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Subsurface Exploration: Importance And Techniques Involved

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Lecture 2

Phases and classification of Subsurface Investigation

Welcome all to Subsurface Exploration, Introduction and Technique Involves. Myself Dr. Abhishek, and today is lecture 2, so the topic of today's lecture will be phases and classification of subsurface investigation.

Last time when we started with lecture 1, we had gone through different requirements of subsurface investigation why we should go for subsurface investigation, why we should go for detail investigation then once we are planning how we have to go for, what are the objectives, what are the requirements of this kind of investigation.

So today also, I mean in continuation to the previous discussion we will be dealing with the basis of subsurface investigation, so concede in the requirements, considering what kind of projects in today life, and we are dealing with an considering different kind of civil engineering structure, we are dealing with because finally every civil engineering structure is the one which is the one which is going to transfer the load to the sub soil, and that's how the importance of subsurface investigation has been highlighted in the previous class.

So we have some phases, how you go for subsurface investigation, it's not like once you select the site you directly start doing some geotechnical or physical test, there are of course some background information is required before you go for detail investigation, so those are known as phases.

What are the different phases, once you know okay this is my particular site of interest or this maybe site maybe one among many sides which are found suitable for particular kind of projects particular for kinds of dams, particularly for kinds of bridges, nuclear power plants, there of course you know lot of geological, environmental, political, financial constraints are involved, so based on that often it is practice to go for at least multiple number of location, multiple number of alignments for those kinds of projects.

And then once you've selected okay for this particular project these are tentatively 5 or 6 sides and out of these I've to select which is the best suitable site considering the resources, considering other constraints with me, so when we go for detailed investigation, before going for detailed investigation and before finalizing the tentative site there are certain requirements, there are certain preliminary investigation which we do in order to ensure with whether the site which we have chosen, it is really suitable for the kind of project we are dealing with, particularly for mega projects where is still choice of site is, choice of the site is still with the hand of that the owner or the decision maker and second thing wherever financial constraints are given lesser priority rather than the safety of the structure.

So in order to make this structure safe, in order to avoid any kind of distress we have to finalize the site which is based on the general guidelines are found suitable and which will also say that okay this site maybe suitable for the kind of project you are dealing with, you can further go for detail investigation.

So starting with preliminary investigation which will tell you what are the kind of site which has suitable for kind of, your project you can follow up with detail investigation of the side, so collectively the findings from preliminary investigation will give you whether you have to go for detail investigation or you can stop it, you have to find some alternate side, because this particular site is not found suitable for the kind of project you are targeting for.

So you go for detail investigation, then based on detail investigation again as I mentioned earlier also that the depth, the details whatever you are requiring for, it varies from project to project, it varies from structure requirement, it varies from the complexity of the structure, it depends upon what are the external characteristics which is governing the design or low transfer mechanism, and what are the overall coming loads on to the structure, that will decide what will be the depth of explanation, what is the detail or what is the extent of details you will be targeting once you go for detail investigation.

At the end of detail investigation what are the requirements, what are the stem characteristic, what is the soil properties, what are the engineering properties, water table, other challenging issues, whatever you have found based on those collectively you will be prepared for execution, you will be prepared for planning how the laying of the foundation, how the excavation, how all these things will be planned, so this is like overall the findings from preliminary investigation, findings from detail investigation will give you some kind of guided path, okay this is the way you can proceed for detail laying, and moreover it will also give you in case you find some kind of problems, in case of some challenging what are the alternate options which particularly a designer or a field engineer who is mostly looking into the construction part, who is mostly looking into a design part, so that they can have some idea about the side, okay this way if you go and we stuck of it because of some site constraints because of some adjourning site constraint because of lot of ecological issues also coming into picture, so what are the alternate options based on which we need not go for sides change, but we can manage with the same side, but we have to make some changes maybe in design consideration, maybe in foundation type choice, maybe a low transfer mechanism, we can provide different kinds of, different choice of foundation which will also decide those things.

So today the in continuation to the last lecture 1, we will be discussing what are the different phases which will tell you whether to go for detail investigation, and of course when you go for detail investigation it's not like for every site the objective of detail investigation will be same, some sides will be there which are particularly selected for, I mean different sides are there which are, which as a designer, as a investigator we will be targeting for different purpose, maybe it is because of new construction, it maybe because of distress, it maybe because of like lot of psychological sides are going now in certain specification, locations are going some kind of distress, so the choices of objective, the objective maybe a plenty, but what our objective we are looking for the site depends upon what kind of project, what kind of site we are dealing with, and depending upon what are constraint, what are governing criteria for investigation, so that is the idea of the today's lecture, so what are the phases and what are the classification, how you go for subsurface investigation, how you go for exploration and what are the requirement of different kind of, different classes of investigations.

So need for subsurface and exploration as we discussed, the slide is basically about the revision of last class for people,
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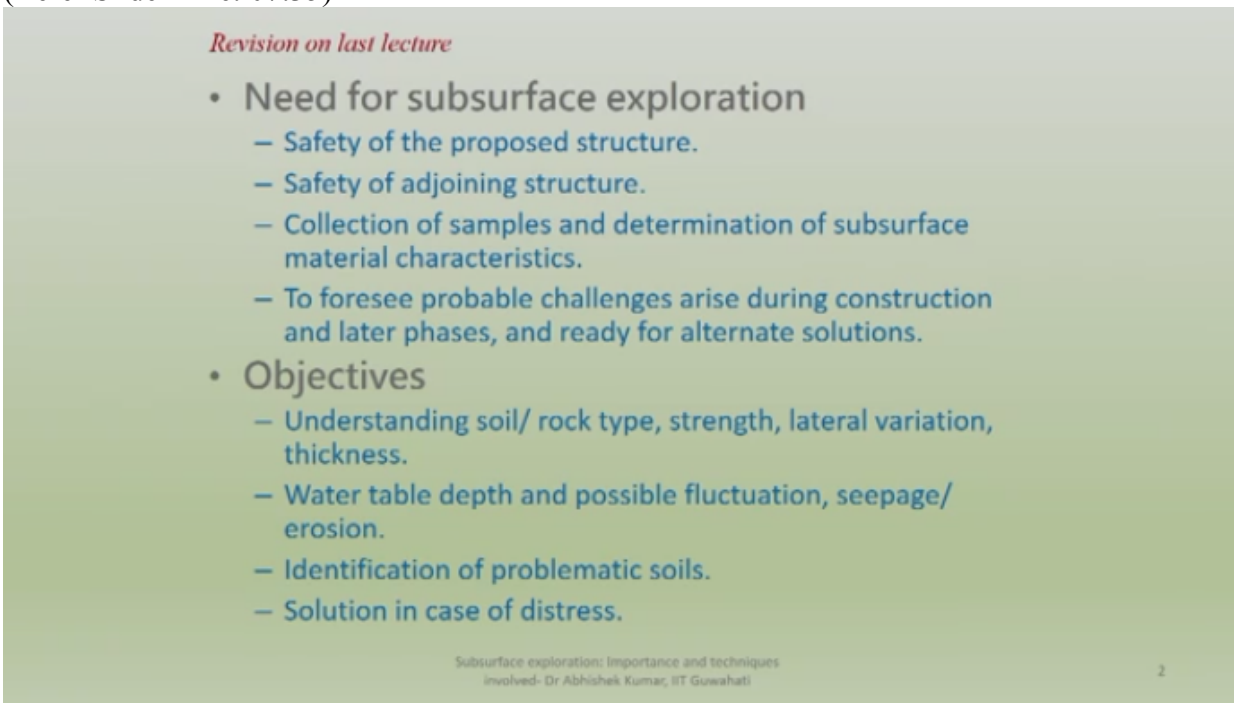

and just for the continuity I thought it will be better if I can put some small write up on whatever we had discussed in last class, so first one is safety, so what are the needs of subsurface exploration? It will ensure the safety of proposed structure, particularly when you are going for new kind of construction, then it will also ensure the safety of adjoining structure, so when we go for safety even excessive vibration which is getting in terms of which can affect the serviceability criteria of adjoining buildings can also be among, one among many regions which we will guide your subsurface exploration program, that will help you in your planning your exploration program.

Then lot of excessive settlements are there, then removal of supports, later support that can also lead to a different kinds of failures to adjoining structures, at times you have legal issues also unless you have done proper subsurface investigation unless you have planned, how you will go for clearance of the side, how you will go for deep excavation, how you go for laying of the foundation, there are always a chance it can cause any kind of discomfort to the adjoining structure, and you will end up with legal issue, so that is another need for subsurface exploration.

Then collection of samples, and to foresee, in order to, and to forecast what are the possible risk or challenges which may arise few particular side, if you consider particular siteand of course if you know what are the challenges you will be also ready with what are the alternate solutions based on which you can overlook those challenges, so these are the needs then we discussed about the objective, so it's particularly about to understanding what are the soil rock types available, what are the strength and lateral variation, how about water table possible fluctuation, what about seepage characteristics and erosion properties, a possibility at the site of intrusion identification of problematic soil which can later on and more uncertainty to your found its design properties, govern design properties or soil characteristic and solution in case you are looking for some kind of remedial action for distressed structures.

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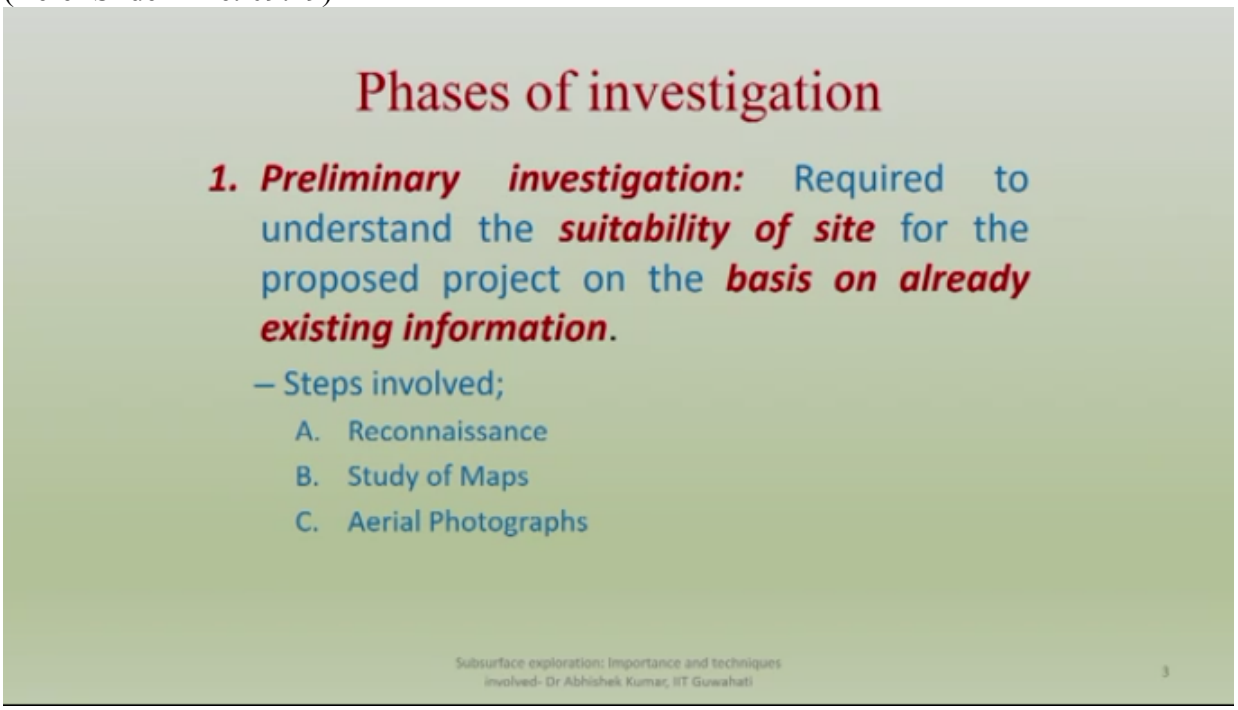

So today we will be discussing first is phases of investigation, as I mentioned initially so when we start for investigation it's like first we'll go for preliminary investigation which will be, I can say a very crude or a very preliminary stage of investigation which will give you whether overall for the kind of project we are dealing with, whether this particular site is suitable or not, rather than directly going for detail investigation, so that is called as preliminary investigation, this is the first phase of investigation.

The other phases of investigation, we will be discussing in coming lectures because when we'll be discussing about those kind, we will be discussing in detail what are different methods, what are the different geo technique or geo physical method which will be used for detail investigation, what are the depths, what are the requirements, what are the geological condition, what are the physical constraints in which you can use a particular test, you cannot use the other test, so when we go for preliminary investigation it is particular required to understand the suitability of the side, so that will give you whether the site is suitable or it is not suitable particularly for the kind of project we, or the proposed structure we are targeting.

As I mentioned earlier this kind of investigation will be very helpful in deciding the site selection or particularly for major projects like dams, bridges, nuclear power plant and at times for the construction of waste containment, normal waste and nuclear waste containment also of course you have to have some kind of preliminary investigation for site selection, so you have to, even for waste containment you have to create different kind of civil engineer structure, so in order that those should not go any kind of distress or failure, you have to start with preliminary investigation.

The beauty of preliminary investigation is most of the investigation, most of qualitative, quantitative assessment about the side, about subsurface of the side, about environmental condition, most of these thing you do based on the existing literature.

So existing literature many of you might not be aware like there are certain agency which particularly deal with geological condition variation, maybe across state, across district, across country also, and then identification of active regions, identification of active faults, the fault which were not there maybe couple of decades before or some faults which are showing some kind of new fault which are coming up, then the kind of mineral deposition, the kind of gas and oil deposits, so all those kinds of information is available in terms of different maps, the kind of subsurface and surface soil type available, there are agency which particularly deal with particularly for tube wells, particularly for irrigation purposes so certain agency which particularly deal with what kind of soil medium is available in a particular region, what is the possible fluctuation in ground water table, so those investigation, those preliminary in data which is required to in order to decide whether your site is suitable for a particular project or not, you can collect information which is already existing without going into detail investigation at the site of interest. So that is the key point like preliminary investigation generally we do based on the already existing information.

So what are the steps of preliminary investigation? First one is reconnaissance, some of you might be knowing like reconnaissance, what are the objectives and how we proceed for, then second one is study of maps, third one is aerial photographs, as I mentioned in the very beginning, a preliminary investigation highlights that a particular site is not suitable for the proposed structure,

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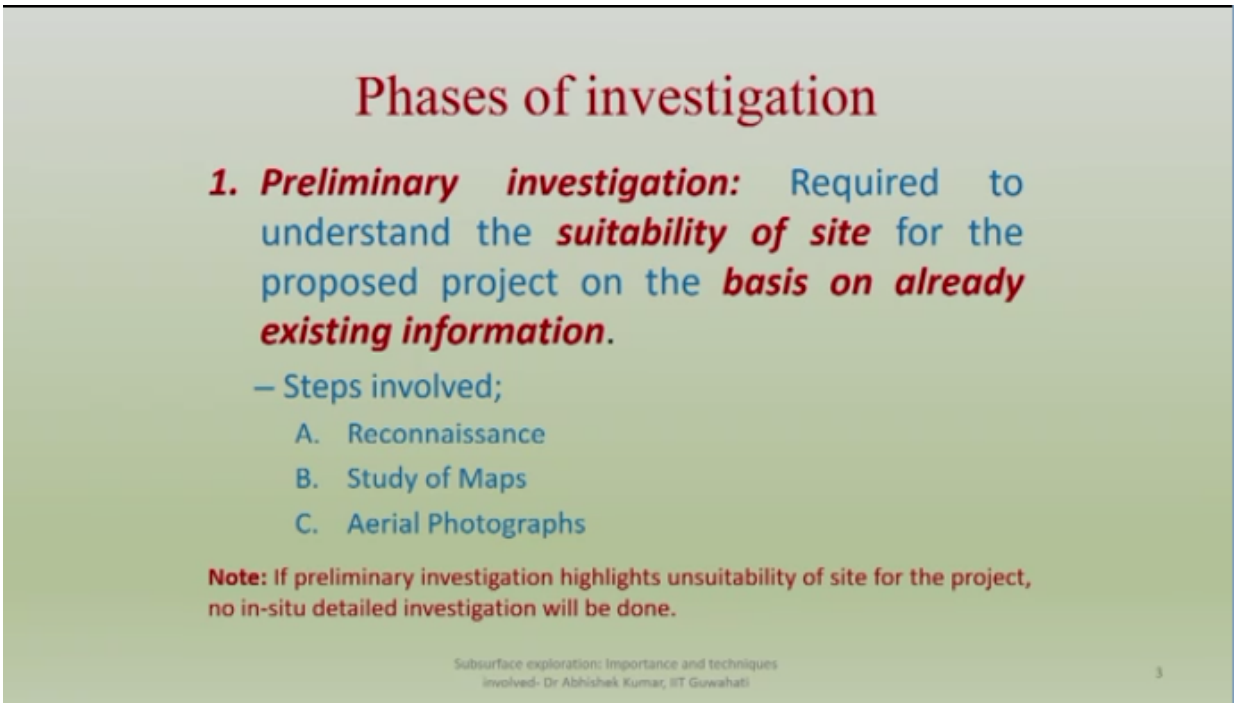

there is no need to go for detail investigation, because in comparison to preliminary investigation in majority of the cases detail investigation will be much much costlier, lot of challenges will be there, at times you have to arrange for resources which were not easily available at the site of interest.

So before going for those kind of complicated decisions to be made, it's always better to go for preliminary investigation to decide whether it is require, so when we come for reconnaissance, it is basically the study of topography, what kind of elevation variation whether there is a cliffs, whether there are mountains,

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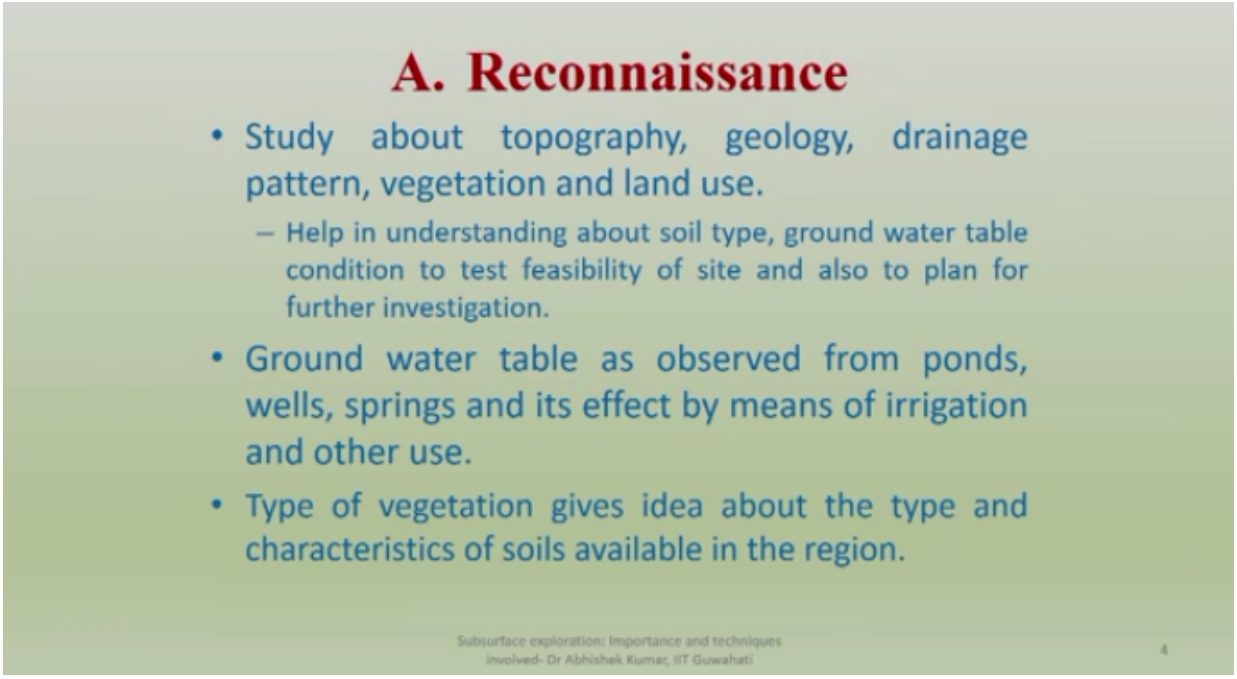

valleys, plains and many more other thing which will possible indication of what is a topographical variation on the study area, then geological deposit whether your quaternary sediment what kind of geological timescale also what kind of deposits have been, so whether there are younger deposit, whether those are older deposits, whether those are, when deposited sediments, whether those are sediment because of deposition done by water bodies and so many things then what our drainage patterns, what are the sources of water, ground water surface water, and water bodies and then vegetation.

Vegetation will also give you very clear idea of course in majority of that cases like depending upon what kind of vegetation is prevailing in particular location, you can get an idea about what are the nutrients of the soil, and what is the possible soil type which will help in growth of those kind of vegetation, so even if you start assessing the quality or the type of vegetation available in a particular region that can also give you much idea about what kind of soil tap is available.

Then land use that will also give you an idea of what kind of land people are practicing, whether it is for irrigation, whether it is for I mean that will also give you an idea whether the soil is strong enough, just for help overall in understanding what kind of soil is there, what is about ground water condition, and overall that will help you in understanding what is the feasibility of the site, so if you find okay, my site is feasible enough for the kind of project, then you can go for detail planning for further investigation, so this is like some kind of input it will give, whether you have to go for planning, if you are going for planning then what kind of planning is required, because depending upon soil type you will have to, and depending upon soil type, depending upon foundation type you have to decide what choice is in terms of foundation, what choice is in terms of equipment, what choice is in terms of excavation are suitable for your site of interest.

Then ground water table, you can observe, so earlier I mentioned about the topographical maps available for the region and geological map also, geological survey of India, yes they also

provide, so those are existing information, only thing many a times we are not aware like those kind of information are readily available, and then we started doing some preliminary borrow at the site of interest which may not give you that quantity of information as you can get from these, because these are based on how regional variation of each of this properties are actually existing at the site or region of interest.

So ground water table fluctuation also you can observe based on some ponds available in the region, wells, springs, and you can also understand if you collect these kinds of information over the period of time from certain agency what is the effect of fluctuation in ground water table based on irrigation and other purposes which are actually depending on even ground water or surface water resources.

Then type of vegetation as I mentioned earlier also gives you an idea like certain kind of crops can be cultivated or can be grown in only in few types of soil, while other may not be so if you know what kind of vegetation is prevailing that will also give you an idea what kind of soil is there, once you know the soil you can at least get an idea about what are the basic characteristics of the soil available at the site of interest, and if not at the site of interest overall in your region of interest.

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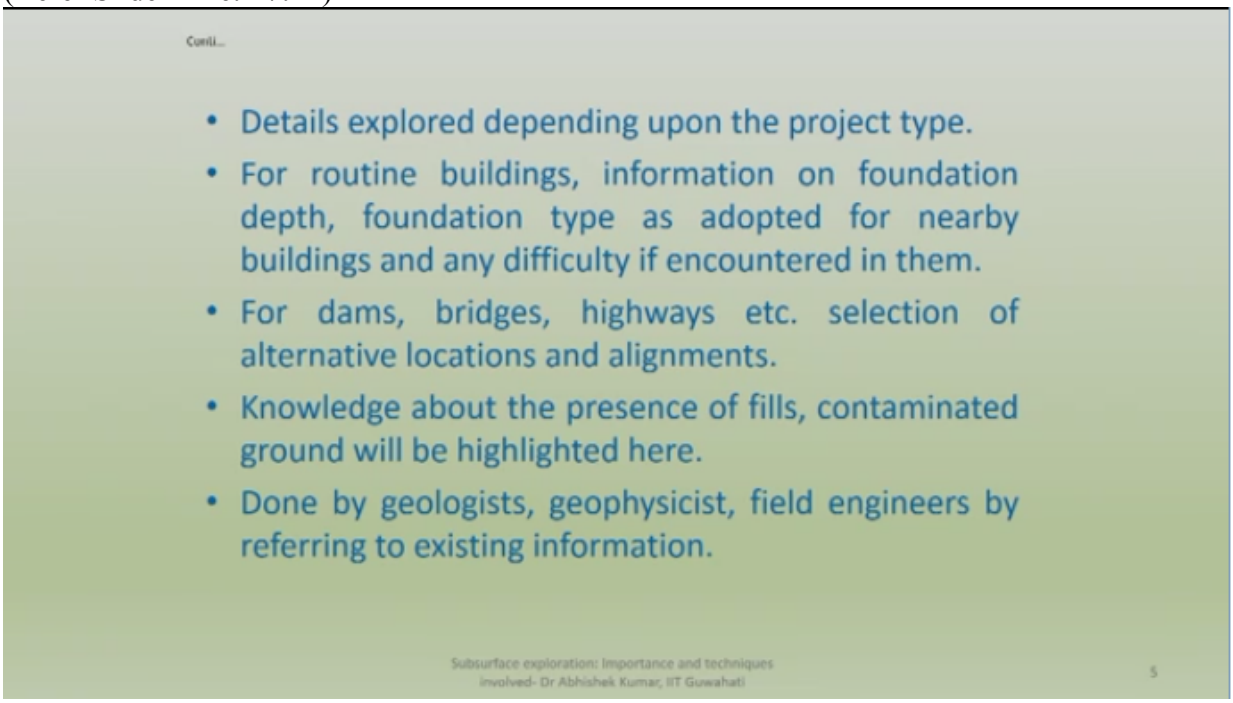

So then you go for detail exploration depending upon, okay this kind of investigation also depends what kind of, what details you are exploring or looking based on reconnaissance survey also depends upon what kind of project you are dealing with, as I mentioned earlier depending upon the project your depth of exploration will also change, your radial extent will also change at times the effect of that particular project also govern the safety of adjoining structure, so that detail which you have to explore or the resources which you have to go through also depends upon what kind of project finally you are targeting at the site of interest.

For routine buildings information on foundation depth, foundation type as adopted in nearby buildings, so that will also give you an idea, okay, for routine kind of buildings, even particularly in case of industrial areas when people I mean lot of coal industries are there, lot of metal industries are there, so what kind of problems it will found when they had actually those kind of industry maybe during the construction or maybe at later stage, you can adopt those information when you are constructing same kind of buildings at your site of interest, so this is particularly when you are going for routine kind of structures not the kind of structure as I mentioned in next point.

For the case of dams, bridges, highways, of course the reconnaissance survey will help you in identifying not only one location but alternate location so that once you, as I told like location of these structures depends upon lot of other constraints, so once you found alternate location then you put those constraint and then you can go for detail assessment.

Then alignment of like particularly for bridges, highways, the alignment is also gone by so many other things, so you should be ready based on the reconnaissance survey you should be ready with what are the possible alignments at each of the alternate location or maybe at same location what are the possible alignments, so those are combination you can get an idea based on reconnaissance.

Then knowledge about the presence of fills, lot of places you may find fills, lot of you may find contaminated ground so that can also be highlighted, you can also identify those kind of information if you know a land use data for a particular reason, you can also get these kinds of information based on resource map which are published on maybe district level, maybe on state level also by different, different agency that I mentioned earlier also, central ground water board is another agency in India which particularly look after the soil type possible fluctuation and even at certain location, contaminated ground if it is there then that can also be highlighted based on refer into such kind of report.

So usually whatever I had discussed so far, whether it's related to topography, whether it is related to lot of other things whatever we had discussed about topography, possibility of fills, possibility of ground water contamination, all these things people have identified, so the people who are generally dealing with those kind of studies are geologist, geophysicist, field engineer, so you can see like almost all kind of people who will be directly or indirectly dealing with decision making, execution even for designing are already involved, but only thing all of those will be involved referring to the existing information, rather than going for any detailed investigation at this particular level.

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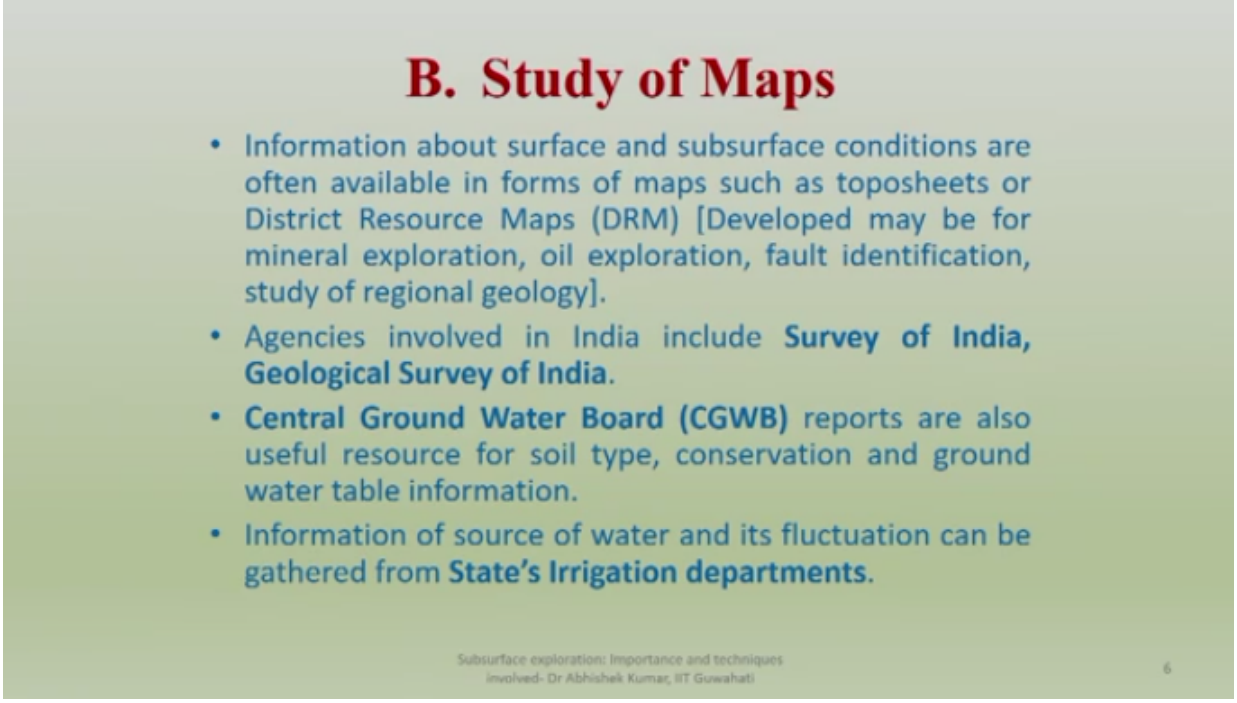

Then second one is study of maps, lot of information again related to surface and subsurface conditions are available in the form of maps to give you an example like district resource map, if you collect district resource map for each district mostly it is available, it is available from this geological survey of India you can get from regional offices, you can get from main office also, head office of geological survey of India and it's, we call it as DRM where you can get an idea what kind of geology is available within, so you can get an ideal like the quantity of information and at what level the information is available, you can get those information even at district level.

Now in many of the developing countries and develop countries what people practice, if some borewell has been doing in the particular location there are certain agencies maybe who are particularly dealing with design guideline development, so wherever they find some information about borewell they'll immediately mark that borewell information as well as the borewell coordinate on district map, state map or maybe country maps, so later on if somebody is interested they can collect those information and use it as an additional information in addition to whatever field the investigation they are planning, that will give you more and more accurate information about the site.

So I was talking about maps, so we are having district resource map, and you are having geological maps also, you are having toposheets also which will give you an idea what are the elevation differences, what are the water bodies, what are the important roads, railways and all those things, so and also of course it can also give you an idea about the study of those thing will also give you an idea where are the actual mineral deposits, oil deposits available, so particularly these geological maps have been developed while addressing for mineral exploration, so people when they were interested, what kind of mineral particularly available in particular location they go for detail investigation as a result of which even you are having geological map, you are having oil, I mean different maps are there, and for the identification

yes based on again geophysicist seismologist were interest in identifying what are the active faults in a region.

Then again that will help you in understanding what is the level of seismic activity or regional scale or levels, national scale, so people came up with DRM or seismic atlas map identifying the active faults which are available, liniment which are available in a particular region, so that is an additional information, particularly if you are going node is, nowadays we know like almost every places susceptible to earthquake, so if you know what are the faults which have been identify based on preliminary investigation which maybe following in certain radial distance from your site of interest that will give you an idea, okay, you cannot completely ignore the seismic consideration but you have to tell that thing well into account, so you can go for again referring to those maps, because I had mentioned here agency like survey of India, geological survey of India they are doing lot of investigations even you can find, I mean lot of like central ground water board as I mentioned also reports what are the soil type and the conservation of soil type in a particular region and then what is the ground water depth what is the possible fluctuation you can have one, so one who is interested for reconnaissance investigation or study of maps can often refer to reports publish by each of these agencies.

Then information about sources of water and its possible fluctuation, at times state irrigation department also lot of places they also keep a record so one who is interested can always refer back to these kinds of data, so overall it will help in understanding what kind of soil is there, what kind of rock is there,
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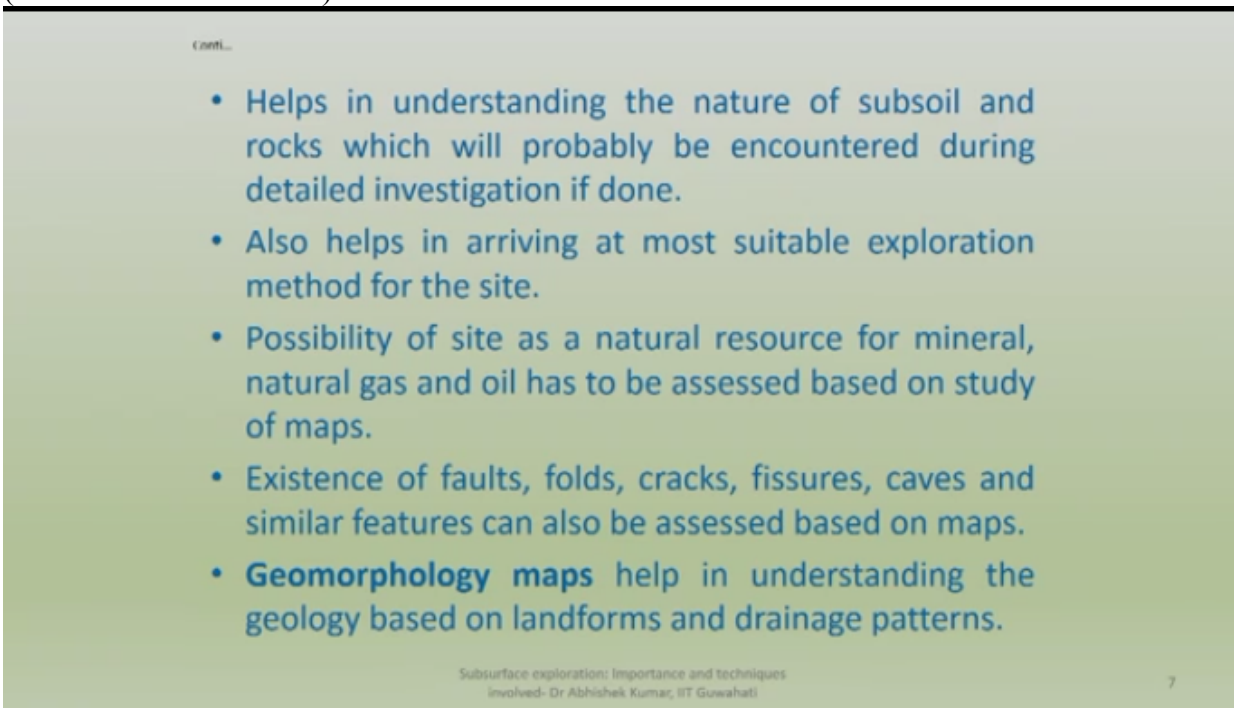

also it will help you in understanding and forecasting like what the possible challenges which can accounted and how you have to go for detail investigation, so which will probably be encountered, because you know what kind of soil is there, what kind of rock is there, so that will be in your mind you can get okay, depending upon what kind of soil is there, this is the

method of boring, this is the method of drilling, you can adopt because other method may not work as indicated by the study of maps.

Also helps in arriving at most suitable exploration method as I mentioned in the previous also, then possibility of a site that is also, that is one among many important parameter points, like a times based on these maps you'll also come to know like the location in the nearby areas are also sources of mineral and oil deposits, even natural gas deposits so accordingly you can take those things into design consideration and SAT selection, again that you can get to know an idea about based on the study of maps.

Then existence of faults, folds, cracks, fissures, caves and other similar features which will also tell like what are the governing features which are, what are the prevailing features of processes happening in the surrounding region which are responsible for development of these kind, each of these kinds of features in the study area, so that will also help you particularly for geologist and seismologist that will also help in getting an additional parameter in understanding the response of the soil, response of the site under different environmental or natural conditions.

Then geomorphological maps, this will also help in understanding what kind of geology is there based on what kind of landforms are available, what is the drainage pattern, so those are called as geology map, geomorphology map.

Again to give due importance in case of legal issues, so whenever there is some kind of legal issues particularly when your site is located very much enclosed proximity to maybe mines, blasting site or maybe some source of vibration which is causing distressed, so those kinds of I mean, though the problem will arise at later stage but you can get an idea, okay, because this kind of activity happening surrounding to my site, so that is also causing some kind of distressed and that will help in dealing with the legal issues, so that is additional advantage if you are going for study of maps.

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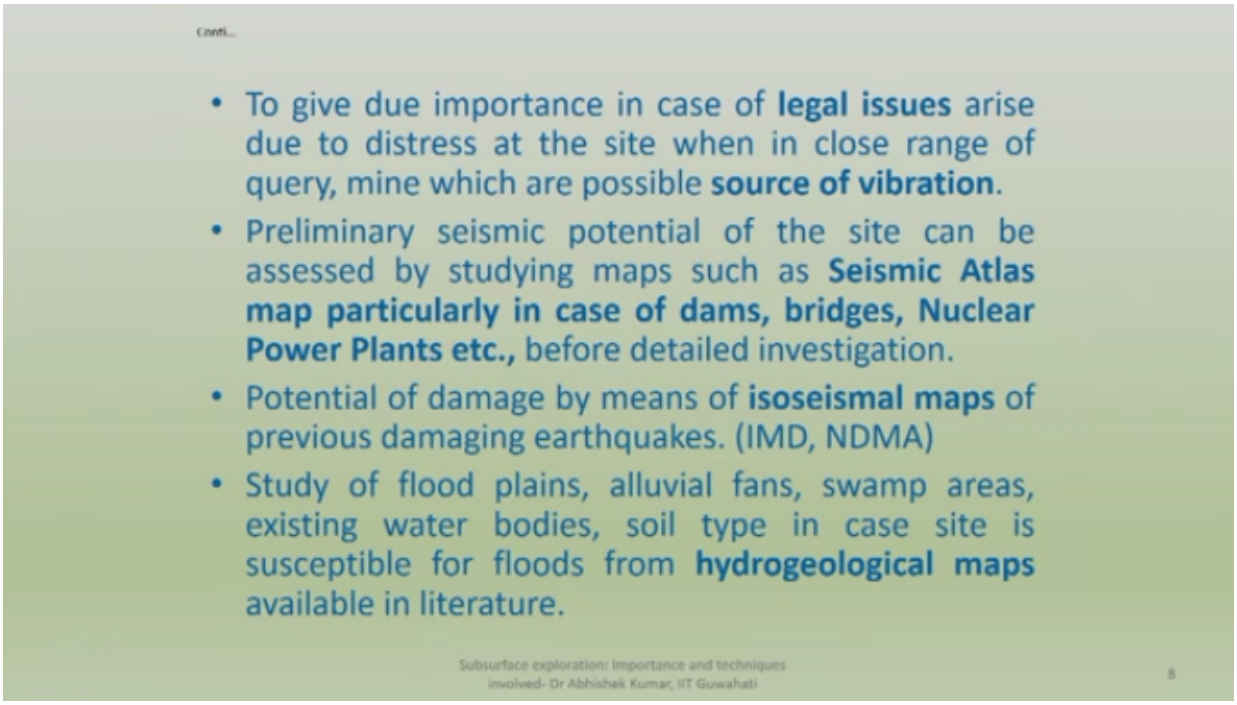

Then seismic potential of the site, seismic potential of the site means need not be the site is always located on the fault, but if the site is enclosed proximity to the site maybe 50 kilometer, 100 kilometer even 200 kilometer and if the sources capable of producing significant earthquake that can cause damaged to the site, that can cause a distress to the site, so again seismic atlas map as I mentioned earlier also geological survey of India has developed seismic atlas map they keep on updating at regular interval, so particularly when you are dealing with dams, bridges, nuclear power plant when where the seismic activity of surrounding region makes major difference in site selection as well as the choice of foundation you are going to adopt, you have to always refer to those seismic atlas map and so, and then the ground motion recording in India started just couple of decades before but if one start rating you can see like lot of damaging earthquake has happened in different parts of the country, particularly in seismic zone 4 and 5 which are seismically two more most activity seismic active regions of the country, so you can also refer to isoseismal map, isoseismal map will tell you what kind of damage, what is the extent of damage which has happened during historic earthquake or the earthquake which had happened before actual recording of ground motion.

So even though at present stage you find your site is no more susceptible to earthquakes, but if you refer to isoseismal map you may find okay, maybe in 1800, 1700, there was an earthquake which cause significant amount of damage at the present location where my site is there, so that will help you understanding the true seismic city of the site rather than under predicting the seismic activity of the sites, so there are agency which can give you these kind of information you can get from NDMA also, identification of regional zonation, zone base seismic activity then India in metrological department also you can refer that will also give you lot of information about historical and recorded current earthquakes.

Then study of flood plains, alluvial fans, swamp areas, existing water bodies, soil types, like each of these information will be always available with concerned agencies, so one can refer to those in case the site is susceptible to flood, nowadays we have seen which, like more and more

location nowadays considering the present scenario you can understand more locations are nowadays susceptible to flood which were not there maybe couple of years back, so there are certain reports which you can refer to like study of flood plains maybe some literature in form of books in terms of publication is also available, you can always, one can always refer and trying to understand what is the susceptibility of your site in order to, I mean for flood.

Again hydrogeological maps are also available in literature, so one can refer those information, so this is like whether you go for geological map, whether you go for topographical map, whether you go for seismic atlas map, whether you go for hydrogeological map, whether you go for mineral deposition based map, so all these information is already available, only thing one has to concern the, one has to contact the concern agency and one should be first of all aware like such maps are available or some can refer to those maps before going to understand the knowledge about the site.

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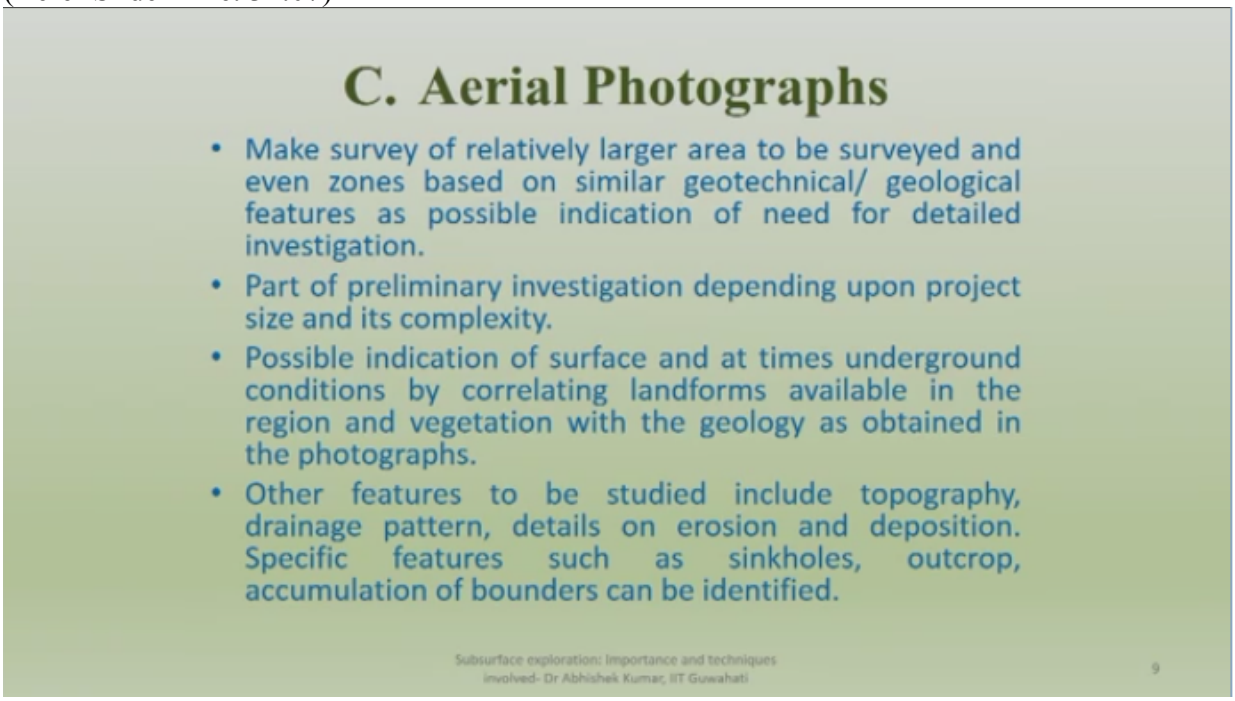

Then aerial photograph, though it's not very frequently practice, but again depending upon what kind of project, what is extend of the project at times aerial photographs give you very good information, very reliable information, the best advantage with aerial photo graphics it will make survey of relatively larger area quickly and even at times if it based on the features you are identifying based on aerial photograph, you can actually divide the entire area of your study to different, different zones based on the characteristics you are observing from your aerial photograph, so that will help you, you need not go for entire area for same kind of investigation, it might be possible in one part of your study areas, different kind of deposit is there, so which require different kind of methods to go for investigation, other area it will be completely different, so rather than applying gathering the resources may not be applicable to most of the study area that will give you an idea, you can divide the entire thing into zones, and apply parallelly different different resources for detail investigation, so that will help you in

significant saving and timing as well as resources as well as finance, so aerial photograph in that case is very useful.

Then these are the part of preliminary investigation depends upon project and its complexity, that will also be possible indication of surface and at times underground conditions by correlating landforms available in the region as well as the vegetation with that geology, so even as we discussed in reconnaissance also based on aerial photograph also you can identify what kind of vegetation is there, and based on that vegetation, based on landforms available from, as obtained from aerial photograph one can get an idea about what kind of geology is available without even actually going to the site, it will also be helpful if the site is not accessible at the very beginning for going for any kind of other preliminary investigation, like the site is almost, there is no structure in the nearby areas, and the site is completely surrounded by vegetation, swamps and so on.

Then those case also aerial photograph can give you lot of information, nowadays people go for even remote sensing data also or satellite data also, so to get more and more information about the site which if you go to the particular site may not be feasible or may not be actually possible within the limited resources.

Other features which to be included based on aerial photographs are topographical drainage pattern, you can very well study these then details on erosion and deposition also of course you have enough aerial photographs and I mean in temporal variation, showing temporal variation you can understand in deposition and erosions activities, then you can also understand specifically features also can be identified like seeing coals, particularly for limestone deposit with marginally high ground water table sinkhole can cause lot of problems, outcrops, if your site is having outcrop you are, I mean that can give you much confidence about the site particularly going for foundation, but of course you have to also take properly in consideration regarding once you are dealing with the vibration part, okay, so that is about aerial photographs.

Then geomorphology, many of you might not be familiar with the terms, so geomorphology like what kind of features available in particular region, whether it's a cliff, whether it's a valley, whether it's a _35:46_ , whether it's undiluted ground, whether it's level ground, so each of these features in a particular region are existing at that particular location because of some natural processes happening in and around of that region, so geomorphology is basically defining or understanding what kind of processes which are responsible for these kinds of evolution of landforms, how those, why those landforms are there at that particular location that you can understand based on your geomorphology maps.

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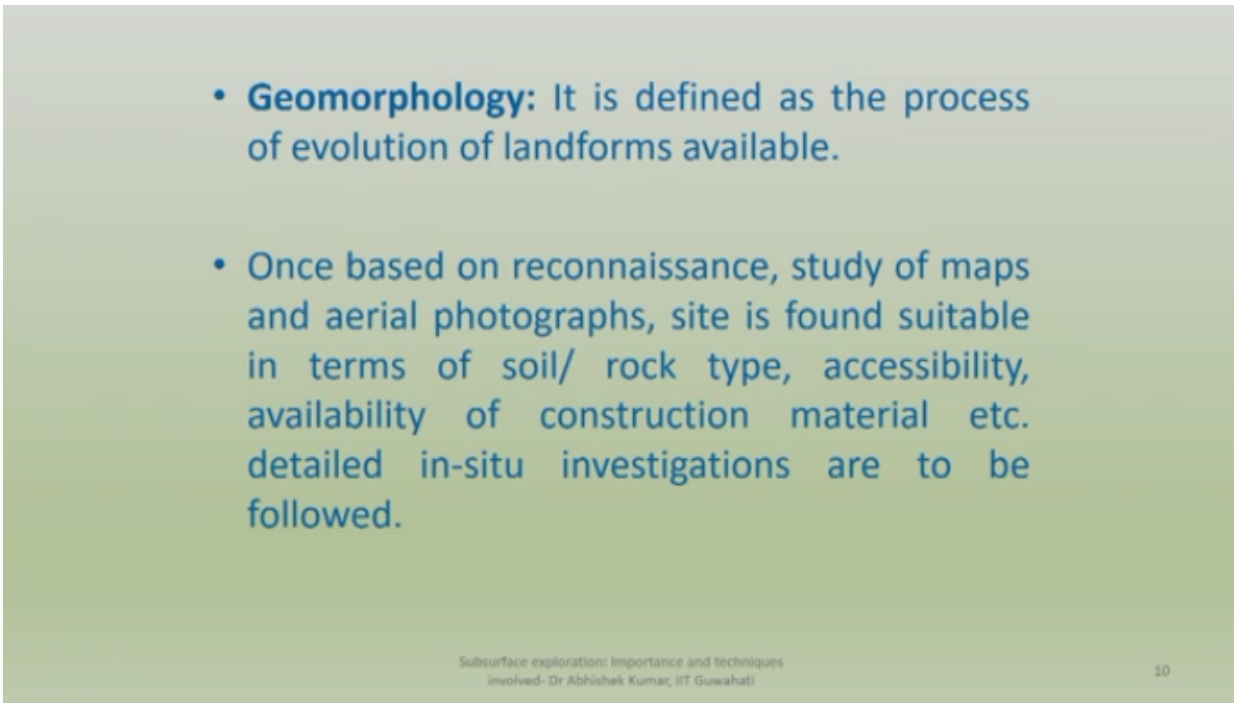

Once based on reconnaissance so at the end, once based on your reconnaissance, based on your study area, study of map, based on your aerial photographs you identify your satisfy okay whatever my proposed structure is there, this priority is act for that kind of structure, now I can give green signal to the next agency responsible for detail investigation, so if that satisfaction can be in terms of soil and rock types available, accessibility of the site can also be another criteria because at times clearance of the site itself is quite financially, I mean it's a financial challenge, and then availability of construction material is another deciding criteria which will help to you in deciding whether the site is suitable, so each of these collectively will tell you whether your site is suitable and whether there is a need to go for detail investigation further, okay.

So this was about the preliminary investigation phases, once based on preliminary investigation if you identify that was particularly for new construction, same thing you can also adopt in case of existing construction also as I mention about safety of adjoining structure also you can always refer to geological maps you can always refer to topographical map, you can always refer to report mentioning some source of vibrations, mineral deposits, quarries which are available in the particular region, so when you go for, so once preliminary investigation is done you have to go for detail investigation, so before planning for detail investigation you have to classify, there are certain classification that depends upon, you are doing detail investigation for what purpose? So depending upon the purpose the classification can be classified into, that's why I have written here,
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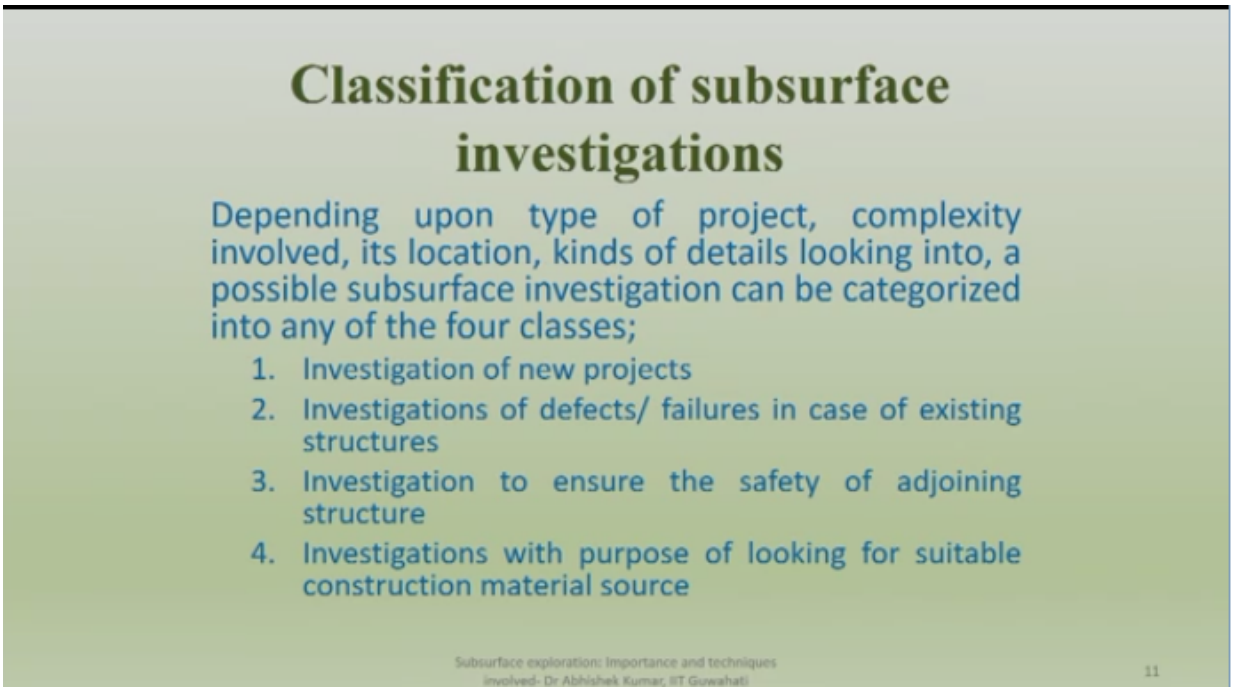

so depending upon the type of project its complexity involved, it's location, the kind of details looking into and the possible subsurface investigation can be classified into four categories or four classes, majority of us know like we do subsurface investigation for whenever some new kind of project is planned at the site of interest, so that is one amount four categories in which you can go for subsurface investigation.

So one is first as you can see here, first one is investigation for new projects, second one is if you find there are some kind of defect distress over the period of time on the particular structure which was build based on certain investigation and you have to provide some kind of remedial action, you have to provide some kind of solution for restoration, so again that require additional investigation, so how do you go for those kind of investigation that is altogether different from new projects.

Then third one is investigation which will ensure the safety of adjoining structures, this is not always possible as I mentioned, there might be possibility like adjacent to your site there are other structure which may or may not be building even some research laboratory they are there, even some machinery operation is there, so you have to take into account what are the design guidelines for those kind of machinery what are the serviceability criteria of those kinds of buildings, and you have to plan your foundation, your investigation programs accordingly at your site of interest, otherwise the safety of adjoining structure because of the activity happening at your site of interest will be compromised.

And the last one is investigation for the purpose of looking for suitable construction material, so that is also another separate part of investigation which will tell you depending upon what kind of project particularly for the construction of highways, nuclear power plants where you have to have continuous and huge supply of a particular kind of material, so from where to borrow this material, again you cannot take out the material you have to have well confidence that the requirement from the material is meeting at the site of interest in nearby to your, the area from

which we are borrowing that soil or rock is meeting with the standard which you are actually requiring for your site of interest, so for that also some investigation will be require, so we'll not be going into detail of those investigations but I'll just give you what are the observation, what are the your opinions, one should keep in mind once we are going for any of these four kind of investigations.

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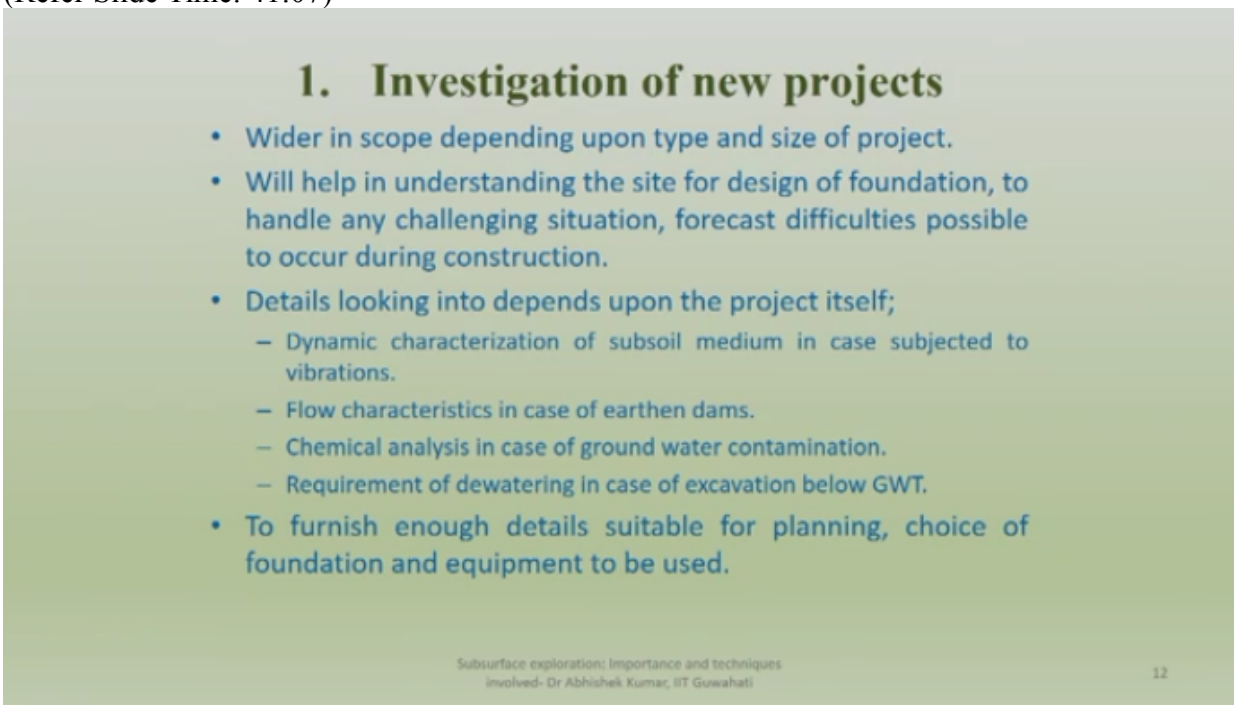

Like investigation for new projects of course because we have very less idea other than whatever you've collected from preliminary investigation about the site, based on this investigation we are going to start excavation, we are going to lay the foundation and then super structure, so overall the safety of the project, execution as well as the design life of the structure everything will be depending upon the information you are gathering from subsurface exploration.

So in comparison to other these are wider in scope, because you are dealing with completely virgin ground kind of and you have to ensure the safety of new structure so that you should not go for safety compromise of other structure and your own structure should not be under any kind of distress or discomfort, so these are wider in scope depending upon that type as well as the size of the project.

So depending upon whether its routine project you will go for routine investigation if it is challenging kind of structure as we had highlighted maybe in introduction class, so different kind of structure, different kind of investigation will be require, then these will help in understanding the site for design of the foundation and to handle any kind of possible challenges which may arise and during construction as well as forecast difficulties, so well in advance you be ready okay there are chances this kind of difficulty may arise during the construction phase so you should be ready for those kind of decision making and alternate options based on these kind of investigation, then details looking into depending upon the kind

of projects, so what kind of details you are looking into also depends upon what kind of foundation you are dealing with, so in order to give you an example like dynamic characterization of subsoil, dynamic characterization is means how particular soil which available at the foundation level and beneath, like in the zone of influence, how that particular soil is going to respond whenever any kind of excitation is there, it maybe because of blasting, it can be because of seismic activity, it can be because of any form of way, any other sources of ways, so how this particular soil which looks very stable during static condition, how it's going to change its response whenever it is going for any kind of dynamic or seismic excitation, as I mention here in terms of vibration particularly for mega structure.

Then flow characteristics as in case of earthen dams, when there will be too much fluctuation in water level, how the characteristics of the material, how the flow characteristics are going to change that also one can address while going for investigation for new projects. Then chemical analysis in case of ground water contamination, nowadays we see like majority of the time we consider okay ground water may not create any problem but we know lot of places is particularly in numerous metros you can see, very easily you can identify ground water is getting contaminated very higher rate, because of maybe dumping of waste into it, maybe because of putting chemical into it by different agencies, so nowadays whatever characteristics of ground water we had assume while designing the foundation, it may or may not be there so we have to do, rather we have to check whether chemical analysis is required for that particular kind of site because of possible ground water contamination.

Then requirement for due watering as I mentioned earlier also, considering the requirement which is more frequently followed nowadays we are going for two or three storey below ground level, so of course you have to go for excavation, and if that excavation has to reach a level below ground water table, then you have to go for dewatering.

So what are the requirement for dewatering, what are the possibilities, what are the soil type up till that particular level, not only at your site of interest but at the surrounding site of interest, so this is another detail you have to look into while investigating for new project, so this will furnish enough data that will help you for further planning, that will also help you what kind of foundation you can go for, that will also help you what kind of equipment you can use for laying of the particular kind of foundation, so each of these things is the part of investigation you are doing for new kind of projects.

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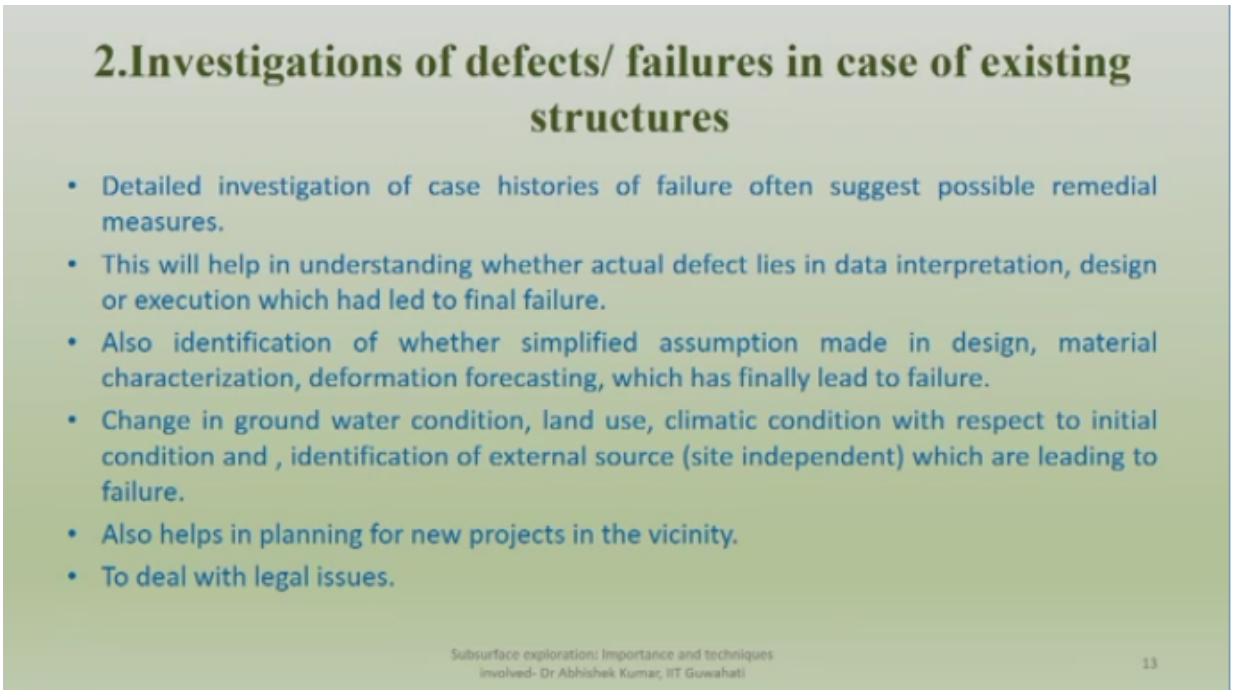

The second one as I mentioned here is the investigation of defects or failure in kinds of existing structure, so detail investigation of case histories, you yourself can see lot of civil engineer structures are going continuous distress in form of bearing capacity failure, it can be because of differential settlement, it can be number of reasons, so often it has been observed like most of these places, the investigation, once you go for detail investigation you will actually understand what is the reason for those kind of distress, what is the reason for those kind of uneven settlement which is actually let to the failure, so when we go for detail investigation for these kind of study that will help you what are the reason and that will also help you in understanding what are the possible remedial measure you can suggest in order to restore if it is possible to the concerned agencies.

This will also help in understanding whether the actual defect lies in data interpretation, data interpretation you did some test at the site well before the construction started, so whether there was a defect in data interpretation, whether you had over predicted or under predicted some parameter, whether there was problem with the design part, so one is with the data interpretation then you will use a data in design consideration, so these investigation will also tell you whether there was some challenge it was, whether there was a mistake or error in design part or whether there was a mistake, so once based on your design, once your design is ready you will go for execution, so possible defects can arise in any of the three things considering there are, I mean as far as the construction material is not having a problem, all these things I mean the defects maybe in any of these or collectively in any of these parameters, like among these three like whether it's based on data interpretation, whether it is based on design, whether it is based on execution, so that you will be able to understand once you go for detail investigation for failure or defects of distress structure.

Also that will also help in identifying whether simplified assumptions were made assumption which we had made it maybe in other location, but may not be applicable for the site of interest, one possible assumption maybe like most of the time whenever we interpolate the soil

characteristics between two test location, so whether you are going for those kind of simple assumption, how you are going for interpolation that can lead to serious problem in design as well as building response as well, so this investigation will also help you in understanding whether simplified assumptions were made in design in terms of parameters, in terms of foundation response, whether there was simplified assumption in terms of material characterizations, material whenever I'm telling it's like subsurface material which is actually governing your foundation safety and deformation forecast, so whether the study is done for, the way the deformation was calculated whether it was correct because the structure is not bearing in that fashion and finally which of these had led to the final failure of the structure, so those are the part of investigation you are doing for this.

And the next one is change in ground water table, land use, climatic condition, so these changes which had happened with respect to the time when the actual structure was constructed, and now so whether any of these had undergone remarkable change which can cause, so though it's not, those this kind of variation could not be identified when going for initial investigation, but finally those are led to failure, then even identification of external sources, many a times your site is fine, your investigation, data is fine, design fine, execution is also fine, but still your structure is going some kind of distress, cracks, so it might be because of the reason which is coming from distance sources, one may be the which are actually site independent, because it's not happening at the site, but it is happening at nearby distance like lot of, like the location which are near to quarries, near to mines, often complaint like there are some cracks happening in those structures, which are nearby area because of blasting happening in these locations.

Even in seismically prone region, again distress can happen which is not related to your subsurface investigation details, but it is finally leading to failures, so once you go for this kind of investigation you will actually come to know what is the actual reason for this kind of failure, this will also help in planning for new projects in the vicinity like if some failure has already happened in the nearby area, if you go for detail investigation or if some detail investigation was done already, you can go through a report that will give you some anticipation okay, this kind of problems may arise at my site of interest also, so I have to plan my investigation accordingly.

And the last one and most important is to deal with legal issues, so later on I mean if you have done all those investigation properly and still it is going, still the structure is going any kind of distress or discomfort, there will be legal issues, how to go with legal issues again you have to have some kind of data which is supporting okay, it's happening because of this particular parameter, it's happening because of simplified assumption, the design it's because of simplified I mean overestimation or mistake in data interpretation, so to deal with legal issues also, because of course it is going any kind of distress, so there are always chance that legal issues will come up, so in order to deal with legal issues, in order to ensure there was no problem with that design or this is I'm telling base from designer point of view, so designer can handle legal issues, stating like whatever assumption, whatever parameter, characteristics I have taken those are very well available at this end, owner can go stating like these are the parameter which are actually available at the site, but designer has not considered, so depending upon which party you wants to go for detail investigation, the objective has considering the legal point of view may vary.

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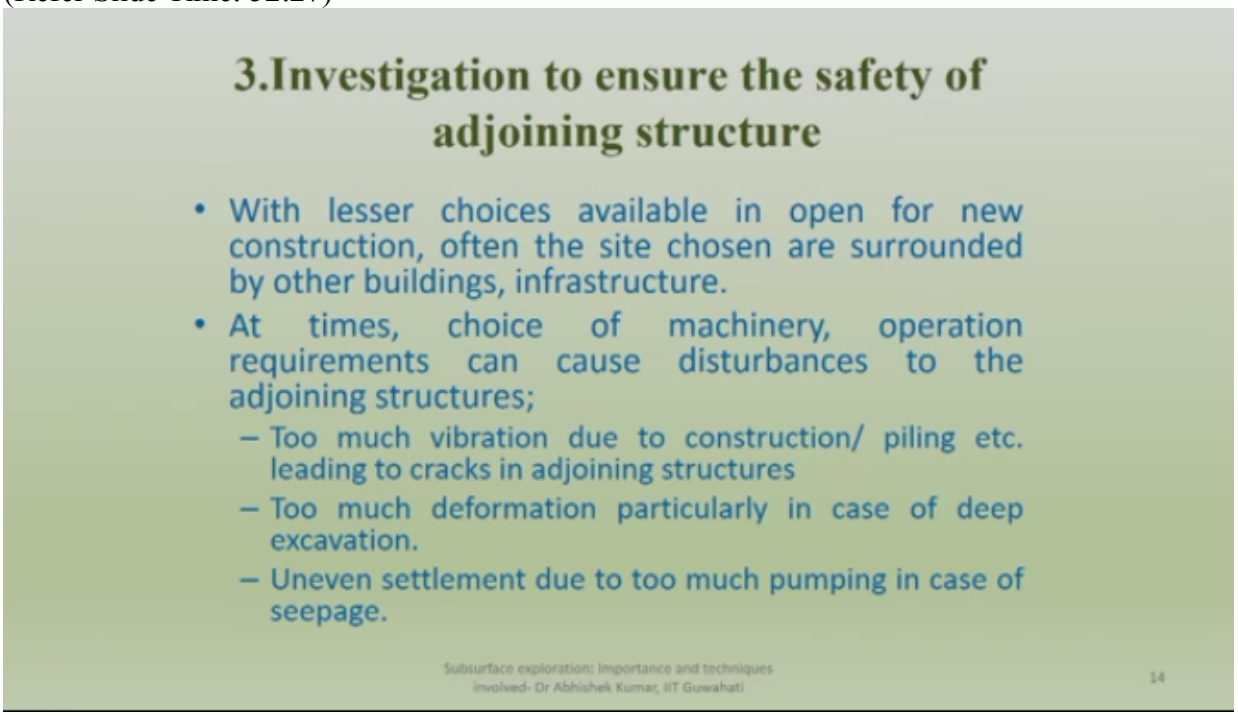

Third one is investigation to ensure the safety of adjoining structure, as we know like with lesser choice available and nowadays in open for new construction like you always don't find area which are very well leveled, with no area in the surrounding particularly for mega structures, so often the site you choose surrounding by other structure, it may be as mentioned earlier also it maybe some chemical factory, it can be because of some pharmaceutical industry, it can be some automobile industry, it can be some machine operation, it can be hospital also, and it can be other building also, I've just given you some example, so some investigation which are particularly done to ensure the safety like any of these kind of different buildings, utilities, are not going any kind of distress or the safety are not going to compromise because of construction happening at my site of interest.

At times choice of machinery which you are using for laying a foundation, operation requirement can cause disturbance to the adjoining structure like particularly when you go for pile driving it cause lot of vibration, lot of noise, maybe possible it cause lot of disturbance to your site of interest, then you go for dewatering with particularly when you are excavating below ground water table it may be possible, you pumped out lot of water which may affect the, which may change the settlement characteristics of the surroundings, I mean the soil which are available beneath the adjoining structure so it will cause definitely some kind of discomfort, I've given some example also, too much vibration due to construction, piling etcetera can lead to cracks in the adjoining area.

Then second one is too much deformation particularly in case of deep excavation can also lead to compromise in the surrounding area, then uneven settlement due to too much pumping can also lead to some kind of distress to the surrounding area.
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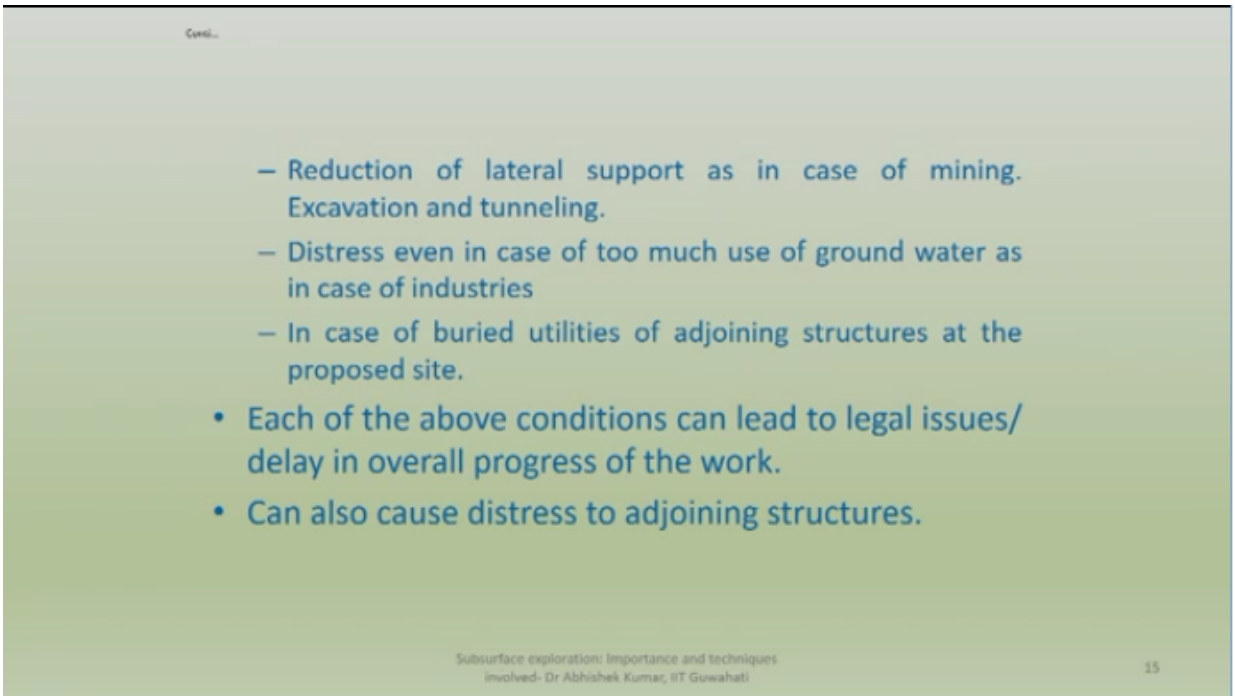

Then removal of lateral support if you are going for excavation and you find some cohesion less soil or like collapsible kind of soil which cannot retain on it zone, and is a part of surrounding adjoining structure, a foundation, then removal of that can also cause some kind of distress in case of excavation internals, distress event can be in terms of if you use, if too much of ground water is used then I think in case of industries also then that can also cause lot of distress to the adjoining structure, in case of buried utilities lot of time you start excavating at the site and you found okay, there was some buried pipeline, there was some transmission cable which may cause, which may halt the construction activity at that time, so those can also come up with later stage, so it's well, it is advisable if such kind of activities can be identified well in advance so that you can plan accordingly and you will have enough time to handle those if possible delays are there in handling or shifting those kind of buried utilities, so each of the above mentioned condition can lead to legal issues also.

So in order, overall it can lead to legal issues as well as it can cause overall delay in the progress of the project, so it can also cause as I mentioned overall distress adjoining, it can cause discomfort or it can compromise a safety of adjoining structures.

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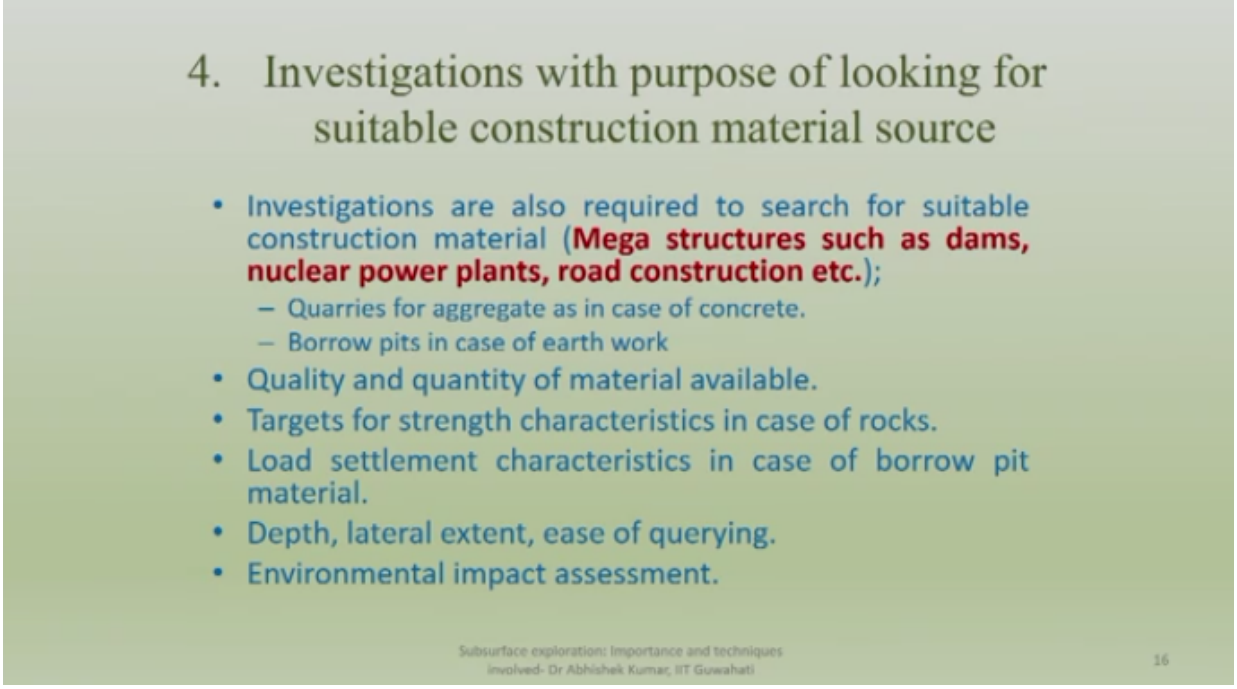

The investigation with respect to looking for construction material, so this kind of investigation particularly required to search for suitable construction material particularly for mega structures such as dams, nuclear power plants, road construction, which require lot of aggregates, particularly for, and it will require mostly aggregate and second thing which may be required in huge supply may be the earth or the soil, so you generally look for quarries which can be, from where you can get the aggregates to use in concrete as we do in case of dams, nuclear power plants and as well as in case of road construction then borrow pits, of course if we are going for retaining structure if you are going for earthen dams, if you are going for road construction you have to have like very recently there was this ministry of railways they are working with freight corridors, so how to get the money because finally entire corridor has to raise by certain amount and if you see that certain amount at some places are of the high top maybe 2 storey building, so from to where to get that kind of earth to prepare the subgrade before you go for other layer construction, so you have to search for some alternate borrow pits.

Again those borrow pits should meet the both in terms of quantity as well as in terms of quality it should meet the standard of the material which you are actually looking, you cannot simply borrow the material without understanding its behavior without understanding its strength characteristic without understanding the overall, I mean how, because considering the drive it's going to respond in as an integral part of the foundation material, how it's going to respond, so if that response requirement is not matching with the material available in the nearby location, you can actually drop the idea of borrowing the material from there, again then the stem characteristics in particular in case of rocks, that load settlement comes in case of you are taking material particularly soil from borrow pits, because that will govern by the such material can be use actually in your mega structure or not.

Then what is a depth, what is a lateral extent? And how easy it is to bring out those material from the actual natural condition to the site of interest, and of course the most, the last and most important one is what are the environmental impact, so environmental impact assessment is also

very important nowadays if you are removing those kinds of material that too in huge quantity for construction of these mega structures, so that also comes as a part of investigation with respect to looking for suitable material for construction.

So this is about today's class there we discussed about what are the different phases of construction, and when we go for detail investigation, so we cannot go for depending upon what is objective or investigation the requirement of investigation will also change like for construction material if you are doing the investigation it cannot be same as investigation you are doing for safety of adjoining structure, the one you are doing for new structure cannot be used directly for failure structure, because new structure you have to of course go for more detail investigation, and considering what information is available for structure which are already under distress you go for more advance of noted detail investigation, but certainly you go for lesser number of investigation in case of some structure is going any kind of distress, so that is all for now. Thank you so much, I advise you people to just go through those lectures and I hope you people find those lectures interesting. Thank you so much.

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