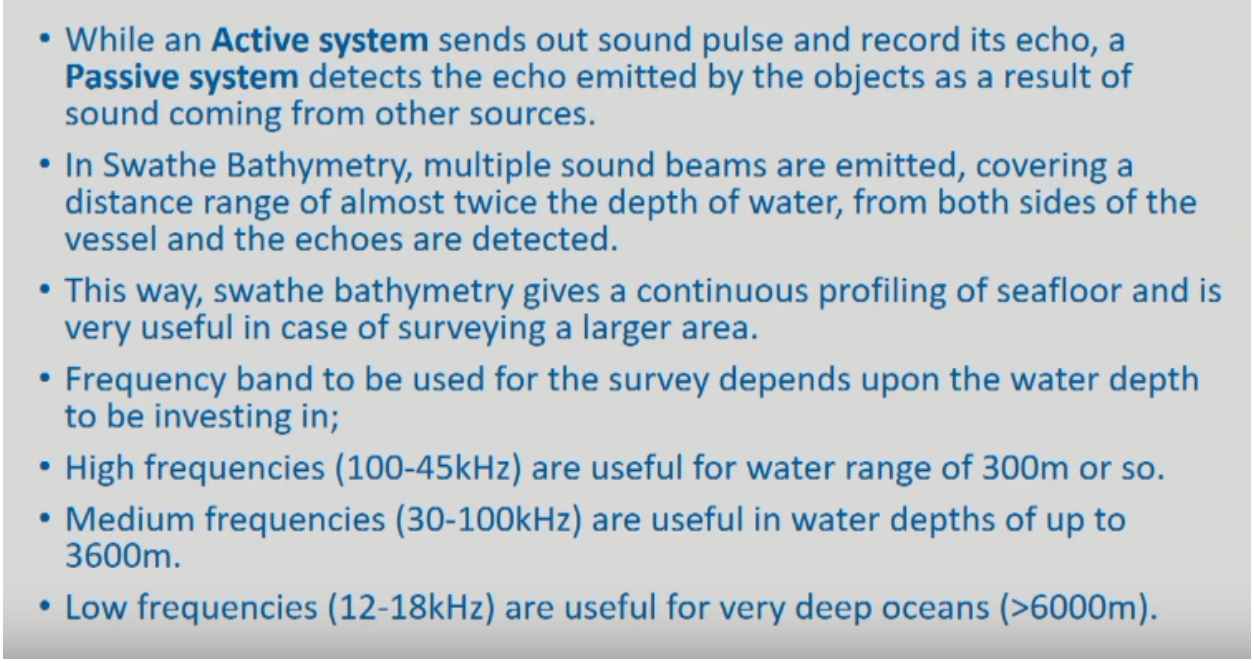

Which will actually detects the echo, which will actually send an echo and record its, which will actually send a sound pulse and record its echo as obtained after reflection from sea floor or an obstacle in, in between, on the contrary you have passive system which will actually detects the echo as a result of some sound coming out from some other source. So, in passive survey you are not emitting some kind of sound wave, but we are actually detecting, so it's a second part of your active where you are having a receiver, you will be actually detecting the arrival time, which is the source may be something else, because depending up on the arrival time, because of the characteristics of the echo, we are actually understanding the characteristics of the sea floor, now this I told about single beam or single impulse, what you do in swathe bathymetry, again the objective is to map sea floor and water depth, so there what we do, we consider multiple beams of sounds which are actually reflecting at the same time, but covering larger area. So, some beam will be near to the vessel, some will be again at some inclination of the vessel so on and so far on both sides of the vessel. So, that's how at the same time, you will be able to record more

number of echoes as obtaining or as reflecting from the larger distance, the larger distance range with respect to the vessel. So, vessel is there, then there will be reflection from some location on the sea floor adjacent to the vessel, later on some reflection will be there from some sea floor which is may be at larger distance with respect to the vessel and so on and so far, you are doing this simultaneously, the same time you are able to map or understand the sea floor characteristics for a larger range. So, generally we go for the distance with respect to the vessel equal to twice the width of the water column at the vessel location for consideration. So, two times on this side, two times on the other side, you can get an idea like, what will be the overall study area which is to be surveyed at same instances.

So, the objectives remains same you are generating a sound pulse actually retracting its echo, in single beam you are actually designed the water depths at the observation points, hence you go for multi beams, you are actually doing the same thing but over a larger area and that too simultaneously. So, this phase swathe bathymetry if you are continuous profiling of sea floor and is helpful if you are going for surveying a very larger area. So, you can again, when you are going for significantly larger areas, you can divide the entire area into number of grids to this kinds of survey along each grid lines, divide the entire area into small small grids along the grid lines, you can do more number of tests that will help you in understanding overall the characteristics of the sea floor or may be possible obstacles defining, now we know depending up on the frequency characteristics, different sources can be used to explore different water columns. So, to give you an idea the high frequency forces which are particularly capable of generating 100 to 450, this should be 450 kilo hertz, this kind of high frequencies you can taker in to account particularly when you are understanding, when you are interested to understand sometimes like water depth of 300 meter or so same way medium frequency can go from 30 to 100 kilo hertz, when you are interested to go for investigation and water depth of up to 3600 meter, third one when you are interested to go for deeper water columns or deep oceans as given here like greater than 6000 meter, you can particularly use a source which is capable of generating low frequencies, that is 12 to 18 kilo hertz, based on this the choice of the source can be made and further in-order to understand the choice, you have to get some idea based on already existing report like what is the depth of water in that particular location, you can choose a particular source or may be you can go for echo sounding test, get an idea about, get an rough idea about what will be the range of water depth at your site of interest and accordingly, you can choose a kind of force you will be required for bathymetry.

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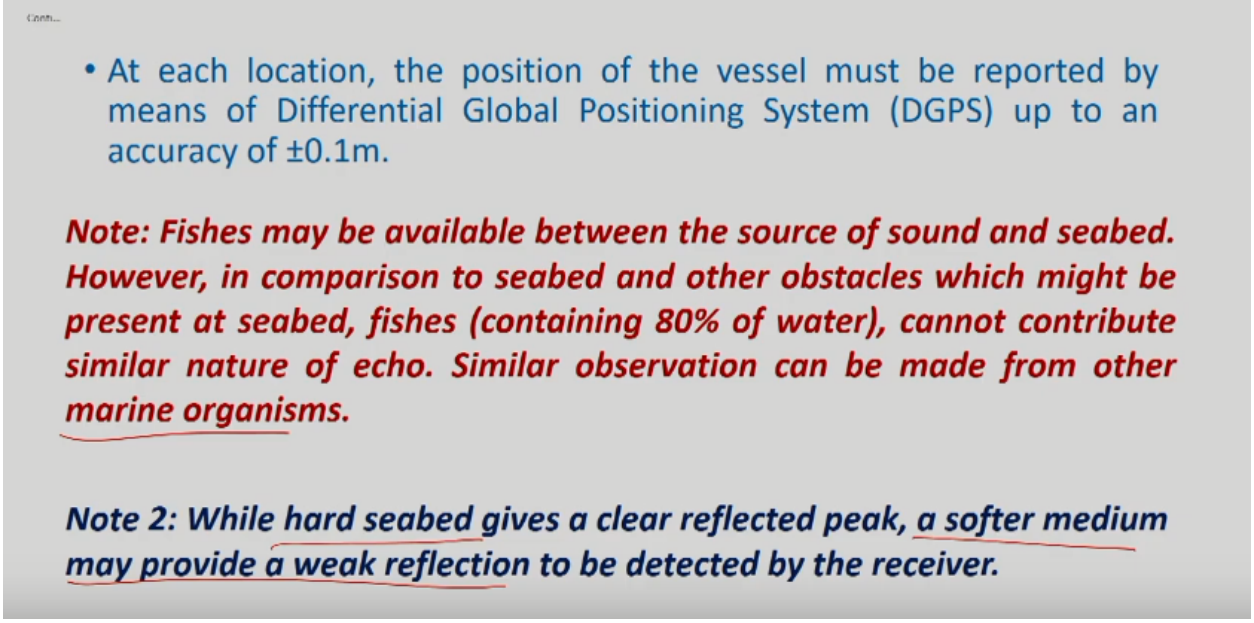

At each location again as I mention like you are the objective is to get the 3D image. So, it is also very important to precise the determine the position of the vessel were actually it is determine the water depth or sea floor mapping, that can be using using the settleate data and based on differential global positioning system, that is DGPS, it is desired that like the position it should be determined as accurately as up to 0.1 meter. Now, two important information which I would like to highlight here, you know like there is vessel, there is sea floor but in between the two there will be number of aquatic lives which are moving continuously here and there. So, what are the chances like you results can get affected, to give you an example for fish, fish, fish is may be available between the source of sound as well as the seabed, however in comparison to the sea floor or seabed and other obstacle which are available on the seabed, you can see like the fish is which contain almost 80% of water, cannot contribute significant, cannot contribute equal nature of echo as contributed by the sea floor. So, that how, that why the chances like the findings of echo sounding towards water depth and sea floor getting affected by the presence of fishes and other marine organism is almost nil. Second thing, this is also important like depending up on the characteristics of the seabed while hard seabed, gives you very clear indication about reflection peak, a softer medium usually provide you a weaker reflection. So, it will be difficult when you are having softer medium to get exact peak and since exact peak is a challenging task again there will that will lead to uncertainty with respect to water table information.

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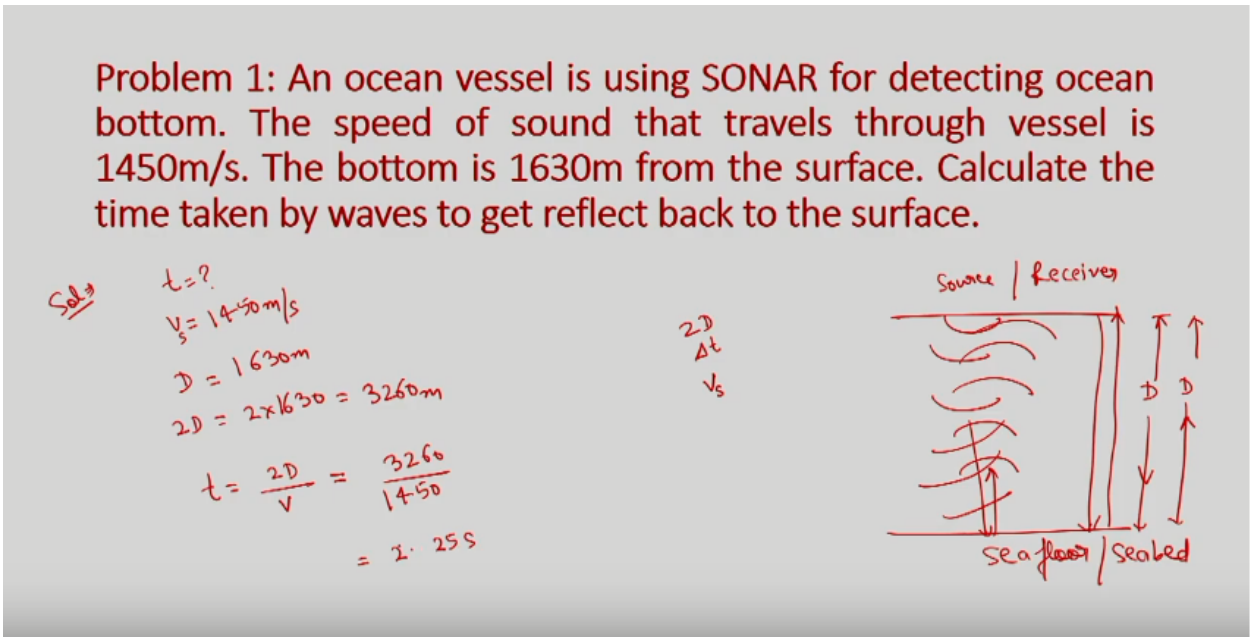

Now, here we are going to see some one or two numerical examples which particularly work on your echo sounding methods, as you mentioned like there is some sounding vessel, it is generating some sound impulse which you get reflecting coming on to the surface, more precisely like I can say here, like you can have a source, receiver, receiver actually imparting some kind of sound here, this is sea floor or seabed. So, once after reflection, it will again reflect and getting detected at the same vessel. So, you know, this is the water depth D. So, they will be travelling your depth D to to the sea floor again it will be reflecting back. So, it will become D plus D, another D which is, so this is going down, this is going up. So, total distance will be 2D. So, time if you calculate delta t, that will give you a idea about, how much will be the depth of this, if you know the velocity here. So, this example says, an ocean vessel, we can consider some SONAR system vessel, using a SONAR for detecting ocean bottom or water depth, the speed of sound that travels through vessel is 1450 meter per second, the bottom is 1630 meter from the surface, that is sea floor, calculate the time taken by the wave to get reflect back to the surface. So, you are interested to find out, after harmost time of since you emit the sound wave, it will be reflected back, or you will detect an equal. So, you are interested to find out the value of time here, to know the value of v of sound that is 1450 meter per seconds, you know the value of D, that is the distance between the vessel as well as the seabed is 1630 meter. So, 2D because one side it will be travelling down, second side it will be coming up, it will be 2 times 1630, that is 3260 meters. So, how much will be the time, as you know that time will be equals to distance divided by the speed, that is 3260 divided by 1450. So, after 2.25 seconds,

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Problem 2: A ship sends a sound wave to the bottom of the sea and received an echo after 0.3s. Consider the speed of sound in sea water as 1500m/s, calculate the depth of water when the distance between the source and the sea water is calculated as 2.3m

You are actually receiving a sound impulse,

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Problem 1: An ocean vessel is using SONAR for detecting ocean bottom. The speed of sound that travels through vessel is 1450m/s. The bottom is 1630m from the surface. Calculate the time taken by waves to get reflect back to the surface.

Sol: $t = ?$

$V_s = 1450\ m/s$

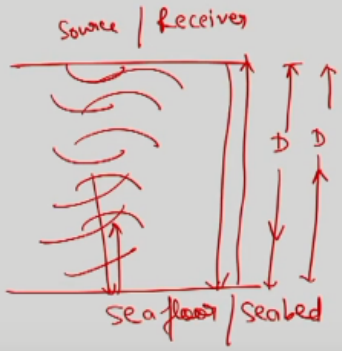
$D = 1630\ m$

$2D = 2 \times 1630 = 3260\ m$

$t = \frac{2D}{V} = \frac{3260}{1450}$

$= 2.25\ s$

$2D$, Δt, V_s



from the source, same way

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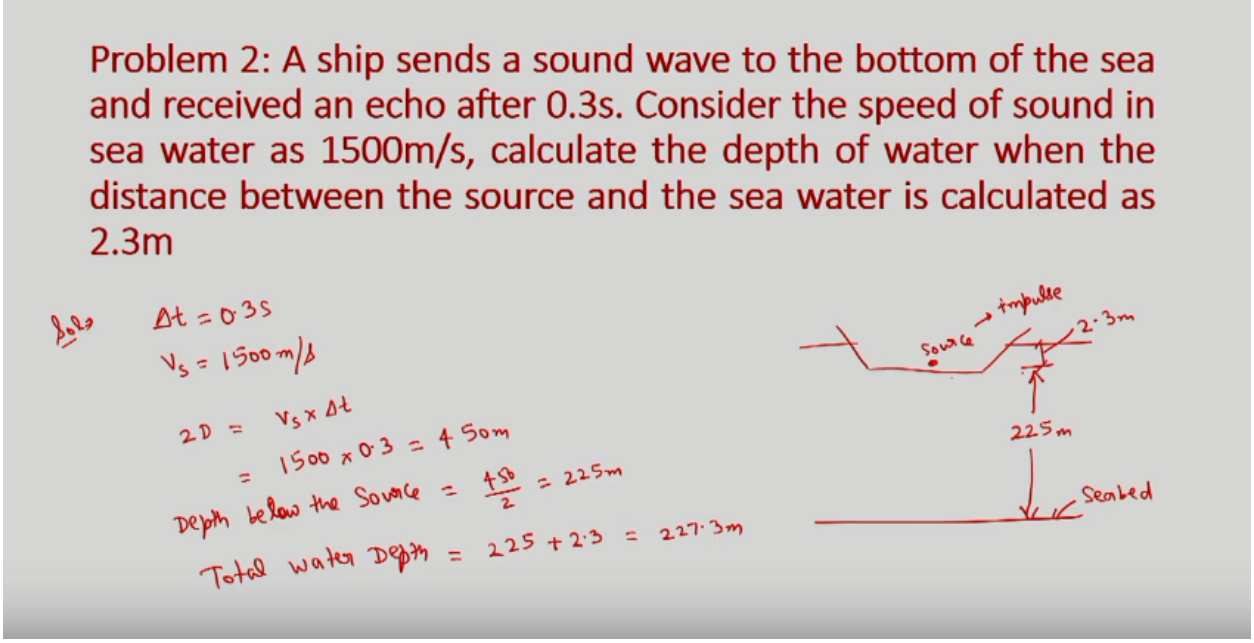

you can go for another example, it's like a ship sends a sound wave to the bottom of the sea and received an echo after 0.3 seconds. So, you have a ship which is actually containing a force impulse is signed, send and equals received after time delta t is equal to, delta t equals to 0.3 seconds, Okay. Consider, the sound so v_s is given as 1500 meter per second, Okay. Calculate the depth of the water, if the, Okay. In-addition one more information is given, like this is your vessel which is containing your source, and this is your sea. So, what it is telling, somewhere here is your source which is actually creating an impulse, it is telling the source is there at 2.3 meter is the distance between the sea water surface as well as the source it is 2.3 meter, now you are interested to determine, how much will be the value of water depth. So, based on this you can get an idea about 2 D, that is the distance travelled by the wave two times that will be equal to how much, v_s times delta t, that is 1500 multiplied by 0.3, that is 450 meters. Now, the depth below the vessel or below the source will be 450 divided by 2, that is 225 meters, this is 225 meters from here to seabed, this is called as seabed. So, what will be the total depth of water, 225 which is up till the source plus 2.3. So, that will become like 227.3 meters. So, this is the total depth of water at your study area, where you are actually use the vessel, such that the source is 2.3 meter below the sea water level.

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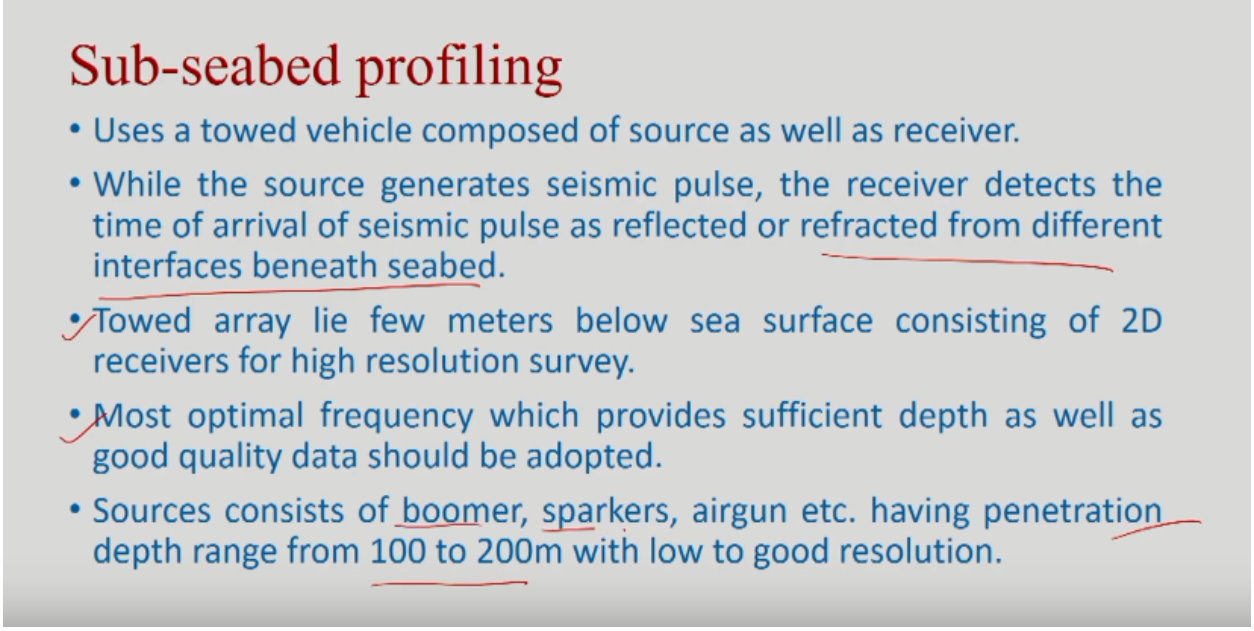

So, this is about that how you can get an idea about sea water depth as well as the seafloor depth characteristics, then above seafloor like the different layer which are available beneath the seabed, that is called as sub-seabed profiling. So, this can be done using traditional seismic reflection and reflection survey, but unlike your traditional survey where you can put actually the sensor as well as receiver on the surface, here actually water is there, above the seabed. So, actually go, the traditional one is consisting of load vehicle that you will be having a source followed by number of receivers or an array of receiver so where the source generate a seismic impulse, the receiver will detect this seismic impulse. So, depending on the sum of arrival of reflected or refracted wave from different, different interfaces that will get you an idea about the characteristic of different interfaces or different medium which is available beneath the seabed. So, you know the water depth, you know the subs, sea floor quality, then based on sub-seabed profiling, you get an idea about a different layer which are available being the surface, I'm not going to detail it, because seismic reflection we have already discussed, while important thing to be highlighted here is in case of this towed vehicle, this is generally available few meters beneath the sea level.

So, that means, below the top surface or mean sea level, it is some where 2 to 3 meters below the ground, below the sea level of water surface and then that 2D array, it is used generally to, to go for high resolution survey. Most optimal frequency, now again you know like depending up on the frequency, you can play with the, you can get confidence about the depth of the penetration, but on this contrary depending on the strength of that particular force, which is creating a particular frequency wave, your quality of the signal will get altered. So, most optimal frequency should be chosen such that the optimal depth of the penetration as well as sufficient quality of your data to be interpreted should be received, that will be always there, if you go for on shore or if you go for offshore based seismic deflection survey. So,

generally the source is which are consisting of boomers, sparkers or air guns which can con, which can target even up to penetration depth of 100 to 200 meter with low to good resolution are often available. So, depending up on the depth of exploration one can go for these kind of sources, certain agencies are there, because these kind of surveys cannot be done or small scaled, lot of enhanced also involved. So, the kind of vessel, the kind of source, the kind of receiver to be used should be, should be chosen based on the experience of the expert, now I told this profiling particularly like whenever we are going for water depth determination, whenever we are going for sub-bed profiling, we are often going for survey which are either on you are doing it from the sea water level or may be certain meter below the water table, now what is in particularly in last one decades, we are having now the autonomous underwater vehicles. So, this can actually help in determining water depth, sea floor characteristics as well as sublevel stratification, by doing the survey even at the sea floor at the seabed itself.

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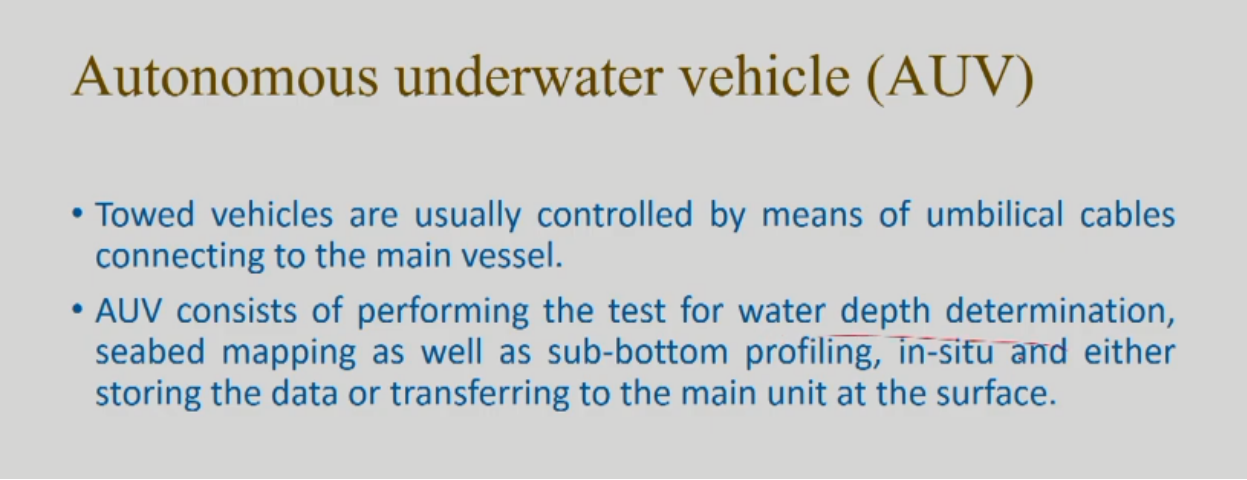

So, towed vehicle are usually controlled by mean umbilical codes connected to its main vessel. So, you are doing the survey, but every time you are transferring the data. However, AUV that is, autonomous underwater vehicle constitute of performing same test for water depth determination, for seabed mapping as well as there is no sub-bottom profiling, in its in-situ condition, it can store data in-situ, and once the test is end, you can bring it on to the surface, transfer the data or by other ways you can keep on transferring the data to the main unit which is kept at the surface, both ways it is possible. So, finish the test, bring it on to the surface, transfer the data or continuous shifting of data from AUV to the surface assembly will also possible. So, with this I stopped, I hope today's class has given you some inside information like how we go for geo physical investigation, particularly onshore environment, offshore environment, what are the depth of interest, what are the frequencies to be looked in to once you are selecting the particular source. Secondly, only the frequency of interest should not be the major concern,

but also the quality of the data because that will also help you getting more and more confidence as far as the interpretation of the results. So, thank you.