Earthquake Geotechnical Engineering

Prof. B. K. Maheshwari

Department of Earthquake Engineering

Indian Institute of Technology Roorkee

Lecture 55

Ground Improvement Techniques: Geosynthetics

I welcome you all again for this NPTEL online lecture on earthquake geotechnical engineering. In this module, which is the last module 6th of this course, we already discussed types of ground improvement techniques that is the chapter 1 is over of this module. Today, we are going to start the second chapter of this module, ground improvement using geosynthetics that will continue for another lecture 55 and 56. So, we have 2 lectures from this chapter and then once it is over then we are going to talk about ground improvement using natural fibers and then verification of soil improvement. So, coming to this geosynthetics what we are going to cover in this chapter 2 particular today's lecture. We are going to talk about the geosynthetics introduction of the geosynthetics means basically what the geosynthetics are.

Then what are the traditional methods of soil improvement we have already discussed in lecture number 52, 53, 54. So, we will be reviewing them from different perspective. What are the objective of geosynthetics that will be also discussed. Then we do have fiber reinforcement or geosynthetics, geosynthetics filters, then finally, we are going to talk about types or forms of geosynthetics which include geotextile, geogrids, geonets, geomembranes and geocomposites.

So, let us start with the introduction. What is the geosynthetics? Geosynthetics are used for various engineering purpose particularly for supporting a foundation of a structure soil is required to improve its strength. So, basically, we already observed that why you require the soil improvement because so that your soil can support some type of particular type of foundation of a structure or maybe whatever load is coming from the structure, the soil is able to carry that load. So, basically it increases the load bearing capacity of the soil as well as it reduces the settlement. Thus, improvement in soil properties by stabilization processes or reinforcing it with various reinforcement material is much needed and it may be required at in many situations or may not be the all.

And as a result, soil reinforcement is one of the engineering areas in the field of geotechnical and geoenvironmental engineering and extensive research is being done in this field. Here coming to this, when we talk about soil reinforcement, I think if you recall, when we talk about different techniques of ground improvement, one of the techniques was

densification. Here what we are going to do, we are going to reinforce the soil which using some foreign material, so which we are going to discuss and it is here. The various forms of first of all reinforcement include ideally extensible and ideally inextensible reinforcement. So, let us say type of reinforcement we can divide in two categories.

One is which can be extended that means have some ductility like very high ductility and some have very, rigid inextensible. So, for example, metallic strips, bars, roars which are placed underneath in the ground has large Young's modulus, hence they cannot extend in both the principal direction because their Young's modulus is quite large, so that they work like rigid. But whereas if you consider geosynthetics or indirectly we say fiber reinforcement, geosynthetics or fiber reinforcements are similar like you can say the reinforcement using some fibers that is also geosynthetics. There is every chance of the reinforcement extending both the principal directions. Only the thing that when we talk about fiber reinforcement, geosynthetics are man-made materials not natural materials, though fiber reinforcement may also include some natural materials.

So, here you can say fiber reinforcement using man-made material is basically geosynthetics and these geosynthetics materials they are extensible. So, they like strips, bars, roars they are not extensible, but these geosynthetics are extensible. So, geosynthetics are planar products which is manufactured from polymers or polymeric materials that is synthetic materials used with the soil, rock or other geotechnical related materials. So, basically why geosynthetics name is given? It is combination of geo plus synthetics. So, you can say it is a kind of a synthetic material which is used in conjunction with geomaterial including soil, rock or others.

There is a large consumption of geosynthetics in the recent past. For example, if we collect the statistical data, there was almost in 1970s there were about 5 to 6 geosynthetics materials was available, but now their varieties all over the world is more than 1000s. So, it is in 1000s with different varieties and the worldwide consumption of it is in billions of meter cube. So, if we have that area of if we cover the area how much area is covered, so it is tremendous. So, like use of geosynthetics are in fact, even in research there are different journals which are on exclusion of geosynthetics.

One of the journals is geosynthetics and geomembrane is quite popular area. Coming to this, continue with the introduction part of geosynthetics. Geosynthetics replace the traditional construction material because in many cases the use of geosynthetics significantly increase the safety factor, improve performance and reduce cost in comparison with conventional design and construction alternatives. The basic reason why one may need to adopt geosynthetic material for improvement of soil is due to many drawbacks of traditional method of improvement. So, basically you can put it like this way, there are traditional method of soil improvement also and sometime traditional method may fail in some situations where you cannot use that.

In that case, geosynthetics may help. So, geosynthetics may be very helpful, particularly in the situation where the traditional methods fails. And they may be economical in that situation, but in the normal situation where the traditional methods can be used, perhaps they are not so economical. So, whether they are economical or not economical, there are different situation to situation, it varies. Coming to traditional methods of soil improvement, we have already discussed in when we started lecture 52, 53, 54 different methods are there.

Mechanical stabilization for example, densification is nothing but mechanical stabilization where you use vibro floats and vibro rods are used, then you have dynamic compaction, blasting. So, all these are parts of densification technique or that is mechanicalization. So, the properties of soil is improved by changing its gradation, two or more materials are taken and mixed also that is also in mechanical stabilization it is done like mixing and grouting we have discussed. Then aggregates provide internal friction and compressional of soil. Now, what are the drawbacks of the mechanical stabilization? Main drawback is it is not useful to improve the bearing capacity of the soil with moderate capacity.

If suppose, if you have already the moderate capacity of the soil, then for example, densification, densification of soil is good. When your soil is loose, you densify it, then your soil get improved. But if your soil is already densified, it has enough densification and we are further densified it is not going to help you. So, for increasing further capacity or let us say strength of the soil, you need to inject some foreign materials maybe including geosynthetic soil. This is used externally in pavement design.

For example, mechanical establishments much used in the pavement design where you use the large sizes of the rollers to establish the soil. But for the foundation design, this does not work much. Then there is chemical stabilizations also. In that case, the soil improvement is done by addition of some chemicals. The main action of these chemicals is that calcium chloride reduces the loss of water in the soil, thereby they are very efficient in silty or clay soils, but it reduces the strength of the soil.

So, you can use like in some scenarios, but not all. The main advantage is that the setting time and curing time can be controlled. However, drawback they are very costly, particularly and the benefits are applicable as long as the chemicals are present. Once they evaporated, then it will be lost out. So, and they are not economical.

Then coming to thermal stabilizations are also there where you have two types of thermal stabilizations. One is let us say heating or freezing. So, that is based on the temperature change which causes remarkable improvement in the properties of the soil. So, wherever there is change in the temperature, then there could be change in the properties of the soils. So, it could be in the form of either heating or another form will be called freezing.

So, in case of heating, improves the strength of the soil by reducing the water contents in the soil. So, by heating, you can reduce the water content. It is very expensive, hence rarely used in practice. Similarly, as far as the freezing is concerned, the strength of soil increases by the freezing of the water in the soil.

It is also very costly. So, these like measures where you use freezing or heating, they do not work. So, basically out of these three traditional methods of soil improvement, most popular is mechanical stabilizations only rather than chemical or thermal. And as far as mechanical stabilization is concerned, we have already discussed in much detail in lecture number 52, 53, 54. So, like and we see that mechanical establishments also have their drawbacks, particularly when you want to improve your soil conditions for the design of foundations, they are okay for pavement design and all that. So, in that case, many times we require geosynthetics.

Now coming to geosynthetics, what are the basic objectives in order to overcome difficulties in the conventional form of ground improvement techniques? Soil improvement, soil reinforcement is preferred. So, basically using geosynthetics, which is we just called it synthetic fiber reinforcement. So, reinforcement of soil is done. An effective and reliable technique for increasing the strength and stability of soils is called earth or soil reinforcement. So, this is done and this technique is no doubt it is reliable and it is very much effective.

Only the thing the cost, geosynthetics are also not because they are manmade materials, so they may cost also. This reinforcement can be varied either in the form of what we call strip sheets or grid CTC and there that depends on shape, the shape could be different. Different texture that is rough or smooth texture could be there. Then relative stiffness, it could be high for some materials and some materials it could be weak, for example, like steel and it could be low for polymeric fabrics. So, different varieties are there depending on their shape, their texture and then relative stiffness.

So, fiber reinforcement or we say the simple geosynthetics, the addition of fiber to the soil not only improve the shear, its shear strength, safety factor and performance of the soil, but it will also reduce the cost of construction in comparison with the conventional construction method. So, the cost of construction will be reduced when you use a geosynthetic material, particularly like where the conventional methods cannot be used. The relative stiffness of soil reinforcement form the basis for classification of the reinforcement as ideally extensible or ideally inextensible. We already discussed in ideally inextensible kind of you have steel roads or you have this metallic strip and ideally extensible are the geosynthetics. Soil reinforced with ideally inextensible is termed as reinforced earth and with ideally extensible is called fiber reinforced soil or ply soil.

Again, which the material if you ask is inextensible, then you can put in the category what we call the reinforced earth. So, reinforced earth is a general term where you use elastic strips or you use the rods, but then another category fiber reinforced soil. The fiber reinforced soil is nothing but it is that is where you use geosynthetics. So, in fact, it is so synonymous that thus geosynthetics may be defined as a civil engineering material that synthesize to use to improve and modify the property of the behavior of the soil. So, the first of all this is a material by using you improve or modify the property of the soil for betterment.

These geosynthetics has been used from many applications for example, from ocean bed to road bed, from foundation on soft soil to landslide control, from waste disposal site to water reservoir geosynthetics have found an important place for themselves in engineering and construction projects. So, their utilities has been increasing day like you know year by year and they are getting popularity even those and their manufacturing because now they are manufactured in masses. So, they are getting economical also comparatively in the early stages. In the early stages they was very costly, but now they are not so costly. Coming to one of the use of geosynthetics is called filter.

Geosynthetics have found to provide highly effective filters in numerous applications. They have become an integral part of the solution to many civil engineering problems. Geotextiles being very versatile material can serve in many functions. What are the like we will discuss in the next lectures different applications of geosynthetics, but before that let continue with the most widely used known as a filter. In fact, when the geosynthetics started their first use was for the filter.

So, many times they also called filter fabrics and when sufficiently thick they can also surcharge the drainage materials. So, rather than like filtering out they can use a drainage materials kind of a to use as a pipe, piping effect. The difference between these two functions that is filter and drainage functions the orientation of the flow. In filtration flow is perpendicular to the geotextile. You keep the geotextile flow is a perpendicular.

While suppose you want to use these materials as a drainage system naturally then it will act like a pipe or layer this side geotextile this side then flow will be parallel. So, flow will be parallel to the geotextiles inside the sea rather than perpendicular. So, the filter and like the direction of propagation of water will be different perpendicular to each other. In most of the drainage and filtration applications use of geotextiles can be justified over a conventional graded granular filter. So, that depends on the situation to situation or sometimes like compared to conventional approach geosynthetics may be expensive.

There may be cases where conventional approach is expensive and geosynthetics may be may give you the economical solution. To be effective the geotextiles must allow the water to flow through the filter in the drain or the life of the project while retaining the soil

particles in place and prevent the mitigation through the filter. So, one of the use which we will discuss later also. Like when this is placed then their objective let us say you have the saturated soil or you have the submerged soil then what will happen if there is no filter, if you do not have any geotextiles then the with the flow of water the soil particles will move. However, the presence of the geotextiles will protect the soil particles.

It may let it go the only water but not the soil particles. So, this may help to avoid the erosion also. So, these all issues we will discuss later. The difference between these two functions is like we already discussed. Coming to this to be effective they allow the water to flow through the compared to metals.

Polymeric materials have large range of deformation modulus and tensile strength. Their use in India is increasing over the time. Now, let us discuss that what types of or forms of geosynthetics are. There are different geosynthetics. In general, when we say geosynthetics is generic term that is a general name for all synthetic materials used in conjunction with soil, rock or any other civil engineering material as an integral part of a man-made project, structure or system.

So, first of all geosynthetics is a synthetic material and this can be used with the soil. It will not be any synthetic material without soil or rock it will not call geosynthetic. Geosynthetics is basically synthetic materials which need to be used with the soil or rock or any other civil engineering. There are different types of geosynthetics used.

For example, they are listed here. First one most popular geotextile, geogrids, geomembrane, geonets and geomeds. The last subscript is telling that type of material like how they look. So, geotextile will look like a textile material. So, it is like a kind of a cloth. Geogrid will resemble with some grids, then you have geomembrane where it will look like you know the you have the membrane.

So, and the nets are also there. So, you can pick up and then nets. So, accordingly if you have textile, you have grid and membrane, then you can identify that this is you. So, add the geowords and then you will find. For example, geotextiles will look like here. This is geotextile and it is kind of a cloth, woven type geotextiles.

So, these products are almost exclusively polymeric, geosynthetics and those based on natural fibers, for example, jute, cotton, wool, silk or coir etcetera are generally not included. So, in geosynthetics, only the manmade or artificial or synthetic fibers included. Natural fibers, which is for example, jute, cotton, wool, silk, coir fiber, they are not included in geosynthetics. Geosynthetics are available in the market under different trade names or designation therefore, they are used mainly in geotechnical, environmental, hydraulic and transportation engineering applications. Now, one of the types of geosynthetics, as we discussed the first type is geotextiles, which is geo plus textiles.

These are permeable polymeric textile products and they are in the form of flexible sheets. Currently available geotextiles are classified into these categories, four categories. One is called, these are broadly classified in four categories. First one is called woven geotextiles and woven geotextiles is made from yarns by conventional weaving process. Then we have non-woven geotextiles, which are made from randomly oriented fiber into a loose web by bonding with partial melting, needle punching or chemical binding agents.

Then you have kinetic knitted geotextiles, as the name suggests they are used knitting like the woolen cloths are knitted. Similarly, they are knitted, looks like knitted. They are produced by inter looping one or more yarns together. Then you have stitch bonded geotextiles, they are formed by the stitching together of fibers or yarns. So, one by one we are going to see, first one woven geotextile, non-woven geotextiles.

So, these two both are woven geotextiles, that means they are weaved like that, like you know that like cloths are weaved. So, you can say that it looks like a cloth or you may have kind of a, you know, mat like a, so little thicker cloths it appears. Then what you have here, this was geotextiles, woven type. Then you have another geotextiles, non-woven types. So, in the A case it is non-woven, it is sheet, you cannot, you do not see the grid pattern on like this one.

While this B part is knitted and this knitting is done like in the knitting of the woolen cloths, wetters and all the things. So, similarly you have this, so you have woven, non-woven and knitted. Then another form of geotextiles is called geogrids, where geogrid is a polymeric mesh like planar product. So, again it is made of polymers only, because it is as we said, geosynthetics are nothing but synthetic material, they are not manmade materials, are formed by intersecting elements called ribs joined at the junctions.

So, the ribs can be linked by extrusion, bonding or interlacing. Extra-geogrids are classified in the following two categories based on direction of stretching. So, geogrids, first of all they look mesh like planar products. So, this is like this, typical geogrids. So, you have mesh here, biaxial mesh and that thing. So, extrudages are classified in two following two categories based on the direction of stretching, one is called uniaxial geogrids, another is called biaxial geogrids.

In case of uniaxial geogrids, they are made by the longitudinal stretching of regularly punched polymer sheets and therefore, possess a much higher tensile strength in the longitudinal direction than in the transverse direction. So, one side you have the longitudinal direction and on another side you have the transverse direction. So, uniaxial geogrids have more strength in the longitudinal direction. So, here let us say this is uniaxial. So, longitudinal direction is this, in this direction, strength is higher compared to what you have in transverse directions.

So, this is L direction while this will be transverse direction perpendicular to this one. So, in case of uniaxial geogrids, the strength in the longitudinal directions is more compared to greater compared to you have in the case of transverse direction. While in case of biaxial grids, they are made both the longitudinal and transverse direction stretching of, so that means their strength is equal in both the directions. They are possess equal tensile strength in both the longitudinal and transverse direction which has been shown here and which looks kind of uniform also. So, whether you go in this direction or in the perpendicular direction, their strength is same.

So, uniaxial is basically keeping in view that one direction is stronger than another direction while in biaxial case both are almost equal strength. So, this was about uniaxial and biaxial. Then there are two other types of geogrids also which is bonded and woven. So, bonded geogrids like it is a grid pattern. So, they are bonded together that means you have like on the top of it, this is, this is placed on the top, one sheet is down and another is and then it is kind of bonded.

Then another is woven where like it is woven means it is made. So, here in this case both geogrids are in the second figure b, d part it is both are woven. So, we have discussed two types of geosynthetics. One is geotextile which is like a cloth and then another we discuss grids. And when we say geogrid, why it is grid? Because you see the grid pattern is there.

So, here uniaxial, biaxial grid that means you have grid has been made. Here again this is so geogrids has been discussed geotextile and geogrid. Now, the key features of geogrids is that the opening between the longitudinal transverse ribs calls aperture. So, when we call this opening are large enough to create interlocking with the surrounding soil particles. So, this opening which you have here kind of aperture, this aperture here or maybe like this aperture, this should be first of all large enough to create interlocking with the surrounding soil particles. If you have these aperture very small, then they are not going to be effective.

If you are going to be very large, then also not going to be effective. The shapes of the apertures are either elongated ellipses, near squares with rounded corners, squares or rectangles. So, the shape is not only one shape, you may have elliptical shape, square shape, rounded corners or squares or rectangles. So, many types of shapes are like possible. However, the dimension of the aperture may vary from about 2.5 to 15 centimeter. So, minimum is kind of 2.5 centimeter which is kind of an 1 inch or like it could go 15 centimeter half of the feet, not more than that. The ribs of geogrids are often quite stiff compared to the fibers of geotextiles. So, in geotextiles, which is kind of a cloth, while in case of geogrid, you have a grid pattern, you have the ribs and these ribs are quite stronger compared to geotextiles. Also, the junction strength is important in the case of geogrids because through these junctions, loads are transmitted from one type of rib to

another when placed into the soil. So, junctions, like for example, I can show in the figure, this is the junction here.

So, these are the junctions which is basically you have longitudinal rib and the transverse rib, joint of that. So, these are the junctions here, the junction will be here. In the second case, you can see the junctions here and these junctions should be quite strong. If the junction is weak, then there are problems. So, junction strength is important in the case of geogrid because through these junctions, load are transmitted from one type of rib to the other when placed into the soil. So, special attention is required that when you have geogrids, then the strength at the junction should be sufficient. So, we have discussed with this geotextile in geogrid. Now, we are going to talk about geonets. Geonets, so it looks like a net.

Geonets are extruded polymer masses and look like a geogrid. They are different from geogrids, not in the material or configuration, but in their functions. So, the function of geonets is different than the geogrids, even they may look like a geogrid only. Geonets have generally diamond shaped aperture that are typically 12 mm long and 8 mm wide.

So, this aperture should be around 12 mm, 12 mm like you can say 1.2 centimeter. So, that was the half, if you recall that was there it was 25 mm and 8 mm wide. So, here the shapes of or aperture size in case of geonet is quite smaller compared to what you have in the geogrids. For example, here is the example of geonets. So, aperture is here also and aperture you also see in geogrid, but the size of this aperture in this case is quite smaller compared to in geogrids.

So, this is the kind of example, it is honeycomb structure. So, it looks like that different, but in this excavated and the size to show it looks in picture, otherwise the size of these apertures are not so big. So, this was about geonets. Then one of the like application or one of the types of geosynthetics called geomembrane. As the name suggests that there is a membrane and this geomembrane are mostly used for to avoid the erosion that soil is not cut down. And geomembrane is a continuous membrane type barrier liner composed of materials of low permeability to control fluid migrations.

So, here the permeability is low and when you have the permeability low, then chances that water drained out is less and it will help to control. For example, for clay you will have low permeability, but for sand you will have high permeability. In case of clay soils which can retain water for some time like permeability is low that is why they are used impermeable layers inside the embankment dams as a core and they help to control fluid migration. The material may be which is used for geomembrane could be asphaltic or polymeric or a combination of these two. So, typical geomembrane is shown in this figure like it looks like a kind of a book and then you know that this is like part of the box and other things and but it is a filter like because this is geomembrane.

So, the membranes are there through which or like you know it may allow to go water out, but it may not allow to soil particles to go out. So, it may help in controlling the movement of or erosion of the soil. So, this we have discussed four types of geosynthetics. First of all geotextile, then geogrid, third is geonet and fourth is geomembrane. However, many times for many problems, these different types of geosynthetics are not used separately rather they are used combination with each other and in that case if you are using more than one types of geosynthetics together, then they will call geocomposites.

So, we are going to talk about the term geocomposites applied to product that they are manufactured in laminated or composite form from two or more geosynthetic materials. For example, two or more it could be from geotextiles, geogrid, geonets and geomembranes and that in combination perform specific functions more effectively than when used separately. So, thus why this two types of geotextiles combined because one is not enough first of all for doing that task and separately is not enough. So, if they join hand together and that forms geocomposites, then perhaps that could be a solution of the problem. As such there can be combinations and what are the combinations? Geotextile, geonet, geotextile, geogrid, geotextile, geomembrane.

So, all three are combined with geotextiles. Then similarly with geonet, geomembrane, you have geomembrane, clay and geomembrane, geonet, geomembrane which are used in different civil engineering applications. So, you have four types of like we discussed four types of geosynthetics, one is geotextile, then geogrid, geonet and geomembrane. So, many times their combination can be used. For example, this is one of the examples where geocomposites have been used. A is saying that geocomposite is used as a drainage separator in part A, while in part B it is used surface erosion control map.

So, this was like for controlling the erosion of the soil. So, this was about geocomposites. In today's this lecture, many of the figures are taken from this first reference, which is a book by Professor A.K. Shukla, which is on geosynthetics and their applications. And this contribution from Professor Shukla to geosynthetics is accomplished and which has been used only for teaching the masses. Then some of the figures are also a couple of figures from the second references. So, with this, I say thank you for your kind attention. Thank you very much.