Earthquake Geotechnical Engineering

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Lecture 56

Ground Improvement Techniques: Geosynthetics

I welcome you again for this NPTEL online lecture on Earthquake geotechnical engineering. We are at lecture number 56 that is the last module of this course module 6 and we are discussing the chapter second which is on ground improvement using geosynthetics. So, we continue with this and what we are going to cover during this lecture on geosynthetics as well as soil nailing. So, topics which we are going to talk during this lecture, first one is manufacturing of geosynthetics that how these geosynthetics are manufactured. Then we are going to discuss the functions of geosynthetics that is basically applications. Then we are going to talk geosynthetics specific applications.

Then modeling of geosynthetics particular for dynamic analysis for dynamic loading when you have the seismic loading or dynamic loading how to analyze that. Then one of the specific tasks which is related to of course, not for geosynthetics, but in general soil reinforcement using soil nailing. One of the technique which is getting quite popular is soil nailing. When we talk about soil nailing, we are first going to introduce introduction.

Then we are going to discuss their construction sequence that when you use the soil nailing, what should be the sequence, then their advantage and limitations will be also we discussed. So, let us first talk about geosynthetics. As we discussed in the last lectures, geosynthetics are made of synthetic polymers such as polypropylene, polyester, polyethylene, polyamide, PVC, etc. These materials are highly resistant to chemical and biological degradation. So, it is not easy to degrade these materials like polythene, polythene which is quite popular, polythene is not degradable material.

Fiber can be continuous filaments which are very strong strands of polymer, stable fibers, short filaments typically 20 to 30, 20 to 100 millimeter long. Fiber may also be produced by silting an extruded plastic sheet or form to form the flat tabs. The extrusion increases the fiber length along its direction thereby its strength. Now, functions of geosynthetics, what are the different applications of geosynthetics? Geosynthetics have numerous applications particularly in the area of civil engineering and they always perform at least one of the following major functions when used in conjunction with soil, rock or other types of civil engineering related material. So, first of all we need to understand, we already

discussed in the last lecture geosynthetics are synthetic material which is used with soil, rock or other material.

If it is synthetic material only, if you are not using the soil or earth then it will not be called geosynthetics. Then the different types of functions you could require only one of them or a combination of these two is used. So, one of the functions are listed here was separation, then you have the reinforcement, filtration, drainage, fluid barrier, protections. So, we are going to discuss one by one different functions. If a geosynthetic prevents intermixing of adjacent soil layers with the different properties during constructions and the projected service period of the geosynthetic reinforced soil structure, it is to have a separation function.

For example, it is here. In this slide with the figures it is illustrated how the separation functions act. For example, here you have this granular fill which is made of gravels looks like this one and then you have soft soils. If I place the gravels on the top of the soft soil then what will happen due to its overburden pressure of the gravels, the gravels will penetrate inside the soil. And suppose if your objective due to one or other reason is that that you do not want that these gravels to penetrate inside the soil.

So, in that case what is the one of the remedial measures is done that you put a layer on the top of the soft soil and below the granular fill which is this is the layer is of geosynthetics. So, this is the layer of geosynthetics which could be geotextiles, or it could be geogrid, then you have the soft soil here. So, what is shown in the figure? Separation function which is granular fill and then soft soil system without geosynthetics and with geosynthetics. So, after using geosynthetics you can keep the soil separated from the granular fill on the top of it. Continuing with the application part, a geosynthetic shows its reinforcement function by increasing the strength of soil mass as a result of its inclusion.

So, when you are included inside the soil mass some geosynthetics, then in that case strength of soil mass will increase and as a result it will maintain the stability of the soil mass also. A geosynthetic may function as a filter and in that case allows for adequate flow of fluids across its plane while preventing the mitigation of soil particles along with fluid flow. So, we already discussed whether geosynthetics can also be used as a filter or it can be used also for to drainage. So, in case of filter the flow of water is perpendicular to the geosynthetics, but in case of drainage the flow will take place along the geogrid geosynthetics or geotextile. For example, here is application of geosynthetics and in this application what we can see you have a soil slope, and this is like slip circle or you can say potential failure surface. Now, when you put a layer of geosynthetics here, this side as well as this side, in that case this layer of geosynthetics will help you to protect this slope because it is connecting actually what is happening this part of the soil slope tries to move away from it. Now, what you do, you try to bolt, fix this ways with respect to the remaining

part of the soil. So, it is like helping in making this slope more stable. So, the stability of the slope is increasing. So, this technique of use of reinforced function.

Another use of geotextiles is filtration function where you see you have drainage stones and then you have the natural soil. Natural soil is on the left hand side while drainage stones is on the right hand side. So, what happens, the natural soils may have keep some water moisture. This moisture will come out of it through the layer of the geotextiles. If you do not keep this layer of geosynthetics in perpendicular which is shown here, in the absence of this layer, the soil particles when the water flows then it will also take away with this the soil particles.

As a result, then erosion will start. So, and then it may damage these drainage stones which are used for the purpose. So, this was about filtration function where geotextiles are used as a filter. Then another application of the geotextiles is in the drainage function that means, when you have how to drain out the water. If a geosynthetics allows for adequate flow of fluids, it is said to have a drainage of fluid transmission function. For example, in the figure which shows that the geosynthetic layer which is adjacent to the retaining walls collect water from the backfill and conveys it to the weep hole made in the retaining walls. So, here water is collected from the backfill if it is saturated or partially saturated and on the top of it rain water comes. So, all together this water will be percolating to this space between retaining wall and the geotextiles. So, this is space and here as the water level little bit increase in this piping then what will happen, the water will come out through the weep hole. So, this is that how the weep holes work in the field weep holes themselves like they are not weeping it is the name suggests rather than through which water is coming out drained out.

Then a geosynthetics may also act an almost impermeable membrane as far as the flow of fluids is concerned. So, for example, figure which is shown below you have in this case, you have one side natural soil and then the top of it you have liquid waste. Now, what happens, your objective is that due to this liquid waste the natural soil should not be contaminated. So, if I dump the liquid waste then all the soil will get contaminated for example, in a pond or in a lake. So, what is done here, a layer of geotextiles has been used as a fluid barrier function.

Now, because this is impermeable layer, so it will not allow to go the liquid waste inside the natural soil. So, that is one of the application fluid barrier function. Then there are some specific applications beside that. A geosynthetic may also perform one or more than one of the following functions in some specific field applications. For example, first one is called protection.

Whereas geosynthetics is used as a localized stress reduction layer to prevent damage to given surface or layer. So, it is protection. So, basically, objective of using geosynthetics

in this case is to protect, it will act like a protective layer. Then it can also be used a cushion and when it may say cushion, so its material will try to help in damping out dynamic mechanical actions. So, basically, when you provide the cushion, it is expected that the damping properties of the system has increased.

So, it provide more damping and once you have in the system more damping for given loading, then what will happen, the energy will dissipate fast. Then another third objective function could be absorption, where the water is absorbed in the process of fluid being assimilated or incorporated into geotextiles. Then you have interlayer, which is a function, it is a function performed by geosynthetics to improve shear resistance between two layers of geosynthetic products or earth materials. Now, one of the like, how suppose geosynthetics layers are known to you or you made a model with geosynthetic material, geosynthetic layers and you want to conduct dynamic analysis, how to conduct the dynamic analysis, which we are going to discuss. In this simplified foundation model is used for geosynthetics, which is basically geogrid or geotextile, and which is reinforced granular fill over soft soil.

So, here is the case, here is a schematic diagram of 1D model and the definition model parameters. So, what you have, you have the soft soil, on the top of the soft soil you have the two soil layers, and one is what you call bottom granular fill layer, another is top granular fill layer. So, let us say Gb, capital G subscript b is nothing but shear modulus of the bottom layer while Gt is the shear modulus for the top layer. And between top and bottom layer you have this layer of geotextiles, geosynthetics. So, this is geosynthetic layer and this geosynthetic layer have the strength Eg Young's modulus of geosynthetic layers Eg.

So, you have two layers, soil layers, when the top layer and bottom layer the properties is represented by Gt and Gb and in between you have a geosynthetic layer and the properties represent by Eg. Below these granular fill layers you have a soft soil, which can be represented by springs because there is a bedrock below that. So, and these two layers, the top and bottom of these two layers, these two layers are Pasternak shear layers. And if they satisfy the condition for Pasternak shear layers, then the analysis becomes easy. The simplified model is extracted according to the assumptions of Pasternak shear layer, vertical planes in the fill layers move relative to each other only in the vertical direction without rotation.

So, this is important, what is the condition, what is the assumption for Pasternak shear layer, that if you apply some load in the vertical direction, then these layers will move only in vertical direction not in the horizontal direction, neither there will be movement in horizontal direction nor there will not be any rotation. So, without rotation they will move. So, this was all about dynamic analysis. The interface between the geosynthetic layer that is membrane, and the two granular fill layers is assumed to be fixed, that is there is a rough

contact, and no slip is takes place, that is also assumption. The wear of the granular fill and the geosynthetic layer is assumed to be elastic.

So, that means we have, it is you assume that loading is not so severe that non-linearity not comes into picture. So, that is their behavior is elastic or you can say linear behavior. So, this completes about geosynthetics different including applications and for analysis for dynamic loads. Now, the last second part of this lecture we are going to discuss what is called soil nailing and soil nailing is getting quite popularly as we discussed earlier. Soil nailing is a method of reinforcing the soil with steel bars or other materials.

So, naturally soil nailing is not geosynthetics, it is basically because made of steel bars or this one, so they become an inextensible material, so they are not extensible materials. So, they will be different than the geosynthetics. So, they are reinforced with the soil with steel bars or other materials. The fundamental concept of soil nailing consists of placing in the ground passive inclusions closely spaced to withstand displacement and limit decompression during and after excavation. The purpose is to increase the tensile and shear strength of the soil and withstand its displacements.

The technique which is used will permit a stabilization of both natural slopes and vertical or inclined excavations. So, there are like, let me give some one of the examples in the soil nailing, you nail with the slopes, let us first discuss, we will come from here. The soil nailing has been used for both temporary and permanent works. The application of the technique for new constructions include, so it can be used both for the new construction as well as for the old construction. Let us talk about first what is the usage of the soil nailing for the new construction.

The nail soil remaining structures are retaining structures to support excavations which are associated with basement construction of buildings. So, whenever you want to construct the basement of some buildings, then they can be nailed soil retaining structures, they can support excavations which are associated with like when excavations is done, then some support will be required and in that case soil nailing may help. This soil nailing for the new type of construction, they can help to find out the slope stabilization, stability of the slopes. Estabilization of tunnel portals and shafts is also another application. Then you have construction of abutments of a bridge or then the soil nailing may require.

Then finally, stabilization of retaining walls may also require the soil nailing. So, whatever listed in the slide are the usage of the soil nailing particularly for new construction. But soil nailing can also be used in the old construction and as a remedial works and what are those works? First repair of unstable and masonry gravity retaining walls. So, you have two types of wall, one is gravity retaining walls and there could be cantilever walls also. So, if your wall is unstable, then using the soil nailing you can make it unstable.

Similarly, if you have some failed slopes and you want to stabilize that slopes, the soil nailing can be, stabilization of failed soil slopes are done. Then another application repair of anchored walls that fail due to overloading or corrosion of tunnel. So, even the soil nailing can be used for repairing of the wall. Similarly, repair of masonry soil walls can also be done using the soil nailing. In this case, the soil nails took over the functions of the original reinforcement strips or fasteners that had been damaged or corroded.

So, because this method we are showing is for existing buildings or they are for the existing works. So, in this case, if repair of masonry soil walls is required, that is the case where the like nails took over the functions of original reinforcing strips or fasteners that had been damaged or corroded. So, it is already damaged in that case it is. In the slides, some of the application of soil nailing is shown and particularly four applications is shown. A, in a retaining structures, so you have let us say this kind of retaining walls and you need to retain some soil.

So, what is done in this case, you provide the nails on the and the nails are because they pass through the backfill. So, in that case, you have this here, in this case, this is the nails basically. So, these are the nails only. Then you have landslide astroblation in the second case where you have slope and this slope, this is the kind of potential failure surface and this failure surface, the slide will take place. So, what is done, nails are inserted inside the soil.

So, nails are like anchored with respect to face and then they are going deep inside the soil, inside the backfill and their objective is to protect the slope from failing. That means, because this mass, the rotor line want to break away and go away. So, that is not permitted, and soil nailing is trying to arrest that one. Then tunnel portal, in figure c, you see this circular, this is the portal of a tunnel through which you can enter inside the tunnel and in this tunnel portal, which is 2D, in the 2D case of course, it is shown in 3D case that will be very longer. So, what you have here, on you have reinforced concrete this side and, on another side, and then when you have the reinforced concrete, the size of the reinforced concrete is used 3 to 4 or 3.3 feet to 12 inch. So, let us say it is basically 3 to 3.3 feet, this is the case here, 3 to 3.3 feet. While in this side, another side of the portal where you use this soil nailing in that case, that this have gone 4 to 12 inch. So, that means, thickness which is required for the portal have reduced very much.

You can say 3 to 3.3 feet is nothing but the first item will be 36 inch because one feet is 36 to around you can have 12, 3.3 feet, so about 40 inch. So, this was 33 to you have the 40 inch. But the thickness of this thickness is required for the portal of the tunnel. But if you use the nails, then the requirement of thickness is left to from 4 to 12 inch only.

So, that means, you have come from 36 to 2 inch, 36 to 4 inch that means, it is basically 9 times saving. So, 9 times has reduced, whatever the thickness of the portal required.

Similarly, in the D case, there is abutment, and this is abutment of the bridge where the soil nailing are used. Now, when we talk about soil nailing, construction sequence is important and without following the construction sequence, it will be very difficult to construct the soil nailing. Soil nailing method is an institute soil reinforcement technique, and it is institute technique that means, it is a fill technique that is used to accelerate the natural slopes.

These are usually, what is soil nailing? These are steel rod, which is 20 to 30 millimeter in diameter. Diameter of the nails, soil nails or rods, steel rod is about 20 to 30 millimeter that means, it is 30 millimeter means, it is almost 20 to 30 millimeter, if average you find will be around 25 millimeter that is 2.5 centimeter around that 1 inch. Standard construction steps for a typical soil nailing method can be broadly reinvented into four steps and these steps are repeated in cycle. So, the first step, what the first steps are? Soil is excavated in lifts to accommodate at least a single row of facing panels.

Beside this, each height of such lift should secure the overall stability of the uncovered soil before soil is ready to transfer the load to soil mass under the critical slip surface. For example, this is the case. What is done in this case, you have a natural slope, which is shown by the dotted line here, then you are using some service of crane and to remove this part of the soil material, which is here, this is removed. So, like using this mechanism, you are removing some part of the soil material and that is the first step. But while removing this material, it should be seen that it does not create a like, because support of this is removed and when the support is removed, so, what will happen? So, here when the support is removed, then it may fall down.

So, that need to be taken care. So, as a result, we go in the height in the stresses rather than in one go, you completely excavate it. In the second case, once you have excavated the soil material, then you put a facing material, for example, facing panels are positions are laid down in rows. So, what you do, this is there, now you are putting this facing panel, this is basically facing panels. So, this facing panel, you have a kind of a slope, and this is basically you have created the slope also.

So, it can be treated like this. So, in this slope, you prepare, put some facing panel. And third step, once this facing panel is attached, first of you excavate and then you have this, this is called drilling, nailing and grouting. So, what is done here, then facing panel is put down here, then you drilled a hole inside that. So, for example, here at least three drills will be required because there are three nails. So, and in this case, what it is doing, the drilling, nailing and grouting is done.

This is the case here. So, this is the C part, and this drilling and grouting is done, drilling and so basically, one slope is prepared, then you are inserting inside the soil, these nerves. So, first step is preparation of the slope. The second step is you have this, in the case of

second step, you put the facing panel, this panel and in the third step, you put, we are putting the nails. Now, once the nails are put down, then in the fourth step, you try to tighten the nails by nut bolt connection, which will be between the facing panel and your nails, so that the tensile bar force near the facing can be mobilized to the design level. It is usually necessary to ensure the stability of the soil slope, which is close to the slope faced in the case of sandy soil.

Once the tightening of reinforcement of particle row is over, the aforementioned steps are repeated for the success of soil nails. So, how these steps are repeated? So, it is done here, like one time you tighten one nut, one nail, then another nail and once it is done, then you put the bolting here. So, for example, at least three types of nut and bolting will be required at three junctions, here, here and here and the idea is there that this soil nails as well as your facing material, which is like a sheet, they remain together, they remain intact. So, that is required to be done and this has been used already successfully for the aforementioned is repeated for the success of soil nails. Now, what are the advantage and disadvantage of the soil nails? First advantage, stability during earthquakes, soil nailing works perform well even in seismically active regions.

So, even if the region is seismically active, then also soil nailing is past experiences, they work well. The coherent and flexible nail soil mass provides a relatively high degree of damping to the rocks. So, that is another advantage that the presence of the soil nailing will give the damping in the system will increase. Then, structural stability, soil nailing uses a large number of nails, therefore, failure of any one nail may not be detrimental to the structural stability, because we do not use only one nail, at least more than like the three, four and even more nails are used. So, multiple nails are used, as a result, even when one nail get failed, it is not going to destabilize your hot problem.

Then, another advantage is space, soil nailing provides an overstructure free working space, which can result in considerable reduction in construction time for basement works and tunnel constructions also. So, during the tunnel constructions soil nailing can also be used. As for performance is concerned, experience and research indicated that the overall moments required to mobilize the reinforcement forces are surprisingly small. So, the forces which is required is small in the soil nailing. The maximum lateral displacement at the end of excavations are generally not more than 0.3 percent of the excavation depth. So, this like it is less than even not 1 percent, it is 0.3 percent only. So, the maximum lateral displacement at the end of excavations are generally not, so, you do not have large lateral displacements, you have a very small lateral displacement. Then simple and light construction equipment for constructing the soil nail, you do not require a very heavy, you know the machinery, rather the equipment required for executing soil nailing, such as drilling rigs for nail installations, guns for short cut application, grouting are relatively small scale. So, whatever you require, for example, you require drilling rigs, you require guns for short cutting of the concrete and grouting and then they can be easily done.

Now, coming to the limitations of the soil nailing, the first of the limitations technique of soil nailing require cuts which can stand unsupported for depths of about 1 to 2 meter at least for a few hours prior to short creating and nailing. So, they can be used only in some area where until you do that, you know the nailing, you put the facing material and then you tighten with a nut and bolt until this operation is over, your slope should be stable, it should be able to carry its own weight. Otherwise, a pretreatment such as grouting may be necessary and will add both completion and cost. So, this was one limitation. The second limitation, mobilization of tension in the nail requires relative displacement of soil and reinforcement.

So, you want to mobilize the tension in the nails, then in that case, both relative displacement of soil and reinforcement will be required. Hence, in urban sites, where ground movement must be avoided, the technique may not be feasible. So, this soil nailing technique can be used easily in remote areas in the heavy areas, but in the urban areas it cannot be used. In corrosive grained durability, consideration ruled out the use of soil nails as a permanent support.

So, if your ground conditions are that, there could be corrosion. You put the soil nailing today and if corrosion starts within few days or even in month, then the soil nailing will be useless. So, this was all about limitations of the soil nailing, we discuss in detail the advantages as well as limitations. The references in this lecture, there was two parts, one was geosynthetics. So, for geosynthetics many figures has been taken from Shukla's book on geosynthetics and their applications and while the soil nailing, the literature has been taken from my book by Swami Saran that is Reinforced Soil and its Engineering Applications. So, these contributions and these references, the authors acknowledge their contribution. Thank you very much for your kind attention. Thank you.