Ground Improvement
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Lecture No. # 23
Introduction to Geosytnthetics-I

In this lecture, we would be talking about ground improvement using geosynthetics. In fact, in the lectures that are to come we would be talking exclusively on the use of geosynthetics in the ground improvement projects. This is one of the spectacular materials that we have.

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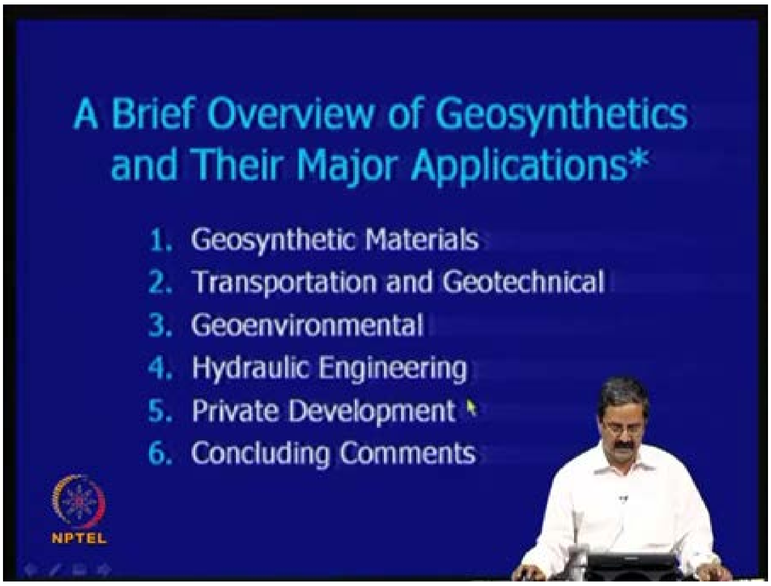

And we will be talking about in this lecture what is this material and how it can be applied in many branches of civil engineering, right from transportation, geotechnical, geoenvironmental, hydraulics. In fact, it is useful for even many other private development and all that. So, we would be talking about these materials that have been so useful in ground improvement projects.

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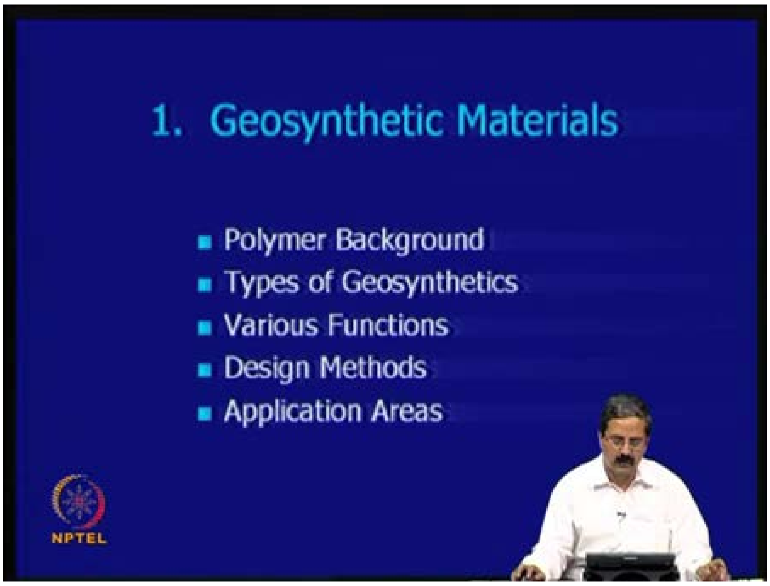

So, first of all, we should be able to understand, what are these geosynthetics materials and what types of geosynthetics we have, what are their functions, what is the design methods we have and what are the applications.

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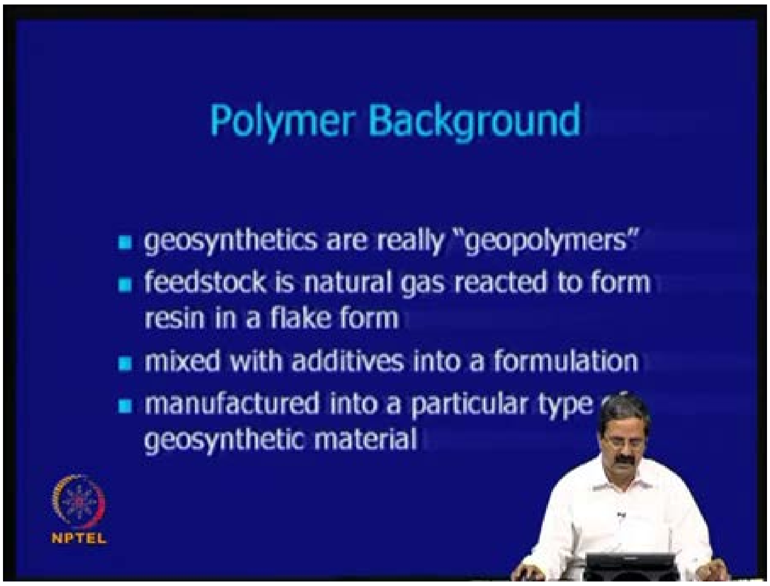

The geosynthetics are essentially geopolymers, in the sense that, they are all polymeric materials. And you know, they are from the natural gas reacted to form resin in a flake form; in the sense that, when you are trying to remove this gas, you know, you have a polymerization, in the sense that, you can do a fractional distillation and all that, you would get some many materials.

And some materials they can be converted into some sort of solid flake form, which can be used to have they what you call polymers. And we try to mix some additives into some formulations and they are manufactured to a particular type of geosynthetics materials.

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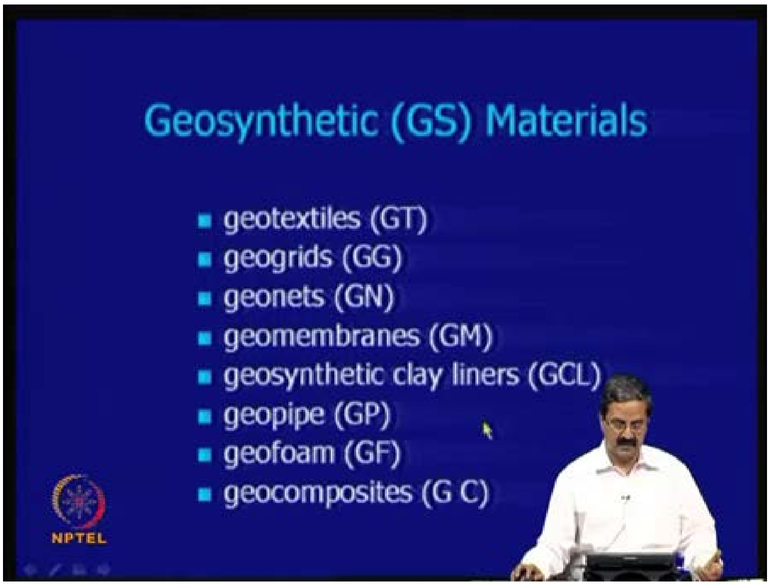

And you have what you call geotextiles, geogrids, geonets, geomembranes, geosynthetics clay liners, geopipes, geofoams and geocomposites; anything that connects ground and improves its performance - ground performance - essentially we are looking for ground performance in terms of the engineering applications.

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Engineering applications in the sense that, as I just mentioned, we want improvement in shear strength, we want improvement in bearing capacity, we want less compressibility, we want good drainage sometimes, we do not want water to come at all sometimes. So, all this things you know, one you know, you have a specific problem, you have a specific solution here; that is an advantage here, like I always say that, like as a civil engineer, you will have only to deal with soil, concrete, steal, but then, you have another material that can come with the help of, if you have this geosynthetic material, if there is some problems in soils, it can solved.

If there problems in hydraulics, because of the water, this can be solved. And even structural design, people have been using, you know, for wherever there is even in bridge apartments, the geomembranes are being used and it has wide applications. These are all geotextiles what you call, and it can be various types of fabrics one can have.

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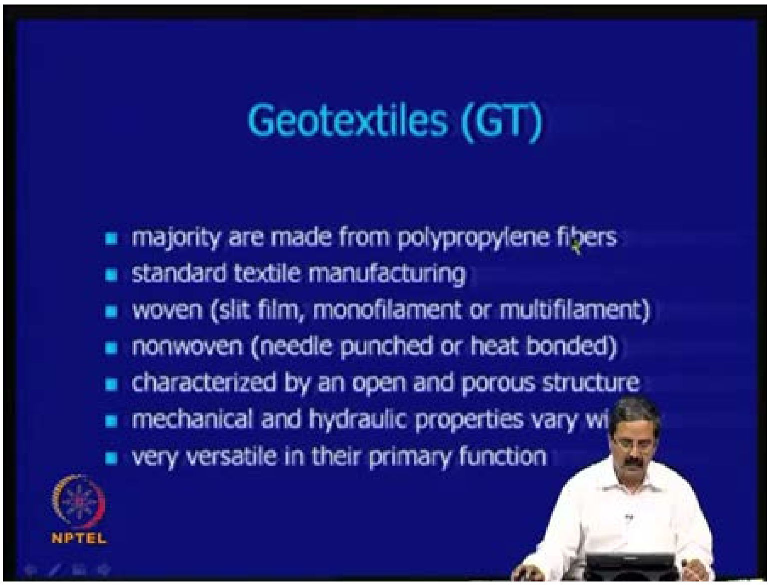

And the Geotextiles are normally they are from, you know, you can have many of the like, it can be from many materials, like polypropylene, polystyrene, PVC; there are many types of polymers.

But essentially we are trying to get, you know, geotextiles are from the polypropylene fibers and then they have a standard textile manufacturing. In fact, many companies have this sort of textile manufacturing companies also manufacture geotextiles; say for example, I want to give the example of Reliance, I want to give the example of Madura mills, there you have lot of geotextiles in India.

So, many companies have this sort of fibers making processes and you divide them into wovens, which are you know woven together, like I will just show you some, you know, it can be a slit film, it can be a monofilament or multifilament like a single filament or a multi a number of filaments together; it can be you know instead of weaving to a few strands together, it can be even nonwoven, where we try to use of heat bonding to combine all of this material. Then, we say that, they can be even needle punched to stitch them together.

Some of these materials are characterized by open and porous structure, because you know geotextiles their application is most of the time permeability and separation. So, we need this sort of open structure and porous structure; then, mechanical properties and hydraulic properties vary widely. In the sense that, you can design whatever mechanical properties you want, whatever hydraulic properties you want, you can calculate and then give us a design.

See for example, if I want a bearing capacity of, just I mentioned you know 20 ton per meter square instead of 7 ton per meter square, I would like to increase the bearing capacity from 7 to 20, I can use geogrids to improve the bearing capacity. So, I can choose that quality of the geogrids to improve that bearing capacity; even permeability is the same thing, they are very versatile in their primary function, they are very effective.

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So, these are called geogrids, like geogrids, the difference is that, it is a textile member. Here, we have varieties of geogrids, in the sense that, this is what we called by oriented geogrid, in which the size is same in both the directions and the low distribution is equal; this is very good in the case of applications of payments or the bearing capacity improvement, where the load is applied and then it should be distributed properly.

Then, this is a mono oriented, in the sense that, tensile strength action is in one direction. And this is also very good in the case of reinforced soil walls or slopes, where the force of application is in one direction and you would like to improve the stability.

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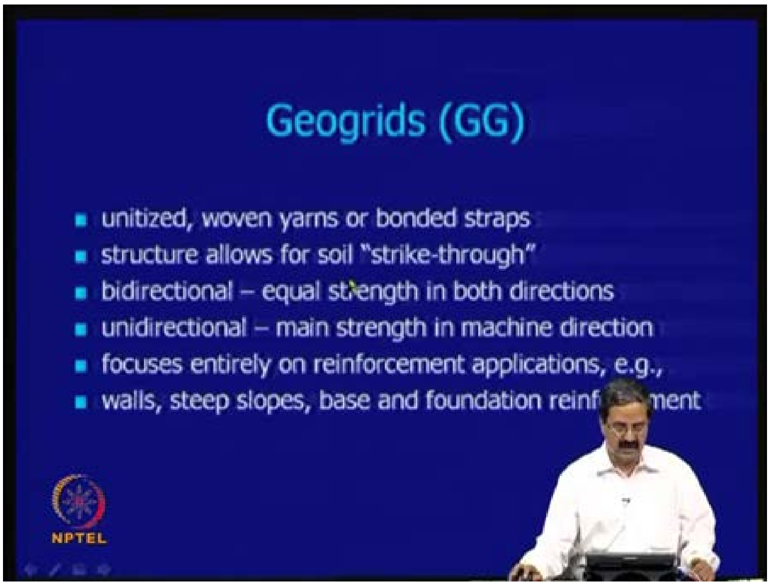

So, the geogrids are something that we have a special type, where the unitized woven yarns or bound straps. Structure allows for soil straight through, in the sense that, there is soil to soil contact as well as soil to grid contacts.

And they are bidirectional, in the sense that, you know I just mentioned, equal in strength in both directions, which is quite useful in the case of bearing capacity problems. Unidirectional - the main strength is in machine direction; why these things that required is that the way they manufacture, the manufacturing process is different and the pulling, you know, the you stretch, these are all chain of molecules of polymers; and if you stretch them to certain their strength, increases in that direction. So, you have to mission your system in a proper way, that you get the appropriate numbers and all that.

Focuses entirely on reinforcement applications, like you know, whereas I just mentioned we are looking only for reinforcement applications, like you know, where the bearing capacity is you wanted like or you know reinforcement particularly in the case of walls; that is what we see lot of R E walls, steeps slopes base and foundation reinforcement, there could be many things.

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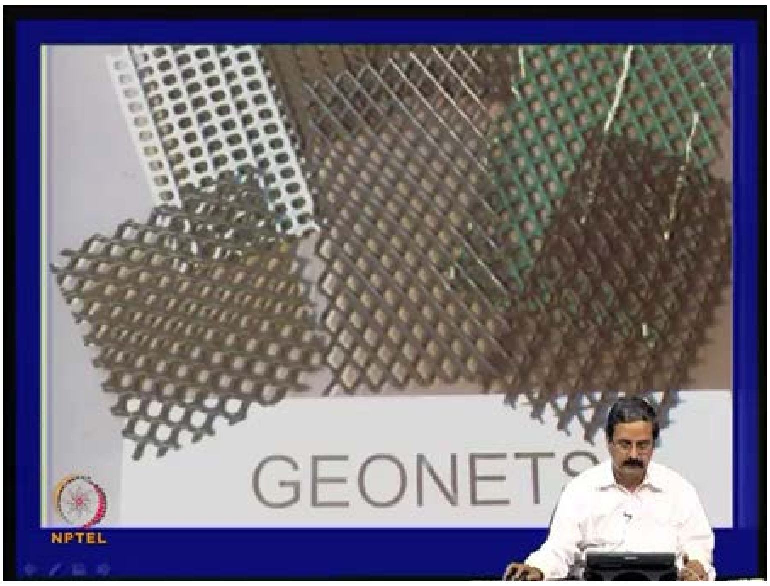

You also have geonets, which are a combination of this; they have a hole and they are also for drainage, also they are useful. These are some materials.

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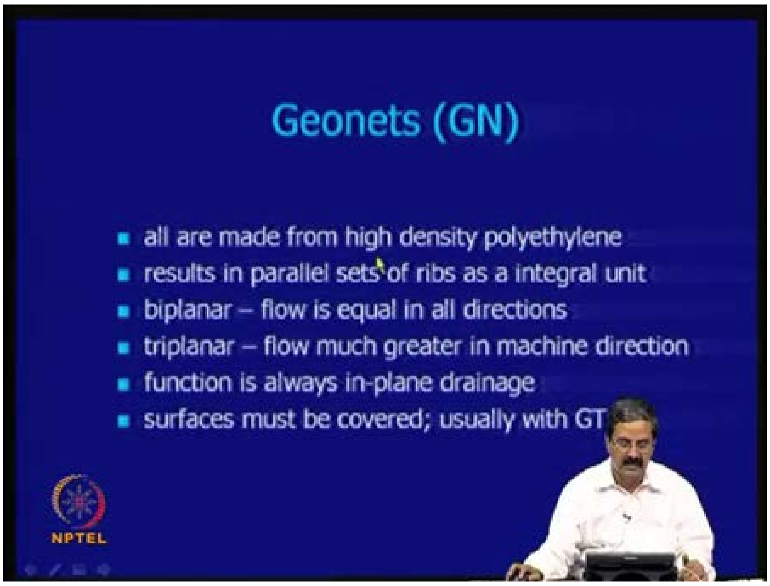

They are all again made from high density polyethylene results in parallel sets of ribs as integral unit. Biplanar like flow is equal in all directions; triplanar - it can be you know flow is greater in machine direction. Function is always in the implant drainage essentially.

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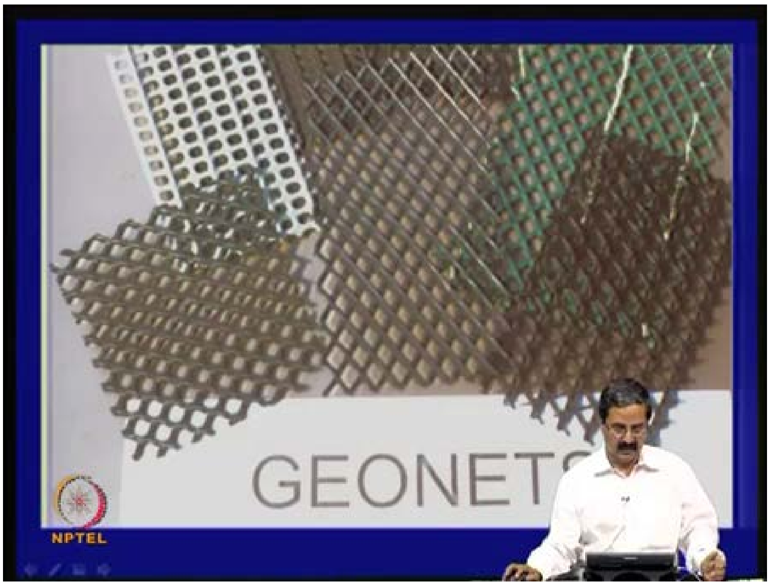

You are looking at, if you just see, you are looking for there are some holes here, because of this, there is in plane permeability; we will talk about that, like you have a filtration, is like you know the if there is a water flow in this direction, and if you have a filter and it only takes water, but it does not allow the soil to grow out; that is called filtration. We will see some of them now, and the geonet has a in-plane drainage facility.

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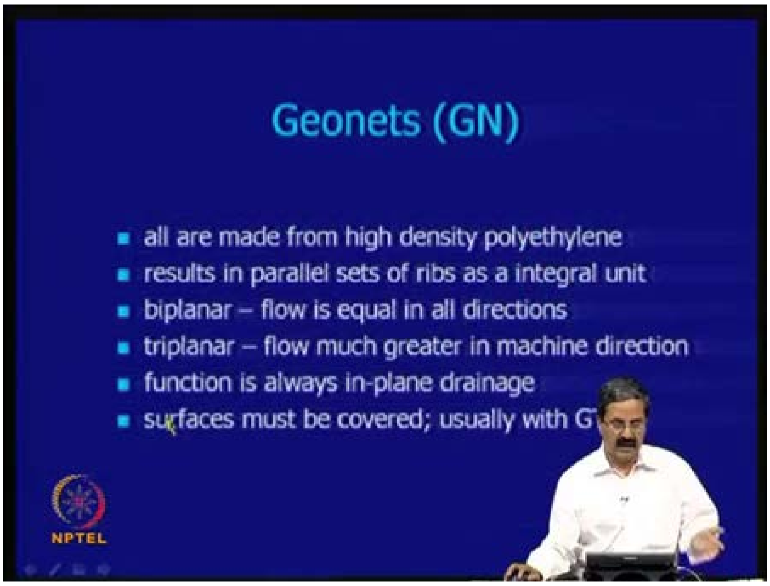

Surfaces, they are actually it should be always covered, because you should not allow them to, if you just do not cover them and you normally have a with geotextiles, you cover them actually, because what happens is that, wherever the drainage is occurring and you put this geonets, and also after that you put some soil there and then put a geotextile there, that is a standard thing that we will see. And the advantage is that, it should be well covered; otherwise, what happens? If the geonet is getting damaged or something, the flow will not be proper.

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So, geomembranes is something that is very excellent, like we do not want in some places applications like you know water to come, you know, water geomembranes, say for example, we have cutoff walls. In the case of dams, you take a dam thing - dam structure - you do not want underground water; you have an upstream side here and then water should not go to the downstream side. And if the foundation is somewhat permeable, then it is a problem. So, put a cutoff wall. People were using in the olden days, bentonite, slurry walls and all that, and if you want to avoid that, you can put a geomembrane; we will see that.

And geomembranes can be of many types, like it can be rough and it can be textured, it can be colored and all that. It is a number of applications of geomembranes are there; in fact, in dams, dams landfills, too many.

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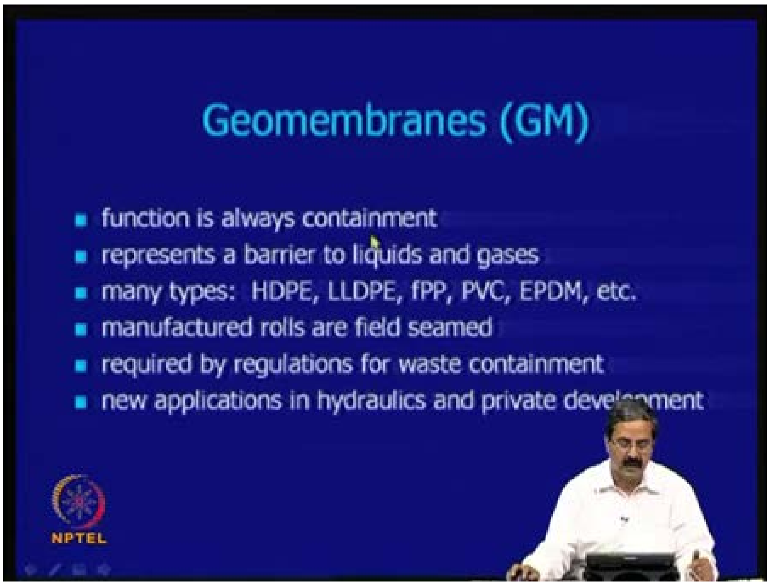

So, the geomembranes, their advantage is that, they are always they contain whatever you know, say for example, the permeabilities minus fourteen, you know, the thing is you know about clays, it is 10 power of minus centimeter per second. But then, these materials are almost impermeable, in the sense, this could be minus 13, which can be actually you cannot even measure the permeability in a conventional sense.

You have to measure the permeability using only the vapor absorption; how much of vapor they can absorb? How much of vapor transmission can go through them? That is the way it can measure. But otherwise, geomembranes, it is not easy to, I mean, in a conventional, there the sophisticated testing is required. And the function is always containment, represents a barrier to liquids and gasses; many types are possible, like see canal linings, you know for example, in India, lot of seepage is there in the canal. And if you want, you do not want, if there is a canal lining and water, you do not want to water to go out of the canal system.

So, what we have in normal practice is that, people have cement concrete linings. If you go to Tungabhadra dam or Malaprabha dam and many of the dam sites, we have only this material which is cement concrete, which are which are very expensive and they are failing.

But if you have this sort of materials, high density polyethylene and all that, they are quite effective. They are all manufactured rolls of field seamed; required by regulations for waste containment.

In fact, even in government of India, we have rules which show that, yes you have to use landfills; and for landfills, you need to have geomembranes, because you have in the landfill contains lot of waste and (( )) should not go to underground water. And to prevent that thing, it is only the geomembrane that can be effective.

What we call? We have what is called composite liner, in which you have a clay liner plus geomembrane and we use this geomembranes in the sense. And of course, in new applications in hydraulics and private development, there are too many; we will see that.

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So, another interesting product that we have in this family of geosynthetics is that, normally people have trying to provide clay liners what is called geosynthetic, I mean, what is called clay liner, in the sense that, in the case of landfill in the old regulations, they say that you have put 90 centimeters of clay liner. And we are calculating that, yes if you have that 90 centimeters and then if there is a head of water of leachate of some number one meter or whatever, the hydraulic permeability of the clay liner is going to be, say for example, some number 10 power of minus centimeter.

So, the amount of leachate that gets transferred to the underground was supposed to be very minimum; that was a old calculations, but people observed that, clay liner is not really very effective, in the sense that, it has lot of cracks, and it is not easy to maintain quality control in the field, because the thing is that, the road contractors we know that they are not very good in compaction, and to get a very good permeability from field compaction is not easy.

And if you get high permeability, the problem is that, water gets contaminated or the leachate goes to the landfill. In order to avoid that, you have what is called geosynthetic clay liner. So, which means that, it is a small membrane, in which you have a bentonite in between and geotextiles on either side. And once this 90 centimeters of geosynthetic, the clay liner can be replaced by a simple member like this; this is an advantage here.

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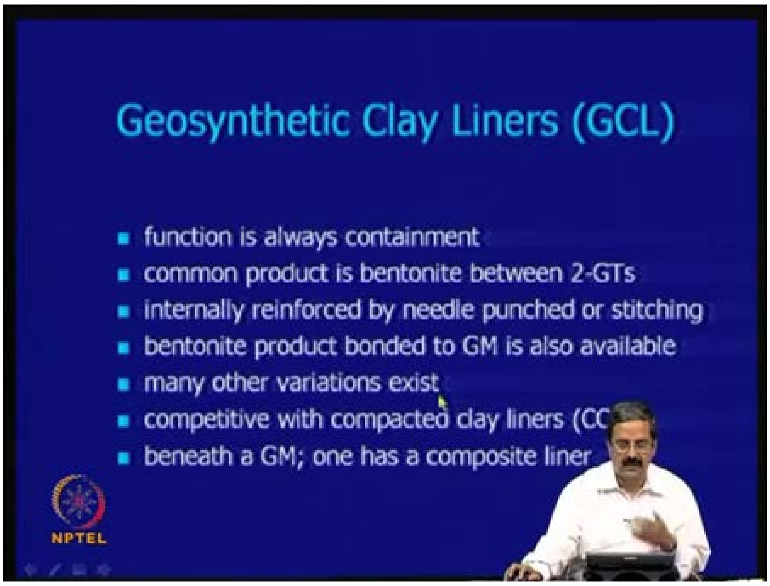

So, the function is that, again their function is always a containment like in the case of a clay liner; clay liners containment, you know, they contain all the waste, ok. So, when clay liners are not effective, better to use clay just with the clay liners, because they are all manufactured products. So, the common product is a bentonite, which is sandwiched between two geotextiles; internally reinforced by needle punch to a stitch bonding.

In fact, I will show you some materials, where there you know to maintain the integrity of the textiles in the bentonite, they stitch together, they have a needle punching stitch bonding. The bentonite product bounded to GM is also available; sometimes instead of the geotextiles, you can have one layer as a geomembrane and then a geobentonite and then a geotextile. There are many variations; they are very competitive in compared to compacted clay liners. Beneath a GM, one has one has a composite liners; normally, composite liner can be even, you know, in many of the products.

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The other one is what is called geopipe, actually in many of the land fill applications. We are using, you know, all the leachate has to come out of the pipes; even our water supply pipes, we do not call them geopipes, why? But then, this term has become very important, because when you are using in the olden days, people were using concrete pipes, where the soil next to the concrete pipe does not have any role to play.

But now people have been using flexible pipes, either steel or even PVC. PVC most of the time, and when the you have a PVC pipe and then you have a soil next to that, the PVC pipe gets deformation, because of the earth pressure that is acting around the pipe.

So, because of the soil reaction, there is a, it is a very beneficial effect it. In fact, the in the case of rigid pipes like concrete pipes, we design that say for example, if there is a rigid pipe exist at 3 meters and we design the earth pressure, we design the pipe for gamma b into half into that over burden. So, that much pressure and also the lateral pressures you have to calculate to see if the pipe will be intact.

Objective is to see that the pipe is intact, but then in the case of flexible pipes, because of the soil structure interaction, the load whatever is applied will not be totally coming on to the pipe; it could be what is called because of the soil arching and other conditions, the load may be much less than what you expect using gamma b into height into that particular, you know, 3 meters; say for example, that it will be much less because of the interaction, ok.

So, it like arch action is taking place because of the. So, that way particularly in landfills and other applications, if concrete pipes broke, then it is very difficult to solve. So, whereas, and then they should also they have little tolerance to deformation. If there is a small deformation, concrete piles fail, whereas, geopipes can take care of more deformation they can stand. So, that is the reason why you have some sort of flexible pipes like this here, which are used you know corrugated sometimes, like you know you have same sheets here.

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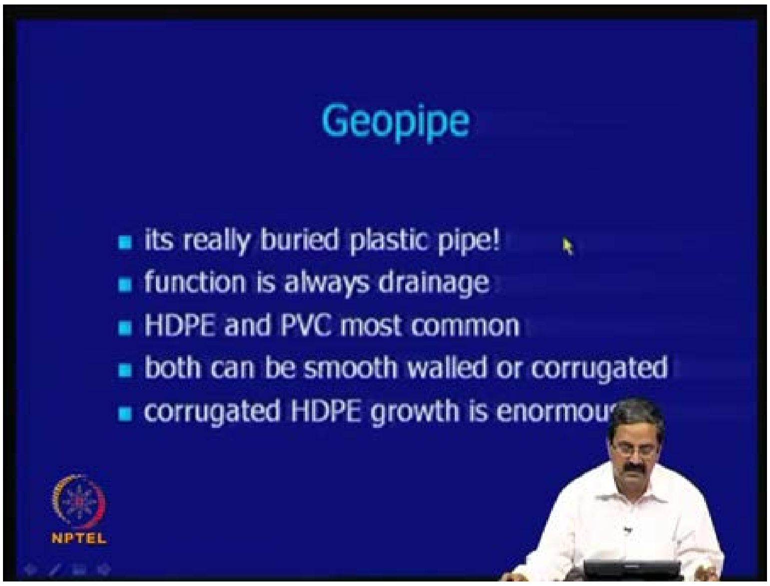

So, it is in fact the geopipe is nothing but a buried plastic pipe; the function is always a drainage of leachate. High density polyethylene and polyvinyl chloride PVC is most common. If you go to lab or even Yashvanthpur anywhere or any place, you know, most commonly PVC pipes are used. Both can be smooth walled or corrugated; corrugated high density growth is enormous; nowadays high density polyethylene pipes are quite popular.

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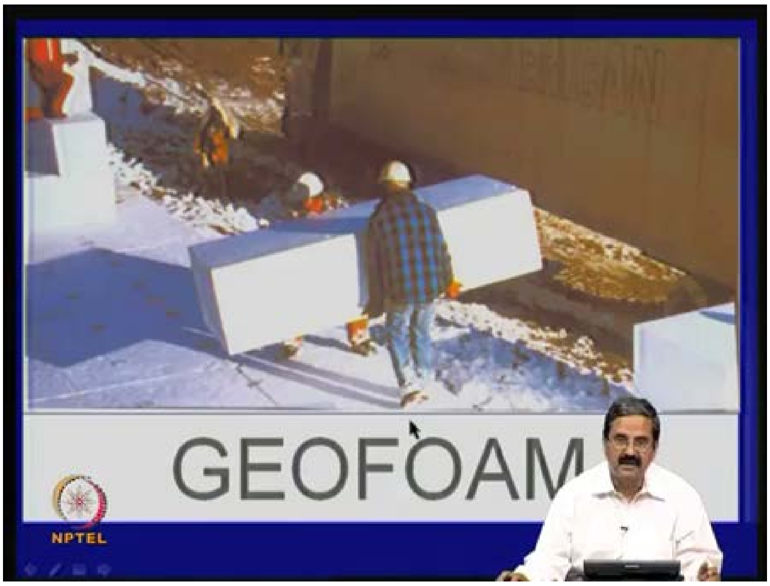

There is another thing that is called a geofoam. In fact, it is another interesting material, where you can it is very useful in many applications.

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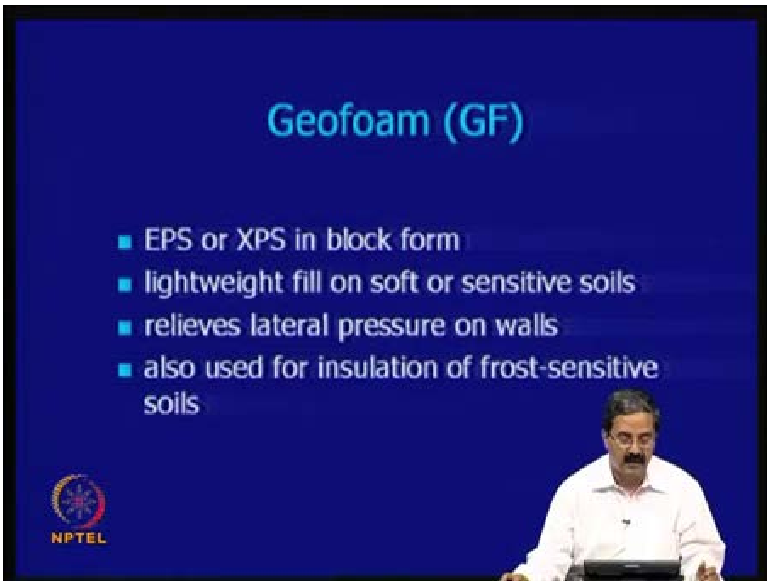

It is like a it is foamy material, it is a very light weight fill on soft and sensitive soils, relieves lateral pressure on walls. It is also used for insulation of frost-sensitive soils; actually its another very important material in fact its compressibility is quite low. But at the same time, its easy to lift, like we have seen that two people have taking it, carrying it.

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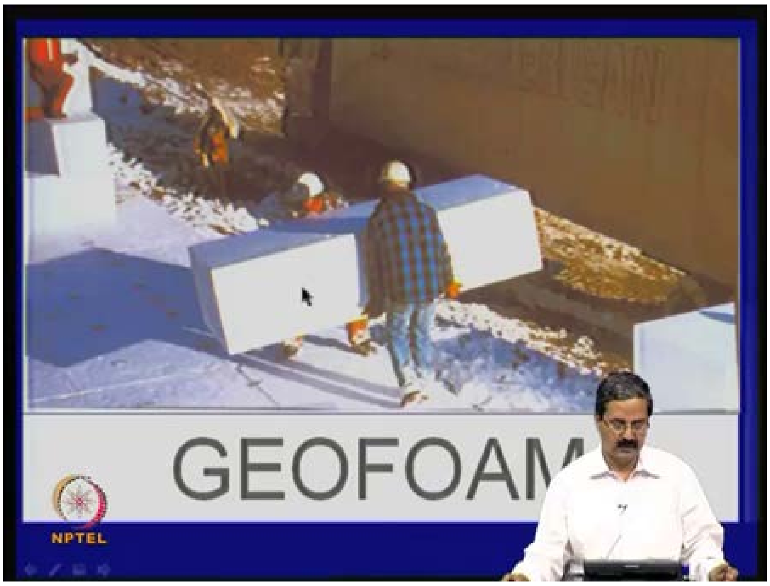

And suppose the advantage is that, it can be even used for road applications; many applications are there, we will see that.

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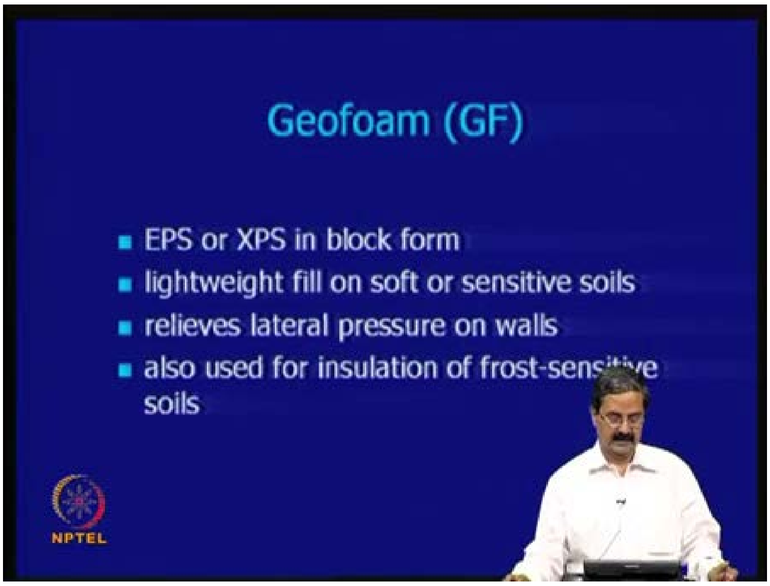

And there is other one what is called geocomposites. Geocomposites are nothing but two materials you know they are glued together, and one can be geomembrane on the top and bottom it can be geogrid; two functions can be joined together, you know, that is what is called.

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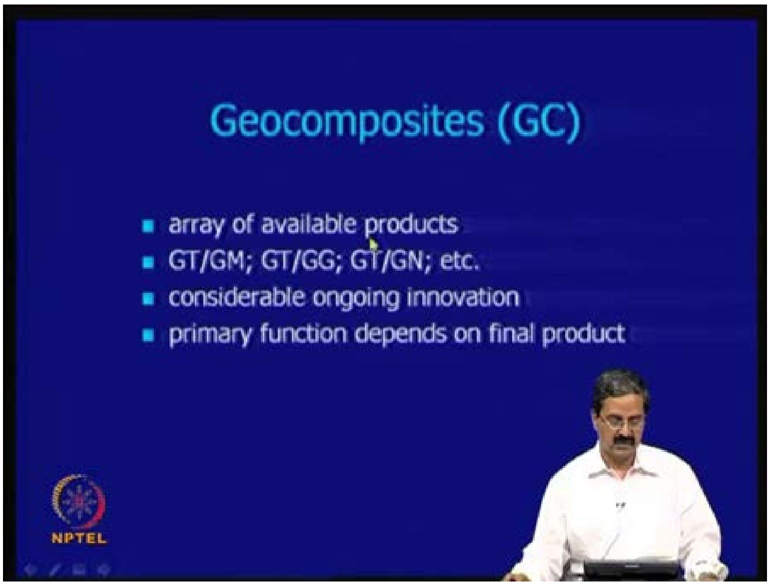

So, geocomposites can be, you know, it can be a geotextiles and geomembrane glued together; geotextile and geogrid you know together, like say for example, geotextile can serve as a drainage material; geogrid can serve as a reinforcement material. So, in this case, geotextile can just act as a filter material or drainage material; geomembrane may not allow all that water to go down.

Geotextile and geonet; so, lot of combinations are possible and you have lot of innovations going on in this direction, because you can really design what function you want, like say for example, you talk about a clay - clay back fill; the clay back fill, the problem is drainage is not good and you want improve the strength. So, you can have a textile also, you can have a geogrid also; textile allows all the pore water pressure dissipation.

In fact, the other day I was just mentioning, even you can put some charges electrical charges to see that they take all the water and then drain out, like a electrokinetic geosynthetics I was just mentioning the example, there too many applications are there, because when the soil is so soft and you still want to construct a retaining wall using a soft soil; there is no other alternative. So, these are all some innovations that have been possible.

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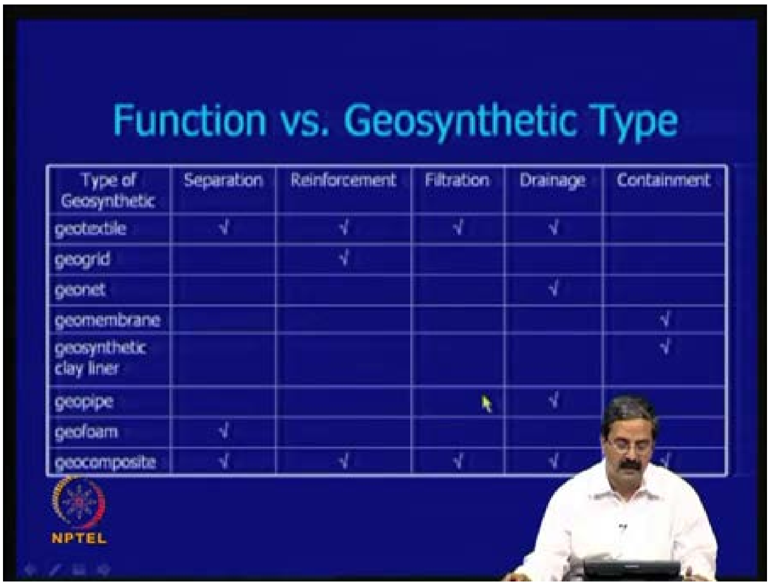

So, I would like to just mention that, they have very good applications, separation, reinforcement, filtration, drainage and containment - their main applications. And geotextile can be used for separation function, and geofoams also can be used for separation function and geocomposite.

Separation means you know you are trying to, two materials you want to, say for example, in the case of a pavement material, you have a sub grid, sub base, base course and varying course. You want all of this materials to perform their individual actions well, but then what happens? Because of the load application of the traffic, the intermixing of layers do take place, because if you just a load is there, you know applied and then released; the bottom material comes top and top it will goes down. So, that sort of intermixing is possible, you do not want to have such things, because it is like bad plus good become bad.

So, you would like to separate those two layers and see that they are intact. So, that function, you know, why is the function in the pavement? Each member like bottom most member has a low strength, next one has a higher strength, next one has a still higher strength like that.

So, in no way, that should be diluted, because load distribution is an important point in the flexible pavement design. So, if the load distribution is not there, then the road totally gets damaged. So, if you put a separate layer, all the three layers separately behave for the and, then they do their job properly. So, that is an important concept here. And this is a that separation is there; then, geotextile you can use it for reinforcement geogrid; yes, it can be done, geocomposites also can be used for reinforcement.

Filtration you have a geotextile, and geocomposite also is there. Drainage yes geotextile can do that, geonet can do that, geopipe can do that, geocomposite can do that. And containment, like as I said geomembrane is very good, gcl is very good. Geocomposite - so the geocomposites are essentially we can design; see any two functions can be combined to get a geosynthetic geocomposite.

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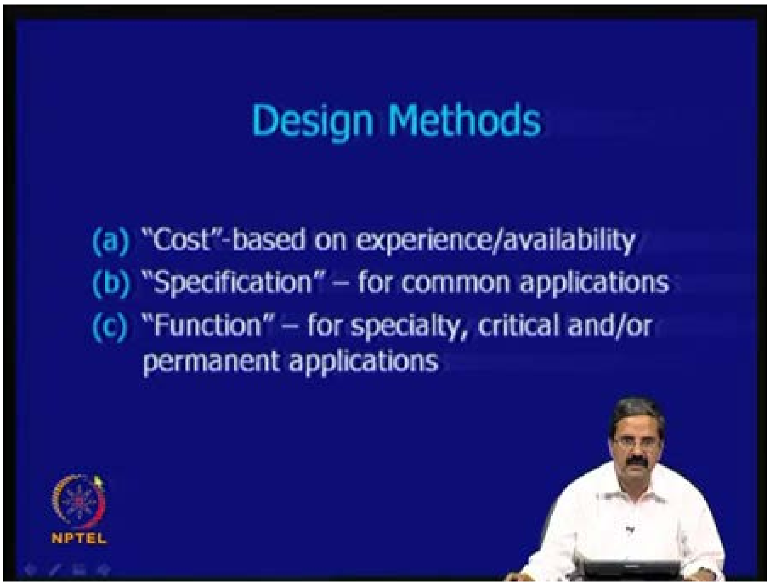

So, actually you know we have see that, this geosynthetic materials are very useful, you know, day daily life like in any engineering projects, and how do you go about design? It is like, one is design is that, it is based on experience; the number one is cost based, cost based on experience, like you know, if it is going to be very expensive in a particular application, then we may not take it. And also the availability, like you know, depending on the availability of a material, you try to design, you know, for whatever work it can be done.

It can based on the experience, you know, like if you see that a particular geotextile has been useful in one application, if you have a similar application elsewhere, you can do that and that is based on experience; that is what people do. We say that it worked there, so it will work here. Then, the second way of doing or implementing these techniques is that, there are some specifications which are for most of the time common applications, like you say in landfills. In government of India, there is some minimum standard guidelines – specifications - you have to follow; like this should be the thickness of the clay liner for the municipality, this should be the thickness of the geomembrane for that area, that is it. And if there is a water logged area, this is the specification you have to follow, whether it is IRC, whether it is landfills and all that, there are some sort of specifications that one should follow properly, right.

So, in a way you know the design methods means the methods that help you to implement; essentially you have, you know, based on experience, one is by specifications, like then third one is by function. Like you know, exactly you calculate what is the function you require and what is the force you require, you specify the material and this is for high end projects - you know reasonable high end projects. And for critical and permanent applications like RE wall design is there, you know you are trying to construct on a reinforced RE wall near Yashvanthpur or (( )) circle or whatever nearby. You know exactly, what is the traffic load, what is other forces of the earth pressure that are coming.

So, you can exactly design, what should be the spacing, what should be the length of the geogrid, what should be the filter media there, everything one can design. So, that is an example of the function; the second thing is specification; yes, for most of the common applications, one should be able to have minimum thing, so that it can help in some things, like say for example, separation. Put some simple layer there, if it can work, yes you will get advantage, because it allows you to see that though two materials do not get mixed up. Of course, based on experience, experience does not have any substitute. So, it is quite useful.

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So, as I just mentioned, particularly when you adopt a design by function approach, like we always have a allowable property divided by required property. So, for example, you are trying to take a geogrid, we know its tensile strength how much is the force. See, as I said earthquake, force is this much or driving force is this much; to resist it, you need to have some sort of reinforcement, and when you have that reinforcement, then the advantage is that you have some tensile force generated. So, you need to have some, you will have what is called allowable tensile property; allowable tensile property, say for example, for that material and what is required, that gives a factor of safety. And we have some sort of test methods that are from ASTM, ISO and GRI design methods or models are available from literature.

Factor of safety application is side specific, like you know, the factor of safety can be application specific; for example, retaining wall, it could be one factor of safety for the slopes, another factor of safety and all that.

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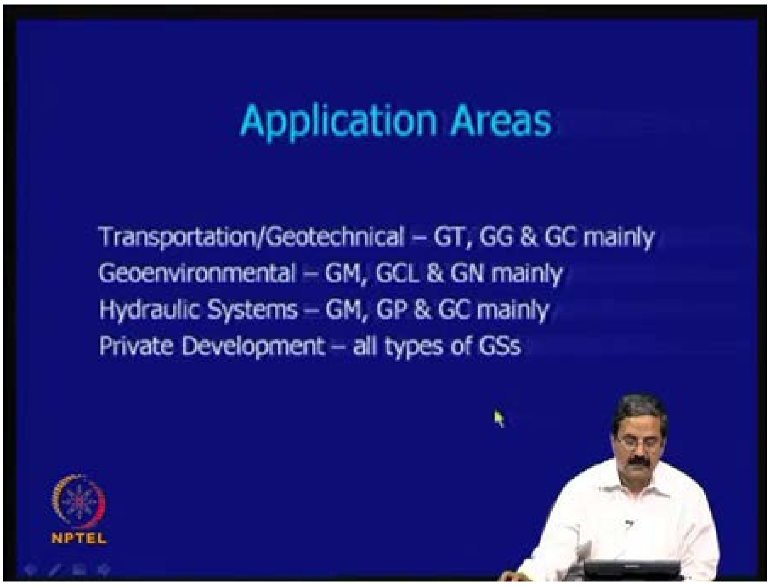

So, I would like to just illustrate you, that some of the application areas, see the as I said, the applications are too many, it can be in transportation, geotechnical, geoenvironmental, hydraulics and all that. So, you can see that in transportation like particularly in pavement and geotechnical, geotextiles have been every effective as filters; their geotextiles and geogrids are as wall reinforcement; geotextiles and geogrids are slope reinforcement; I was also mentioning actually we have studied this PVD's, prefabricator vertical drains.

So, they are also called wick drains; they have been quite effective in consolidation applications. Then, geoerosion control, they are also quite useful, like you know, where this slope erosion is taking place; you can have the geocontrol, this erosion applications as well. So, what is geotextile filtration? Actually how what is mean by the filtration criteria. The filtration criteria is that, it refers to the cross-plane flow; GT acts as a filter and not as a drain. See the thing is that, the water is coming in this direction, it filters all the water; water is just going in the normal direction, soil is just left there.

It is not like a drainage, where you know, drainage comes after filtration actually, like you know, because suppose all the water has to be drained properly. So, the drain capacity which is not sufficient, you have to have more openings, like geonet can do that. So, geotextile filtration refers to the cross plane flow. And here the design requirements, there should be adequate flow, proper soil retention, like you know, you should be able to retain the soil, and also long term flow equilibrium, you know, you should be able to filter for a very long time.

Say for example, twenty years or ten years, five years, whatever, because it is not easy; this is a very important concept, particularly you know, what happens? In the long term, the possibility is that the filters get clogged you know most of the time; that is what we see in water filters. The problem with water filters is that, particularly in house hold items, the soil gets like small fine particles that you have in water gets deposited in the filter and that is a reason why you have to boil them quite often; that is what we do at homes.

But then, in the geotextiles, say that that is going to happen in the natural soils also. If you are trying to use a gravel, you know, you use gravel or sand as filter, sand you know you may say is a very good filter; but over a period of time, if the clay and sand gets mixed up, then there is a probability that there is not a good flow in the long term.

So, you put a geotextile in that place, definitely it has a better performance. And the other thing that we make a correction is that, we try to really increase the size of the opening size of the geotextile. We make a small allowance for the geotextile even to a long run. How much of accumulation of particles may take place and still we allow flow to take place; so, that is one thing. It is very good for retaining walls, erosion control systems and pavement drains.

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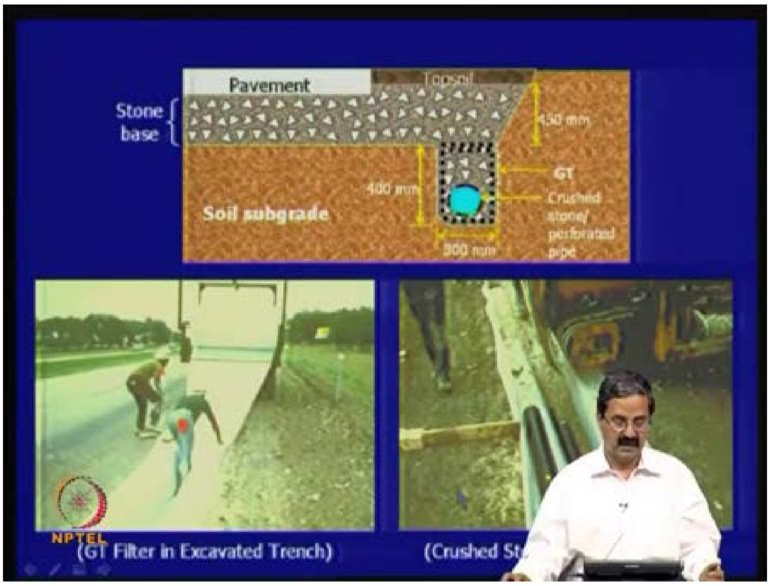

Number of examples, like you can have a pavement here; if you have a material like this, here geotextile layer is here. So, you can have a system like this, right. Then, when you are trying to talk about reinforced wall, particularly when you are talking about the flyovers and all that I just mentioned, you are using a geotextile or a geogrids here like here.

So, internal design, actually the earth pressure that comes from the retaining wall has to be resisted by the reinforcement. See reinforcement, because of friction between the soil and reinforcement, like if there is a force coming here, you have a geogrid and soil there - backfill soil; there is a friction in opposite direction that resist that earthquake force.

So, when you are trying to, so when your internal design means, what should be the spacing of the geogrids, how much of spacing I should have and what is the length of the geogrid I should have. To calculate or resist the earth pressure, so that earth pressure is based on the internal design. So, the spacing length and facing connection stress. In fact, what happens I will show you that, even some force also like comes on to the facing, how do you do that?

So, this internal design, external design is like similar to our retaining walls. We do overturning stability, sliding stability, bearing pressure calculations. And this is external stability, this is internal stability; and since you are using geogrids, you have to calculate all this numbers from the laboratory tests.

So, you should know exactly what is the allowable strength, because you are designing the wall for its design, like say for example, fifty years or hundred years. In the case of steel reinforcement, you give some sort of corrosion allowance and then appropriately increase the thickness. In the case of geogrids, may or geotextiles, we should take it is going to serve as hundred for hundred years. So, you should correct; then, what happens with end of this materials? There is some immediate strength and it gets reduced over time.

So, you should calculate that reduction strength over time, say for example, it can be ten years fifteen years or fifty years or hundred years, that number should be used in design, because you want it to stay for hundred years or fifty years or whatever. Then, so, the reduction factors on the reinforcement are important; the factor of safety is another important variable, like you know, because finally for all the factors of safety you know, like external stability, internal stability, then these factors are there; one should be aware of that.

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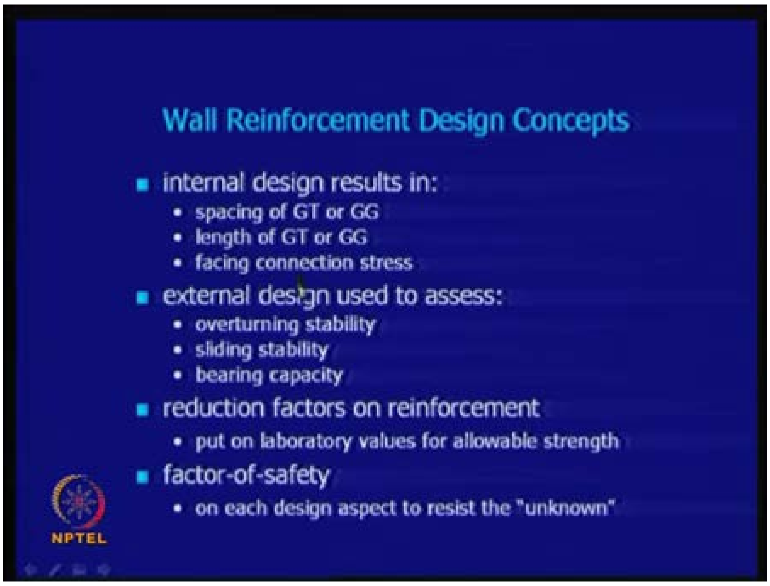

This is a simple example, like as I just mentioned, like this is a geotextile actually; you know, we call it this is a wraparound geotextile and we know that this is a 45. You know we have studied that the failure wedges can form in different angles and all that. So, this a 45 minus phi by 2, this is a 45 plus phi by 2, this is a retaining wall. And you have a geotextiles placed like this, like the way we will see how it is done also. So, you have a surcharge - p 1, this is the surcharge that say you try to construct some road there, that is called surcharge. Then, there is a live load, there is a concentrated load, all of them will induce some sort of earth pressures, right.

So, what is this earth pressure? This is like this soil pressure; it is nothing but hydrostatic pressure like this. Then, surcharge pressure, then you can also calculate what is a live load pressure; whatever is the pressures, you have you can always calculated and you sum up all the pressure. So, at any point here, say for example, if you are calculating this is earth pressure coming here, so this earth pressure should be resisted by the friction between the soil and reinforcement, ok.

So, if you are able to put at every level reinforcement like this, then your system is fine, even you can add earthquake force also; earthquake force also adds some small changes to some of these things, and you can do that the earth pressure distribution, you can get and do that there is no problem.

So, it has another thing that we should know; this spacing is there, one spacing of the geogrids, like SV is vertical spacing, because horizontally they come in some meters; you know one meter and all; so, it is layers. So, you have this spacing. Then, length, how much length is there? The length has two things: one is reinforcement length and the another one is at anchorage length; there are two components here and I think you should see l r l e and l o, ok.

So, what it means is that, in some case, say for example, in this case, this is say take this case this is force and this is called active length, this is called you know passive length; you know there are two lengths here. We calculate tensile force and see that this there is a resistance offered from this. It should be, it should not slip reinforcement should not slip. So, you have an additional length that we have to provide.

So, for example, tensile force is mobilized, that tensile force has to be sustained; whatever is a tensile force, you know, you should have a length here at least could you know, because of the friction between the soil and geogrid, that force should be able to be twice the force mobilized in the reinforcement. We will see those calculations also subsequently. And we have to calculate every stage, that the length of the material should be such that, there is an adequate length to satisfy this requirements of tensile force and pullout force.

Actually the movement we put that length, you should not come off easily; you know length, say for example, if you provide, if you think that you can only provide this much length, no it is not possible. We have to have this much of length also to hold it; this much length is also required to hold it, this what it means.

So, the thing is that, one other interesting thing is that, the earth pressure is less here, because you know you can see that the earth pressure is somewhat less, but because of the loading, it is somewhat here more you know. Normally, if you take k a gamma h or k naught gamma h, the earth pressure is less here, but because of the surcharge you know it is here.

So, normally you have to have a uniform length, that we will see some of them, or sometimes depending on, you know, if the system is like this, you can have variable length also. So, you can see that, once you have an earth pressure t is taken care of by this, the near the facing know earth pressure is minimum there is no, in fact, there is no pressure. So, but then, you cannot leave just the soil like that. So, you need to have some sort of erosion resistance; some length of this geotextile coming like this, so that, that is what we have to provide some sort of length, may be 1 meter, 1.5 meters.

You take a geotextile put like this (( )) like this; so, everywhere it is like that. So, this is some sort of length that can hold it on, I mean, so that, that thing is avoided. And in some cases, you know, if the geotextile is normally, you know, it is for a permanent application like retaining walls with lot of loads, we cannot have it. So, what we go for a concrete facing.

So, you do for concrete facing or it can be any other facing, because now the advantage of the facing is that, you can design the facing in such a manner that the earth pressure,s we know that the earth pressures are very minimum here. Otherwise in one case, you are trying to provide, say one meter, you know the thing is like a we have some rules, right. If seven meters is the height of the wall, 0.4 time should be the base, you know, or top width will be some point one h or something. If you just see the specification of the retaining wall, you have to provide a minimum thing like that, which leads to lot of cost implications in terms of the heights and all that. In fact, I have a case in somewhere, where you know in some place in Andhra Pradesh, where 35 meters is the height of the retaining wall.

If you want to create a base width for that, it will be about 35 means; about at least 20 meters, if you take horizontal pressures and all. 18, 18, 15 to 20 meters you have to provide base width which is quite expensive, whereas with this type of technology and with type of thing, it is going to be very effective, ok.

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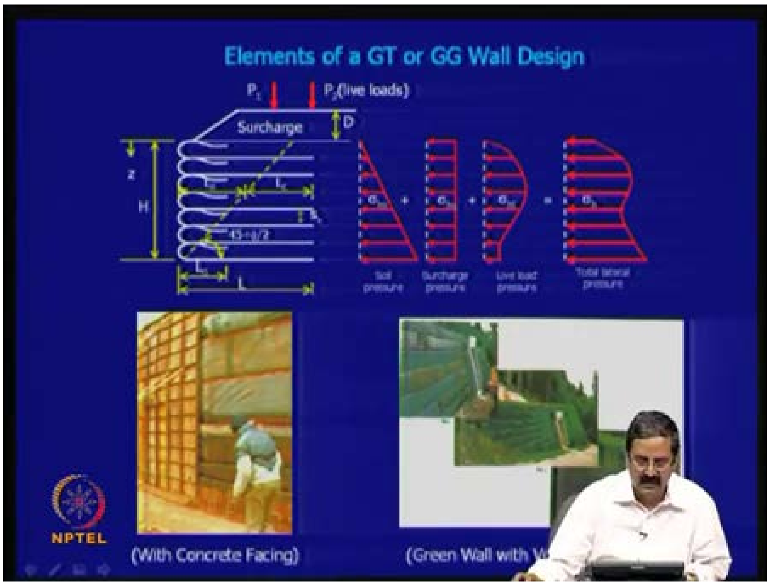

Now, you also have number of types in the case of RE walls, like this is we call them tide walls. And wall facing can be like anything, like they are called modular blocks. In fact, the advantage of, you know, one can have a facing of full facing or even modular blocks; the advantage of the modular blocks is that, one can easily lift it and all that, whereas in the case of panels like this, which we have bigger panels; it could be little more labour intensive, whereas this can be hand held and done simply, you know, like an artist. So, the advantage is that, this is what is called we call them as segmental walls or a modular blocks, because the blocks are modular in nature.

And then, it refers to actually any type of wall facing can be having, aesthetic blocks you can have. And it is an very important use of a advantage here, you know, we call it modular blocks and you have a computer programs also. Nowadays, if you buy from a particular company, they will show you what the software they have; the design philosophy is same, like you know, earth pressure have to be resisted. But then, if you are trying to put different types of facing, facing should be very good.

So, they only suggest the facing, they only. So, you can even check you know or you can you may have lot of choice of facing. So, you can chase, you can pick up one type of facing, which suits the aesthetics and also design the connections properly. We will discuss some of those things later, but then, even connection design of the, like say for example, you may have facing here, facing here, that connection design between the reinforcement and the facing is important.

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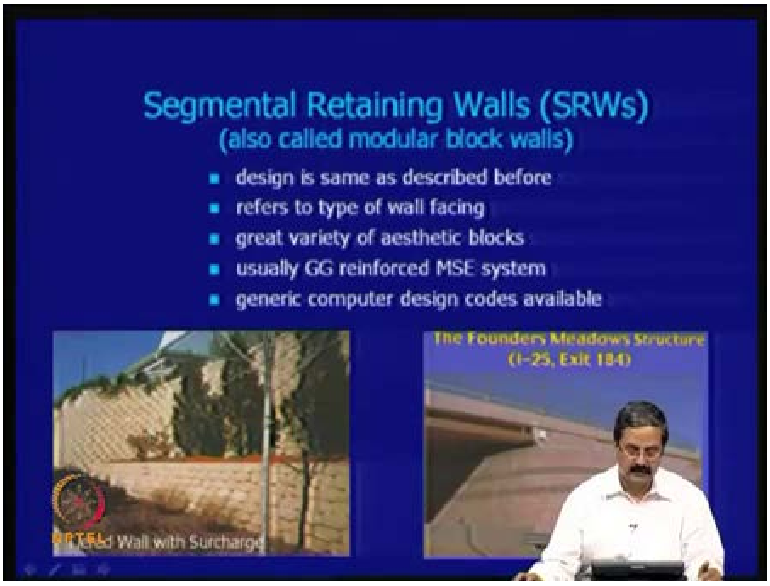

So, that is about RE walls, which is has a maximum applications; it is too many and may be you may have 50000 or many number of walls in India, which are quite effective; particularly in the recent, may be ten to fifteen years, they have it has taken a very big jump.

Then, reinforced soil slopes, we know that, soils cannot be made steeper; you know they have an angle of repose, like say for example, the (( )) is to two is to one slope like more than twenty six degrees if you go then it slides right.

So, one way is to put some sort of reinforcement to increase the slope angle or the height, essentially there is no limit for the erosion and various placement patterns are possible like what you are trying do is that ,you can have a material here ok.

Like, which can be even it can be seventy degrees, eighty degrees, there is no problem about it. And this is you know ,you can have depending on the loads and all that ,you can have a uneven spaced or even length. You can have many even spaced ,even length ,with short facing .Then there can be many possibilities are possible.

And essentially what you are trying to do is that, we know that the failure surface or the wedge step can occur; And if you are able to place this reinforcement properly, then that type of failure can be avoided.

There're also failures I mean, they particularly you know with we have seen many failures ,see here the with reinforcement the slope can be as steep as eighty five to ninety degrees; Reinforcement slopes are possible like you can see that it is very steep, may be seventy degrees here, may be eighty five degrees here.

Ah this, we have seen geo-composite drains, they are also called prefabricated vertical drains; They allow rapid consolidation of the saturated fine grained soils and it consists of a drain core as I showed you, which is a drain core and also the filter.

And they are just hundred mm ,by you know thickness is also very small and you can see that they are all small materials. You have a [meti/mechanism] mechanism to dry hole drive the p v d's and these are all the p v d's.

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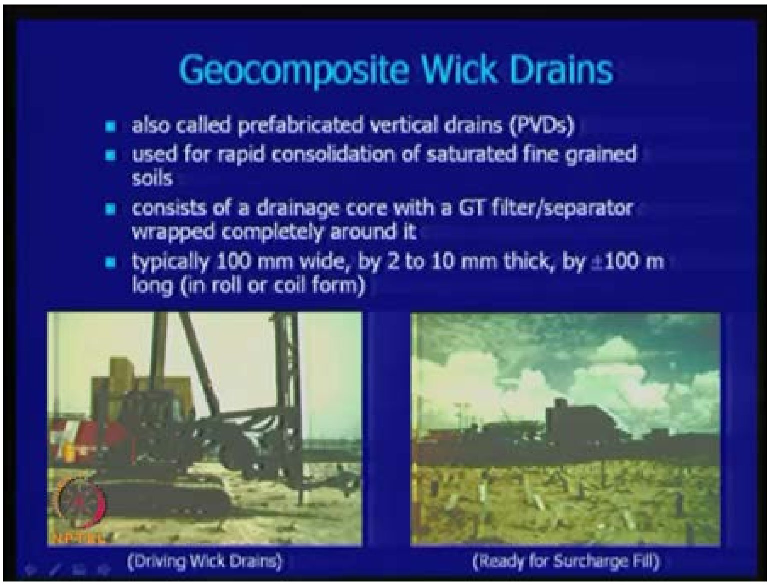

Then you also have geo-composite erosion erosion control systems, because erosion is one of the biggest problems in soils soils ,because particularly when there is no over burden at the top say for example, there is no over burden here, there the soil particles has a tendency to fall of very easily, because of rain or wind or anything.

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So, you will have lot of erosion and erosion leads to lot of problems, because in the erosion of slopes: slope is a structure that has been designed in a geotechnical sense and if the slope is falling off ,or the soil material at the top of the material is falling off, then it is instable right. So, what we do is that , we try to use some sort of materials; geo-composite into erosion control system we cover them. You know in all the material for like say for example, slope protection, channel protection, they can be permanent, they can be temporary, there can be many variations that are possible to control erosion.

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Then, as I just mentioned we have another set of applications, what is called geoenvironmental applications. And there are too many like, they can be used for landfill liners, covers, vertical cutoffs, surface impoundments and liners for heap leach ponds.

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We know that waste is an issue, that everybody has to address and on the waste if the precipitation occurred it generates leachate. Leachate takes characteristics of the waste and the leachate is a highly variable and site specific and the flow is always downwards. And we should see that, the groundwater is not contaminated, because of this leachate travel and you need suitable barrier and a clay leachate collection system.

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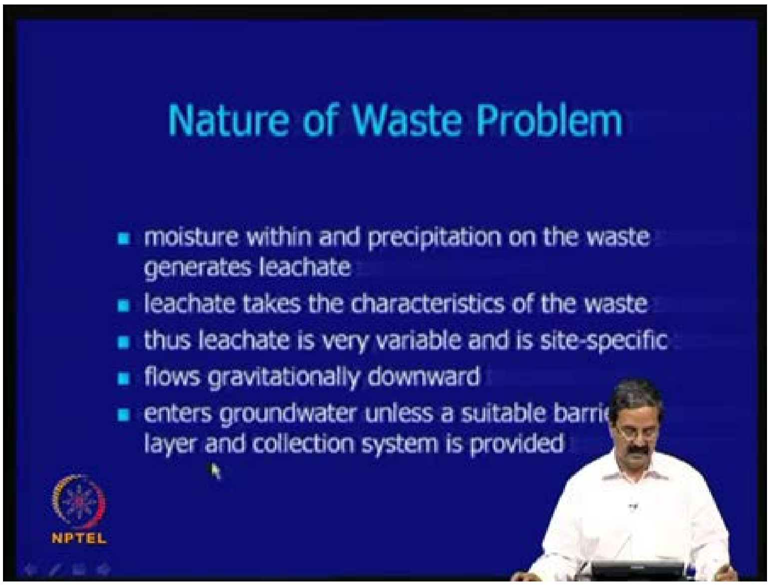

This is how it looks like: you have a landfill here, I mean waste material here and you have a pipe here, as I said you have a varieties of layers of geotextiles here, one can have. In fact, it is there in many places, in India also we have it.

And you have a perforated pipe here, to take care of the all leachate collection; you also have, say for example, you can see here geotextile is at the top here as well as here; geotextiles are there everywhere, then geonets are there, then GCL's geosynthetic clay liners are here, geomembranes are there. Actually this is a, I will show you later, the specifications - some specifications - demand that you need to have double liner systems, like geomembrane here as well as here.

Because if there is a water table here very close to this, then you cannot contaminate it right, say for example, leachate collection comes here; the leachate water should be collected in some sense, then it should be pumped up. There are so many operations that are there and I will show you a detail presentation of the actual landfills in many places.

And see the thing is that, you have all these materials and geogrids are also there, because if the slope is vary, say, this is about as I just said twenty six degrees, if you want to have more than twenty six degrees, you cannot have it and this is a forty five degree slope. And you can have a geogrids like this, and then, increase the factor of safety to whatever you want. Otherwise, forty five degree slope factor of safety is less than one, right, if you use c and phi.

Say for example, take whatever c and phi, it will be less than 1, you know, friction angle say thirty degrees of cohesion 0.1. Then, gamma b equal to, say, 18 kilo newton per meter cube; use this and do a stability program, run a lot of software are available and you will find that the factor of safety is less than 1.

The movement you put this material like a geogrid and give some tension force, like you know, say for example, five kilo newton per meter five, something like that you can give, it is all tensile element. The software I will tell you, the factor of safety now is 1.4, it is fine like that, ok.

So, you have as I just showed you, you have number of liners, you know, primary you know the see the thing is the top one, we call it primary collection system, the second one is called secondary liner system. What is happening is that, leachate should be collected and should be contained within this; then, you have one place where it gets drained off, and then you take all that material and then treat it all the leachate; you should never allow it to the water resource.

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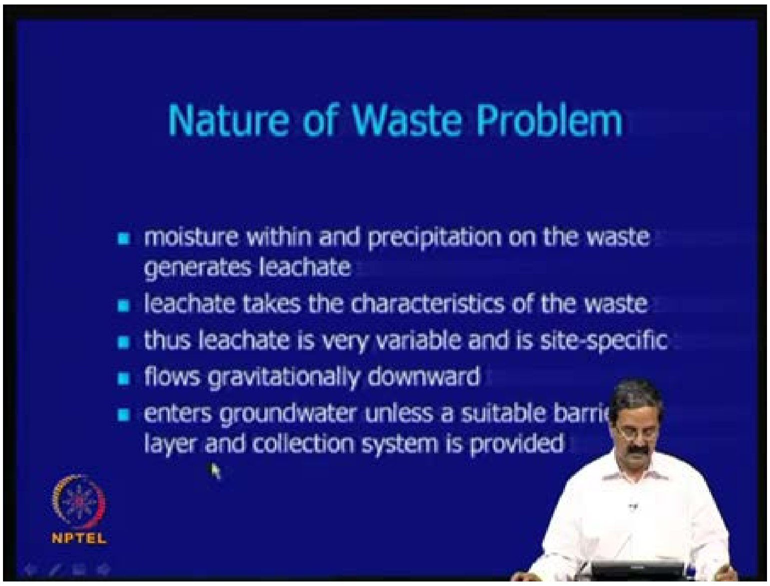

So, for that, you have a secondary linear systems in the field; that is how it is installed and you have leak a geonet leak detection systems, like you know. In fact, you will have lot of sensors in the field; in fact, I will show you some photos, where they will measure in the particular landfill like this, because of the rain, how much of leachate is generated.

Say for example, in this last month, there is lot of rain how much of leachate is generated. At this point or different points in the landfill, you have lot of sensors everywhere; and then, if the leachate generation is going to be high, it means that, our drainage system is not working well. So, they try to go and then repair they will have auto type automatic type of flushing and all that.

They will have highly sophisticated systems, where they can repair in the sitting in the office, yes, increase the pressure, create all that they make such an automatic system in the landfill, that all this things can be solved. So, in this case, some different layers of geogrids primary composite layer.

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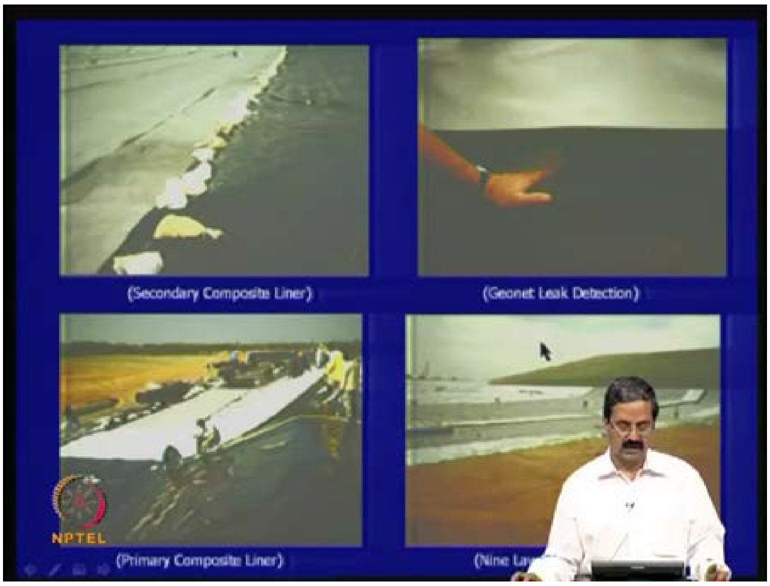

So, once the landfill completes, say for example, landfills are designed for ten to twenty years or thirty years as per the government of India regulations or even elsewhere, like you must be able to estimate the landfill capacities and also design them properly. And once you estimate them, and once the landfill reaches its full capacity, you must be able to close it also; that is what we call it final cover system. And what you have is that, you have various layers here and one is called at the bottom, you have geogrid; then, all this even you know all that there is even a gas collection also, say for example, leachate, apart from leachate goes down, but there is also lot of leach gas also in the like methane and all that, one can collect it.

Actually you have gas collection layers also in the system here and then they go, and then connect one can take methane out of it. So, then cover soil is there; this is again to increase the see the stable of the cover soil, you have a geogrid here. Then, we have an erosion control map, like you know, nice green cover at the top, ok. So, you should it is very clear that the landfill is a containment system, which has lot of geosynthetic materials at the sides as well as at the top; they are very useful actually, otherwise it is very difficult.

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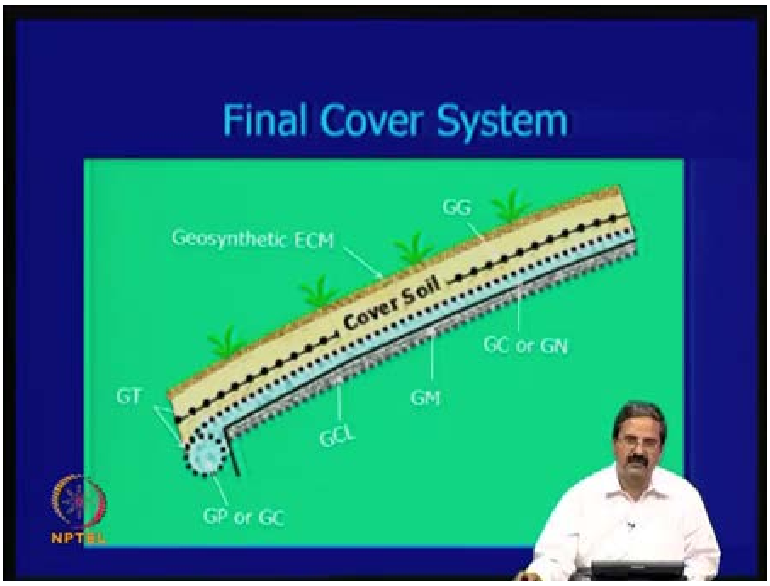

These are some examples of you know a big area in some place, where landfill is being you know treated. An aerial view I will show you some more photos in some cases; sequential filling up of the geosynthetic layers and there could be many layers of geosynthetics as you saw just now, like you know, you saw different layers: one, two, three, four, five, something like that. So, there could be many products.

So, you can have, if you want to really design properly, and you should be able to take advantage of some of these things and it should be a safe. Finally, the advantage of landfills is that, they should not contaminate the groundwater resources; it should be able to operate very well. In fact, I have seen landfills which are quite useful, like people are generating lot of waste gas from that and supplying into their own town, a town supported by the landfill gas a small town.

If somebody is very sure and intelligent, some can somebody can do that. And for some these to ensure efficient operation of the landfills, you need to have geosysthentics. This is a small example how we can have different layers in the landfill and the another important application is that, see, you have already a waste material and you do not want to allow that the waste material travels to a lot of distance, what you call I just said cutoff walls.

Cutoff walls means, they should avoid the flow. So, there is an abandoned dump and there is lot of infiltration of water, and then, that because of the leachate generated on the from the dump, one should see that, that leachate should not go to the nearby say agricultural lands for example. So, one can have a sort of a geomembrane layer like this; this is utilized at abandoned dumps for the control of polluted groundwater. Typically, placed in a slurry supported trench with soil or cement, soil asphalt, or soil fly ash as backfill, right, ok.

The backfill both geomembrane plus this is a geomembrane you can see that, you have a backfill material here. The system is greatly enhanced with a geomembrane placed up the gradient, thereby forming a vertical composite linear system. So, you try to put a material like this in this form, and you know, you are trying create a barrier the cutoff. So, there is an excellent system which is quite good; we will see some them later.

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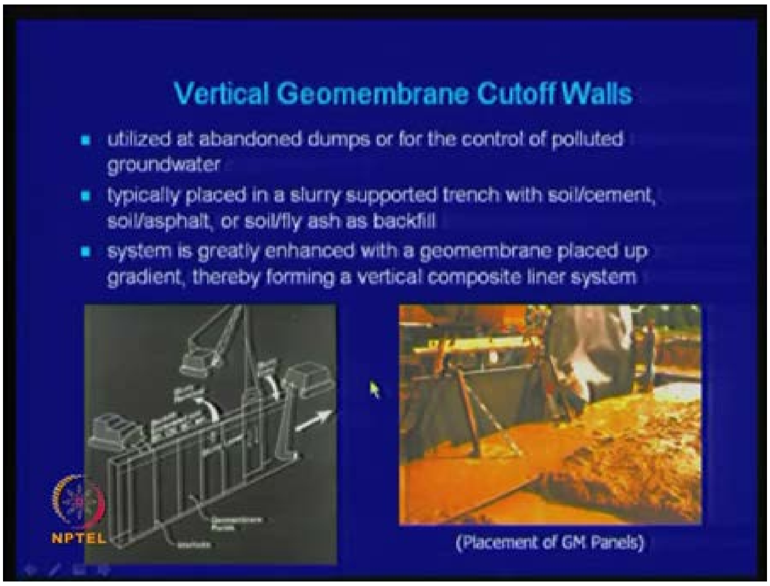

So, some places, it can be used for surface impoundments, like in the case of geomembranes, there are many issues that, like you know, geometry cross section, geomembrane selection, thickness, subgrade stability, cover soil stability and all that, we will see that.

In some lined, you know, the thing is that, in some waste, in industry some industries what happens is that, lot of leachate you know they have to store, like if you go to some chemical industry, there is lot of waste fluid; they have to store it in some ponds, ok. So, that ponds, you know, they will have a double line hazardous waste pond, like in this case, this particular pond has two liners. And suppose you do not put proper lining, the possibility is that the geomembrane may just get up and then there could be lot of problems.

And then, see the thing is that, the geomembrane has to be laid on a subgrade, you know, it cannot be just laid as it is; you have to have some sort of sand, I mean soil cushion, then compacted properly and put a geomembrane. And if you do not put a properly geomembrane like you know, because the soil interaction between the soil and geomembrane, the friction coefficient could be less. So, it may slip off; I have seen cases where it slipped off, because of the rains.

And once you if something failure occurs, then it is very risky. So, here, you can see somebody trying to do a leak detection in system, they will have a leak detection system in a land in a area hazardous waste liquid; he has all the dress and then checking for all the material, that can all the contaminants; he has a leach leakage, I mean detection system.

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Sometimes the geommembranes are quite tricky to deal with wheather to leave the geomembrane as exposed or to cover with soil. Then, suppose you expose it durability is the key, like you know, you should not. So, if it is covered, then it is fine. And it also depends on the type of liquid you have to address; you know the many types of waste industry or the waste industries have different type of waste. So, it should be compactable, like you know, the material should not get spoilt, when it comes in contact with that chemical.

So, if geomembrane slopes are there, slopes will be relatively flat. As I just mentioned, the friction between the geomembrane soil is going to be less, and if it if it can be even less than your friction angle of the soil itself, so the slope will be a little flatter. So, slopes will be little flatter and stability is a major issue; that is one thing one should be little careful, because you may put your slope is all right like one is to two slope, but you put a geomembrane; the geomembrane gets spoilt, because the friction between the soil and geomembrane is not good; they that may the system may not work. So, one should really do some more engineering there. In some of the existing mining areas, the problem is that, you have lot of mines that one can have and one should be able to handle some of these materials in a proper sense.

And this is also very important in mining industries also, there is lot of applications of this materials. There are many applications I think, I will be able to handle it in the next class, because there are too many issues that we have in this geosynthetic applications.

Thank you.