INDIAN INSTITUTE OF TECHNOLOGY, GUWAHATI

NPTEL

NPTEL ONLINE CERTIFICATION COURSE
AN INITIATIVE OF MHRD

SUBSURFACE EXPLORATION: IMPORTANCE AND TECHNIQUES INVOLVED

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LECTURE: 21
CONCLUSION

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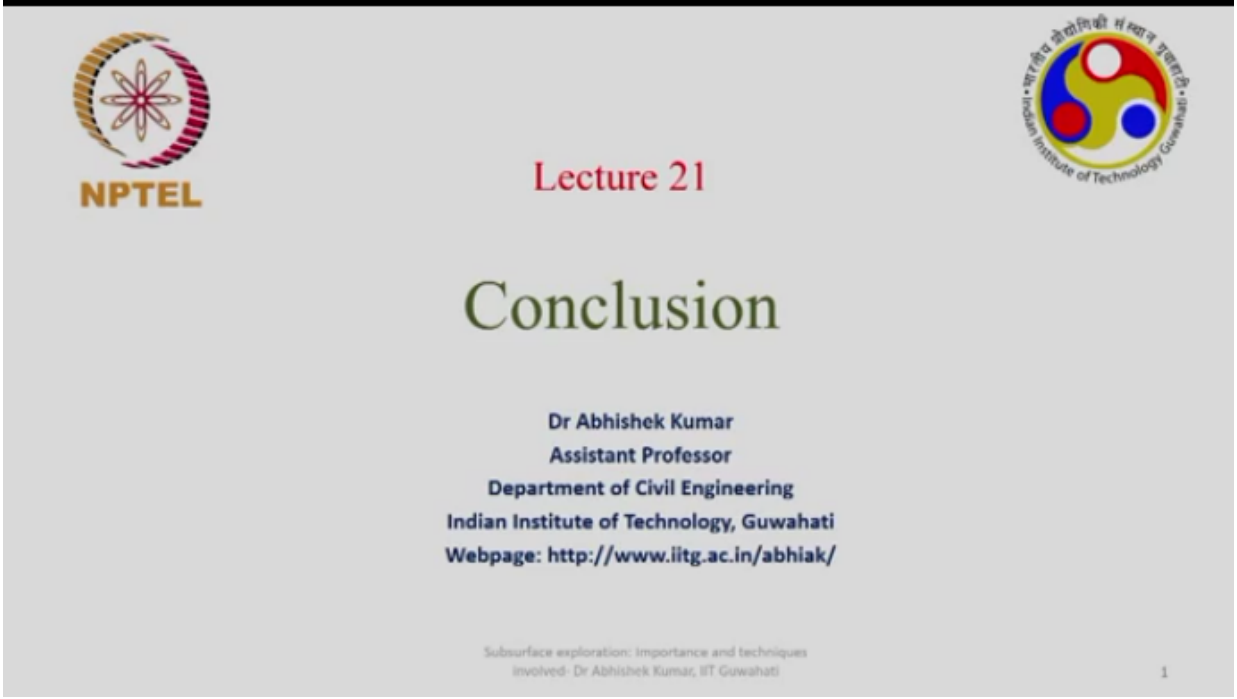

Welcome all to lecture 21 about Subsurface Exploration, Importance and Techniques involves. So today's lecture it's going to be summarizing of whatever topics we have discussed so far, that's why the name is conclusion, because when we started the topic we told like what are the importance of Subsurface Exploration, then what are the typical methods people are using, depending upon very important structure which can have very complex foundation design or maybe very simpler kind of designs, you can go for different geo-technique, investigation technique, geophysical investigation technique, you can also explore if similar kind of structure

is there by in the nearby region you can get to know what are the possible challenges which were face during that particular kind of investigation or maybe during the construction phase.

Similarly this kinds of construction activity as well as investigation activity will help you in understanding what are the possible challenges which can be arisen during later stage and what are the alternate option, so that at later stage also you can make some kind of modification in that design as well as construction practices.

So the entire syllabus for this particular course was divided into 5 modules,
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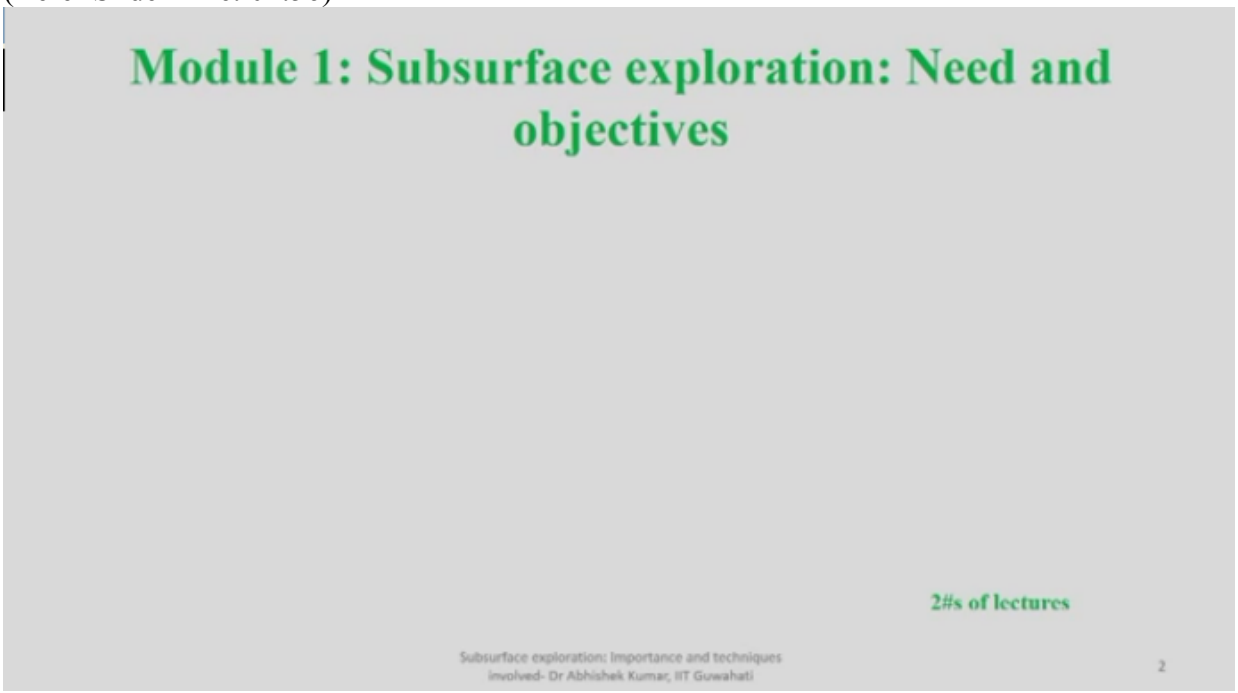

so when we talk about the first module we discussed about what are the need, what are the objectives of Subsurface Exploration in overall, like why a person should go for Subsurface Exploration, what are the needs and what are the objectives for which once should go for Subsurface Exploration, starting with the role of subsoil,
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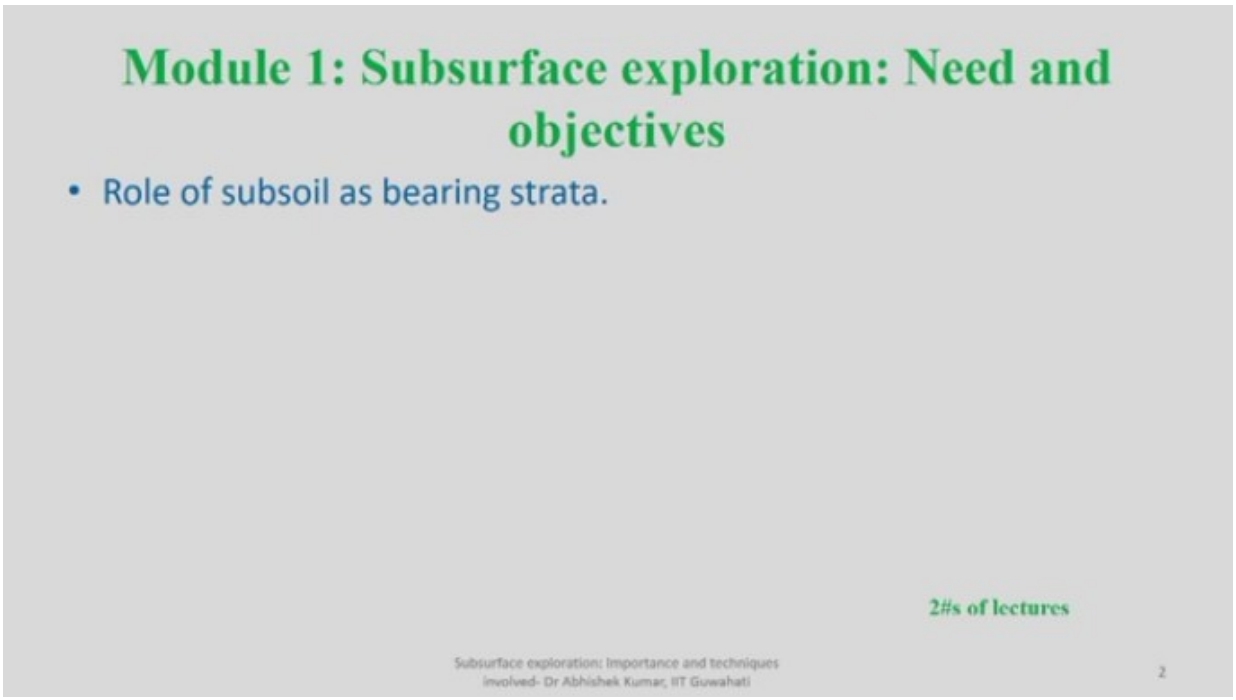

so at time the subsoil is used as bearing strata, so as to transfer the overcoming load from the structure, it can be direct load, it can be live load also, and other loads which can be maybe seismic loads, wind loads, or even because of in particularly in colder regions because of ice also what kind of possible kind of loads can be there then if it is subjective to some kind of vibration also from other sources then earthquakes, so what will be the role of that particular site, because depending upon the role of the site you have to design a particular kind of foundation, you have to ensure not only the safety of your structure, but also to ensure the safety of adjoining structure.

Also in case the soil you are using to, as a part of filling material in other projects, what is the suitability of that particular material to be used so that will be also explored, when we go for subsurface exploration method, so the achieve is to understand is bearing strata, because what you do, you go to the particular site, you choose this particular investigation method, it can be starting with preliminary methods like test pits, trial pits, and all that which will give you up till shallower depth, what is the kind of soil available, what is the stratification, and you can collect the soil sample, you can go to the lab, conduct some field investigation as well as laboratory investigations, or you can go for geotechnical investigation that will help you not only in understanding the soil samples, disturb or undisturbed, but also to qualitative as well as quantitatively assess the stand characteristics of the medium, in order to ensure how the particular medium is suitable for one of the kind of structure.

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Then we go for depending upon what kind of medium is available at the site, depending upon what kind of load or overcoming on to your foundation, what kind of like possible fluctuation, ground water table, any possible contaminants are also there available in the ground, or any kind of challenging condition which can compromise the safety of the foundation, or the safety of the structure or project as overall, so that will help you in understanding what kind of foundation will be more optimal for the kind of subsoil available and the kind of structure we are targeting for, so this we highlighted depending upon like whether it can be simple building, it can be up rigid, can be dam, tunnels, nuclear power plants so on and so forth.

Then decision making, as I mentioned like initially particularly like couple of decades where we are having I mean, for almost for every kind of structure the land available was plenty,
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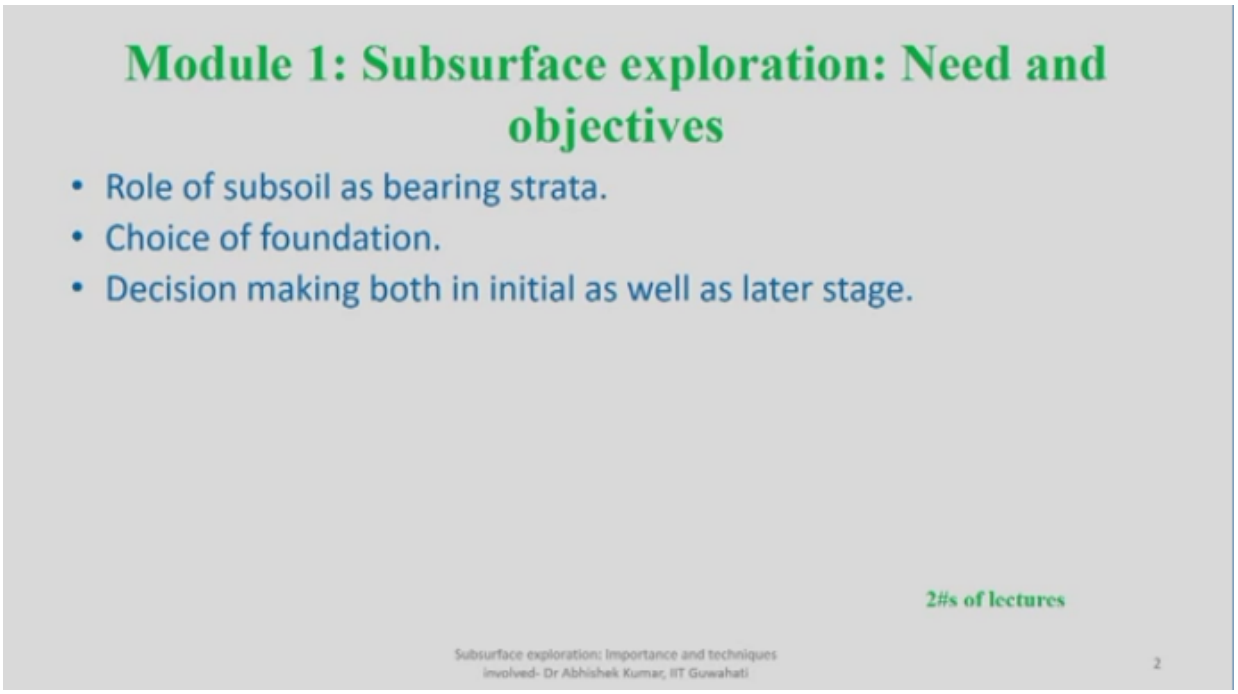

but as now we are witnessing every here and there, the choice of land which is available to the designer or even to the owner is very limited for any kind of structures, particularly for buildings or dams, so as a part of designer or expert in geotechnical engineering, we have very limited choice left in order to decided, in order to give your opinion whether particular site is suitable or its not suitable for a particular kind of structure, most of the time the choice whether the site is not suitable may not be there rather you have to go for some kind of alteration in the subsoil properties in order to make the site suitable for particular kind of structure.

So decision making, whether the existing characteristics of the soil is suitable you can utilize the existing characteristic and go ahead with the design foundation laying and construction of the foundation, or you have to do some kind of adjustment in the foundation type or some kind of treatment in the ground before you actually go for laying of the foundation or even excavation or way in the times waterproofing if the groundwater table is too high and you have to go for excavation, so those kinds of decision making can only be done once you know upper subsoil information including possible groundwater table and problematic soil which is available at the site, so this will also highlight what are the objectives or why it is needed like you should go for subsurface exploration.

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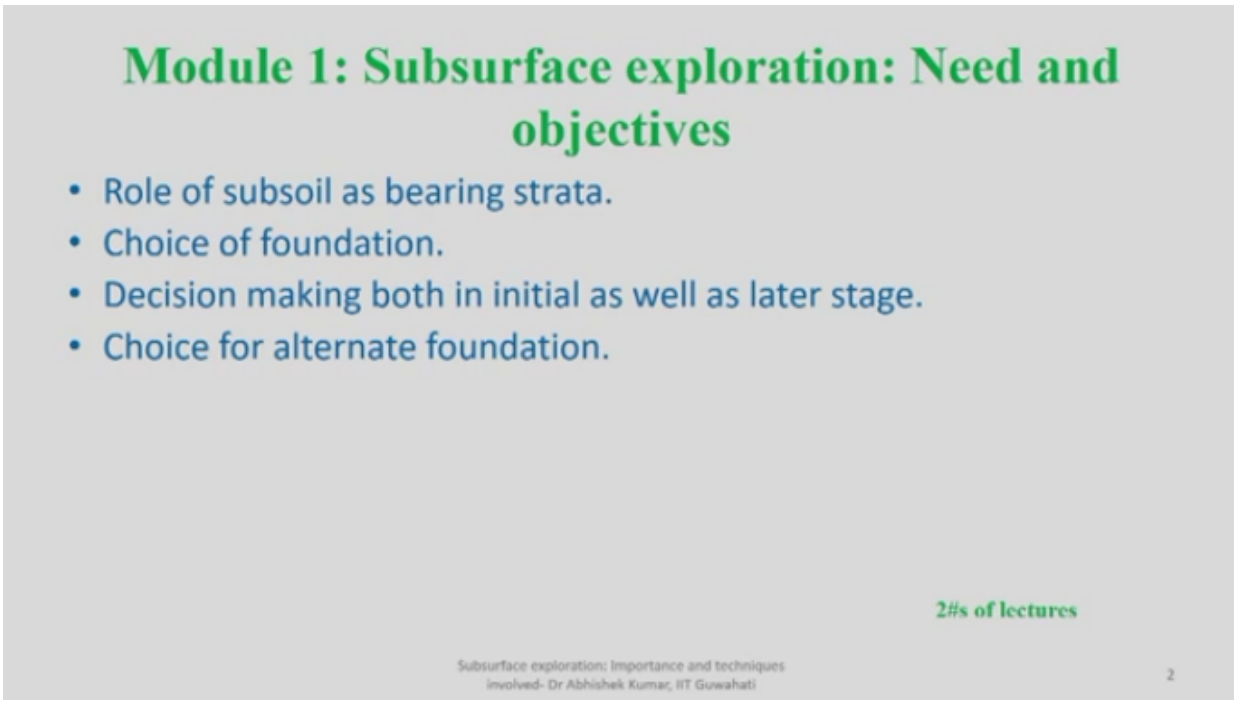

Then choice for alternate foundation, you start with shallow foundation or you go with deep foundation but the foundation you chosen at the beginning of your exploration whether that particular foundation is also found suitable at the end of your exploration we will come to know with the exploration program or interpretation based on your particular exploration methodology.

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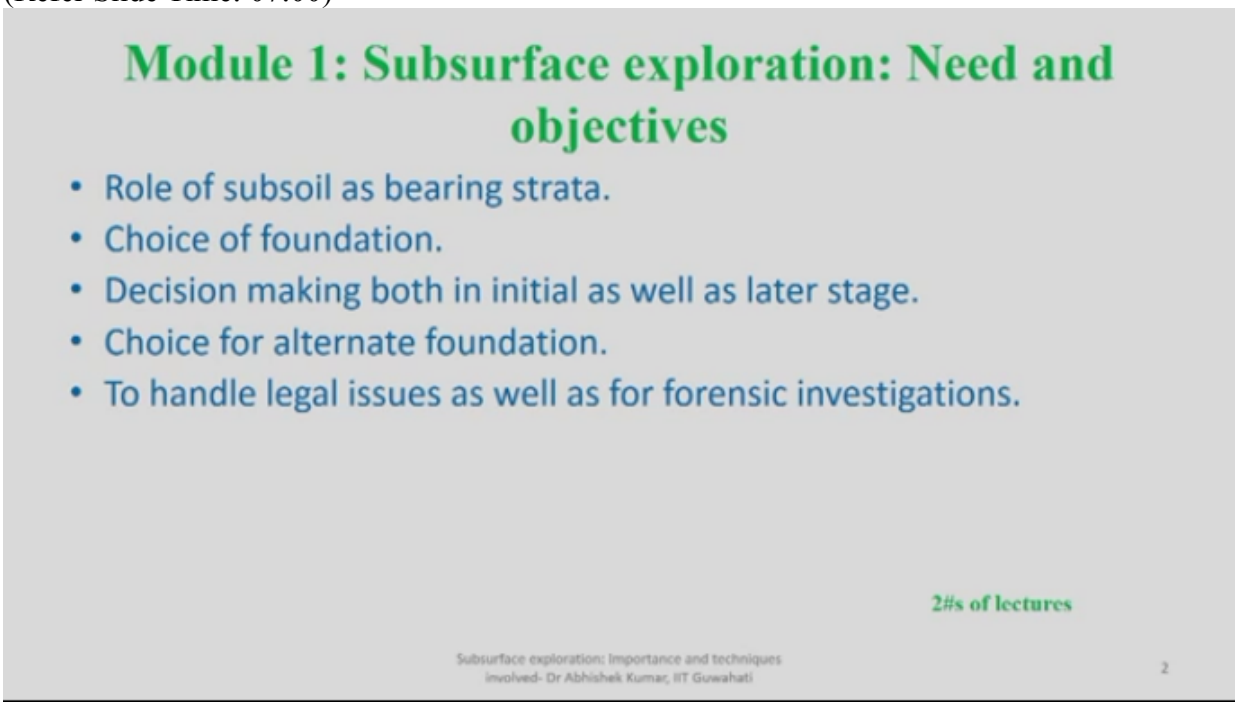

Again another important thing which comes very here and there nowadays like because limited areas are there for the construction for a particular kind of projects, so it is highly possible like your site where you are going to construct a particular type of structure, it is in closed proximity

to already existing structure it can be routine building or it can be very high important, very high importance related building, so for those kinds of things if you are going for any excavation or you are going for any kind of foundation laying equipment which is producing lot of vibration which can also compromise a safety of adjoining structure, so you will end up in legal issues, so at times whenever some kind of legal issues also come into picture, this exploration results based on your detailed investigation will also help you in coming out of these legal issues based on your technical expertise, based on like once you know what kind of soil is there, what kind of most suitable foundation type, execution methodology, where adopted that was most suitable for particular kind of project, that will help you in tackling those legal issues very well in front of the law.

So even for forensic investigation, we discussed forensic investigation means already some kind of failure has happened to your, maybe retaining structure, maybe because of dam foundation, maybe some slopes, so you go to the site, you try based on your exploration method like what was the, whether your strength characteristics of the soil, whether the soil property where the stratification, where the water table depth were optimal or were estimated properly at the site before going for detailed investigation, so that will help you in understanding whether there was a flow in the design part, whether there was a flow in execution part or there was some change either in medium characteristics or loading characteristics in and around of your foundation type or building type that has related to complete failure of the structure or maybe partial failure, so that comes under forensic investigation, you go to the site, you collect the in-situ properties which are available at the site and try to do some kind of back analysis in order to find out like whether you are input parameter you have taken it for design purpose, whether your steps you followed for execution part, whether those were proper or there was some issue or there was some problem with those parameters.

Secondly in comparison to when you did the test, at present is there any change in the material characteristics or some additional material inert, some forensic material has come on to the site which is actually problematic in nature that had led to complete failure.

So the overall, the topic was divided into two lectures, module 1 was covered into two lecture, one basically about, so repeatedly we discussed about what is importance and why there is requirement that one should go for detailed subsurface exploration rather only going through the already existing reports or reconnaissance are which may be available on a broader scale rather than site specific, but more detailed information.

We also discussed like depending upon the project, at times the exploration program can be, the overall cost of the exploration program can be as low as maybe few fraction of overall cost of the project and to as high as 7% also in some cases.

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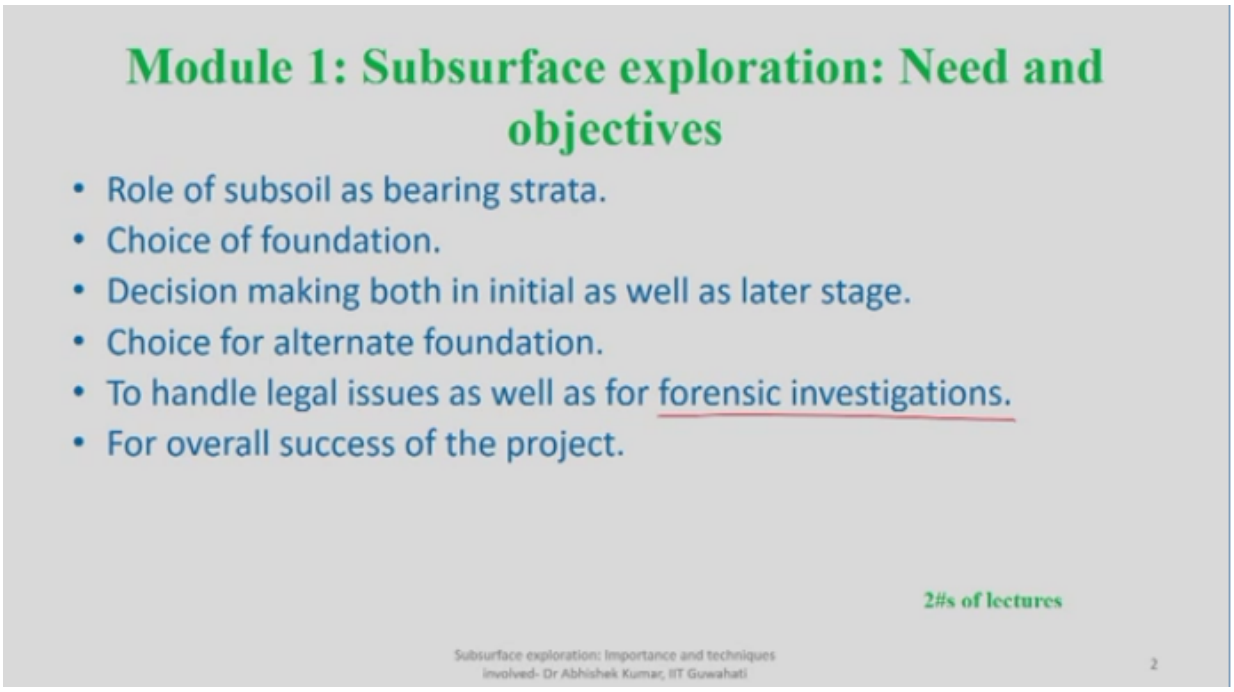

Then we also discussed how your exploration program controls the overall success of the project, so whether it can be because of bearing capacity failure you are able to attend, whether too much settlement also you are able to attend, overall success of the project because of adjoining structure not to undo any kind of failure, so that can also be coming, the safety of adjoining structure also we had highlighted.

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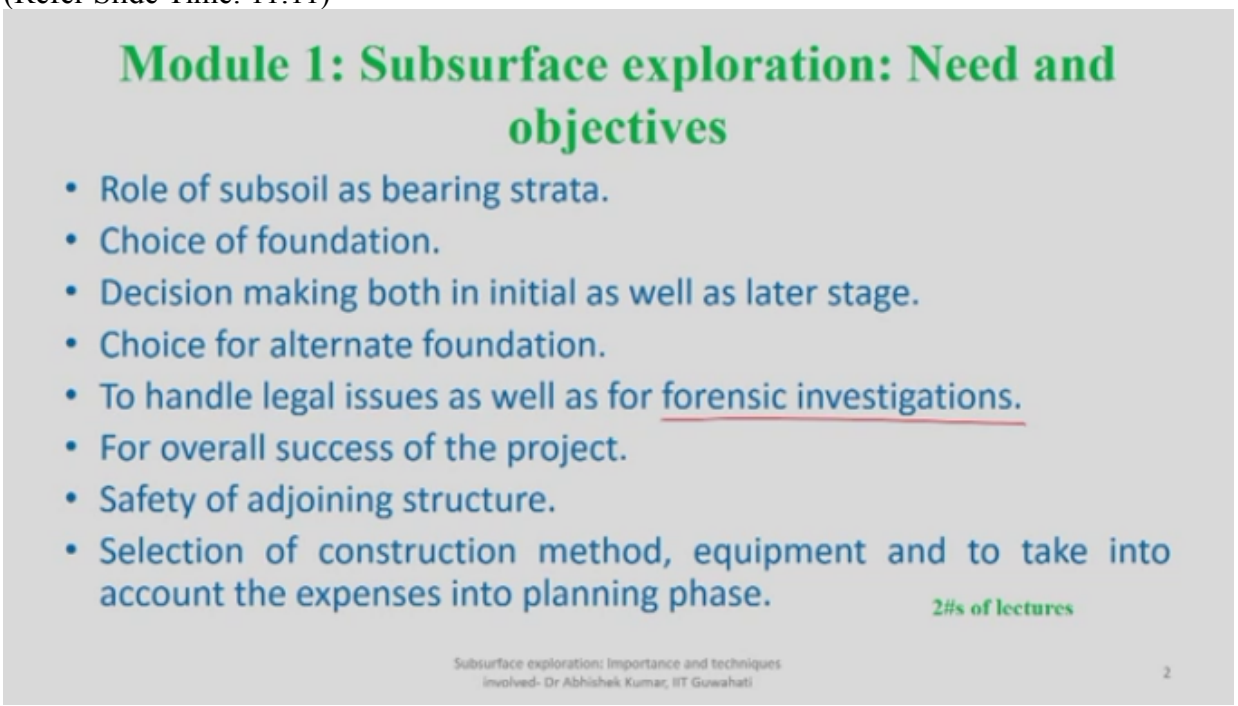

Selection for construction material, what method we are going to use, what equipment we are going to use depending upon what equipment is available in the nearby location, and also to make a decision whether the site, the material which is available at a particular site whether it is

soil or aggregate, how much those are suitable if you are going to use the same for any portion of your construction activity at other location, this can also help you in better planning for your construction activity and also in order, I mean well before any problem arise this will help you in forecasting those kinds of problem so that you can have multiple options or better options available before actual problem arise at the site, so decision making overall, the decision making will be very clear at different stages of construction and laying the foundation once you do proper subsurface exploration.

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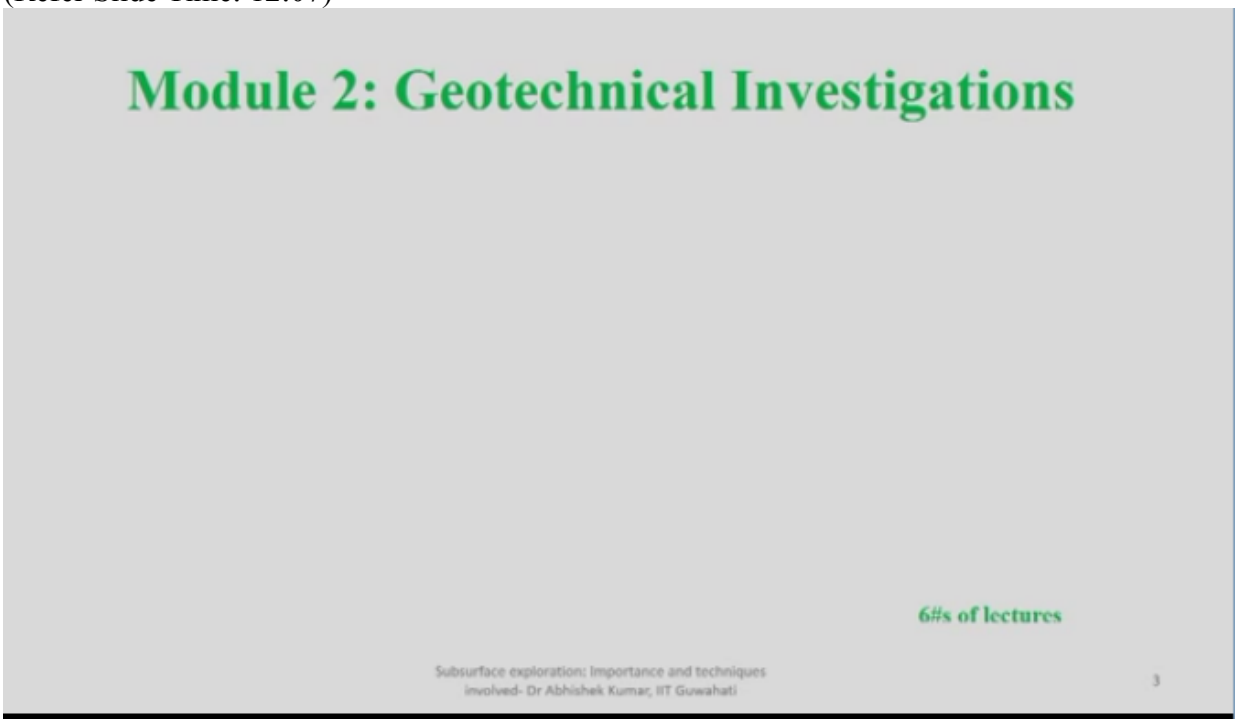

Then we went to module 2 of the course which was completely divided into 4 lectures, which was primarily geotechnical investigation we started with,

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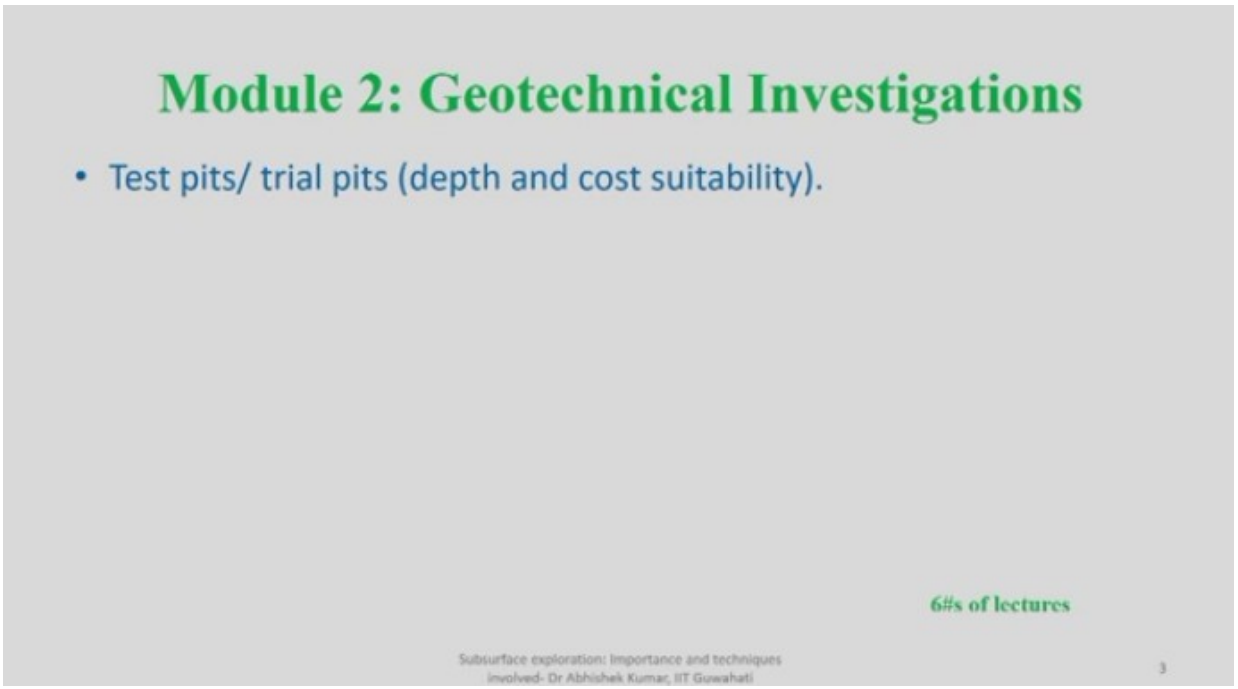

so we discussed with test pits and trial pits, we told like this kinds of tests though it's like direct methods for subsurface exploration, but usually there depth will be very limited to maybe few meters below the ground surface because you are actually going to dig at the site, and collect the sample which maybe representative soil sample based on that you can go to the laboratory and try to understand their qualitative and quantitatively you can understand the strength characteristics, you can understand the soil classification and all that, but of course there depth of exploration will be very limited, again if you are going for slightly deeper depth you have to provide some support, lateral supports or bracing so that, the vertical phases of your excavation should not fall inside, and from cost point of view also, it's very uneconomical to go for test pits and trial pits for deeper depths, so that we had started.

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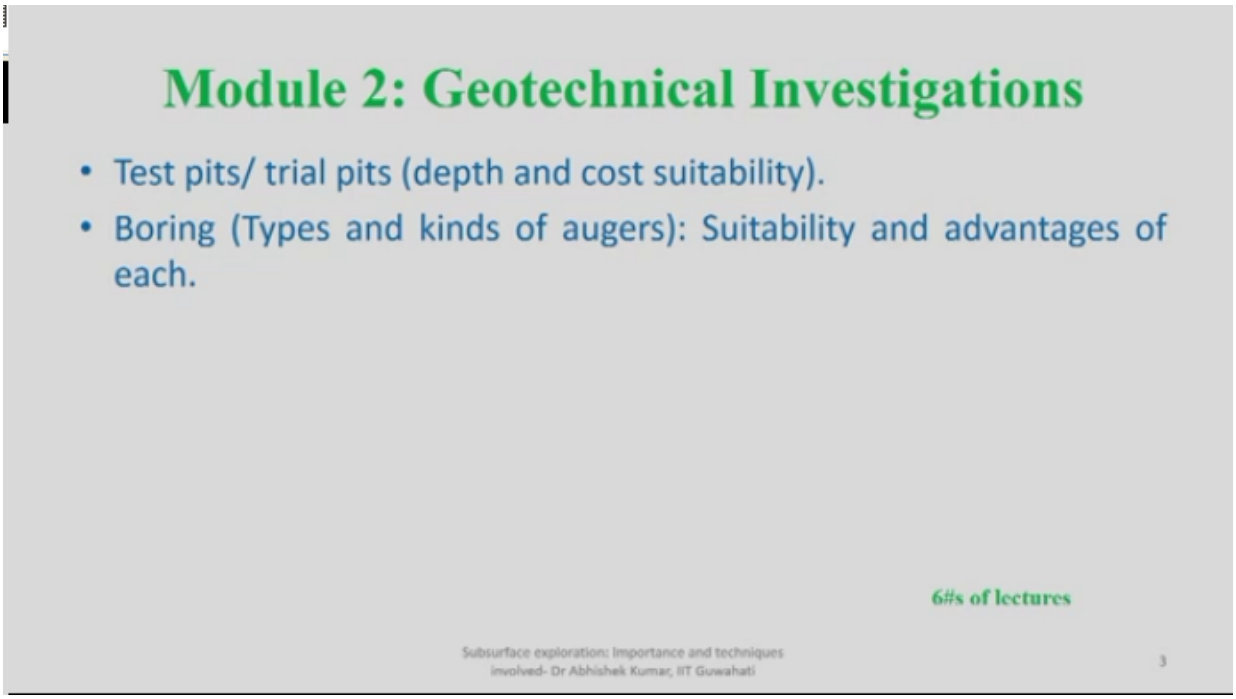

Then we went for borings, particularly started with the, whenever we are interested to find out from the surface, what difference stratifications are available at different depths, so depending upon what kind of soil is available, then depending upon whether the soil is consisting of organic material like plant roots and all that, or it is composed off fragments of rocks you can go for different kinds of boring method like wash boring, auger boring, percussion boring, and depending upon each method the rate at which the boring exercise can be progressed, hourly basis or daily basis can vary from one method to other method, then what are the different kinds of auger which are available in the market, so depending upon the soil, depending upon whether its sandy soil, whether it is clayey soil, whether it is organic soil mixed with the clayey, or it is like rocky medium, so depending upon the kind of medium which is available at the site you can go for different kinds of augers, so what are the suitability of different kind of boring methods, what is the advantage of different kind of boring method, in which particular case you should go for percussion method, in which case you should go for wash boring, all those things we had discussed in module 2.

Then we started with what were, because sometime whenever you are going for wash boring, percussion boring, you get some representative or somewhere actually you are getting some portion of material or at the site of the interest, so how you characterize that particular material can be used for soil classification, it can be used for strength characteristics, so broadly it can be divided into disturbed sample and undisturbed sample,
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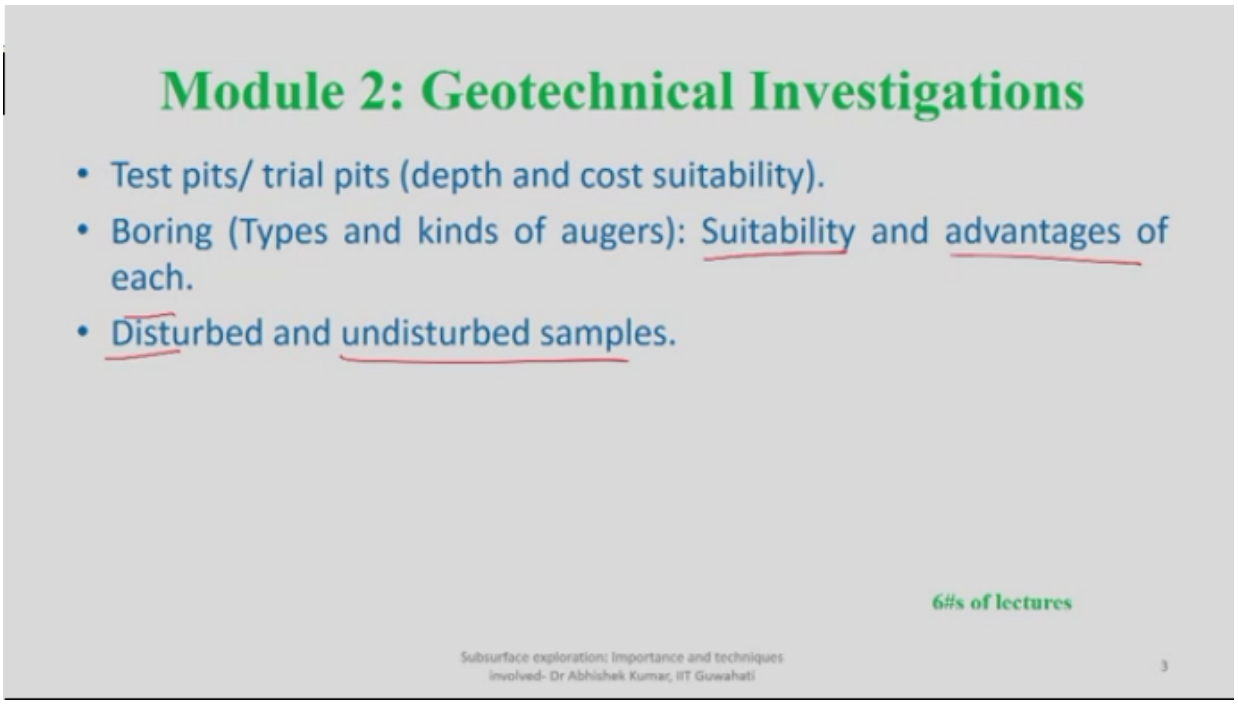

we discussed in detail in which characteristics on which condition soil sample can be called as disturbed, in which condition the soil sample when we called as undisturbed soil sample.

Then whether the soil sample is disturbed, whether can be use it for bearing capacity, strength characteristic determination or not, or soil sample which are undisturbed in nature, whether those can only be used for determination of strength characteristic and identification of soil type, we had already discussed.

Then groundwater table and its possible fluctuation, it is important because depending upon the soil type which is available, primarily for clayey soil, the presence and absence of ground water table,
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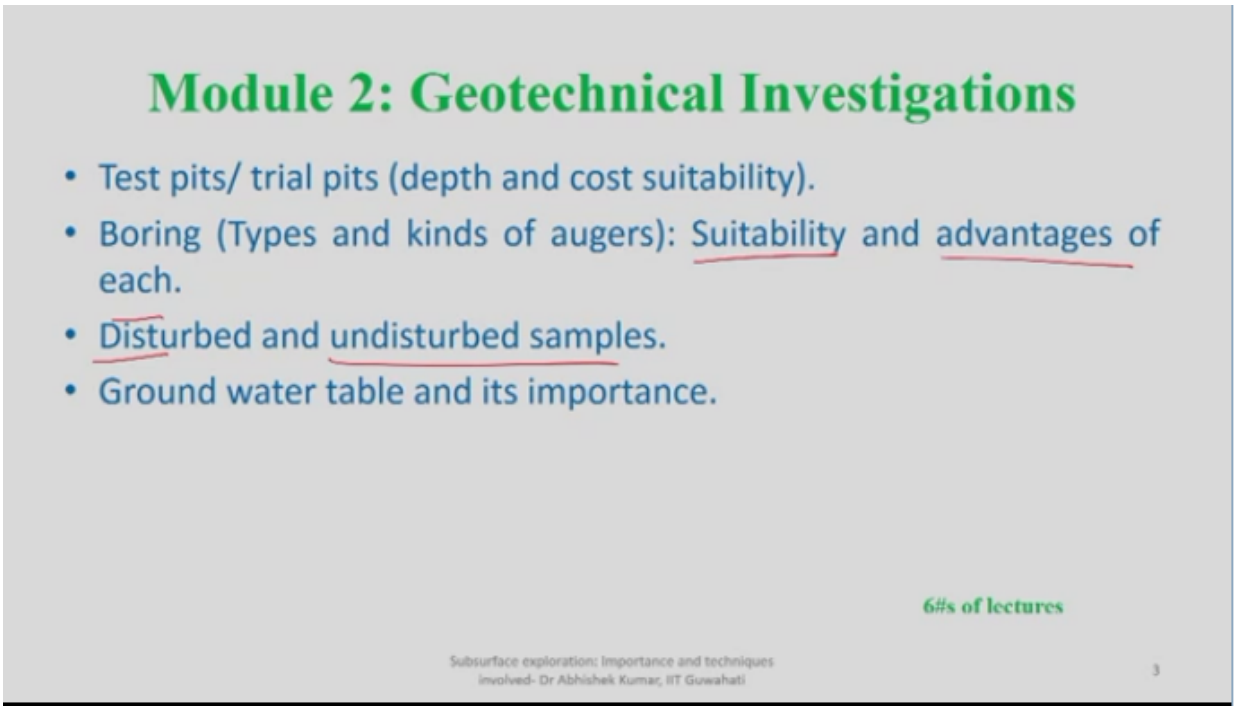

drastically changes the soil characteristics, and that's how it will control the bearing capacity and settlement characteristics of the foundation medium, so what is the depth of water table, what is its fluctuation, so as I mentioned earlier particularly when you go for borehole drilling, you try to observe possible fluctuation in ground water table, if it is sandy soil the water table will get constant, I mean there will not be any further fluctuation within couple of hours, on the contrary if it is clayey soil then sometime you have to wait for couple of days also in order to obtain some steady state of ground water condition.

So what is importance? As we mentioned here, this will also help you in understanding if the groundwater table is very high, and you have to go for some kind of excavation, so what kind of dewatering arrangement you can do or you have to go for some kind of water proofing barrier before you proceed for deeper excavation, otherwise you keep on excavating but every time there will be ingress of water which will finally affect your overall progress of the work as well as it will also compromise the safety of people who are working in the inside actual excavation, so that we had discussed.

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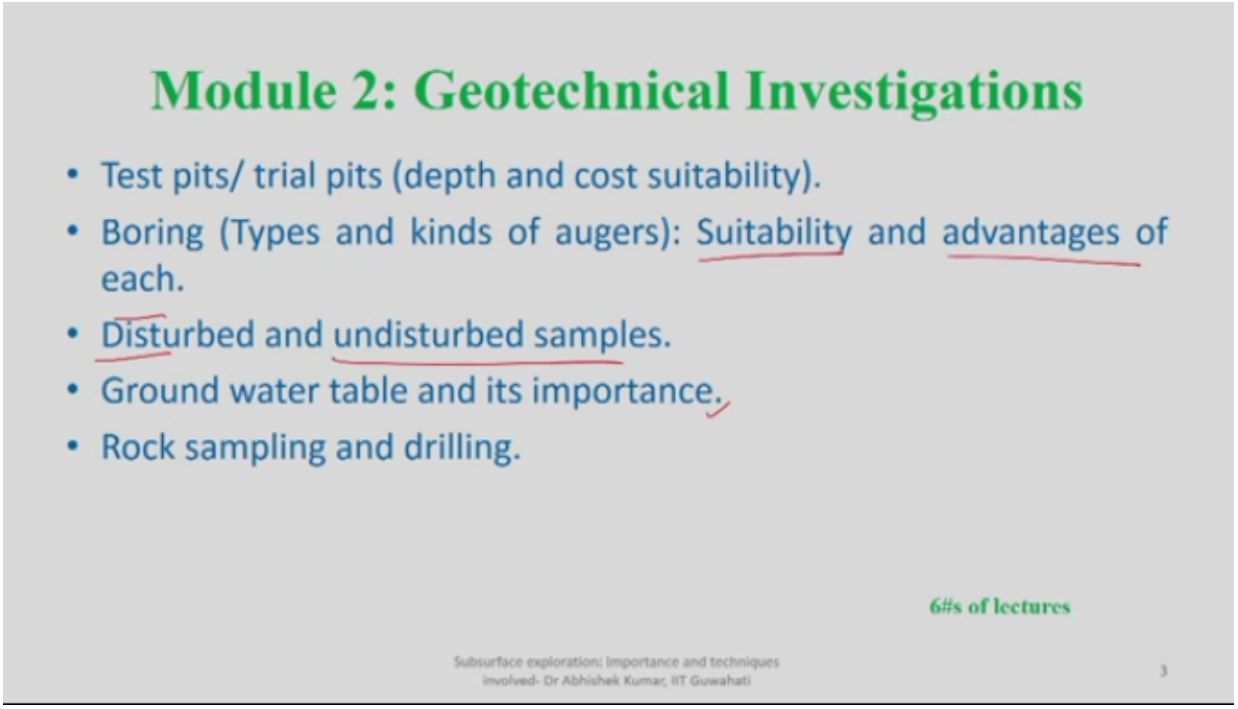

Then we also discussed about rock sampling, what are the method by which you can do the rock sampling, we will discuss different kinds of drill bits, and drilling fluid which will also be required because when the drill bit is rotating at a very high speed, there will be chances like heat will be generated, so you have to continuously circulate some kind of drilling fluid as well, so what kind of drilling fluid will be there, what particularly people use, and there particularly for boring and rock sampling, at times you keep on recirculating the fluid, in addition to that the characteristics of the fluid should be like it can retain the vertical phases of borehole in its position, whether collapsing it.

Then depending upon the sample which you are actually getting from your rock sampler, how you can characterize the sample, whether it is based on rock quality data or total core recovery or rock quality designation, you can discuss all those things that is called as rock RQD or and total core recovery TCR we had discussed based upon each of these values which will directly tell you how intact the rock samples were, in comparison to the total length of the core that will help you in understanding, in natural condition what is the, whether you can call the rock as very good quality, whether you can call it as poor quality rock, and depending upon that whether what is the suitability of that particular rocky medium for your particular kind of project that also we can get to know.

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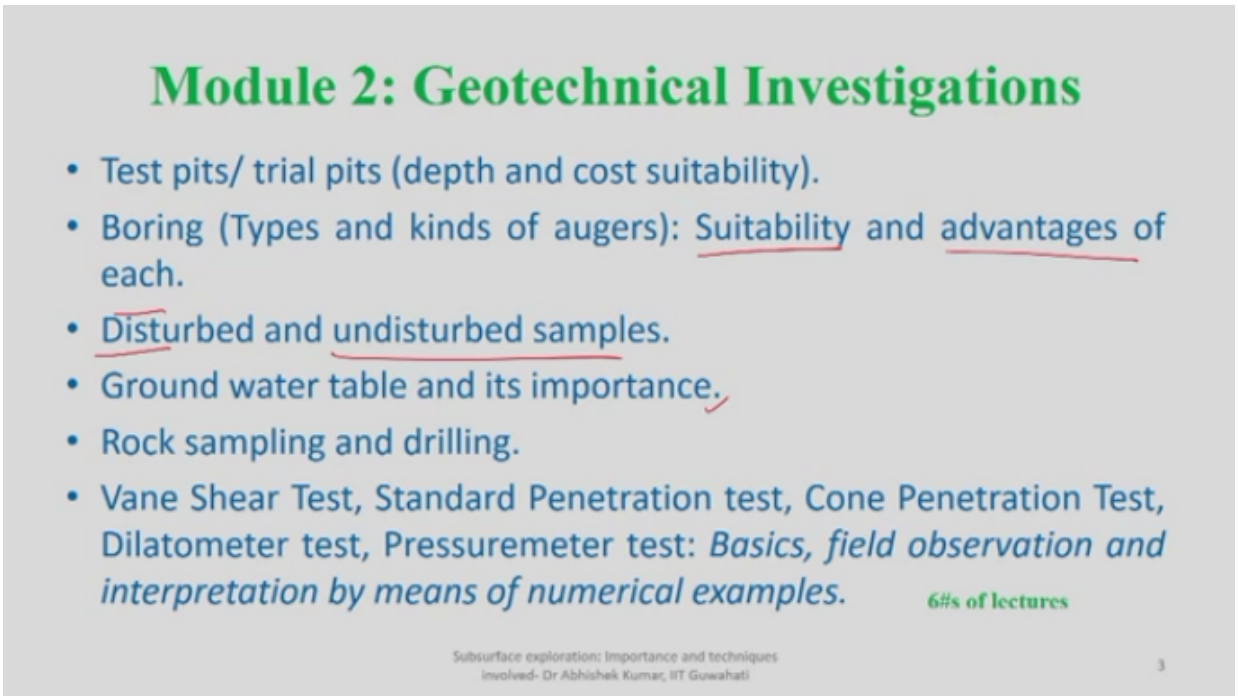

Then we discussed different geotechnical test, it's like when you collected the sample, other method which can actually help you in understanding the strength characteristics of the medium, there itself in its natural condition, so we started with Vane Shear test, for what kind of medium you can go for Vane Shear test which can directly tell you in terms of the torque applied, what is the in-situ strength characteristics of the medium, then we started with standard penetration test which is widely used geotechnical test, so how you do the test we had discussed, then you have some split spoon sampler, so you drive that sampler into the soil, depending upon the number of loads required for some standard penetration, you count number of blows and depending upon the number of loads required you characterize the medium also whether it is soft medium or whether it is hard medium, whether it is weathered rock and so on and so forth.

Then what are the corrections required, because as you are going deeper into the medium, there will be some kind of resistance offered because of that particular level layer available at particular depth, so we have to apply some kind of correction, then correction will be required if you are having like you are doing test, like cone penetration test, so what are the different corrections required for cone penetration test, what are the typical field measurements required for cone penetration test, then we started with dilatometer test that is DMT test, what are the typical field observation, how you calibrate your dilatometer setup, then what are the standard pressure readings at the surface at position, what are the different positions at which you have to actually measure pressures required for the buzzer at the first time to put sound and then next time, and then based on that you can find out what is the in-situ characteristics of the soil, this is as I mention this is dilatometer test is nowadays very popular, not only in onshore condition, but also in offshore condition, people are using it, dilatometer has special advantage particularly when you are using it for identification of failure surface in slope stability problems, so that is another advantage.

Then pressure meter test, we discussed like based on pressure meter test how you can find out the load settlement characteristics of in-situ soil medium, based on depending kind of load then what are the boundary condition which are, they are in pressure meter test how you applied load, what are the measuring cell, what are other cell which are available at other extremes of the measuring cell, so we discussed, overall we discussed what are the basics of each of these test Vane Shear test, standard penetration test, cone penetration test, dilatometer test, pressure meter test, along with the rock sampling and boring we discussed the basics, we also discussed for each kind of test what are the typical field observation, and then based on some typical field records we tried to interpret like suppose we are doing similar kind of SPT test in the field, and if you know at different depths what will be the number of loads at different different depths, how it will help you in interpretation, because finally the objective of each test is to help you more precisely like what kind of soil is there, and how that particular soil is going to respond when you are applying some kind of external loading whether in terms of pressure, whether in terms of penetration, whether in terms of number of loads, or indirectly it is going to help you in understanding the in-situ strength characteristics, because finally the objective is to ensure your foundation which you are going to lay or rest on that particular soil, should not undergo any kind of failure.

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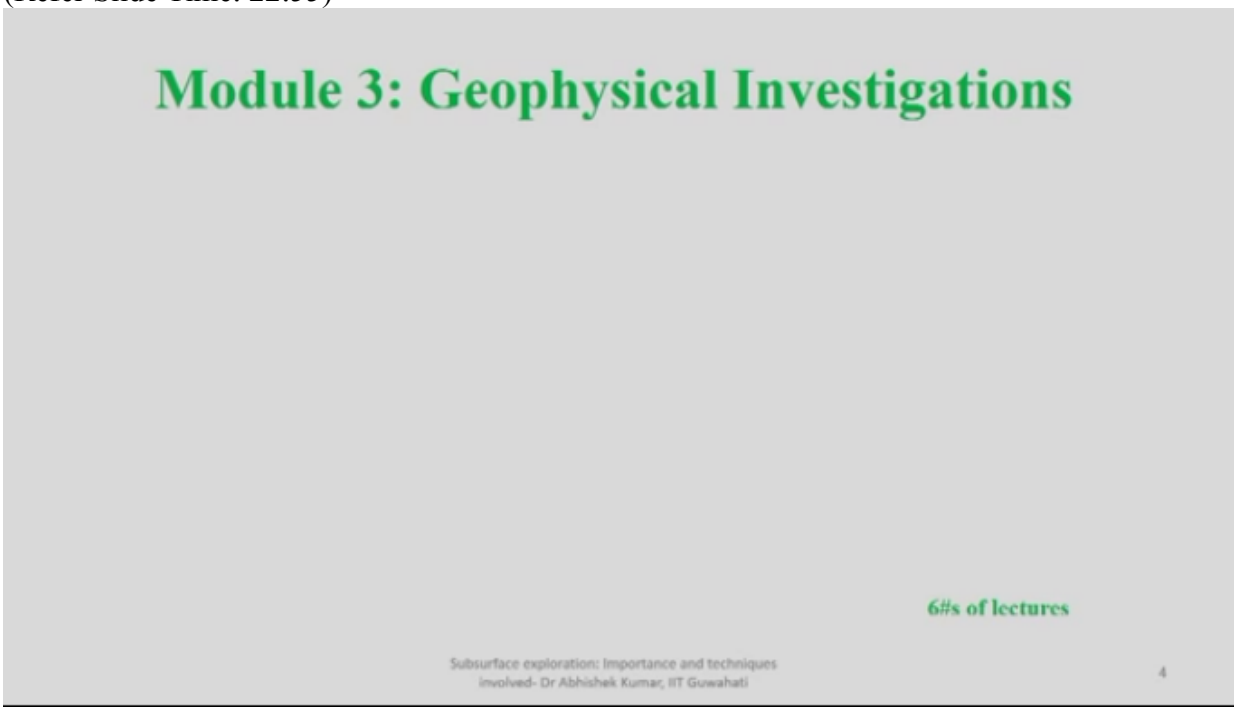

So we discussed couple of numerical examples also under this part, then we went for our module 3 which was also covered in 6 number of lectures,
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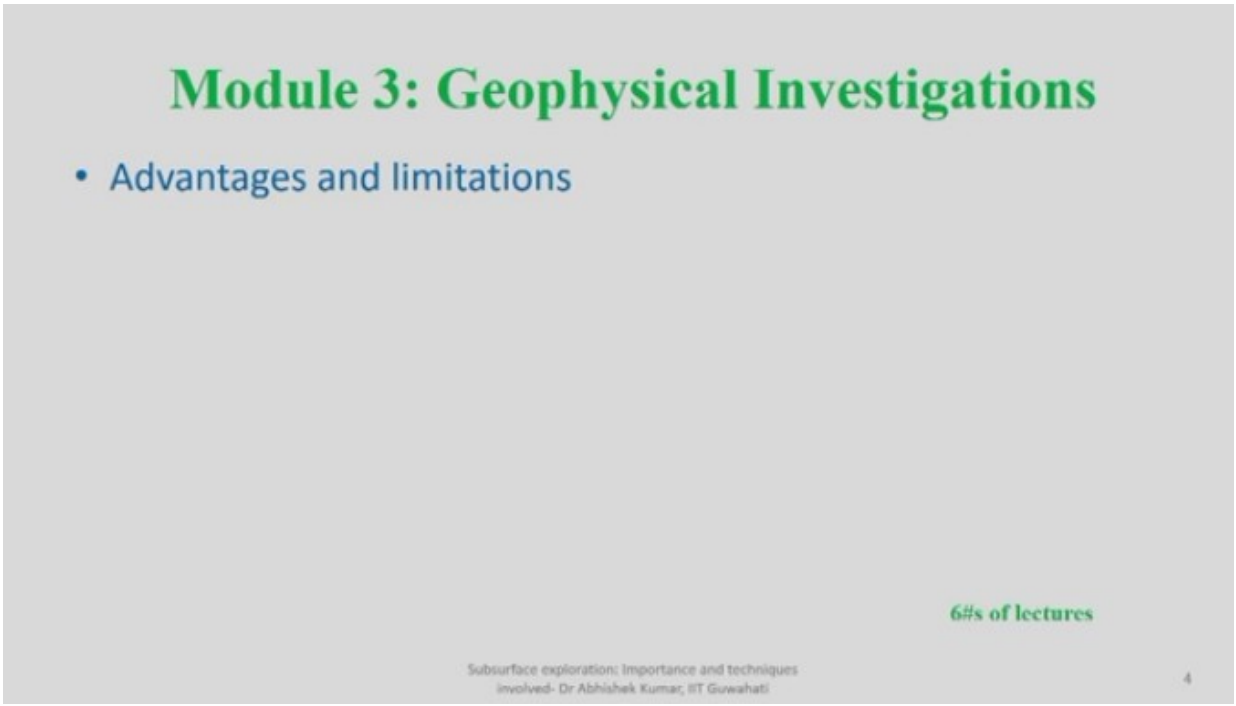

so here we discussed about geophysical test, I told like geotechnical test because every time particularly for geotechnical test you have to drill a borehole, if you are going for like standard penetration test and other test which actually require the sampler to be, sampler or the setup to be inserted into the soil layers, so depending upon that you decide what kind of reaction frame will be required, so most of the time it has been observe like geotechnical test will be more suitable, but there advantage, they have limitation in terms of the depth suitability, so particularly beyond certain test you cannot use beyond maybe 10 meter, 15 meter other test, it will be difficult to use beyond 30 meter, 35 meter, because the reaction which will be required to apply external reaction to that particular depth layer will be completely different, so that's why but only advantage with geotechnical test, most of the tests its like you are getting several samples, so you can bring those sample particularly in SPT you can bring the sample, first of all you are actually seeing the sample, so you can get an idea based on visual inspection what kind of soil is there, you can collect that sample and test in the laboratory you can determine the other properties.

Advantage with geophysical test, because these have become more popular particularly for subsurface investigation and couple of decades now, so advantage is there, first of all these are non-distractive test, you need not go for any kind of drilling or boring inside the soil, so you can do those test at the site of the interest, and non-distractive test mostly are very low strain test, but only disadvantage in geophysical test is like if you are not getting any kind of samples, so all kind of interpretation are based not indirect measurements, whether you are using seismic refraction method or other methods, every time you are indirectly, based on your quantity, you are trying to interpret the result, you are trying to correlate, okay, this possibly this can be the medium type which is available at that particular depth, so that was in, that was one limitation, that's why majority of the guidelines which are proposed by natural codes,
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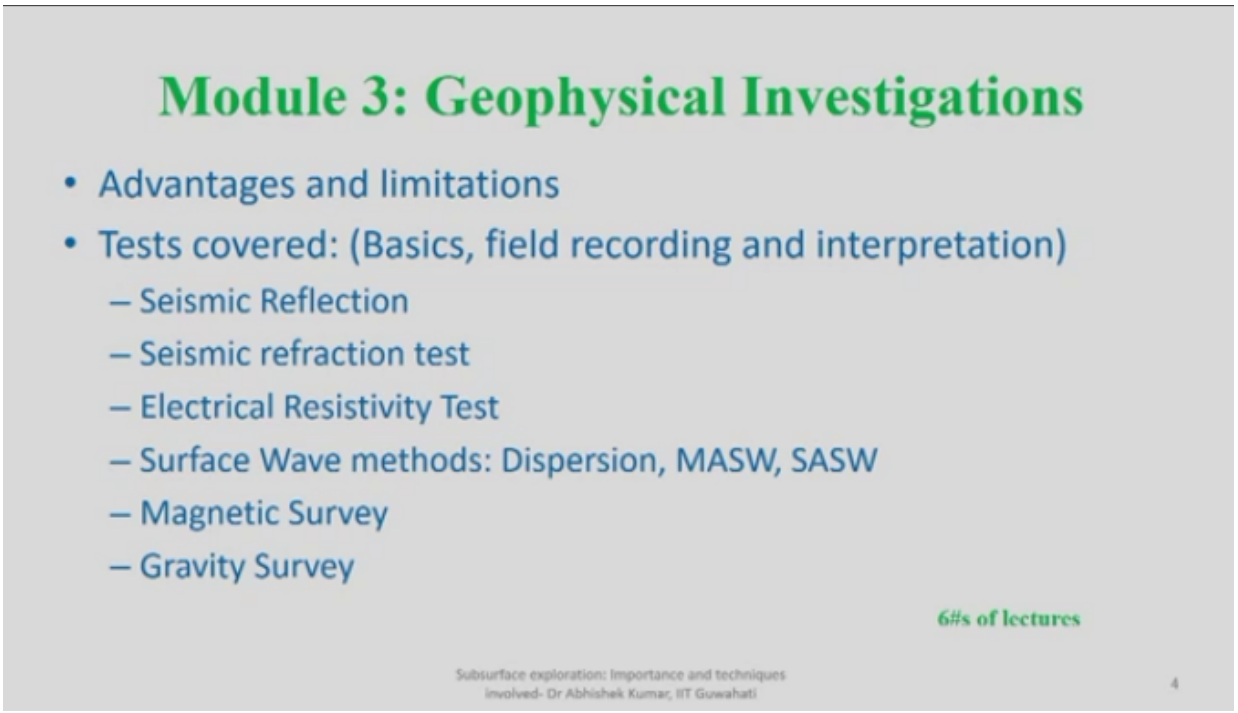

particularly for geotechnical investigation or understanding the subsoil properties, it suggested like you go, it's better to go for more than one test, so your short coming in terms of depth limitation can be avoided, you can also avoid the limitation of geophysical test in not getting the sample, so based on geotechnical you can actually get the soil sample based on geophysical you can actually interpret for relatively deeper depths.

So what are the test we had discussed, we started with seismic reflection test, seismic reflection test, how the methodology in each case works, and how seismic reflection and seismic reflection test can be differentiated from field measurements, how each of these test can be differentiated, then we went for electrical resistivity test, in electrical resistivity test also we discussed what are the basics, so we have electrodes, current electrode, voltage, potential electrodes, and based on the apparent resistance offered by the ground to supply the current, we will be able to understand what kind of medium is there, only thing it is going to give you apparent resistance, because every time as the spacing increases, the depth of exploration targeted by the potential electrode will also change, which will directly influence your interpretation.

Then what are the standard arrays which people practice particularly in electrical resistivity test, then we move around to surface wave methods which are again like, because of the dispersive nature of surface waves or more precisely Rayleigh wave like different frequency content can travel at different velocity, depending upon the characteristics of the medium, we discussed in detail what is the, what is the meaning by the dispersion and how dispersion can help you in understanding the subsurface medium characteristics particularly in case of dispersive medium, so using this characteristics two methods we had discussed, one is multi-channel analysis of surface waves which is you are trying to understand the dispersive characteristics on multi-channel or larger frequency content.

Spectral analysis of surface wave very much similar to that, but in this particular case you are doing multiple number of recordings in order to interpret, or in order to differentiate between fundamental modes and higher modes which exercise not required in MASW.

Then we discussed about magnetic method, more precisely about magnetic anomaly, why it is evident like at every location having magnetic deposits available, it might be possible like what actually the magnetic property should be there, it is not there, so there is change in the magnetic property of the medium, we call it as magnetic anomaly, so based on magnetic anomaly you can get to know what is the characteristics of subsurface medium.

Then same way we discussed about gravity method, in terms of gravitational anomaly,
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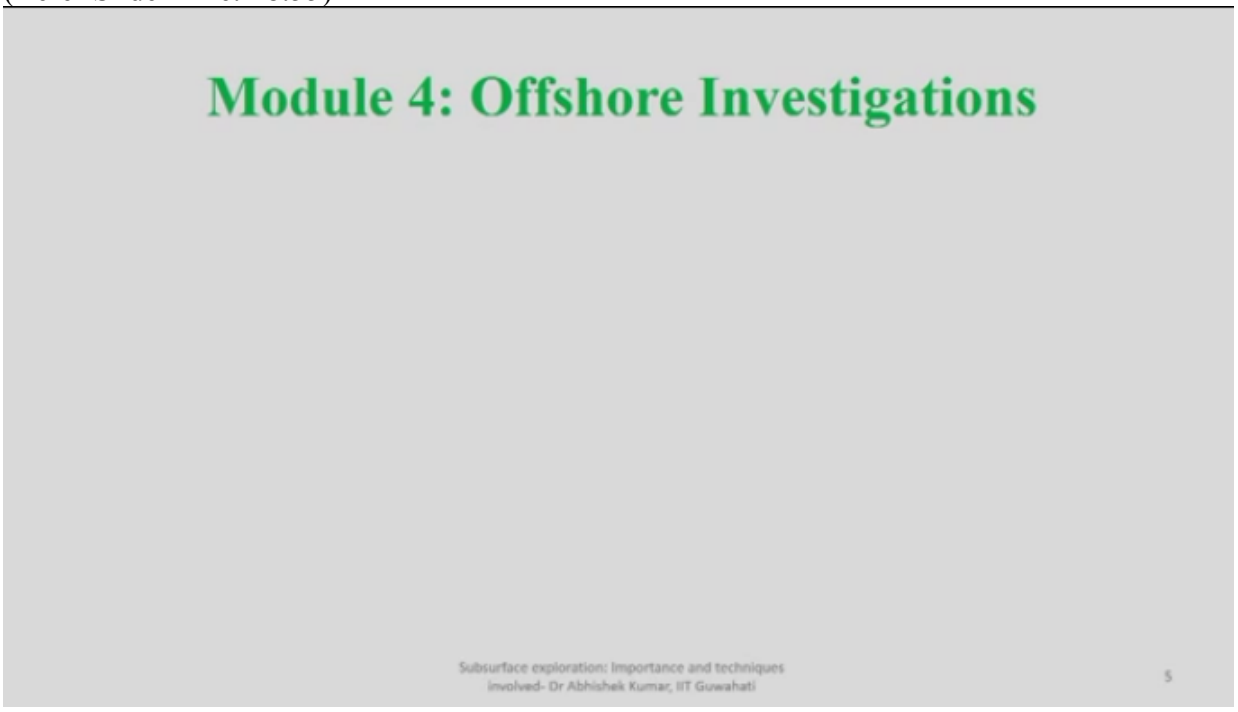

then we moved to offshore investigation, we discussed like what is the advantage in what cases people are going for offshore, whether it is for artificial islands, even for tourism purpose, even for aircrafts, airports development, other than oil and gas exploration purposes, so under this we discussed like because offshore environment is possibly the first time in any geotechnical course,
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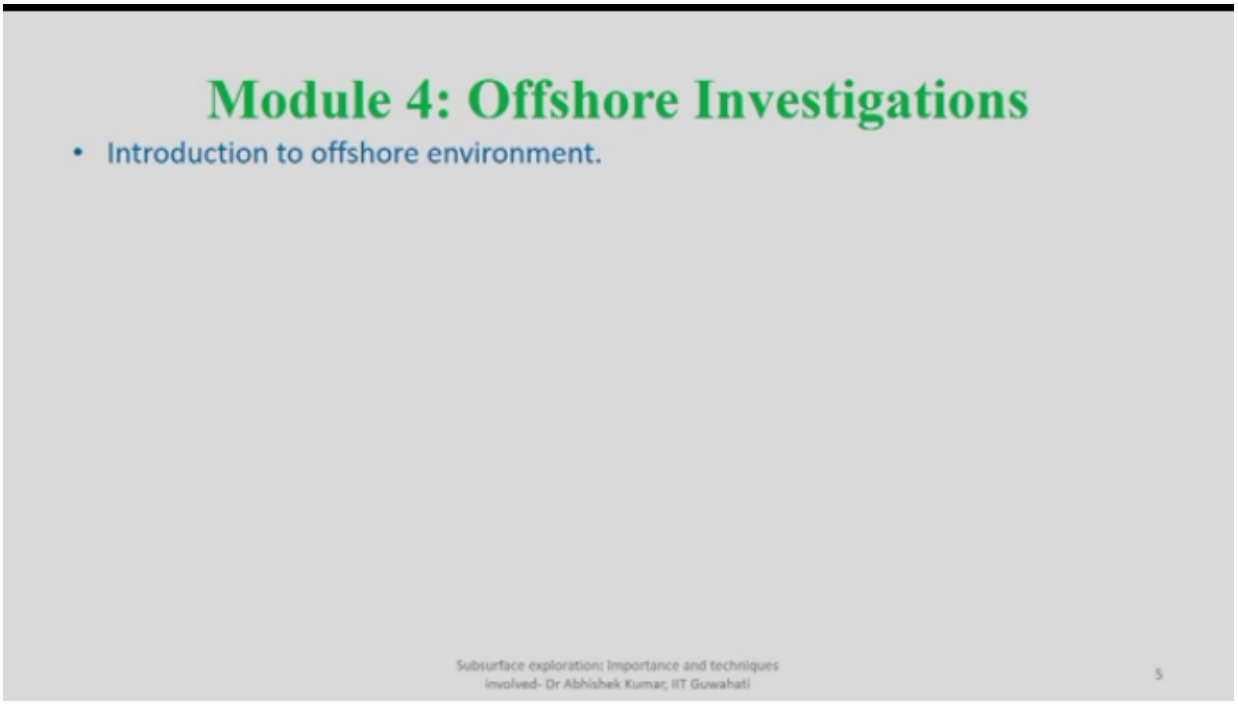

we had discussed about offshores, we discussed like what do you mean by offshore, what kind of possible challenges which can arise during offshore structure while one should go for offshore structure.

And then we discussed different kinds of anchors depending upon the depth of water, depending upon the kind of load which has to be transferred there, so we have different kind of structure, what each of those kinds of anchors can be differentiated, then depending upon the deposits, depending upon the characteristics of medium which are available at the sea floor, sometime it can compromise the safety of the structure, sometime it can be dangerous in terms of casualties also, so we had detailed discussion on what are the possible challenges citing example of different kind of deposits available.
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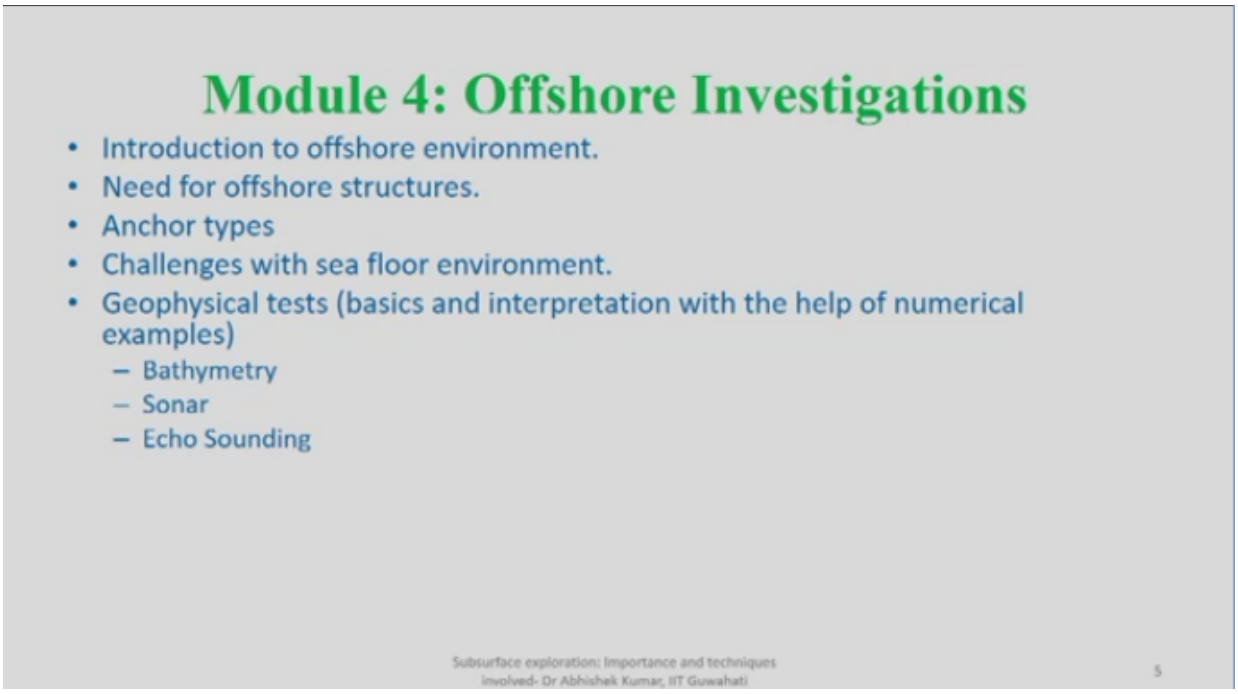

Then referring to that we started with geophysical test, so the objective particularly in offshore investigations are two, one is to find out the water depth, second one what are the possible obstructions which are available at the sea floor which are not actually belonging to the sea floor, so that based on bathymetry test, based on sonar, based on echo sounding test you can characterize the subsurface, offshore environment we had discussed, then once you go for geotechnical investigation what are the different challenges that also we had discussed in module 4, then when you go for sampling, what are the different ways because whatever samples you are collecting, it is available at minimum depth is sea bad which is submerge under certain depth of water, so the routine way of sampling which we generally use in onshore cannot be used in offshore environment.

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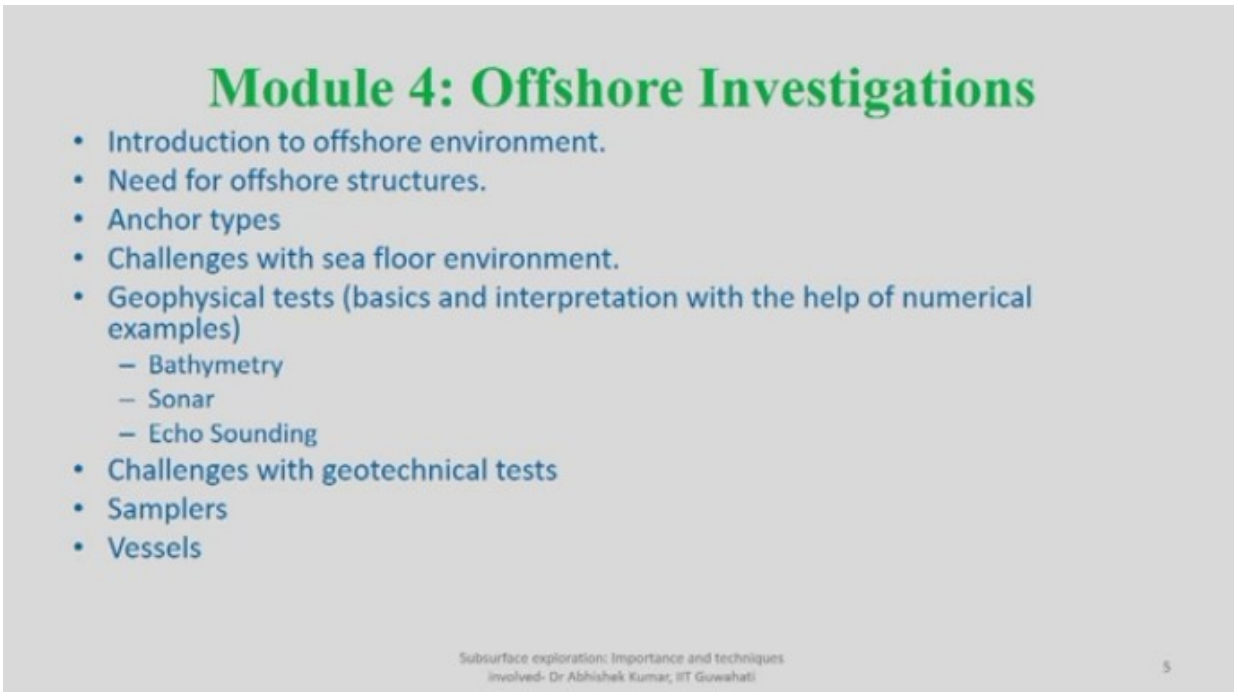

Then what are the different kind of vessels people use, once because these are not routine vessels which we are able to see every here and there, so these kinds of vessels are dedicatedly design for offshore investigation purposes, then jack-up platforms, anchor platforms we discussed all these things so that.

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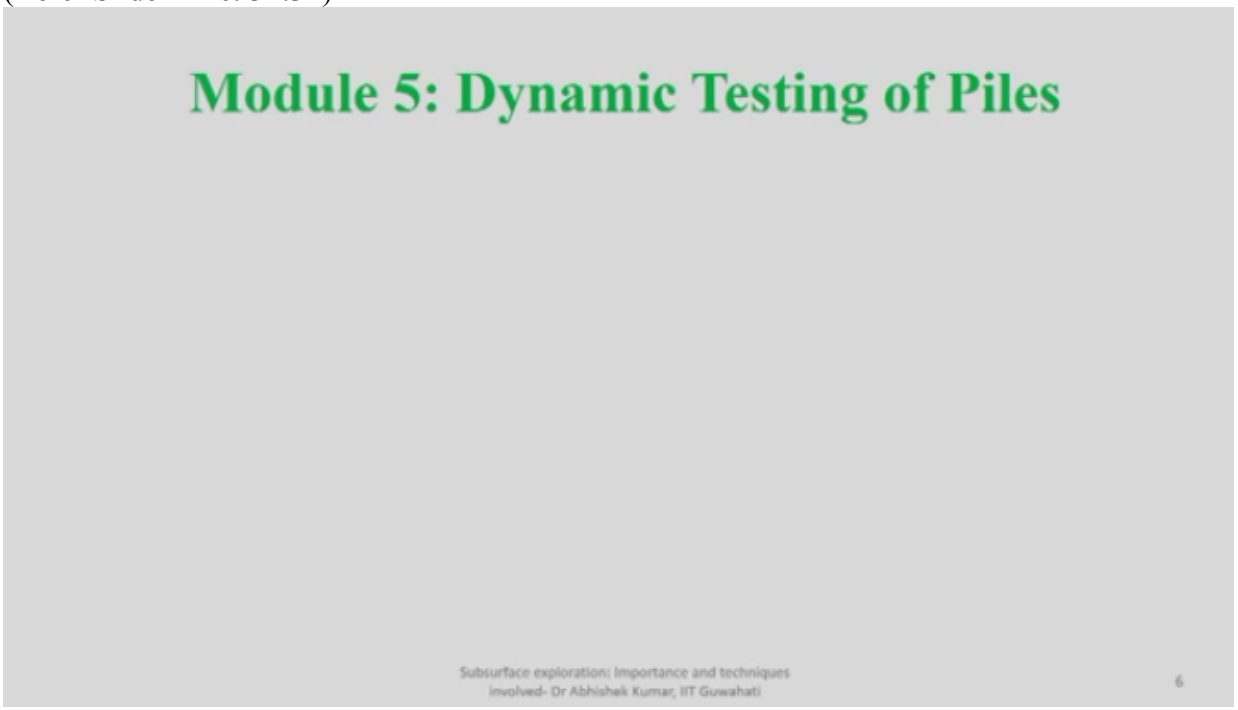

Then the unit 5, that is module 5 we discussed about dynamic testing of piles, we started with the, because most of the time because problematic soil is there, or harder strata is not available at that particular depth, so we are going for pile foundation, but in order to ensure that whatever

is the design of the pile, as per the design whether the same pile has been executed at the site, considering the length, considering the diameter, so dynamic testing of pile is very much important for that aspect, so in this we discussed what are the issues involved why people started discussing and understanding the soil behavior, pile behavior using dynamic testing, then introduction to dynamic testing, what do you mean by dynamic testing, particularly we started with hammering which is required for pile driving, that can be used by means of some senses to understand the characteristic of pile cross-section as well as pile length, even the variation strength characteristics.

So what are the typical setups required we had discussed there? Then interpretation, we discussed in terms of pile drivability analyzer based on so what component is coming from the site,
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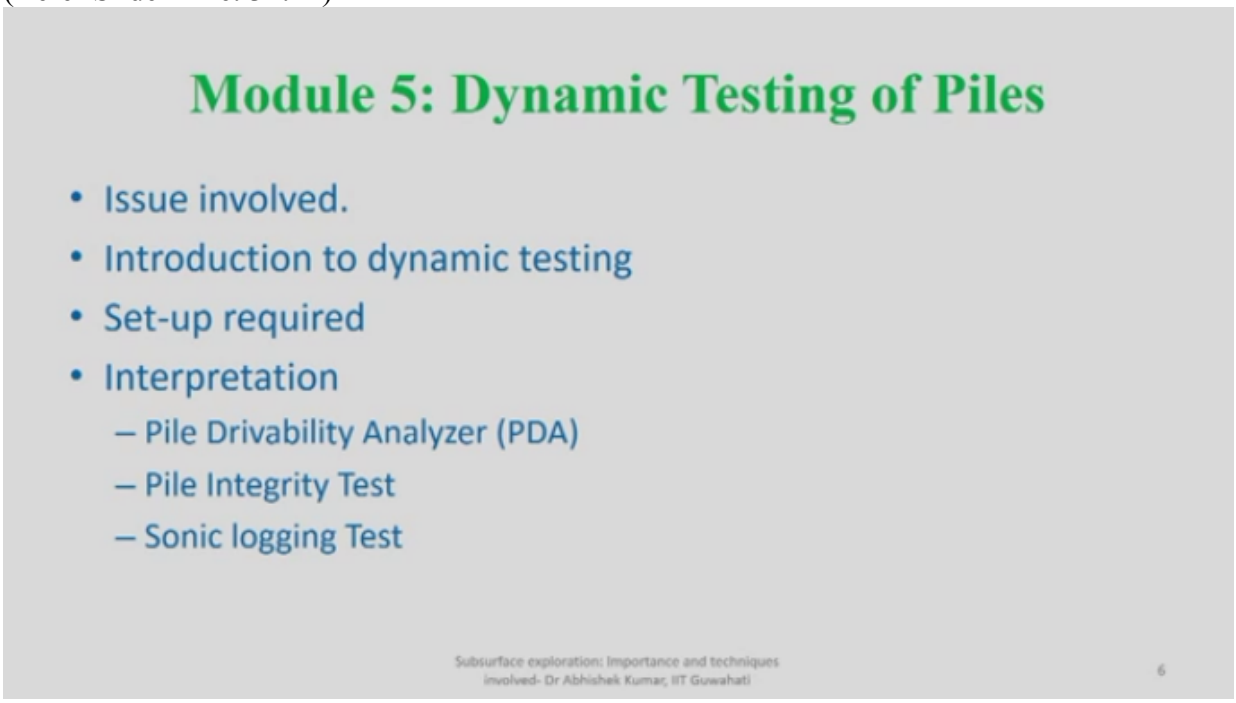

what component is coming from the depth, that if you are able to get based on your typical sensor records you can actually get an idea about what is the overall resistance, the pile is offering as skin pile or maybe end bearing pile or combination of both.

Then about the integrity test we discussed two methods are there which can be used to understand whether there is some change in the cross section, whether some change in the strength characteristics of the material, which has been used for in the pile material.
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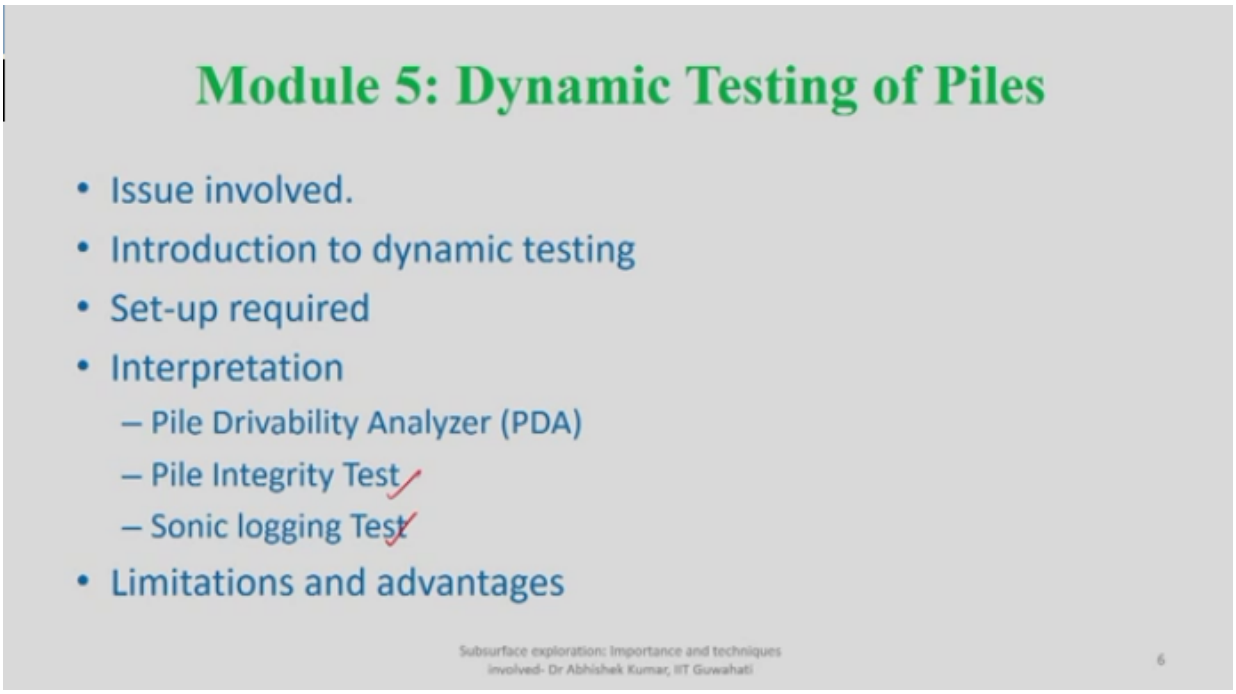

Then what are the limitation and advantage in which cases this test you can use, in which case you cannot use this test, we had detailed discussion on that, so this entire module 5 was discussed in 2 number of lectures, so overall this course, I mean this was the concluding lecture in order to give you the brief summary like what are the test we had discussed, and what are the different topics we had discussed here, I hope this test, once you finish the entire course you will have better understanding about the test which we are using as geotechnical, geophysical, either in offshore or onshore environment, and the last part that is dynamic testing of the pile because this has become more and more mandatory nowadays for overall safety of the structure. Thank you so much .

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