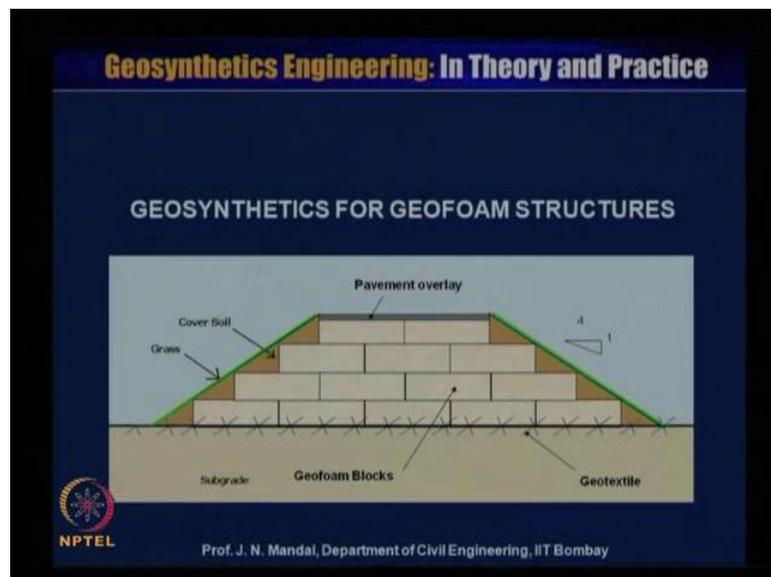


**Geosynthetics Engineering: In Theory and Practices**  
**Prof. J. N. Mandal**  
**Department of Civil Engineering**  
**Indian Institute of Technology, Bombay**

**Lecture - 58**  
**Designing With Geofoam**

Dear student warm welcome to NPTEL phase two program video course on geosynthetics engineering in theory and practice. My name is Professor J. N. Mandal, department of civil engineering, Indian Institute of Technology, Bombay, Mumbai, India. Now, this is module 13 lecture number 58 designing with geofoam.

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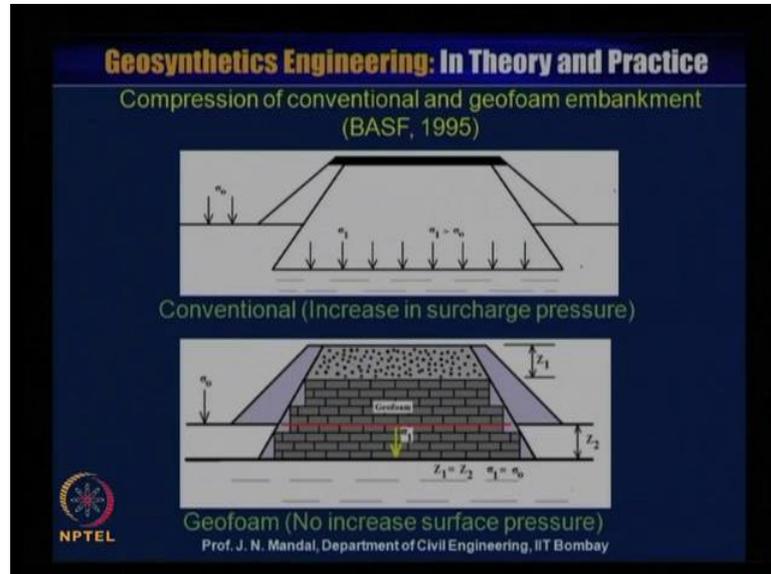


The rigid plastic foam were developed in 1950 and it has exclusively used for the cushion packaging as well as thermal insulation, and then lot of research work have been began in 1988. Lot of application also have started around the world in sometimes in 1960 and 1970 onwards. So, it has a several alternative term, it can be called as a geoblock as a geoinclusion or geoboard.

Also the geomaterial and also the geo solid, so this is what is called the geofoam block and you can construct the embankment on the soft soil, this is alternative to the filling material and then top of the geofoam, you are provided with the pavement overlay and in the side slope, you can fill up with the cover soil. Then grass can grow, so it looks very

green, also you can place the one layer of the geotextile material in between the geofoam and the sub grade soil which also separate the geofoam and the subgrade soil.

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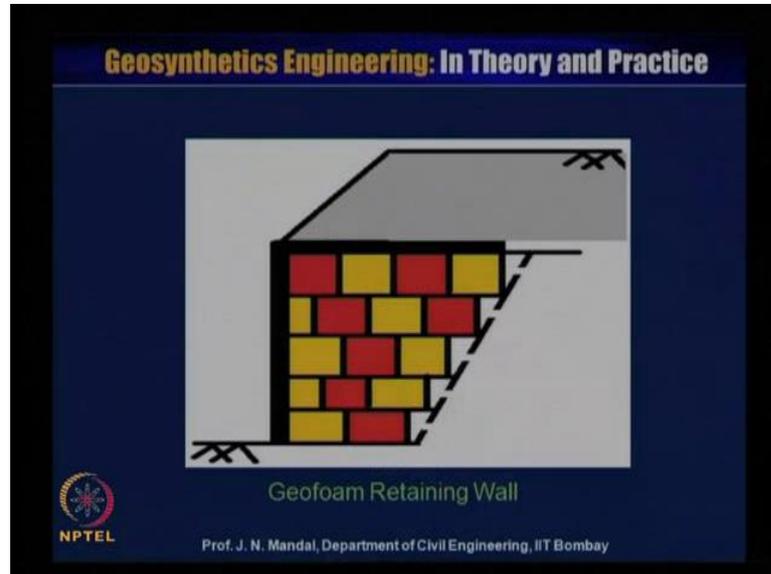
Now, compression of conventional geofoam embankment as per BASF, 1965, you can see here when in the traditional, how the increase in the surcharge pressure if the pressure here is the  $\sigma_0$ . So, due to the application of the load and there will be an increase of the surcharge pressure that means this  $\sigma_1$  will be greater than the  $\sigma_0$ . So, what we do we provide with the some filling material, to construct an embankment on the other hand.

Now, if we introduce this geofoam material alternative to the conventional filling material as the geofoam material is a superlight material and we have introducing this geofoam material here. On the top of the geofoam, this is the filling material and whose depth about the  $z_1$  and here, the thickness of the geofoam material is  $z_2$  and  $\sigma_0$  is the stress and when apply load. Here, we can see this is the  $\sigma_1$  development of the stress at this level, so here that  $\sigma_1$  is equal to  $\sigma_0$  in the conventional method.

There is a increase of the stress in surcharge pressure that  $\sigma_1$  greater than  $\sigma_0$ , when you are introducing this superlight material like geofoam. Then there is no increase of the surface pressure, so here the  $\sigma_1$  is equal to  $\sigma_0$  and this also the  $z_1$  equal to that  $z_2$ . So, from this example it is observed that the geofoam material is effective and

geofoam material does not reflect any increase of the surface pressure with respect to the conventional method.

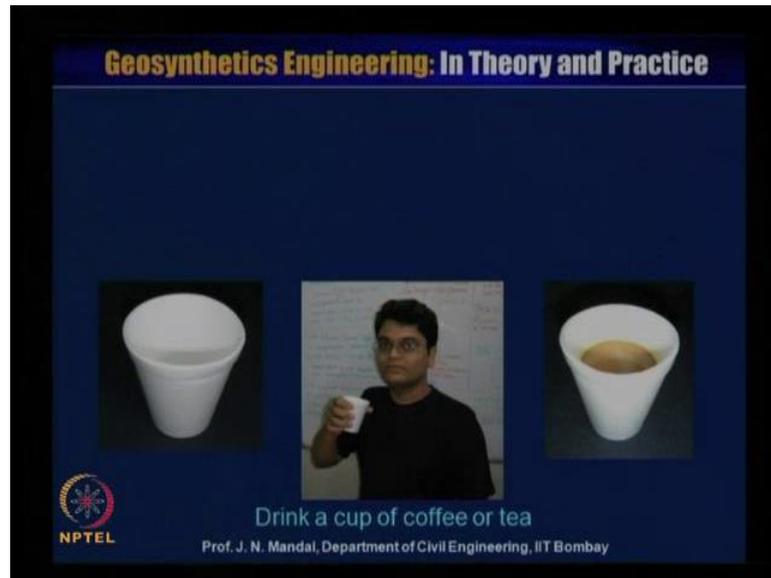
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This is another example, so geofoam which you can construct a retaining wall, so if this is the wall retaining wall, so you do not need to fill up with any other kind of the filling material. You can place only this geofoam block, because this lateral pressure will drastically reduce due to the deployment of the geofoam material.

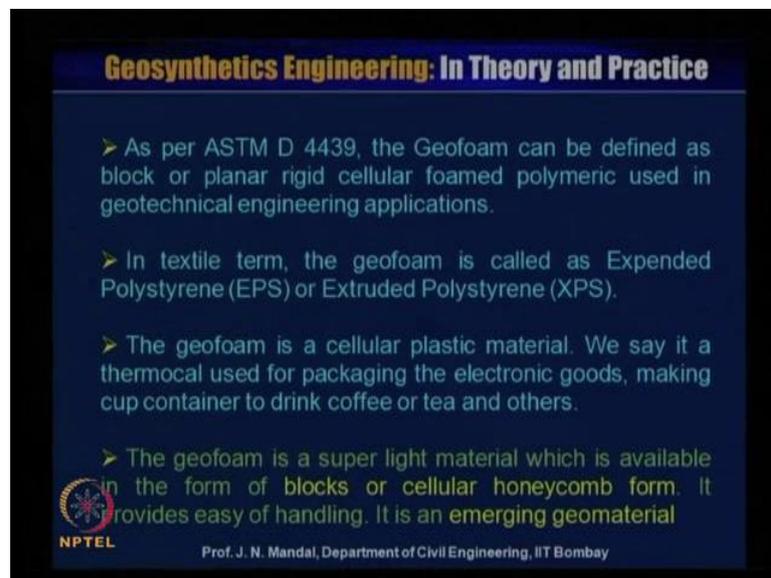
So, we observe that it can be used for the construction of the embankment on the soft soil where as the stress can be minimized and also in case of the retaining wall the lateral pressure can reduce the drastically, so what is the geofoam material. So, most of the time, we use this thermocol for the packaging, so we even then take a cup of tea or the coffee using this material.

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This is called thermocol and this thermocol is nothing, but in geotechnical engineering called the geofoam. So, this geofoam also has been included under the family of the geosynthetics.

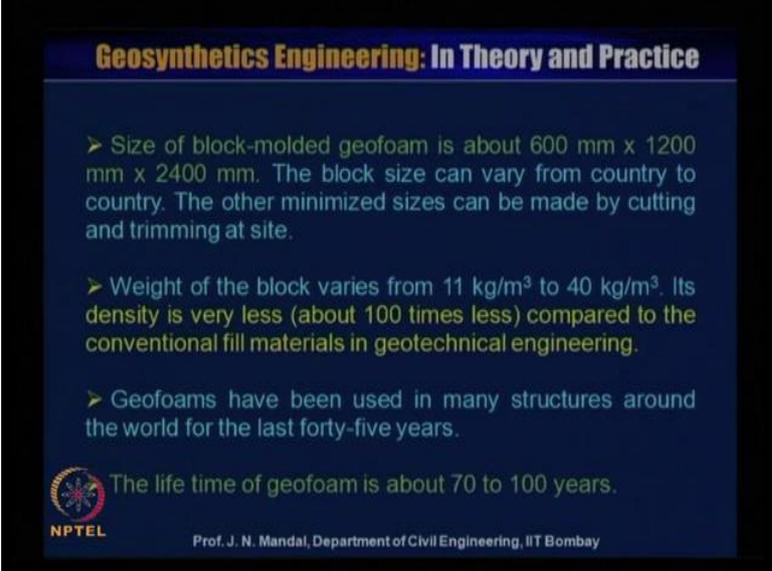
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As per ASTM D 4439, this geofoam can be defined as the block or the planar rigid cellular foam polymeric used in geotechnical engineering application in textile term. The geofoam is called as expanded polystyrene or extruded polyester, the geofoam is a cellular plastic material. We say a thermocol used for the packaging the electronic goods

making cup container to drink coffee or tea and others, the geofoam is a superlight material which is available in the form of block or cellular honeycomb form. It provides easy of handling it is an emerging geomaterial.

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**Geosynthetics Engineering: In Theory and Practice**

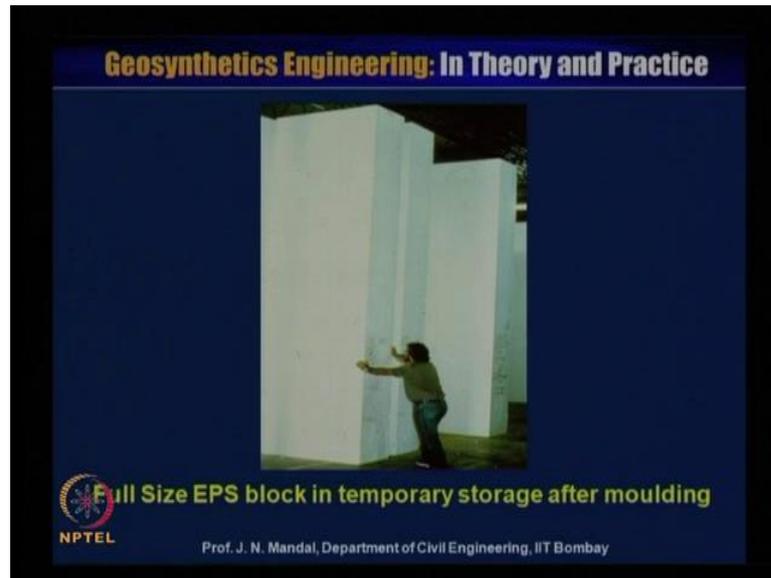
- Size of block-molded geofoam is about 600 mm x 1200 mm x 2400 mm. The block size can vary from country to country. The other minimized sizes can be made by cutting and trimming at site.
- Weight of the block varies from 11 kg/m<sup>3</sup> to 40 kg/m<sup>3</sup>. Its density is very less (about 100 times less) compared to the conventional fill materials in geotechnical engineering.
- Geofoams have been used in many structures around the world for the last forty-five years.

The life time of geofoam is about 70 to 100 years.

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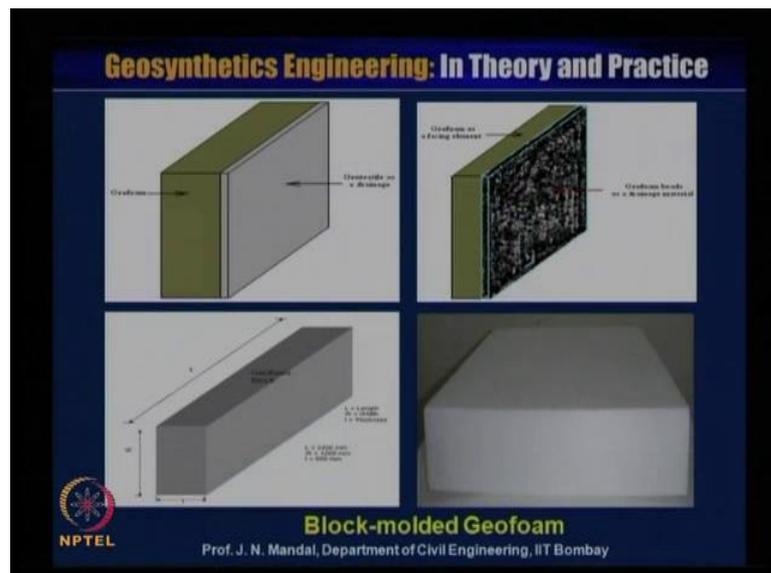
The size of the block molded geofoam is about 600 millimetres into 1200 millimetre into 2400 millimetre. The block size can vary from country to country, the other minimized sizes can be made by cutting and trimming at site weight of the block varies from 11 k g per metre cube to 40 k g per metre cube. If density is very less about 100 times less compared to the conventional fill material, in geotechnical engineering. Geofoam have been used in many structure around the world for the last 45 years, the lifetime of the geofoam is about 70 to 100 years.

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So, here you can see that full size of the E P s block, this E P s is called expanded polystyrene in textile term in geotechnical term, we call the geofoam. So, this is the full size of the block in temporary storage after the moulding, so we can cut the block as per your requirement at the project site. You can have for various densities and various thicknesses, so this these are the block moulded geofoam or expanded polystyrene material.

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So, this geofoam material act as a separation function and this geofoam also can be laminated with the geotextile material where the geotextile material is act as drainage. So, when it is required, the separation and the drainage for any project then you can laminated the geotextile material with the geofoam itself, apart from that this geofoam material itself.

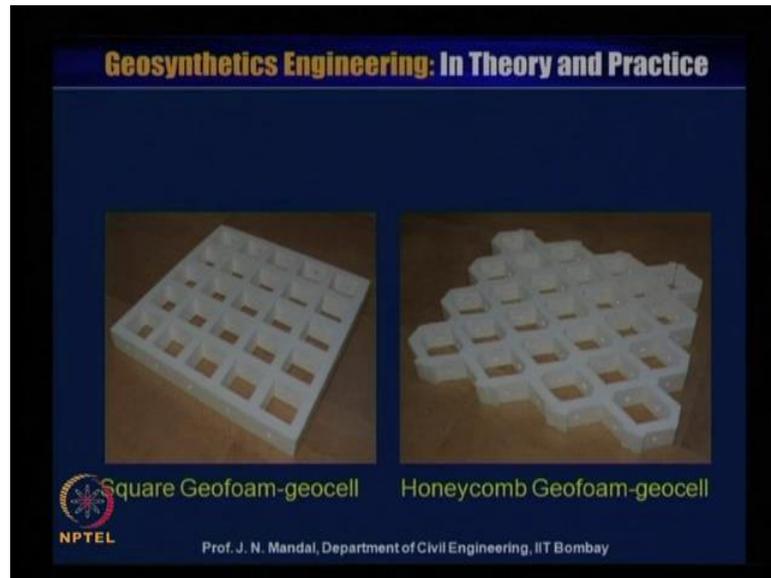
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So, this is the geofoam beads and from this beads this drainage material has been manufactured, so you can see this is a number of the balls and there is a four side. So, it is easy to water can percolate through this kind of the geo drainage material and this is the geofoam or expanded polystyrene material. So, this geofoam can be laminated with this geofoam drainage material, this geofoam material will act as a separation function.

On the other hand, this geofoam black or white combination will act as a drainage, so for any project where you require both the separation and drainage. So, you can laminate this drainage material with the geofoam material. So, this is the size of the block is generally this available, I have told you this dimension of the block and this expanded polystyrene block is weight about 36 kg. Two people can easily handle and it is a very superlight material.

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So, this also we can see another geofabric material, so here apart from the because this geofabric material. Also, you can have in different configuration you can make it this geofabric in the square form. You can see this is the geofabric and you can make in the square form of this geofabric material. Here is the square form geofabric material, so what we can reduce the size of the geofabric from the solid geofabric.

You can cut and can make this square form, this also is very much necessary in geotechnical engineering job, you can fill up with the filling material and also this geofabric material can provide is very confirming. Also effect you can have it in the square form, as well as you can have also in the hexagonal form. So, this is one which we can see in the hexagonal form. So, lot of research work is going on in this institute that using the different configuration of the geofabric material.

Either it may be the solid block or it may be the square form, or it may be the hexagonal form and also it has been also optimized that what size and shape and configuration will be the best for the use in the practical field. So, what should be their dimension and whether the square or the hexagonal gives the best result, so this is square geofabric geocell as I showed you and this is honeycomb geofabric or the hexagonal geofabric cell.

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**Geosynthetics Engineering: In Theory and Practice**

- Norwegian Public Road Administration (1972) used geofabric as light weight material for the construction of road embankment.
- Lots of research works have been carried out on geofabric by various researchers i.e. Thompson et al. (1995), Aaboe (1987), Duskov (1991), Horvath (1992), Stark et al. (2004), Horvath (1997), Mandal (1998), Nimbalkar (1999), Hazarika (2006), Waghdhare (2006), Mandal and Nimbalkar (2004), and Horvath (1995).
- It was reported that the temperature of geofabric should not exceed of 95° C.

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So, Norwegian public road administration 1972 used geofabric as lightweight material for the construction of road embankment. Lot of research work have been carried out on the geofabric or expanded polystyrene by various researcher. They are Thompson et al 1995 Aaboe 1987, Duskov 1991, Horvath 1992, Stark et al 2004, Horvath 1997, Mandal 1998, Nimbalkar 1999, Hazarika 2006 and Waghdhare 2006, Mandal and Nimbalkar 2004 and Horvath 1995.

It was reported that temperature of the geofabric should not exceed of 95 degree centigrade geofabric has been exclusive used in Belgium, Canada, Finland, France, Germany, Japan the Netherlands, Norway, Sweden, United Kingdom and USA. Though its use in India is in infant stage, all of that region may be that many engineer are not aware of this new geomaterial. There is a possibility of the cost of the geofabric material itself, but if you look in terms of the overall cost of the project, then this kind of system is more economical and advantage, because you do not need almost any equipment.

You do not need any compaction equipment you do not need so much man power, you do not need very good quality or material transport from one side to the other side. So, if you look in terms of the overall cost of the project then geofabric material is the best. This is very fast construction, because this is a superlight material, it is easy to install easy to construct and also its resist the very good earthquake related problem Frydenlund.

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**Geosynthetic Engineering: In Theory and Practice**

- Geofoam has been exclusively used in Belgium, Canada, Finland, France, Germany, Japan, The Netherland, Norway, Sweden, United Kingdom and U.S.A though its use in India is in infant stage.
- Frydenlund and Aaboe (1994) reported that geofaoms have been used over 150 projects in Norway. Bearing capacity of clay or silt can be considered equivalent to compressive strength of EPS i.e. 100 kPa.
- Arellano and Stark (2009) recommended to provide lower density of geofoam at lower portion and higher density of geofoam at upper portion of the roadway embankment for economical design solutions.

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Aaboe 1994 reported that geofoam have been used over 150 project in Norway bearing capacity of the clay or silt can be considered equivalent to compressive strength of expanded polystyrene or E P S. That is 100 kilo Pascal are Llano and Stark 2009 recommended to provide lower density of geofoam at lower portion, and higher density of the geofoam at upper portion of the roadway embankment for economical design solution.

So, it has very nice to place the geofoam material with proper density because this geofoam material is available at various densities. It may have from 11 to 40 kilo Newton per metre cube at the same time. The placement of the geofoam also very important, you can change the density of the geofoam, so lower density you can place and also higher density can place at the upper portion and lower density can be placed on the lower portion.

That way, you can make more economical and design because the cost of the geofoam material also depend on the density of the geofoam material itself. So, you can minimize the cost by considering the proper kind of the density of the geofoam and some research work also have been completed in this institute using this different types of the geofoam and different densities. Either it has been placed on the lower portion of the embankment or the higher portion of the embankment, because you have to observe which one provide the most safe and suitable design.

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**Geosynthetic Engineering: In Theory and Practice**

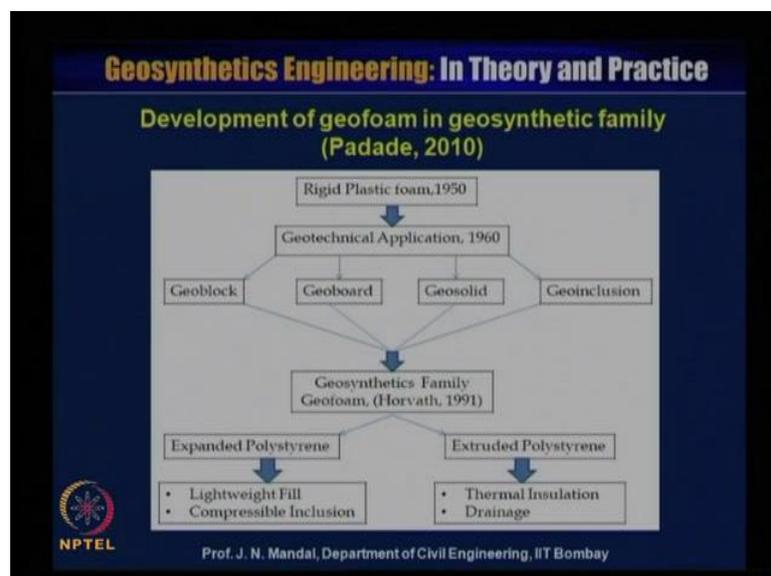
- Huang and Negussey (2011) reported modified test methods to determine California Bearing Ratio (CBR), resilient modulus and modulus of subgrade reaction of geofoam.
- Aytekin (1998) reported that the cost related to damage because of swelling is double of the cost related to damage from earthquakes, floods, tornadoes and hurricanes.
- Since the early 1990's, geofoam has been a generic term for any synthetic geomaterial created in an expansion process using a gas (blowing agent) resulting in a texture of numerous closed cells.

➤ Geofoam is not just one material or product but a very diverse family of many different kinds of materials.

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Huang and Negussey 2011 reported modified test method to determine California bearing ratio that is CBR resilient modulus and modulus subgrade reaction of geofoam. Aytekin 1998 reported that cost related to damage because of swelling is double of the cost related to the damage from earthquake flood tornadoes and hurricane. Since, the early 1990s, the geofoam has been a generic term for any synthetics geomaterial created in an expansion process using a gas that is blowing agent. Resulting in a texture of numerous closed cell geofoam is not just one material or product, but a very diverse family of many different kinds of material.

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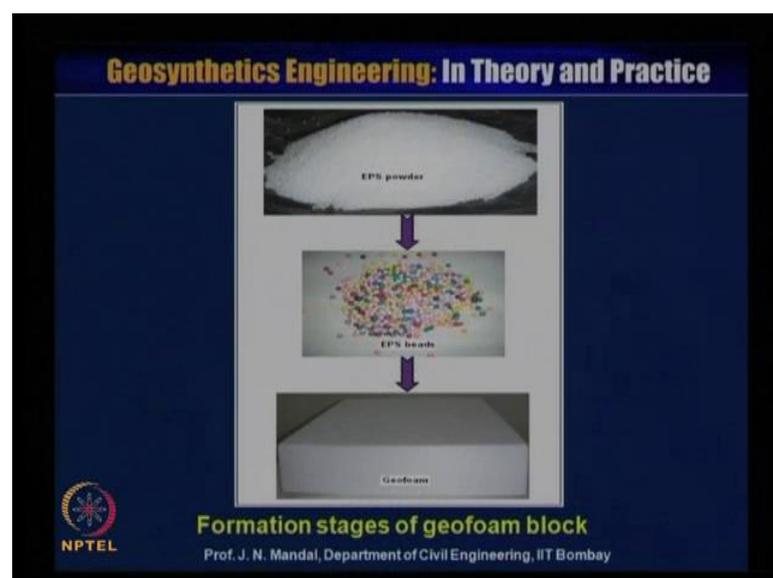


So, this is development of the geof foam in geosynthetics family Padade 2010, this is rigid plastic foam which is developed in 1950 and this application of the geof foam in geotechnical engineering. It began in 1960 and this you can we see that geoblock, geoboard, geosolid, geoinclusion or say you can say geomaterial. So, these are the geosynthetics family, this is geof foam, this is Torvath in 1991.

It may be the expanded polystyrene material which is light weight material and compressible inclusion, because light weight material. You can construct the embankment as a filling material and also it is a compression inclusion because we can provide at the back of the retaining wall which will act as a compression inclusion. The lateral pressure fell dramatically reduce, whereas extruded polystyrene material, this is a thermal insulation and also the drainage.

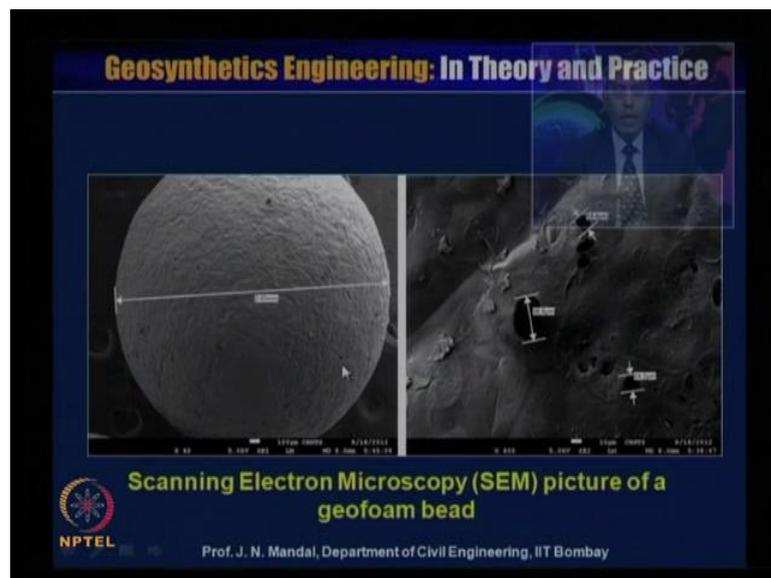
So, it is required sometime to store the material and we use some conventional system with the gravel stone etcetera. So, alternative to that you can use the geof foam material and you can save the power. So, I will give you later one example provided with the thermal insulation also that the problem related with the embankment construction on the soft soil. Using the light weight field material and as well as for the retaining wall where you can use the geof foam material, and geof foam material itself can be used as a retaining wall.

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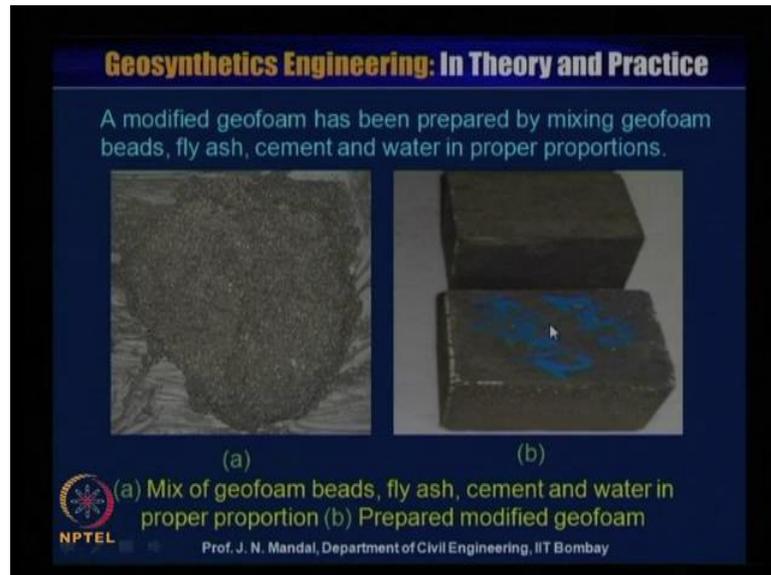
So, here you can see that expanded polystyrene is available in the form of powder, you can see here almost like a powder and then you can make beads. So, you used something bag EPS beads bag, so this is a kind of the beads which is produced from the EPS powder. These beads also can be used for the drainage this EPS block also used for the other application and from this EPS block beads, you can produce the geofoam, so this is the formation of stress of the geofoam block.

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If you take a scanning electronics microscope that is SEM picture of the geofoam beads, you can see how it looks this bead. And you can see that what the opening of the beads material is...

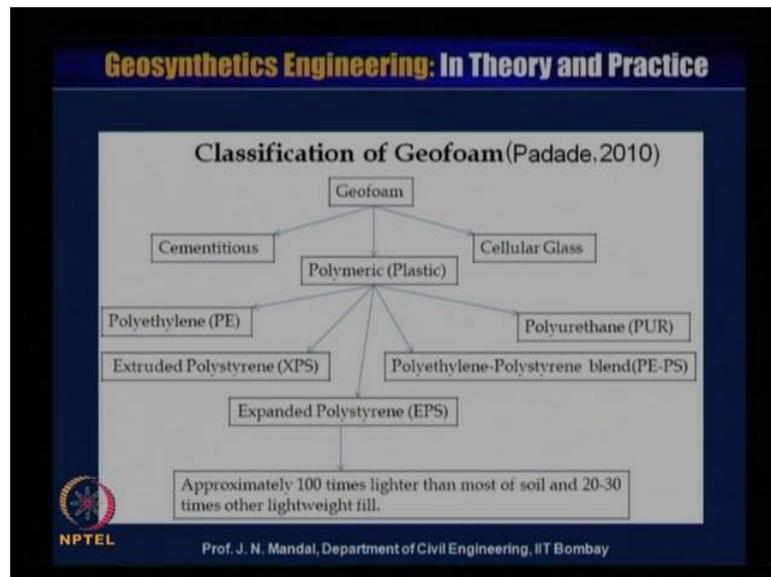
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This is a modified geofoam, has been prepared by mixing the geofoam beads fly ash cement water in proper protection. So, this work has been carried out in this institute and this is the mixed geofoam beads fly ash and the cement and water in proper proportion and this is the prepare the modified geofoam block.

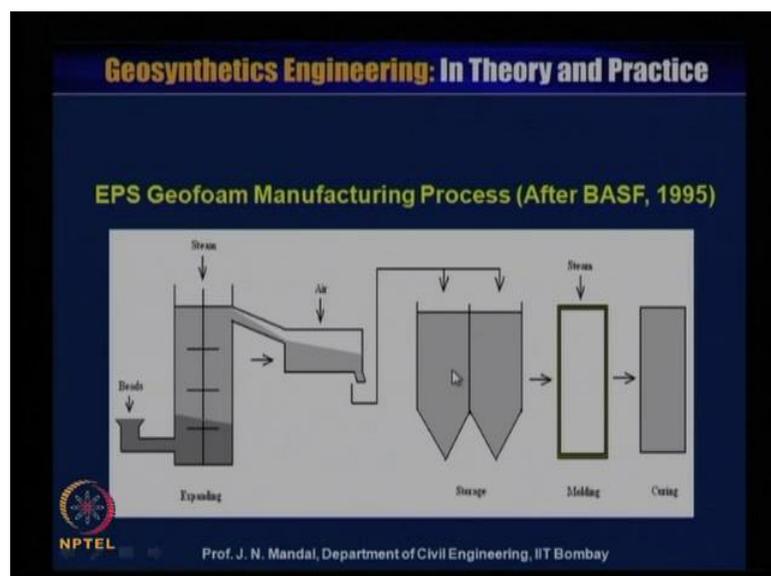
You can say new geomaterial, because we are using here the waste material, that means fly ash and as well as that, if we find that geofoam material or expanded polystyrene material is expensive. So, alternative to that geofoam material, so you can make use of the new generation geomaterial which is also very light and which also can provide very good compression effect. So, I will later focus on this related material.

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Now, classification of the geofoam Padade 2010, this is the geofoam, it may be cementitious or it may be cellular glass. This is a polymer plastic, it may be polyethylene or polyurethane or it is extruded polystyrene XPS or the polystyrene and blend that is P EPS or expanded polystyrene which we call EPS in the textile term. So, approximately 100 times lighter than most of the soil and 20 to 30 times other light weight field material.

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So, here we are focussing E P S geofoam manufacturing process after BASF, 1995. So, you have observed the beads, this beads it is to be inserted here and then this steam are provided from this top. This will expand when beads will be expanding and then it passes through the air and then it can store, there is steam storage and then this is the steam and this is the moulding. So, ultimately you can make a mould either in the rectangular or in the square and then you have to keep it for the curing. So, then ultimately you can have the different mould, or the block either in the cubical form or in the rectangular form in a solid and this geofoam material has various density.

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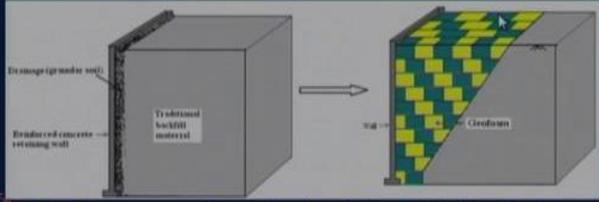


So, in terms of the application in civil engineering geofoam can effectively be used in various engineering application. Embankment and the pavement retaining wall and abutment, any road widening, railway, foundation problem, side hill fill, landscape, dike berms, below ground wall of structure, tunnel and buried pipe. Tunnel, clay liner, flood control levees, parking, clay heave protection, sound barrier, landfill and gas venting. I will show you some of the application where and how can make use of it.

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**Geosynthetic Engineering: In Theory and Practice**

- In conventional method, good quality granular materials are used as backfill behind retaining structures. Sometimes the materials are scarce.
- The inclusion of geofoam reduces the lateral earth pressure dramatically



The diagram illustrates the transition from a traditional retaining wall to one using geofoam. On the left, a cross-section shows a retaining wall with a drainage pipe (D) and a traditional backfill material. On the right, the same wall is shown with a layer of geofoam (represented by yellow and green blocks) behind it. Labels include 'Drainage (p. under soil)', 'Eroded concrete retaining wall', 'Traditional backfill material', 'Geofoam', and 'Soil'.

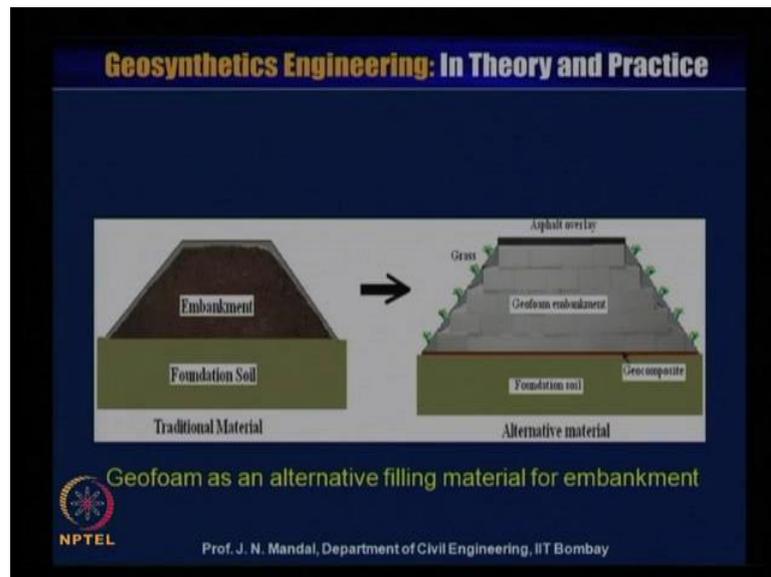
**Geofoam as an alternative backfill material behind retaining wall**

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What do you do in conventional method? You got good quality of the granular material is used as a backfill behind. The retaining structure, sometimes the material is scarce and realized as it is expensive. So, inclusion of the geofoam reduces the lateral pressure dramatically. We can see here, this is the retaining wall and here providing with some drainage material. Here, it is a granular material you are using and we provide with the traditional backfill material, this is retaining wall and the back of the retaining wall you have to provide with the drainage material and good quality of the material.

You have to provide for drainage and then you have to be provided with the all traditional material alternative. To this, you can use simply geofoam material like this, so you do not need any compaction, so simply you can place this block at the back of the retaining wall. So, because this material is very superlight material, its density is 100 times less than the soil. So, it will provide the lateral pressure and that lateral pressure reduce drastically for the inclusion of the geofoam material. So, here the geofoam material has an alternative backfill material behind the retaining wall.

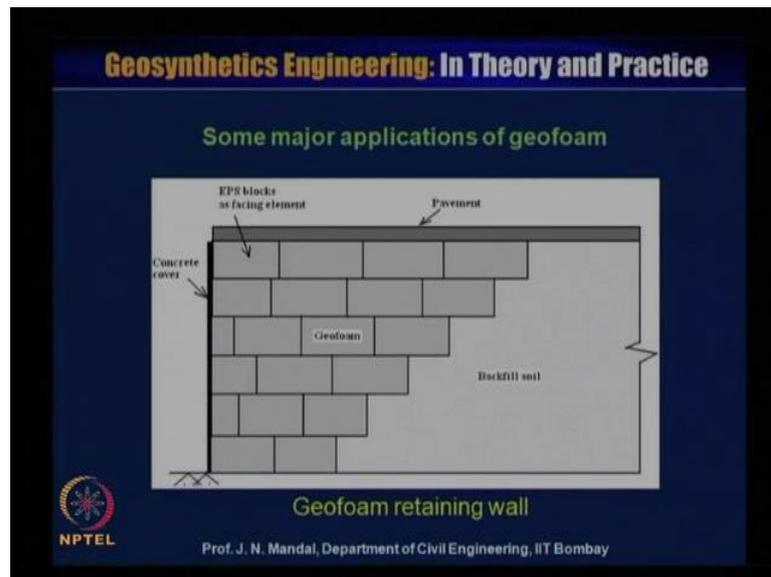
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Now, if you want to construct that embankment, most of the cases, you know traditional method this is foundation and you require good quantity of the Murrum and in Bombay. This Murrum is very expensive, it is like gold sometimes not available and in the conventional method, and you provide this as a filling material soil as a filling material, but on the other hand you need the compaction. Other alternative to this, as a filling material, so you can simply place this geofoam block.

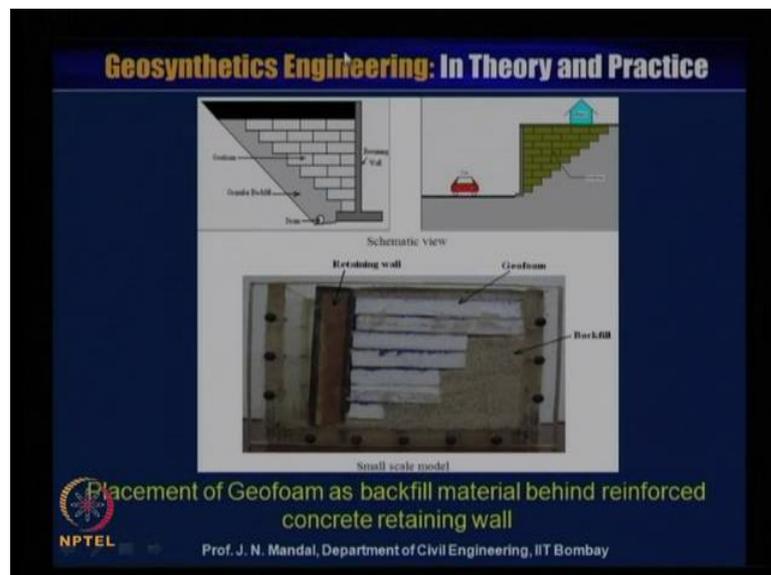
So, here geofoam material will act as a filling material and then you can put on the top of this with the asphalt overlay or you can concretize also and at the side of the embankment slope, you can fill up with the soil and the grass can grow. So, it is environmental friendly it will give a greener structure, you can place also one layer of the geocomposite material in between the foundation soil and the geofoam block which will act as a separation and also act as a drainage material. So, this construction using this geofoam material is very fast and also economical.

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Here, some major application for the geofoam is a concrete cover and this is the EPS block or expanded polystyrene block or the geofoam material. This is the pavement and this is the backfill soil, so here geofoam material also is act as a retaining wall, so you do not need to construct a reinforced concrete retaining wall.

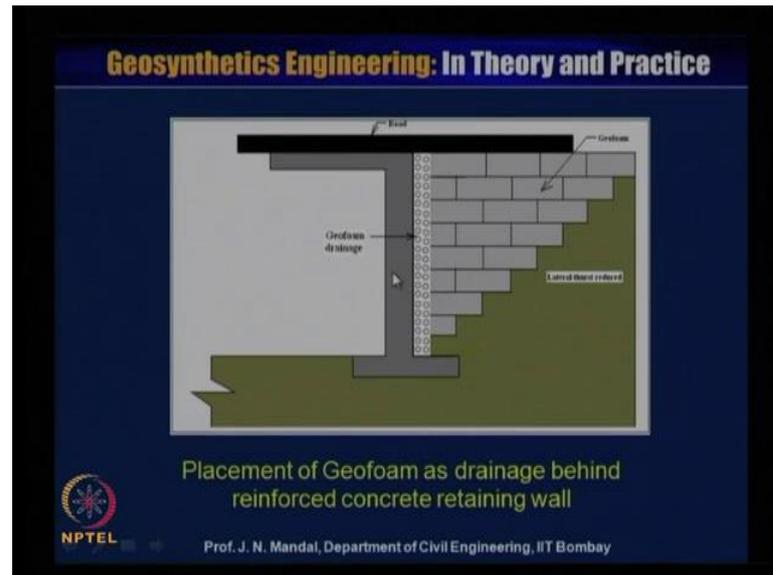
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So, here you can see this is the retaining wall and here geofoam block has been used and also there is drainage. It can be drained it out, sometimes if you in this kind of the situation and you can place because it is kind of the slope. So, you can place the geofoam

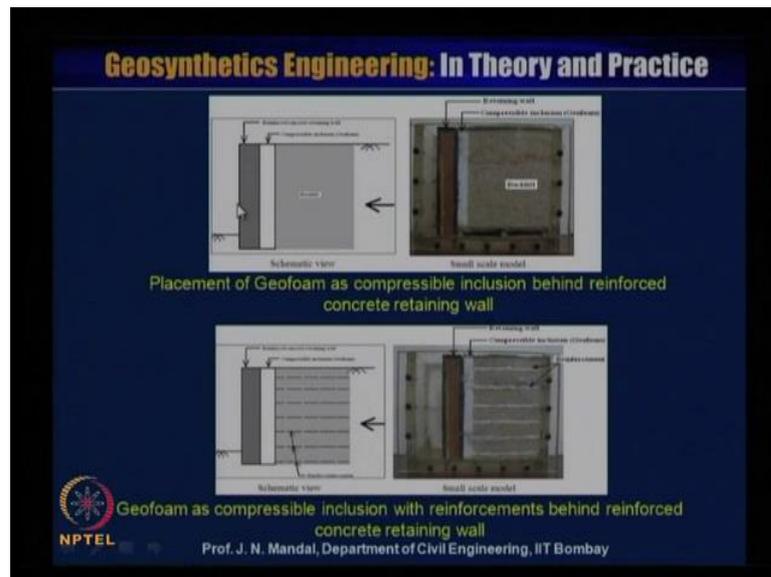
material and you can construct the house and also at the back, you can see you can make a road. The vehicle can pass through this area, so there is no problem. So, here is the placement of the geofoam material as a backfill material behind the reinforced concrete retaining wall. Here is a retaining wall, and the back of this you can see that geofoam block has been forced this is a small scale model.

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Now, this is the placement of geofoam as drainage behind the reinforced concrete retaining wall. So, you can provide the drainage material I showed you that what will be the drainage material. So, you can simply provide also the drainage material and then the geofoam, so this geofoam which will act as a drainage and as well as it will act as a compression inclusion.

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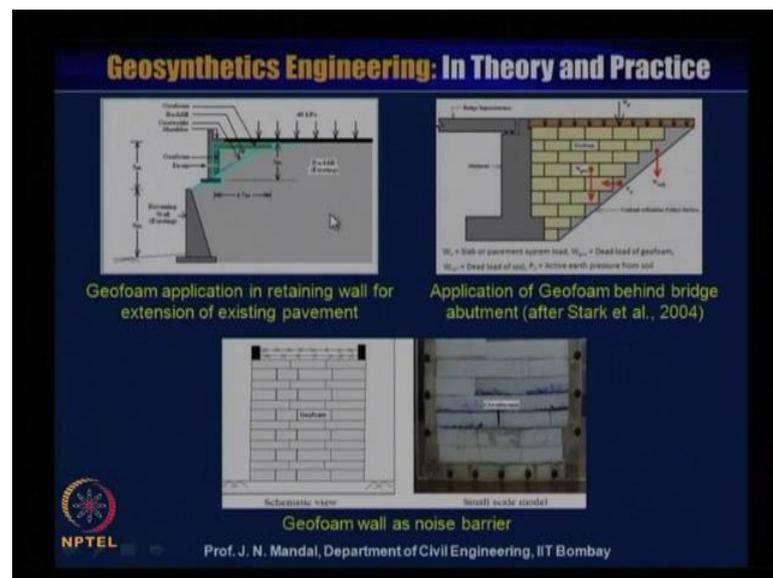
So, here the placement of the geofoam as a compressible inclusion behind the reinforced concrete wall, so if this is the reinforced concrete wall, you are providing some thickness of the geofoam material. Here, you can see if this is the reinforced soil, this is the wall and at the back of this, you are providing this certain thickness of the geofoam material. This is white colour and then you are providing the backfill material, now this thickness of the geofoam material varies also that what kind of density you wanted to use and what should be exact thickness of the geofoam material.

So, you do not require the high or very thick geofoam material, so you can design and we will be able to say that what kind of the thickness of geofoam material you should place on the back of the retaining wall. So, here this geofoam material will act as a compression inclusion and also is reduce the lateral pressure. Lot of research work have been carried out here. I will show you with one example that with the thickness of the geofoam material, how this the lateral pressure can reduce and it depends upon the density of the geofoam material.

Also, it depend upon the thickness of the geofoam material and also how you can design that what should be the thickness of the geofoam material. We will later discuss more about this problem. Now, apart from this, if this is the wall and this is the geofoam, you can place a number of the layer of the reinforcement. If the situation arise like this, so you can you can see here, it is the wall and this is the geofoam and number of

reinforcement layer has been included this is multilayer of the reinforcement. So, here the geofoam will act as a compression inclusion and here the reinforcement will act to resist the tensile stress. And then wall can be much more the stable, and the lateral pressure also will reduce.

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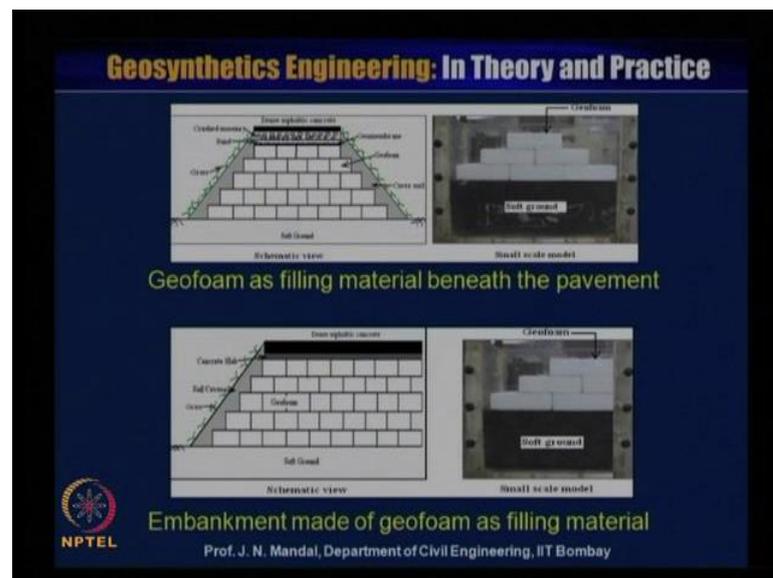
So, here is the geofoam application retaining wall for extension of the existing pavement. So, this is one area where this is the retaining wall existing and this is the slope and again this is the road. This is some area in Pune and this road is to be expanded up to this. There are different types of the technique, someone can feel that you can go for the soil nailing this that, but you can use this geofoam system and it will be the very fast. So, this system you can provide that extension of the existing the pavement, so you can make use of this road by the inclusion of the geofoam material.

Now, here the application of geofoam beyond the bridge abutment after Stark et al 2004, where this is the weight of the pavement system, also that what you call drain load of the geofoam. If there is also any seismic aspect that also you can take into consideration also drain load of the soil and also there will be the active earth pressure. So, all this has been also considered for the design, now this geofoam material also acts as a noise barrier.

So, here it is the geofoam, you can construct the wall of the geofoam and you can keep with the barrier here, you can see here. So, you can use this geofoam material as a noise barrier and it is not so expensive, because you need the very thin thickness of the

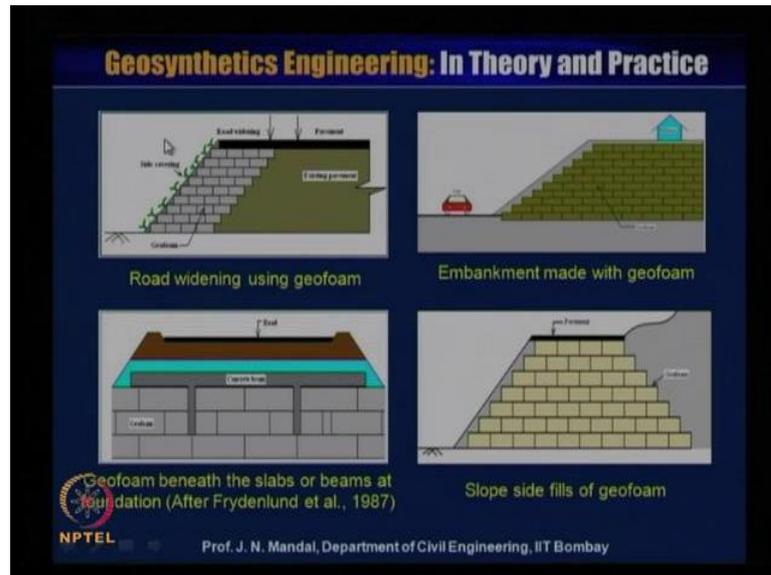
geofoam material. It is lighter material and also the country use the R E wall for the geogrid reinforced soil wall as a noise barrier. Sometime, some other alternative system they provide, but this is the more suitable attractive and also easy to construct and it is much more economical. So, this kind of the system can be adopted for a noise barrier.

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So, this is geofoam as a filling material behind the pavement, I am showing you here that how the pavement can be constructed with the geofoam. This is the embankment made of geofoam as a filling material, here is the geofoam then how you can construct this embankment using the geofoam.

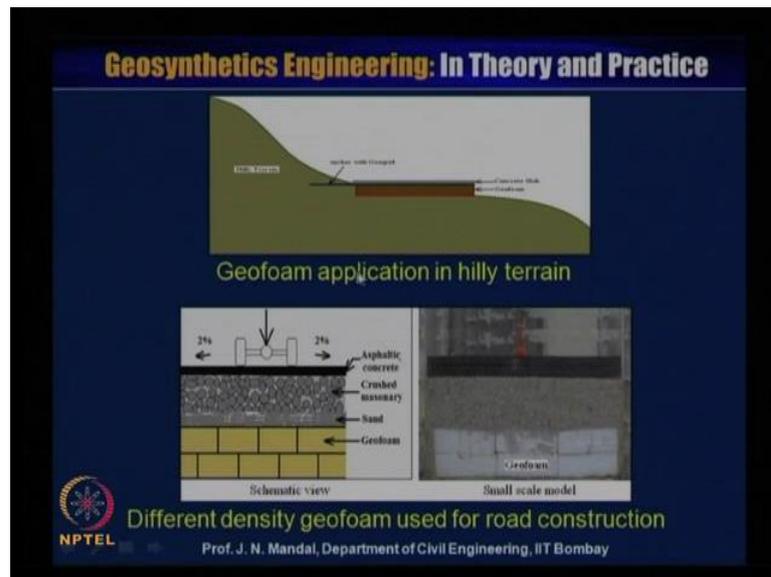
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Here, if you require the widening of the road, so when you want to widening of the road with this slope. So, you simply can place this geofabric material and you can extend the road and then on the slope, you fill up with the soil and then grass will grow. If this embankment, you want to make with the geofabric material, even then you provide with neither the slope nor the vertical. Then also you can see that vehicle can passes through this area of safety.

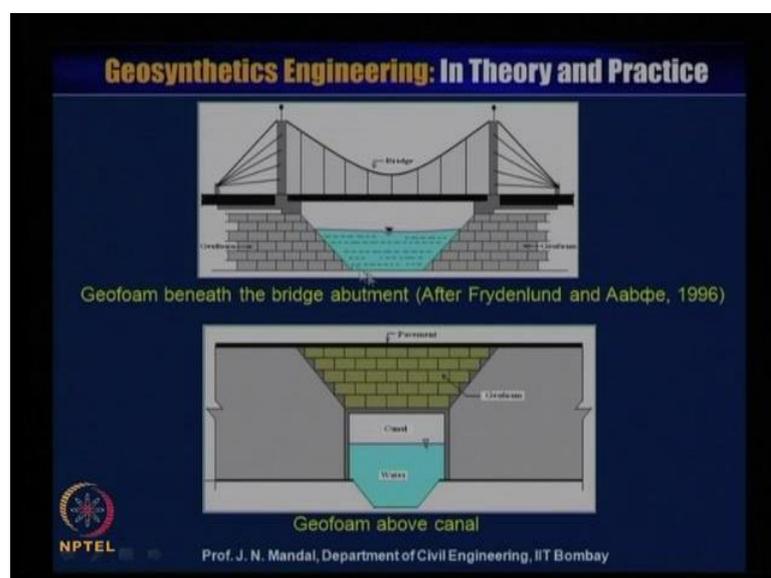
Also, you can construct a house on the top of this road here the geofabric beneath the slab or the beam at the foundation after Frydenlund et al 1987. So, here is the beam, here is the concrete beam and here is this geofabric material. So, the geofabric beneath the slab or the beam at the foundation will help you to reduce the pressure and here is the slope side fill of geofabric. Any slopes in this area, you can see like this, so you can place the geofabric material and you can construct the slope side fill with the deployment of geofabric.

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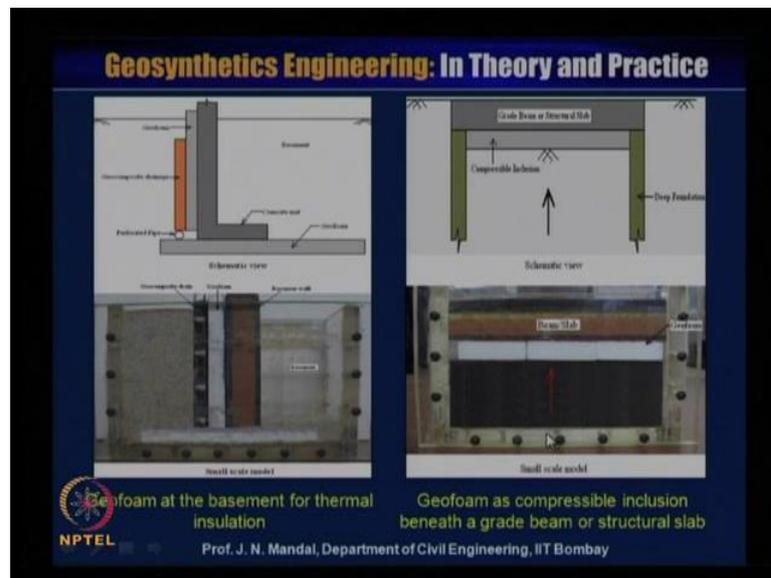
Some geofoam application in the hilly terrain, it is very difficult sometime to construct, but you can simply place this geofoam material and concretizing. So, you can construct the road here is the some theoretic view of different density of the geofoam is for the road construction. So, here is the geofoam, then the sand then the crushed masonry and then asphalt concrete and then you can provide with the certain slope at 2 percent. So, you can construct the road like you can see on the right hand side. This is small scale model where it has been used the geofoam and the crush sand and the crush stone at different density.

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So, here is the geofoam beneath the bridge abutment after Frydenlund and Aabobe in 1996. You can see the water is passing here and in the bridge abutment where in this slope, the geofoam has been used and this is the bridge, huge bridge. Its height may be about 4 to 4.5 metre and this expansion is about may be 36 metre. This is one of the case histories in Netherlands. Also, geofoam you can provide above the canal, suppose if there is a canal and you construct the road on the top of this canal, so it is very difficult. So, you can you can introduce this geofoam material because if this is the canal, this is the concrete canal and water is passing through that and you wanted to construct this is the place and you wanted to construct this road or embankment. So, you can simply place fill up this gap and you can construct this embankment.

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So, geofoam at the basement of the thermal insulation, so here you can see that concrete this is the geofoam this material and here is the drainage. So, here you can see here it will act as a thermal insulation, so when there is a difference in the temperature inside the room and the outside the room, there will be difference in the temperature. So, you wanted to keep the room in cool, so you can provide with the geofoam material. Then you can see the difference in the temperature where this geofoam material will act as a thermal insulation.

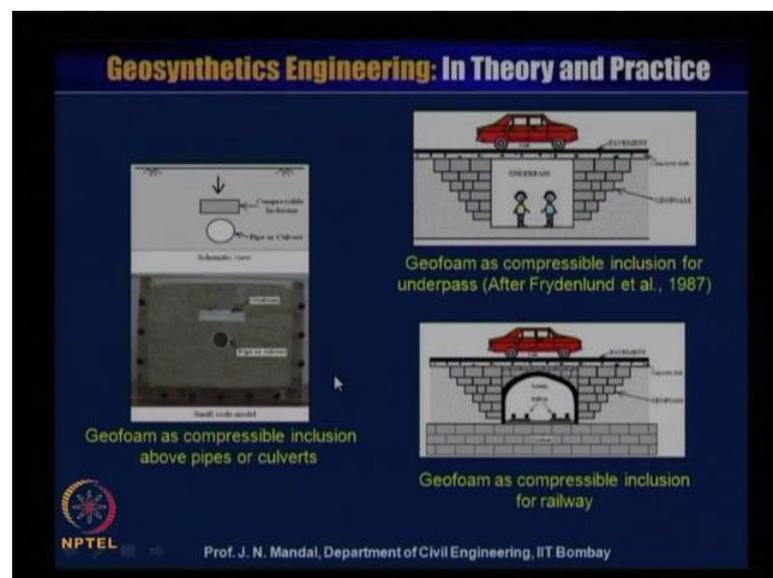
So, I can show you with later on with some example where the geofoam material has been used as a thermal insulation either for the foot protection. So, we have to keep the

foot in cool temperature for the safety. Similarly, for the house you wanted to keep the house cool, so in that case instead of the conventional material that is granular material, you can introduce this geofoam material. You can find that room is cool or the storage is cool so your food is also safe.

Now, most of the time we can see that there is formation of the crack of the building when particularly rest on the swelling soil. So, geofoam here as a compressible inclusion beneath a great beam or structural slab, so this is the structural slab, this is the deep foundation and this is the graded beams around. On the base of this beam, you can provide the geofoam, here you can see this is the geofoam.

This is the beam or the slab because for the swelling soil there is a upper thrust, so this upper thrust can be minimized by the introduction of the geofoam material. So, it will not affect the building and this you can prevent the building from the cracking. If you go for conventional method, then there is a formation of the crack, but here because due to the geofoam material which will act as a compression inclusion. So, this building will not be any problem, there should not be any formation of the crack.

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Now, here that geofoam as a compressible inclusion above the pipe or the culvert, sometimes you can see that any pipeline or pipe passes below the ground surface and you require filling up with the soil up to certain depth. So, you can minimize the depth by the inclusion of the geofoam material where geofoam material will act as a compression

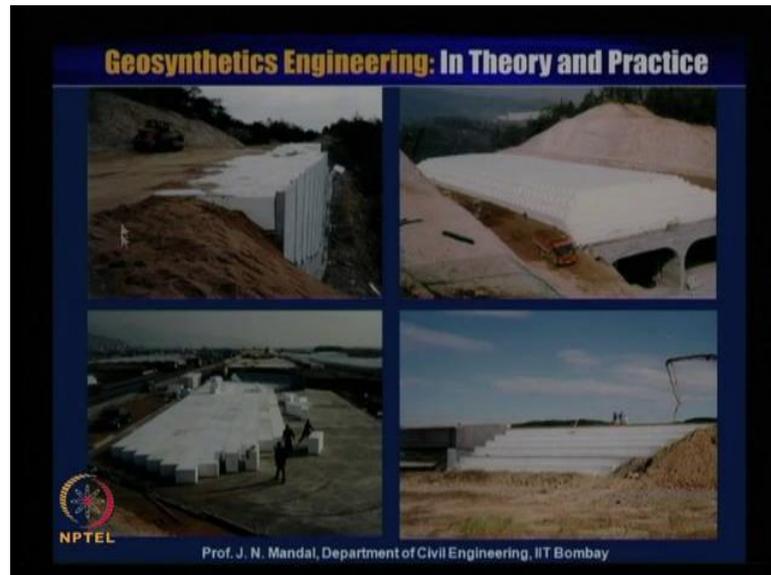
inclusion. Some research work also have going on in this institute where that pipe and also geofoam material has been used and you find that it is very effective.

You do not require very higher depth with the filling with the material above the pipe. So, you can minimize the either the depth of the excavation or fill up with the soil. So, here you can see this model this is the pipe and this is the geofoam. So, initially if you find that if you provide with A at a certain depth and if we apply the load and there is a possibility for bending of the pipe. So, you need to increase the depth of the filling material.

So, alternatively if you can provide with the geofoam material either in the semicircular form or in the rectangular form then because for its compressible inclusion. Then stress cannot be distributed to the pipe, and then pipe also will be the safety due to the application of the load. You can see some of the very interesting application this geofoam has a compressible inclusion for under pass after Frydenlund et al 1997. So, you do not need just to place this geofoam material and is the top is the pavement.

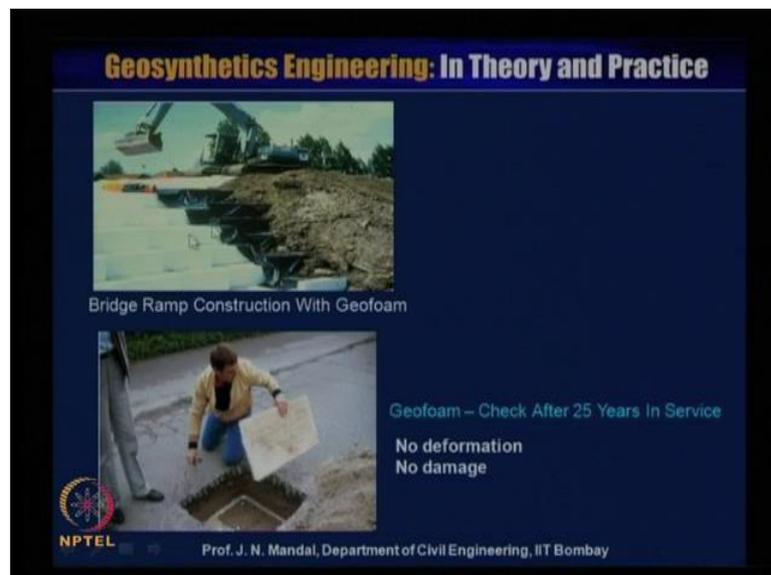
So, vehicle can pass through the people can easily can pass through this way, you can see some also the geofoam for compressible inclusion for the railway. So, this is the railway, so on the top of the railway also you can provide with the geofoam material. Here, you can place the geofoam, you can construct this railway here and then on the top of this you can fill up with the geofoam material and then pavement can be constructed. So, one way the rail can pass below the ground and also the car pass on the road. So, this is kind of the geofoam you will act as a compression inclusion for railway.

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This is some of the example, this is the geofoam where you can construct the retaining wall and this is the geofoam material. This is like a tunnel or where geofoam has been used and this is how we can see the geofoam has been placed also, here is along the slope that how you can use the geofoam material.

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So, this is the side slope where you can place the geomembrane and then you fill up with the soil, because sometimes that if there is a petrol then geofoam will be very effective. So, you can provide with the layer of a geomembrane material or polythene material

which can be protected and then on the top of the polymer material, you can provide with the soil and then grass can grow and also bridge ramp construction. Also, with the geofoam, you can see here the how the geofoam has been used and it has been checked after 25 years in service.

So, there is no deformation of the geofoam and there is no damage of the geofoam material. So, we conclude that here that geofoam has a lot of potential application and it is very much needed in India and some also developing country that where we can make use of the geofoam material. We have a plenty of the geofoam material in India, so we can make it more economical and stable structure and this construction time is very less. So, with this I finish my lecture today; let us hear from you, any question.

Thanks for listening.