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ADVANCED GEOTECHNICAL ENGINEERING

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Lecture No. 60
Advanced Geotechnical Engineering

Welcome to lecture series on Advanced Geotechnical Engineering offered by Indian Institute of Technology IIT, Bombay. This is I lecture which discusses about the entire course series which we have seen in seven modules and we try to look into the different areas which are there in the Geotechnical Engineering, and this course also has very well organized excellent material basically to create an impetus and also a knowledge towards the Geotechnical Engineering aspects.

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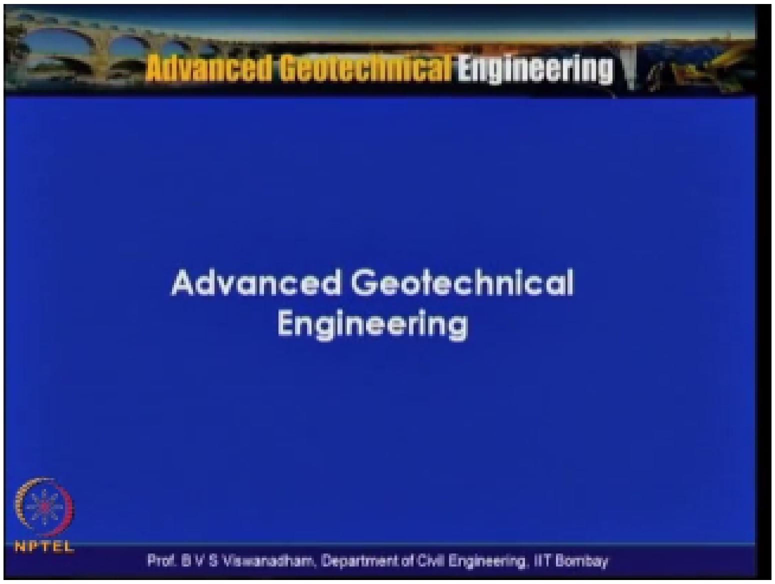

So this is the course on Advanced Geotechnical Engineering and this course actually has seven modules and in total about there are including this lecture there will be about total 60 lectures. In module one we have discussed soil composition and soil structure.

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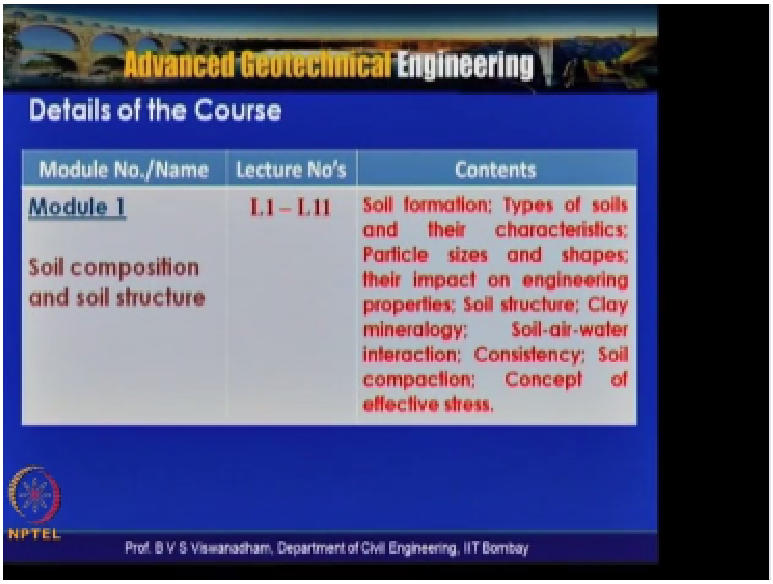

And basically we have tried to cover these lectures in length from L1 to L11 where they are the formation of the soil, types of soils and their characteristics were discussed. Particle sizes and shapes and their impact on engineering properties, soil structure that is the fabric arrangement soil fabric and clay mineralogy and soil, air, water interaction, consistency of a soil compaction and concept of effective stress were discussed under the module one. In this module we also have discussed about number of work examples and also solved number of problems which are pertinent to this module.

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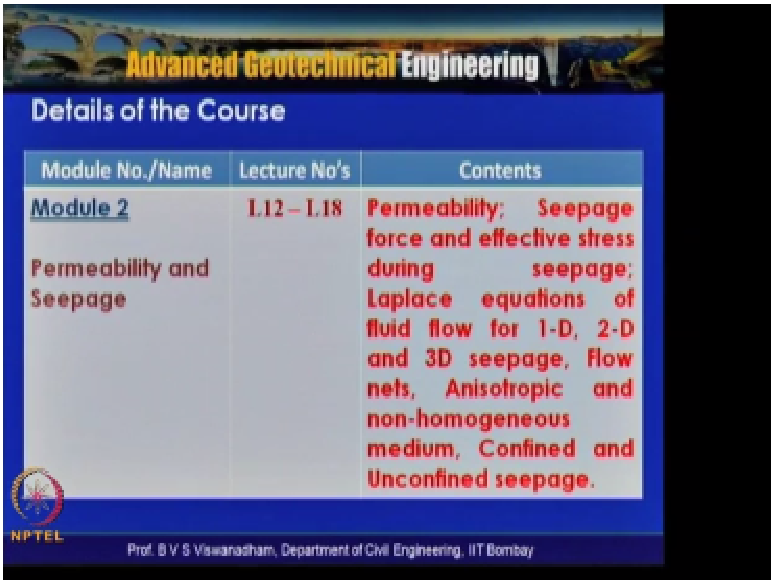

So in a module 2 we, the title of the module is permeability and seepage. In this module the lectures were covered from L12- L18 and the contents basically are a property of a soil permeability and the condition seepage were discussed in length. And seepage force and affective stress during seepage were discussed and Laplace equations of one dimensional and two dimensional conditions and inside for 3D seepage was given and flow net methods conventional as well as the methods by using the demonstration examples from the Geo studio 2012 using CW program were also shown.

And there also we discussed about Anisotropic and non-homogeneous conditions and confined and unconfined CPS conditions and in this module along with the theory the number of worked examples have been solved basically to give insight into this particular important module where the permeability and seepage are concerned.

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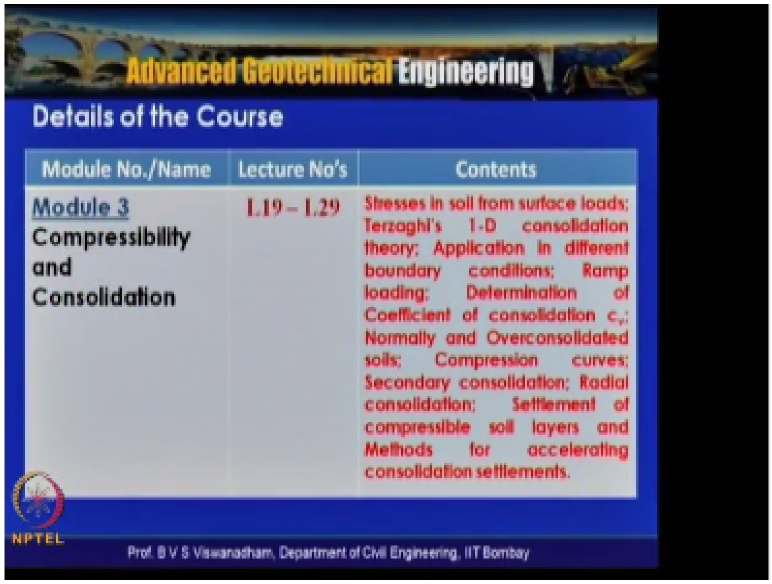

In module three the compressibility and consolidation particularly these lectures are covered from L19- L29 and wherein the stresses in soil from surface loads and Terzaghi's 1 dimensional consolidation theory and application in different boundary conditions and especially the conventional Terzaghi's theory is instant is loading, but incase of ramp loading how this can be done has been discussed and determination of the coefficient of consolidation particular.

And also we discussed about the normal and over consolidated normally and over consolidated soils and compression curves, secondary consolidation and radial consolidation and then we introduced to the Barans theory and then thereafter the settlements of the compressible soil here for 1 dimensional consolidation as well as considering the 1dimensional well as the radial consolidation was discussed.

And methods for accelerating consolidation settlement especially in this we discussed about preloading alone and preloading with sand rings and preloading with prefabricated vertical range and we also discussed about some novel methods like vacuum consolidation alone and vacuum consolidation along with prefabricated vertical range, and these methods were basically to give insight into the methods for accelerating consolidation settlements particularly in the soils which are actually soft in nature and when we require these excess pore water pressure to be dissipated in a short duration of time and this method was, this particular concepts are really, will be helpful.

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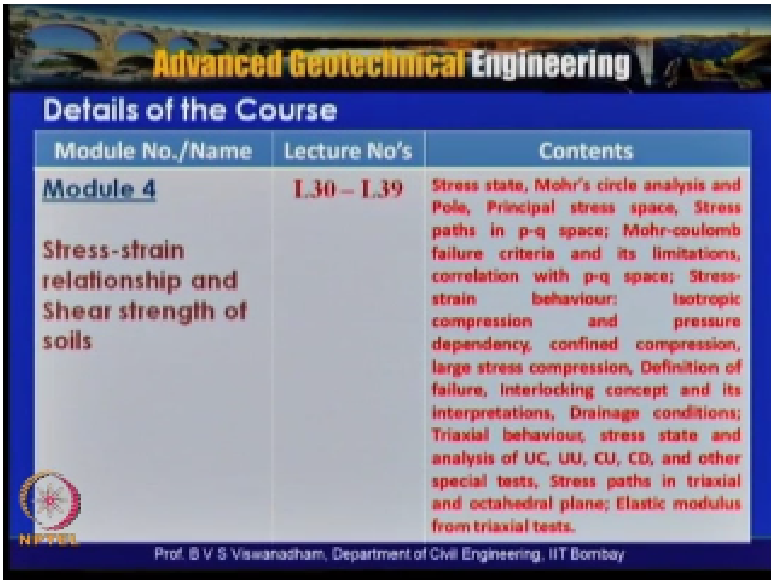

Then module 4 it deals with stress strain relationship and shear strength characteristic of soils and in this module the lectures are covered from L30 to L39 and basically the stress state was introduced and Mohr circle analysis particular pole and principle stress spaces were discussed in length stress paths in p- q space and Mohr column failure criteria and its limitations and correlation with p-q space and stress strain behaviour and Isotropic compression and pressure dependency and confined compression and large stress compressions, definition of failure.

And interlocking concept and its interpretations and drainage conditions especially with triaxial behaviour and connected with stress paths for unconsolidated un-drain and unconfined compression test and consolidate un-drain and consolidate drain test were discussed. And stress path in triaxial and octahedral plane were introduced and elastic modulus from the triaxial test, how to interpret elastic modulus from triaxial test were discussed and then we also have solved some couple of worked examples basically to give insight into this module which is on stress strain relationship and shear strength of soils.

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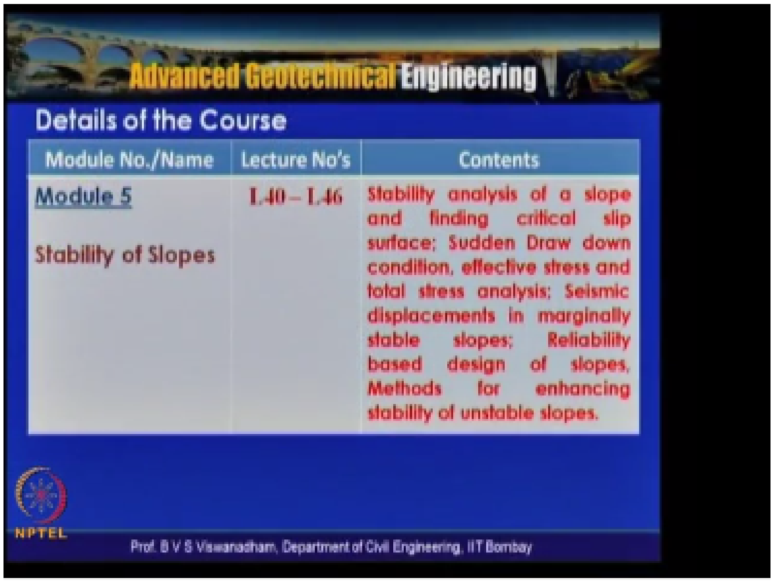

Further in module 5 the stability of slopes which is discussed in L40 to L46, that is lecture number 40 – 46, and in this the stability analysis of a slope and finding critical slip surfaces, sudden draw down condition and effective stress and total stress analysis and seismic displacements in marginally stable slopes and a concept or we can say a introduction to reliability based design of the slopes was, attempt was made and in depth discussion on the methods for enhancing the stability of unstable slopes.

This was actually discussed. Basically the methods like slope stabilization by piles and the reason methods like biotechnical stabilization and some methods like solution by soil needs and stabilization of a slope by piles, vertical piles. So these stabilization were discussed and basically this, how and what are the different methods of slope stability analysis methods and how these methods can be used for determining the factor safety of a given slope and what are the merits and demerits of different methods which are there in the, for analyzing the slope and also a detailed discussion on the enhancing the stability of unstable slope was covered.

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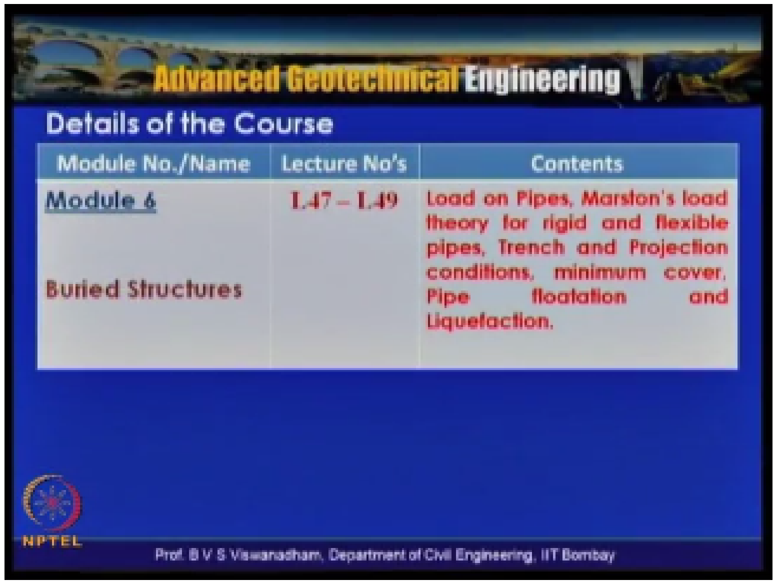

In module 6 a brief discussion on L47 – L49 that is three lectures which was made on buried structures. Basically here a load on pipes and Marshton's load theory for rigid and flexible pipes and trench and projection conditions were covered and minimum cover required and pipe floatation and also liquefaction issues were discussed. Interestingly a recent case study which actually happened in one of the power plant sites were actually discussed and how these situations, this type of failure situations can be averted was demonstrated through a Geo studio 2012 analysis as a case study example.

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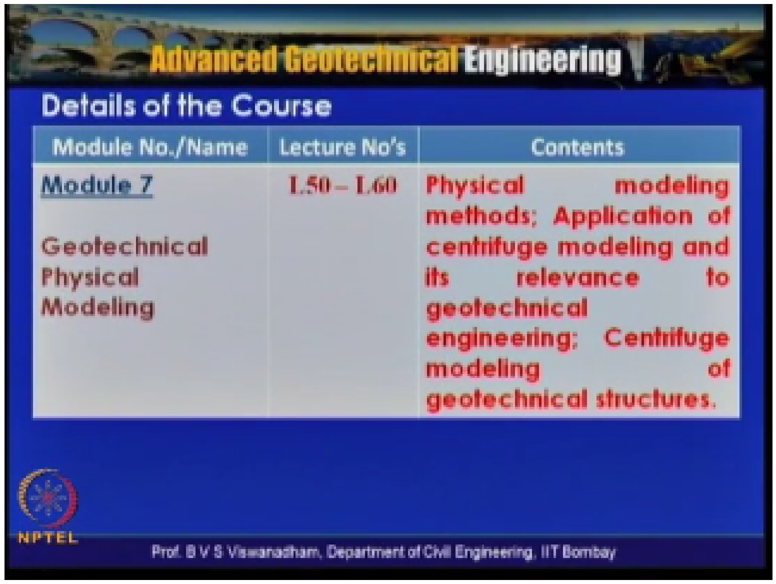

And module seven finally a detailed discussion on geotechnical physical modelling was discussed and wherein the, in principle the lectures run from L50 – L59 where all the aspects which are actually required for geotechnical physical modelling were discussed and wherein physical modelling methods, application of centrifuge modelling and its relevant to Geo technical engineering and centrifuge modelling of geotechnical structures with actual live examples of centrifuge based physical modelling which is activity which are being carried out at IIT Bombay are covered in length and then an also attempt also has been made to bring out the relevance of Geo technical based, centrifuge based Geo technical modelling for understanding the behaviour of Geo technical structures.

And for different examples like a slow stability problem and a bearing capacity problem and also like returning problem has been discussed and then the merits and demerits actually have been covered. So in this particular course as you all see the course is actually very much relevant and has got lot of prominence not only in India but also in many places and many parts of the world, and as far as the India is concerned where we have got varied soil deposits from North to South and East to West in India.

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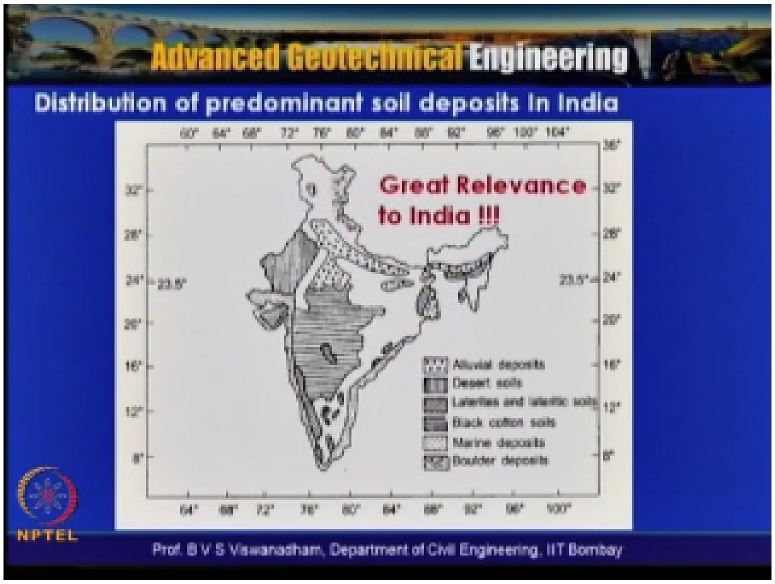

Particularly if you are looking to this we have annual deposits along the rivers and particularly where we have got what verbal's and then we have about 6,300 km of costal belt and wherein we have about the very soft soils, the marine deposits which are actually having normally consolidated soils throughout the costal belt are there and majority of the ports and harbor structures are major activities which are actually takes place, they are actually on this particular marine deposits, and then towards the Northern part of India where we have got the border deposits or silt tone areas which are actually there in Delhi and Uttar Pradesh and other parts of India.

And similarly towards the North East we actually have got the soils which are of the order of some sort of desert soils and also we have some laterite and lateritic soils and towards the Kerala or this side we have about the laterite soils again here in this part of the region and then we have got a huge chunk of the area which is actually covered with black cotton soil deposits which actually has got very typical behaviour of having the swell shrink behaviour, and then we also have out of this if you look into this there are many areas which are actually classified as vulnerable to earthquakes.

So the, particularly the relevance of the soil mechanics or geo technical engineering has got lot of prominence because some of the techniques which are actually adopted in one region may not be applicable in other parts of the country.

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So there are different challenges which are actually there like typical challenges in geo techniques, basically if you look into it we have the conditions of the roads particularly on expensive soil deposits in Madhya Pradesh and Maharashtra can cost lot of distress or recting and other failures and then with increasing in urbanization there is a possibility that the municipal solid waste generation actually takes place very rapidly and this actually has been projected that the generation of the soil waste is on the higher side in urban areas.

And on date unaccounted records it says that 10,000 tonnes per day is collected in places like Mumbai and similarly the storage of this waste if it is not proper there can be failures like this which actually can cause a situation which is very difficult to manage. And then we have got number of structures of, the long structures of the railway tracks running on weak formations and particularly with increase in need for increasing the speed of the trains there is a need for arriving at the proper track under laymen structures wherein one of the, some of the typical methods which are actually modern methods or novel methods which are required to be adopted so that the falling of the branch can be prevented and also the resistance which is required for the high speed train movement can be ensured by putting some sort of strengthening measure.

And similarly we can also think of also considering the scarcity of the natural materials one need to evaluate the materials which are actually can be substituted like railway amendments which can be constructed with fly ash or coal ash as a coal material or some reduction in the thickness of the aggregate if we are able to achieve then there is a possibility that the huge sharing's can be achieved. In addition to that particularly in elite terrain particularly where the trains run through this several cuttings and amendment sections.

There is a possibility that these during monsoons particularly because of the loss of the suction makes it actually to have reduced shear strength and this makes many slopes to fail and also have got, if these slopes have got huge rock boulders and there is a possibility that these leads to the dislocation of rock boulders and which leads to failure as well as some of the cases have been reported where in the, they end up in meeting with the targets which are actually nothing but the transportation vehicles.

And we also have some highway structures where actually because of the flash floods and because of the, some instability problems that can be unstable suctions can be avoid. So this is an example, some of the typical examples which actually show.

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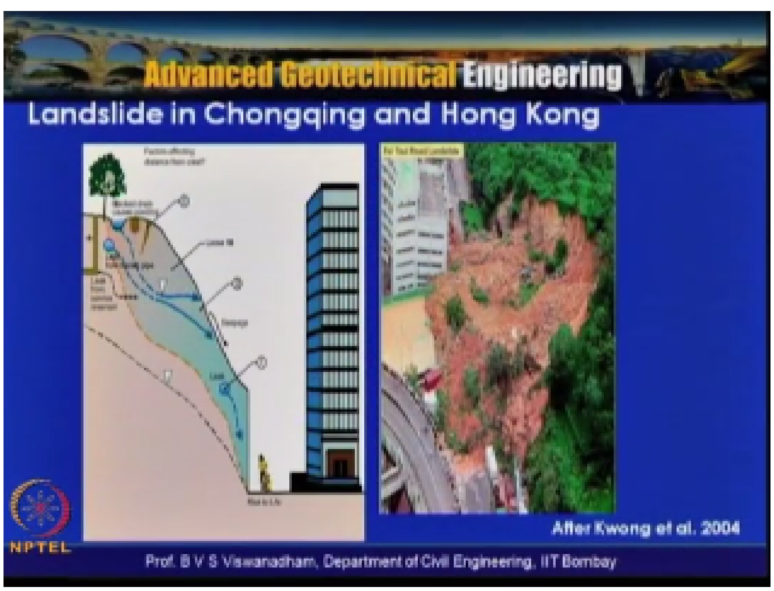

The requirement of some of the modules which are actually covered, so here it can be seen that a landslide in Hong Kong area where you can see that the area which is subjected to high range buildings and when it is subjected to groundwater table changes within the slope or if there is a burst pipeline that can actually create an instantaneous increase of seepage and can create an instability and which can be hazardous like the way it is actually shown here. So this can actually lead to a distress which actually can create the transportation infrastructure can get affected or also the surrounding or buildings which are actually very close can be badly affected.

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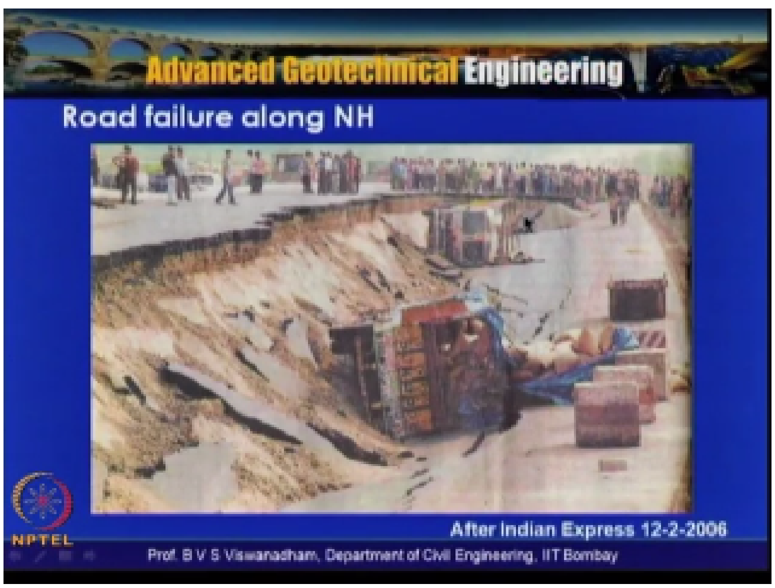

Similarly the construction on soft soil particularly where we have got a soft ground, if that soft ground is not treated properly and even if it is bund is constructed with proper quality control, but however this type of failures actually can happen. This is one of the case study which is actually reported in 2006 where red ferrous soil wall on a soft clay is subjected to failure because of the distress which is actually reported, a base failure which has been reported where 170m of section of wall subjected to failure.

So these type of things can be averted by proper understanding of the compressibility and consolidation here of a sub soil and then after adopting an appropriate method then a super structure that is actually wall can be constructed on that. This can have a better performance of a structure which can be constructed on such type of soils.

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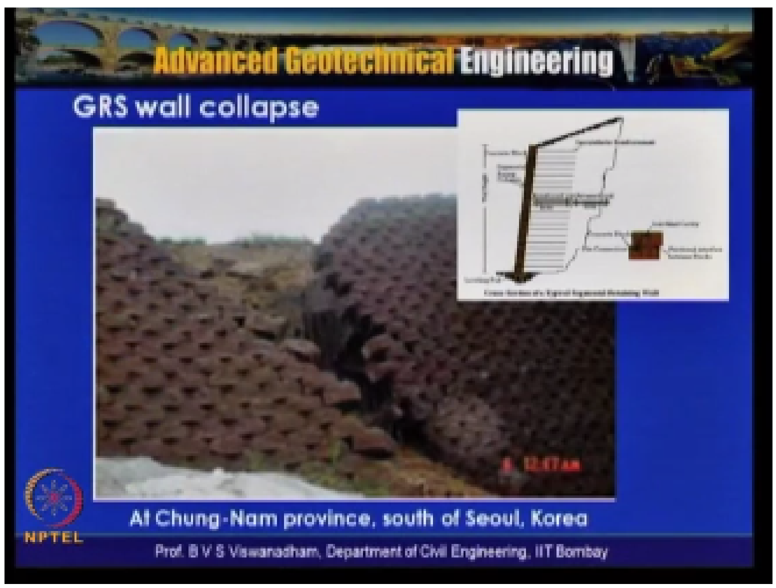

And this is a typical geo grid reinforcement soil wall failure at Seoul, Korea. This actually happened in 2004 after you at all in 2004 and here what actually has happened is that this is called reinforced soil wall, this is called in forces soil zone and this is called the back field zone, so here it is generally preferred that at least in the reinforced soil zone it is preferred that we need to have very highly preamble soil.

But in case of non availability then there is a, there if you are actually using soil with high percentage of fines, in such situations what will actually happen that when there is an increase of water there will be an increase in pore water pressures and this increases actually the forces in the reinforced layers and which was actually not designed for and can lead to failure. So this is one such example, a segmental block wall failure is actually shown here.

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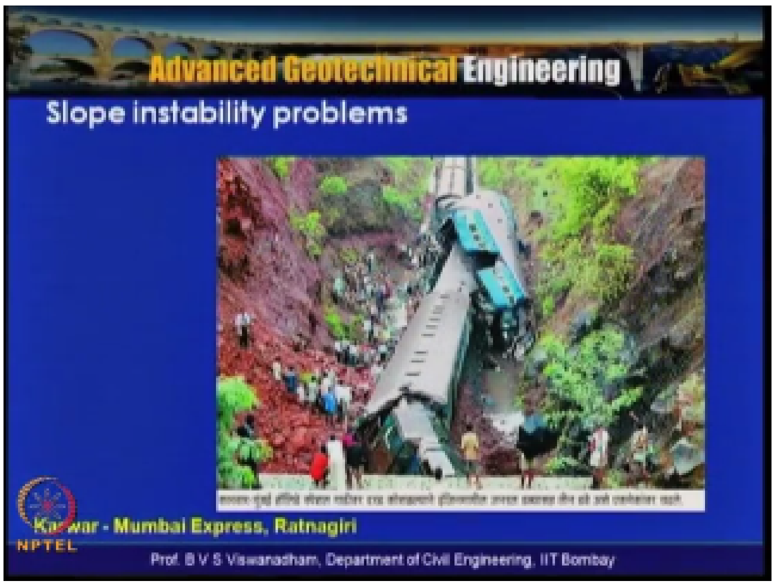

This is the case which is in 2001 wherein the slope instability problems which are actually reported and this is one of the trains actually met with an accident where, which actually lead to the severe rock fall as well as the damage due to sloping stability problem.

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And this is at the similar location, at the same location where close to Rathnagiri station where we have a typical railway amendment failure where in 2005 because of the heavy rain which actually occurred and this led to the entire section of a slope amendment of about 24m subjected to a failure and wherein you can also see that the restoration methods are actually have taken place subsequently also been subjected to failure.

And this is the track which is actually here which is shown was observed to settle in 2005 by about 1.7m, subsequently by another 0.8m. So in total percent about 2.5m and this actually has led to several issues particularly with the instability problems for that cotton field amendment which is actually constructed at that particular site.

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And this is a typical slope failure particularly in Egathurie region where in the monsoon these are actually far prevalent because of these situations which actually can be hazardous for the journeys to take place in this direction. So a proper appropriate two methods need to be adopted basically to avoid these dangers.

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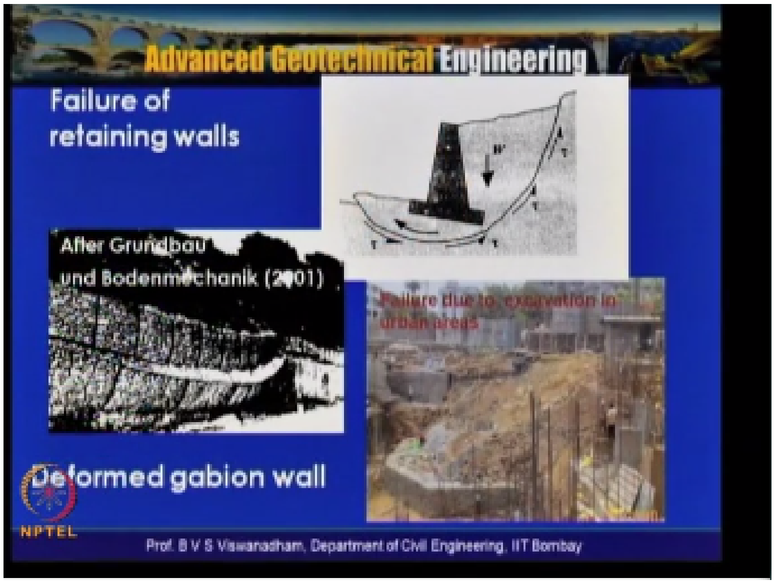

And particularly here in the urban areas, particularly where you have got the gabion walls and there can be possibility that these gabion walls can undergo deformation; that means that this is the when wall actually moves from back field, you can see that how the gabion wall deforms and similarly here, when we have got let us say failures surface actually passes below the retaining wall then there is no need for this retaining wall because this retaining wall also is subjected to failure. So in such situations there is a need for maybe adopting a deep slope stabilization technique particularly in this situations can be piled slopes is one, or if the returning wall is provided with the piles these piles can actually, can increase the slope, the factor safety against the slope stability failure.

Similarly this is a case study where failure due to excavation in the urban areas particularly when you are actually doing very close to the property lines, these property lines when the excavation is made the amount of excavation actually can cause a distress to the existing structure foundations, like the foundation can actually can be a shallow foundation or a D foundation, but can lead to eccentric or increasing stresses.

And these stresses cause a distress in the existing buildings and can lead to a collapse of the buildings because of improper care or proper protection measures are not taken. This is one such case where the failure actually happened because of the excavation in the area which is actually close to having a five storied building.

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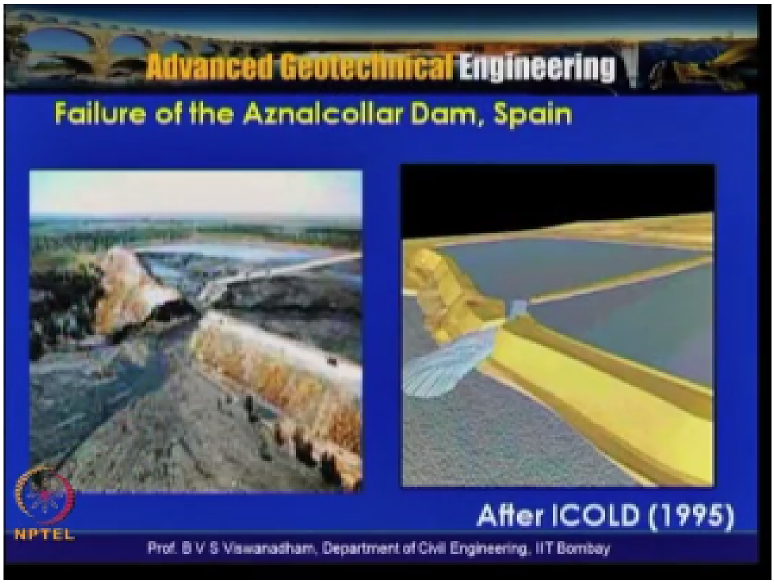

And this is a failure of a dam in Spain wherein the breaching failure was reported, this is after I cold 1995. So these type of things can actually lead to a catastrophic dangerous of submersion of the flood waters. So these things need to be addressed because these type of case studies are also reported in New Orleans in 2006 when the Mississippi river over topped the ravine and it had subjected to, entire New Orleans was actually submerged under water and this actually caused a lot of destruction.

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And this is in Singapore particularly when, this is a deep excavation which actually has taken place and the idea of interest is that this building needs to be protected and it is required to be protected because any excavation, any change in the ground water table can lead to settlements in this building and so herein.

This is a soiling type shore protection system was actually adopted basically and then the surrounding area is actually connected basically to increase the stability and to prevent any loss of support so that this existing building will not actually experience any distress. So then this also basically a proper shoring system also allows to adopt and construction in that area which has been earmarked for development.

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So this is a type of shore protection system which is being adopted in India and many places very, so in this the piles are actually placed closely and we can see that these are the beams which are actually connected to anchors so three level anchors where placed and these anchors actually prevent the wall from undergoing rotation. So these anchors will ensure the stability to the, this retention system and then this is actually area which is actually open for development.

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And this is a famous 35m deep Nicoli highway collapse in Singapore. So this is actually shown this type of situations can actually, can happen when we actually have got the failure of some struts and leading to some retention system or shoring system which actually had been in place.

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And this is a typical road which is actually shown, but nowadays with the requirement of need for development of underground railway stations or underground networks there is a need for creating void spaces below the populated areas.

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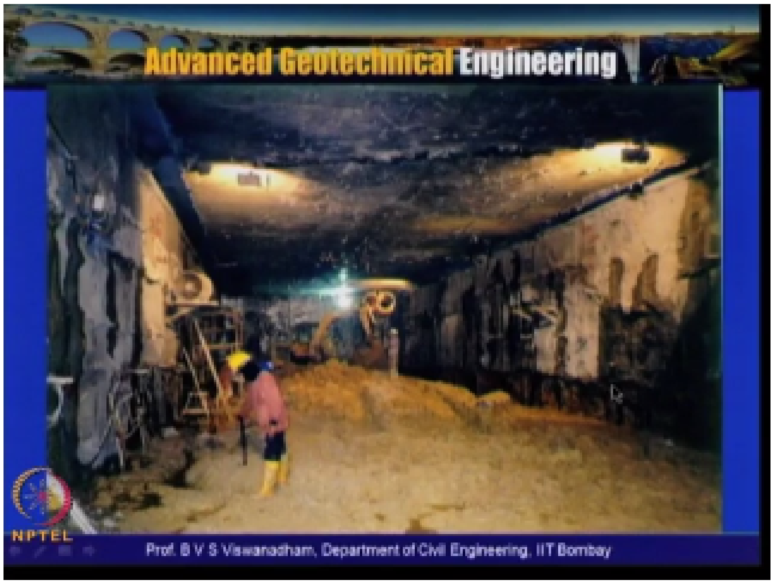

So this is, if you take section below this is actually underground substation which is actually being developed by a technique which allows creating void spaces so these spaces are used basically to maneuver the trains or underground systems and these are also nowadays being used for putting number of underground utilities and communication cables and other accessories.

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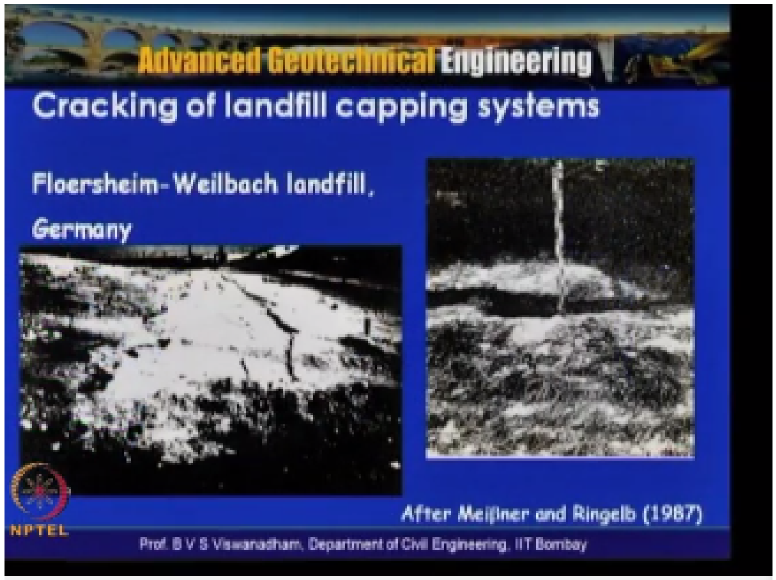

And this is a typical example of cracking of landfill gapping system and this is particularly when the waste which is actually covered and when it is subjected when the waste beneath the land field is subjected to some movement because of the ongoing composition, what is actually happened is that the cover system including the liner inside the lining system inside the cover system is subjected to distress and is subjected to both dissipation cracks due to drying and wetting which actually takes place, and as well as bending cracks which actually can lead to the loss of integrity and can cause gas migration from the shield land field into the surrounding environment.

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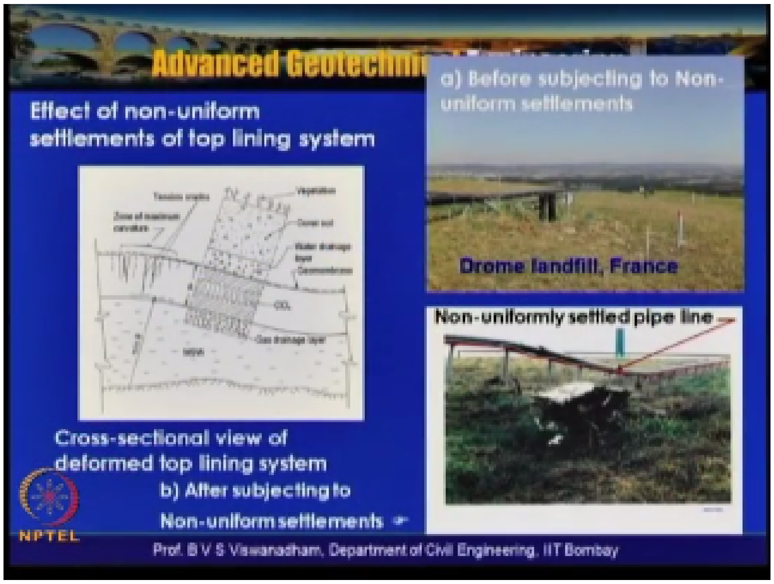

So this is a typical example in France particularly in area by Drome landfill and this is after government cut all in 2010 and this is what actually happens is that this is a landfill site in France where you can see that this pipeline is straight at the time of installation, but however after certain period of time you can see that this pipe line undergone non informally settlement; that means that this landfill what you see is the cover system which actually has got a cover soil which is about 1.2m height or so.

And then we have got a gas drainage layer and then we also have got compacted clay in the system and then there is, this is the gas drainage layer, this is water drainage layer, so this water can actually drain out so that rain water will not enter the land field and then this particular clay area can undergo tension. Because the clay can take only very maybe not more than one percent strain, and once it actually exceeds this strength strain the material undergoes tensile crack failure and which leads to the loss of integrity.

And also leads to the gas migration which actually can take place through the cracks which actually occur because of this deformation. This is the scenario; if you take the cross section may look like this thing. And another typical problem which is possible is that the pollution migration like particularly if you are having a pollutant which actually takes.

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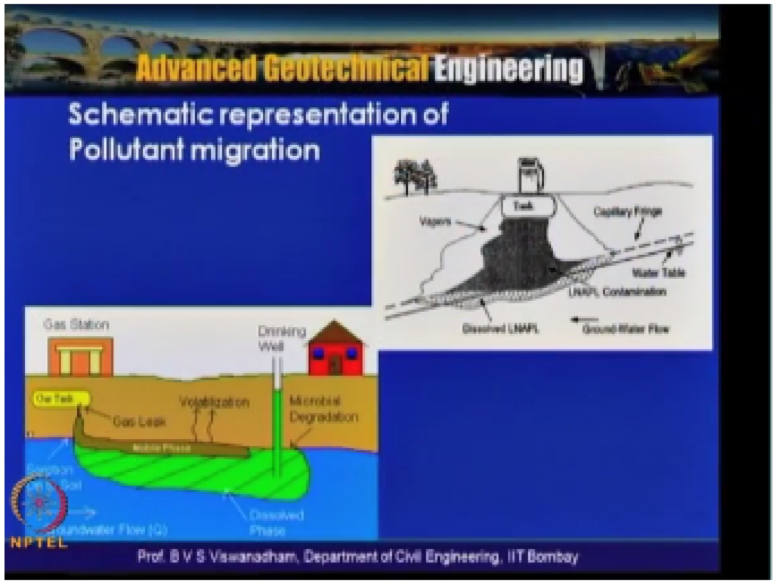

Let us say a certain amount of time to reach from one destination to other destination but in order to design barrier systems particularly vertical barrier systems one need to adopt proper physical modeling methods so that the systems can be assessed and ascertain basically and the methods can be designed with a performance so that this actually lead to a proper functioning of the designed barrier system.

So here are two examples of, one is that LNAPL migration, the other one is the so called gas migration which is actually shown for my gas tank. So this is another example, this is the blown up view of the, this is shown LNAPL release and subsequent. So when the ground water table flows it can lead to the contamination and then can take away this, it can actually promote the migration of LNAPL which actually released inadvertently.

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So the, another issues which are actually there in Japan and many other countries is the earthquakes which can actually occur particularly if you are actually having sand deposits, up to certain amount of fines there is a possibility that a momentary loss of strength can lead to you know very rapid settlements.

This is the particular photograph where this has been, actually been taken after the earthquake where it can be seen that this ground floor now looks higher than the original floor level, because what actually has been happened that this shop has undergone settlement and then settled. So you can see that this is the sunken portion of the building.

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This is the rear sidewalk which is damaged due to the earthquake and particularly here these two roads used to be at the same level, but because of the distress created due to earthquake this actually has got experienced the failure.

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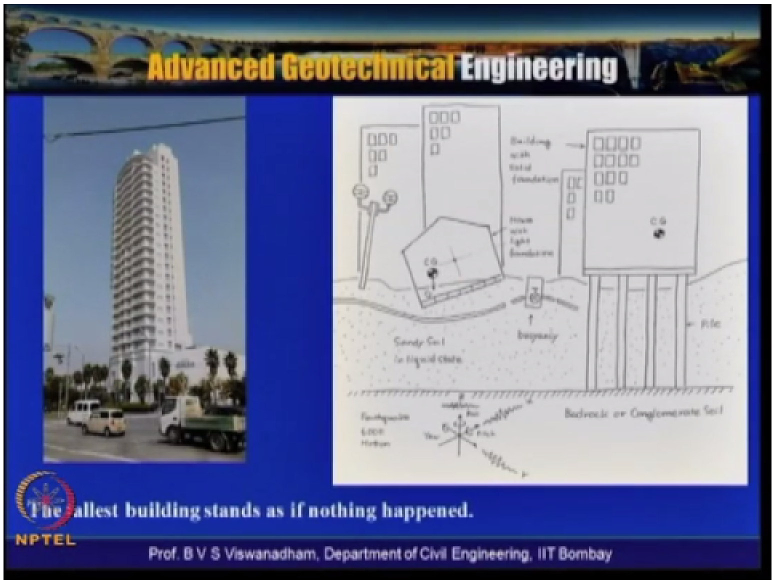

And similarly when you are actually having a building which is actually designed with un-proper foundation system then they are actually observed to be tallest buildings stands as it, nothing happened, but the systems without any proper system can be subjected to distress which is actually shown schematically in this particular slide.

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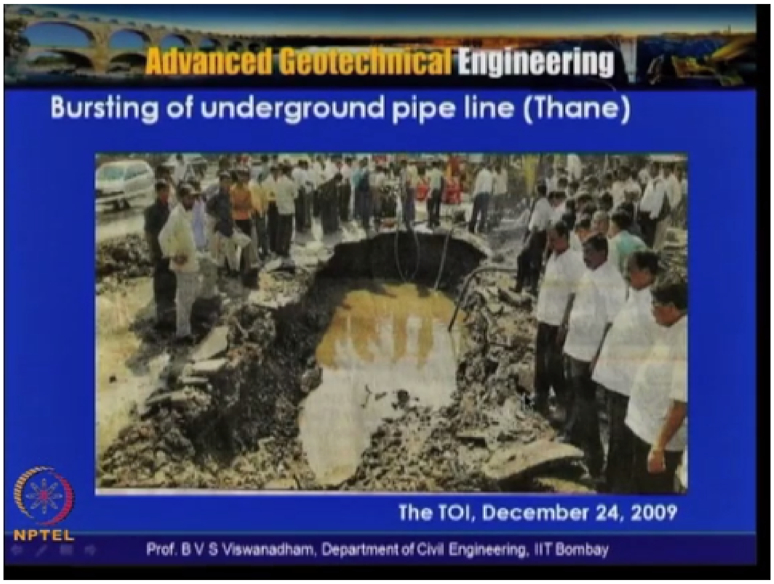

Another problem is that bursting of the underground pipeline, particularly the pipeline is old or if the pipeline joint failure occurs and this is actually very repeatedly happening for the past three or four years and this can actually lead to the destruction which actually shown here and this is a damage which actually has caused to this area because of the bursting of the underground pipeline.

Because here what happens is that these pipelines are operated with certain operation pressures, but with increase in surge in the pressure what will happen is that there will be a burst which actually can take place because the surged pressure cannot be taken by the damaged portion of the pipe or a weak joint.

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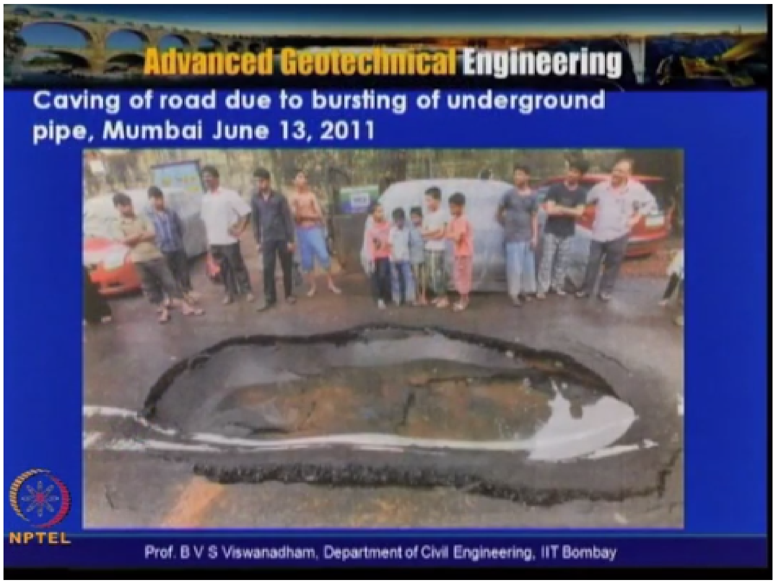

Similarly this is another example which is a similar trend of failure, you can see the caving of the road due to the bursting of the underground pipeline.

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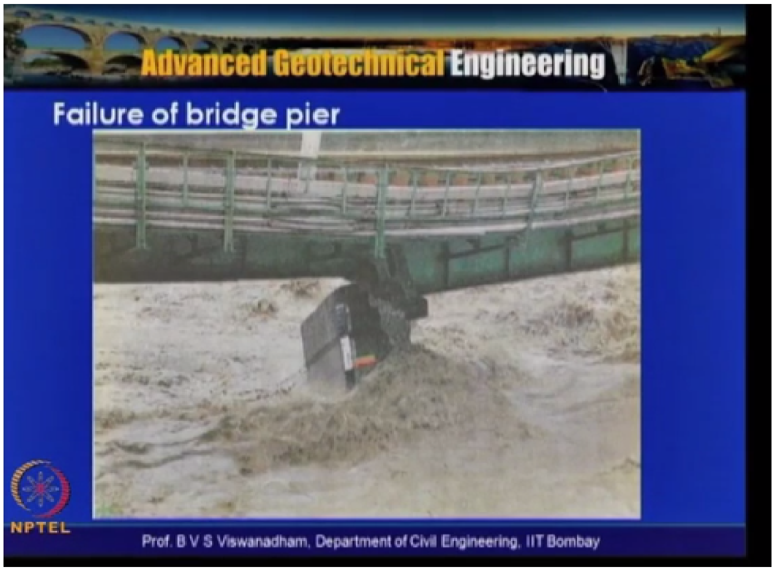

The, another typical failure which is actually shown is that because of the flooding which actually takes place because during the rivers and these failure of a bridge clearly that is shown here, you can see that how the pier is actually, is about to be displaced so you can that the massive effect which is actually shown by the flowing water on the pier which is actually there, which can actually lead to very high amount of cover.

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So this type of failures can actually occur because of these, the loss of confinement can lead to the bearing capacity failure and can actually have the decks can actually settle like this and then can lead to failure.

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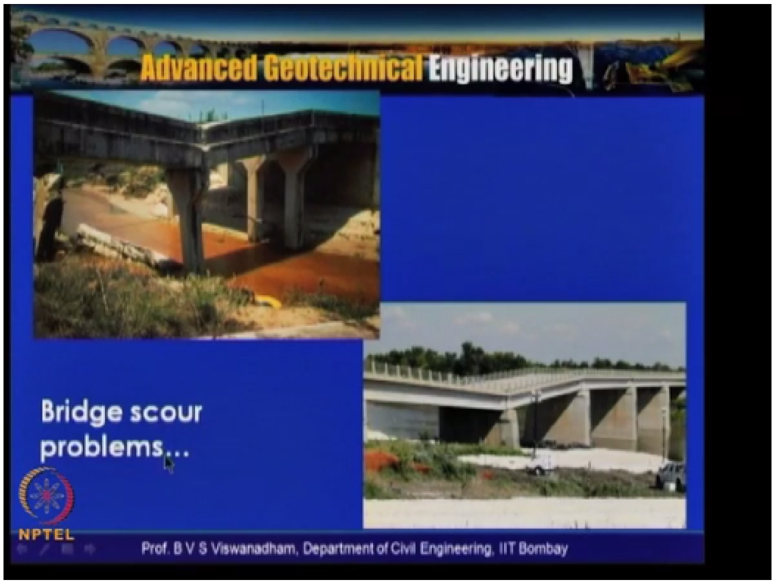

So this is a typical scour problems which are actually shown in a number of places and these are very typical in nature.

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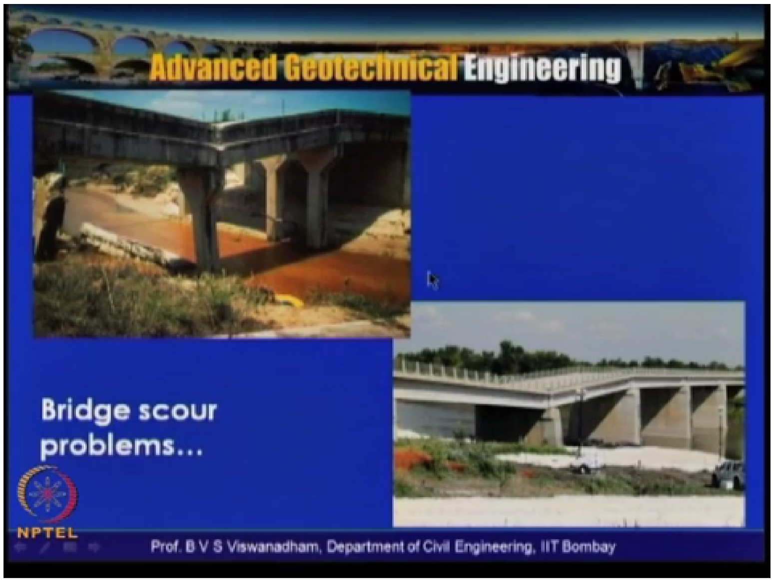

And this is in 2013 actually which has happened and the instability problems along the hills particularly, which actually due to the flash floods and can lead to lot of instabilities and dangers which actually can happen because of this cloud burst and other issues which are actually happening in India and other parts of the world.

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So, this is an example where how the destruction actually has taken away the portions of the buildings and led to the severe causalities which actually result from the failures.

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So this is another look of the destruction which actually has taken place. So you can see that the round boulders which is actually indicates that the flow of water which is the history of the flow of water can be seen from this here and this is the river which is actually flowing along this banks.

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And this is a typical landslide which actually causes the road to cut off and the particular number of villages which actually can lead to cut off because of this massive landslide which actually can occur either due to earthquake or due to rainfall or due to some construction activities which are actually taking place in these areas.

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And this is that power plant due to failure where you can see that this is, before removing the soil a failed pile line is shown here and this is a bean shaped pipe line is actually shown here and this is another pipe line which is intact but you can see that this pipe line is subjected to failure. This is because nearly because the flowing water actually exerts very high pressure and that led to the pipe buckling which actually has induced this failure.

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And this is a fire safety water tank in one of the construction sites so basically this is actually the used area which is actually designed with a concrete lining, it can be seen.

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Then you know but because of the, some instability issues we can see that in with the increase of rain water the, how much the amount of the pressure which actually exerted and led to the failure particularly here in this areas and the close look of this you can see that the, this lining actually experienced a severe failure.

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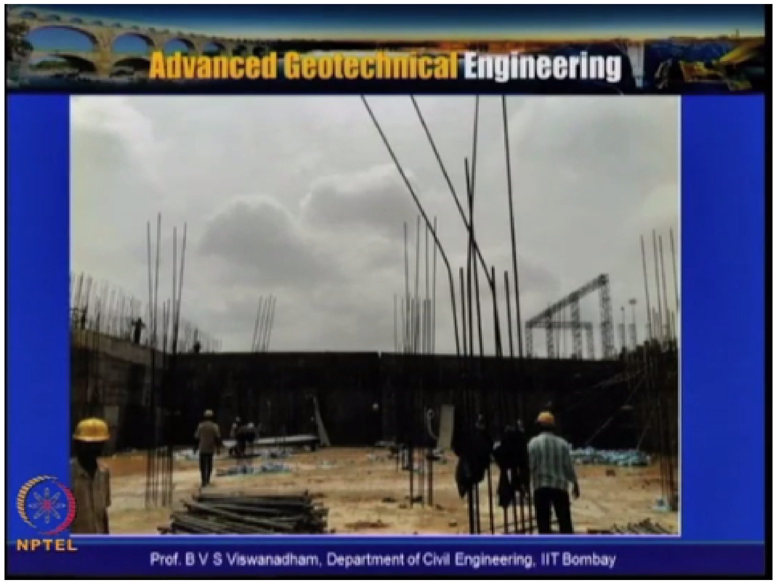

And this is this is a large fire water storage tank, so in this basically what actually happened is that how the uplift of the water can actually create distress can be seen here. The water tank was actually designed for a water table at certain level but when the water table raises because of the increase of the rain water then there is possibility that what actually happens is that the rain water exerts a very positive pore water pressure on the base of the tank and which actually has led to the bending of this slab.

You can see that the deformed shape of the slab and this is a barrier baffle ball which actually has been subjected to cracking because the bending is actually is maximum at this particular point.

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So this is another instability problem in land fields particularly when waste undergoes the instant movements within the land field and these lining system which are actually placed can lead to failures and which is a clear example of instability problems in municipal solid waste land.

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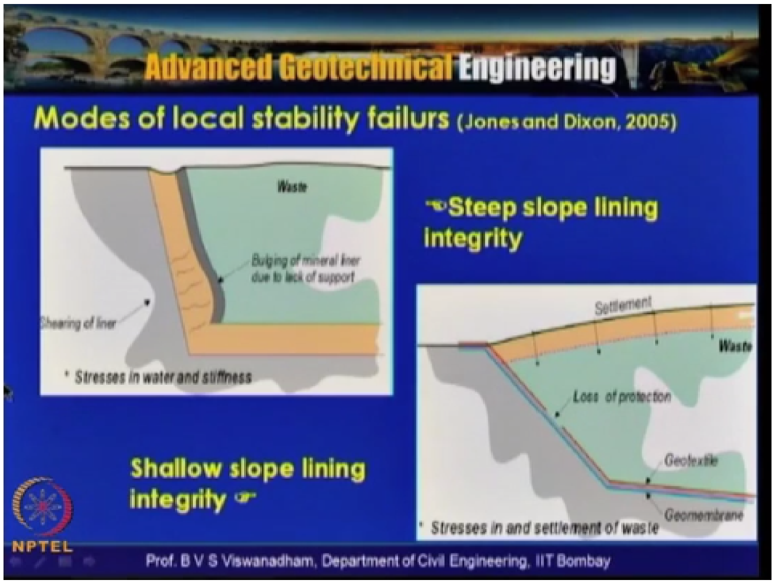

And these are the typical schematic figures of the local instability failures particularly when there is bulging of the liner due to lake of support then liner actually moves like this and this can actually lead to failure here, and sometimes what will happen is that if you are got a lining system but if it is loss of production due to.

This is particularly possible when you are actually having certain liners and when they are subjected to some swell and shrink cycles and in between they can lose the protected area. So that can actually lead to some sort of that portion at the zone behaves like as it is unproductive.

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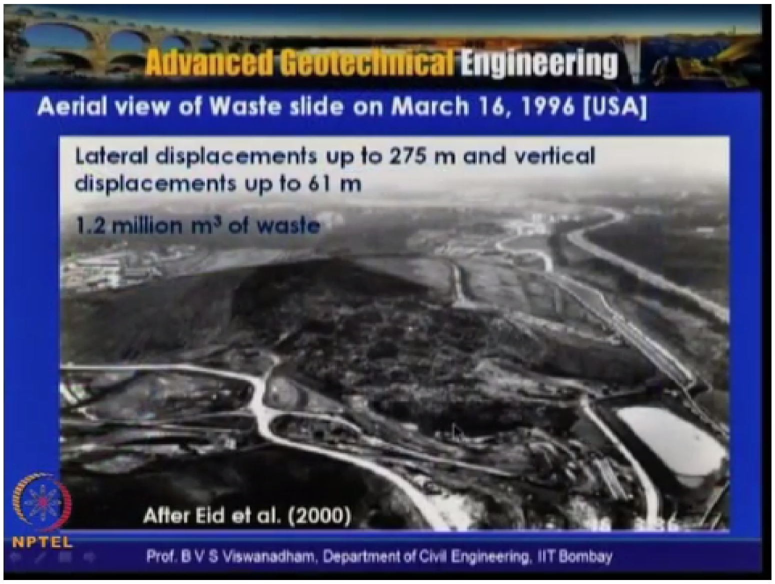

So this is a typical aerial view of the waste slide that actually was reported by Eid et al in 2000 and the lateral displacements were measured to be up to 275m and vertical displacements up to 61m and 1.2millionm^3 of the waste was actually observed to move. So the lateral displacements up to 300m were actually were measured and vertical displacements up to 61m were observed.

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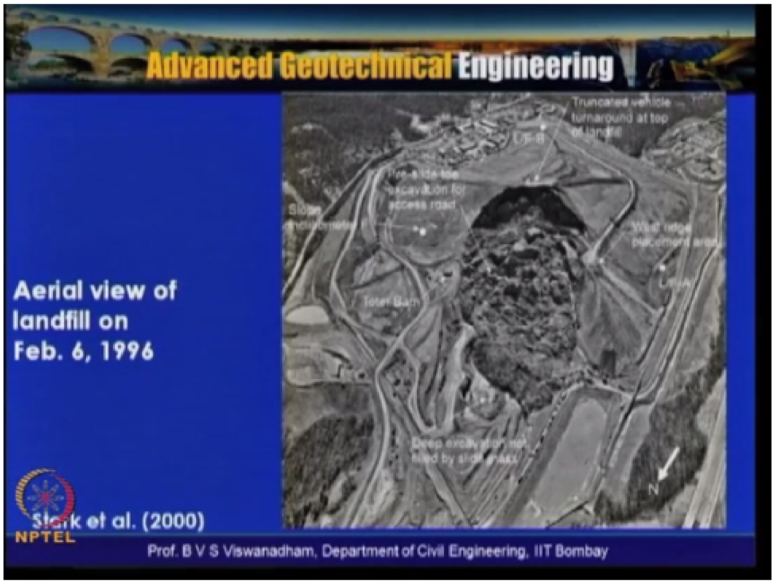

And this is another view of reported by Stark et al in 2000 and where you can see that the distressed area which is of a land field is actually shown here.

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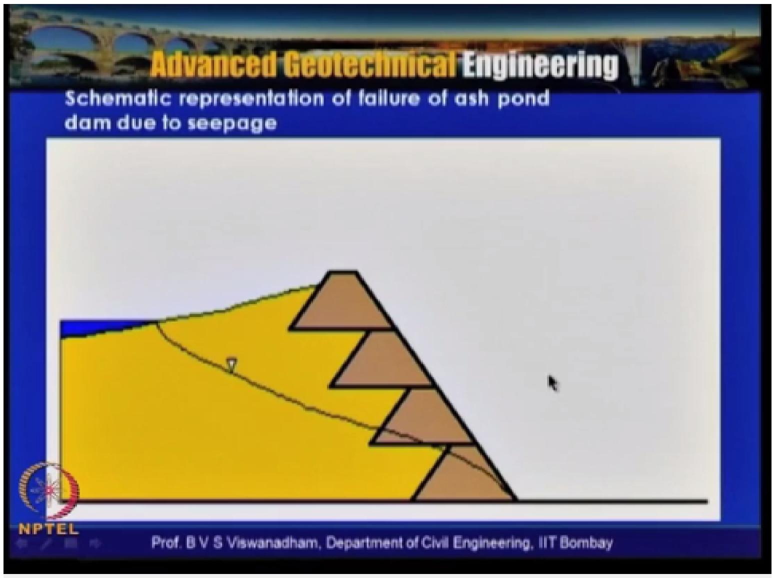

So this is a typical schematic representation of the failure of ash pond as has been discussed that these ash ponds were actually designed, this is a method which is actually called as upstream method. What will happen is that the first bund which is actually constructed with the soil and then the second bund and subsequent third bund and fourth bund they are actually required to be raised, mostly generally with a bund of five meters height up to 20m or 25m height it is the general practice to construct.

But because of the non availability of the soil or the need for the use of local available material like coal ash or fly ash there is a need for constructing this portion of the first stage or second stage or third stage bund with coal ash. Which coal ash is the coal material and then surroundings are actually made with a clay blended material and which actually has got good erosion resistance.

But when the water, this is a big hydraulic structure, when the water is exerts a pressure there can be possibility that this type of instability failures can result because of the seepage problems and these type of problems are also can occur when you are actually having even tailing dams or coal ash pond dams.

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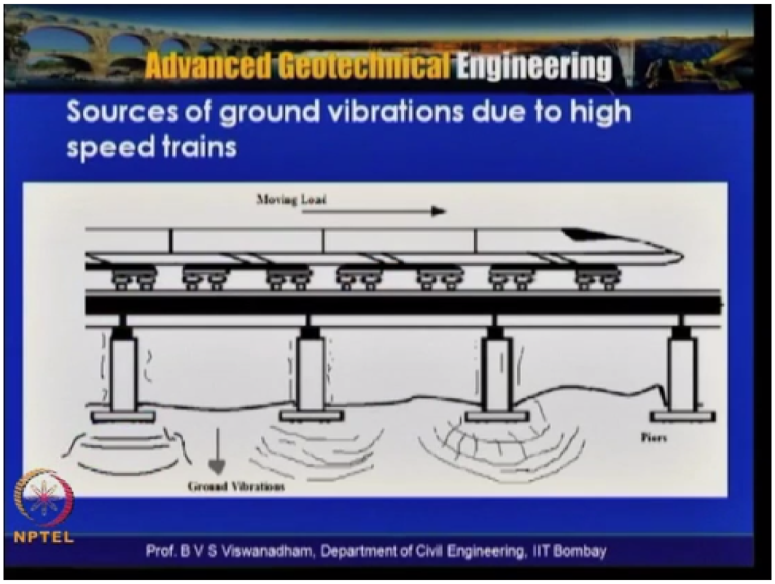

This particular slide which actually shows the problems which actually can come with high speed trains and this is from Tokyo Institute of Technology where in Japan they have investigated about, the effect of movement of high speed trains on the bridge peer foundations and particularly when high speed train travels on the bridge and the bridge which is actually resting on the say sandy soil and these bridge peers are subjected to localized liquid faction.

And then these vibrations are actually sometimes the peers are closed then there can be interference actually takes place. So in order to study these problems particularly like the, which type, how these damages can be prevented and to allow the traversing of high speed trains. Then there is a need for the so called adoption of isolation systems so in order to design the systems with performance and all then geotechnical based physical model studies particularly especially this centrifuge based physical model study can be used.

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So this is in recently which actually happened along Mumbai - Pune express way in June 2015 wherein because of the instability of the rock slopes there can be a problem which is actually can cause because of the instability occurs due to the detachment of the rock pieces and led to the number of causalities also, and, so to avert these things the proper system need to be in place. So this is actually being discussed to, just to bring the awareness about the magnitude and order of the problems which are actually there in the advanced geotechnical engineering arena.

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Similarly with increase in urban population with generation of the urban based there is a need for proper disposal of the waste, for example this is a scenario in some megacities but if these waste is actually confined properly and this can lead to generation of good gas which actually can be used for producing the, at least electricity to support the land field activities.

So these need to be handled properly and apart from whatever the methods which are actually adopted to reduce the waste, but there is in ultimately, there is a land fields are the ultimate disposal methods which are actually for disposing the waste.

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So these are the typical examples how they can actually lead to the order of contaminate which actually can occur and it can be seen that this type of areas can actually have the serious effect on the prior joining properties and the generation of the gases can lead to the environmental hazards and contamination of the water bodies beyond the high toxic levels.

So these need to be done with, this comes under the environmental geotechnical area. And connecting to the very recent developments nowadays which is required to have not only you have a foundation but also the foundation which actually has to also takes, supports the cooling and heating systems within the buildings.

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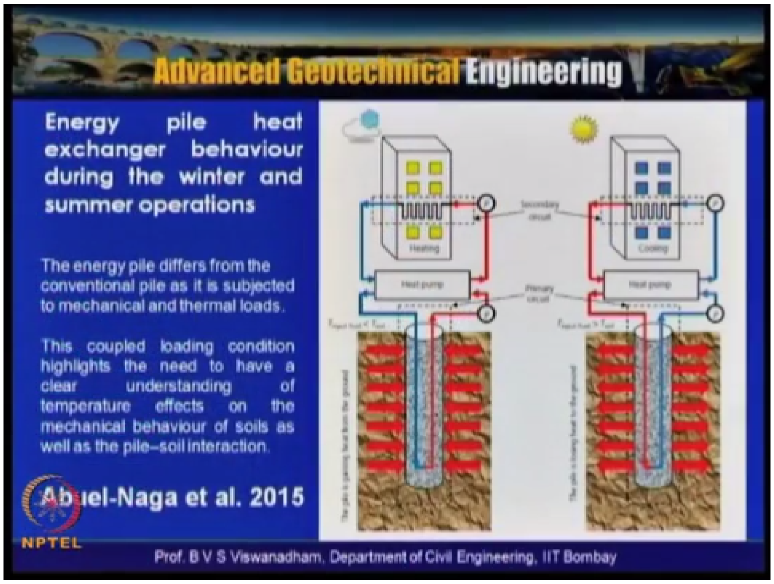

So these are actually, the green buildings are proper green buildings which are actually coming up. So energy pile which is nothing but a foundation and which is basically defers from the conventional pile foundation because it is actually subjected to both mechanical as well as thermal loads.

So thermal loads means it can be, so this couple loading condition basically highlights the need to have a clear understanding about the temperature effects on the mechanical behaviour of soil as well as the pile soil attractions. So what will happen when you are actually having different temperatures on the interfaces and what actually happens on the pile soil interface and similarly what is the effect of the temperature on the mechanical behaviour of the soils need to be understood.

So these energy piles concept is actually proving to be, see this you can see that this is in the winter and this is in the summer. So wherein it actually used in winter is used to heating the building and in summer it is used to cooling the building. So this is a new concept which is actually being reported by Abuel-Naga in 2015.

So this advanced geotechnical engineering which is actually has got multi faceted interest particularly from engineering point of view, from the transportation engineering point of view or from the structural engineering point of view to actually have construct this high range buildings one need to understand about the compressibility consolidation and stressed and behaviour of a soil.

And from the performance point of view in order to understand the behaviour all these aspects which are actually sometimes when the proper materials are not available then the need for the optimization of the designs, when we wanted to improve the performance of the design and then we actually need to retort to the appropriate physical modeling methods and these methods which actually can lead to a betterment in the behaviour. But not all geo technical failures end up in embarrassment, however most do.

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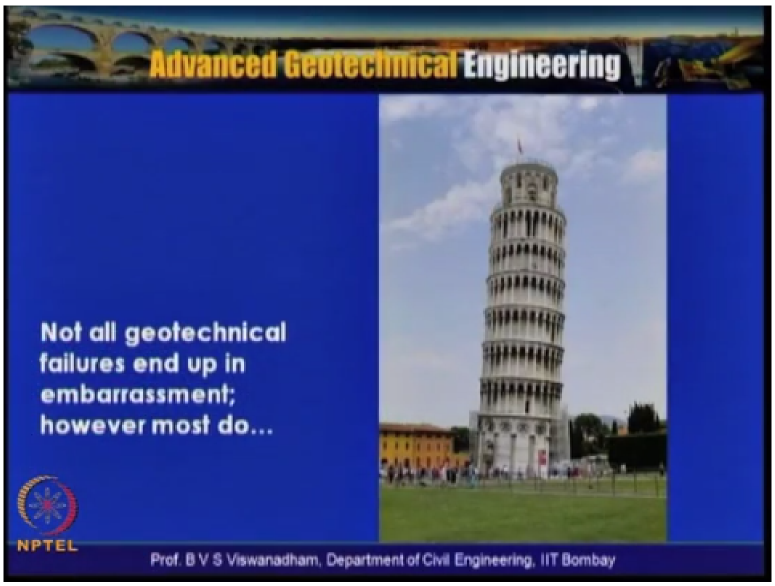

This is a famous example of Leaning Tower of Pisa in Italy which is 400 to 500 year old and which is subjected to a sort of distress because of the consolidation or compression behaviour of clay. So before giving the references at the outset I would like to thank for patient hearing.

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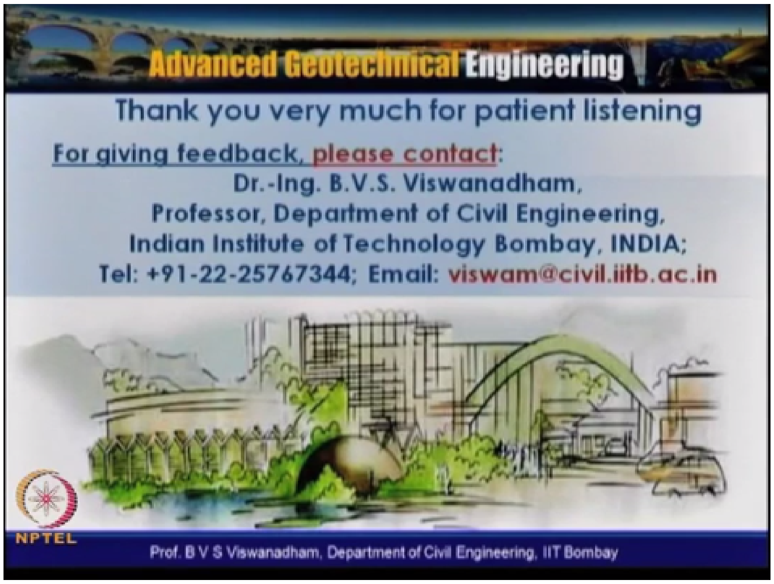

And I also would like to thank the center for distance education program and the NPTL phase II staff for their excellent support and motivation provided for completing this course from time to time. So for giving feedback on this course please contact myself which is actually written here, Dr. B. V. S. Viswanadhan, Professor, Department of Civil Engineering, Indian Institute of Technology, Bombay, India and the telephone number and e-mail id which is actually given here. And this is the iconic symbol of Gyan Pramandam of IIT, Bombay.

So now some of the references which are actually used in this particular course are given here and these references are not in order.

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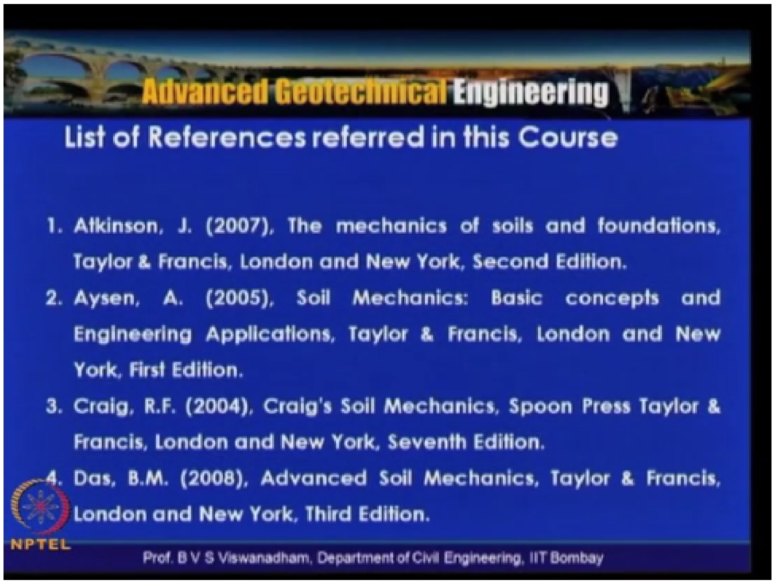

But number of references were actually used, so these majority of the references are listed here and if any of the references are missed they are actually missed only from inadvertently where they could not be added. But here Atkinson (2007) mechanics of soils and foundations and Das (2008) advanced soil mechanics, Craig R. F. (2004) Craig's Soil Mechanics.

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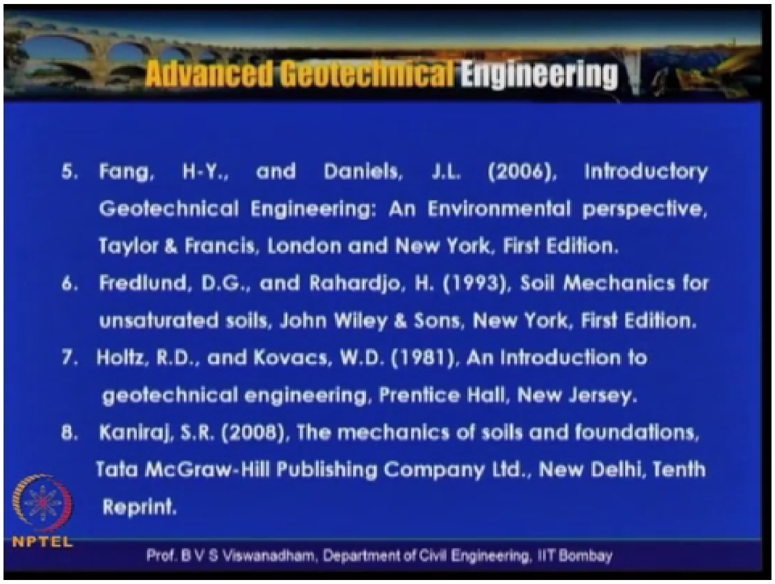

And some of the references which are actually given here they are actually Holtz and Kovacs introduction to geotechnical engineering which was actually referred.

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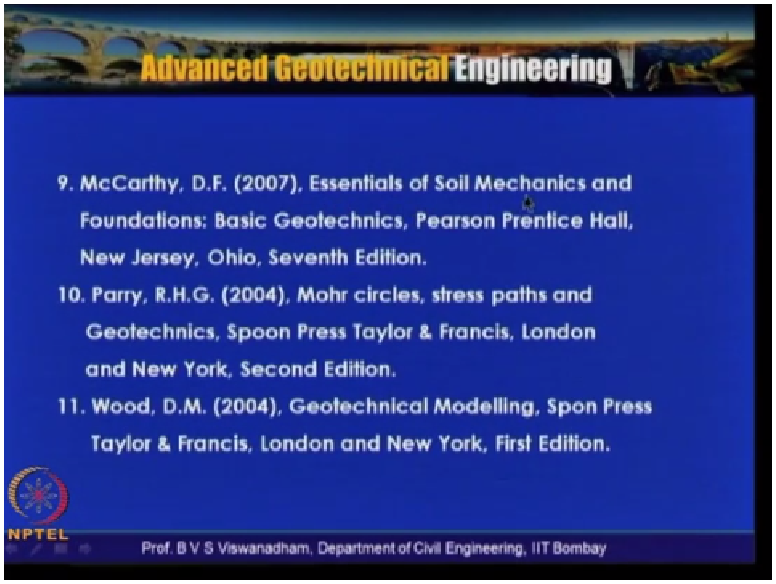

McCarthy Essentials of Soil Mechanics and Foundations and Basic Geotechnics, and Parry R. H. G., this is basically for Mohr circles, stress paths and Geotechnic were actually referred, shear strength characteristics of soil and Wood, D. M. Wood actually, book was actually basically referred for some examples and discussions which are actually made on geotechnical physical modelling and centrifuge based physical modelling. So the geotechnical modelling aspects were actually covered from this particular book.

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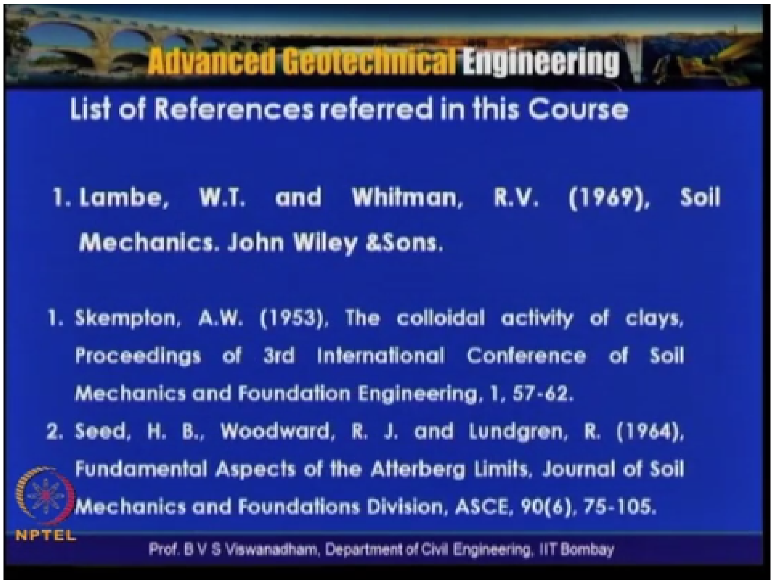

And the basic soil mechanics book Lambe and Whitman (1969), Soil Mechanics book by John Wiley which was actually used and these are some of the cross references which are actually shown here.

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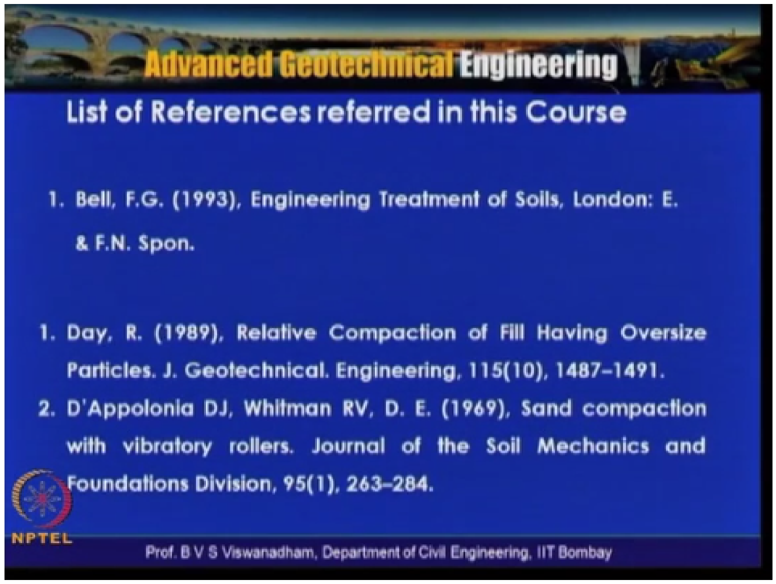

And then these are some of the references which are actually listed in the literature or which are referred or indicated here.

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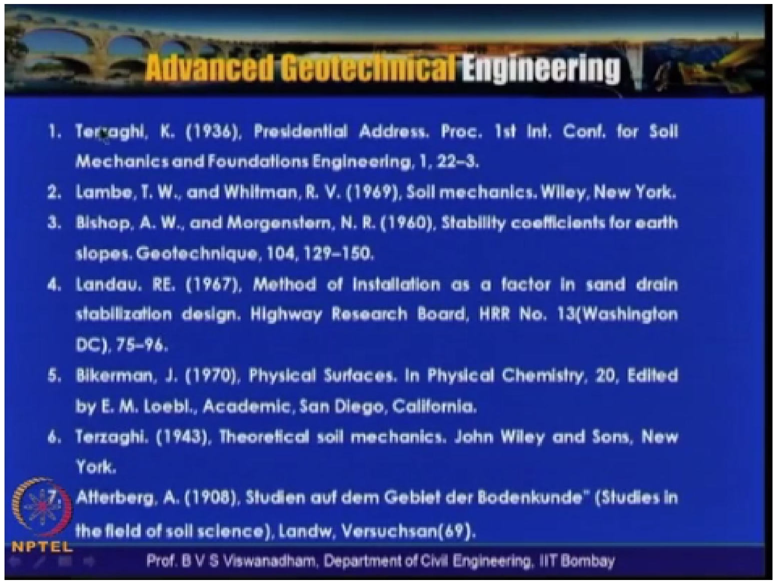

And these are the some references Terzaghi and Lambe and Whitman and then these theoretical soil mechanics by Terzaghi in 1943, this was referred for some of the in the derivations.

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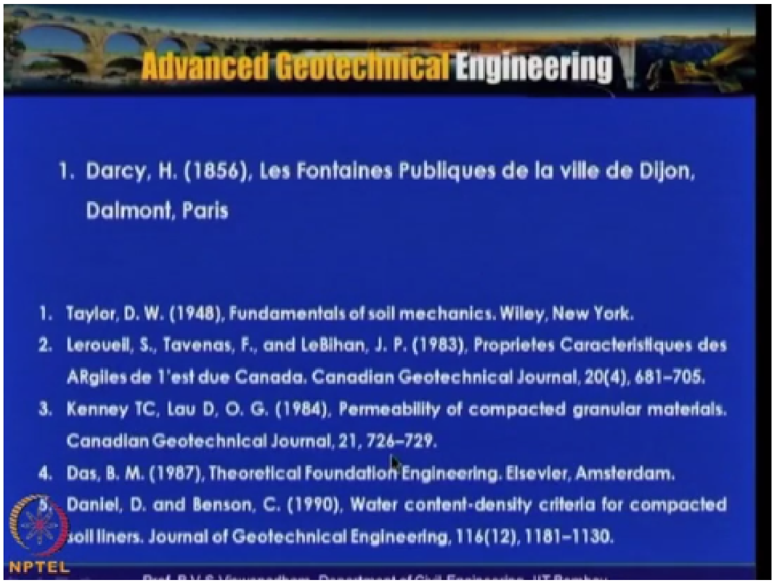

And then Taylor (1948), Fundamentals of Soil Mechanics this was actually referred and theoretical foundation engineering by Das (1987) was actually referred.

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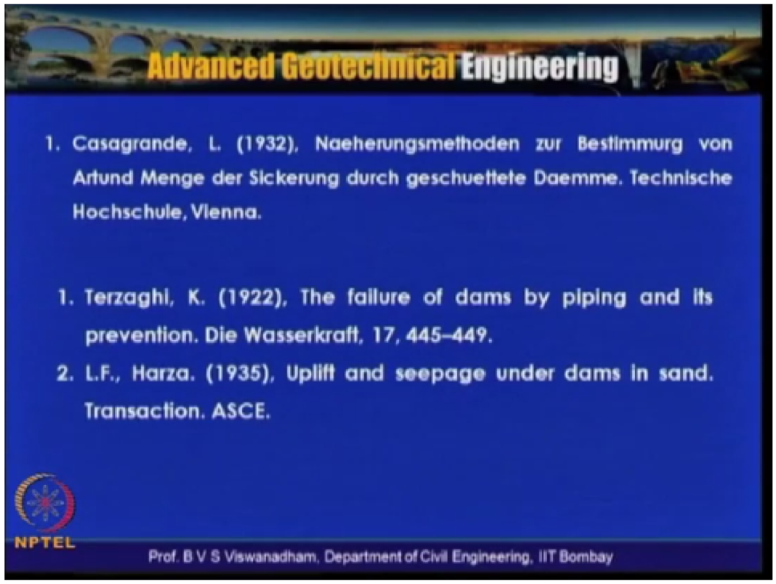

And then again Harza particularly for in the seepage analysis, up lift and seepage under the dams and sand, this was actually referred.

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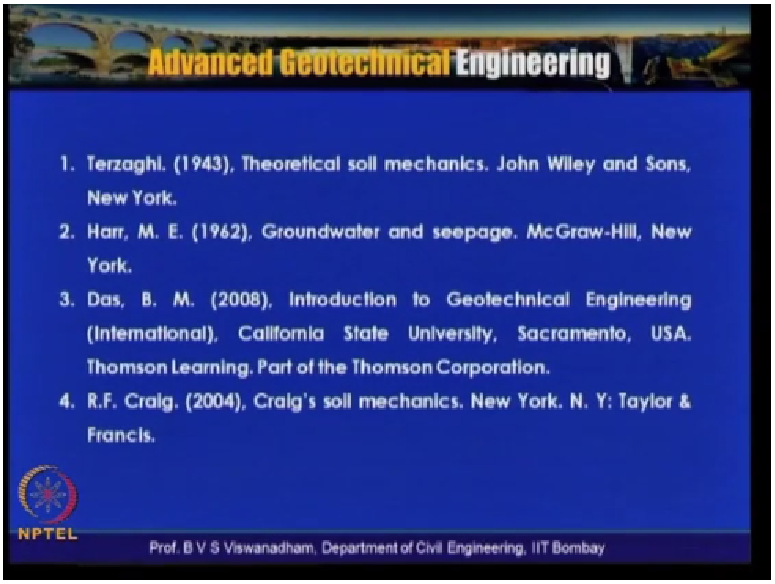

And M.E. Harr groundwater and seepage, this was actually referred for discussing about the seepage relevant aspects in the particular module.

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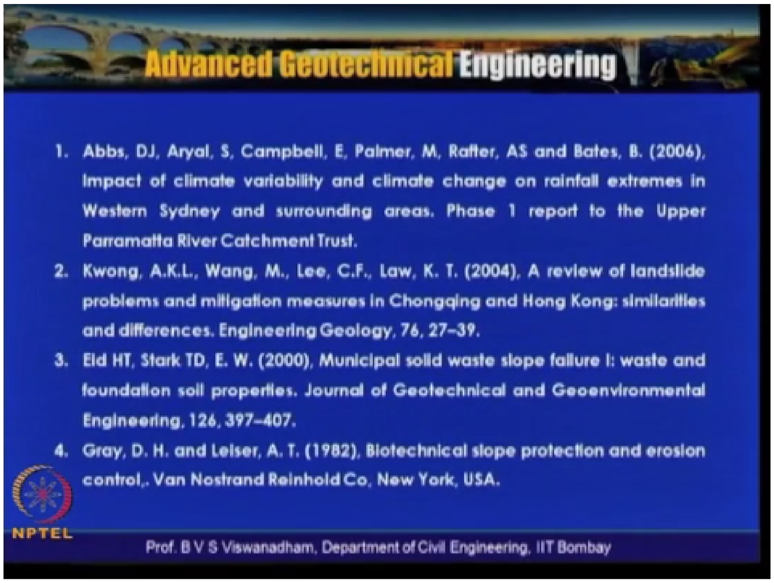

Then these are the some references which are actually listed in this particular lectures.

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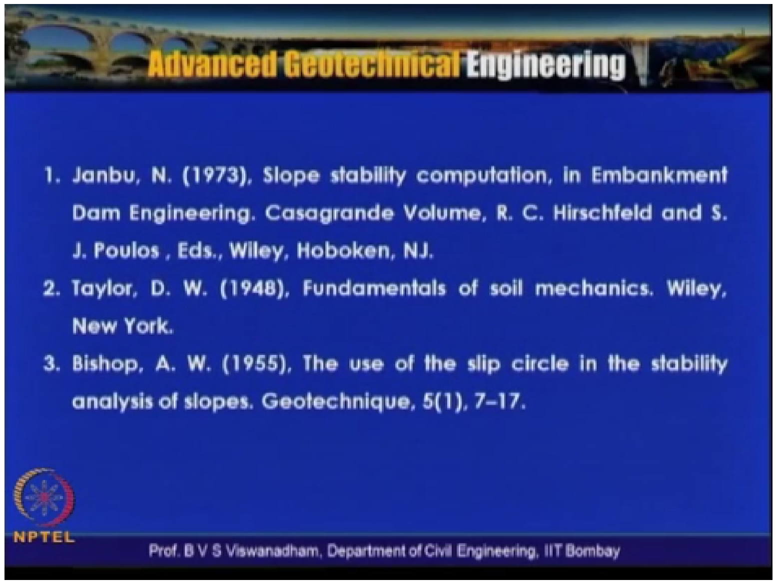

So this is in slope stability computations according to Janbu's method.

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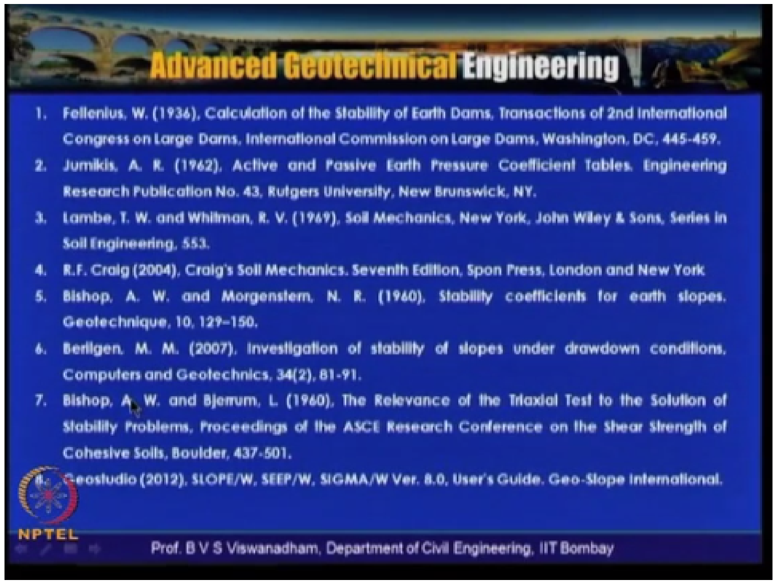

And this is for Fellenius method and then we also have covered the different, this is A. Jose (2012) and the excellent software package for calculating the slope stability and seep/w and also for stress sigma, sigma/w for loading conditions this was used.

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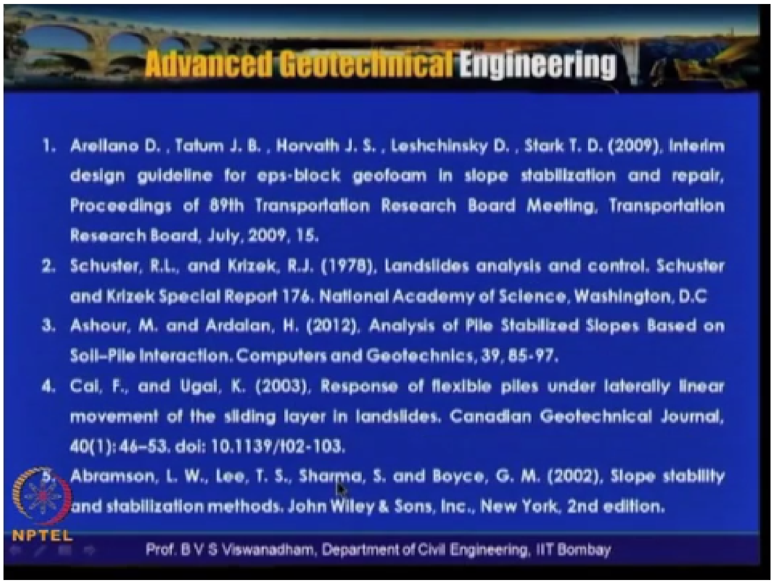

And also fake w was also used for stimulating some problems on earthquake aspects and then these are some references Cal and Y (2003), response of flexible piles under laterally linear movement of the sliding layer in landslides and this while discussing piles stability slopes were actually referred.

And landslides analysis and control, these again under slope stability aspects and stabilization methods were actually discussed. Abramson, this is Abramson et al (2002) was referred for slope stability and stabilization methods, which is after John Wiley and Sons and then some of the books which are actually referred.

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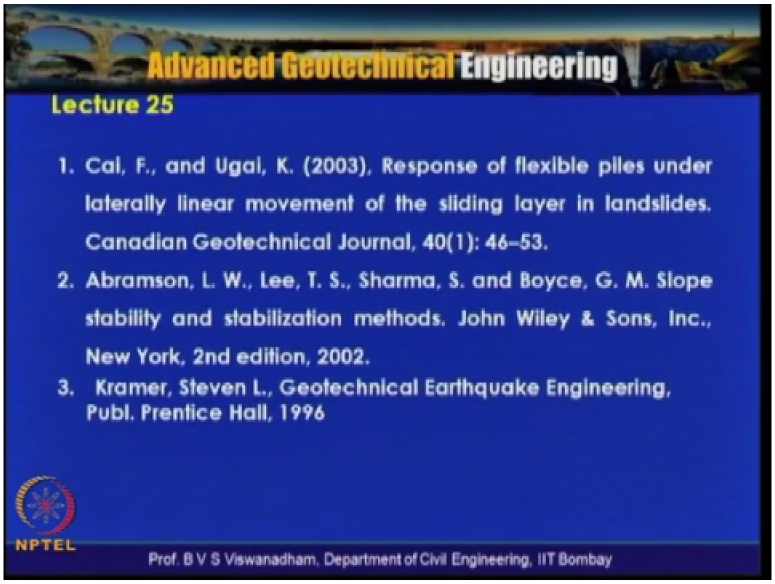

Are papers referred to here and this is again the Kramer which is on Geotechnical Earthquake Engineering was actually referred for discussing about the seismic aspects of the slopes.

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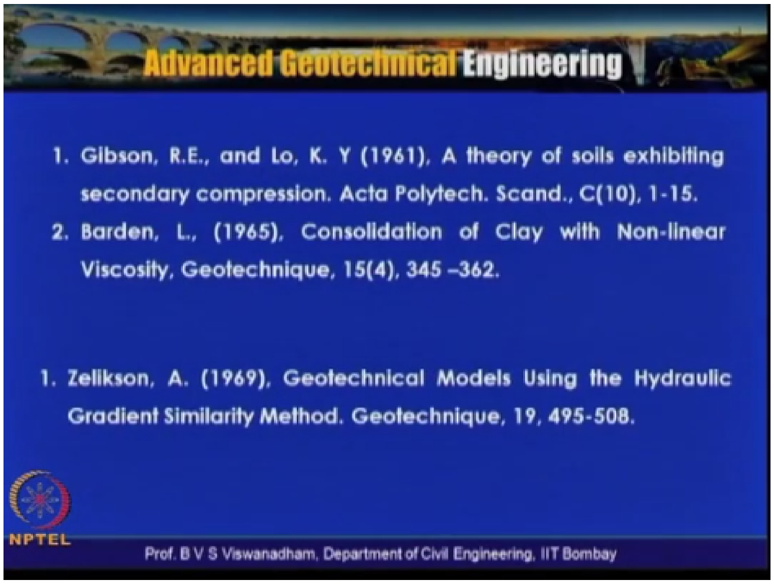

And then in the Geotechnical Physical Modeling, Zelikson (1969) was actually referred for Geotechnical models using hydraulic gradient similarity method and then Barden (1965) Consolidation of Clay with Non-linear Viscosity and this is actually referred in from geotechnic.

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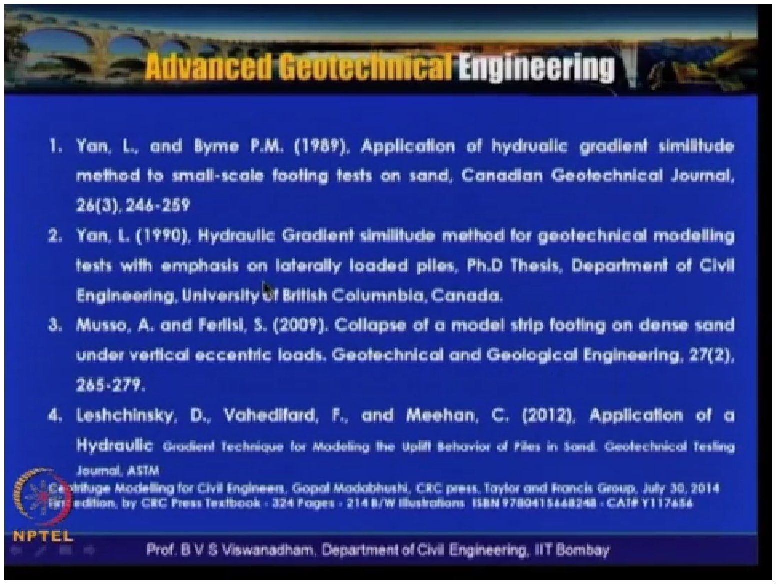

And then there are number of references which are actually listed here, which are actually shown here.

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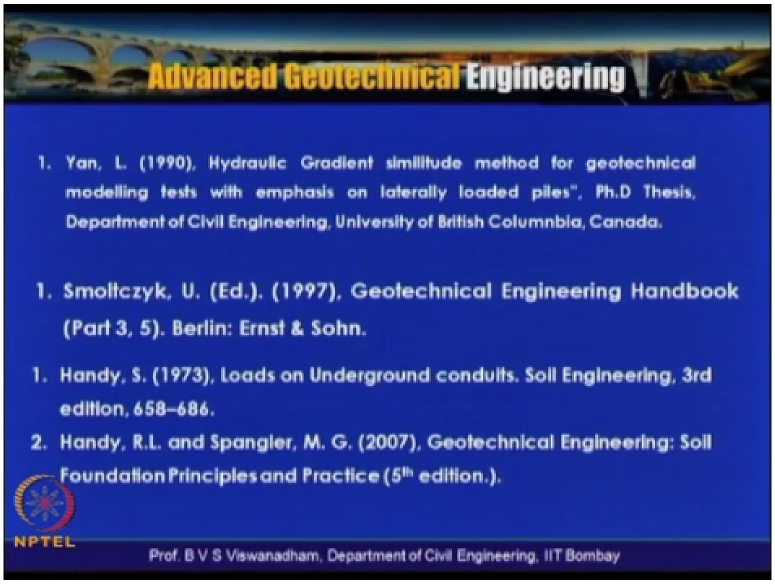

And then the geotechnical engineering ground handbook that is geotechnical engineering handbook that is group bound ball mechanic pattern book was actually referred for some salient examples which are actually documented by professor Smollczyk. Part 3 and Part 4 were referred and in case of buried conduits, handy notes on underground conduits for engineering and handy and Spangler geotechnical engineering soil foundation principle practice is actually referred particularly for handy was referred for the worked examples and then theory which is actually relevant to buried conduits or buried structures.

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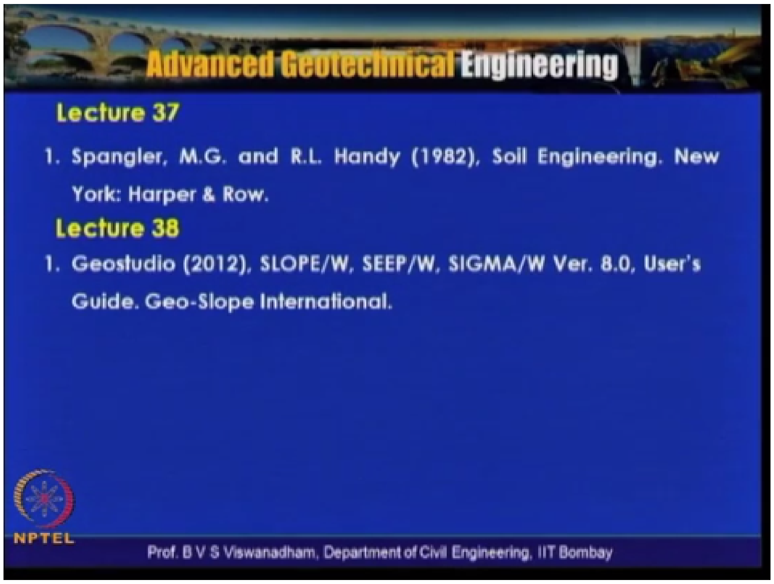

And then in some of the lectures, these are actually the Spangler and handy soil engineering where this book was referred.

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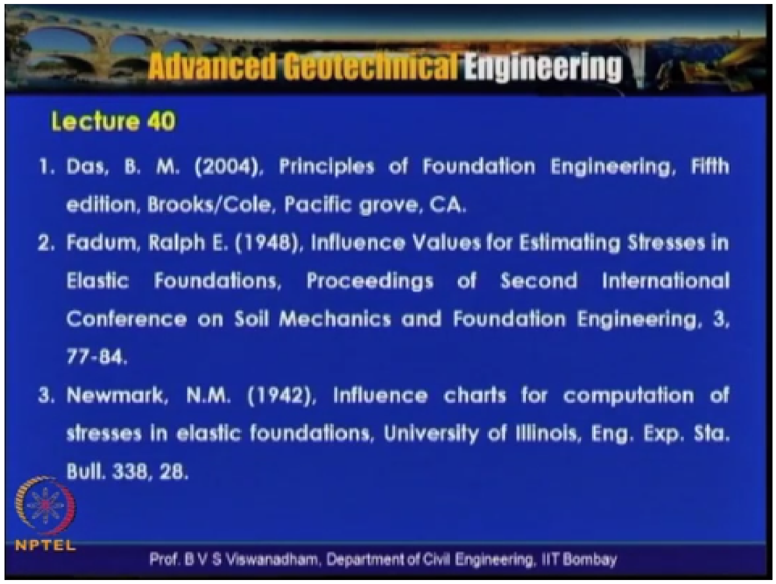

And this is another references.

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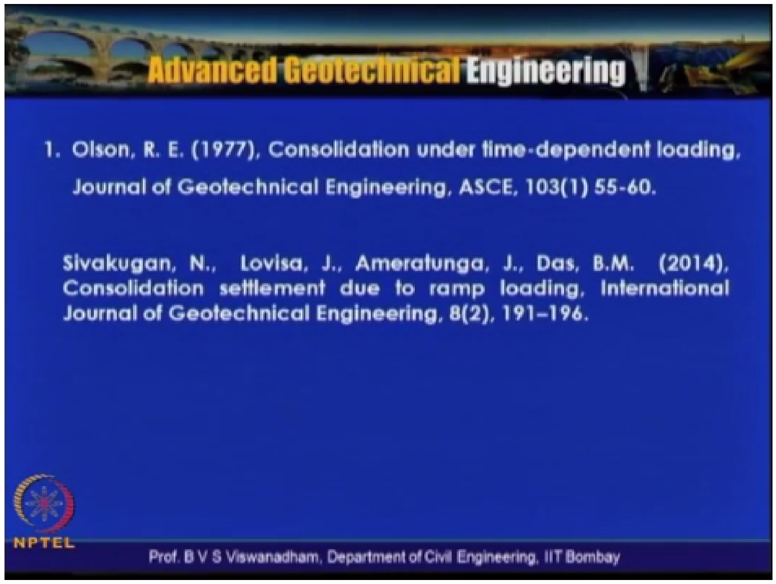

And this on the consolidation settlement due to ramp loading, this was actually referred after Sivakugan et al (2014).

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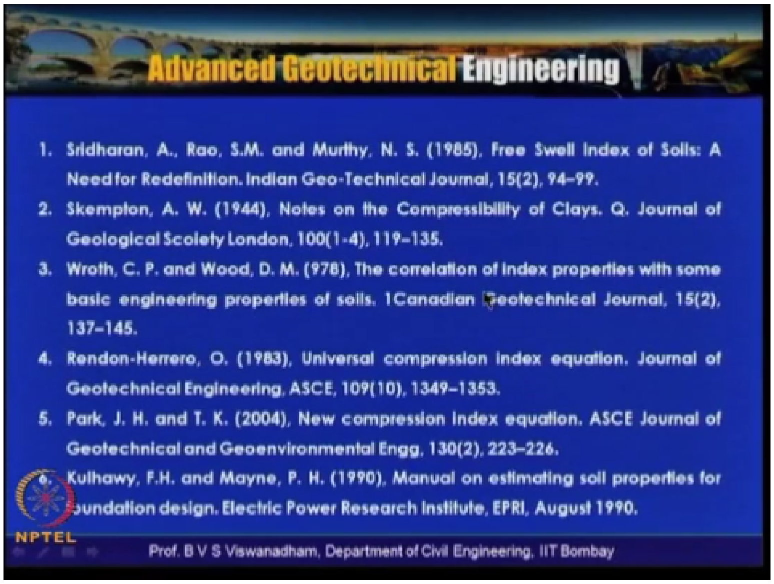

And these are some of the references which are actually listed.

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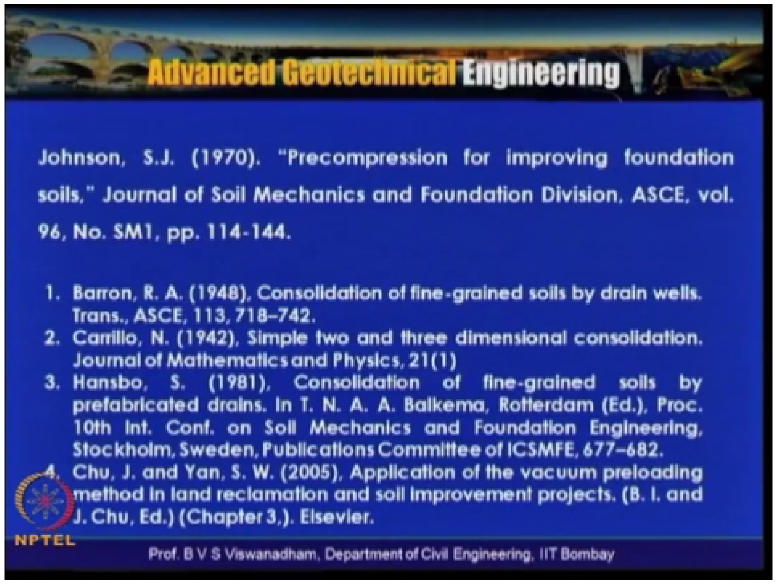

Which are shown here.

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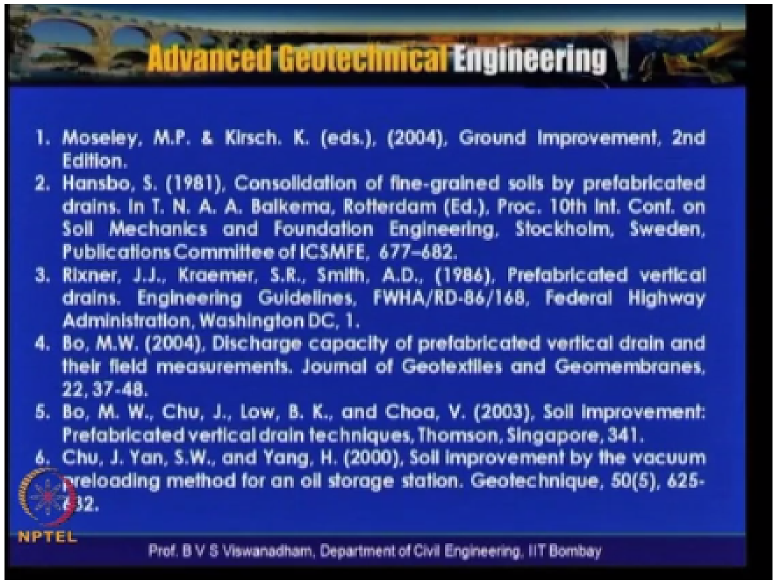

This is in ground improvement.

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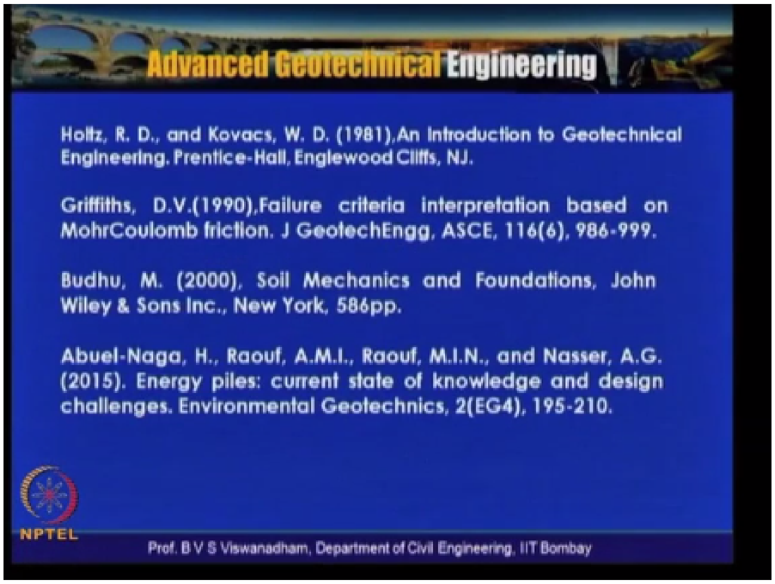

So for more details and feedback on this course the details can be obtained here at this address which is actually shown here.

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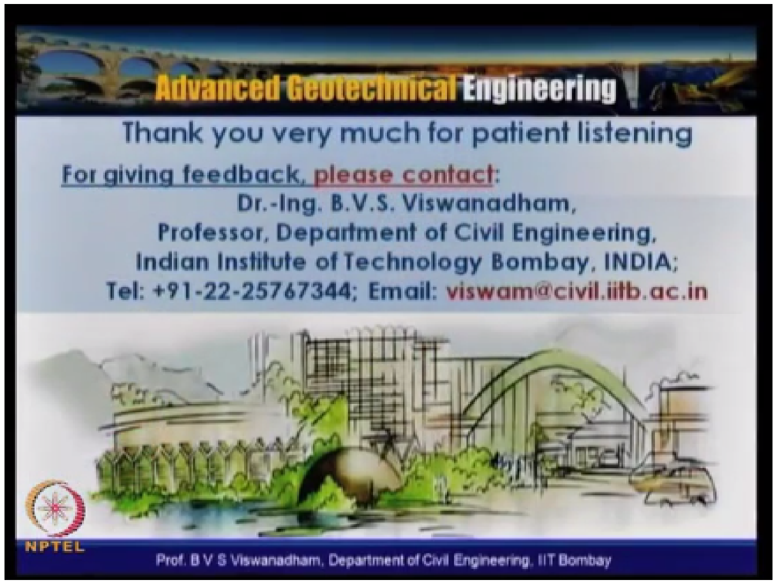

This marks the end of advanced geotechnical engineering course and this course also supported by the worked examples and some exercises which are actually done already in the slides are also going to be provided basically to show more interest in the subject, and to also gain practice and experience in solving some difficult problems and these problems are actually mostly practical oriented, so that this can lead to lot of insight into the subject on advanced geotechnical engineering. Thank you very much for your patient listening.