**Introduction to Civil Engineering Profession**

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**Lecture – 07**

| **Geotechnical Engineering** |
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Today we will discuss Geotechnical Engineering which will be our 7th lecture in this module. So, far we have introduced this term geotechnical engineering quite a number of occasions in this course I believe is not it and as you understood that this geotechnical engineering is the one that builds with what lies in it, what is the there below the structures, that can be anything, that can be a bridge, that can be a building, that can be a water treatment plant, you should have gone through, that can be a dam in hydraulic engineering for anything.

So, basically Geotechnical Engineering comes as a part and parcel of all other branches of civil engineering because everything has to stand something on it. So, that is where the geotechnical engineering's importance come into the picture.

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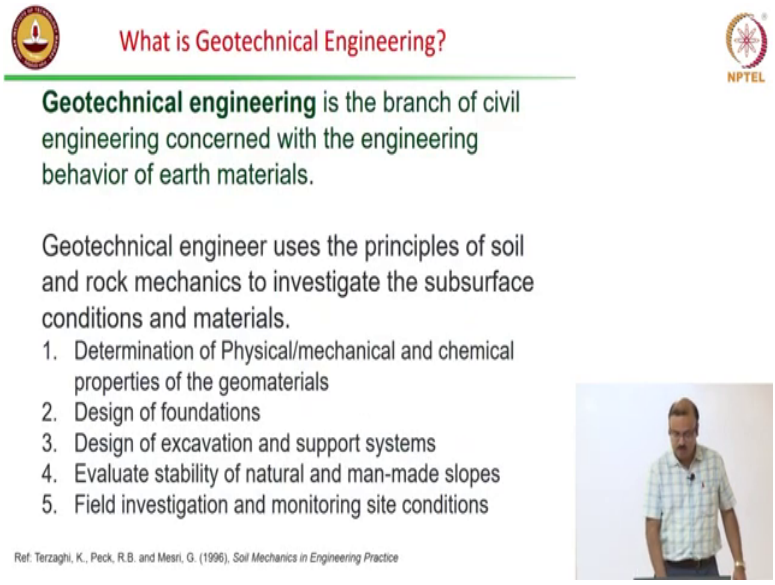


Now, what is geotechnical engineering? Geotechnical engineering is the branch of civil engineering concerned with engineering behavior of earth materials that is the key word here. So, what is available naturally in ground, what forms the top part of the earth on top of the crust, we are generally worried about that because that is where the load of the structure will be transmitted because this building let us say it is standing on ground right. So, who is taking the load? The load is going to the below the foundation and to the finally, to the mother earth. So, we kind of worried about the behavior of this earth natural earth material which is finally, kind of taking the load from the structures.

So, geotechnical engineer uses the principles of soil and rock mechanics to investigate the subsurface conditions and materials. So, what is their rule? Number 1, determination of physical and chemical properties of geomaterials, very important. So, what are the properties the soil there, what are the properties, how do you characterize a soil, physically or

mechanically. In fact, it can we have a same physical property, but completely different chemical type of compositions.

Design of foundation of course, each of the we will discuss this in the subsequent slides also that the foundation; that means, each of the structure will have a certain structural material below ground which is been not been visible from the outside that is called foundation of the building, now how to design that foundation for different type of soil different type of building, different type of structures, as such.

Design of excavation support system you must have seen lot of excavations in the urban areas those who are from Chennai or any kind of metropolitan cities you see that we are doing lot of excavations and tunnelings for the metro railways all the cities major and semi major cities. So, for all these metro railways whenever it goes down below the roads or any kind of land you need to do a lot of excavation I mean you need to dig up the soil.

Now, how to stand do you think, a soil is a very soft material as such compared to concrete or steel. So, if you dig up say 10 meter or 15 meter definitely both side of the soil will try to collapse right, you cannot simply just dig up of course, you can dig up upto certain level beyond that the thing will collapse the cave will collapse.

So, how to support that, that is where the excavation and support systems comes into the picture. So, when you do the excavation there should be an engineering behind it, how do you register the collapsing of the soil, what are the depth is required or how much depth you can do safely without any support system, all these thing comes into the purview of the geotechnical engineers.

Next one number 3 is the like number 4 is the evaluate stability of natural and man-made slope, many of you have seen I mean one for your traveling to the any kind of hilly site right hilly terrains, hilly terrains how we do the kind of extend our road networks it is like that it is like a meandering path it will go like this right. It is a hairpin bends are there, some part you will see that the road are very narrow, some part suddenly it is a bit wider and then it is a very

challenging it is a because there is a gentle slope at the same time it is like a helical type of network.

Now, unless the slope the surface of the hill is stable how you are going to construct this road is not it, see if there is a continuous fall of rocks occurring, then nobody will be able to drive that road right. So, basically geotechnical engineers responsibility is to ensure that the slope of the hill which now naturally there. So, if it is naturally it is not safe then you have to do something you have to cut the slope, you have to kind of do some kind of engineering so that the slopes are stable in nature, it is not falling to the road.

Same thing applies for let us say landslides happens, see landslides there are various reasons for landslide, but as such like earthquakes is a natural phenomena you have to design your road or design your slope so that it can kind of resist. Even if there is a chances of taking I mean external agents external reason for the landslide the slope should be able to hold it up, but still there are maybe some landslides right we are seeing every time some rain happens or earthquake happens in hills there will be a landslide, there will be road blocks, all kind of stuff.

So, the geotechnical engineers responsibility also holds on there that how to kind of prevent continuous landslides to happen or two frequent landslides to happen and even if there is a certain region which is a landslide prone what are the precautionary measure you have to take, how to stabilize that slope that is all this thing comes into the picture.

Whenever you visit a hill you please now onwards you just please make a note of it, you will see many places the slope when is when you just watch out of windows of your car or of your bus you will say that some kind of treatment is done, I mean it is not natural there is no not much tree there and that particular section where we tied with some cables, there are certain maybe big bulk of the stones kind of mounted or can be a just a reinforced concrete. The simple resign be reason behind that is we are just doing something so that the slope will not collapse to the road.

Finally the very important thing the fifth one, the field investigation and monitoring the site conditions. So, all good things said and done once you have come out of the site general

tendency is to think that away this will be fine like we buy something. So, let us say we buy a laptop right, initially first few days we will be very careful do not touch anything. So, that everything is nice we do update regularly all those things, after 1- 2 years what will happen we taken for granted right we just simply use it without thinking it is health.

So, same thing stands for the all the geotechnical structures even more actually. So, we do something all we protected kind of slope, we have designed foundation with a marvelous accuracy and engineering sense, but unless you monitor continuously the performance then you may end up losing the design life.

So, let us say a particular tunnel our design for our design life of say 100 years, unless you continuously monitor that is there any water seepage going on inside, is there some part of the short critic; that means, the surface of the tunnel it is getting deteriorated. So, all this thing will tell you that what is the health, what is the condition, it is just like our health same thing, what is a condition of the tunnels or same thing applies for that bridge foundations or regular foundation.

So, there are certain level of electronics involved here because you have to continuously monitor with a certain type of sensors. So, you install those center sensors and then you get the data back in your office with nowadays data is not a problem. So, you continuously see that every 15 days let us say you just take a stock, how is the performance is going on. So, there are several types of sensors are available which is also purview of geotechnical engineers to maintain the power, battery, everything how do how do enhance the battery life of those kind of sensors, everything comes under the for certain areas of geotechnical engineering.

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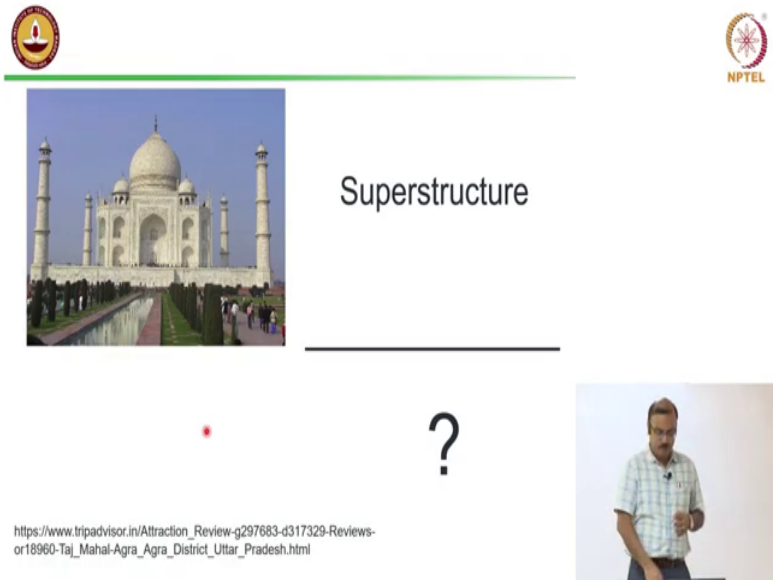


Now, everybody knows this right Taj Mahal right, it is one of the wonders of the world, but the problem is superstructure we all see, but what is there at the bottom, we have almost no clue until very several years. There are a lot of speculations, there are lots of old scriptures are there, that what is there how the foundation of the Taj Mahal.

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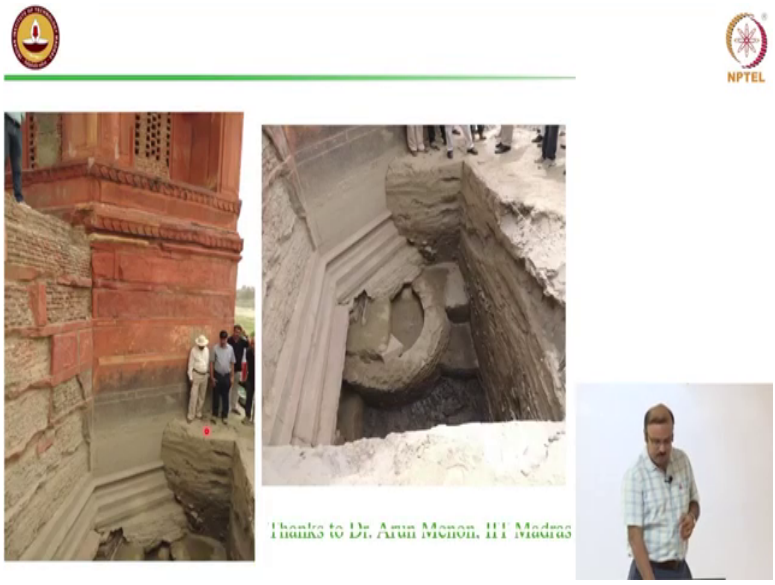


But finally, what happened is our part of our structural group Doctor Arun Menon he has given you lecture on architecture and the edited structure. There are archaeological survey of India part of the side of Taj Mahal kind of excavated and what we saw here is very interesting I am. So, this is the excavation we did and this is the base of the structure and this is what the foundation is, is this kind of oval type of shape, have you seen this? This is a oval.

So, this is a this is called a special type of foundation element is called oval foundation it is just like your regular ovals. So, it is below the Taj Mahal there was a scripture it is not that we are completely surprised to see this. There are earlier old scriptures which says that there is a oval foundation used in Taj Mahal below that.

So, it is a very interesting thing. So, these are the ovals there are some 100s of ovals are there below this structure and this inside these ovals it is filled up with some any kind of debris,

whatever debris is that time they have a level nearby there is a just dumped it some wood pieces, some tea tree trunks, all kind of stuff they dumped it do some little bit of compaction whatever possible in those days and they build the structure and it was so nicely standing.

So, there is no problem at all in the foundation or any kind of tilting of the superstructure. So, these are the very interesting fact without knowing foundation engineering itself people are doing that kind of wonders, because these are the these are coming from the practical sense.

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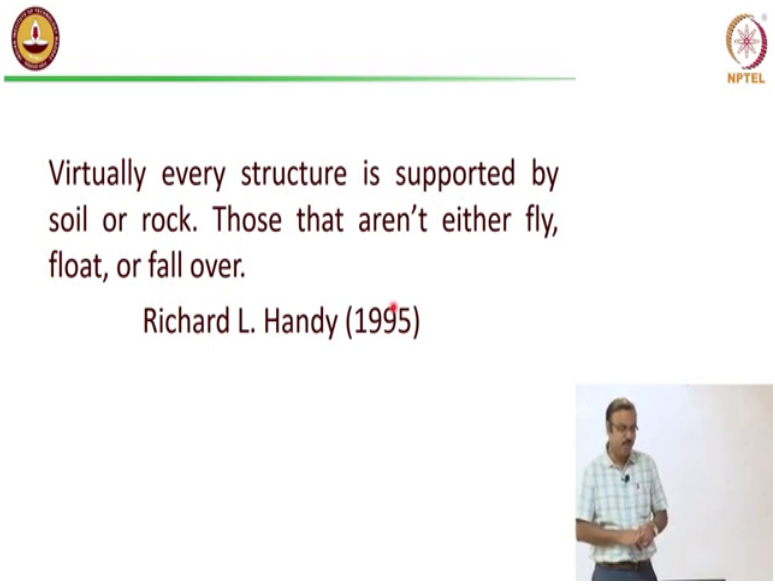


So, what does it say? So, Richard Handy says a very interesting comment that virtually every structure is supported by soil or rock those that are not either fly float or fall over, it is very very important it is a very cynical second line, but this actually tells the entire story, that everything there is a foundation it is without foundation it will never be able to stand ok.

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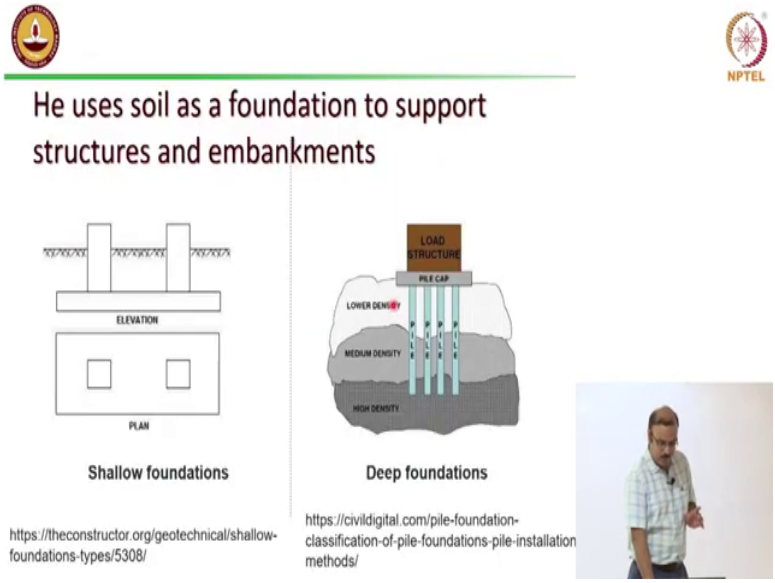

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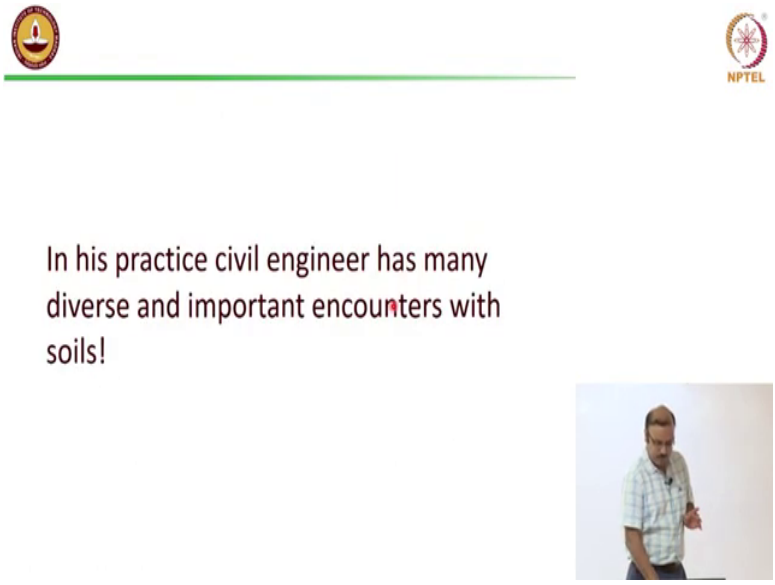


So, in it is practice civil engineer has many diverse and important encounters with soils. So, where as a civil engineer will, we will just go through the different situation, we have just started with the introduction part now you will see that where exactly what are the different challenges a geotechnical engineer will have, I mean as a passed civil engineer you will be handling.

First one of course, as I said there is a foundation, now there are foundations means there are two types of foundations generally available; one is called shallow foundation. Shallow foundation so, this is your superstructure very obvious and at shallower depth you have this slab in plan you will be something like this. So, this slab is nothing, but your foundation so, this one we call it shallow foundation. There are different types of shallow foundations

available isolated footings, combined footings, raft, different type, but one of the common feature of there is this depth of the foundation is kind of not in a very large value.

So, usually the criteria is the depth of foundation should be less than the width of the foundation. So, it is that is the thumb rule we specify for shallow foundation, but you can understand that shallow foundation is a one which is rest or which will transfer the load of the superstructure at shallower depth that is the idea. So, depth of foundation so, this is the ground here and this is the foundation. So, it is a very nominal depth compared to you see the size of the foundation, size of the foundation is quite big right. So, the dimension is quite large.

Now, this is fine, these type of foundation is I mean perfect and in fact, I would always prefer this because the cost is less construction and problem is less, but there is a but here, the but the soil surrounding this should be good enough to take that load is not it, see ultimately what is the purpose of foundation for where foundation is transferring the load, whatever load coming from the superstructure via this structural element it is transferring to the adjacent soil.

Now, if adjacent soil is very weak means what they will not able to take. So, what will happen, if you put a brick in let us say in a kind of a very muddy type of environment what will of it? That guy will settle is not it same thing will happen because why it is settling, because you are giving a foundation to a soil which is not capable of taking it. So, what they will do is, they will say no I cannot take you try it below. So, inter structure will go down sink below that is what we are do you think that a building or a bridge which is settling you will be very comfortable to stay there, no right. So, one of the major serviceability requirement for any structure is the settlement has to be in a certain nominal zone. There are codes for it that how much settlement is allowed and all this thing, but generally you do not feel comfortable if something is settling every day is not it.

Now, in those kind of situation what you have to do? The foundation by sinking itself gave you an hint that there is a soil, it is not that the soil is bad there is a soil which is slightly below than that area which can take that load. So, that is why I am sinking up to certain level. So,

what you have to do is, simply you have to transfer the load to a deeper depth. So, that is what that term deep foundation comes into the picture.

So, now there is this is a structure maybe heavily loaded structure then there is a piles these members are like your columns. It will transfer the load to a much greater soil which is having very high density maybe the rock itself we will can transfer the load. It is very similar to your stools piles are very similar to your stools which we see it. So, you sit on top of the some kind of platform right if there is no leg what will happen you and the platform both will collapse. So, there are 4 legs to the platform.

So, this legs what they are doing, your load which is resting on that platform on top getting transferred through those 4 legs to a ground which can take that load is not it. So, those 4 legs in geotechnical engineering is it is just a deep foundations or piles, there are many types of deep foundations one of the most common one is piles.

So, wherever the soil is good at much lower depth to reduce the settlement of the structure we generally transfer the load to that competent soil layer. So, this is a keyword competent soil layer; that means, the layer is competent enough to take the load of the superstructure. So, that is what deep foundation will be doing.

Now, this is a first job that design of foundations whether it is shallow or whether it is deep, how to design, what should be the depth, what will be the size of piles, like you have stools like 4 legs stool you can sit it is safe, but it is elephant is sitting means it may break right. So, you have to design a stool, design those legs based on the loading. So, that is what the size and shape and the depth of the piles everything will be determined by the geotechnical engineer.

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Now, very important this is in fact, you know need to know anything that civil engineer uses soil as a construction material how many years we are doing this I do not know ancient itself we have the mud houses is not it, they said is the mud houses very standard everywhere now still there in the villages is not it and these are technically it is a simple, but it is kind of sustainable we are seeing that.

Now, the more importantly the soil can be used as the embankment material like you see this is constructed by the soil only. So, this side the water so, what is the purpose of this, this may be the flowing river. So, this embankment what we will do is, even at the raise height of the water they this embankment will protect so that the water will not flood in this agricultural field, well.

There may be cases that the rise of water beyond the depth of it is I mean the height of the embankment that time it will flow, but that is extreme situation, but in general under what we do is, under high flood situation what should be the height of the water, we keep some 1.5 to 2 meter on top of that and we create the embankment based on the soil.

Now, there will be of course, certain properties of the soil that will be evaluated to choose the material not all the soil whatever soil available locally you can use it. There are certain characteristics of the soil is required to create to be selected as a good embankment material, but this is where another major infrastructure day to day life of the people will be kind of involved is not it this is a everywhere we see this we call it earthen embankments.

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Now, as I said the excavation and support system you see this is the excavation what I am saying this is a typical metro rail or similar type of excavation site and you see the depth of the

excavation is a ground is somewhere here actually, the depth of the excavation is maybe sometimes it is a 3 storey building. So, 3 storey building means it can be about 10 meter height minimum. So, 10 meter to 12 meter to 15 meter 20 meter thirty meter excavation also there, if you have a very deep basement or certain activities like you have a metro station which is the below ground.

So, in that kind of situation what you have to do? See if you do not put this walls so, these are this may be different types of retaining wall the term retaining wall suggest that it will retain the soil in place, soil means the soil in the backside. So, if this wall is not there what will happen? The soil from the backside will start caving in the excavation zone, you may think what is the problem ok.

It may cave in then I may remove it after sometimes then again continue, no if the soil surrounding caving in what about the surrounding structures, they are already existing right they are I mean you it is like you are standing and below your ground is going. So, what will happen to the building? They will definitely will collapse tilt or damage or cracked and then what will happen the owner of the building will put a case against this work is not it. So, everything is stopped so, these are very critical things.

So, geotechnical engineers job is to ensure two things here; one is you have to have a safe working environment here. So, that the people who are working will not get buried by the soil collapse, at the same time you have to ensure that nearby or adjacent structures should be list or no damage by the your excavation is not it. So, there are two major responsibilities and it is a lot of lot of money involved.

Secondly, second side is these excavations for the tunnel you see these tunnels are going through this ground, it can be a rock tunnels; that means, tunnel that process the hills or it can be a simple tunnels in the in soil like in Chennai many places we have the metro rails going through the tunnels and those tunnels are not through the rock it is just simply in the soil.

So, there are certain machines which can dig the tunnel in rock, there are certain machines it is like your drill machine in a mega scale which can drill that is clay, which can drill the sand or

which can drill that rock, depending on the soil you have to choose the machine, because they are also important selection of the exact tool otherwise you will be end up in nowhere right your work will be delayed. So, based on that soil characteristic physical behavior or mechanical behavior you have to choose your type of equipment to be used ok.

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Then that soil can be encountered those whatever we discussed now is a kind of a standard thing you can have a foundation, you can have excavation, you can have embankments and all those things, but there are certain cases where you may encounter soil in some very very specialized or sudden severe situation one of them is let us say it is someplace earthquake happened, what will happen?

If there is a earthquake happen usually there are two phenomena very very common; one is called liquefaction, another is called sand boil. So, it is something like this you shake it the

ground will be shaking right earthquake means ground shaking right ground will be shaking, what will happen? The topsoil if it is certain characteristic it is not so favorable what will happen that, topsoil will behave like a water that is not it is like a liquid.

Now, we all know that liquid has shear strength of 0 right liquid cannot take any shear water cannot take any shear so, that is simply thing it happened. Now, what will happen? The building is standing now like this very safe very nice we are having class here then bottom it is started shaking. So, the foundation and adjacent the soil because of the shaking because of certain property of the soil become almost liquid. So, what will happen? This guy will fall that is what happened this building, you see this building just tilted back this happened in Japan in Niigata earthquake one of the severe earthquake happened and it is collapsed all the building got tilted because of this.

So, it is an instantaneous phenomena it is not that the soil adjacent to the foundation will be forever like liquid, it is for a instance it will just like a liquid, but to kind of tilt a building for a instance of that kind of a loss of strength is good enough. So, that is what happened to this structure. Now, even if there is no structure in the in just regular road highways or something it there is a chance that with this there may be some kind of fountain type of behavior generates.

So, the bottom soil as the top soil now it is almost liquid bottom soil will start floating and coming like a boiling type of situation will occur. So, it will happen? These are the thing very common happened in Bhuj earthquake in 2001 in Gujarat these are the these are very very common features.

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Another major catastrophe is the piping. What do you mean by piping? Just now we said the embankments right. So, this is the embankment and this is the storage reservoir, this is the water stored. It can be for agriculture, can be for drinking, can be for any industrial application something is a big reservoir, but due to certain reasons certain failure certain lack of monitoring that is what I say the monitor is so important, lack of monitoring what will happen is, there will be certain problem in this downstream side. So, this is your off stream side where the water is stored, in downstream side a situation come something that water from this side forms a like pipe below this embankment and it is coming up here.

So, this water is basically coming from the reservoir itself, you may say that is a little bit of water coming what is the problem, it is not that amount matters. First thing is that small amount of what the years may cause a substantial loss of water from the reservoir. At the same

time what is doing here is, while going through below the dam what will happen that part of the dam material it will get washed away of the water.

So, finally, what will happen is this part of dam will become extremely weak and this zone will become critical in geotechnical term we call it is a critical hydraulic gradient has been reached; that means, there is a flow occurring and the flow is such that the ground is not able to contain that flow. So, the flow is coming up this water and form a nice stream. So, that is two problem occurs from that one is you will be losing water from the reservoir, at the same time your dam itself inside it is becoming weak because it is getting washed away everyday ok. So, this is another challenging situation where geotechnical engineers interventions we require.

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Now, finally, there is one more very important thing is called expansive soil. So, there are certain type of soil which has a very bad affinity for water so; that means, in rainy season when

ground is completely wet they will absorb the water. Now, while absorbing the water what will happen? Their volume will increase is not it, it is the simple common sense right. If you have a loss of soil you pull pour some water the volume will increase because they will observe it that is fine.

Now, next time monsoon is over now it is a bright sunshine and all those thing rises in what will happen? They will expel the water very fast. Now, while expelling the water what will happen? The volume of the water will volume of the soil will reduce right, it is a kind of a shrink it will shrink to a small volume.

Now, consider a structure is standing like this a below a soil is doing this kind of thing, it is rainy season heating absorbing water increasing the volume and the dry season it is expelling the water and kind of shrinking. What will happen? This guy this building below when volume got increase of the soil will have a uplift type of pressure it is an upward force and then next time when that after 6 months it is a completely dry season in the summer it is getting shrinked, what will happen this guy again will go back to it is original situation.

So, there are situation where the buildings may not be able to take this expansion and the contraction of the soil which may end up with getting cracks in the buildings like typical cracks in the buildings is like this and more importantly in India we got major problem in the road sectors. See buildings still can be manageable small cracks it is you the residents will take care if it is a small crack immediately they will do something, but kilometers long highways and enter our Telangana or middle plateau Deccan plateau is full of this type of soil. So, we are getting every time lot of problems of the cracking in the pavement due to the expansive nature of the foundation soil.

The soil below it is same thing happened right the soil below pavement will expand and contract regularly, what will happen? There will be a enforcing stress induced to the bitumen layer the top layer. So, definitely it will try to open up depending on the extensiveness of this volume change. So, this is called swelling and shrinkage in nature of the soil it is a key word is swelling and shrinkage nature. So, the soil will swell and shrink depending on the amount of

water going inside the soil and this is very very dangerous particularly for lightly loaded structure.

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This one is from Chennai you see this is called subsidence or collapse this happened in 2017 I believe it is taken from the newspaper itself, you see that this is the one of the major road in Chennai where the below the metro rail works was going on and what will happen? Due to certain activities or metro rail metro tunnel dealing drilling there is a certain subsidence of the road happened and then this car and the bus got all caved in.

So, these are the situation also geotechnical engineers will be called and they have to run around and see what are the reason behind that, what should be the precautionary, because that that the issue about those geotechnical engineering is you cannot simply say no we should not do the tunnel, tunnels to be done right because you have to run the metro, but at the same

time you will not be able to say that let the bus collapse no right so, you have to manage both side.

So, you have to design your tunneling methodology in a way that it will have a minimal disturbance to the road in top. So, this is the real challenge, because soil every part will be different along the long stretch of the road. So, you have to have a proper identification of the soil, what type of soil now you are digging, what kind of precaution now you are taking. So, again continuous monitoring will be the important the key issue here.

So, all around we should have a continuous monitoring to see is there as gradual because this may seems gradual sudden, but this kind of thing will happen in gradually it is not just that one day collapse like that, over the years there will be a settlement going on over the months at least. So, you have to have a telltale sign that again see there is a settlement is going on it may be excessive. So, you do some necessary precautionary measure that is what the geotechnical engineer's job also.

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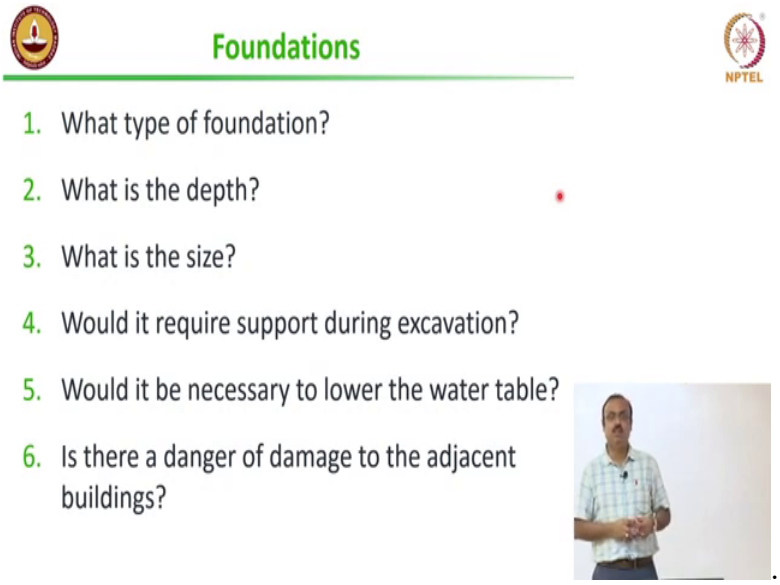


So, now foundation let us because you see of all set done you will be 50 percent of the geotechnical engineers job will be related to something to the foundation. So, let us look at in a bit detail in the foundation part. So, we have to decide what type of foundation? What is the depth? What is the size? What would it is require support during excavation? That means, while you are constructing the foundation whether you need the surrounding sub support the soil so, that again safety of your people who are working there, at the same time safety of the adjacent structure to ensure.

Would it necessary to lower the groundwater table? That means, grounded, but let us say in all the coastal cities ground water table is almost at the surface level right. And what will happen if you dig up a soil water will start flowing in, if water flows in means it is not only inconvenience to the people who are working at the same time you will have the machineries electrical lines which will be getting affected. So, you need to lower the groundwater table in

the vicinity of the work site and then you do the work, after that you recharge it after the work is over you just let the groundwater table come back to it is original level.

So, whether it is necessary to do that, is there a danger of damage to the adjacent buildings? With all these all the work activities are you disturbing the nearby structure of the resident, you may have a pile like you have seen in the foundation pile. So, when pile is getting installed there is a method we have to drive it so, there may be a noise coming to the building. So, nearby residents may complain that it is like a hammering sound, it is a day and night there will be hammer. So, these are the practical challenges what geotechnical engineer also has to face.

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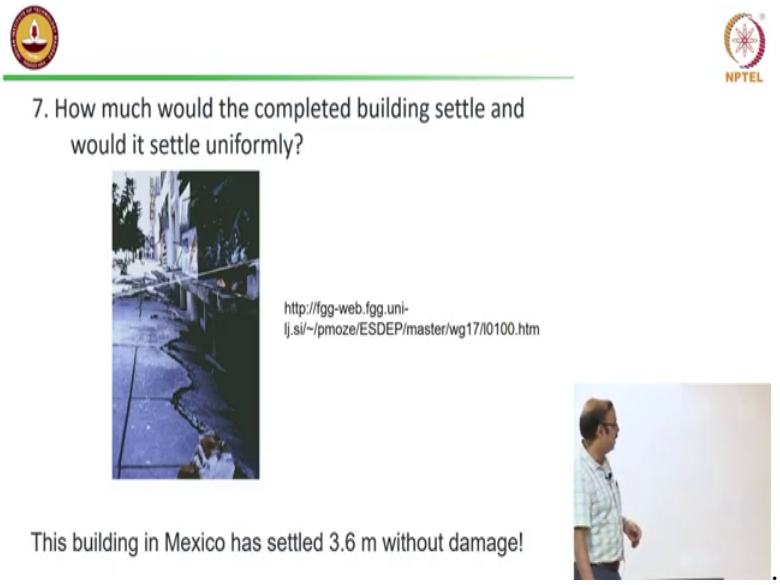


So, this is a building see it is almost 3.6 meter settled. So, the road is something here the road is actually here the road level, now the building level went down like this. So, almost 3 meter it is almost one floor more than a floor it is got the floor supposed to be that the bottom of the

willing supposed to be at this level, but it went down inside because of the that is what I said that foundation is not capable enough to take the settlement.

Now, the problem here is why I am showing this thing is there are settlements which may not be that bad in looking; that means, entire building is settling in same level. What will happen? Maximum thing is your ground floor height will be reduced or most of the time now we have the ground floors or car parks. So, your car parks depth is little bit of reduce, but as a structurally there will be no damage to the building because everything settle uniformly, instead of some level it is just went down to say 100 m m.

Now, uniform settlement will not be a problem structurally, but the problem is there a pipeline going down below. So, let us say there is a sewerage pipeline or water supplying pipeline the buildings are 100 m m means all the pipe will get broken right, connections cannot take particularly if it is a concrete pipe or something the connections will not be able to take that kind of pulling or pushing effect is not it.

So, it is not just the structurally you have to think by utility point of view also, are we touching; are you touching something to the optical fiber lines going below the building. Are we doing any harm to the electrical lines or sockets, are you doing anything to your safety tank or reservoir water reservoirs within the building within your property. So, all this thing comes into the picture. So, it is not just a settlement it is like settlement will cause are not only the main building it can cause the problem to the associated structures or utility lines as well. So, that is what the problem.

Now, if it is does not settle no uniformly, then that is even more problem; that means, one part is not settling other part is settling what will happen. The thing we tilt it may break the beams and columns because beams and columns will not be able to take that additional disturbances of the moments coming.

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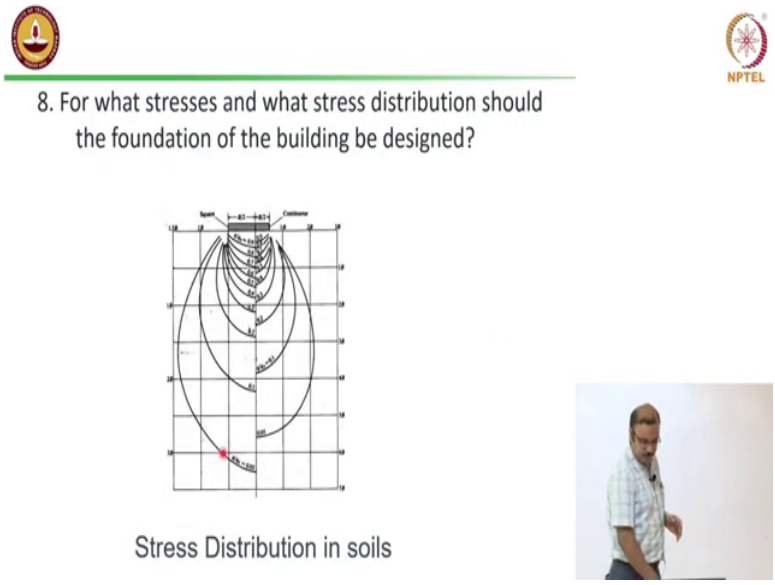


So, how we analyze the stresses below a foundation? So, stresses below I said let us say this is our foundation, stresses below foundation is like the building load is coming on top, it will be distributed over certain zone. Let us say I have a 100 meter depth of soil and you have a foundation like this, do you think that 100 meter below this building will be stressed? No, right there are after certain time after certain depth there may not be any load coming from the building.

So, what is the zone below the foundation which will be active; that means, which will be stressed? Obviously, at the below here it will be maximum stressed. As you go down for the deep your intensity of the stress is getting reduced and beyond certain depth it can be negligible. So, that is where it is called pressure valve below the foundation. So, it is a very

important term it is called pressure valve. So, pressure valve below the foundation is a zone where due to the foundation load the stress will be of significant in nature.

So, whatever the settlement occurs another thing will be the settlement or compressibility nature of the soil within this pressure valve. So, the soil within this pressure valve will compress we will get reduce in thickness.

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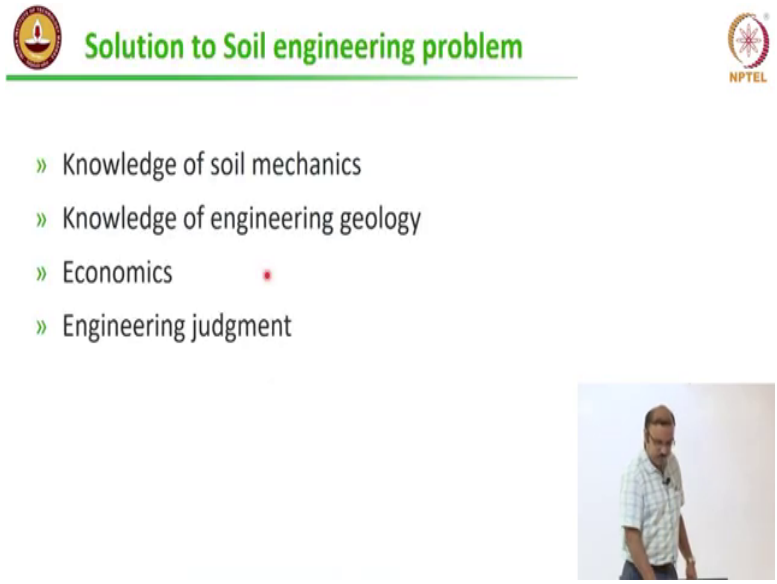


So, solution to the soil engineering problem you need to have a soil mechanics, engineering, geology, economics, engineering judgment, we have seen in the earlier classes also.

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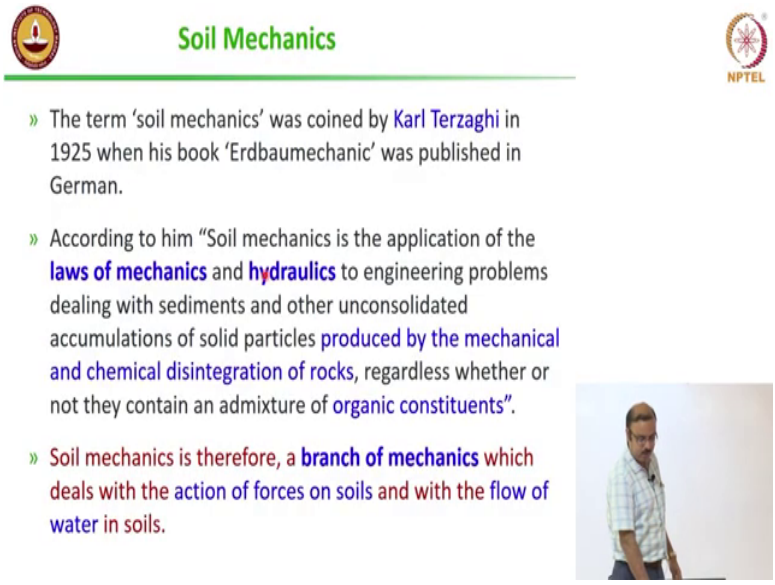


The term soil mechanics was coined by a professor Karl Terzaghi in 1925 in his book written in German he is considered the father of geotechnical engineering Karl Terzagh.i Soil mechanics, he says according to him soil mechanics is the application of the laws of mechanics and hydraulics to engineering problems dealing with sediments and other unconsolidated accumulation of solid particles produced by mechanical and chemical disintegration of the rocks. This is very important the soil mechanics term he is first used in technically. So, soil mechanics is the one that deals with the sediments, the sediments which is kind of form wider the weathering action of the rock.

So, soil mechanics is therefore, a branch of mechanics which deals with the action of forces on soils the importantly is the flow of water, because below you there is a water and soil mix up is not it there is a groundwater table also there.

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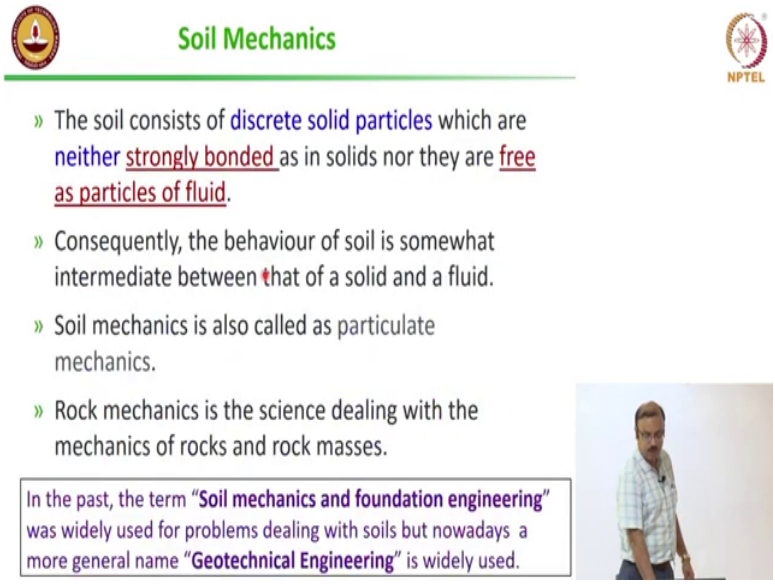


So, the that is where the problem comes because here the you see solid mechanics and soil mechanics is slightly different, solid mechanics you are talking about the fully solid material, but in soil mechanics or geotechnical engineering you are dealing with a material which is having solid, which is having liquid, at the same time which is having void space also, which is neither solid nor liquid is like a some kind of air in field.

So, always in soil mechanics are in a foundation engineer or civil geotechnical engineer deals with a situation where are 3 different phases always present, solid, liquid and the gaseous phase. Anytime you take a sample of the soil you will have the water, you will have the soil particles; that means, solid phase you will have the gaseous phase. So, that is the big challenge that is why some people who want to call it as a particulate mechanics.

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Now, Karl Terzaghi has famously commented this in 1951 that on account of the fact that no glory attach to the foundations, that the sources of success or failures are hidden deep in the ground, building foundations and always been treated as stepchildren and their acts of revenge for the lack of attention can be very very embarrassing. So, this is a classic comment Terzaghi make that most of the dying foundation engineers, civil engineers ignored the foundation, like I said that after some years we do not care about the laptops another thing, same thing we think that it is there and it is not visible in the naked eye.

So, that is how you kind of forget that there is a material there which is actually taking the load, whatever beautiful structure you constructed ultimately load will be going to the foundation to the below, unless we take care properly in the foundation it can be catastrophic in nature.

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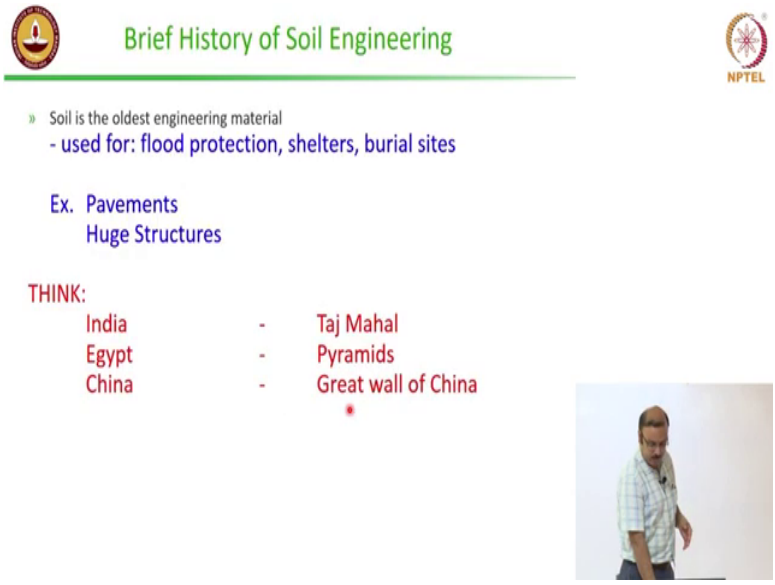


So, brief history of soil engineering we have used for many many structure historically you have India we have a Taj Mahal, Pyramids, Great Wall of China in China, all kind of marbles, but everything stands there is a serious involvement of geotechnical engineers up there.

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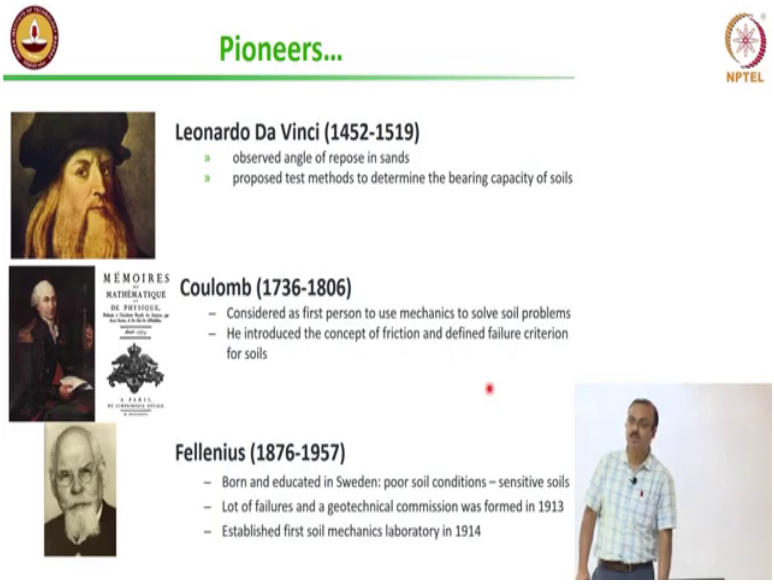


So, what the pioneers in the field? This is the famous person Leonardo Da Vinci although he is known for his some other works, but he is the one that first started analyzing the soil in mechanics away ah. So, he started he coined a term called angle of repose of sand; that means, without support how much what is the angle through which we will stack the sand, what should be the optimum angle beyond which the sand will start rolling off. So, he started a test method to understand the bearing capacity; bearing capacity means just now I said how much a soil can bear the load. So, that capacity how much is the resistance they can provide to the building. So, he started all this thing in a very interesting way.

Next one is the famous person another famous Coulomb he considered is the first use of in fact, he first designed some kind of geotechnical structures in terms of the embankments for the counter fort walls to fortify the certain forts in Caribbean and he is the one first he introduced the term friction and that changed the geotechnical engineering completely. He is a

he is the first used the term friction that the soil that strength of the soil is coming from predominantly from the frictional nature of the particles.

So, finally, this is Felonious is he is a more recent person I mean I would say that he is the one of the pioneer figure in our recent times, he is he born in educated in Scandinavian countries Sweden which is having traditionally very very poor soil condition where the soils are extremely weak in nature. So, we have to intervene I mean invent various methods to treat that to construct buildings, construct harbour and the port structures for this kind of thing. He is the one first created soil mechanics laboratory in history he is the fire on the creation of a laboratory for soil mechanics.

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Finally the Karl Terzaghi he is the father of soil mechanics he is born in prague he is actually interestingly as a mechanical engineer he understood that solid mechanics and then from that

he extended his knowledge of solid mechanics to soil mechanics. So, he kind of include the effect of gaseous phase and the liquid phase in the solid mechanics, all our major theories are developed by Karl Terzaghi.

So, he wrote this book and it is kind of still win practice we are still using this Karl Terzaghi and his students Radloff pick their book is the first book in soil mechanics.

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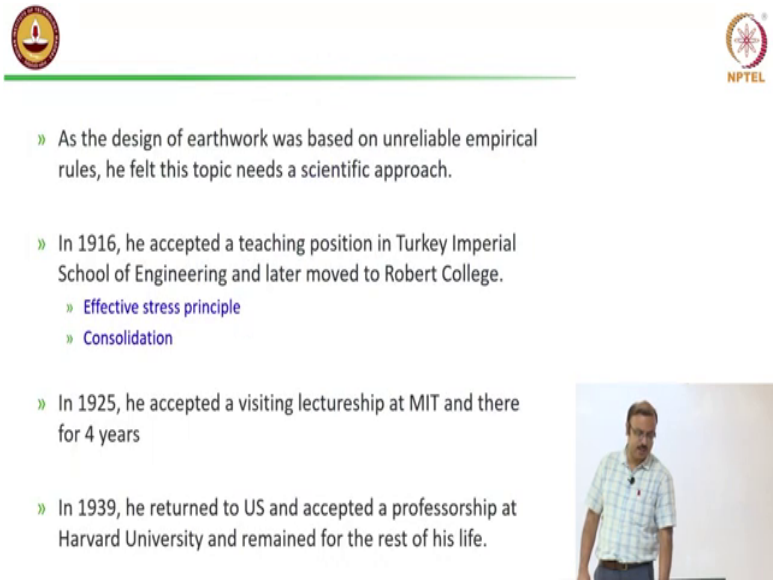


So, he felt why he as a mechanical engineer why he was interesting it is a very I mean very enlightened story, because he was doing something on the dam constructions in Europe and he understood that there are so many empirical equations the engineers are using, but without knowing the soil. So, they may be using empirical equation which can be valid for the rock, but they are implying it for the soil or vice versa, even within soil something can be for the

granular soil, something can be finer soil, but we are not knowing where we are I mean kind of applying those empirical equations.

So, from that he started understanding the soil he created his own small lab and he started testing different materials and from that he developed two major principles, one is called effective stress principle, another one is called consolidation theories. These two is the kind of pillar of soil mechanics these two theories, all our soil mechanics theories are actually stands on effective stress principle and consolidation theory. So, you as later become a faculty in Harvard University and MIT and he is kind of considered the started the journey of soil mechanics and foundation engineering as such ok.

Thank you.