NPTEL

NATIONAL PROGRAMME ON TECHNOLOGY ENHANCED LEARNING

CDEEP
IIT BOMBAY

ADVANCED GEOTECHNICAL ENGINEERING

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IIT Bombay
Lecture No. 45

Module-5
Lecture-6 on Stability of Slopes

Welcome to advance geotechnical engineering course we are in module 5 which is on stability of slopes.

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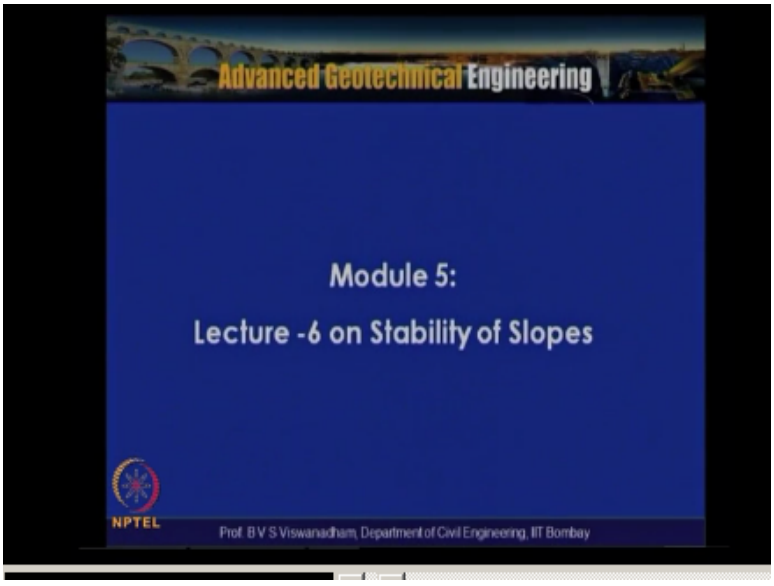

And this is lecture number 6 in stability of slopes in this particular lecture we are going to concentrate on slope stabilization methods.

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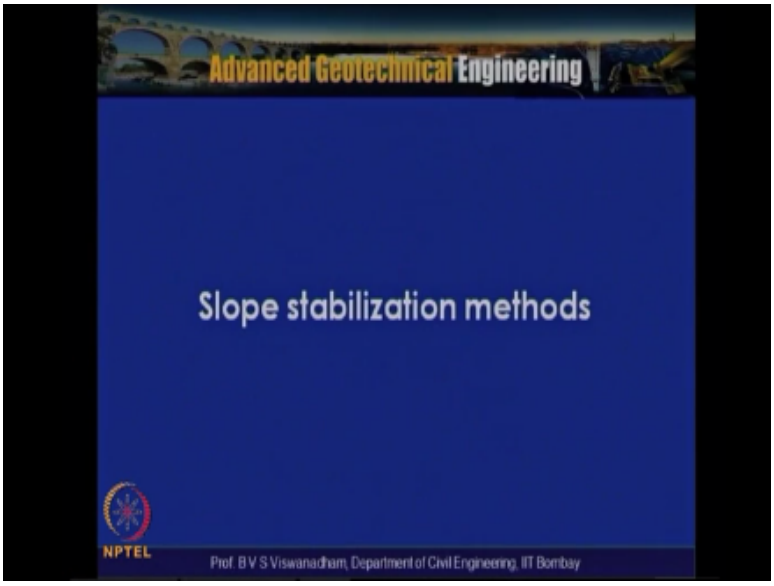

In the previous lecture we have discussed about different slope stabilization techniques and in continuation of our discussion we will try to discuss about how line times are time slurry injection can be helpful in enhancing the stability of a slope there is a part of the type of chemical hardening.

Which we have mentioned in the previous lecture then the another method which is for Institute slope stabilization is soil nailing so that we will try to discuss in detail and finally we look into the method which is called as biotechnical stabilization or biotechnical slope stabilization which is gaining momentum in the recent past with a requirement of eco-friendly awareness before going into the typical slope stabilization techniques for natural slopes as we discussed there are two types of slopes one is a naturals loan other one is say man-made slopes and embankment fall in the man-made slopes category and in this particular slid.

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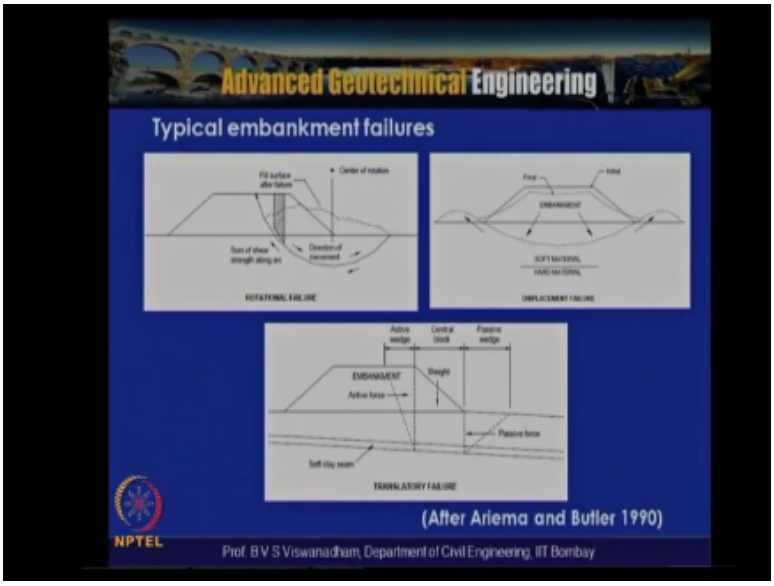

A typical embankment failures are shown the first figure on the leftmost left corner is the rotational failure of an embankment which is actually shown and this is possible when there is underlying clay is a soft in nature then the direction of the movement is vertical and then outwards in this direction so this is actually also called as a base pay which is actually happens if you are having a underlying soil.

Which is soft in nature then the another failure of the typical embankment is that there is a displacement failure where a management portion settles down with maximum settlement at the center and heaving on the both the sides so this is typical nature for the soft material and we are actually if it is the hard material is here nearby to the bottom surface then you can actually have settlement and a heave which is actually takes place on the both the directions suppose if there is an underlying layer is a soft clay seen beneath the soil surface and there is a possibility that a translator failure can actually happen to avoid.

These magnet fail use one of the popular alternative is to stabilize the man-made slope on an embankment slope by constructing a berm, any combination of you know stabilizing via stabilized with stone columns or so the effect of the firm on the slope stabilization if you look into is in.

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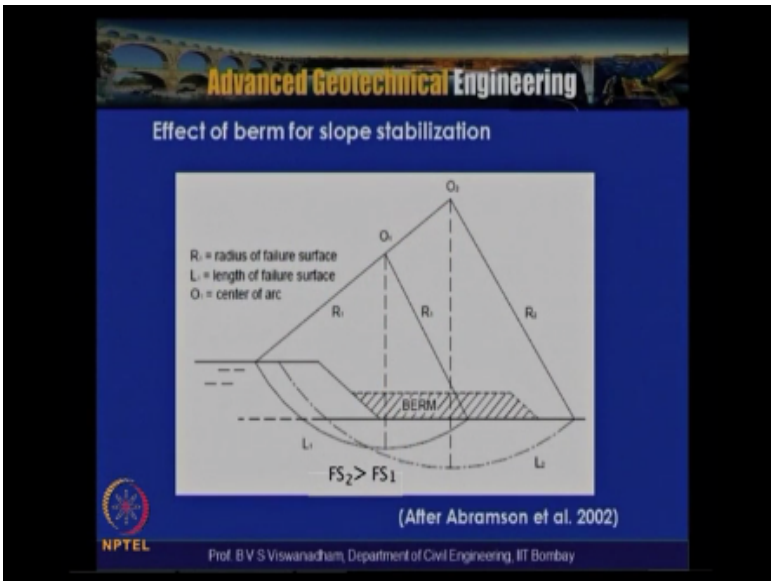

This particular slide where an embankment which is subjected to a failure a base failure or rotational failure with a circular arc 11 with the center of arc woven is shown here and which you will say factor of safety FS 1 then without providing a berm the center of the arc shifts 202 and the radius of the arc becomes say are two so which yields a factor of safety FS 2which yields which is more than the FS1.

So the provision of the berm helps in enhancing the stability of a slow so the question is that you know the extent of the horizontal extent of the berm from the toe of the slope that is important and the height of the berm which is required need to be a setting so sometimes what will happen is that it is not possible to extend the berm up to you know large distances in such situations one can actually resort to adopting you know the yesterday lecture in the previous day lecture previous in the previous lecture we discussed about slope stabilization is using stone columns that can be combined along with this are incorporated into gate.

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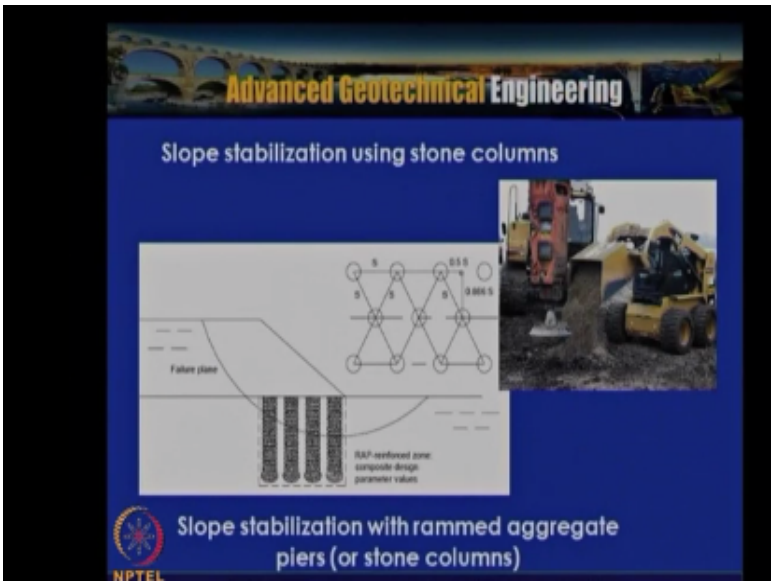

So the next slide what we are going to do is that the slope stabilization using stone columns which is particularly a method which is used for installing these rambled peers or it also called a stone columns and in case there is a slope is existing and then the Bund is required to be constructed on that they burn the additional with reddening of the Bund is required here then what we do is that we drive the sheet pile wall from the top so this is in this particular slide atypical installation of stone column is shown here where in the borehole.

Which is actually made of required diameter and the stones charge which actually faded so there are two different types of feeding techniques one is called top feeding technique other one is called a bottom-feeding technique in the top feeding technique once the borehole reaches to the a certain depth then the charge is actually feeded in installments and then it is compacted by using the same rammed by using this bailer so this technique nowadays the availability of the vibro floats and done helps to compact these stones charge efficiently.

And also helps in constructing the stone columns efficiently so this is a particular technique where the slope stabilization of a existing embankment can be enhanced or in a magma to be constructed on a soft soil can be enhanced by using this particular technique now as we discussed that there is another technique which is called slope stabilization enhancement basically by using lime slurry injection or line columns.

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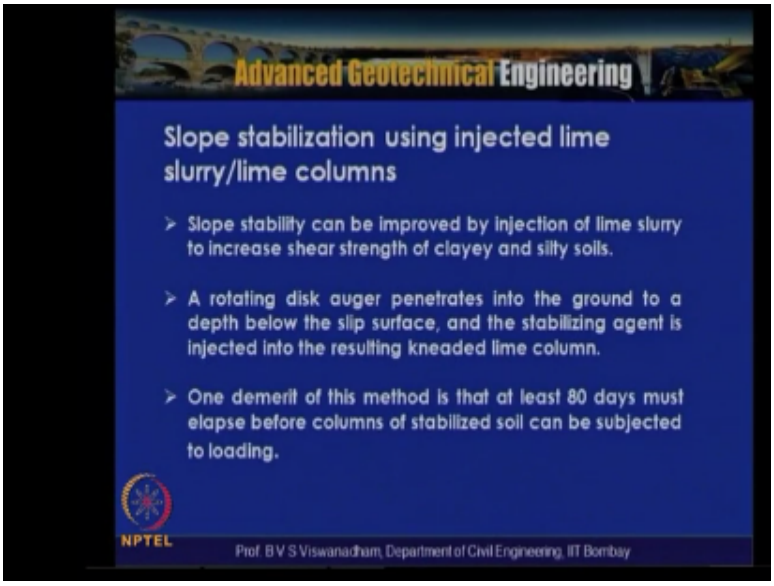

Nowadays the line and fly ash injection is also getting popular because of the abundant availability of the fly ash they appropriate combination of line and fly ash are being used so this slope stability can be improved by injection of live slurry to increase the shear strength of clay and de silty soils and it is not much successful with the sandy soils the slope stability can be improved by injection of line or line fly ash inappropriate combinations.

In the form of a slurry to increase the shear strength of the clay and silty soils and this is also sometimes is done in the form of pile line columns or line piles where in similar to stone columns a drilled hole is filled with a line.

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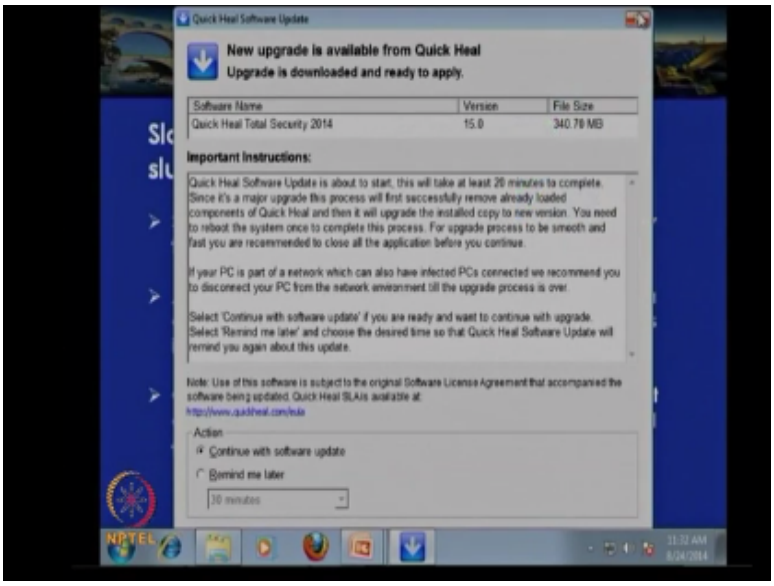

Of an appropriate type of material which is specified in the specified and this is actually done basically by a rotating order penetrates into the depth up to a slip surface are sometimes beyond the surface and the staging agent is injected into the resulting near into the needed line columns and one demerit of this method is that the at least 80 days must be must elapse before columns of the stabilized soil can be subjected to loading.

But however the rate of increase of this strength for a period of time was found to be increasing because of the mobilization of the reactions which actually takes place with the presence of the line so this though this method actually has got at least the requirement of 80 days is required to before you know the stability soil is actually subjected to loading so in this particular slide the installation.

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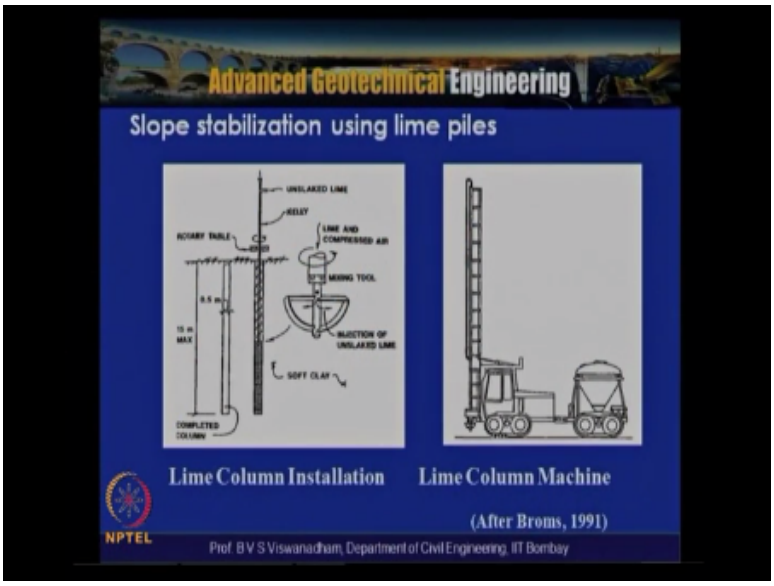

Of line column or line piles is actually shown here where a point five meter two point eight meter diameter hole is actually made and they can be used up to 15 meter length according to Broms, 1991 and where the drilled hole is actually filled with the help of this line column machine and is and the lime is actually fitted and their lime columns are actually constructed and this is a typical you know slope stabilization by using injected lime slurry shown.

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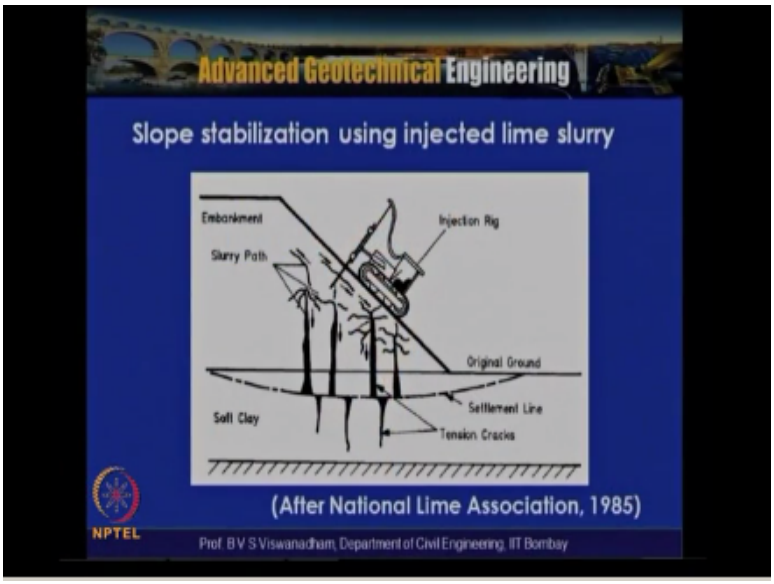

And nowadays with the availability of the portable Rick's there is a possibility that it can be mounted easily on the slope surface and the injection is actually given along the slope surface so this is particularly for you know wherever when we have highway a railway embankment which are actually constructed you know with the line and posing problems because of the swelling and shrinking cycles and in such type of cases the adoption of a this technique seems to be promising however in the field.

The injection of the line has to be done with an appropriate selecting the appropriate pressure and an appropriate quality of the line.

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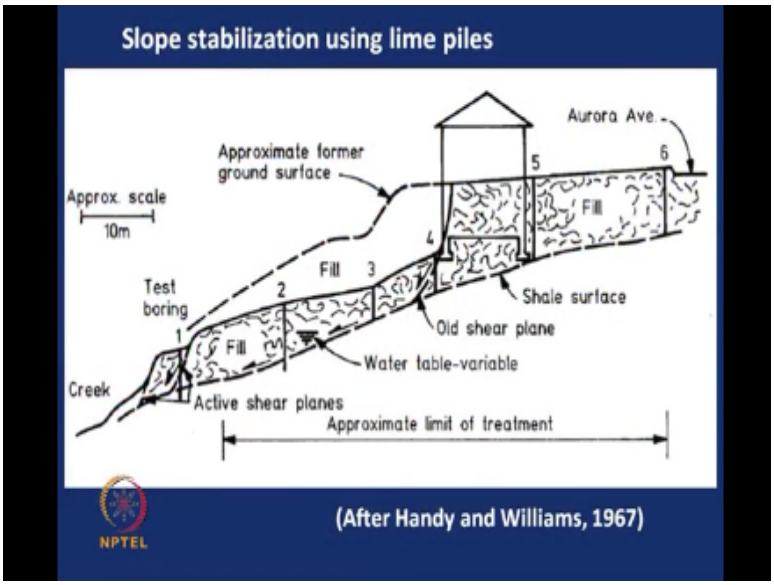

So this is a typical stops operation slope stabilization using lime piles which is actually shown here in this particular slide where you know the stabilization is actually adopted for a clay soil the approximate lime limit of treatment is actually shown here so in this one then the portion is actually you know improved with by installing lime columns.

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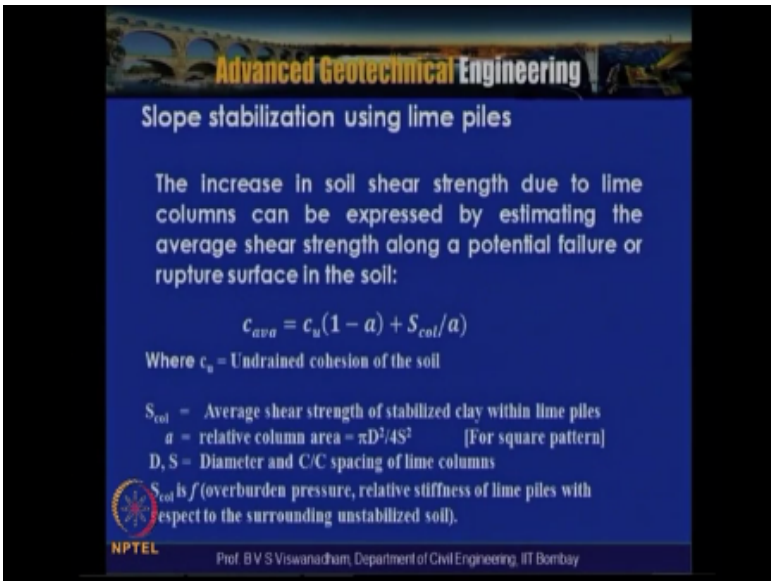

So the increase in the soil shear strength due to lime columns can be expressed estimating the average shear strength along a potential failure or rupture surface in the soil so this is actually obtained as C average is equal to see you into 1 -A +S column /A so here what is actually see you is the average cohesion so CU is the average untrained cohesion of the soil which is you know off the untreated or unsterilized soils column is the average distance of stability clay with inline piles and suppose if the columns are arranged in say square pattern.

And then let us say at it S be the spacing of these lime piles then the soil in between which is that the gain instant that is average shear strength of stabilizer k with within lime piles is treated as S column / A is nothing but there are two column area the column area which is nothing but π d square divided by 4 square which is nothing but π d square by 4 is nothing but the area of the area of the single line pile divided by S square is nothing.

But the area some covered by this line piles from there s is the center-to-center spacing of lime columns or lime piles and raise the diameter of the line column or lime pile this S column is basically is a function of war button pressure and real to stiffness of lime piles with respect to the surrounding unstable I say,so s column is found to be reported by Broms 1991 as a function of war button pressure and relative stiffness of lime piles with respect to the surrounding unstable soil so with this once we get the C average strength or a period of time let us say after elapsing certain time after the installation.

And this can be used for you know arriving at the enhance the effect on the increase in increase in the stability of a slope so lime treatment as a mix in place technique has been widely.

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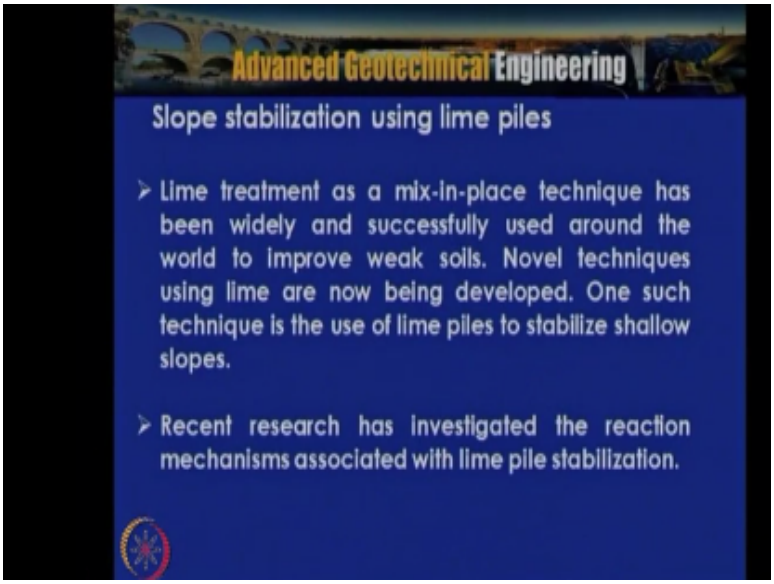

And successfully used around the world to improve week soils and normal techniques using lime are now being developed and also to add to this you know some modern materials like nonmaterial and which may be helpful in enhancing the performance and this soul I am use of line piles particularly if you are having a requirement of for the you know short term requirement which is which is not a long term stability of a slope.

But for a certain period of time and for stabilizing shallow slopes and use of lime piles seems to be very promising and recent research has investigated the reaction mechanisms associated with the line pile stabilization however with the current standard the further work is actually warranted in this direction to understand and quantify about the slope stabilization using the line piles so then that we actually have said that the another technique.

Which is a can be used for enhancing the stability of a slope are an excavation is by soil nailing technique.

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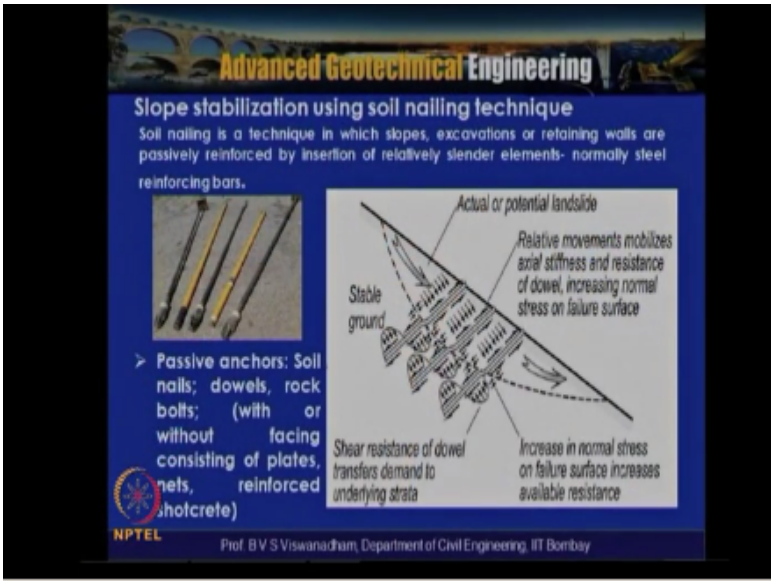

And this is a technique which is gaining popularity for the past four decades and as the soil leading technique is a technique basically in which the slopes excavations or retaining walls are passively reinforced by insertion of relatively slender elements the slender elements are nothing but normally steel reinforcement bars and they are passive anchors in the in which you know these nails are not priest rested and there they are actually soil nails.

Which are called as soil lanes and doubles and rock boots and this technique also you know in alight way it is used in stabilizing the rock slopes also and these nails are actually placed along the slope surface again in the you know two different patterns what is the square pattern where with the SH is the horizontal spacing between the nights and web is the vertical spacing and the length of the nail which is actually to be penetrated into the ground to be inserted into.

The ground is are commended in the range of 0 point 5 20 point 7 h where h is the height of the slope to be treated and this technique is very useful particularly when we are actually using you know when suppose if you are having an abutment we need the bridge and the road widening needs to be taken place and previously the abutments with say natural slope and when we wanted to widen the road then there is a requirement of the steepening of the slope in such situation there is a need for enhancing this by using this you know.

The soil nailing technique so in this particular slide this these are the no reinforcing bars typically shown and the different types of nails are there which we are going to discuss suppose if this is the potential failure surface and the this is a portion which is called as a stable ground or

this is say active ground or actual or potential landslide zone so what will happen is that the relative movements mobilizes axial stiffness and resistance of double or oil nail and increase the normal stresses on the failure surface and basically.

It enables you know mechanism which actually enables the develops the resistance again is the failure and the shear resistance of the double or a nail transfers demand to the underlying strata that is in the stable ground and increase in normal stress on failure surface increases the available resistance so here increase in the normal stress at this particular portion enables to increase the resistance to the failure along the East your surface in addition.

To this is actually in addition to the resistant offers offered by the soil so the in the soil nailing technique based basically they are, they are the passive anchors and they are inserted in the form of within the way they are standard slender elements they normally steel reinforcing bars and these are done with a with certain layout what is called as a nail layout and also their space they are you know inclined at a certain inclination.

And they also have been provided with certain facing which we are going to discuss so here the slope stabilization using soil layering technique.

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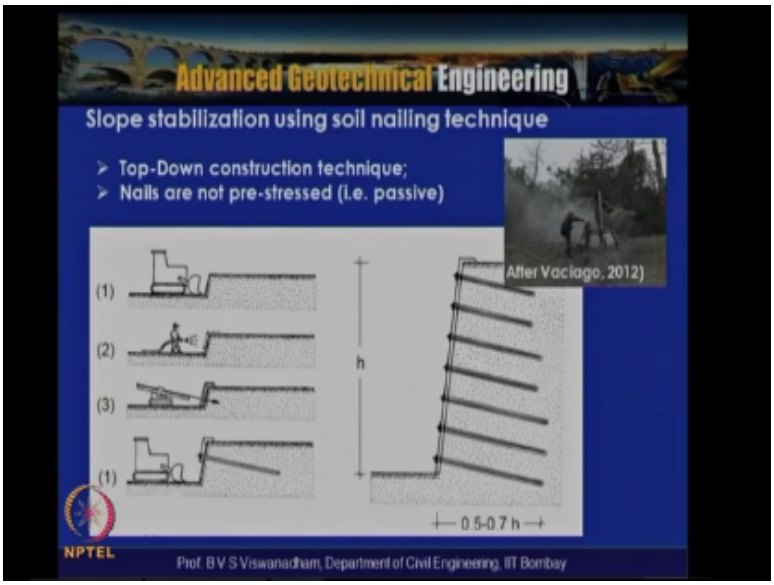

Wherein this is basically a top-down construction technique wherein in fact this is actually very useful for temporary showing purposes in underground excavations like suppose if you are

actually excavating a certain ground in a soil slope area so excavate the level one and then the next method is to you know provide a short preteen on the surface and then drive the nail or you know install the nail and then you know x squared further so like that one actually can do the installation of this noise from nail1,nail2,nail3,nail4,nail5,nail6 nail up to nail up.

To bottom of the other to of the slope in this fashion and this is a typical you know installation of nail by using you know fertility specific rig which is actually used in the field is actually shown here so the slope stabilization using soil any technique basically a top-down construction technique and as we have discussed the nails are not pre-stressed there they are basically called as passive elements which actually are used for stabilizing the slopes or excavation faces.

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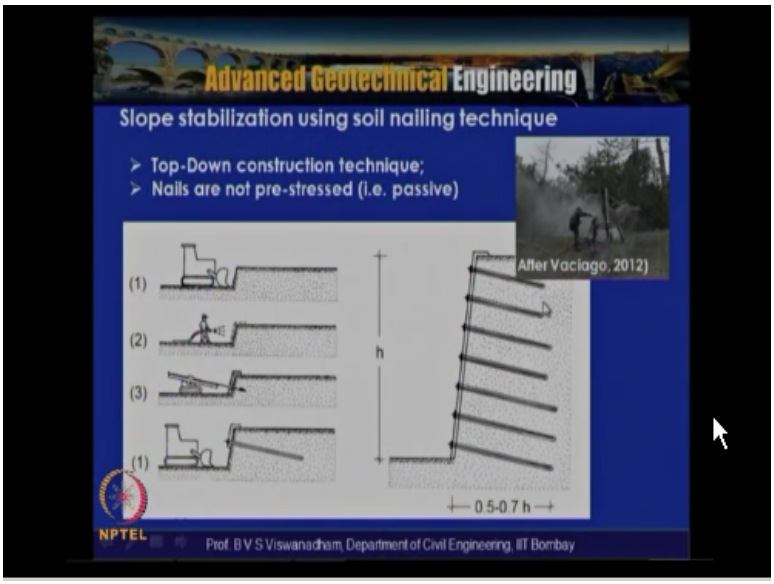

And the depending upon the requirement so there can be some curtailment of the length of the nails also can be done but this is that .t 5 to. 7 h the origin to the minimum required and this is the vertical spacing of these nails and along this slope surface the horizontal spacing will be there and this is the facing element which is required and there is at this portion where the nail is actually is bolted so that is where actually hear the head of the nail will come into picture and though the nails are actually inclined generally up to 15to 20.

But however this depends upon the back slope inclination and also this depends upon the slope inclination for vision is nearing nailing technique is used so various types of the soil layers in the sense that two popular types are driven and growl turning in the ground nail.

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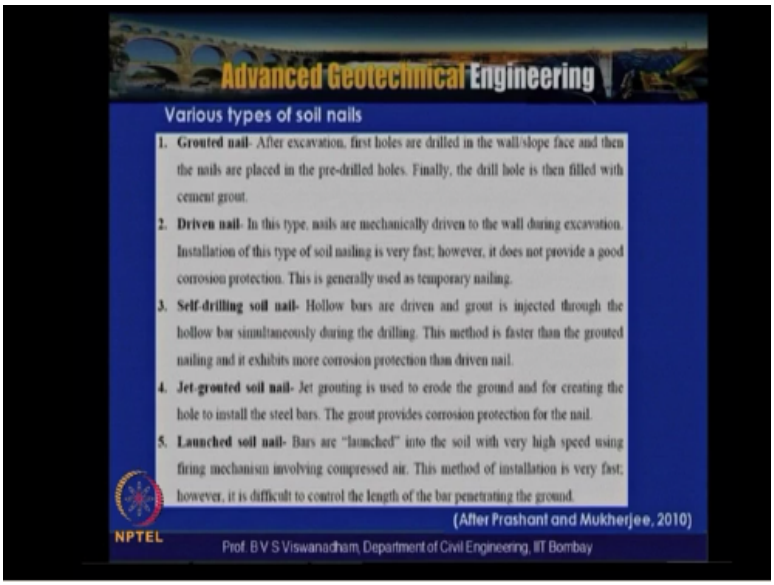

The after excavation the first holes are drilled in the wall or slope face and then in the nails are placed in the pre-drilled holes finally the drilled hole is filled with the cement plot so in this portion the entire length of the nail is actually filled with cement grout.

So the you know the placement of this cement grout also helps in you know bonding the nail grout surface with the surrounding soil efficiently so in the grout a nail after excavation the first holes are drilled involves in slow phase and then the nails are placed in pre-drilled holes at a particular inclination generally there are two types of you know placement of this grouted nails one is a routing one is the grout e driven grouting where in the Nitra the grout is allowed to flow with natural gravity the other one is the pressure driven installation of the grout.

So nowadays with the current research actually shows that the pressure driven grout found to be efficient because of the increase you know participation of the surrounding soil in mobilizing the

soil nail ground resisting shear stress the driven nails in this tape the nails are mechanically driven into the wall during excavation an installation of this type of nail soil healing is very fast the sense that the nails are placed at that they nail bars are actually fired into the soil however it does not provide a good corrosion protection.

This is generally used for temporary kneeling for example wherein we need you know some immediate remediation measure and then these driven nails can be used it very effectively and self drilling soil nails in the sense that hollow bars are driven and the grout is inducted through the hollow bar simultaneously during drilling so this method is faster than the grounded nailing and it exhibits more corrosion protection than the interval nails grouted soil a basically here outing is used to erode the ground basically.

The presence of water jets and a Jets will allow the creation of a sort of erosion at the tip where this is done and for creating the hole into the install steel bars and the grout provides a corrosion protection from for the name the launch its soil layers or bars are launched into the soil with very high speed that is what actually is called firing of the needs involving composite aid and this method of installation very fast.

However is difficult to control the length of the bars penetrating into the ground so depending upon the soil resistance so launching soil needs the other one is the driven nails so that popular types of nails are grouted nails and driven nails and the as far as the type of installation of grout is concerned the jet bloated soil lane is another type and other one is called self drilling soil need where hollow bars are driven and the grout is injected through the hollow bar simultaneously during drilling so as we have discussed that there are two you know zones.

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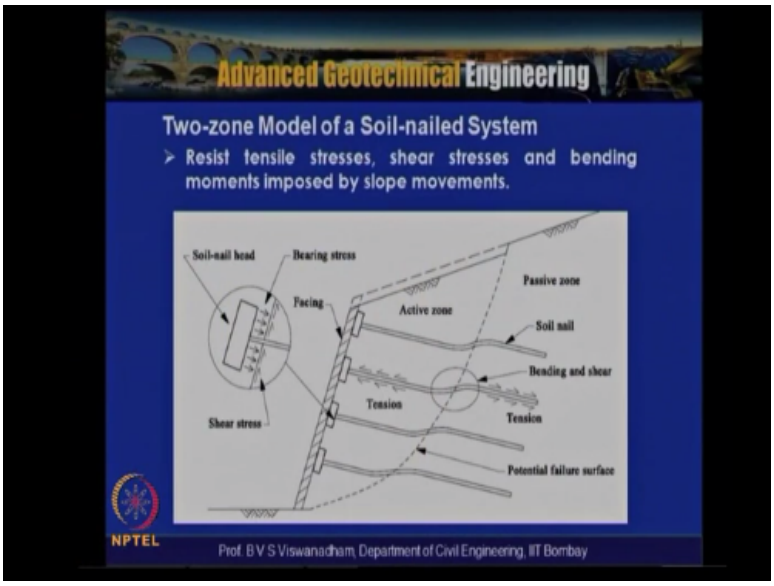

For the in the soil nail system wherein we have here active zone and then passive zone so with the movements which are actually happening in the slope in the active zone the nail publishes resistance in the form of tension as well as the shear and bending so the slope which actually is a you know reinforced with soil nailing resisted tensile stresses shear stresses and bending moments imposed by the slope movements.

In the process what will happen is that the slope will get the enhancer instability and the possibility of occurring or attaining steep slopes can be achieved can be obtained so here it is also the it also depends upon the resistance offered the bearing stress offered by the facing at the nail head that is this portion which is actually shown here so and then the shear stresses which are actually mobilized at this area also you know corroborate for the you know functioning of this you know the soil layer system.

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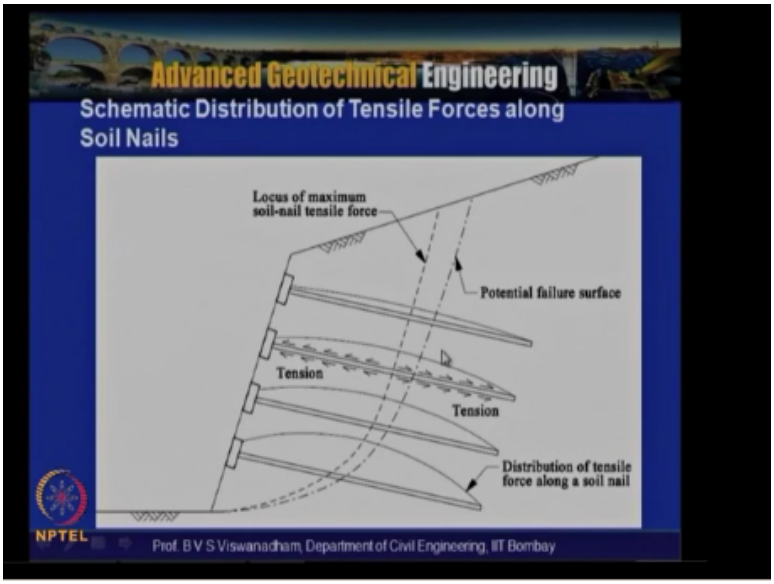

So this is in this slide the schematic distribution of tensile forces along soil nails are shown here and it is shown here the tension is mobilized along the you know nail length like this and almost zero at the zero at the facing and zero at the other end of the kneel and this is the you know potential failure surface and this is the line of the maximum soil nail tensile forces and the force is supposed.

To be maximum the distribution magnitude will be high here and as you go come to the top the mobilization of the nail in tension force will be less here but if the length is not adequate beyond the active zone area there is a possibility that the nail is actually subjected to float fail you so in this one of the checks is to also to do a institute load tests to ascertain the load capacity of these nails with that the nail capacity can be ascertained and another possibility is that the given soil layers are installed and there is a can be clubbed with an instrumentation.

So with that these monitoring of this soil nail wall system can be our soil layered slope system can be achieved so before looking into that the potential failure modes of a you know soil nailing system can be seen there are basically two types one is called external failure and internal failure.

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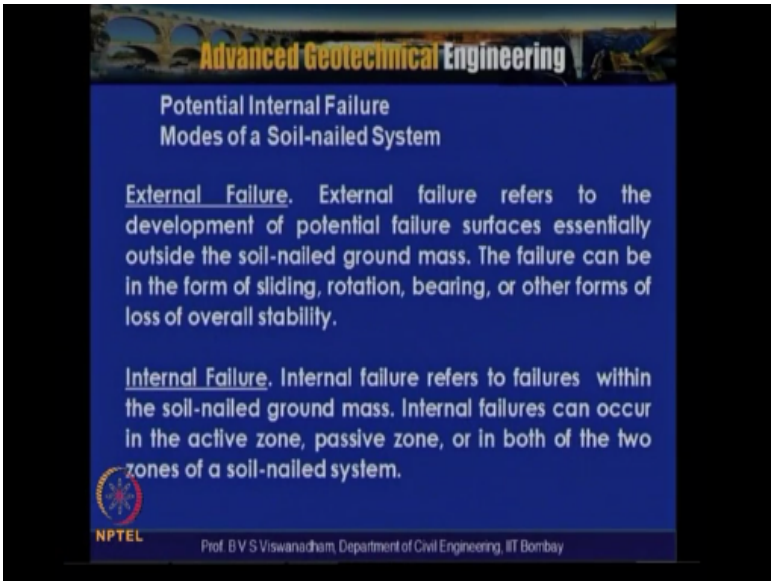

The external failure refers to the development of the potential failure surface essentially outside the soil net grout groundmass so and the failure can be in the form of sliding that means that entire soil nail block including the up to that means that up to which the length will the nails were installed the sliding can take place and rotation are bearing particularly if the ground which is housing this particular structure say is not having adequate bearing capacity that bearing failure can occur or other forms of loss of our stability.

So external failure basically refers to potential failure surface essentially outside the soil near ground surface and the failure can be in the form of sliding rotation or bearing or other forms of aura or global stability the internal failure refers to failures within the soil layer groundmass so that means that it can be you know breaking of the nails or breaking of the nail head and in the within the active zone basically the interface occurs within the active zone and a passive zone basically occurs.

In the form of a float it takes place or in both of the two zones of the nail system so internal failure can actually happen in active zone as well as in passive zone that is passive zone or the stable zone beneath the active zone so in both the are in both the zones of a soil nail system so in the active zone basically the internal failure mode include a failure of the groundmass that means that the ground disintegrates and the flows around the soil nails and the soil nail heads.

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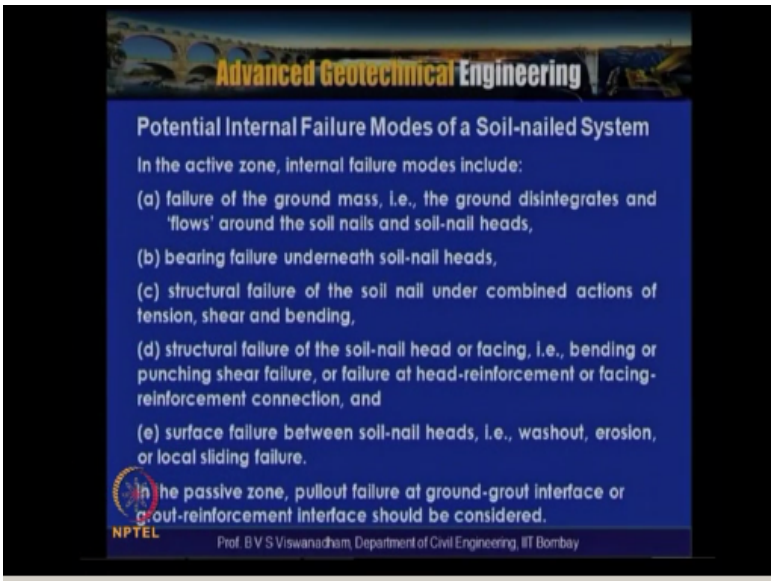

And the other thing is that bearing failure underneath the soil nail heads that means that if the facing is not having adequate you know load carrying capacity and then there is a bearing failure can occur and the structural failure of the soil nail under combined actions of tension shear and bending that is that the structural failure of this so the adequate if the a structural capacity of the soil is inadequate then the structural failure of the soil nail can occur under combined action of tension shear and bending and structural failure of the soil nail head are facing.

The bending or punching failure can actually occur or failure at the head reinforcement or facing the reinforcement connection and surface failure between soil nail heads washout erosion our local sliding value there can be happen because of the event seeping of water the local failures can actually open erosion and lock and sliding value in the passive zone basically the job beneath behind the active zone the piloted failure at ground grout interface possibly.

This occurs at the top surface of the slope or wall and up the grout reinforcement remains basically should be considered so in this particular slide what we have seen is that in the active zone the internal failure modes include failure of the groundmass basically and the bearing failure underneath the soil heads and the structural failure of the soil nail under combined actions of tension shear and bending and the structural failure of the soil nail headland the surface failure between soil in heads and then other in the passage or what we said is that the plot failure at the grout ground interface or grout reinforcement interface.

That means that if the reinforcement bar is pulled out of the grout surface that also can occur within the within the soil lane or if a plot failure can also occur between the grout and ground surface also so two modes of failures can actually be possible when we are actually having a failure in the passive zone as far as the pullout failure is concerned so here the whatever we have discussed it is all shown pictorially.

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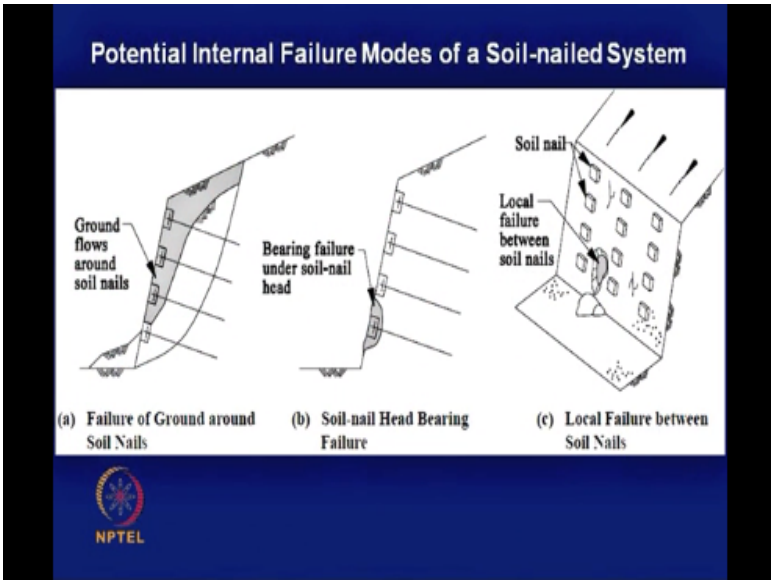

This is the potential internal failure modes of a soil system wherein the failure of the ground of soil nails is actually shown here where the failure surface passing through the needs and ground flows around the soil nails so we are in you can see that this failure of the ground around the soil layers can be seen and in this soil nail head bearing failure where this portion of the nail got punched or failed this is a bearing failure under soil nail head can also is one of the failures and the other one is that local failure between the soil needs that is the facing element failure basically.

Here and this can actually cause because of the inadequate phase in thickness and this is the local failure between the soil nails.

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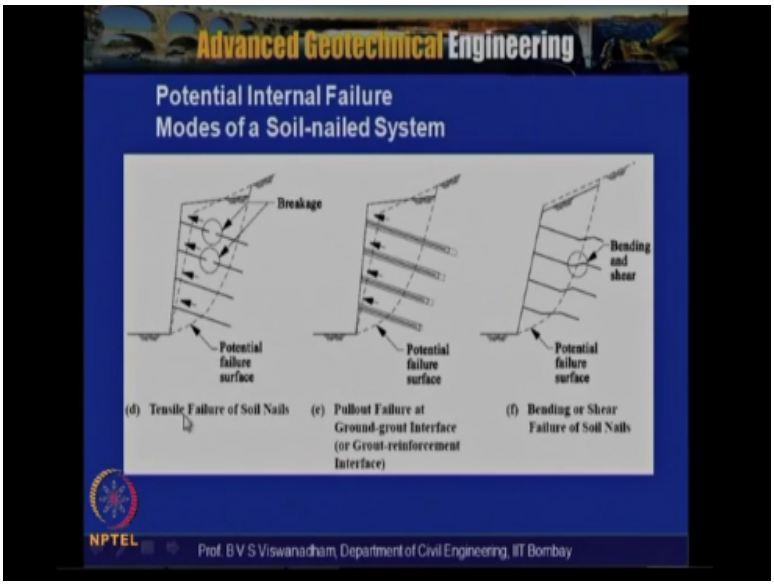

The other one is that tensile failure of the soil it is because of the rupture or breakage of the soil nails can take place with that what will happen is that the nail the slope surface moves this forward and then there is a possibility of the instability and their float failure of the at the ground grout interface that is ground and grout interface that is here which is can possible and a grout our grout interface grout reinforcement interface.

So these things will lead to again the slope to move outward and then undergo failure then we have bending or shear failure of soil nailed suppose if the installed soil nil's not having adequate bending and the resting against the shear then there is a possibility that along the potential failure surface there is a possibility of the bending and a shear can be observed which can lead to you know the failure so with the locus of the maximum tensile force mobilization then matches with the failure surface at this location here similarly.

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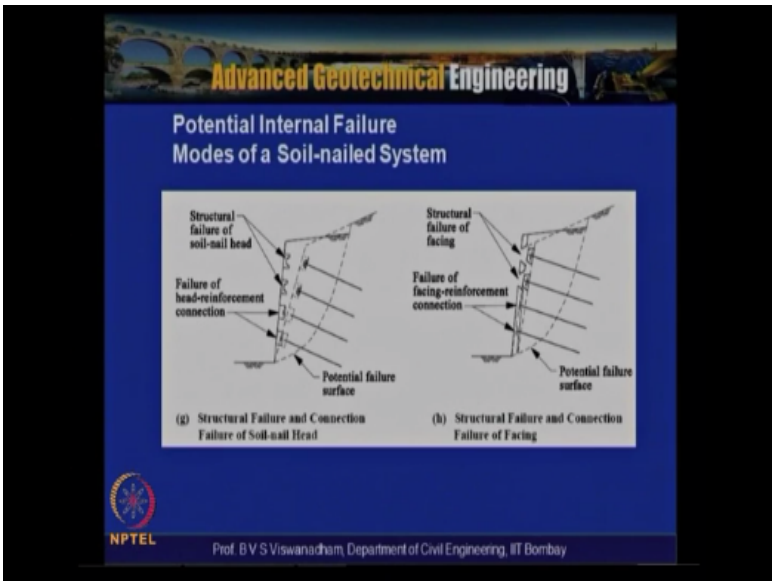

Here for the potential internal failure modes of a soil system in a continuation and this is the structural failure of the and a connection failure at the soil nail head that means that nail and the soil head we can get detached and then the slope surface can actually you know can deform so here this is the structural failure connection or failure of the facing wherein you can see that the structural failure of the facing the facing is subjected to failure and here failure often facing reinforcement connection .

Which can actually is depicted here so these are the typical internal failures of failure modes of a soil aid system.

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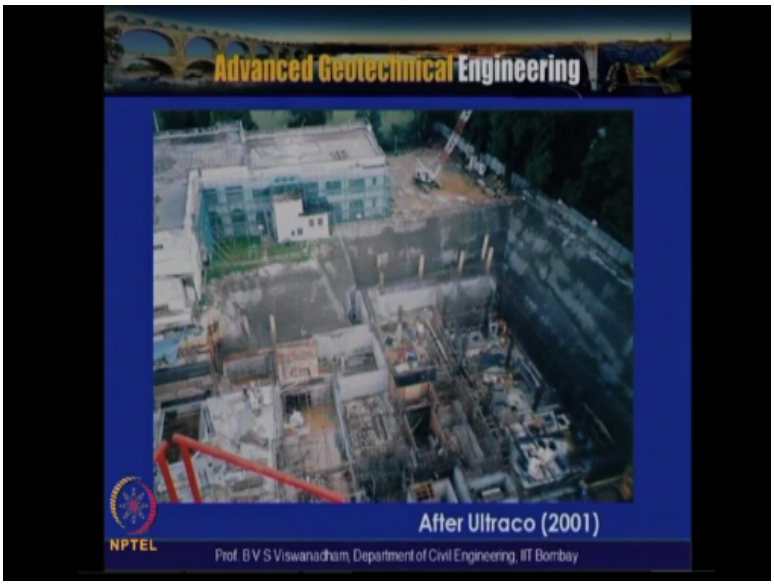

So in this particular slide atypical you know use usage of this technique for installing this usage of this technique for slow production in an underground excavation is shown here what you see here is a is a short treated surface and then the nails are actually placed here particularly with the presence of this buildings.

Which are close to the slope surface and this seems to be a very viable and then which is required because the protection of this slope is very important and to safeguard the existing structures also to facilitate the construction in the area of the interest so here this is atypical example which is actually shown how the race of the ground water table and infiltration of the rainwater create seepage pressures within.

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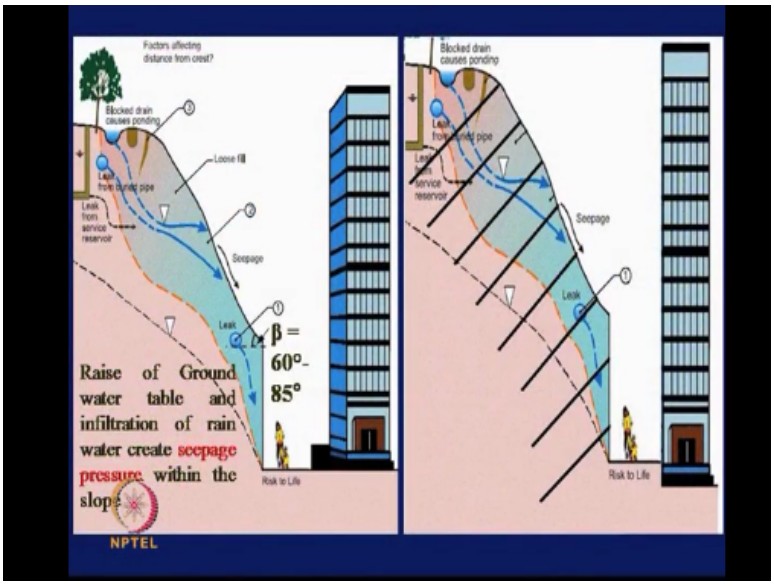

The slope and with this what will happen is that when the buildings are actually constructed close to the hill slopes and this type of slopes are prone for you know can cause instability venues and with the surrounding soil is the slope is actually made of slope then the adoption of a soil nailing technique for this is a viable option wherein you know this technique and shows that the slope is actually is you know protected and then you know the safety can be ensured.

So this is a typical application for this but however the effect of the raising ground water table and the soil nail ground interaction need to be addressed so that the you know this can be attended properly so the another application of this technique is to you know using for railway the suppose.

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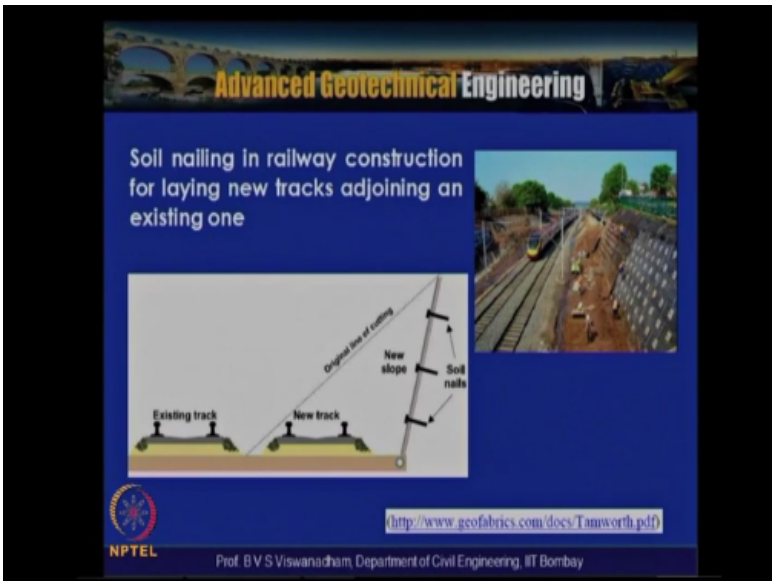

If existing tracks and new tracks had to be late then when it is in cutting need to be widened or steep and so in the process what actually happens is that for placing the new tracks and then the slopes can be protected by using this technique so here the different facings are used sometimes we are wire mesh fencing or in gabion wall facing or there is you know a you know these are the plates which are actually head and these are the nails so you can see that the nails are actually placed at a certain horizontal and vertical spacing covering.

The entire area so this ensures that the stability of a this particular slope and you know helps to you know creating additional space for laying new tracks and all so this is a typical cross-section of a drill soil nail slope is shown here.

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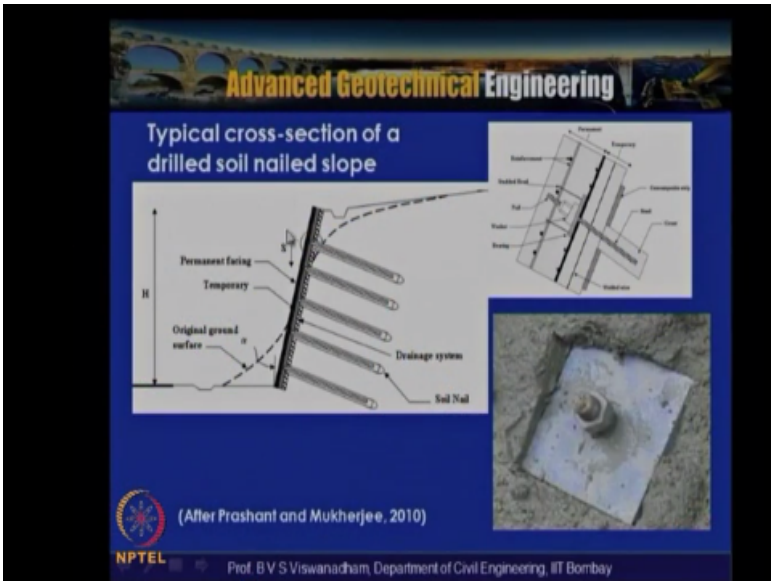

And where this is the facing and some geo composite drains are used to facilitate the drainage of water rainwater and this is the close view of the nail head along with the nail bolting arrangement so this is the nail head and L bolting arrangement you know detailed view is actually shown here.

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So this is a you know how the construction of soil nailing is shown a typically preparation of the slope surface and mobile drilling rig a alignment and I in mind and driving of the name and then installation of the steel bar and then grouting process this is shown basically to acquaint with the how the construction happens in the field.

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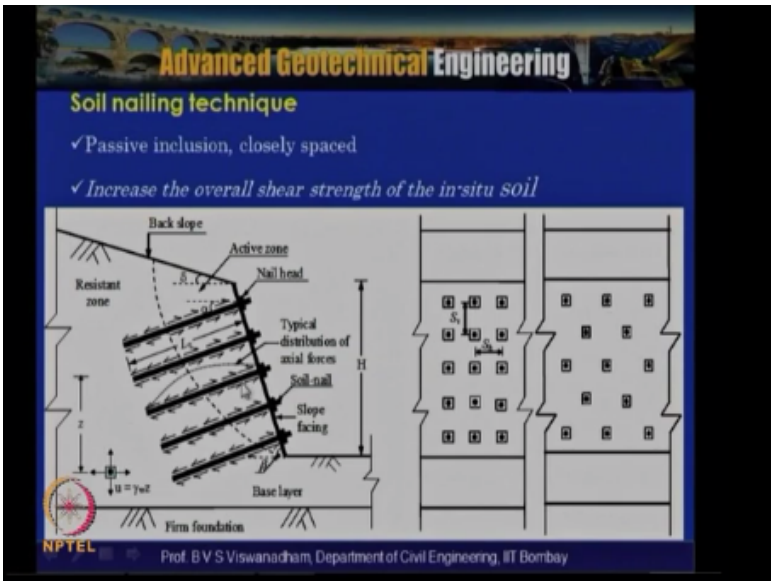

So now looking into you know the how you know the type of you know what should be the inclination and what should be the you know the length of the nail and what should be the facing how you know these actually affect on the you know slope stability parameters can be looking to eat so as we have discussed with that soil nailing technique particularly the passing pollution technique and these are closely spaced along the horizontal surface and 2,2 patterns.

Are possible one is Square and other one is a staggered arrangement wherein a 2,2 patterns are possible one is a square arrangement where they has such is the horizontal spacing SP is vertical spacing and this is called as a staggered arrangement in which the nails are actually spread out over the surface and with the mobilization of a slope movements in the active zone the forces tension shear and bending are actually mobilized in this nails and the resistance is actually developed the way it's actually shown here.

So when there is an increase in ground water table within the slope either due to rainfall water in full infiltration so there is a possibility that the forces in the nails get enhanced.

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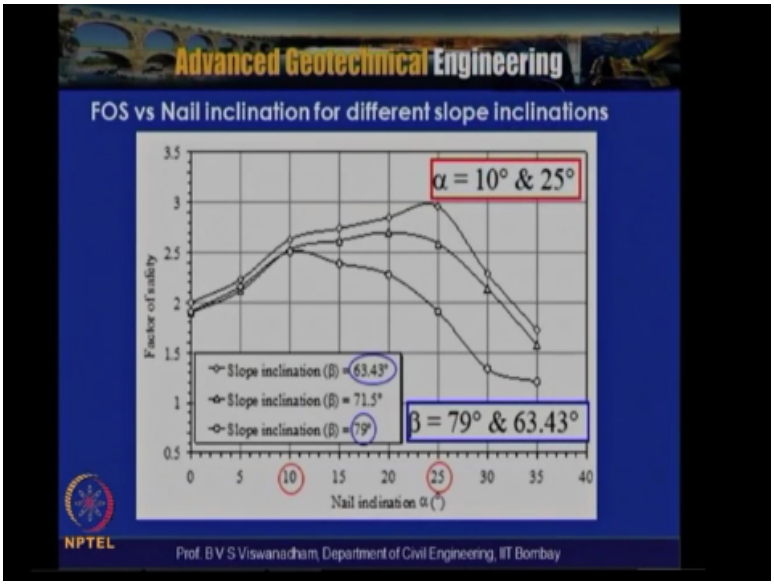

So here in this particular slide the factor of safety of the need inclination for different slope inclination is shown here so here two very steep slopes are considered one is 63.4 three degrees which is nothing but two vertical one horizontal the other one is 79 degrees slope inclination which is five vertical one horizontal so as can be seen that with a back slope of inclination of zero that is the slope surface is horizontal.

You can see that as the Nail inclination increases there is increase in factor of safety and then there is further decrease in the factor safety so this implies that there is a certain optimum inclination for which actually the factor safety is high so this analogy is actually performed by incorporating nails and by using the modified bishops method of slopes measures method of slices and with this with this the factor of safety of a soil nail slope concept based on limit equilibrium approach could be obtained.

So it can be seen that for a nail inclined at 10 degrees for a slope of ink relation of 79 degrees it found to be optimum and for a nail inclined at 25degrees for a slope inclination of 60 degrees for found to be optimum you can see their further increase in the you know nail inclination lead to the decrease in fact safety so it must we must remember that the nail inclination need to be selected based on the slope configuration whether it is with the back slope inclination or with a slope inclination and in this particular slide two different thicknesses like four different thicknesses are actually considered.

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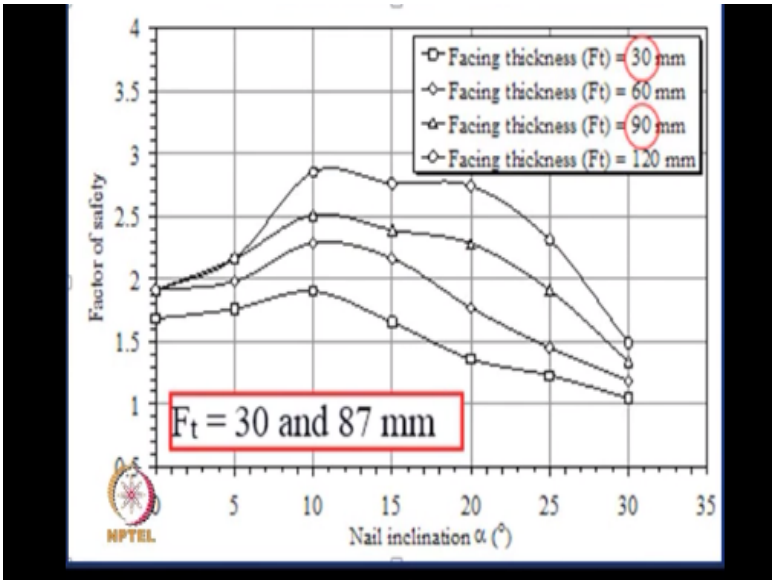

With an increase in thickness of the facing the factor of safety was found to increase so you can see that the with an increase in thickness the thickness of the thickness of the facing then the nail you know the contribution of facing in enhancing the stability of a slope can be seen.

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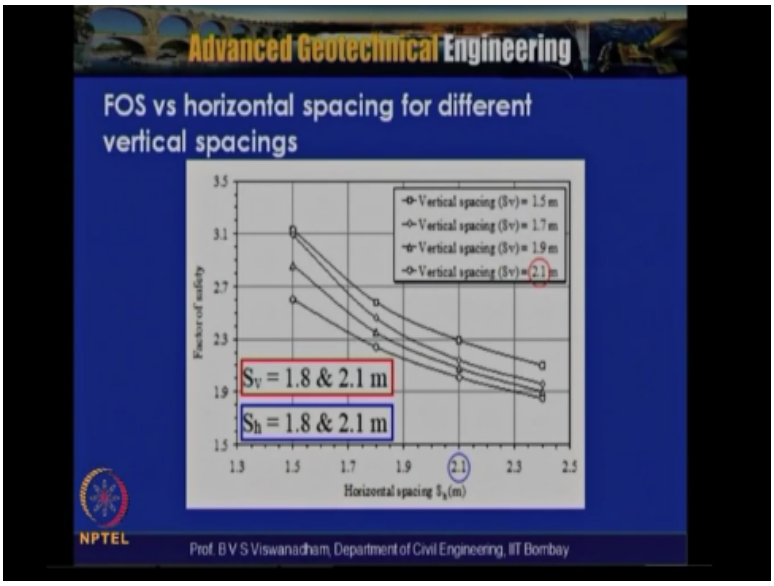

And if you with a variation of horizontal spacings let us say that you know for our general spacing of 1.3meter to 1.5 meter and when the odds are vertical spacing is increased for example here with a vertical spacing of 1.5 meter so what you can see is that with an increase in vertical spacing there is a decrease in the you know factor of safety so it can be seen that say for example with the vertical spacing of say horizontal spacing of 2.1meters and vertical spacing of 2.1meters the factor these with an increase in vertical spacing days a decrease.

In the factor of safety which actually can be seen from this analysis similarly here the diameter of the nails so basically we said that the reinforcing bars are used and these are enforcing bars are actually having the you know different inclinations, different inclinations as well as the different diameters.

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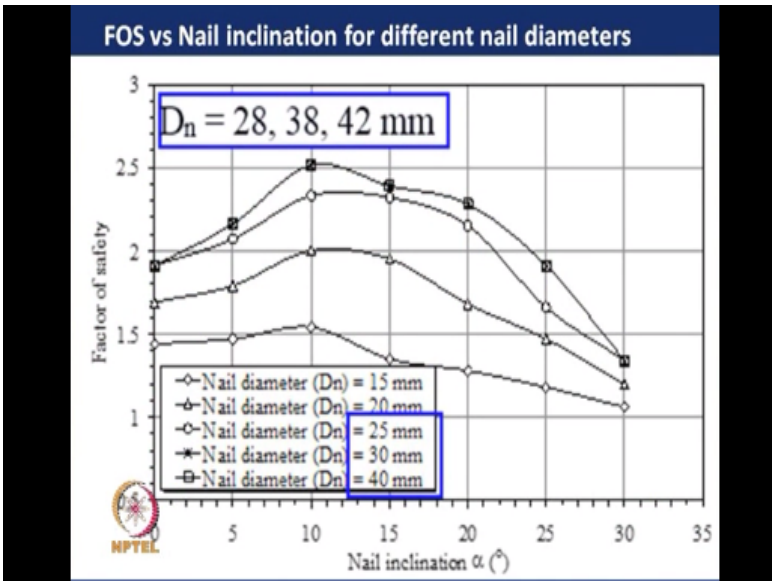

So particularly these reinforcing bars from 28 38 42 mm these are the nominally available materials they toured straight bars they are used and so as can be seen here with the increase in the you know diameter for example here this is for you know the this is for the Nail diameter of 20 mm and 15mm their increase in the factor of safety and this also found two you know the rain inclination also found to have the similar effect parade for a 60-degreeslope inclination which is actually shown here.

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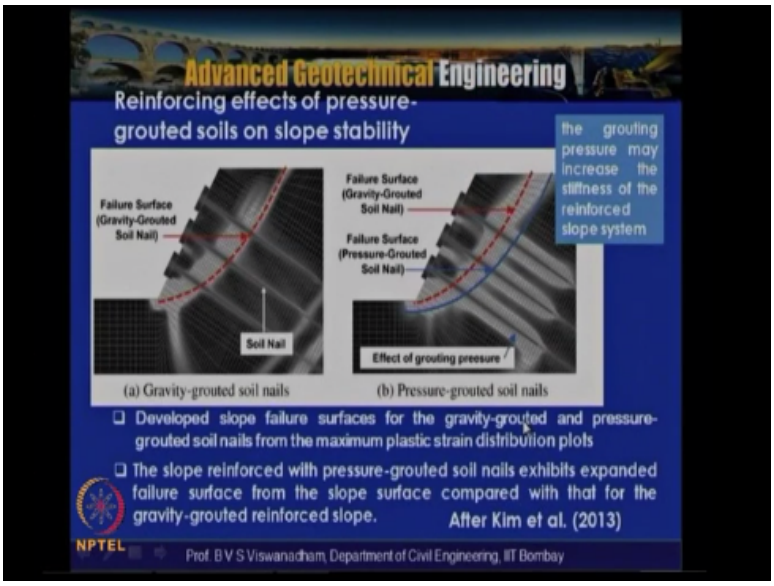

So in this particular slide the influence of pressure grouting on the slope stability is actually shown the reinforcing effects of pressure grouting on the on the slope stability so here in this affirm analysis of a gravity grouted soil nails is actually shown here and this is the failure surface of the gravity grouted soil layer surface and this is again super imposed here and this is in this is the pressure grouted soil nail surface so this is at all this is after metal 2013 where the developer slope failure surface for the gravity grouted and pressure grouted soil is from the maximum plastic strain deformation plots.

So these are actually failure surface were actually developed for the gravity grouted and pressure grouted soil nails from the maximum plastic strain distribution plots and the slope reinforced with pressure bloated soil nails exhibits expanded failure surface the failure surface was found to move towards the you know passive zone or a stable zone and compared to that of the gravity grouted in for slope and the grouted pressure may increase.

The stiffness of the info slope system so what is happening is that the grouting pressure influences and in a big way in enhancing the stability of slope because the surrounding soil is you know relatively compressed or compacted and offers higher resistance across each nail and that makes the pressure grouted soil nails for how to perform grouted soil lane stabilization technique for found to superior than the gravity grouted soil stabilization technique so with this what we have understood is that the reinforcing effect of the pressure grouted soil nails are

superior in enhancing. This slope stability of atypical slope which is actually shown after Kim et at 2013.

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So this is a you know adoption of the soil nailing technique for a water treatment plant in one of the sites in Kerala and we are in this is the slope of about 24 meters height and we are in at the top of the slope a hundred kilo Pascal's you know unit which actually imposes a load of under glow Pascal's water tank was actually place for supplying water by gravity method to the surrounding villages so the soil is basically a lateral type of soil and which actually get softened during you know the interview in the rains particular the ingress of rainwater.

So we can it can be seen that the patches of water seepage can be seen here so here in this you know a spacing of 1.5 meter by 1.5 meters adopted for a typical you know nail lengths and nail inclination is an optic and by this analysis was actually were carried out by caldron you know software which actually includes the effect of the solid nails in the modified method of Bishop modified bishops method of slices we are in the this is consideredand the this particular site was actually you know done basically to increase.

The stability of a slope to carry the additional load of 200 kilo Pascal's at the top of the slope and to house the water tank at a at the top of the slope so then another you know stabilization technique what we have discussed it is called biotechnical slope stabilization technique.

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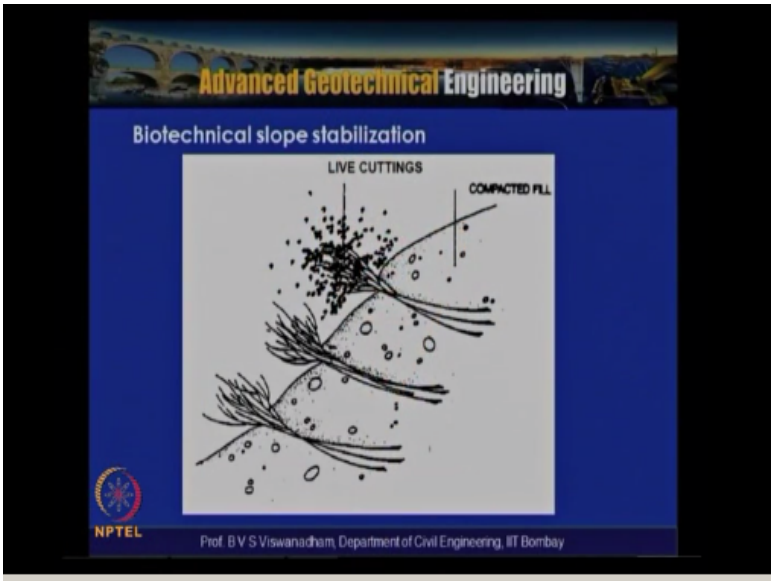

And which is gaining popularity and we're in here a selected you know seeds were placed along the slope and these the roots of these plants are penetrated into the ground and then the group surrounding soil interaction our found to enhance the stability of aslope so very recently also some of the live polls are actually used for enhancing the stability of a slope and we are in these are actually used for improving the stability a one of the natural way of these using the technique of vegetation the vegetating the slope surface and enhancing the stability.

So in this particular slide a typical you know live cuttings and a compacted fill is shown and mostly this is actually adopted for as well as for natural slopes of man-made slopes so this actually and shows the green effects surrounding the areas then in this you know this typical combination of you know nowadays is combined with erosion control blankets these erosion control blankets are embedded.

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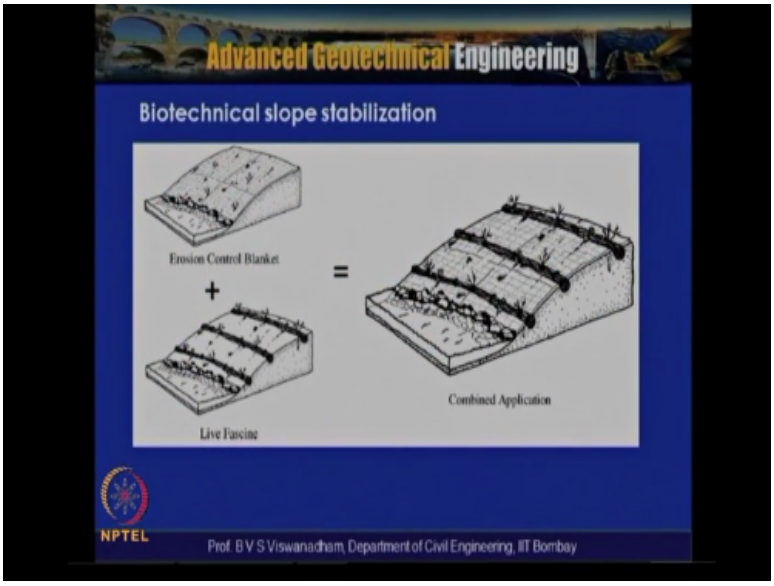

With materials like jute which is jute orchid which are actually placed on the subsurface in a in a blanket form and they are actually also you know attached to the sloped surface in the form of a packing and then life essence for place and planted which actually helps you know the combination of combined application actually we are in both you know erosion control blanket and life I since helps in maintaining the slope stable so here these are actually adopted as also the combination of even soil nailing or you know or by using.

You know your cell on the slope surface where the erosion also can be controlled and as well as the life essence can be used for enhancing the stability of a slope.

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So in this particular slide what actually has been shown is you know a particular slope how it actually has been you know created by creating a steps and small berms here along the worms these you know selected plants are actually placed and then after you know this is a typical retriever glass system after certain time it can be seen that you know these growth of this grass actually tons this entire area green and this is you know a one of the promising area for the you know slow civilization where the lot of work is actually also happening.

So in this slope stabilization techniques you know particularly after having discussed the several causative factors of the slope failures what we have understood is that a different types of you know methods are therefore enhancing stability of slopes like you know simple techniques of you removal of the you know materials from the head of the slope that is the you know replacement with you know heavier material with lighter materials or by benching the slope at the top portion that also can actually enhance.

The stability of a slope or we also said that the use of light materials like zone helps in enhancing the stability of a slope then we also discussed it that you know there are methods like drainage techniques in this there is some surface radius techniques and subsurface drainage techniques and this is a prime and important technique where if the slope is actually some has efficient of drainage system the stability of a slope can be enhanced nowadays you know the techniques of combining reinforcing the slope as well as you know facilitating the drainage these are actually called as hybrid way of establishing.

The slopes are in vogue and not being research it widely and then we also discussed about a typical technique of stabilizing the slope by using stone columns or gravel drains so they these stone columns are proud rains work for you know as a dual function one is that to drain the you know also the these stored columns can also function as a gravel drains to drain the water and also they can increase the resistance against the slip and increase.

The amount of resistance in addition to the soil shear so they can actually have you no further effect enhancing the stability of a slope as well in reinforcing the slope as well as a facilitating as a drain is actually something called you know deep trench drains and another technique what we have discussed it is that you know a type of technique by using chemical hardening wherein the technique of you know using the line and lime slurry injection a line columns is one technique way of seeing and in addition.

To that there are also some technique like use of electro osmosis that means that by placing the you know the electrically charges from positive charge and a to charge and this actually also helps in you know in improving the stability of a slope the piece that the slope the water is actually drained by maintaining a electric potential between the anode and cathode and that makes the you know the slope surface hardened and increases the shear strength of the soil and then we also discussed today one of the techniques.

Which is a soil nailing technique wherein this is an institute or enforcement technique which can be adopted for existing slopes natural are also man-made slopes like I have a railway magnets which are required to be protected or stability to be enhanced and this also technique can be adopted for you know existing slopes are slopes to be exposed for excavations as a shore protection systems a very this is a type of showing for the you know showing technique for enhancing the stability of a you know a particular slope and this can be done both for the installation the nails further in this technique is done from top to bottom construction so nails are actually instead of from top to bottom up to the of the slope and the finally we have actually disgusted with regarding the biotechnical stabilization technique where in this technique allows to maintain the you know a selected machines or grass systems can provide the stability of a slope in a better manner.

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