Geotechnical Engineering I
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Lecture-13
Soil-water interaction-II

Just few conceptual things that might help you sometime in your career. I like to show you 2 situation because you are asking about the Vadose zone. And someone from here was talking about the Vadose zone.

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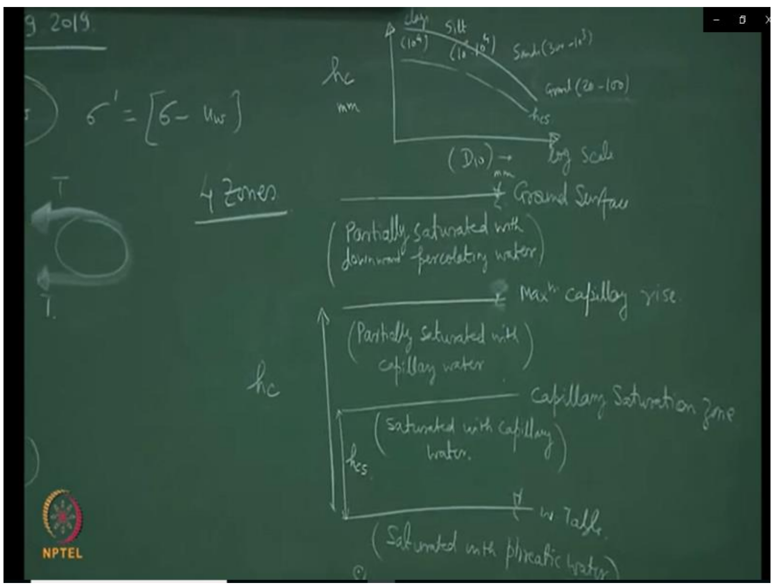

They are normally 4 zones of soils. The ground surfaces is this. There is something known as maximum capillary zone or sometimes it is also write it as maximum capillary raise. Then we have, I should not show it as the water. This is the capillary saturation zone and this is somewhere the water table is. This is what I have defined h c, in some of the books you will find this h c as h c max also.

But I hope you can realize that this is the maximum possible height of the water which can be in the tube. So, normally I do not write h c max. Instead, I will try to differentiate between the 2 by giving this as h cs capillary saturation zone alright. And this is a water table. Somewhere here you will be having the bottom of the bottom surface. What are the peculiar characteristics of these zones.

Below the water table everything is saturated. Here everything is saturated because of the capillary action. Here also the material might be saturated might be partially saturated. From here to here it is a dry state because capillarity has no effect on this one. So, I will write it down and you might use this information. So this is partially saturated with downward, percolating water table. This is partially saturated with the capillary water.

This is saturated with capillary water. This one is saturated with which type of water, phreatic water. So this is a zone, this is another zone. Have you understood this. Ground surface, then there is something known as the maximum height of capillary followed by the saturated with capillary. Then you have free water table which is phreatic. Each and every point below the water table is going to be in the positive state of stress.

Wherever the capillarity comes in picture it becomes negative. When capillary action seizes there is no water, it is a dry condition. Some of the questions are related to this discussion. Have you got the answer to your question or still if you have a question. I will try to answer. There was some confusion related to the phreatic line, is this clear. There was something related to the capillary thing that is clear. You were talking about something, is this okay. Yes. we will come to that.

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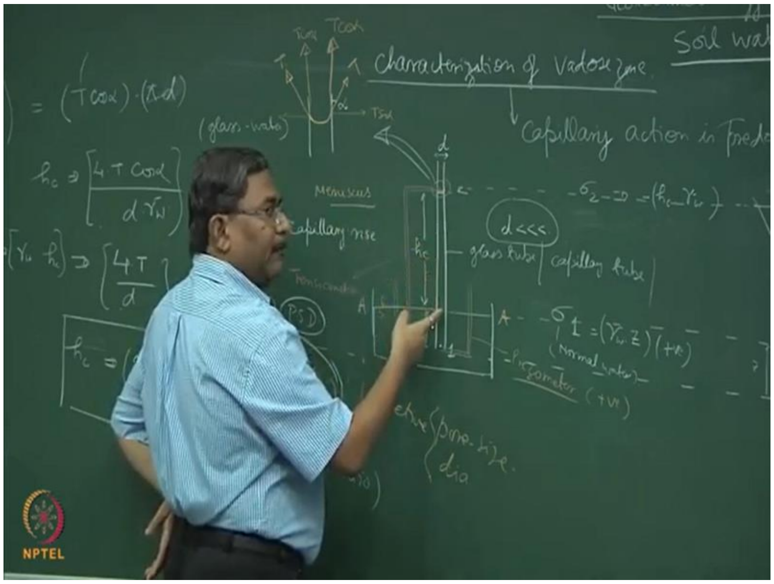

So, first thing you understand is below phreatic line everything is saturated, is under positive stresses, clear. Anything about the water column and where the capillary action is taking place might be saturated, might be unsaturated and the pressures are negative. Because of suction, only water is getting lifted up from here to here. And suction is being caused because of surface tension. This part okay.

Once you have taught all this in the class, then only the guys can learn your geomechanics otherwise, it is a whitewash. You will not realize the big, big companies they do not know even the concepts of geotechnical engineering and major losses to the government and to the private houses. So what I do, I do every day maybe 10 corrections of the reports which comes to me from defenders and I penalize them for giving the wrong solution.

Have you realize this. These are the basic concepts people have forgotten, nobody knows and they are consultants. How to use what parameter for computing the state itself person are not aware of, very poor state of affairs in civil engineering. Just to give you an idea about. How much the capillary action could be if I plot at h c versus the D 10 on a log scale. This is also in millimeters and this is also in millimeters.

The first thing is as D 10 increases h c will drop down. This is h c, this is the line for h cs. Somewhere here you have clays and the magnitude of h c would be 10 to the power 4. Then you have silts, 10 power 3 to 10 power 4. Then you have sands 300 to 10 power 3 mm. Then we have gravels, 20 to 100 mm. Normally gravels are not supposed to show you the capillary action. That is just to give you an idea, I hope now you can get an answer that why an deserts cactus survive and cactus can lift water from 100 meter, 200 meter deep as well. You must have done this problem in your engineering mechanical course.

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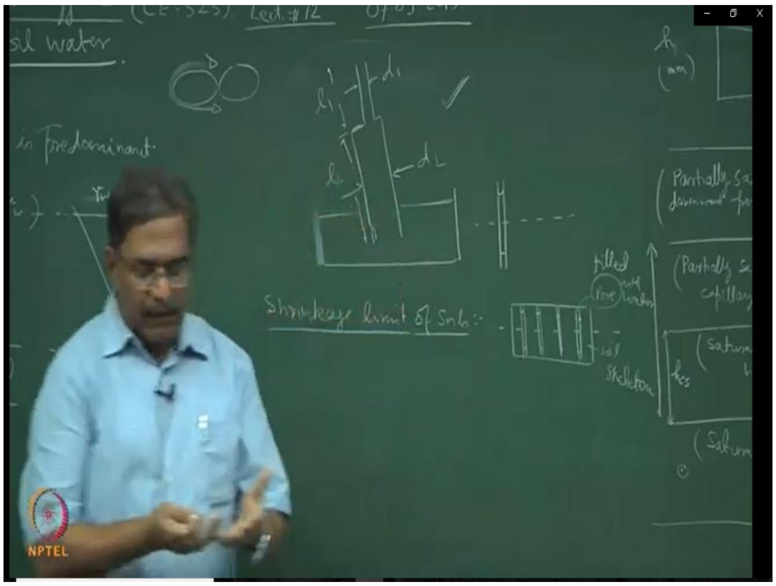

Suppose if I give you a capillary tube sorry, sorry h c is a millimeter or this is h c and this is h cs. You are talking about gravels, say it is 10 power 3 to 10 power 4 rough numbers. So do not go by what I have written. The idea was to show that trend that as the diameter increases the h c decreases. I should write this would be h. You must have done this problem in your undergraduate first year d 1and d 2 diameter, this is l 1 and this is l 2 and this capillary tube is kept in the water bath.

You remember this problem. And what will be the height of water column in the capillary tube. You agree. You have done, I am sure. You can solve this problem or try attempting this. Different cases you study and see what governs the capillary action in the tube, whether d 1 governs or d 2 governs using the same concepts. This capillarity phenomena is normally use in define the shrinkage limit of soils or in other words shrinkage is guided by the capillary action.

You must have done laboratory experiment where the soil sample is taken and then you are air drying it. Now this is how I can idealize this, this specimen is having pores. So this is the pore and this is the soil skeleton. And this is a center line. So best way to define shrinkage of the material is, remember I had drawn this free body diagram of the 2 grains. What surface tension does. It brings particles closer to each other, water is under tension. So soil is under compression. Is this correct or not.

Now, what happens is that these pores are filled up with water and when I am allowing the free evaporation taking place from the soil. This is how the meniscus gets form from both sides. So enlarged view would be like this. This is the centerline of the sample. This is the meniscus formation and this is the meniscus formation. If I use this concept because of the water and surface tension the grains are under compression.

So when evaporation takes place from the soil, soil sample gets compressed and it comes up to the shrinkage limit, by definition shrinkage limit is the state of the material where air has not entered into the system and it remains saturated, clear. So this is the model which can be utilized to show how the shrinkage of the soil mass is taking place. So, capillarity and its application is in determining the shrinkage limit of the soil.

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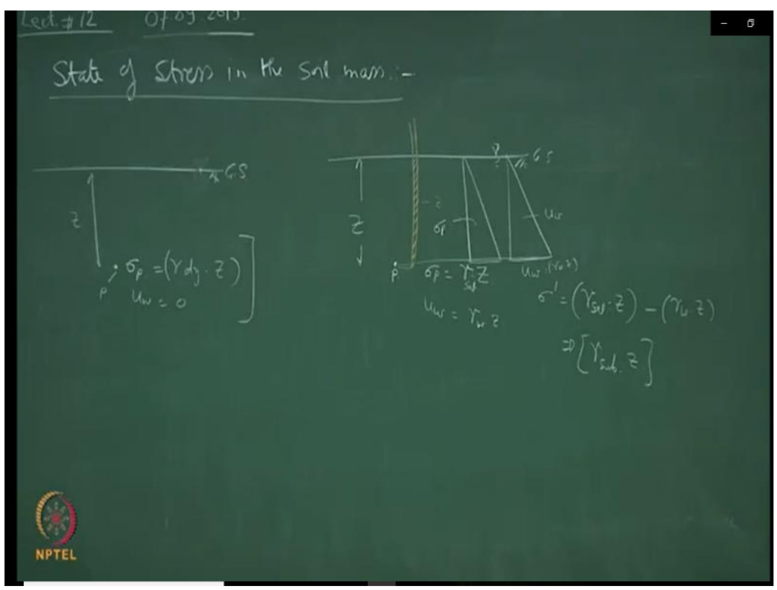

State of stress in the soil mass. Let us start with the simple ground surface and at a depth z, I want to find out what is the state of stress. Now, this state of stress is normally defined as sigma. If I define this as let us say point number P, sigma p as long as it is dry, sigma p will be equal to gamma dry into z. This is the state of stress at this point. But suppose if I say that the water table is also here, so in the first case your pore water pressure is also going to be 0 without water. I will not mix it with this know.

However if you have the ground surface and there are water table and if I asked you to find out at point P the state of stress. This is z, so sigma p air would be gamma into z, but this gamma is saturated now because the water table is here. if you want to find out the pore water pressure at this point, the pore water pressure will be again the same concept. You have to put a piezometer here and let this piezometer show the height of raise in water up to z alright. So the pore water pressure at this point would be gamma w into z.

So, what is the effect of pressure air. This will be gamma saturated into z - gamma w into z. This becomes gamma submerged into z, is this okay. I can draw the pressure diagrams also. So, the pressure diagrams would be this is for you w, which is equal gamma w into z. And for sigma p also I can plot the pressure distribution. So, this is for sigma p and this is for you w. I think this is what you are discussing.

So I hope you are understood now, how to compute the state of stress at this point P and the pore water pressure. So, I can plot the variation of pore water pressure if I substitute z and if I know z I can compute the normal stress also. The third situation could be when you have a partially saturated system. Suppose if I say there is a partially so this is situation 1, situation 2, situation 3. Ever wonder why buildings collapse in Bombay city during rains. The answer comes from here.

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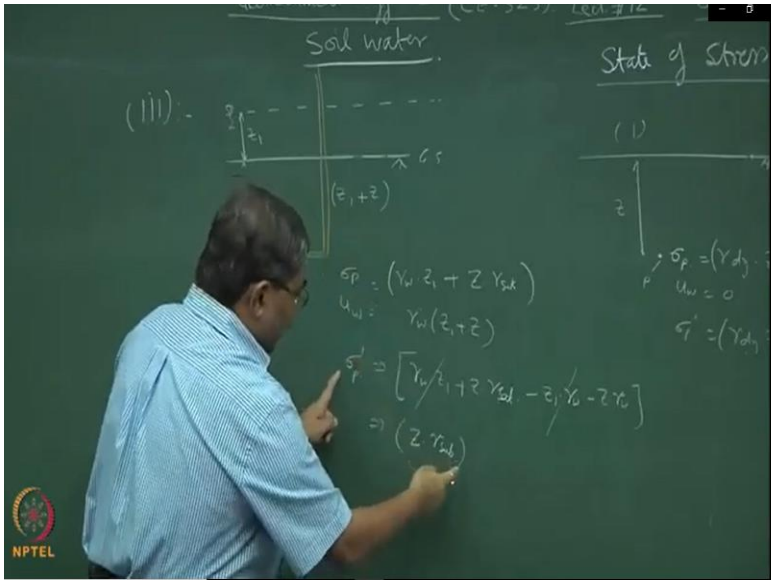

This is the ground surface and during rains, what is going to happen. Suppose if this is the point P water logging, is this correct, says z 1 and this is z, what is an intuitive feeling what has happened to sigma p and you w. Quickly, sorry, yeah, do it systematically. So, sigma p will be equal to gamma w z 1 + z gamma saturated, is this okay. This is the overweight and up to this point this is the whole system water table is here. So, the whole soil mass is saturated.

At this point, the stresses will be gamma w z 1 + gamma saturated into z. what is the pore water pressure at this point. Put the piezometer again. So if I put a piezometer here, where is the phreatic surface. This becomes phreatic surface atmospheric pressure line exposed to the atmosphere, clear. So height of the water column here would be z 1 + z. So that means you w will be equal to gamma w z 1 + z.

So what is happened in terms of the effective stresses at point P alright. So this will be gamma w z 1 + z gamma submerged – z 1 gamma w - z gamma w. When I cancel these two things do not think that mathematically I am canceling something. You get my point. It is not that mathematically I have cancelled gamma w z 1 and gamma w z 1. What is the physics behind this. This water column is contributing to both the pore water pressure as well as a surcharge, that effect goes.

So water logging never creates a problem, remember throughout a life eater logging is welcome. Is this okay because what has happened to effective stresses. Now gamma submersed sorry please excuse me. This is gamma saturated alright. So z gamma saturated - z this will be z into gamma submerged. Effective stress remain constant whether the water table is on the surface or whether it has gone up.

So what is the problem, why buildings collapse. When water level drops down and let us try to analyze that situation. If you can maintain the water level up to that point forever, there is no issue. So let is do a quick analysis situation number 4.

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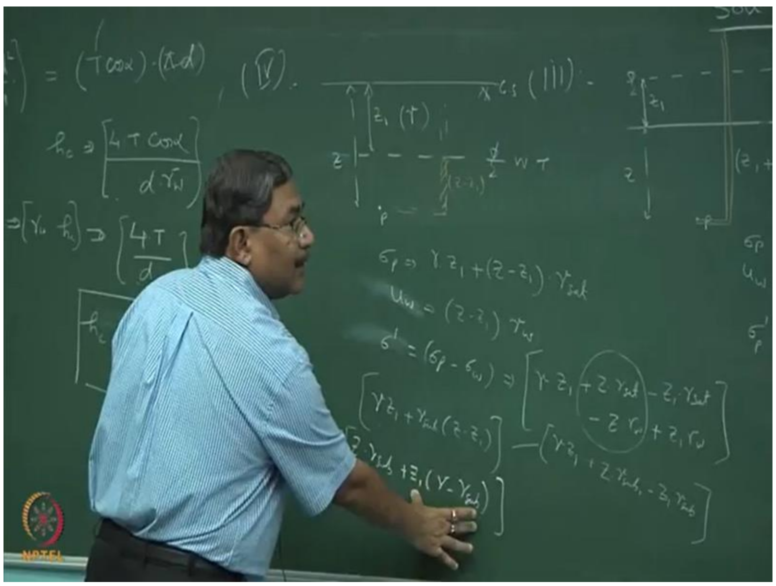

This is the ground surface and the water table has gone down. There is a drop in water table and I am interested in finding out the state of stress at this point which is at a depth of z. This has gone down by z 1. Can you compute out quickly and see what is happening, do it. So sigma p will be equal to let us take a simple case of this material as gamma. This is where I can play tricks that depends upon the type of soil you are dealing with the granular, coarse, compacted, capillary action, no capillary action, all those things.

Simple case this will be gamma into z 1 + z – z 1 into gamma saturated. What is a pore water pressure at this point you w normal simple guesses granular material is filled up over here. This will be z – z 1 into gamma w. Remember the pore water pressure sorry the piezometric tube has to be kept here. And this goes up to the phreatic table. So this is z – z 1. This is fine. What has happened to the effective stresses. This will be gamma z 1 + z gamma saturated - z 1 gamma saturated.

This pore water pressure is positive – z gamma w + z 1 gamma w, z gamma saturated – z gamma w, we can quickly take care of this will become, + z gamma submerse, clear, z 1 gamma saturated - gamma w – z 1 gamma submerged + gamma z 1, is this correct. So truly speaking this function has become gamma z 1 + gamma submerged z – z 1, it is okay. What to do you feeling. z gamma submerged.

And here what has happened, you have z gamma submerged I can write this as z gamma submerged + z 1 gamma - gamma submerged, is this okay. So what so into the feeling, what has happened. What I am trying to prove. This component has got added up with this agreed. Effective stresses increased at a given point. So if effective stresses increased at a given point, Calcutta Metro tunnel.

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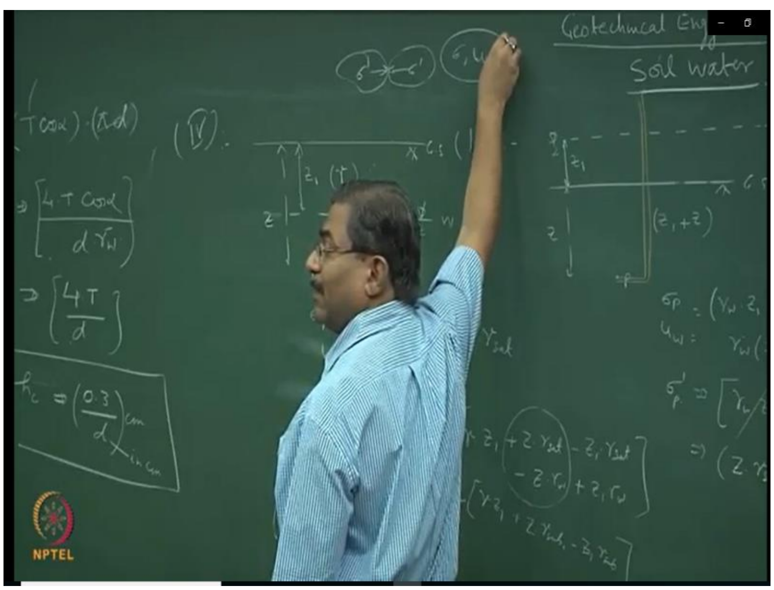

This is a grain and this is the grain because of the thin film of water surface tension they came close to each other. And this is your sigma prime exactly, sigma prime cannot be measured. There is no way. Sigma can be measured, and you w can be measured. Now repeat your question. I will answer. Your question all different, balancing what. So answer to your question is not balancing anything.

So suppose because you are discussing, suppose this was a confined system alright. And suddenly the confinement got broken dams. So what is going to happen. If this gets broken the water moves out or water table drops down, collapse occurs alright. So whenever there is a movement of water table below drop in water table, this is going to be detrimental. Confinement can get removed in several ways you had done sheet piling.

Remember 2 years back, what happened in one of the prime locality of the Bombay. Times of India first page, clear, sometime back what happened somewhere else in Bombay city. So confinement gets removed could be because of anything. I may remove the piles. Piles are not designed properly, there was a deflection, clear. You are doing underwater, underground watering and your containment fail. So these are construction techniques.

Your question has been answered. So it so happens that you cannot do anything with this. So what I should be doing. Just wind up today's lecture. Pumping the fluids and that what Venice is doing. Read the Venice case. So what they are doing, they are trying to lift the entire city up. What they have done. They have dig out, maybe at least 40, 50, 100 deep wells and what they are doing now in those deep wells. They are pumping in the water.

Why. Look at this, there to bring it up. So the more and more water you are consuming, what is going to happen. This is what is happening, underground tunneling. Bombay city is having maximum number of tunnels now. I never have this very close to IIT, there is a big failure. So quickly give you answer how to tackle with these problems. Tomorrow some of you will become consultants. This is cut. My job is to tell them the answer.

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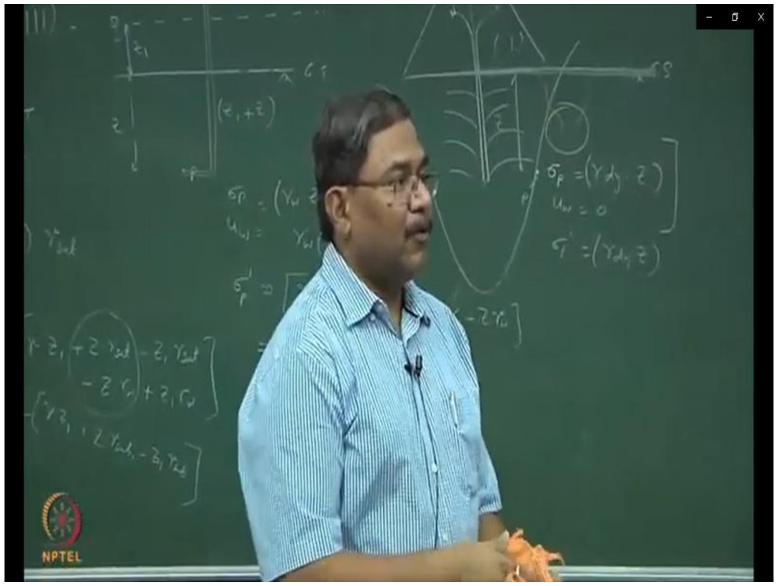

So suppose if I was doing a tunneling over here and the water table earlier was here. And if I am not careful, what I have done. I have done tunneling and the water starts entering in the tunnel. I have created a situation like this. You are talking about the same thing. Lack of confinement. what here happened is different case. Because of creating a void, I have allowed water to seep into any type of lowering a water table is going to cause this.

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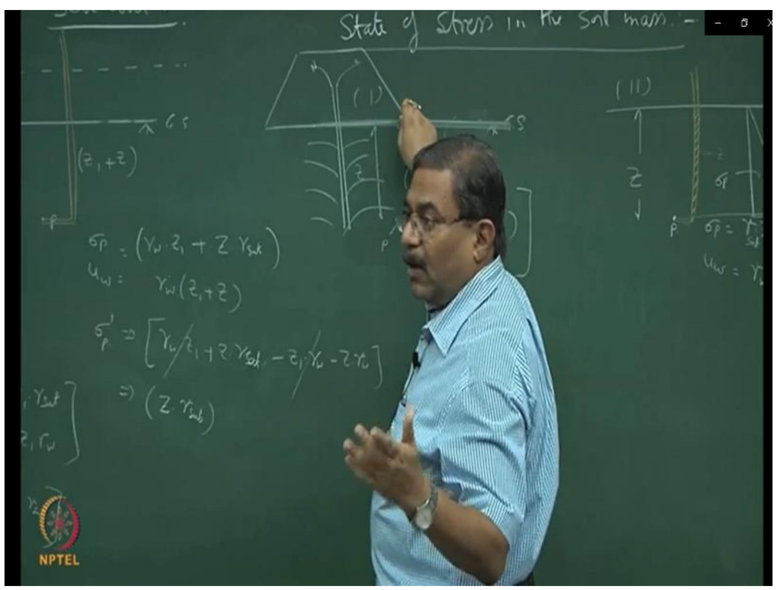

I can I might be doing pumping also. So I can install a pump over here. Tube wells, and these tube wells are taking on water to irrigate the land or whatever industrial purpose. What is happening. Initially the water table was somewhere here. Then it went down to this and this and this, everything will collapse. The same problem hydrocarbon extraction guys are facing.

Remember you are sitting on the top of this in the form of a hydraulic platform or what to call this as a Jakka platform. So you are basically sitting on your own grave.

It is a very difficult task and that is why the charges are 1 lakh times more than whatever you get in the onshore industry clear. Now what you are doing this is a well passing through your platform and you started extraction of hydrocarbons. So what is happen. This whole thing is vulnerable to collapse and this is how the accidents occur, fine. So this is the geomechanics. We will be talking about this in details. Hope you are enjoying it.

And one more situation, there was an aquifer let us say somewhere here alright. This is an aquifer water table means this is aquifer. And I punctured it by putting a shaft of a tunnel. What was going to happen again, same thing. Water is percolating through this tunnel, water table lower now. So gas extraction, hydrocarbon extraction, water extraction, mining processes all of them are going to be difficult situations to handle.

So what we are supposed to do. Our job is to tackle the situations. Somebody is asking how would you tackle it. This is how I will tackle it.