Ground Improvement
Prof. G. L. Sivakumar Babu
Department of Civil Engineering
Indian Institute of Science, Bangalore

Lecture No. # 12

Dewatering – I

We were discussing a few silent aspects of the vacuum assisted consolidation, particularly to reduce the payloads; as I just mentioned, this field trials have been conducted in many places, and they have been very effective.

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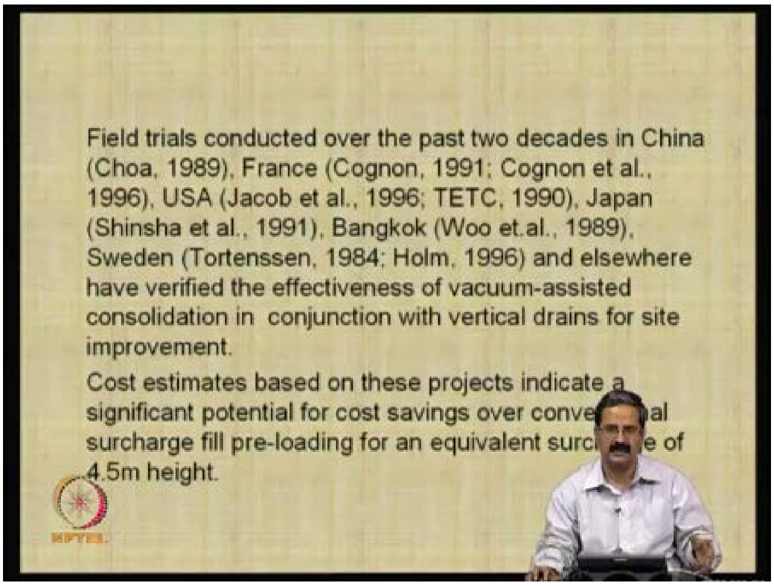

And people indicate that, you know all these studies indicate, that there is a significant potential for cost savings over the conventional surcharge placement, and for at least, you know 4.5 meters height, why it is, is that, we know that, it is a 1 kg per centimeter square or 1 bar or 100 k p a is pressure suction, you can apply.

So, theoretically about you can get 5 meters or 4.5 meters or even 4 meters, if you are things are, you know, properly done, if the vacuum is very good, definitely one can go for about 4.5 equivalent pressure; so, you do not need to really apply the surcharge, but then, you can get the equivalent effect by having the vacuum, that is a meaning here.

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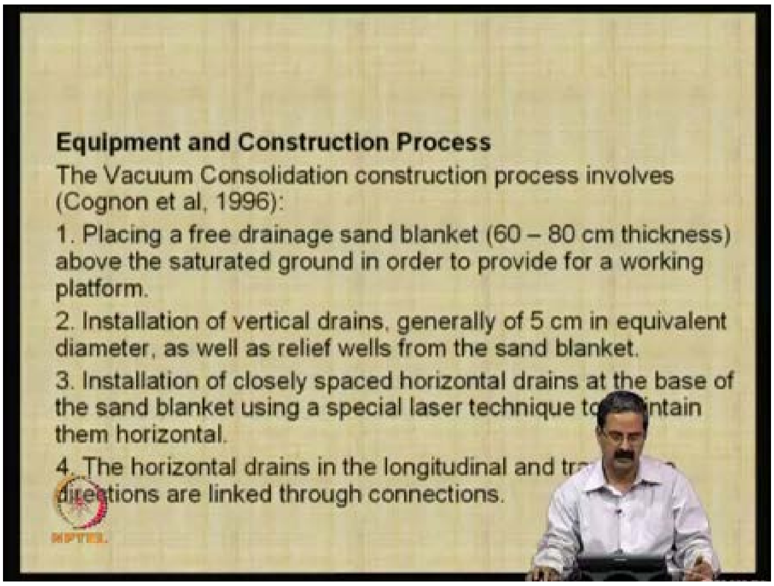

And how do we, this is something, that we should see what we do, is that, because sometimes, you know, we should understand the construction sequence very well, because the implementation of the construction sequence is very important, and if there is a mistake in one place, it could lead to cascading effect, and then, it the whole project may have difficulties.

In this technique, we have a drainage blanket, sand drainage blanket of about 60 to 80 centimeters thickness of the saturated ground to provide for working platform. Installation of drains generally 5 centimeters an equivalent diameter, like you know, whatever, as well as of relief wells from sand we do that.

Installation of closely spaced horizontal drains at the base of the sand blanket using a special laser technique to maintain them horizontal; in fact, all along that at the top itself, like we have horizontal drains, you know, here the thing is that, you have this particular area, you need to collect all the water, that comes at the top, essentially we can only provide the drainage at the top.

So, we collect water, and then because of that thing, we just collect all the water, and so, we need this horizontal drains, and in fact, people have used lot of sophistication here in terms of using this laser techniques to maintain them, that they are horizontal, and so, they both horizontal drains, and there are transverse, there are linked.

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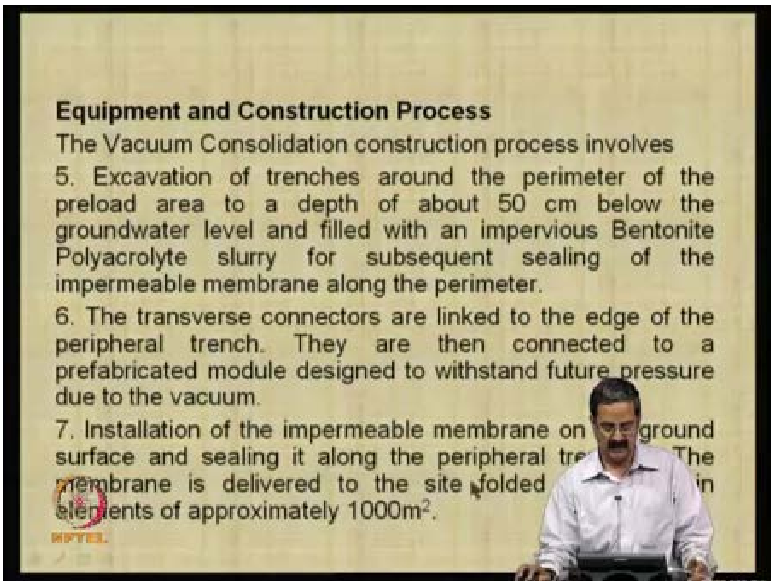

And excavation of trenches around the perimeter of the preload area to a depth of about 50 centimeters below the groundwater level, and filled up with an impervious Betonies Polyacrolyte slurry, for subsequent sealing of the impermeable membrane along the perimeter.

In fact, as I just mentioned, we were trying to provide the geo-membrane layer, because you know, the, it should be a sealant, what we are trying to do is, a putting a sealant there, and then, you know, vacuum should not that capacity, should be, you know, very good, all that area in that area whatever you are trying to have that area the vacuum should be very effective, then only it is possible.

So, that is a reason, when people have perfected this vacuum technology, then it has become possible. So, what they are trying to do is that, they are trying to have the sealing of the impermeable membrane along the perimeter, all whole perimeters, it has been sealed. Transverse connectors are linked to the edge of the peripheral trench, they are then connected to prefabricated module designed to withstand future pressure due to vacuum.

Installation of the impermeable membrane on the ground surface, and sealing it along the peripheral trenches, the membrane is delivered to the site folded and rolled; actually, we have a, the geo-membranes are normally delivered on to the site.

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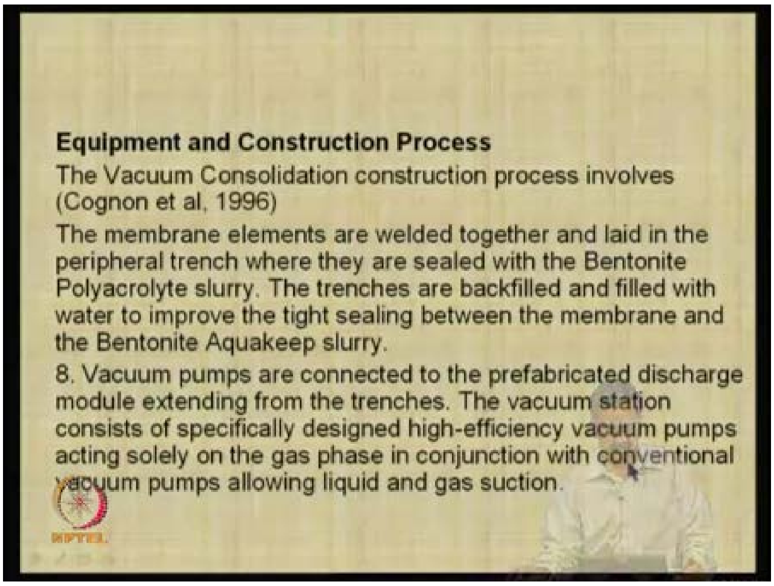

Then actually sometimes the membranes elements should be need to be welded also, and they are sealed with Bentonite Polyacrolyte slurry, the trenches are backfilled and actually filled with water to improve the water tight, the tight sealing between the membrane and the Bentonite aqua keep slurry. So, vacuum pumps are connected to the prefabricated discharge module extending from the trenches, the vacuum station consists of specially designed high efficiency vacuum pumps; actually, vacuum pumps, you know, the technology is so good now a days.

Acting solely on the gas phase in connection with conventional vacuum pumps allowing the liquid and gas suction.

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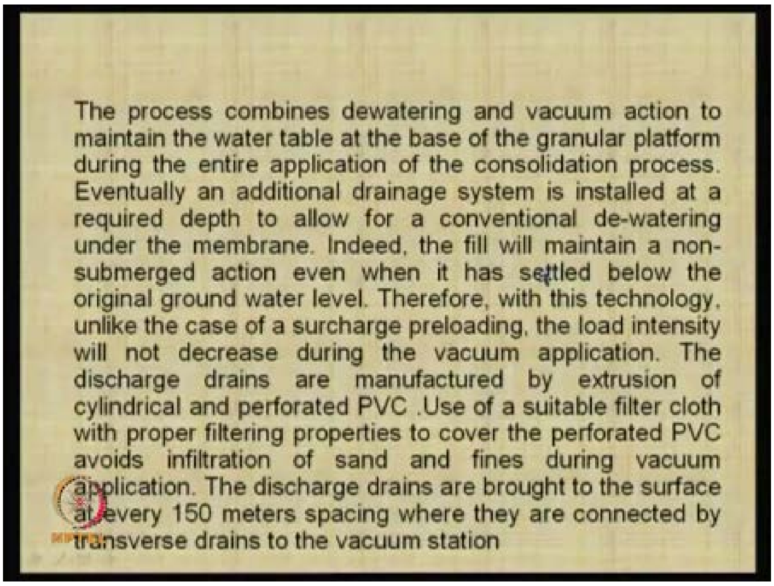

So, you have this, a process in which you apply this vacuum.

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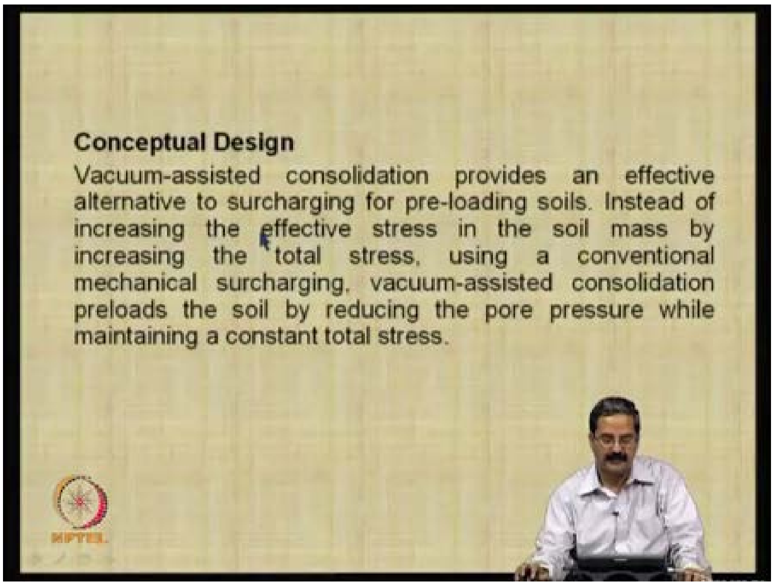

And the, this is like, the this is very effective, and people can, you know, conceptually design this using, you know, one can, if you want to really, you know, once you know, how it works.

So, the objective has been to just create a balance between the preloading, you know, like you know preload, you do not want to have too much of preload, you want to take advantage of the effective stress increase. You would like to take advantage of the effective stress increase; so that, the total stress net is increased, as I just mentioned the total stress also increases.

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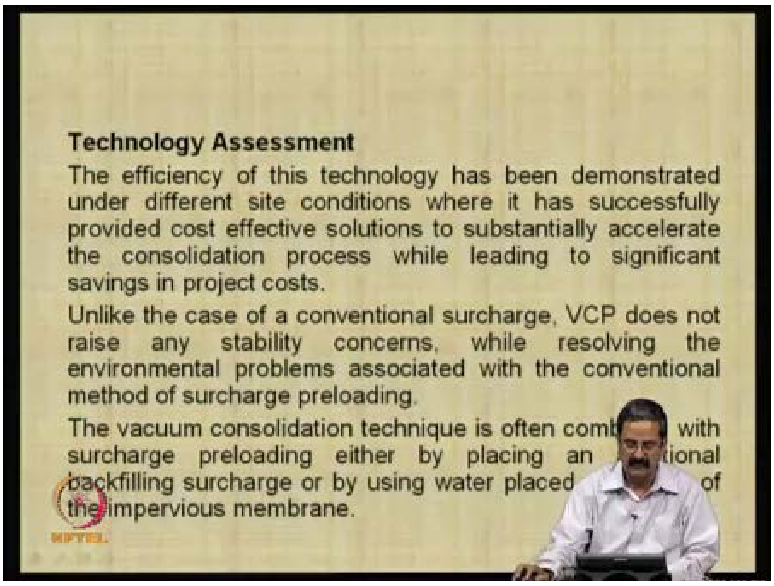

So, this is what the actual concept that we have is, and a technology, if you want to say was it effective, yes, it has been very effective in many places. And the main thing is that, it does not really have any stability issues, because particularly, you know, you are trying to get the thing is, when, why you are going for this sort of technology, is that, in a place, where there is a full of soft soil to get preloading material is quite expensive, maybe with water you can preload, but you know water, the density being 10 kilometer per meter cube, and the people do it all sorts of loads, you need to apply, but then to get the loads, you know, you may have to get the aggregate from different places, and all that it is environmental issues.

So, that way what we mean is that, vacuum consolidation technique has been quite effective, and you place, you can also place the surcharge you know.

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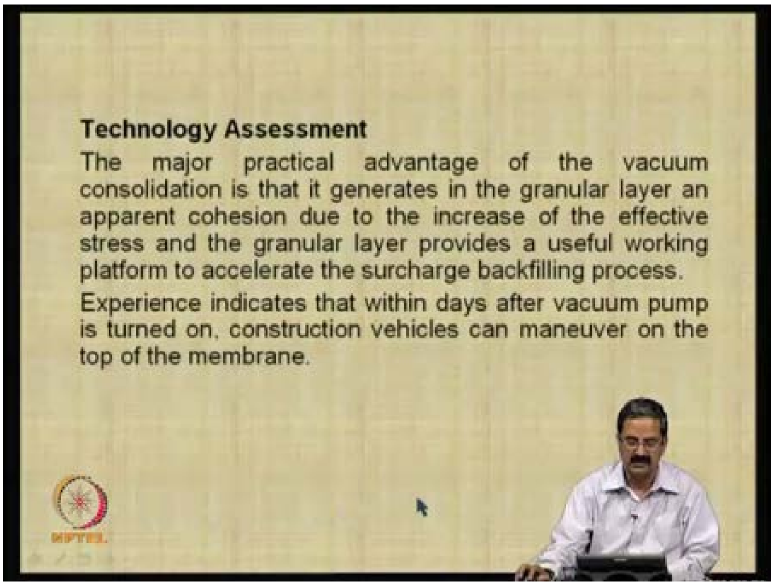

So, it has been another advantage, has been that it has an apparent cohesion in the soil layer, top layers also as I just mentioned. If you make proper connections, you can also have a some sort of apparent increase in the cohesion, due to increase of the effective stress, and you know, in a granular layer itself, like you know, you are, what you are doing is, you are trying to create some sort of negative pore pressure, negative pore pressure increases the strength of the soil. So, you, if you understand this concept, yes it is very easy to do this.

So, the experience indicates, that within days, after the vacuum pump is turned on construction vehicles maneuver on the top of the membrane. In fact, as I just mentioned, during the construction process itself, like if you are trying to have this vehicles, you know, they should must be able to move around, and with little bit of suction, if you can increase the effective stress, so that, the vehicles can move, it is fine.

You do not need to have big surcharge, and also consolidation, and effective stress increase, and bearing capacity issues, you can just apply proper suction, what is the load coming from the construction vehicles on to the soil, you calculate, and if the, you are able to maintain higher effective total stress, because of the vacuum then it is fine. So, you are able to, you know, you have a higher resistance strength is higher than the load applied; so, you can see that, that can, that combination can be done.

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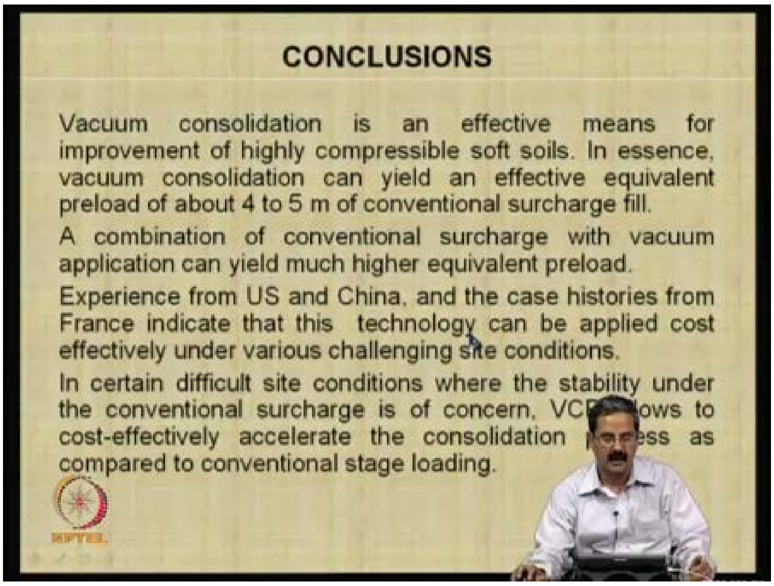

So, it is an effective technique that can be useful for the highly compressible soils, and it can be useful for about 4 to 5 meters definitely very useful. And the, an experience in US and China has been, that it is very good, and people have been working on this further.

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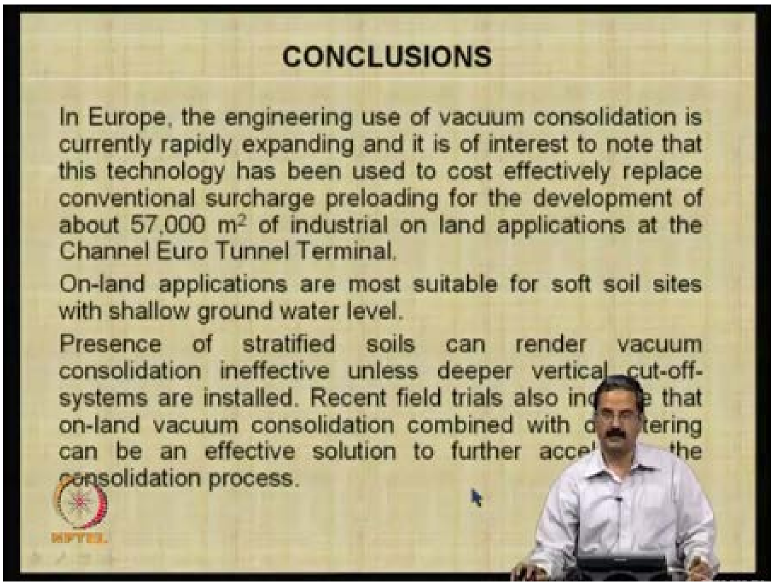

So, I am sure, that in the coming days people have in a particularly geotechnical engineering professionals will pick up this technique, particularly in many of the developing countries. And actually, there is another small nice case study here; in Europe, actually they have tried to use that in particularly on one of the applications, they were able to really, you know, replace the conventional surcharge preloading for the development of about 57,000 meter square of the area in some place, you know, in one of the areas.

So, that way pre loading using this vacuum consolidation has been effective, and it is also very effective for places, where you know, you have a soft soil sites with shallow groundwater table, when difficulty is that, if you have stratifies soils like different layers, then there could lead to some difficulties, but I think still people have been able to use this technology in a comfortable way.

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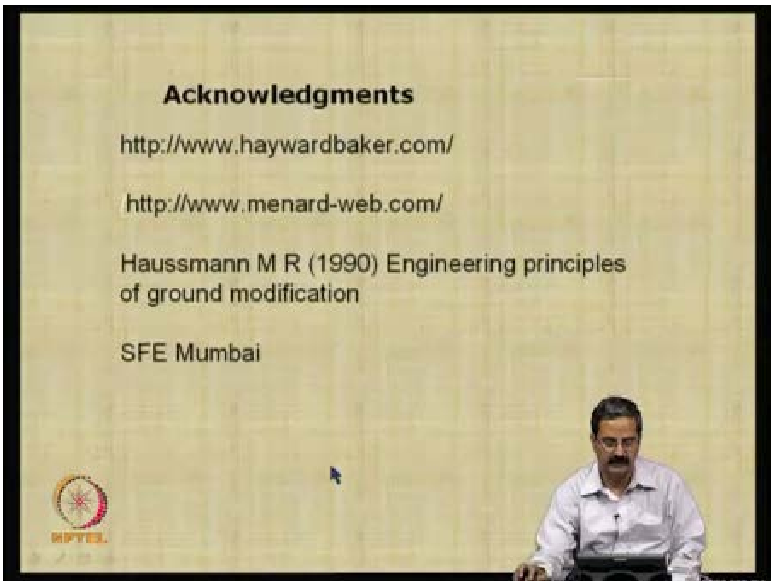

So, I must thank many of the, you know, where I could take down some materials from this, and also the some companies, and Haussmann book, which where I took lot of material, and also from the Soham geotechnical group which have the prefabricated vertical drains material, they were able to share with me.

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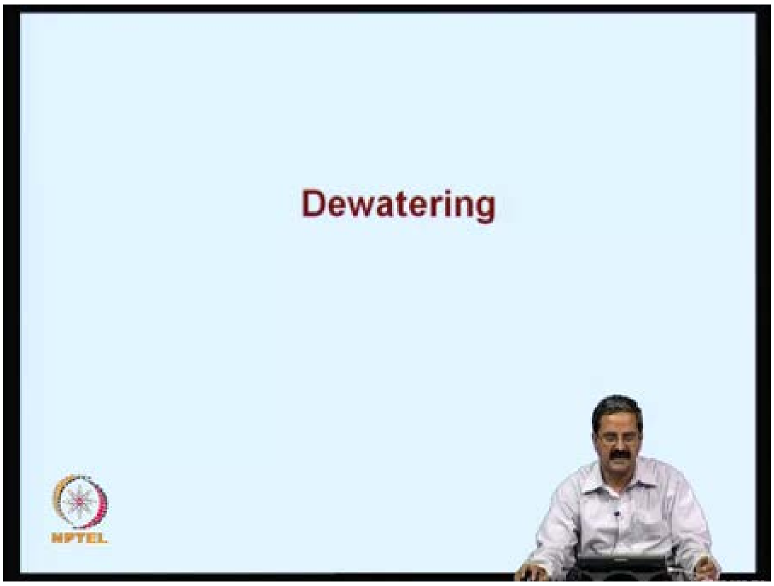

So, now, I would like to take on what is called, the, another lecture that will go, where we talk about dewatering. Actually, this, what we did in the previous case was also dewatering, in the sense we removed water and increased effective stress. So, dewatering is a standard means of increasing the strength of the soil.

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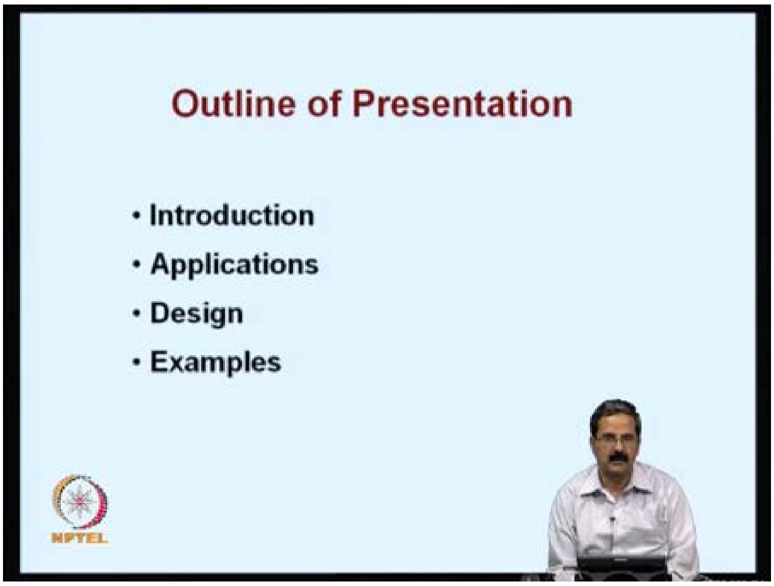

So, what do we do here is that, again we will talk about even say in a conventional foundation areas, how do you do this, maybe soft soils are there in a many places, elsewhere across the coastal lines, and some interior areas or at leg beds, and other things. But how do you handle groundwater problems is what we will see it now, and I would like to show you what exactly it means, and we will talk about some applications as well some examples, and why do you need dewatering.

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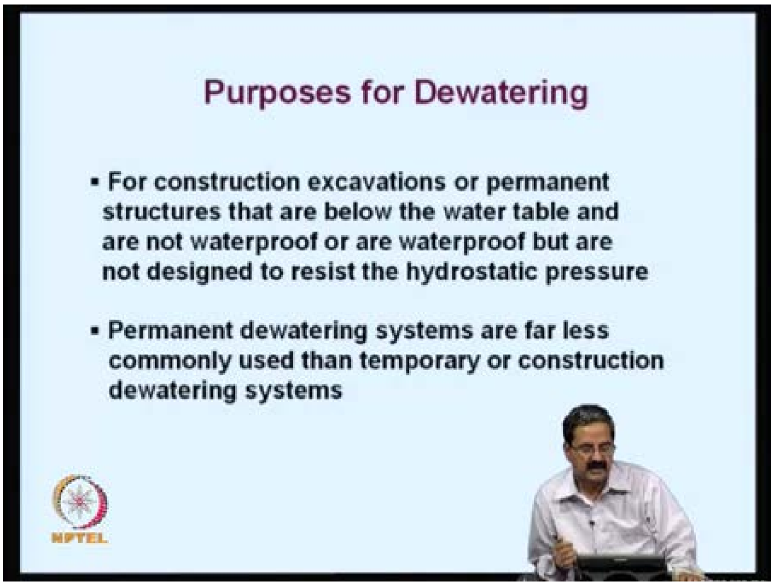

Dewatering essentially is that, particularly in urban areas, when you are trying to construct or make excavations below the water table, and which are, you know, the difficulty is that, you, it is very difficult to design the, you know, structures to take care of the hydrostatic pressures; normally, you design with gamma b into height, you know, the pressure acting at any point is, you know, gamma b h square by 2.

But then, if you have water also, then water pressure also gets added to that, you know, gamma w, you have to add plus gamma w h square by 2 again. So, the pressure is huge, so, you do not want that to, you do not want to design for hydrostatic pressures; essentially, what we do is that, we do not want to design for hydrostatic pressures, and we would like to dewater the whole thing or see that the drainage occurs properly, that is our objected.

So, permanent dewatering systems are far less commonly used than the temporary or construction dewatering systems. In fact, permanent dewatering to maintain is not easy, like in a building, you have a, you have to just to continuously dewater, it is going to be expensive, the house owner will not be comfortable.

So, what we have to do is that, we have to have some sort of systems, which are very you know, how do you dewater actually first, how do you maintain that and see that the buildings are waterproof or they have a full drainage, all that we should see.

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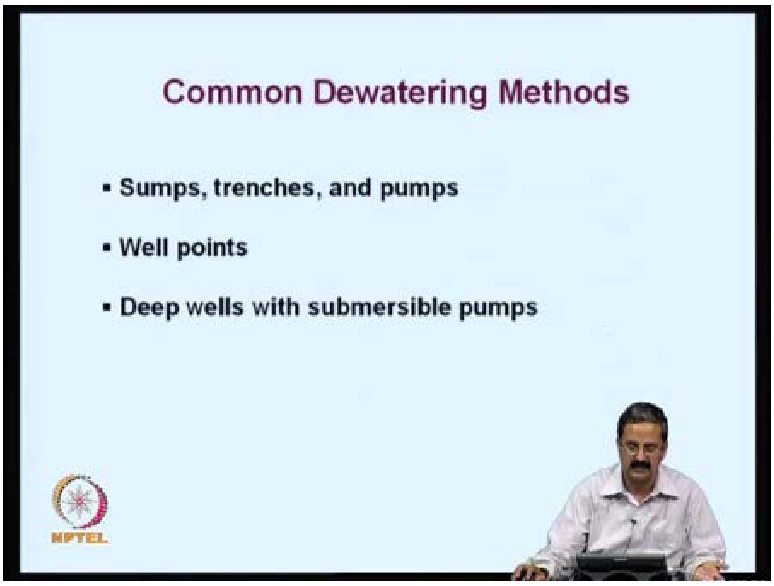

So, what are the common dewatering techniques, you must have seen in places, we are familiar with them, like you have a sump, you have a trench; you have pumps well points, deep wells with submersible pumps.

So, normally we use a combination of many of these things to dewater, say for example, the water table is at the ground, ground level, and you want to construct foundation at 3 meters level, what you are doing. So, you have to really take down the water table to below 3 meters, maybe 3 and half to 4 meters. So, you have to make suitable calculations, and see that, that you can make calculations of how much of the discharge of water should be removed from the area, you know, which are the influence area, and all that, and how do you calculate, how do we store that water, how do you connect the pumps, and also the pipes, for all that, all that we should understand right.

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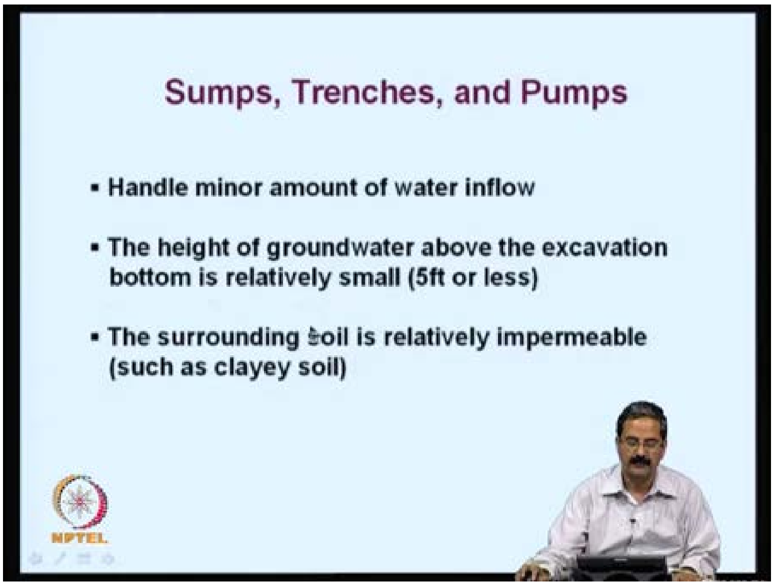

So, sumps, trenches and pumps, one can handle reasonably a minor amount of water flow, and the ground water table above the excavation, bottom is you know, say for example, you have an excavation level at three meters or some you know. So, the excavation, you have a small height of maybe 1 and half, 2 meters, one can handle with this.

And in the surrounding soil is relatively impermeable, you know, if the surrounding soil is very good, like is a good drainage material there is no problem at all, but if the soil is surrounding soil is not clay, like water is not going at all, so you have to remove the water.

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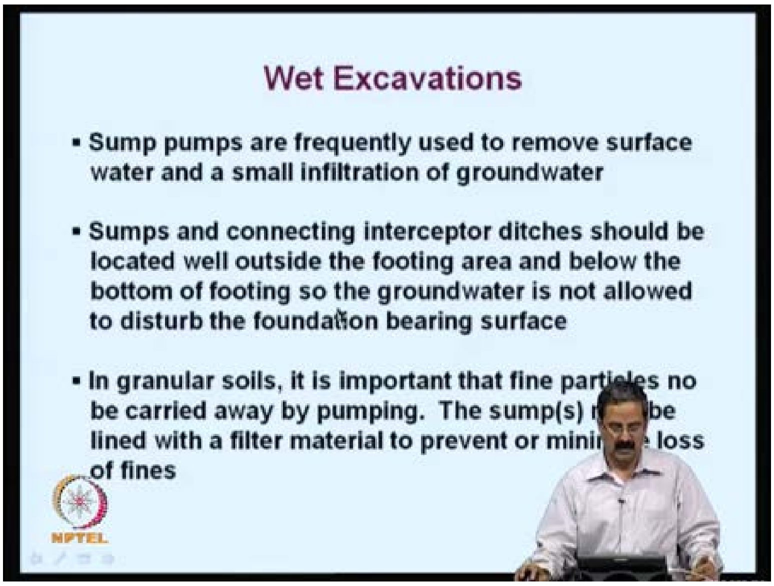

So, sumps pumps are frequently used to remove surface water and a small amount of infiltration of the groundwater. Sumps and connecting interceptor ditches should be located well outside the footing area and below the bottom of the footing; so, the groundwater is not allowed to disturb the foundation bearing surface.

In fact, if you are trying to do the concreting, you want to have it dry, you go to some, say for example, somebody is constructing an apartment and basement, say first five meters, there is no water, but after that next 5 meters, there is a water table, then that man has to take that foundation, he has to start from that point; so, you need to dewater, say for example, it is a foundation level is at minus 10, the water table should be much down like minus 12 or minus 11, one should calculate, because it depends on the draw down, you have to create a draw down situation.

And see that you know, when you are trying place a concrete or trying to have this foundation bed, you know, you do not have a difficulty, otherwise, you know, the thing is, if the during the placement of the concrete for the foundation itself, there is a problem of differential settlement, it is going to be very risky, you do not want that. So, what we do is that, we do not want, we want water table below the bottom of the footing that is the important thing.

And in the granular soils, it is important that fine particles will not be carried away by pumping actually in some sometimes, what happens, that you try to pump; so, the fine particles they have a tendency to come out, because you know, because of the pressure, that you have harder particles or bigger size particles will stay back, but then the small size particles get collected; so, you need to filter them out. So, that is a reason why sumps maybe lined with a filter to prevent or minimize loss of fines, this is very important

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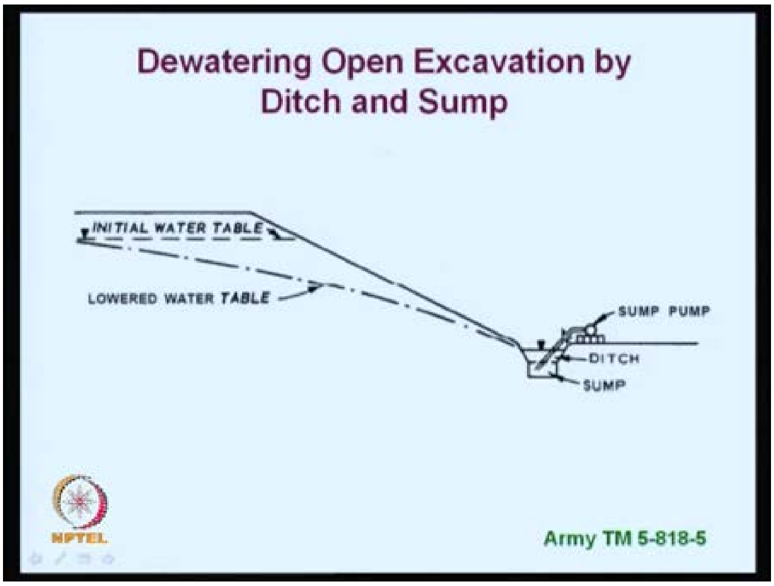

This is what is an example, in facts, it is an initial water table level, and this, you would like to lower the groundwater table, you have a system like this, see you have a sump here, you have a, you have a, made a ditch here, you have a sump pump here.

Actually, these are all copy; I mean, in the sense, these are all, you know, extracted from the technical memorandum of the U S corps of engineers. It is in a valuable document, that one needs to see, and in fact, this is also one of the contributions from many of the people, that they could make some of these ideas and useful to people who need dewatering.

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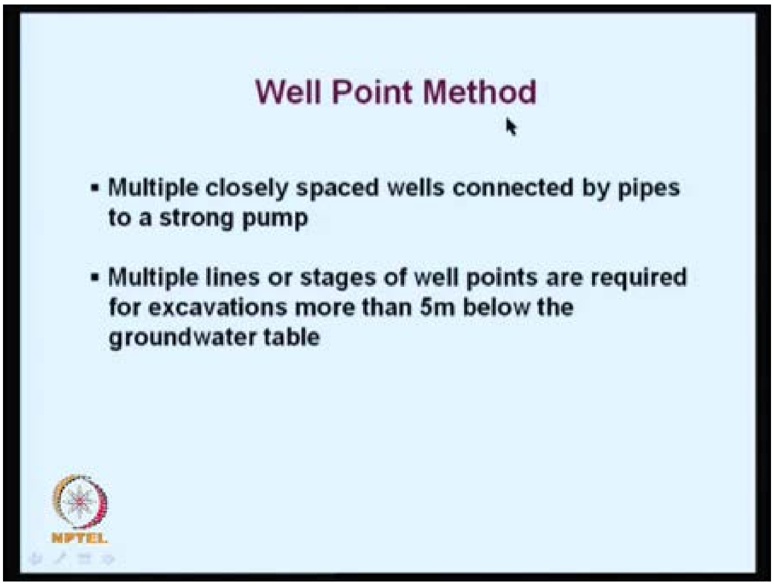

So, that is pump sumps in one, well point method. In fact, there is another important thing, like if the water table is somewhat, you know, it is the depth of water, I mean, removal of water is going to be high; he need to go for, you know, say for example, below 3 or 4 meters you need to have this. So, in the well point system what we do, we have a multiple closely spaced wells connected by pipes to a strong pump, you have a number of pipes connected to a strong pump, then multiple lines or stages of well points are required for excavations more 5 meters below the groundwater table.

In fact, there was one side, that I was visited, like below next to the, see for example, you are trying to construct a nice resort next to a sea, but you know, there is a water table all the time right, the, there is all the, all the time water, but you know, but you are trying to construct a foundation. So, you have to really doing the process of dewatering, you should have well points well points, we will see that, and it is a very elaborate preparation, because suppose you have to constructing for about one year, in during one year period all that dewatering should be perfect, like all the system should be working correctly, particularly there is a rainy season, it should be really you have to see that it works very efficiently.

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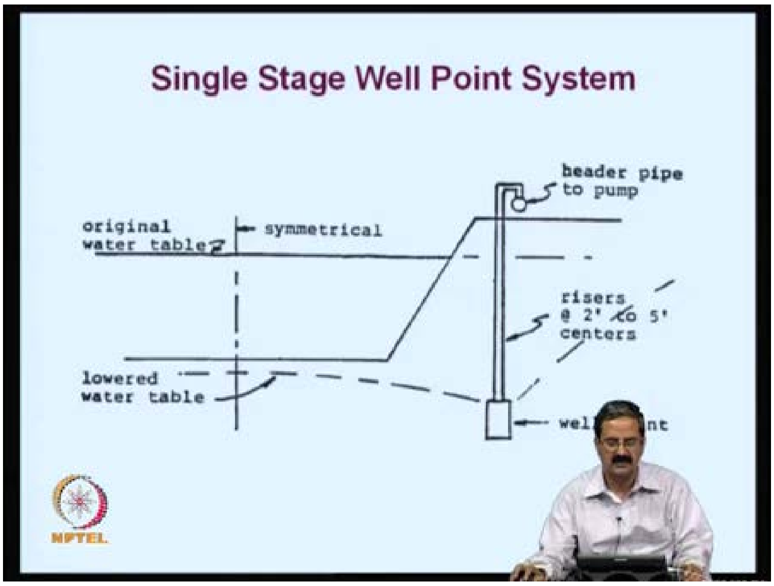

So, for example, there is a single stage well point system, like you have a well point here. So, this is the original water table and this is what the bottom of the foundation; so, you have the water table like this. So, these are all connectors, and all that, this is from Caltrans California department of transport, and this is the header pipe, and all that you can see a typical arrangement here.

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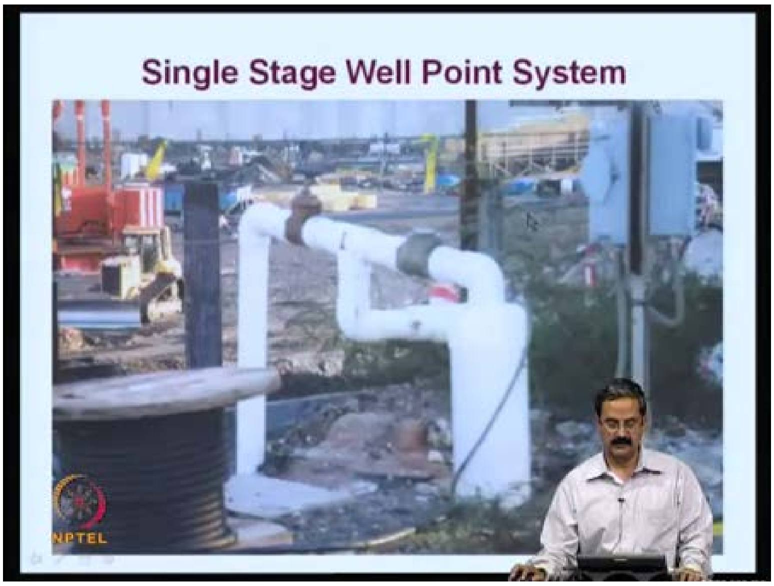

This is a typical example, like you have a static water table, and you have a system like this, you have well point here, you have another well point here, and so, the groundwater table, it has come down compared to the previous static water table level.

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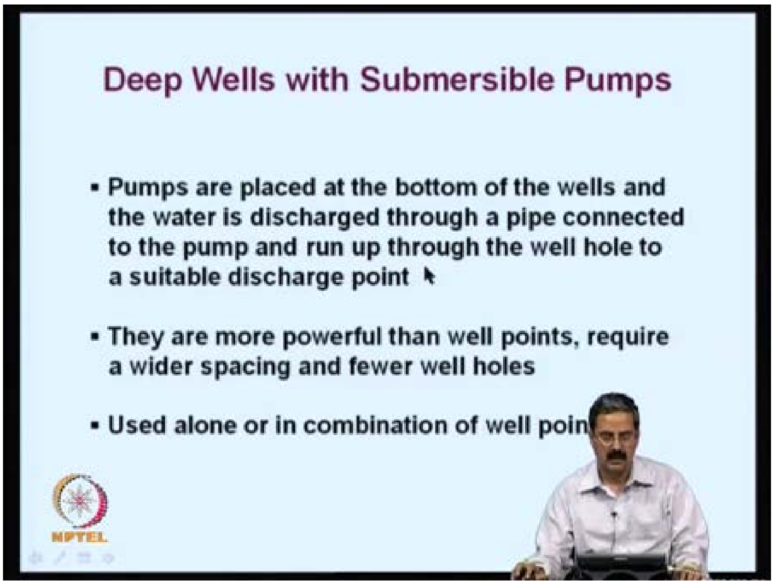

So, this is what we need to do. So, there is another one which is called deep wells with submersible pumps; here the pumps are placed at the bottom of the wells, and the water is discharged through the pipe connected to the pump and run through the well hole to suitable discharge point. See all the pumps are at the bottom of the wells, and the water is discharged through the pipe connected to sump to the pump, and no essentially we will see that, they have, they are more powerful than the well points, and require a wider spacing, and fewer well holes used alone or in combination with well points.

Actually deep wells, you know, you have to go for a very deep well put a submersible pump with which means, it can be, you know, it is, you can even put under water and all that. So, you have a suitable discharge point, all that one should calculate properly. Actually you have see the thing is depending on the depth of depth, and a water that you are expecting to be removed, you have different varieties of methods here, and it is very important that, see they are all flexible, like depending on the situation, you must be able to see that the their combination can be used.

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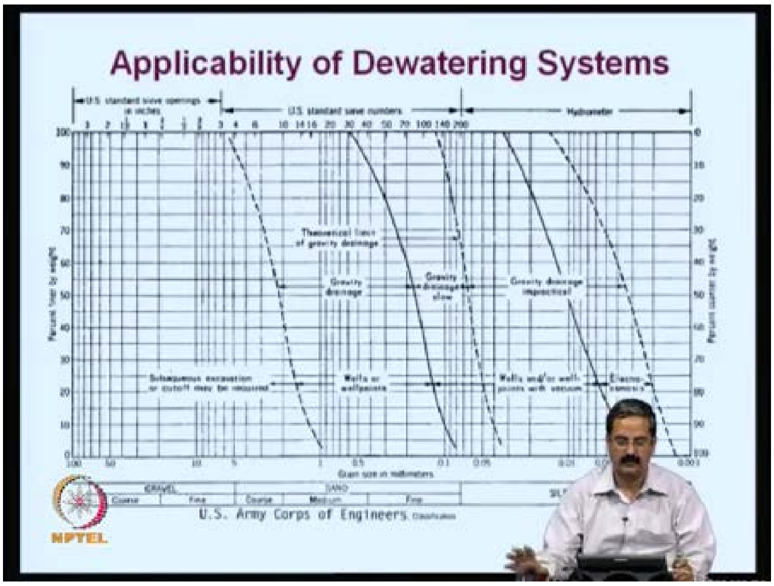

This is very important, because how do you dewater and what type of soils can have what method, say for example, this is a grain size distribution U S corps of engineers; this is a fine grain size distribution like 0.001 to 0.01, 0.11. So, these all gravel, this is all sand, and this is silt, and clay. you can see that, if the material is like in this gravel, you know, gravelly material subaqueous excavation or cutoff maybe required, you know the thing is that, sometimes if you have a cutoff wall, sometimes it may be all right, because the pore size being bigger, and all that, and there is one case that, but still, there, you know, you need to still dewater here.

Here, you know, particularly why I am mentioned is that, what we call there is a, you know, you have to have what is called, you can see that, there is some range of particles 1 to 0.01, 0.1, where there is a gravity drainage, like you know, you can by gravity alone you can remove the water. And so, here you have wells or well points, and essentially what you are doing is, you have a well point at the bottom, and it is, it creates that suction and the water starts going towards that, you are trying to create a field of a point of attraction. So, that water goes towards that, it is not against gravity one should understand that, that you are trying to see go to lowest bottom most point, and then try to draw the water.

So, when the process, what is that you are trying to create a gravity field, and so, that works very well for wells or well points, and if the grain size distribution, you know, you have to do a grain size analysis of the soil area, and then, if the grain size distribution is in this range, definitely gravity is worth and well points, and all this things will work very efficiently like, you know, sand medium fine to medium sands.

But gravity, you know, if the grain size distribution is little low what happens, the gravity, you know, the effects are not really that dominant, and sometimes you know, if the grain size distribution is very less like 0.07- 0.75 microns or something gravity drainage may not be possible; so, you might have to apply vacuum actually.

We can see that, you need to even align, no, you can apply suction pumps, you know, even I have, you know, even the laboratory we have, so then, if the, it is too much of fine material electro-osmosis, like you know, if the thing is that, we know that clays are negatively charged, and you try to remove some ions along with cations, water starts coming out something like that.

So, you have electro-osmosis also. In fact, lot of work was done on this lines and one should be able to understand, that is the method appropriate, of course, is just say for example, one should understand how do you design this well points or you know wells or well points are this system.

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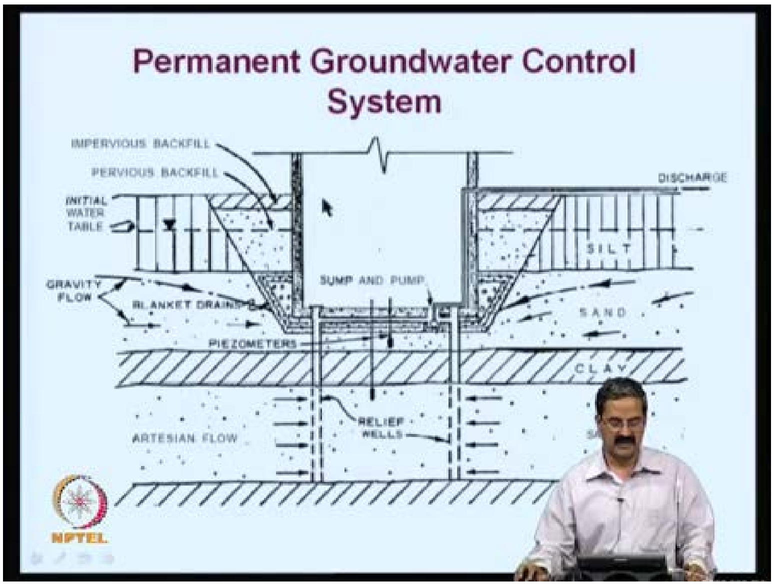

So, we will see that some applications; this is a very important application, again you know, this is a, see you have some places, this is may be a basement and this is a permanent groundwater control system. In places, some places what happens is that, you need to have, you know like I have seen, you have to design the base of these, you know, like foundation; how do you design, actually the thing is that, there is lot of water coming up, you know, you have to design for the water pressure, like there is an uplift pressure that is created.

Suppose there is a 5 meters of water, and then, at you go down, it is 5 meters into that unit weight of water, that much of pressure is coming up, you know. So, if you place a foundation there, there is so much pressure acting, so you have to design, say for example, you have a raft foundation in some place, you have to design people design for the uplift pressure also, that is called uplift pressure.

So, in big areas, and all that, that is, so people design, you have like you know as high as 3 meters 4 meters thickness of the concrete is quite common. In fact, there is a couple of enquiries and how to reduce this thickness of the concrete, you know, if when, it is 2 to 3 or 5 meters, it is too huge, how do I reduce this pressure. Because I am designing it for uplift, actually the uplift is maximum pressure acting and that is the worst condition one of the conditions that I should consider, because the uplift should not be creating any problem.

So, in that case, this is an example, you can see that, this is the initial water table, and you have a pump and sump system, and assume that, you have a, like you know there, there is a piezometers here, there are two piezometers here, then you need to have relief wells. Suppose, actually you know this wall, this is a typical illustration of how it can be done and there is an artesian flow, what they created was, relief wells were created here; relief wells it means, there is a like you know, you as, you go down there is lot of water, water pressure is there.

So, you would like to create all that removal of water pressure should there. So, you create some sort of sand drain type of thing or you can even put a prefabricated vertical drain here, it is very interesting; even you know this, you can create a particular prefabricated or any drain, and then, see that the earth pressure, you know, whatever is a water pressure gets, it comes up, it gets released, and it comes as a water here, and then it gets pumped, and all that, and then you can see that, it just goes up to the pipe, and then it gets discharged here is it not.

It is very simple, that say the estimation of water pressures are quite, like. So, you need to really, you know, gamma w into height or the depth, say for example, say for example, the initial water here, the initial water table there is no problem, but you brought down to this level, and you are trying to put this foundation. So, at least from here to this level there is a, this much of pressure, you know, at least a few meters down, that pressure will be created.

And you should also release this artesian pressures you know, you know, because there will be always this pressures, that could lead to difficulties. So, you should see that, this is also released, so what happens in this process is that, the water table gets lowered, you know or gravity flow, you can see that at this point, it is at this level, it, then it goes like this, all the water comes here, then it enters this sand materials, and all that, and you have a system of this thing and then it gets removed.

And you can also see that, you know, it is all, you know, little, it is made impervious. So, that, you know, water table, you know, in this case, of course, there is maybe impervious nature of silt in the sense.

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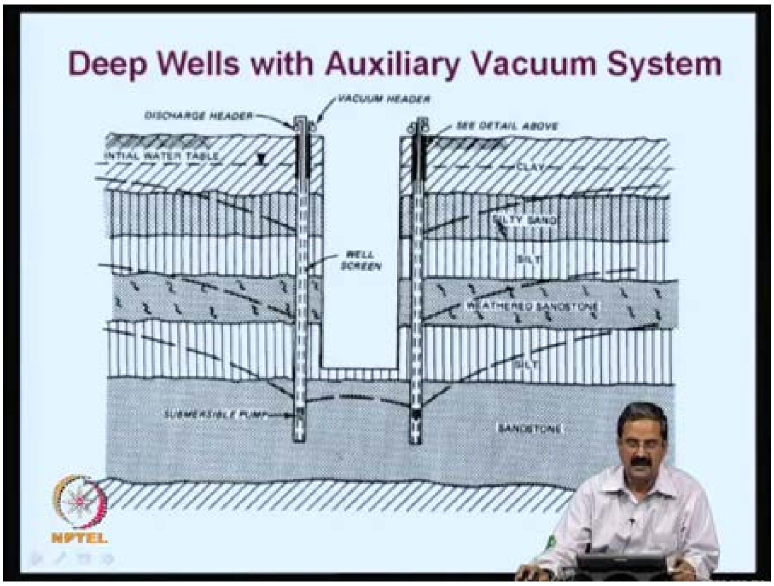

Essentially, one can design a system of permanent groundwater control also is what, it shows, there is another example here, like you have a sand, stone, alternate layers of, you know, this which can occur, you know, because of the deposition sequence in nature.

You have alternate layers of clay silty sands, silt weathered, sand stone silt, and all that, it is quite natural, and objective is like, suppose you are trying to make a shaft, vertical shaft anything, you know, like you see that this is a thing.

So, you would like to see that, again you create a deep well with the auxiliary, you know, why you know, why this is vacuum system is required as I just mentioned, you have clays, also clays and sand stones and all that to increase the efficiency of the whole process. So, initial water table level is here, so, you have a submersible pump here, then when it starts working, like you know, the water table level can come down to this level, this is what it means.

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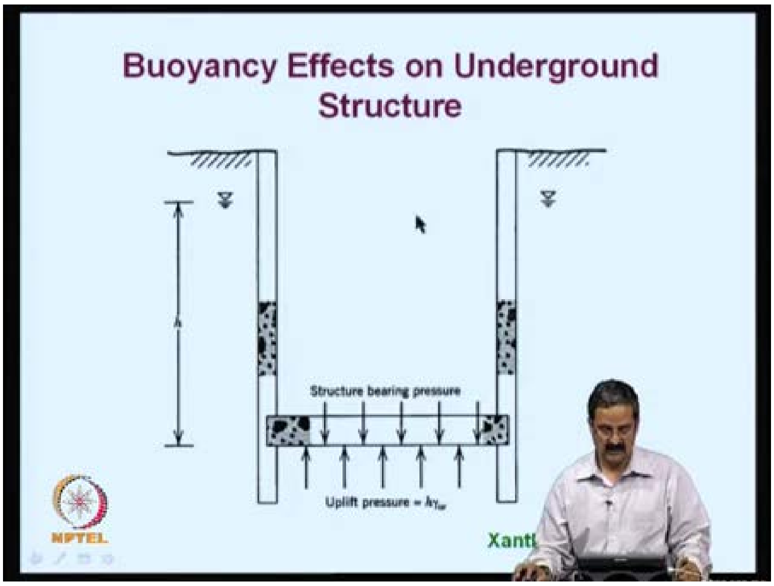

This is what I was just mentioning, that you have a water buoyancy effects on underground structures. So, structure bearing pressure, maybe say 10 ton meter per square or 15 ton per meter square, but then there is an uplift pressure. So, you have to design this system properly that is very important.

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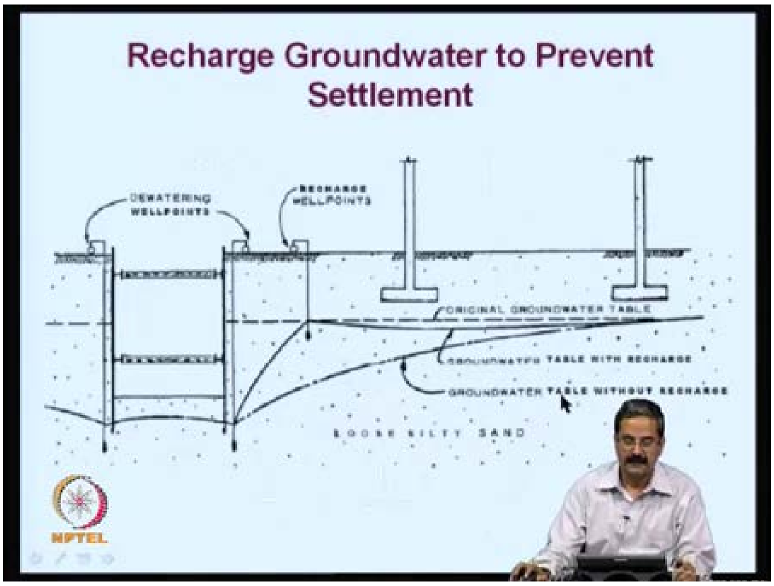

This is another interesting example, In fact, for Bangalore metro also, they were trying to checkup with us, if this is possible, recharge the groundwater table to prevent settlement, actually why settlement occurs is because you would with remove water, when they, we remove water, water is removed what happens, there is a difference, there is a two footing here, and when you remove water, actually the rate of water remover is higher here compared to this.

So, definitely there is an effective stress higher here, then this definitely the there is a tilt, you know, sudden change in the effective stresses, there will be some changes in because of the changing the delta sigma, sigma you have more settlement.

So, suppose you are trying to construct an underground station here. So, you do not want, like you do not want that, so you are trying to construct a retaining wall here; you are trying to construct a retaining wall here, but then, there is a water table here, how do you construct the retaining wall, and then you have a water table, how do handle this the metro line has to go here, it is a very complicated problem, what should be done is that, you know, say for example, I have, actually we are able to do that to some extent, say in some, you know, example, I was able to suggest them, this is the water table.

Now, I would like to see, I use actually soil nailing for retaining wall systems; suppose, I just put a nail here, like you know, I cannot put a nail here, because there is already water. So, what I do is that, the, I just little, you know, the release I mean, the dewater, a bit and then put the nail.

Actually, the thing is that, we should do this nailing operations so fast, that you can see the thing is that, the nailing sequence is quite fast, like you know, you excavate put nails, suppose I, this is say for example, this is 5 meters depth, I can dewater this whole thing in a process of very short time, and also insert nails, and allow the water to go back or sometimes additional water can also be pumped in to see that, water table close to this foundation is maintained. In fact, you can even construct a cutoff wall here.

See that this will not create too much problem, say for example, if the water table goes down below this footing, that is a problem; so, you try to maintain that, and see that, it likes a tub of water is always maintained next to this footing of the same level. So, one can do this so, but then, one should be very careful. So, what are you doing here is, you are trying to recharge the groundwater table to prevent settlement, this is very important this. In fact, L and t, and I do not know, what will happen to many of the projects.

So, they are looking at it very seriously, because you have, so many existing structures already, and because of these metro operations, there should not be any difficulty. So, one should to be able to either isolate this area, So that, the water table changes are not, will not affect this buildings, and also see that, this is area is you have to do the retaining system also.

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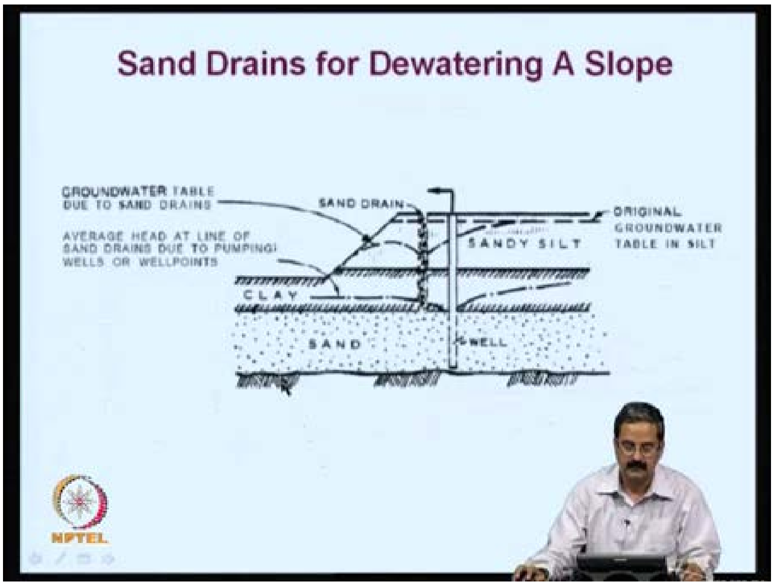

In the case of slope, how do you do, this it is very important again, because you know that, this is a slope which exists, and you want to calculate the slope stability like already the initial original water table is here.

So, when it is saturated water table, the problem is I mean, it is not easy, actually waters keeps on coming on to the surface, you know; so, you are trying to make an excavation here. So, what you should do is that, you have to really like again lower that, you know, you have a well here sufficiently lower, it like this.

Properly you, actually you should be able to understand the geology of the site properly. So, that you put a proper well system here, and also one sand drain system here. So, you, this well is able to remove the lower, the water table this also helps to some extent. So, in the process, what are we trying to do is that, say for example, you can see that in the absence of the well maybe the water table is like this, but because of this sand well or a drain you are able to little bit lower.

So, in fact, if you are able to see that the actual, you know lowering is much below this, you know, this is a actually tau of the slope tau of the slope is a very weak point in a slope the possibility is that, if water starts coming, then there could be a possibility of failure. So, we should really dewater to such an extent that water table is here. So, whatever this is a typical example and one can really do short of a good dewatering system on these lines.

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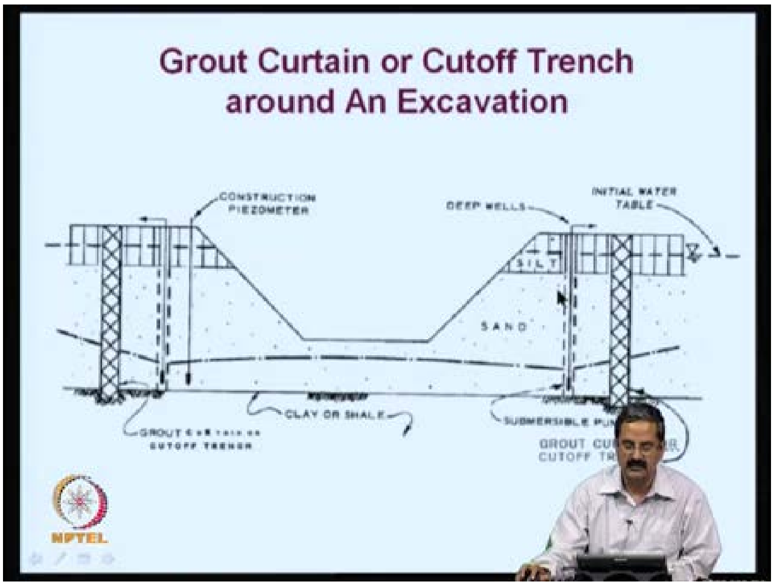

So, this is another example, as I just mentioned grout curtain or cutoff trench around an excavation. Here grout curtain or the cutoff trench is, it can be with a Bentonite, it can be with a I mean, it can be with cement slurry, sand cement plus Bentonite, there are different slurries there, one can, you know the objective here is that, this is a original water table, and this is a actual area that you want, that water it should be water free.

You want to have this water free, like maybe you want to construct a big mall here. Let us assume that, you are constructing a very big mall and you are trying to have a nice green setting here with some parking, and all that and whatever. So, one can have anything, and what is that we did here, we can do here is that, it is just that first thing, is the water table level should be very much lower, is it not, that is our prime purpose, and how do you do that, we have a deep well here with a proper capacity. In fact, you should calculate, how many numbers of wells are required, what is its discharge capacity, what is the volume of water that you are handling?

This is so much of, see the thing is this, at least this much of water is removed, like the whole area into that, that much meter cube of water, that where is it going, you know, you have to have a proper drainage system, because that is very important, and you can see that, here you are able to lower to this point using this two material. And also you have a piezometers which will tell you that, yes, is a water table, you know, the you know, it will give you how much of water hide is there, like is it 3 meters or 2 meters, it will give in water hide.

And so, if it is going to be more, then you should be worried, because there it is going to touch. So, you must be able to control this by suitable pumping, and operations, and you also have in the other thing, that the, so that, it does not lead to lot of variations in water table, because this is a sandy layer, you know, it should not, say for example, there is lot of rains there, you know. Suddenly rains come, and then the problem is that, suddenly water table starts rising, but the problem is that, if we have a good, I mean, if you have nice grout curtains on either side, grout curtains on either side the possibility is less.

So, like you know, the water takes more time, and you know, you have, gave some sort of technology or some sort of method, in which you can handle to see that, the pore pressure or the or the which is measured from these piezometers can be low, that is a actual point. How do you go about design is something, that we should see, because sometimes I know that, there are many constructors in India, but you know, in fact, they have been doing, in fact, I, we get lot of enquiries, you know, they have, say for example, in some place, nearby they have they have to go for in a excavation of about 18 meters, and the water table at 9 meters, because 18 meters is something that you know, you have, want to have you know basement parking, and all that there is a good, you know, the because of the land value that it has.

You need to really go ahead with construction, because since the water table is there at 10 meters, I cannot say that, I cannot go beyond that below that. So, one should be very careful and people are ready, because whatever you recover in that process, like if the pumping costs are, you know are, but your business is much better, many times higher, then it is fine, that is what people have been doing.

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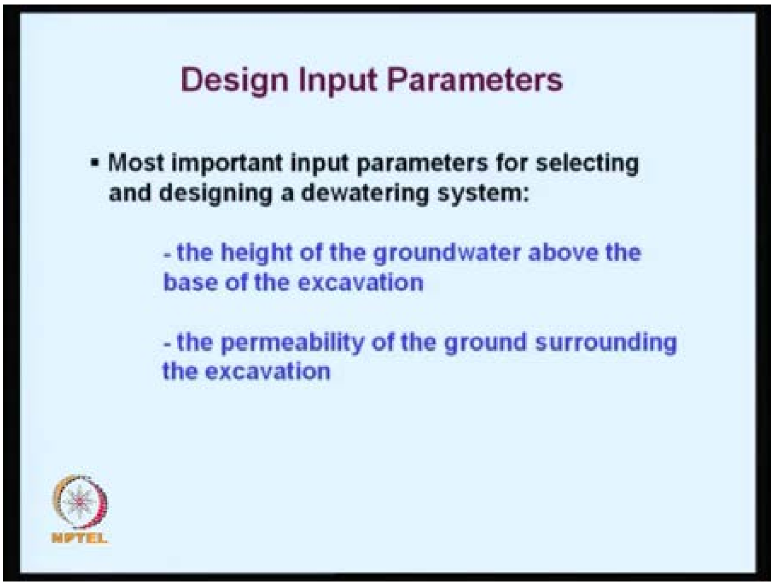

So, how do you design this is something that, one should know, and what are the important parameters, the height of the groundwater table above the base of the excavation, then the permeability of the ground surrounding the excavation; so, these two, like what is the height you would like to handle. What is the permeability of the, this is an engineering parameter, this is our own technical requirement.

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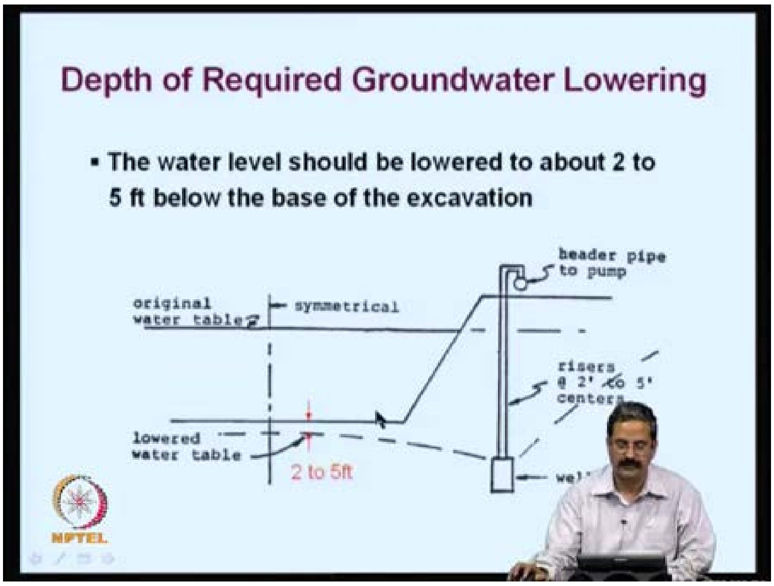

So, depth of required groundwater lowering, the water level should be at least about 2 to 5 feet below the base of the excavation, this is, it should be some sort of design criteria you have, because you cannot do concreting here, this is a well point here.

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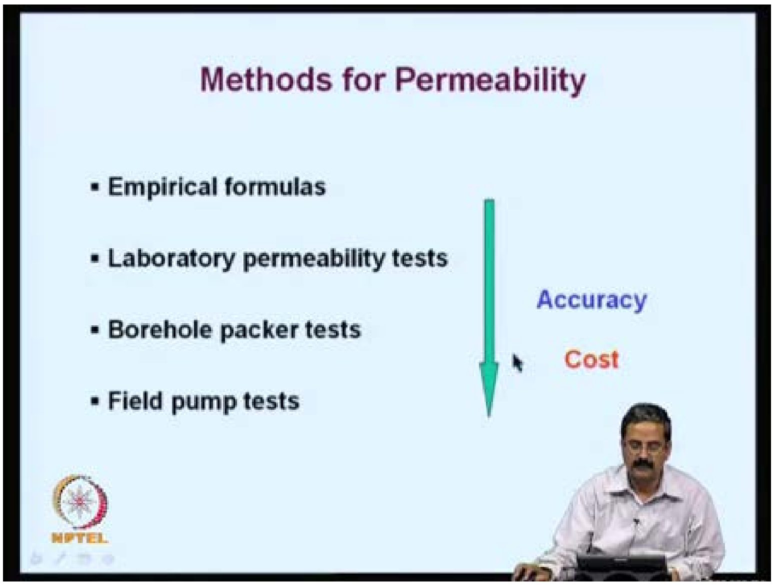

So, now, how do you get permeability, because that is an engineering parameter, and actually people use based on grain size distribution, we have some empirical formulas, like if you know the d 10 of the material, I will get some k value, then you should do laboratory permeability test, you have borehole packer tests, and field pump tests. Of course, accuracy and cost will make it little expensive, but the thing is that, one should really do good field test then using some empirical formula that is a bottom line.

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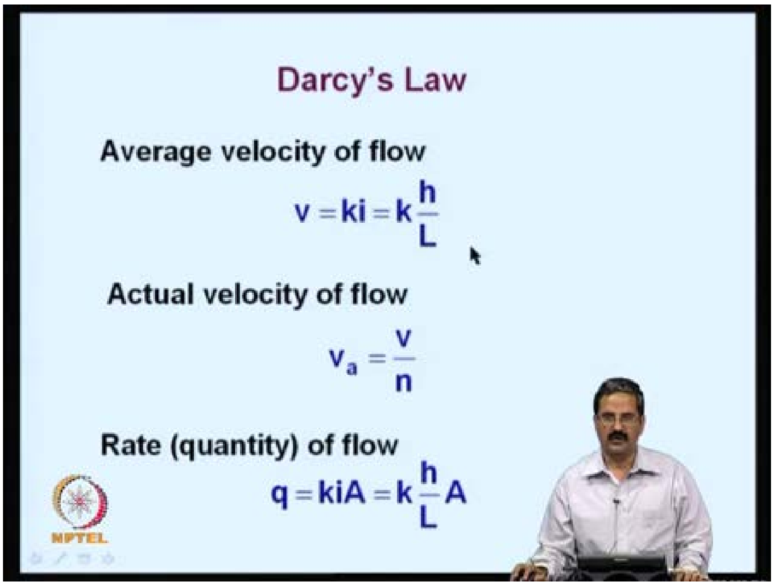

And how do you get them, in fact, we know, the, how do you calculate using Darcy's law, you know the velocity, and then it is equal to the proportional to the hydraulic gradient velocity of water coming out of some of these thing is the proportional hydraulic gradient, because that is a head of water acting. So, velocity you know, and then the porosity is another factor, that you need to consider, and you can also calculate the flow, flow of water that you should handle, all, the pump should handle this flow.

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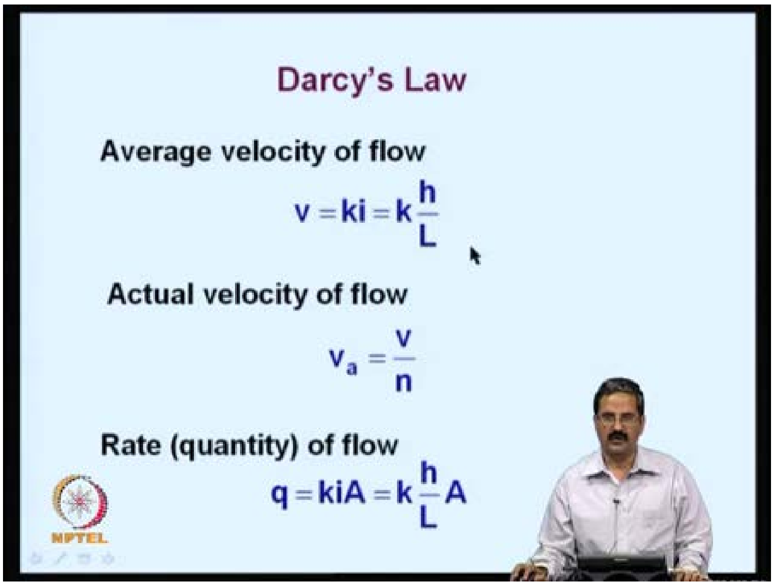

So, these are all the typical values of permeability, you can see that, they are quite high, it there is a big range of values, like depending on the type of gravel clean sand, fine to medium sand, and all that, and many things are there.

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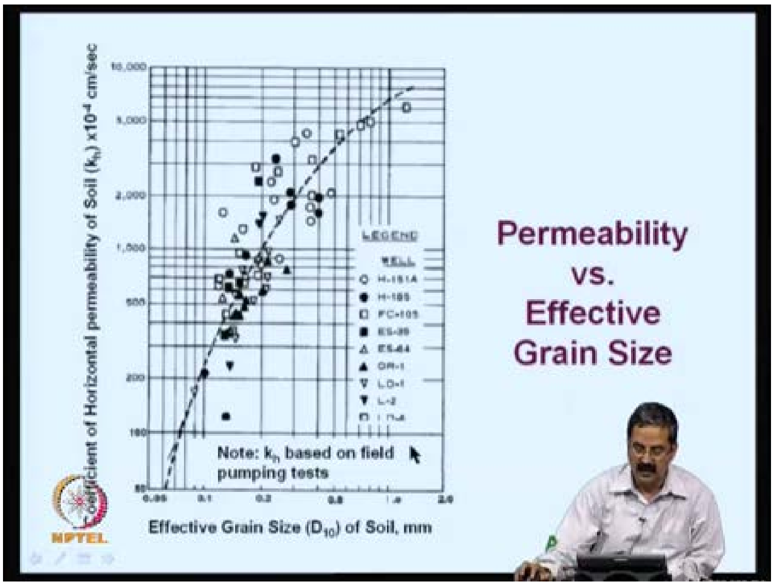

Of course, as I just mentioned, depending on the d 10 size of the soil in mm, you have a permeability coefficient, one can get in centimeter per second. So, this is some sort of actually people have used, you know, see suppose, you go to a site, you measure the d 10 of the particle, like you know, you have, say normally we do against a distribution analysis, you also measure permeability. So, if you are cover enough, you can plot all like this, you have so much data, you know, in the particularly in field projects below 100s of grain size distribution curves, 100s of values.

So, if you are able to plot a curve like this, that can be used for the design basis in the same, you know, you are handling a big site of 100 hectares, and you want to have some understanding of that, you know, you may have understanding of shear strength properties, compressibility properties, permeability properties, then in-situ test, all that can be done. And for the same material, that you have, you can really plot some relationship; I have this site, this grain size distribution there, what is the k value, it can have; so, this is what one can plot this is very important.

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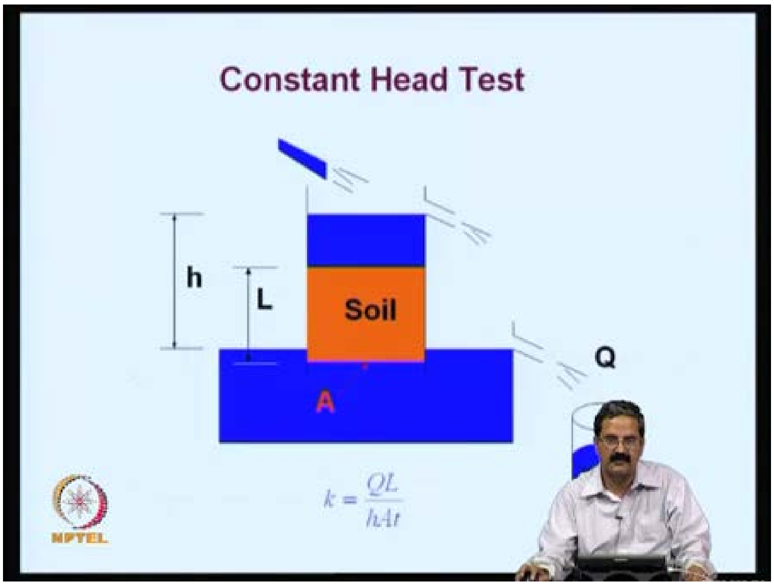

So, you have constant head type of test, where you know, for sands, we use that you calculate, you would get the discharge use the formula k L Q L by h A t area, say area of the soil, t is the time of monitoring the flow for the required height. And you also have falling height, height at a two different times, we calculate the height of fall, because what happens is that, in permeability of the soils is clays are particularly so, low that sometimes it is better to see what is the difference between two heads, what is a difference between or the height of drop at two time intervals, and calculate the k value knowing all the other parameters.

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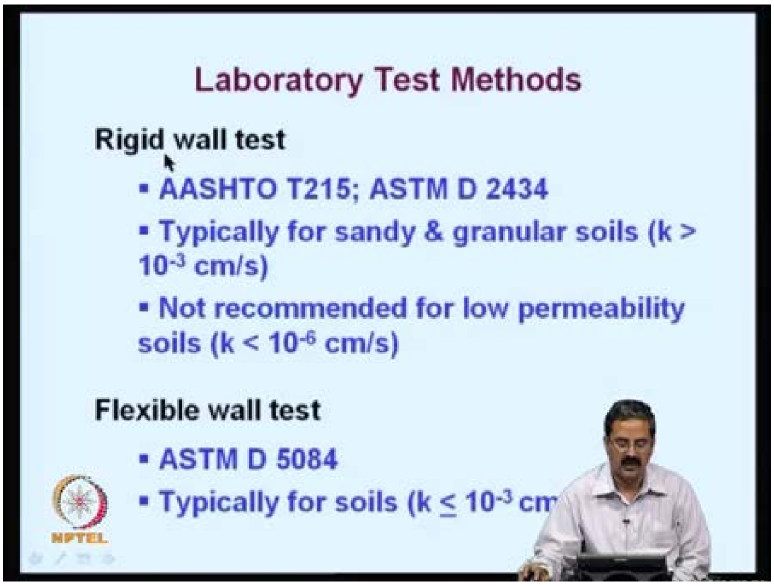

Of course, we have many number of tests in codes, like you have what is called rigid wall permeameter, in the sense that, what you do in the some, the consolidation testing, and all that, you call it rigid wall permeameters, and it is typically for sands, and all that we use, and we do not really recommend for low permeability soils. Say for example, sands and all that, if you are trying to do, it is, but if the permeability is less than 6, we try to go for flexible wall test, and what is the difference between rigid wall and flexible wall, I will explain.

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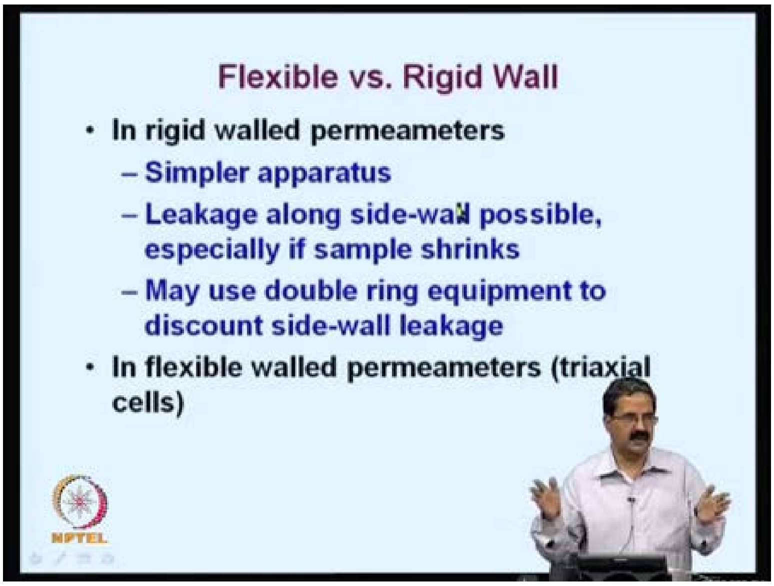

In rigid walled, this thing it is a simple apparatus, you know, you have a tracks the consolidation type of equipment, the, it is a rigid, it is a rigid, whereas, in a, you try to measure in a triaxial testing, the rubber membrane is there. So, there is leakage of the, say side wall leakage is another a big issue, actually say leakage along the side walls is possible, especially if the soil sample shrinks; if there is some volume change in the soil, then there is a problem. So, many may use double ring equipment to discount side wall leakage.

In fact, there are some people, you know, consolidation rings are there. So, people have been using this rigid walled permeameters to get k value, but it is better that people go for flexible walled permeameters tests which are triaxial cells, there is no side leakage and effective stress varies, because the other advantage of the, you know, like we know the difference between a diaxial test and a a triaxial test, where under an effective stress, you can calculate k value; what is a effective stress, you can find out and calculate k value that is an important things.

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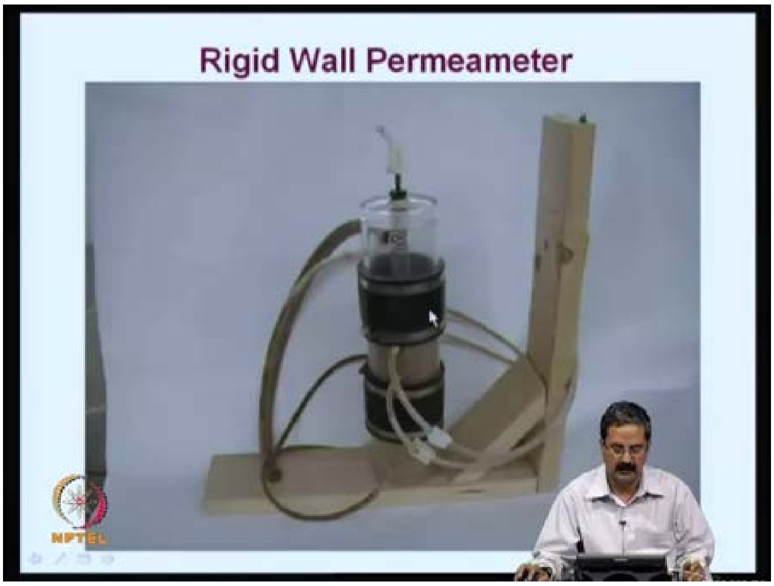

So, this is a typical rigid wall permeameter, people can, you know, just if you have a sample which is in has a rigid, this thing like. So, you can measure permeability, there is no problem, but at the same time, like you know, you have all that arrangements for pipette, and all that you have some more equipment like this, which are essentially for rigid wall, like sands and all that even compaction permeameter, like you know, essentially what you are trying to do is that, you put inflow and measure outflow. So, that can be one and this is a typical type that you have.

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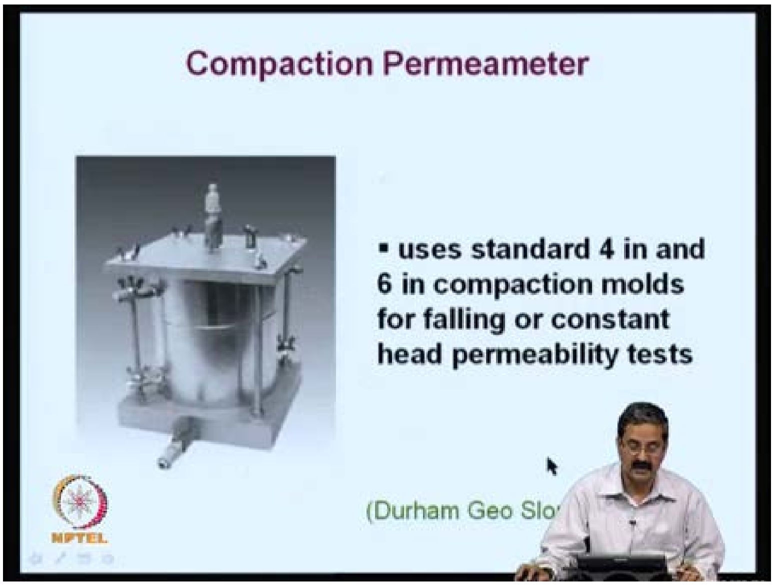

So, what are you trying to do here is that, you have the flow here rigid, this is, again these two are rigid walls and water comes here, and then goes to the porous stone, and comes like this, and these are all. So, these are all some equipment, that people have been using edge flow, you know, sometimes there is a possibility, what happens that edge flow is higher; we do not want corners, you know, leakage and all that.

So, one should be very careful in the assessment of the k values, particularly when you are dealing with rigid walled permeameters, that is one thing, particularly when you are trying to deal with clays.

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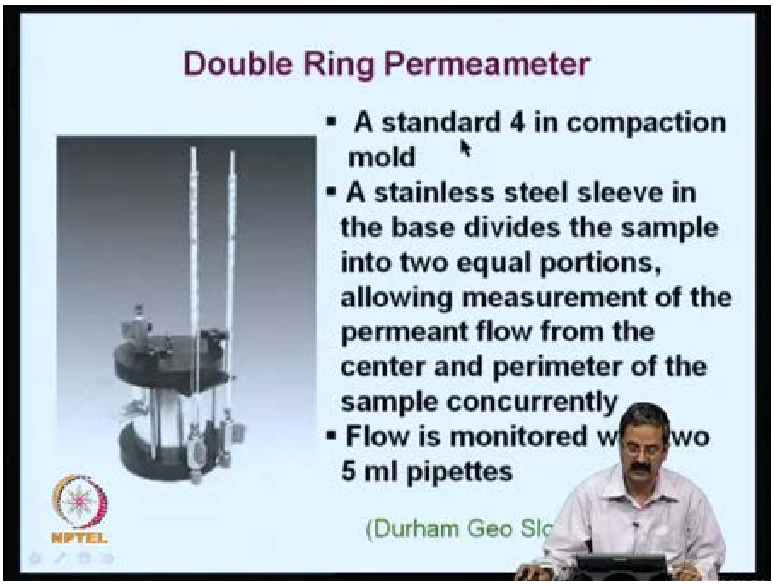

You also have what is called double ring permeameter, again it is an equipment measures the permanent flow from the center, and the perimeter of the sample concurrently flow is monitored with 2, 5 ml pipettes.

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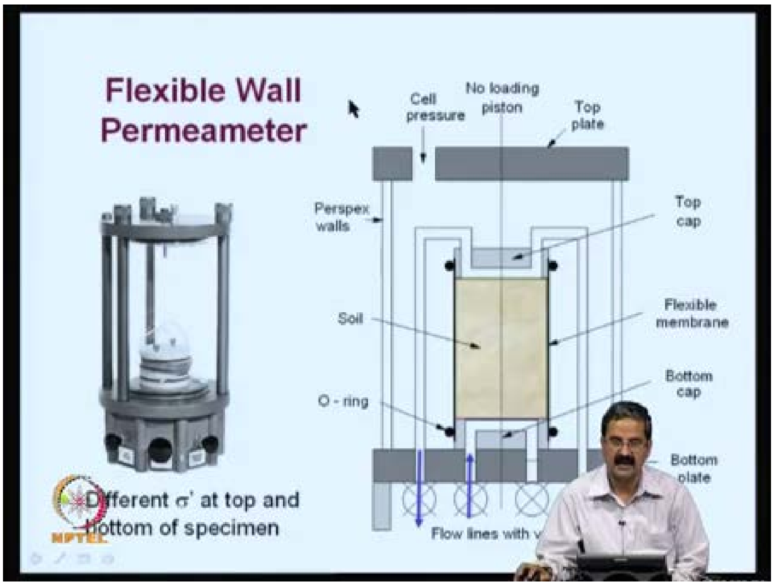

So, again you know, that is one thing what is flexible is here, like as I just said triaxial, different effective stresses, one can apply at the top and bottom, say for example, the effective stresses could be different, and this we are familiar in a triaxial sample, there is a flexible membrane is there, you have a bottom cap, and top cap, and measure the flow, essentially you can measure the flow.

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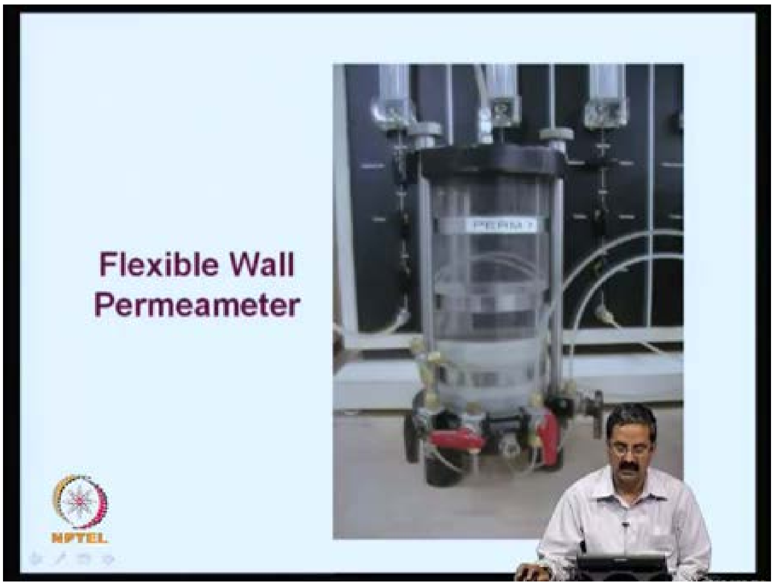

So, there are some more equipment one can design, and it is not an issue at all, and essentially permeability measurements are quite important, when you are deal with drainage.

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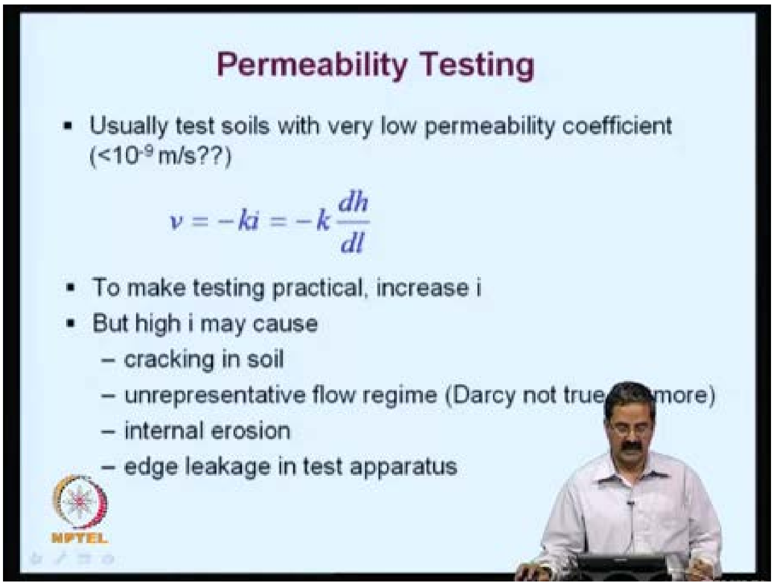

Sometimes what happens, if the k the permeability values know, particularly in clays, it is very difficult to do, and what see the, particularly there is a problem, you know, the thing is that, the problem with associated with laboratory measurements of permeability have come, I mean, about 10 to 20 years back, because you have a laboratory test results, they give some k value which is minus 7 or minus 6 minus 7, but in the field, it is minus 4, like it is 100 times its more, and the thing is that, there is some, what we are doing in a field lab was that to measure the k i value, the the k value, you apply lot of heads, high heads, you know, high hydraulic gradients not less than 50, 40, we create, like if the sample size is 1 centimeter, and you or base width is say 10 centimeters, you have at least 10 times or 20 times ahead.

And then, the hydraulic gradient is very not practical, and so, we try to make it, I mean, you know, to get some value, we try to increase high, but it leads to cracking in soil, like you know, high heads, like you cannot sustain unrepresentative flow regime, like particularly, where lab, you know, if you have high hydraulic gradient, it is not, then it may lead to sometimes internal erosion.

Edge leakages in test apparatus, see sometimes all test apparatus cannot are not perfect, and then, there is a possibility of side leaks. So, these are all typical values of hydraulic gradients recommended.

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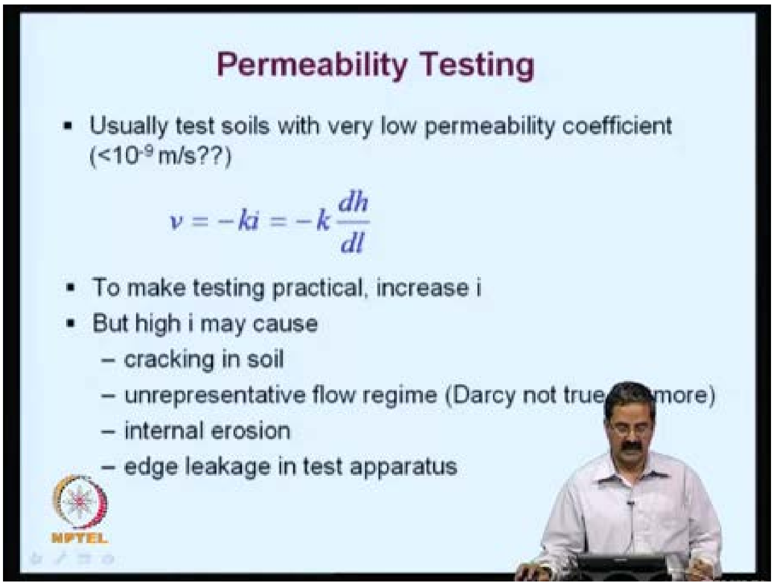

See the thing is one should not, say if the k value is in this range minus 3 to minus 4, the hydraulic gradient should be maximum 2 or if it is minus 7, clay 30 hydraulic gradient could be 30, but it should not be more, you know, what happens as I just mentioned internal erosion of the soil particles takes place, and it leads to wrong values, like k values will be totally, you know, sample would have failed, because internal erosion, means, internal shear resistance is lost, there will be particles will be floating under the water, and you measure permeability, and it will be very high value, it will be misleading, it is not a equilibrium condition.

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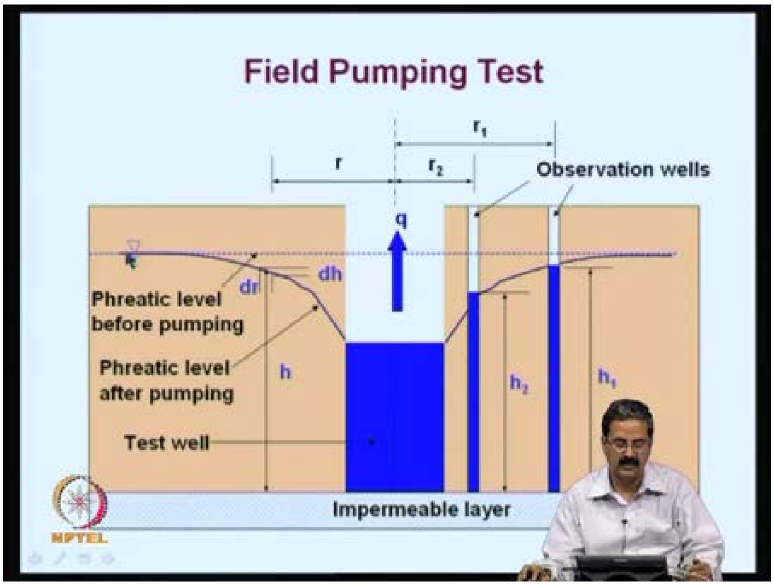

So, that is a reason, you go for field testing, and the way that we do the field testing was that is, that like you have two observatory wells and this original water table, and you try to lower the water table, and h 1, h 2 are the observed values at a particular intervals of time, and this observation wells are at distances r 1 and r 2, and so, what happens, because of this, you try to measure periodically and there is a drawdown that occurs.

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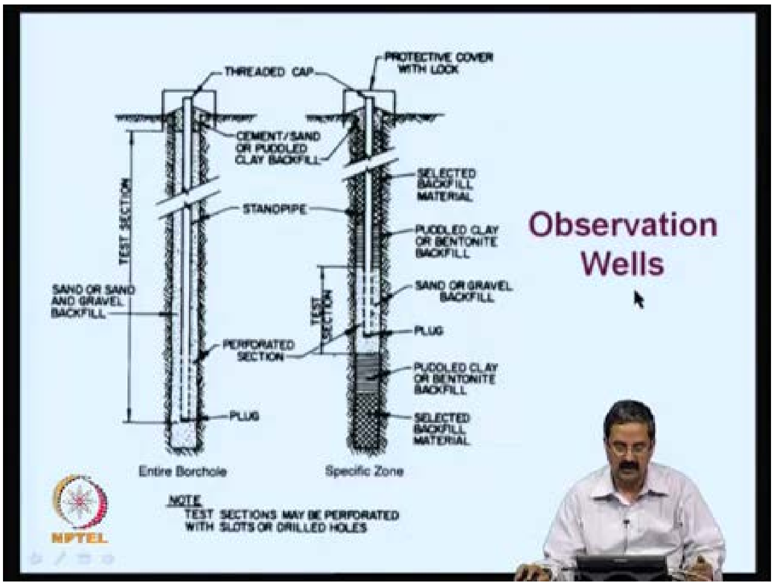

So, how do you do this, of course, you have some sort of observation wells, how do you do this in practice is something, that one should know, you have, like you have a pipe here, you have a threaded cap, and all that, and sealed you have a, you know proper system puddle clay or a Bentonite like. Actually this area, the water level, you know, it should be in a water, it should be allowable permeable, you know, you can see that it is slotted; here also you can see that, the top the bottom portion is slotted and there is a plug.

So, waters enters here or you know whatever is that, you know there should be a provision for water flow, so that, you are pumping out, you are the, you are removing the water from that, and then this will measure the actually levels. So, this is an important point in the observation levels; this is actually a standpipe, the standpipes with slots at the bottom portion or wherever.

In the, if this is, the, if the area is here, wherever you place, if this area is permeable, then have the slots there, see that the slotted area is in the permeable data, like sand and gravel back, all that is there, and all that.

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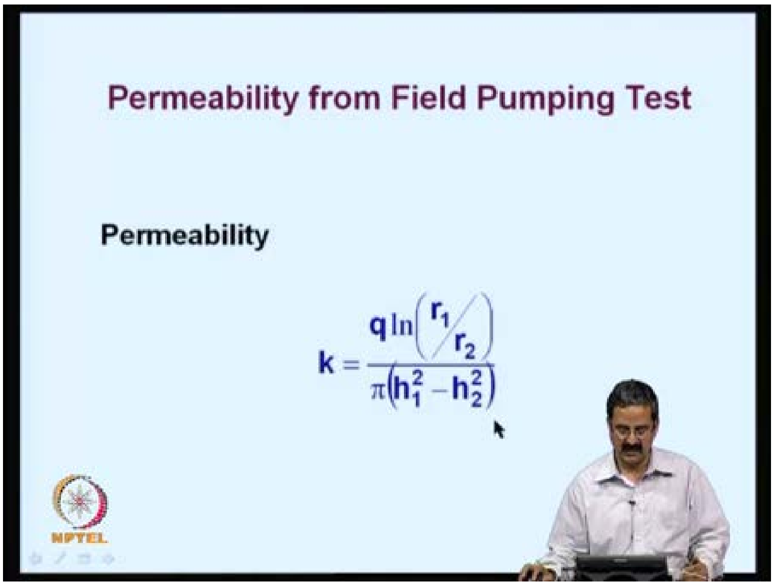

So, these are all some sort of expressions that one can use, like you know, the discharge measured, and then r 1, r 2 are the radius, and then h 1, h 2 are the heights, the heads.

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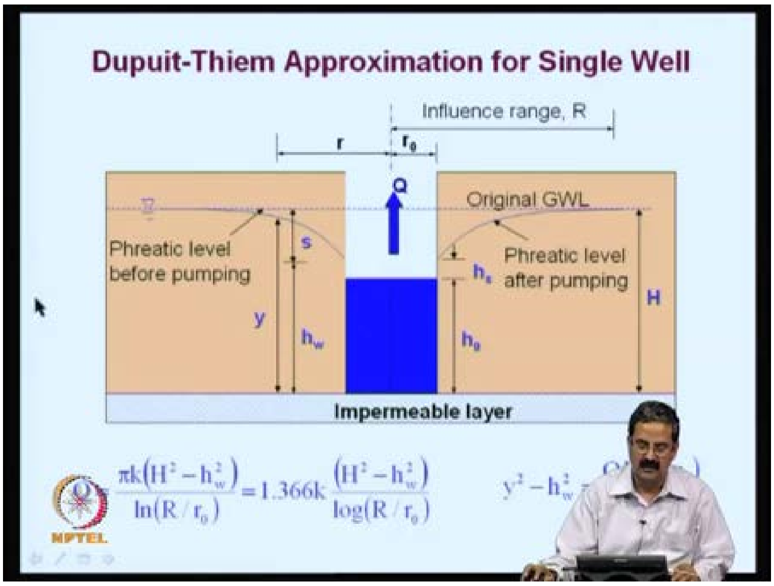

So, of course, there are many equations, that people have developed, like this is a one you know Dupuit-Thiem approximation for single well phreatic line, how it changes. Actually this one thing is that, here h is this, what we saw was at any point, but this h is related to this, where this head, at which, you know, this is actually the depth, actual depth of the water table .

So, this is another expression that we have, where we have, so that way r naught is related to that, like influence range we call it r divided by r naught is the radius, h is the height, and the h w is the water drop at any point, and using this expression, one can calculate q, and once you normally measure this q value, and once you know the q value, you can get k. So, there is another expression for the height of free discharge surface, there is some sort of equations that people have proposed, and how do you get this influence range, some expressions are available r equal to like influence, that radius is in this form, and depending on the k values, and the height of drop, and this is another important thing, that I would like to just tell, and then close today with this lecture.

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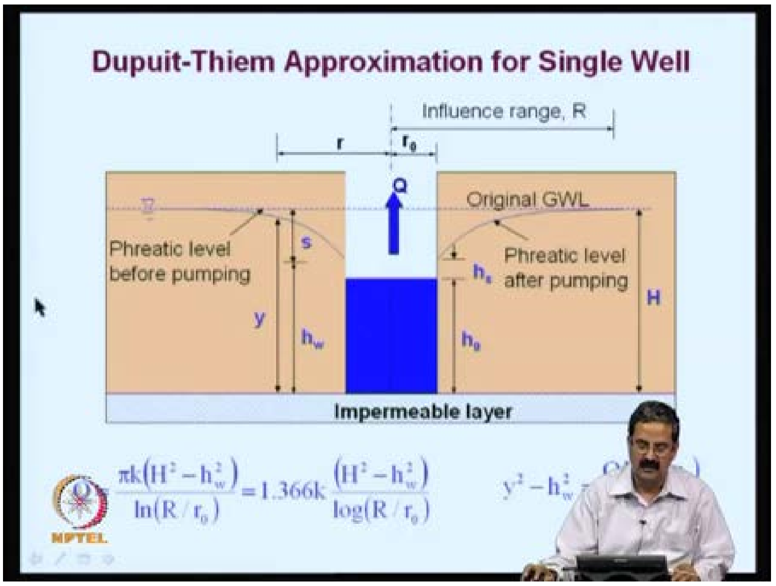

Actually as I said well points, well 1, well 2, well 3, there are three wells, and then, this point p at which water is to be removed, and then their distances situated distance are h 1, x 1, x 2, x 3.

So, our objective is you know most of the time, say for example, this is an underground basement, you know, some place, you would like to excavate remove water, you know, how much of water is to be there; so, you have to design well points, properly with the distances, and you have an expression for it, p i k into H square minus y square by L n r minus 1 by n, n is a number of points into L n x1, x 2, x n, and then circular arrangement of wells.

Suppose you know this is one arrangement that you have, actually this is a special case and if all the x 1, x 2, x 3 all are equal, and then you can use this expression, where a is a radius, suppose you are trying to have a circular area or a rectangular square area, and all that, you can just use a some sort of well points everywhere. And measure them, and then see that you are discharging is in such a way, that, that y whatever is the y, you know, y is you are trying to monitor this y, y and all that, and see that you are able to design with well points proper system, and you have a multi wells here.

So, with this I think you are able to understand, what is this dewatering systems, and actually, see the dewatering is an issue, and this is what we say you know, like as I just mentioning that you have mechanical modification, you have a hydraulic modification, means, you are trying to remove water, by removing water you are increasing the strength of the soil.

And PVDs is one type, where you try to remove the soil, accelerate the consolidation, and then design it properly, and then do that, that is one situation; in other cases, where you know, you have to do dewatering this is one case, where one can effectively do this using some proper concepts of permeability, and pressures, and some sort of design can be given. And again you know, one should really measure monitor this, like you know, we monitored settlements in pore pressures in the PVDs or sand drains, you have to measure, again here water levels, and see that, whatever is designed, even everything has to be monitored properly. So, with this I conclude thank you.