Geotechnical Engineering I
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Lecture-05
Classification of Soils-III and Challenging Situations

First category is of marine deposits.

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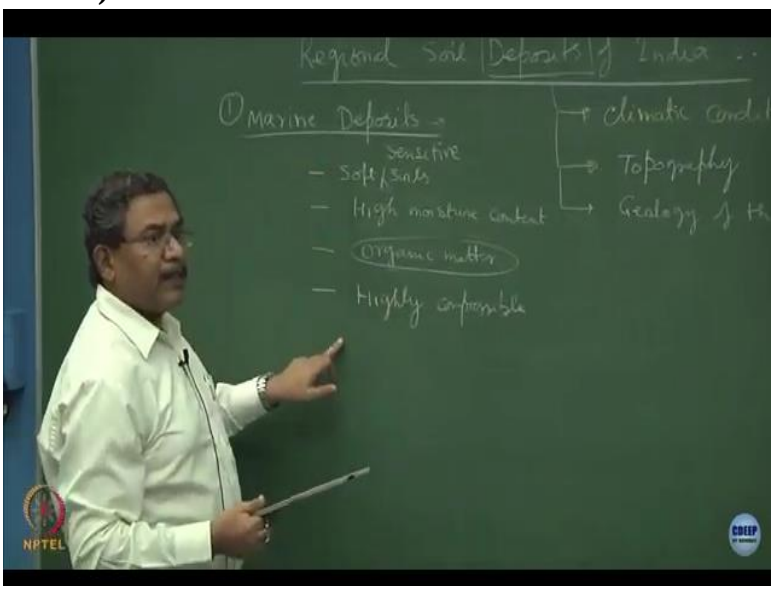

Very soft soils, very high moisture content, substantial portion of this type of soils would be organic matter. Now when the soils are soft and when they have high moisture content by virtue of these 2 things they will become very, very compressible alright. Now, when they become compressible what will happen is a boon or it is a bin, so submarine deposits by virtue of their nature that they are close to the marine systems have very soft sensitive soils. Let me put a word sensitive here.

When we say human beings are very sensitive, suppose if I say you are very sensitive what is the meaning of this, you get influenced by everything very quickly is it not somebody that he is not good. Now, you will be down for at least 6 hours clear like that only these soils are very intelligent materials, they are very soft, but very sensitive also, the moment you touch them they get disturbed, alright very difficult to take out the sample from the ground to bring them to the laboratory.

And to test them and to get the parameters which can be utilized for design purpose. So, these are very soft, sensitive soils high moisture content why because they are in the water body all the time, organic matter is present it is the bane for geotechnical engineers, but boon for boon for what which industry I am yet to see any culture form sitting on the marine clays only oil forms can be there, hydrocarbons.

So organic matter which becomes a bane for me is a boon for the guys who are into petroleum industry Bombay Hi. There is only one Bombay Hi, have you got about anything else, except for kg bass and now in Assam, you have some oil fields in western part of the country now we are talking about Australia and all these our plans, which have come out very recently in the deserts. So, wherever you have organic matter by the calcium carbonate present in desert soils could also be organic in nature clear it could be an organic also.

So, this organic matter plays both ways. These deposits are known for good oil reserves okay, these are the petroleum reserves. But as far as laying the foundations construction of infrastructure is concerned, creation of buildings is concerned, very big problem. These are highly compressible just like sponge okay. Another category is let us talk about the black cotton size, if somebody was discussing.

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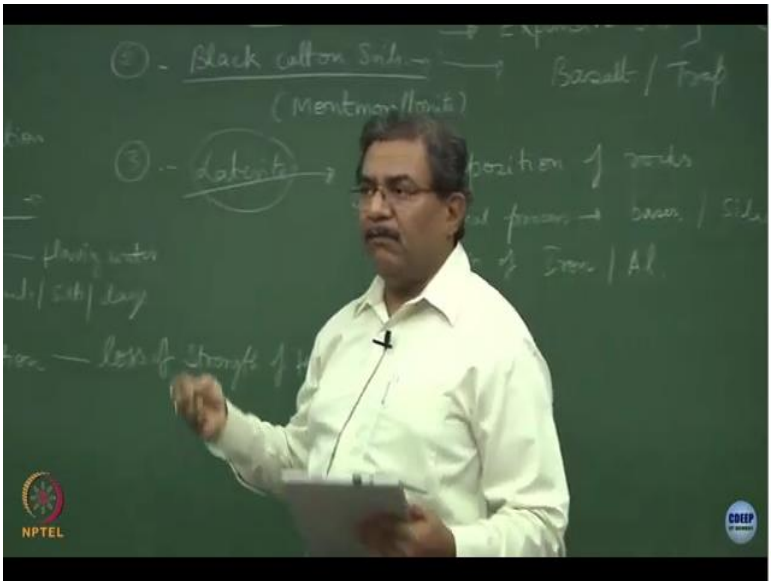

But believe me you are lucky that you are studying geomechanics in the coastal region. Look setting at the marine deposits. The saying is those who start their professional marine deposits flourish much more. I hope you can understand why. Because the challenges and the ways to learn the material and perfected are much more as compared to any other part of the country. So the guys who are setting the northern region or hardcore Southern Peninsula, unfortunate.

We cannot practice this event much. You know, when I say practicing, I hope you understand the meaning of the word practicing is this part clear, what is practicing of a subject, what do lawyers do, they practice law you agree. So this is a subject which has to be practiced, is this part clear. So, black cotton soil is by virtue of the minerals which are present in it is a expansive soil. Mind the spelling of the word is not expensive.

And most of the interviews that I said most of our graduates they say is expensive, so it is not expensive. It is expensive. The meaning of the word expansive is somebody is from Weatherbug, who is from weatherbug you not really but in the or not in those parts of Karnataka, Nagpur yeah, but these are the deposits there you have black cotton soil Nasik is a beautiful example alright.

So these are the places where you will have mostly black cotton soil where you see the cash crops being grown. So these soil deposits are very good as far as cash crops are concerned, Whatever cash crops cotton, number 2 yeah you are right healthy I do not know okay healthy, third one cash crop are men cash crop sugar cane, big sugar industries are there in the whole Maharashtra region alright.

So, because of the property of the black cotton soil it is retains a lot of moisture not because of being organic and fibrous in nature who was talking about fiber you were talking about the fiber not being fibrous in nature but by virtue of its minerals. And the minerals which I present in this material are known as montmorillonite clear. This is cousin brother of bentonite, another cousin brother of these minerals is smectite, where do you use smectite in which industry, sports clear.

So if you want to make pictures so you have to have smectite much more in proportion, it becomes a good recipe. So black cotton soil, soil will have mostly montmorillonite which is the type of bentonite. But it is quite rich as far as the agricultural properties are concerned why the soil particles are very active chemicals. So, somebody was talking about in the very first lecture sorption capacity of the particles is too much clear.

So the moment you add fertilizer, not even a fraction of fertilizer will go unutilized, each particle of the fertilizer or each drop of the fertilizer in the liquid form will adhere on the particles because of their mineralogy clear. And this also is a curse been why by virtue of all these things they attract moisture a lot. So, the moment they come in contact with free water, if it is raining heavily and water gets logged, this mineral is water thirsty, hungry.

What it does, it can take as much as moisture as possible clear. So, that is the problem and when the dry spell comes, dries even comes, this moisture gets lost. So it is let us like a spring action, a soil shrinks. So as far as the buildings are concerned, it is a not a welcome material. In earlier days the thumb rule was get rid of this material, excavate and replace the soil with better soil.

Nowadays the problem is the constructions have become so big, huge, how do they get where you will place it, how would you bring soils from other place, how will you compact and so on of challenges are there. Now, as far as the formation is concerned, these are formed mostly from basalt and trap. Trap is type of rock, and that is why we call it a decade trap decade Peninsula in India and this is mostly basaltic in nature alright.

So the type of rock which we have in Bombay region is very dense, very hard basaltic material. It is okay. So that is why it is very difficult to make infrastructure here. You know, excavation is very difficult. So this process is known as swelling and shrinkage. This also hints at the property that this soil is very intelligent it can sense that mostly a very soon, is it not. So the moment the atmospheric conditions change, it starts behaving.

Incidentally, in case you get a chance to work in pharmaceutical industry. Most of the geotechnical engineers govern pharmaceutical industry, by the way, I do not know whether you

are aware or not. There was a time when I did a lot of consulting for Santos. And there is a very interesting process later on. I think I told you about my association with reliance life sciences also, because we were talking about, you know, controlled porous media in the form of a controlled drug delivery system.

So I can play with the minerals, I can make them so poor us, like rasagulas alright. So, those who have diabetes what do they do. They squeeze out all the sugar syrup correct and they eat the coarse part, people like us who are fat, they have consumed a lot of sugar and the bellies are out clear. So, this is the difference, I can create a porous media where I can keep anything inside. I can keep a fertilizer, I can keep, let us say chemicals, I can keep bacteria whatever.

So, this is how you can play with the minerals. So you can fill them with something you can squeeze out, you can allow them to shrink and so on and you can use them. Another category is anything else which I thought of turning out the black cotton soil no. So these are the good crop yielding soils, most of the farmers in Nasik and Satara and all these areas you know they grow a lot of sugarcane, then cotton, cashew nuts 3 are cash crops 4th you know pomegranate you are talking about healthy I am not sure.

And what else somebody said no pomegranate is a big business in Maharashtra alright, the another one is laterite. How many of you are from Kerala here. So maybe the northern part and the middle portion of the Kerala bordering with Karnataka I think you would have laterite. Incidentally when this concavely was being done 1995 96 the big challenge was how to cut these type of rhetoric rocks and that was my first or second project. I was associated with concord railways you know very hard rocks, but perforated, basic tools they would be having and that is because of the leaching.

So, anybody from here from Mangalore, oh which part of Mangalore you are from near airport area or maybe towards the refinery, what is the name of the place, Kodikal so, somewhere close to Nitk Surathkal. Yeah, that is mostly literati belt alright red color soil, you will be having impregnation of yellow and white inclusions. These are magnesium oxide, iron oxide and so on.

The big problem is like human body all these minerals keep on leaching out, in local language they call them as shedi soils, have you heard about this shedi soils. So, a lot of people who have done research in this. So, all these soils keep on leaching out because of excess rains and the system becomes vulnerable, clear. So, these are the by decomposition of the rocks say interesting chemical process which goes on by this what happens is that basis which are present in the system all sorts of basis hydroxides and silica.

So, this is getting removed and these are mostly oxides of iron and aluminum. In layman's language we call them as red soil and part of Northeast also you will be getting the lateritic material. So these have a lateritic formations, then comes the alluvium or alluvial soils a typical alluvium is the one which is river broad sediments getting deposited over somewhere. Now this is what is known as alluvium alright a deposit of sand, mud etc form by flowing water.

So, these are the layers of sands, silts, clays and this is a typical alluvium, these type of soils are who was from Raipur yes, these are prone to liquefaction, is this okay can you read this. So, if earthquake comes this strike this strata the soil mass start behaving like liquid lique liquefaction just behaves like a liquid and we will study the state of the material, what type of state of this material is, how it gets induced because of the earthquake triggering.

So, the more and more motions which occur in the ground are alright in the form of the shear waves, the liquefaction might occur fine silty, sandy material is very prone to liquefaction. But I am sure you must be aware that a lot of money's now invested in the eastern part Behar and lot of big, big factories are coming over there now, particularly DLW spending a lot of money, Siemens is doing a lot of work there, a lot of land reclamation is being done there and so on.

This is a villain if you can take care of this you can do very good infrastructure will discuss about what liquefaction takes place. Now liquefaction is loss of strength of the soil mass due to earthquake, earthquake is the natural phenomena it could be manmade also. Yes or no, how Idukki dam is a good example of manmade tremors. Is it not taeri is a beautiful example of manmade tremors.

I might be laying a foundation of a moving let us say vehicle or a forging unit, where the hammer gets dropped from a height under all those circumstances, there is an impact and impact is causing the loss of strength of the soil because of any vibration movement, shear waste traveling through the system this is ok. Another category is desert soil, we have discussed a lot about it and I hope you understand the issues.

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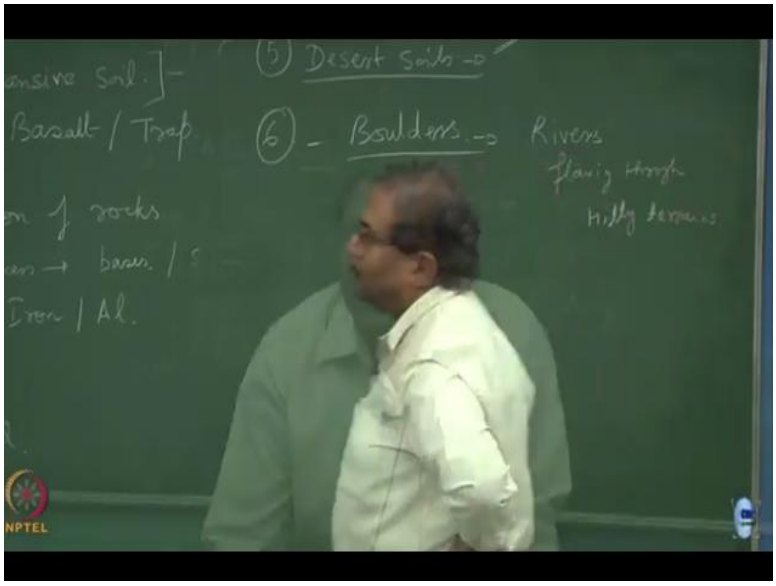

Very difficult to stabilize these type of soils either these are aeolian or loess which we have discussed today. I am sure those of you are from Rajasthan area must have realized that after independence, several 10s of years it took to create a railway line over there. You agree with this after jodhpur if you go towards Bikaner and all no king was such a big fool to create artificial lakes, you know this, they were good engineers good technologist.

They have just utilized the geomorphological features of a place to convert it into a beautiful city and they were sustainable. Remember, we are dying for water. Bangalore has no water. Mumbai city might not have any water, who knows. But these are the places where perennially, there is no issue of water shortage. I hope you agree with this. You will never hear that in Udaipur water shortage, water scarcity is a miracle, but not miracle.

It is the scientific part, which was executed very nicely. So, we have discussed this now, I was talking about the infrastructure over there. The biggest problem is as I give an example about the Indoor Pak border, you cannot create even railway tracks, what happens the soil gets eroded, is it

not because of the rain, so dessert soil is the biggest problem, how to stabilize there in an or we are doing a lot of good work there.

Incidentally, if deserts are not there, where we where we would have tested our nuclear weapons imagine so, this is a boon do you agree, where Pokemon was done very close to Jaisalmer 30 40 kilometers from Jaisalmer. So, if you are going towards Jaisalmer you will be passing by the area which is called you know by completely by in an army, they do not let you go over there. So if you get a chance to work with atomic energy, A or B or B, or C or like these type organizations you will realize that how the detonation of the weapons is done in sands and why.

So, you might get an answer to this question as the subject grows slowly and slowly fine. There must be some mechanisms. So, I was talking about the shocks earthquake, then I was talking about the shear waves, then I was talking about how the migration of the shear wave occurs. And then if I have to test the weapons, which are nuclear, these are the right place or the sea where would you like to do out of the 2 places.

Testing of nuclear weapons. It is not a given country alright, then comes the boulders. I think we discussed about this when we are talking about colluvium deposits. If you remember alright. So, on the steep slopes, many times the boulders clay metrics it falls down, it gets deposited and then it becomes very difficult to create infrastructure over there. These are the typical deposits of the country, mostly the boulders are because of the rivers which are flowing through hilly terrains.

Try to come out with the challenges associated with these deposits as far as engineering and you know infrastructure development is concerned. Though I have been telling you all sorts of problems but it is a good idea to go through this in a literature form and read this and in case you have a feeling that you want to give back to the society, from where you have come after a few years, this is going to be a very good homework.

So, this is not time bound, this is for your entire life know your region properly try to solve the problems of the region and for that you are to study all this, how to do engineering, how to do

technology demonstration in most of these deposits, which are so difficult to manage, where people are unable to give a solution alright. This is what you should learn.

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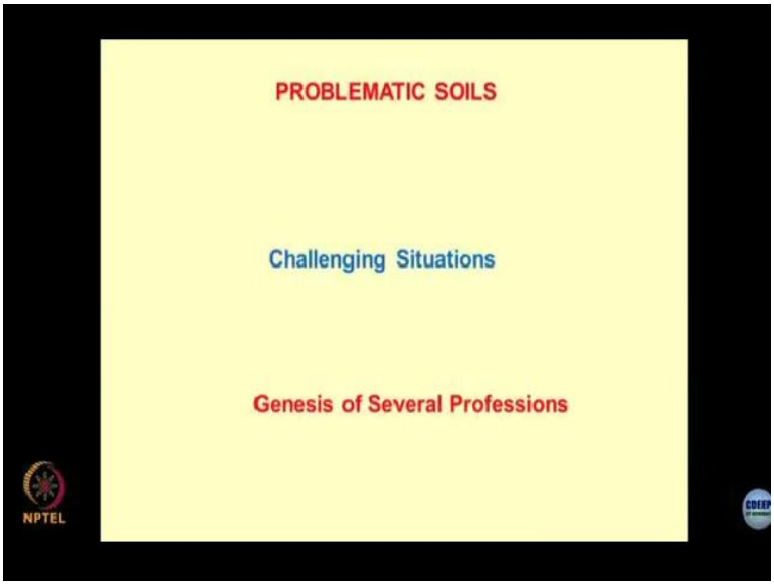

So, let me take you through the some of the most challenging tasks which geotechnical engineers are imposed upon in their career. And people described them as problematic soils and let me tell you one thing that this is an old concept. So, when I was a student, you know, this is how we were introduced the topic problematic soil. But after due course of time, I realized that there is nothing known as problematic soils.

These are challenging situations. And if you are not having challenging situations, the profession would not have been so prospering, you understand. So this is where I write that because of the problematic soils, our profession flourishes. I do not know whether you guys know or not, I am the consultant to Navy Mumbai International Airport. The whole project was my brainchild. And I convinced the government that this is how it should be done in the least time and with the least money.

Ideas have just come and teach in the classroom and somebody asked me a question. Reclamation is one of the examples of how this Navy Mumbai International Airport has been, so before I stepped onto the ground the site was problematic because it was a part of the creek and active sea is a Pineville Craig, I do not know whether you are aware or not, Craig is the one place where most of time water remains stagnant. It might be flowing also.

So Pineville Craig, if you see on the Google map is adjacent to that is the 1300 acres, which is 3 times the IIT Bombay campus. And this is what your new airport is going to be. Just for instance, I am giving this example. So there was a time when this problem used to be a problematic situation. But now if you go there and if you go see it on the Google Earth 50% job is done by applying some technology.

So what I am trying to convey to you is unless the problematic soils and challenging situations are not there the profession cannot flourish. So when I was making these slides today, I got a phone call or somebody wants to meet me at 6 o'clock. You know why I will show you, this profession is becoming mostly you know, a sort of a legal, techno legal social profession. So, this is what I write that it creates a lot of professions.

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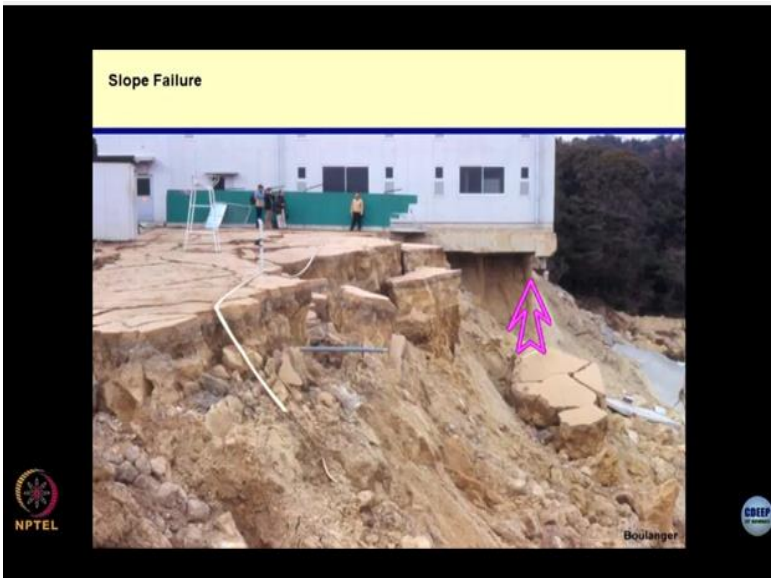

Let me describe few situations. I am sure you must be coming across these type of problems, this is a common problem why to go to Himalayas even in Bombay itself this is a big problem. Most of the slums are located on hillocks and every race you read in the newspaper that the buildings have collapsed, is it not. So, look at this, the entire slope has got washed out. Now this is a typical boulder you know, we were been talking about the whole soil profile is whethered soil it was a beautiful basalt Deccan traps in the due course of time, over maybe millions of years.

The top surface of this rock god weather and these are the remains on which people have started making their buildings. So, because of the rains, what happens the whole slope has got washed out and look at the foundation. Foundation is hanging on. The clever Ajanta Bombay what they will do, they will create a pillar over here and then support the building again. The beautiful example whenever you are going to these places I did not to name such areas where you will find such type of solution which are exist indigenous solution.

And people are living comfortably. I cannot of course, pipelines are got exposed is a typical boulder clay silty deposit appears to be a weathered material, you were talking about weather material somebody from this section I think you were talking about whether it is material or before the break. Anyway, this is the weathering of the material, mostly caused because of water ingress and water causing pressures in the material, material gets fragmented.

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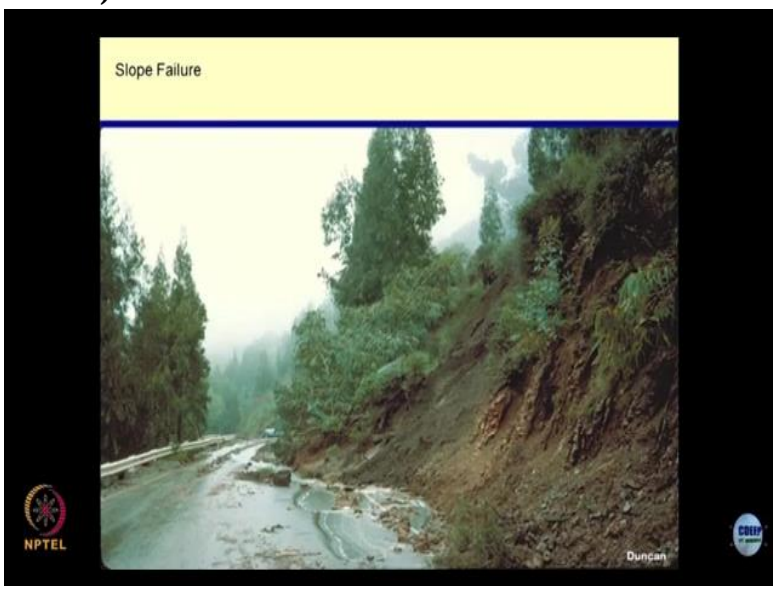

This is also a type of a slow failure. So when you drive through Rupnagar area, you know there are so many slopes (()) (29:10), all these areas where you will find a lot of a landslide occurring mud slides, mudflows we call them. So the entire mud has you know come down as a typical class of problem with geotechnical engineers come across, we have to open up your highways. I do not know how many of you read newspapers.

And there is a big debate going on in the parliament also now a famous highway which is engine K, and with the one constant and about 1 and half month, 2 months back there were 5000 vacancies got stranded over there because the landslides.

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It is another interesting problem you know pipelines are the veins of the country, arteries and veins of the country. Why, like your body you know veins and arteries, what do they do, they flow blood. These are the pipelines which are flowing as a water. You must have seen water comes in Bombay city from Nasik, most of the dam ride through the Nasik highway. We are not water sufficient by the way we get water from different dams in Nasik.

They were done by Britishers or oil, crude oil, again the economy. Now, if these pipelines are located in the regions alright this, where the ground is not stable, what is going to happen, it will result in losses alright. So, rather than conveying the fluid there is lot of spillage, the pipeline's get distorted, they might get broken and so on. The cause over here is if you look at this, the foundation has got completely washed out.

So next time when you are traveling from Thana towards Nasik remain awake and keep on looking at on the left hand side of the entire pipeline system and see what type of foundations they are provided by several touch, if somebody blast of the foundations is a right now NSG topic to work on National Security Council you know, how to stop sabotage against the

pipelines, which are getting precious oil, hydrocarbon or water, water is also very precious by the way.

So look at this soil erosion has occurred, subsequently the road has collapsed, these pipes have also yielded and just because of the poor drainage.

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I am sure this you must be seeing every day in your hostels also or maybe buildings where you find cracks which are occurring on the walls. And this is again because of you remember we are talking about the climatic conditions and black cotton soils too much expensive material. It attracts water, repels water and so on, separation of the wall, there are several situations where the doors and the partition which are done, they got separated from the floors or the walls.

And this is again because of the differential settlement. So we will be discussing about the settlement in details. It is a classic example of 1945 1947 when the entire road has become, you know, almost like a sneaky, we call it topsy turvy why collar it is all because of settlements, most of the roads in the city are like this. So, what do you call it derogatory, to live in a society where the roads even cannot be made properly.

Look at this another interesting case where the this is the beam, which is getting detached from the wall and the crack is developing these cracks would be they could be traversing top to bottom in a zigzag manner. They could be vertical splits, they could be even horizontal also, depending

upon the situation. What are the interesting cases which I am dealing with right now is for an MNC where the tolerance limit of the turbines I think I gave an example, u are aware of it half mm.

So, when you design the turbines, the tolerance is 0.5 mm. Now, ultimately the turbines are going to sit on a foundation which is located on the ground. Imagine if this type of situation happens, what will happen to the turbines how do you wonder. So this is the industrial activities get too much influenced by the stability or instability of the ground or the soils.

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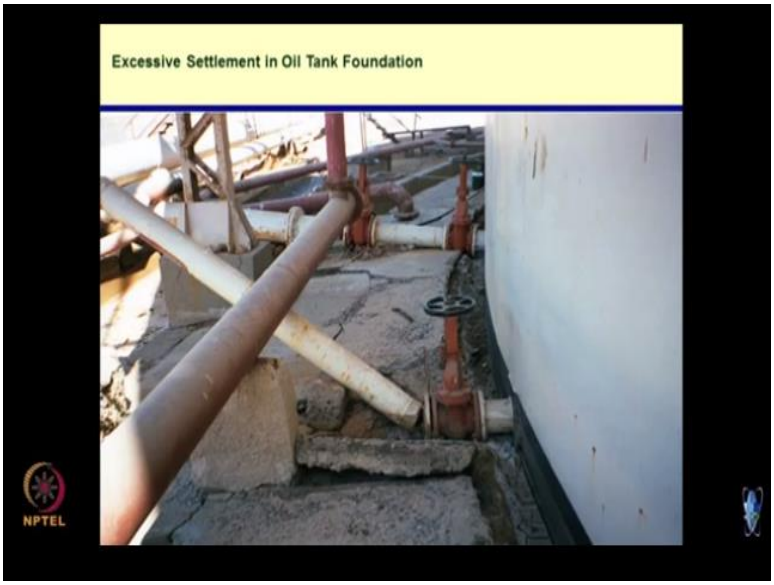

Look at this situation. Again, as I said the oil tanks are the economy of the country, and if they are flourishing, economies flourishing. And that is the reason the western part of the country is flourishing as compared to the other parts of the country. Because we are into the oil business here alright, so we dictate the terms to the international market. Unfortunately, the place where you are storing oil, sometimes might be undergoing heavy distresses in the form of the settlements.

So, in case the settlements occur in huge Structure the other day I was giving a dimension of oil tank is about 50 55 meter diameter. Height could be anything from 30 meter to 45 meter, depending upon the storage and the amount of land which you have. So, this is what's going to

happen, your tanks are not stable. I will show you some other picture also. Sorry, this is the one look at this, the overhead water time, you know, it is differentially settling.

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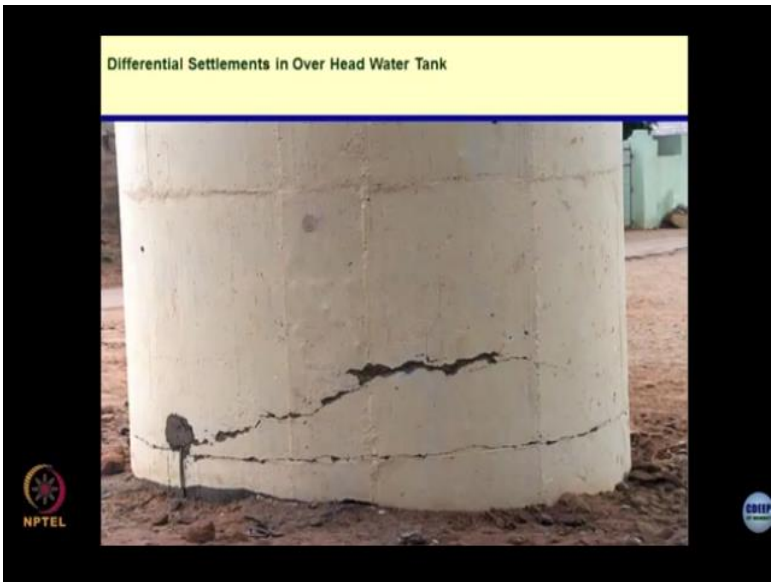

So if you have a very close view on this, you will see that the whole tank is settling on the one side, and it is cracking also from the base. Again, because of the poor soil conditions, silos, I do not know how many of you are aware of silos. Silos are the places where you store greens alright , fertilizers, granular material. So there is no difference between sands and wheat and rice and sugar. They are all granular materials for me.

So the way I would like to store rice, the way I would like to store fertilizers, I would like to store sugar also there. So these are the silos which are huge structures they could be for army also, I might be storing there this soils, I do not know whether you are aware or not place very close to Bombay has these type of silos, they are often strategy importance. So there they are storing something different.

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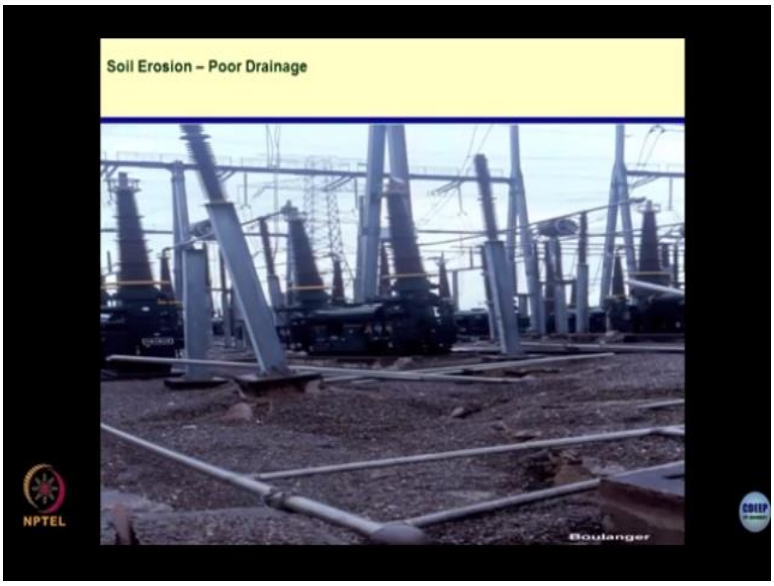

Now, look at this, this soil erosion is occurring and these are the transmission what do you call them power houses alright. So, this is where the foundations of most of the power structures are located. But because of the soil erosion, what is happening, all the structures are in a dilapidated condition. How would you deal with this type of situation, say strategy situation.

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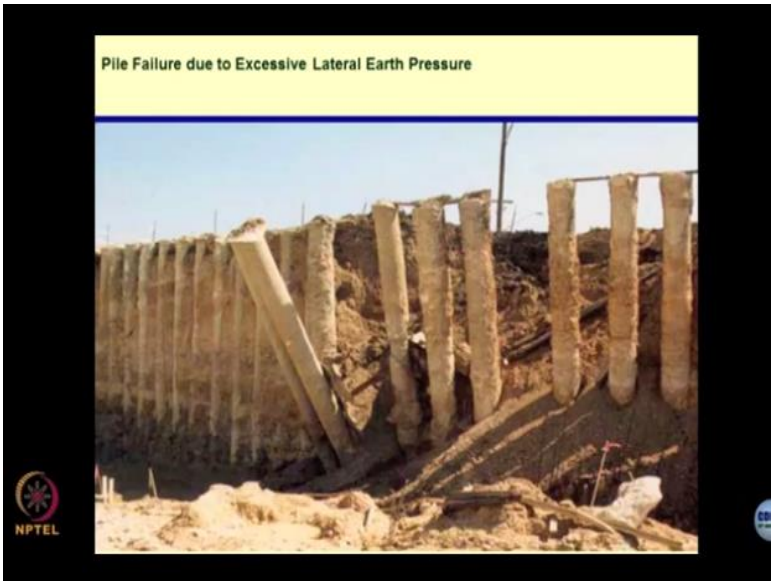

All these things are related to each other. The piles have failed, and hence the podiums which you create on in multi storey buildings, there was a collapse. Go and see this places, then you will learn what is happening over there, what the problems are. So, I am sure you can realize over here that these are the piles which are failing some compacted soil mass and some of the piles have failed.

So, that means the soil which was retained over here to create a you know important structure above the ground because of some reasons this system is going to fail that means you cannot lay the foundation for those type of structures. We call them as lateral earth pressure, the soil which is retained on the right hand side of this pile, these are known as piles. These are the structural elements.

The pressure is so much or maybe because of the erosion the slide has moved out and the piles have failed alright. Most of the buildings in Bombay city are at elevated podiums. And if you go and see next time onwards, you will realize what I am trying to discuss and why this was in the newspapers.

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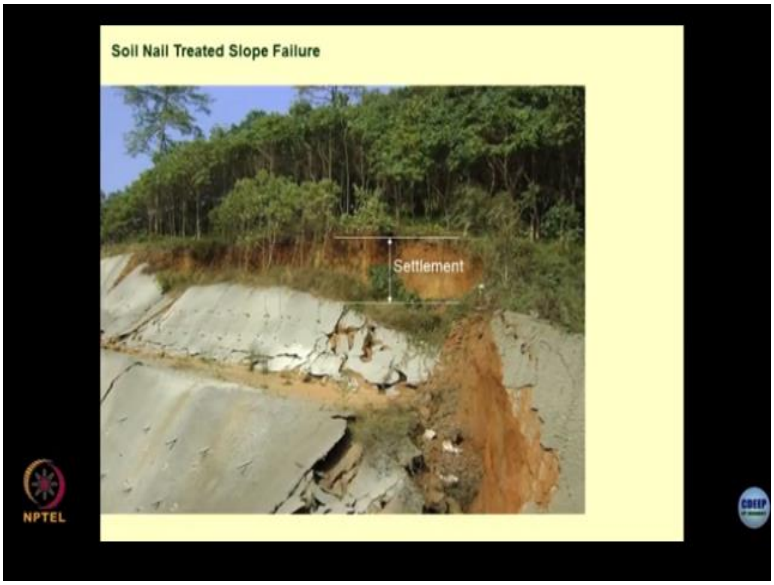

There is something very interesting. I do not know whether you are aware of this or not soil nailing. Did you see something of this sort where nailing has been done to retain this hillocks restrict clifs, the nails have been embedded to stabilize the slope, by the way, all these nails are wrongly done. And that is the reason the collapse has occurred. So this becomes a case of litigation, the guy spent money and it failed who is responsible.

So, there are several cases the more and more infrastructure is happening, the more and more problems are being observed becoming a critical situation. So here the slopes were stabilized, but the entire thing has failed.

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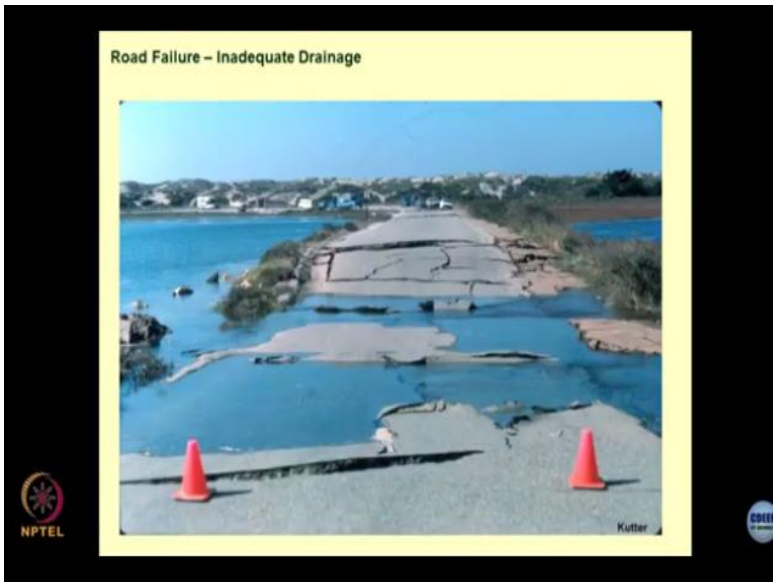

Look at this , this is the road failure, again because of the inadequate drainage, so both sides of water bodies and or the same water body and this was reclaimed, did not allow drainage to occur, water has found its own path, the road has collapsed.

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There is another good example of how building settles, I was talking about when we were discussing, the staircase has completely got detached from the building. The plant has cracked, the building is going in, as a matter of few days when this will be in the national network.

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There is a beautiful example you know, the staircase are still hanging in air and where they are supposed to be. The entire thing is settle down but very uniformly, grace God had it NTL. I will show you what happens then. So we are going to do all these analysis. We are going to study these things, how to find out how much settlement has occurred whether the building is safe or not and so on.

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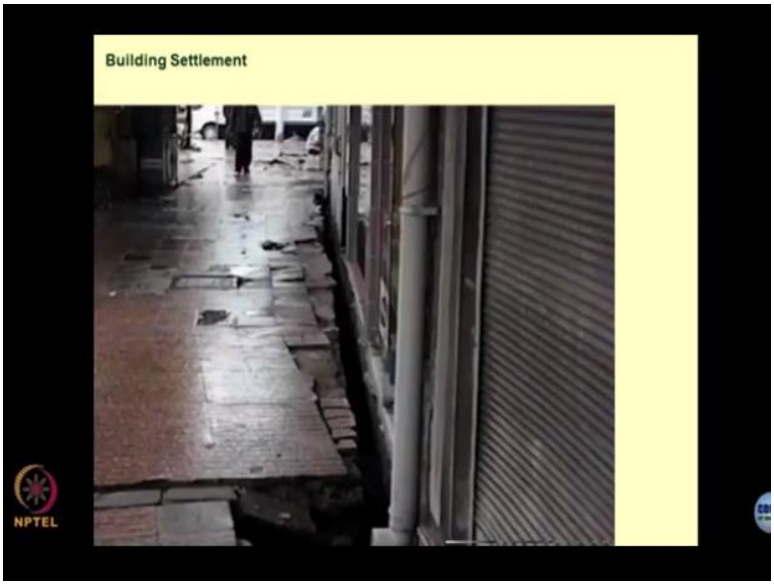

There is a beautiful example of other side of the building which I showed you the whole building is settling down and there are cracking taking place, you know, all along the building from the planes and so on.

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I do not know whether how many of you have seen sustainable structures in Bombay city.

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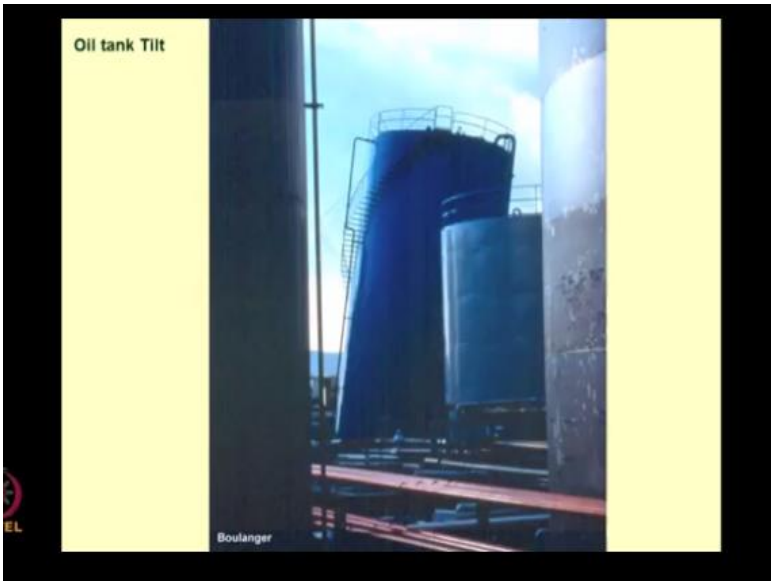

Most of the oil tank forms are having this state. Had it been water tank, I would not have bothered so much crude oil, hydrocarbon if it collapses it is going to be an absolute disaster. I hope you understand why clear, it is not only that is going to fall on your head before it falls on

your head is going to be a time bomb. It will catch fire and God knows what is going to happen may explode even.

So this is a modern day civilization. And one thing is sure people have ignored soils completely. They thought that whatever is sitting beneath is not going to be problematic ever. But it is not so, all these structures remind you that what is the importance of studying the issues related with soil, sand, rocks and the subsurface.

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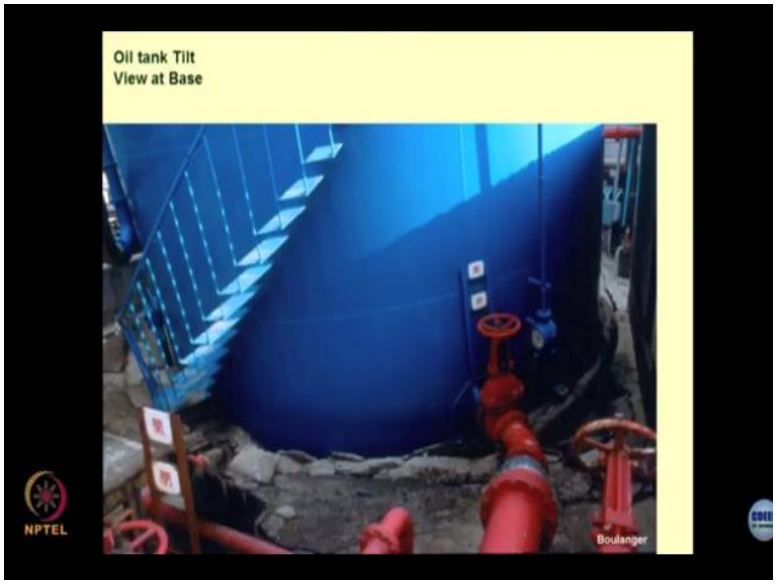

This is a very close look at what was the problem is this type of situation occurs in the tech forms, all the piping arrangements which have been done at the funk, they have cracked why, because you are designed these pipelines to be connected to a certain portion of the tank. When the tank settles, so these pipelines have got sheared off or veered off or they have got cracked completely.

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How many of you have come across this type of situation. Now this is known as soil subsidence collapse. We also call it caving in and the sinkholes you must have come across sinkhole. This happened Sakinaka about 5 6 years back. This is the story of 3rd August 2019.

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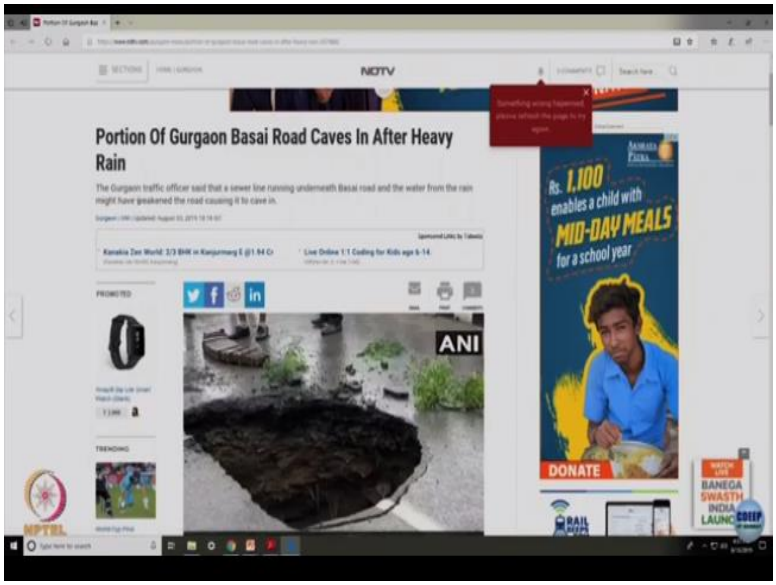

So the Gurgaon traffic severe line, running underneath road and the water from the rain might have weakened the road causing it to cave in. It is happening very frequently. Read about this process while it is happening.

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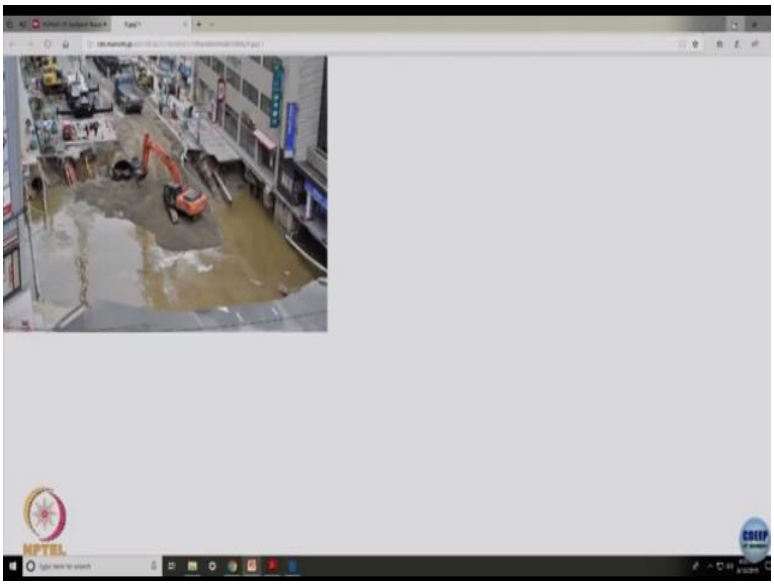

Another interesting case you have to concentrate on the picture to realize what is happening here is because of complete water logging, look at the parking is here. The whole thing is a big crater which has got form you know, this is the pedestrian pathway. These are underground utilities in Japan. So, this is the road pavement and the whole portion a big chunk and this is also by the way the road you can see the remains of the road.

So, this was connecting earlier over here and because of excessive rains, water logging, seepage, the whole thing is caved in what is known as a sinkhole or caving in process, why will try to answer this.

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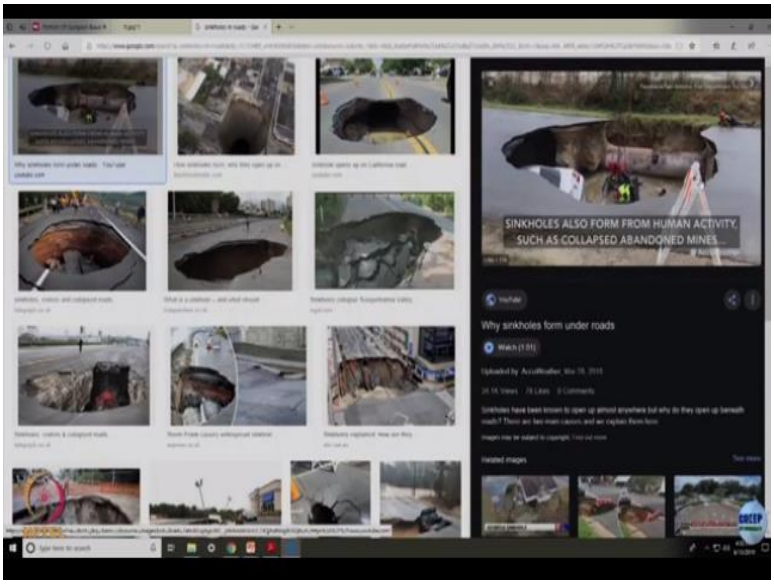

Look at this complete website is devoted on sinkholes. I hope you can realize what is happening over here is so dangerous. Now, what is written over here is sinkholes also form due to the human activity such as collapse abundant minds u are getting this point. So the more and more mining operation which are occurring and when you are trying to sustain the present day society this was going to happen.

This is a beautiful thing to see. Look at this at the middle of the road there is a huge crater getting form. And because of what I have dealt with few situation in Bombay city also.

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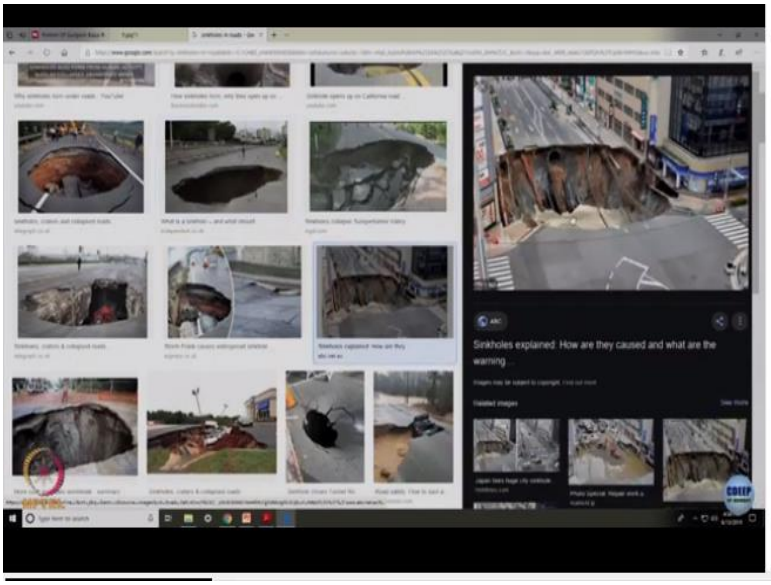

There is another interesting situation with might be again from Tokyo. So, if you have to analyze the situation you have to study the mechanics of the material which are being used for creating these systems.

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Typical landslides Bombay, Puna highway is famous for this. Go to the northeast every days occurs maybe in parts upper reaches of JNK, the big problem is landslides, road getting blocked, closed and so on, how to stabilize them. How to create these type of roles for our country man and so on is a big question.

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The beautiful scene I do not think have you ever seen this, have you ever gone towards the upper reaches of Srinagar, I do not know whether you can realize it or not. These are the big boulders and this is the highway and imagine it is only a matter of time and this boulder is going to fall down. Very good example of Badrinath and Kedarnath, when you travel from Dehradun towards the sides.

Every now and then these boulders fall on the cars and moving vehicles and so many people died. They do not even report it Chardham yatra.

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These are the transmission towers I think there are several cases in India where you know transmission towers get uprooted. And these transmission towers are the ones which are carrying electricity from hydroelectric dams or units. It could happen because of the wind. It could happen because of the foundations here what has happened the entire foundation system has been uprooted. So, what you are seeing over here is a foundation.

Now, because of the moment and the talk which has occurred on the entire tower, which is about 50 meters high, weighing about 40 to 50 tons alright, still the whole foundation is not lifted up and collapse occurred, what is known as uplift failures is a loss of contact between the soil and the foundation okay, how would you handle this type of a situation.

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The RE wall failures, you must be reading in newspapers, there was a video also recently that the RE wall has failed somewhere. This is a good sign to see that how RE reinforced earth wall. This RE means reinforced earth wall it has failed. Look at the cracks which have developed.

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Another beautiful example of how RE wall has failed from the foundation itself, the soil which you have filled up inside is getting washed out.

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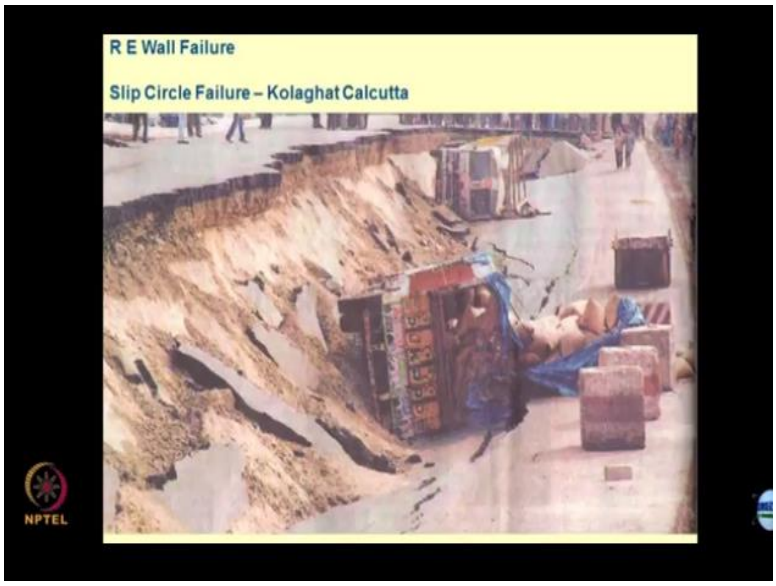

Now, this is the time of the construction of the highway. Anyway the essence of the story is that half of the road has collapsed. And these are the real life photographs, poor filled material or maybe lack of compaction or whatever, look at the whole system has cracked, the foundation failure.

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Another view of the same you know, which shows you how the entire road payment has collapsed. The foundation soil has ended and has this tragedy has occurred.

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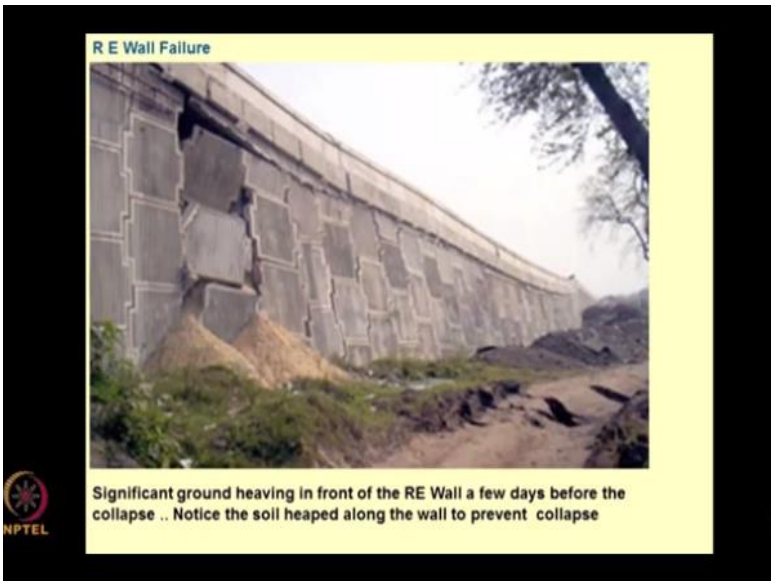

If you see from the other side of the RE wall, then you will see that how the collapse has occurred. The pile material has come out of the wall, panels have dismantled and the wall is defunct. Remember each of these projects is going to cost at least 40 50 crores. And once these type of things happen, there is no retrofitting. You cannot retrofit anything. You cannot make them overnight.

So it is a loss of time is a loss of properties, loss of time, money and what not, inconvenience to people because when this was being constructed people are facing problem. Now this different people are facing problem, I cannot dismantle and throw it away anywhere. So, these are the issues which have to be borne in mind.

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Here some other shots from different angles, you are doing investigations to see what went wrong.

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This is an interesting phenomena. I do not know how many of you have really seen this sand boils, I think we were discussing about this is a very peculiar condition which happens in the deposits, you know which are prone to liquefaction, we were talking about alluvial soils, very notorious. This is what happened in Ahmadabad, you know, building is intact. The entire thing got uprooted from the foundations very sad.

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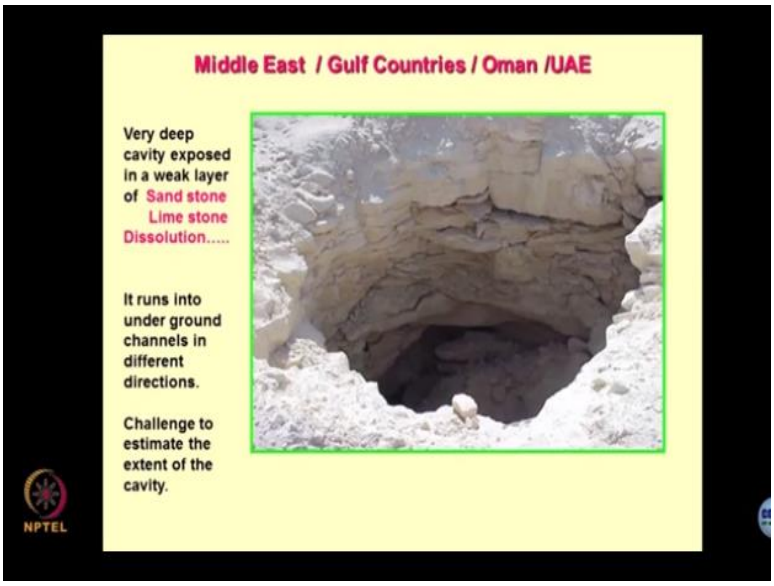

This is what I have been discussing the last lecture if you remember, you know, dissolution somebody asked chemical processes. I do not know somebody was sitting over here. And he was discussing about this chemical processes and I discuss about the dissolution occurring in the limestone because of the humidity and see action at extremely high temperatures, but this is one of the situations.

So most of the middle east Gulf countries, Oman and all these places the big problem is you want to develop infrastructure fine, is the beautiful sandstone, limestone formation adjacent to sea, seawater interacts with this formations, very humid climate, extremely high temperatures. And sea water has not have salinity, clear chloride content, sulfates, what do they do. They start eating up these formations.

This is one of the examples of chemical processes which are destabilizing the soil mass. Now it is very difficult first of all to diagnose how these cavities are. You cannot keep on changing the plan of your building. You agree. So by the time you go and start executing the job, you will realize where the columns are supposed to be and where the foundations are supposed to be there you have a cavity like this. Unfortunately, these cavities cannot be sealed even.

You start pumping cement concrete, millions of tons of cement concrete will go inside, but you cannot close them. There is a very famous Hospital in India, particularly in Delhi, where this happened. Try to find out the history of that place. And then we may discuss.

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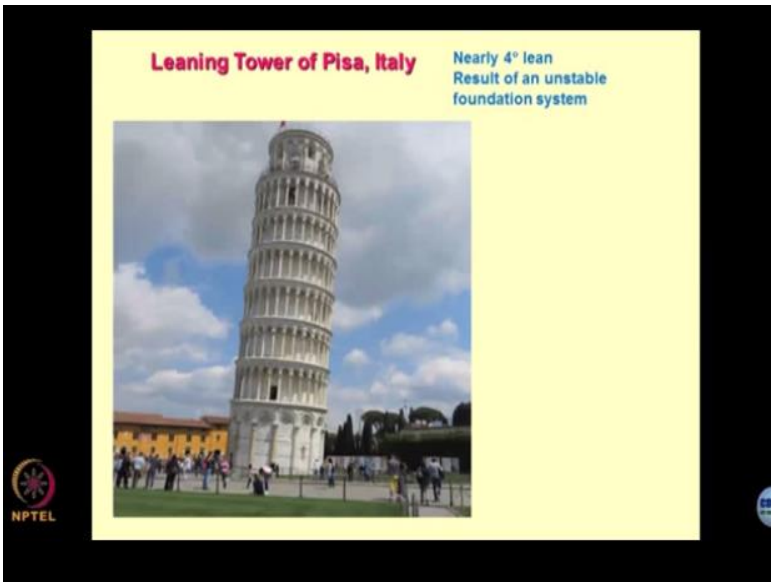

Go to place called Pisa in Italy. And get a feel of why I am asking you to go there is a 4 degree lean. By the top time you go on the set on the top of the terrace. You literally realize that yes, your CG is getting affected. Psychologically, it has been retrofitted are you ever, but it has been left as 4 degrees why, because if you make it if you correct the settlements then nobody will come over here.

And this is a big tourist place, I am sure most of you are aware of the wonder of the wonders is that the building is intact, no cracks nothing and it stands there, whenever you get time please go there. And then you will learn a lot of things related to this.

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This is what happens when you know geo materials are ignored, these are the slides made by illegit. So, this is what happens the entire building has toppled. Fortunately, this has not happened and this is in Japan.

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This is the recent one, this is also from Kerala by the way. So, he has contributed this slide and it works.

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This is the recent phenomena where the dam has burst. This is a recent failure in Brazil in January 2019. And as the aftermath of this failure, the entire dam has burst and then like manmade lava which you are talking about the other day, it has gone 10s of kilometers, just flown like avalanche of the residues are the main tailings that you are talking about.

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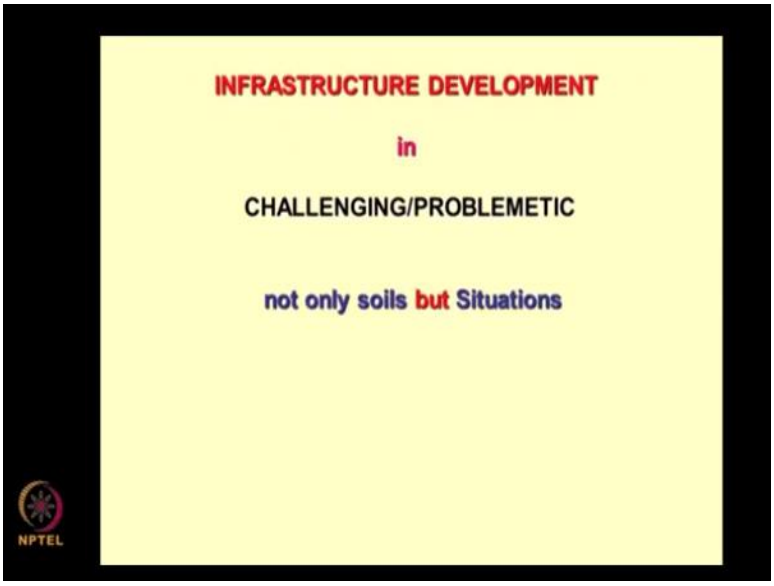

So anyway so coming back to the point when you are doing infrastructure development in problematic soils, challenging soils, leading a solution is very difficult. And this is what I will try to address when I am discussing this course with you.

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What are the major issues just to sum them up quickly. And particularly to avoid failures, we have to learn from failures. We will be talking about soil investigations in this course, for infrastructure development projects, roads, road widening, widening projects, boards, power houses, fertilizer plants, specialized facilities and so on, establishing the sub surface profile so that we know where the hard strata is and we can lay the foundations.

You are doing no you are not doing foundation that will be in the fourth year. So once you have the basics of soil mechanics, geo technical engineering you can use them in creating the best possible foundation system. Anomalies are very important. So, when we are trying to establish subsurface profile anomaly I showed you know anomaly like big, big cavity is getting formed because of dissolution.

Geotechnical exploration and sample collection, I will try to discuss this also, what are the techniques which are used for geotechnical exploration and sample collection and once you have retrieved the samples, how would you test them. Just like pathological examination which most of the doctors rely on. And of course, the last issue would be how would we ascertain the suitability of geo material soils and rocks for construction.

And the question is, if you find that these materials are not suitable, how would you go ahead with the project. So, this is where the engineering and technology comes in.