Expansive Soil
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Lecture 25
By Inclusion or confinement

Hello, everyone. Welcome back to the course Expansive Soil. Today's lecture will be the twenty-second lecture of this course, and we will be continuing with this, the treatment of expansive soil and today's topic will be the treatment of expansive soil by inclusion or confinement.

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As I explained before, there are four main objectives of any ground modification that is to increase the shear strength, to reduce the compressibility, to control the swelling and shrinkage behaviour and to control the permeability and reduce the pore water pressure.

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So, all these objectives has to be achieved using all these four techniques of ground modification. In the previous classes we learned about the various mechanical methods, hydraulic methods and chemical methods. In today's class we will learn about the methods which include the inclusion or confinement by which we can achieve the ground improvement of expansive soil.

So, this method can involve the soil nailing, geosynthetic and the ground freezing. So, on these three topics, I will be discussing in today’s class.

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First of all, I would like to start with the geosynthetic. Geosynthetic is one of the most versatile and most widely applicable method of ground improvement. Due to its various shapes, various sizes and different product related to geosynthetics, it has been used quite widely for ground improvement. And when we talk about the geosynthetics, the geosynthetics are made up two terms. One is geo, which relates with the earth of which we need to improve the soil, or we need to improve its performance. That is the, it refers to the end use associated with improving the performance of civil engineering work involving the soil.

The second part made of synthetic. That is the material from which the geosynthetics is made of. So, therefore, the second part refers to the materials are exclusively from man-made product and when we combine together, we get the geosynthetics. So, geosynthetics is a man-made product which can be used to improve the engineering behaviour of the soil.

When we use a geosynthetic, generally, it has basically two aims to perform, one to perform better and to be more economical than the other methods. When we use geosynthetics, mostly it performs five major functions. One is separation, reinforcement, filtration, drainage, and containment. So, we will learn about all these different functions of geosynthetics as well as different types of geosynthetics in this class.

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The advantages of using geosynthetics over other material is, it is a non-corrosive material and its lifespan is quite more in comparison to other material, it is highly flexible, it occupies less volume, it is very light in weight, and also it is very easy to transport it and store it. The installation technique is very simple and also the method of construction or the speed of construction is quite high when we use the geosynthetics and we can make it more economical as well as environmental friendly and also it provide a very good aesthetic look to the structure. So, these are the basic advantages of using geosynthetics.

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When we talk about different type of geosynthetics, the geosynthetics material are available in wide range of products. So, we will look into all those products one by one.

The first one is geotextile. Geotextile is a textile kind of or fabric kind of product, which are permeable and it is made of polymeric textile product in the form of a flexible sheet and here we can see, these are the different geotextile material. And the main advantage of using geotextile material is it pervious in nature, that is a permeable in nature. That means it is porous to liquid flow and this porosity can vary to a large extent.

When we use this geotextile, it can perform four different functions like, separation, reinforcement, filtration, and drainage. This geotextile can be made like woven geotextile, non-woven geotextile, or knitted geotextile. Sometimes natural geotextiles are also be made. Those are made from jute or coir. So, those are known as jute geotextile or coir geotextile.

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Next is geogrid. Geogrid is a planar polymeric product consisting of mesh of net likes regular open network of intersecting tensile resistance element, which are known as ribs. So, these are the ribs and these are connected integrally to each other. These geogrids can be uniaxial, if it stays along its length, then it will be uniaxial. If it is stretched, both in longitudinal, as well as in transverse direction, then it will be known as biaxial.

And between these ribs, there will be openings. So, these opening is known as apertures and these apertures hold the soil particles in between them and therefore it produce an interlocking to the particles.

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Next is the geonet. Geonet is also a planner polymeric product consisting of regular dense network of integrally connected parallel sets up ribs overlying similar sets of various angles. And it will perform one of the four discrete functions, such as separation, reinforcement, filtration, and drainage. And these are the openings or aperture of geonet. And if we compare with the geonet to geogrid, we could see the aperture sizes of geogrid are quite large in comparison to the geonet. So, geonet is a dense network of ribs.

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Next is the geomembrane. Geomembrane is mostly impermeable sheet like structure. And generally, it is made of synthetic polymer materials. And because of its low permeability, it is used to control the fluid migration in a project to act as a barrier or liner. So, due to its impervious nature, mostly it is used as a liner material as well as a barrier material. And main function of this geo membrane is the containment and it can be used at various location where we need an impermeable layer such as a barrier layer inside an earth dam or as a liner in a landfill.

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Next comes the geocell, a geocell is a three-dimensional honeycomb structure, which is permeable. And a geocell can be defined as a three-dimensional, permeable polymeric honeycomb, or web structure assembled from geogrids. So, here we can see it can store a large amount of soil particles, thereby providing a resistance to sliding.

The next comes geofoam. Geofoam is created by polymeric expansion process resulting in a foam that consists of many closed, but gas filled cells. So, this is an example of a geofoam. These are very light structure and also used for a lightweight fill. In terms of volume, this is quite large in comparison to the other product of geosynthetic.

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Next comes the geosynthetic clay liner. This geosynthetic clay liner is made of geosynthetics and in between two geosynthetics, layers of bentonite will be sandwiched. So, this is a geosynthetics, this is geotextile and this is a bentonite, which is expansive in nature. And because of presence of bentonite, the geosynthetic is very impermeable in nature, or it has a very low value of hydraulic conductivity. Therefore, it can be used as a liner material at the landfill.

And these two geotextiles can be stitched together by needle punching or by stitching or by physical bonding. Here, we can see, this is an upper geotextile, this is a lower geotextile and in between the bentonite clay is present and an adhesive is also present, which will hold this, the upper layer and lower layer along with this clay particle.

If it is a needle punched, then it will be, there will be upper geotextile, lower geotextile, the bentonite clay, and it will be stich by the needle punched method. Then it can also be stitched like in this way. So, this is geosynthetics, which can be mostly used as an impermeable layer.

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The different geosynthetics are made from different polymer. Say for example, geotextile can be made from polypropylene, polyester, then polyethylene and polyamide, whereas, geogrid can be made of polyester and polypropylene and high-density polyethylene. Whereas, geonet can be made of medium density polyethylene and high-density polyethylene. Whereas, geomembrane can made of high-density polyethylene, linear low-density polyethylene, then polyvinyl chloride, and polypropylene. Whereas geofoam is made of the EPS.

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When we use the geosynthetic, it can serve different functions. Say for example, reinforcement function. In a reinforcement function, a geosynthetic performs as a reinforcement by improving the strength of the soil and due to their inclusion, the strength of the soil will increase and the earth, which will be reinforced with the geosynthetic material is known as reinforced earth. And the soil reinforced with geosynthetics exhibit a higher compressive strength and tensile strength.

Here, we can see, this is an example of an earth retaining structure, and this is a potential failure surface. Now, if we include a layer of geosynthetic, so, that will increase the strength of this structure quite significantly. When we use a geosynthetic material, mostly it performs in a three way that is shear or sliding, pull-out and membrane. So, these are the three reinforcement mechanism of the geosynthetic, which is acting as a reinforcement material.

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Next comes the separation. In most of the structure, we can see a soft soil present below the subgrade layer. These are the large subgrade, which are made of granular fill, and this is a soft clay. So, due to repeated dynamic loading coming from the wheel of those vehicles, this large granular fill can goes into the soft soil, thereby this will degrade the pavement. Here. we can see in this case this is a sub pavement without any separation layer or any geosynthetic layer.

And because of this movement of this, our granular fill over here, we can get an uneven surface. Now we can improve the pavement by include a layer of geosynthetic. This geosynthetic will act as a separation layer. Here, we can see this is a geosynthetic layer of geosynthetic and this geosynthetic is acting as a separation layer. And this will separate the coarse particle from this soft clay. So, by definition, under this function, the geosynthetic prevent the inter-mixing of adjacent dissimilar soil and the fill material.

So, this will prevent the pumping of the fine particles into this course granular fill. Mostly this is used in case of a highway or railway embankment.

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Next comes the filtration. Under this function, the geosynthetics material allow the movement of water with a limited migration of the soil particles across it plane. So, here we can see, this is a pipe without any layer of geosynthetics as a filtration layer. Now what happens when there is a flow of water takes place and when there is an absence of filtration layer, then the soil particle can goes into this structure and thereby it will start clog this pipe.

And if we provide a geosynthetic layer, then it will prevent the migration of this fine soil particles through it, but it will allow the movement of water. So, therefore it will prevent the or minimize the flow of fine soil particles or only it will allow the flow of water and it will act filtration layer. So, thereby it can prevent the clogging of the particles. So, here we can see, this is a soil layer, and here we are providing a layer of geosynthetics as filtration layer.

Now this geosynthetic layer will allow the movement of water and it will allow a limited movement of the fine particles across it, so thereby, it will act as a filtration layer. So, when, a geosynthetic filter is placed adjacent to a soil base, a discontinuity arises between the original structure and the structure of the geosynthetic.

This discontinuity allows some soil particles, particularly particles closest to the geosynthetics filter and having a diameter smaller than the filter opening size to migrate through the geosynthetics under the influence of seepage flow. For a geosynthetic to act as a filter it is essential that a condition of equilibrium is established at the soil-geosynthetic interface, as soon as possible after the installation to prevent the soil particles from being piped indefinitely through the geosynthetics.

At equilibrium, three zones may be generated, which are known as the undisturbed soil. The second zone is a soil filter and the bridging network. A soil filter layer, which consists of progressively smaller particles as the distance from the geosynthetic increased and bridging layer, which is a porous open structure. Here, you can see, this is a bridging layer. Once the stratification process is complete, it actually the soil filter layer, which actively filters the soil particles.

So, when we provide this geosynthetics it will form with three layers; undisturbed soil, soil filter, and bridging network like this, which will allow some migration of the soil particles and the movement of water particles through it.

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Next comes the drainage. Under this function, the geosynthetic allow the movement of water through it. We know that the presence of water is detrimental to many of the structure. In the presence of the water, the pore water pressure will be developed, and if those waters are not removed, then that will bring the instability to structure. So, in as a drain layer, the geosynthetics allow a clear passage to the water along it.

So, here in this case, we could see this is a backfill material and a retaining wall and the water, which is coming to the structure can be drained out using a geosynthetics, which will act as a drainage layer and ultimately it can be removed from these weep holes. Thereby it will prevent the development of the pore water on the back fill.

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The next function of a geosynthetic is a fluid barrier or containment. Some of the geomaterials are very impermeable in nature. Say for example, geosynthetic clay liner or geomembrane. Due to their impervious nature, this GCL or geomembrane can act as a fluid barrier or containment where we need to store the water.

Say for example, in a landfill liner, we do not want the leachate to migrate into the soil, thereby we can provide a layer of geosynthetic clay liner or GCL, which will act as a barrier between the leachate and the groundwater. And therefore, it prevents the migration of the leachate into the groundwater. Similarly, we can use a geomembrane to provide an impermeable layer to store water like this one. So, this can help in prevent the migration of the liquid as well as the gas.

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So, if we look into the various function of different geosynthetic material, the geotextile can act as a separation function, reinforcement function, filtration function, and drainage function. Whereas, geogrid can act as a reinforcement and drainage function. Geonet can act as a drainage function; geomembrane, and geosynthetic clay liner can act as in containment system. Whereas, geofoam can act as a separation function.

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There are various applications of geosynthetics, particularly it is most widely used for the retaining wall or slope stability. In a retaining wall, the geosynthetics is mainly used as a function of reinforcement. Here, we could see this is a back fill and, and layers of geosynthetics has been provided.

And this geosynthetics or presence of this geosynthetics increases the strength of the soil and it resists the lateral earth pressure and thus maintain the stability of the backfill. Similarly, it can act as a filtration and drainage as a secondary function on the retaining wall and mostly woven geotextile and geogrids with a high modulus of elasticity are used as a soil reinforcing element in geosynthetic reinforced retaining wall. So, in this, we can see this is the layers of geosynthetics which has been used.

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The next comes the embankment. When the embankments are constructed on a soft soil, geosynthetic can be used to increase the bearing capacity of the soil. And also it can serve a reinforcement, drainage and separation or filter function. Generally, geotextile, geogrid or geocomposite are used.

When we use the geosynthetic as a reinforcement function, it will increase its factor of safety. When we use this one as a drainage function, it will help in dissipate, the pore water presser, thereby accelerate the rate of consolidation. And when it used as separation function, it will prevent the of the intermixing of the embankment material and soft foundation soil. So, in this case, this is this has been used as a vertical drain. This is a layer of geotextile and it is layer of granular soil here. Here, it is acting as a separation layer or separation function. Here it is acting as a drainage function. And also it can act as a bearing or reinforcement function.

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Next comes the foundation. Generally, geosynthetics can also be served as a reinforcement material to improve the bearing capacity. Say for example, in the case of abutment, or it can be used or a pile foundation. Here, embankment or this is an abutment. In this case, layers of geotextile, geogrid, geocell or geocomposite can be used as a reinforcement material.

In this diagram, we could see layers of geogrids are being present, which is acting as a foundation material to improve the bearing capacity of the soil. Here also a layer of geogrid as a reinforcement material is present.

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In pavement due to the dynamic load coming from the vehicle, the granular particles present on the soil subgrade can penetrate into the soft layer. This is a soft layer and these are the stone aggregates or granular particle, and due to the wheel load or repeated load coming from the wheel, this stone aggregate can penetrate into the soft layer. Once this happens, then there will be a deflection which will occur and as a result of which the structure may get failed.

So, when we use geotextile over here, this will act as a separation layer. So, it will prevent the intermixing of this stone aggregate and the soft soil, thereby, it will not allow the movement of the stone aggregate into this soft soil. So, in this case, the geotextile and geogrid can be used for this purpose. And also geosynthetics can also be provided to serve as a filtration and the drainage function, but mostly it can be used as a separation layer to prevent the intermixing of the granular particles or migration of this granular particle to the soft soil.

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Similarly, this geosynthetic material can also be used for railways. Again, if the rail is resting over a soft soil, and we have the ballast here due to this repeated loading, the ballast can migrate into this soft soil. And also there will be mud pumping can happen. And because of this mud pumping, the subsidence can occur. And when you provide a geosynthetic layer, it will act as a separation layer which will prevent the intermixing this ballast into the soft soil.

So, in this case, geosynthetics can be used as a separator between the soil subgrade and the ballast, and it can be used to prevent the filtration of the soil pore water rising from the subgrade. So, this will prevent the filtration of the soil pore rising from the subgrade. And also the presence of geosynthetics prevent the mud pumping and the subsidence of this layers.

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Next is the landfill. In landfill, geosynthetics particularly in the form of geosynthetics clay liner, geomembrane are used to provide an impermeable layer. Mostly in a landfill liner, the waste products are stored and this waste material with time produces leachate. And if this leachate migrates into the groundwater, the groundwater will get contaminated. So, therefore, we need to provide layer of geosynthetic clay liner, which will act barrier layer between this waste material and the water.

Thereby preventing the movement of leachate into the groundwater, not only geosynthetic clay liner, geomembrane can also be used. This is geomembrane can be used as a barrier layer at landfill site. Similarly, geosynthetics can also be used as a separator in a landfill cover system. So, this is a landfill, particularly if we look into the diagram, this is a landfill liner system and on the top of that, there will be a cover system.

So, in the cover system, also we can provide a geosynthetic material, which will act as a separator.

So, this is all about the different geosynthetics and their functions. So, this geosynthetics are more widely used because of their large application and also availability of large type of geosynthetics material. And also we can modify the product as per as the requirement. So, therefore, the geosynthetics has been used in a huge scale in many ground improvement methods.

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The next comes the soil nailing. Soil nailing is a process of reinforcing the soil using nails. These are the different nails, which has been driven into the soil. So, these soil nails are rigid bars, which are pushed into the bore holes and subsequently it will be filled with grout material, and then it will be covered with a facing. The main purpose of soil nailing is to increase the tensile and sheer strength of the soil and restrain the displacement.

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The basic concept of a soil nailing process are to reinforce and strengthen the existing ground by installing closely spaced steel bars called the soil nails into a slope as a construction proceeds from the top two bottom, the construction will be from top to bottom. First, the top soil will be reinforced with a soil nail. Then once this is done, then second and third and When we look into a soil nail, it will be generally consisting of three things. One is tendons. This is tendons, the main bar, then the centralizer, this is the centralizer and a grout material.

This central reinforcing bar are generally 15 to 46 mm diameter. This is a tendon. These are the PVC centralizers. These are generally placed at a regular interval of 1.5 m to 2 m along the length so that the grouting can be uniform throughout this nail.

In this diagram, we could see this is a grouted soil nail. This is a reinforcing bar or the tendon. These are the centralizer and this is the grout. And this then connected with the bolt and nut & bolt and then a facing has been provided. So, reinforcing action are developed through the soil nail-ground interaction as a ground deformed during and following the construction.

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The different sequence of a soil nailing process are, first the excavation of the slope. In this process, the soils are excavated in lifts to accommodate at least a single row of facing panel. In this diagram, we could see first it will be excavated to have a working platform. Generally, this is 3 to 5 feet in depth, and this will be unsupported cut.

So, in the first step, the excavation will be performed to go for the first layer of the soil nailing. Then the nails will be driven in the second step. So, in the second step, the drilling of nail will be carried out. So, in this case, we can see this is a soil nail will be driven into the soil. Once the soil nail is driven, then it will be grouted using concrete. So, in this third step, the design nails are inserted into the holes and grouted to develop a strong bond between the soil and the nail.

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Once the nail has been grouted into the soil, then in the fourth step, a facing will be provided. So, this is a facing, which will be provided using a nut and bolt connection to the tensile bars. The nails are tightened by nut bolt connections so, that the tensile bars forced near the facing can be mobilized.

To confirm the perfect contact between the back of the facing panel and the soil surface, the gap between the facing material is filled with injecting a cement slurry. So, once this process is completed, then subsequent layer will be constructed. Say for example, once the first layer is done, then the second layer in this case, again, the excavation will be carried out. And in the second layer, after the excavation is carried out, the soil nail will be placed.

Then it will be grouted, again facing will provided and then the facing will be tightened, and then the sides will be filled with the different concrete mix. Then once the second layer is over, then the third layer and fourth layer, and the final layer will be carried out.

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So, once all the layer has been finished, then a final facing layer will be provided like this, which will cover all the facings of the different nails. And in this also, in this step also a foot drain will be provided at the bottom. Generally, the soil nailings are applied for retaining structures, slope stabilization, stabilizing tunnels, construction of abutments.

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There are different advantages of soil nailing. This is more economical method in comparison to other methods and it can result in saving an approximate amount of 10 to 30 % in comparison to the other methods. The equipment which are used are very simple and light materials, and it can be adopted to different and site conditions and the performance wise, the maximum lateral displacement at the end of excavation is less than 0.3 percent of excavation depth.

It gives a very good structural stability, and also it is suitable during the earthquake. So, these are the different advantages of the soil nailing method.

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The next method is the ground freezing technique. In the ground freezing technique, the water present inside a soil will be freeze using different techniques. So, this method is known as the ground freezing. Ground freezing is a process of making water bearing strata temporarily impermeable, and to increase their compressive and sheer strength by transforming the joint water into the ice.

This is generally used to provide structural underpinning, temporary support for an excavation or to prevent the groundwater flow into an excavated area. Sometime this is also used to prevent the migration of the contaminant. For example, if the contaminant is present here, then the soil around this contaminant can be freeze. So, that the contaminant cannot move from one point to another point.

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The principles of ground freezing techniques are, in this method the water present in the soil are frozen. Therefore, this method is more effective for a saturated soil. But in the absence of water, or if the soil is not saturated, then water can be added such that the soil can be frozen. And also the effectiveness of this process depends on the temperature of the freezing, the water content of the soil, as well as the nature of the soil. And this is more ideally suited for a fine grained soil, such as silt and clay.

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If we look into the process of ground freezing. In this process, suppose if this soil has to be frozen, then initially the tubes will be inserted into the ground. And then the secondary coolant or the primary refrigerant will be inserted in this tube and this coolant material, or the refrigerant material will then solidify the soil surrounding these tubes and thereby providing an impermeable layer.

In this, we can see this is pipes before the freezing, the pipes are inserted, then the secondary coolant or the primary refrigerant will be injected through the tubes and that will initiate the freezing process. So, soil around this tube will start to freeze and gradually when we decrease the temperature of this frozen material or when we pump more and more this coolant material, then more area will start to freeze and then finally, we can see, we can get an impermeable frozen earth layer surrounding these tubes.

Generally, a temperature of plus 20 degree Fahrenheit may be adequate in sand. But in case of soft clay, a temperature of minus 20 degree Fahrenheit can be required.

So, these are the different process of ground improvement by inclusion and confinement.

In this module, we will learn about different types of ground improvement technique, starting with the mechanical method, then hydraulic method, chemical method. Depending on the soil condition, the requirement we have to adopt any of this method. So, this is all about this chapter.

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These are the different references used for preparing this lecture and thank you.