Ground Improvement

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Module No. # 08

Lecture No. # 24

Introduction to Geosynthetics – II

In this lecture, we would be talking about the use of Geosynthetics in Ground Improvement. This is a continuation of the previous lecture and what we would be seeing today, is that, what are the types and functions in the application of Geosynthetics, we will also see what are the principles of reinforced soil.

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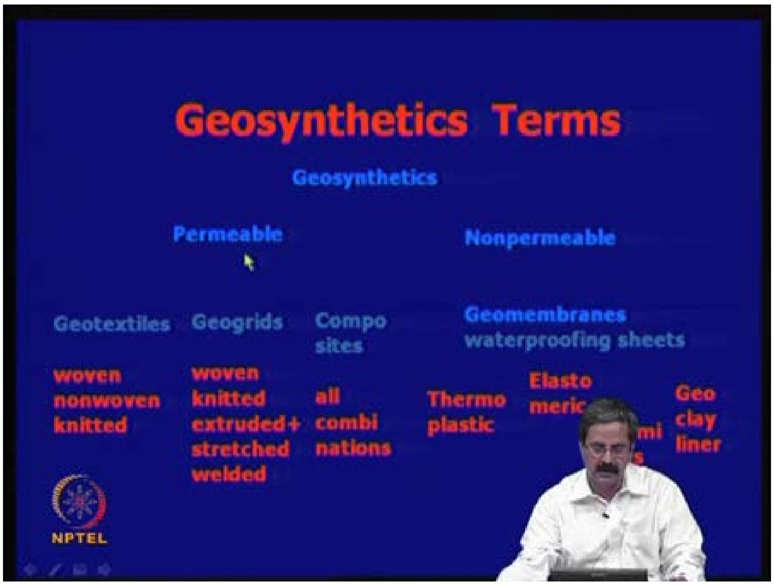

This Geosynthetics is a big family of polymeric materials in which you have two types; one is a permeable members and non-permeable members. And, permeable members means, they allow water through them; as I just mentioned in many of the ground improvement problems, the use of water is something very serious and the presence of water which leads to a lot of difficulties, because it leads to pore water pressure mobilization and all that. So, if you have some sort of a textile like this, which can be a geotextile, where the water can really be permeated through this, then it is much more simpler. So, in this, we have many types of materials; one is called woven, the other one is non-woven one, other one is knitted.

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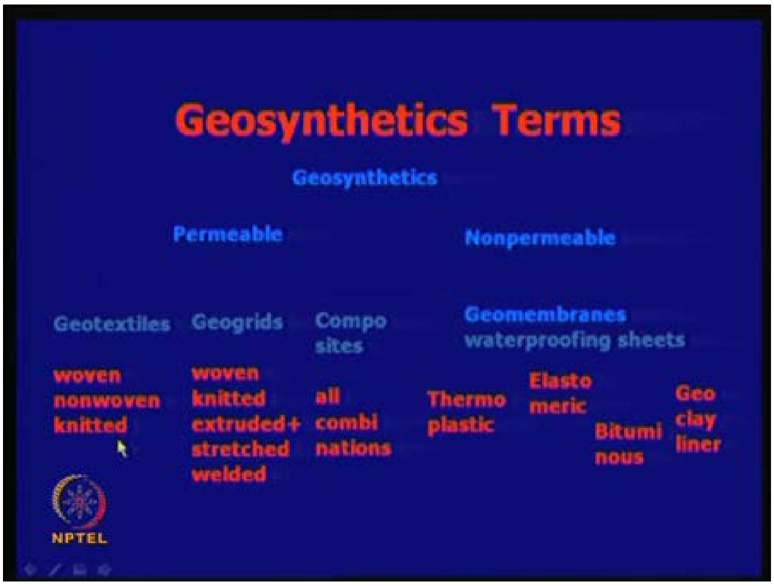

So, you have, depending on the type of the manufacturing, the process in which it is done; this, this is classified whether it is woven in the sense, one material over the another; and then, it is simple weaving; that in India, we are used to that textiles mills; have this normal ones, either they are heated. Knitted is another method. So, we have another family called, is with geotextiles. We also have Geogrids; what you have here, like this, is called a geogrid, and this is also a geogrid.

And, many of them have, you know, they are extruded sometimes, stretched and sometimes welded. In fact, welding by laser is also possible; we have different types of materials here, which are essentially, geogrids. Geogrids, we use it for the conditions where we need very good tensile strength; then we also have what you called, geocomposites, in which many combinations of geotextiles and geogrids and geomembranes are possible.

This is one case in which you have a geotextile also as well as a geogrid also. So, you have many; you can just see that here, you have a geotextile. The geotextile in between, and you also have a geogrid here. So, the advantage would be that. So, this is another composite in which you have a geotextile and also a geomembrane, geomembrane at the bottom. And this is another one where you have a geotextile on both sides, and also, the net, netting, it can serve for drainage applications very well. So, you have some of these materials; and, non-permeable means Geomembranes.

Actually, in the case of textiles, the permeation is, water permeation is possible or even permeation of permeation of any other fluids is possible. But in the case of Geomembranes which are something that are impermeable, you have like this, which are, you know, the permeability is very low and they are all, you know, from different families; one is called thermo-plastic, the other one could be elastomeric.

And, even sometimes, we try to coat the materials with bitumen to see that their permeability is quite low, and we also have what is called geosynthetic clay liner, in which you have a geotextile on either side, and you have a bentonite mixture powder inside, and that also provides reasonably low permeability or very, very less permeability. Compared to permeable textiles, this could be in the range of minus 2 or if this could be minus 8 or 10 or 14. In fact, 14 centimeter per second, it could be very low; whereas, it could be very high here.

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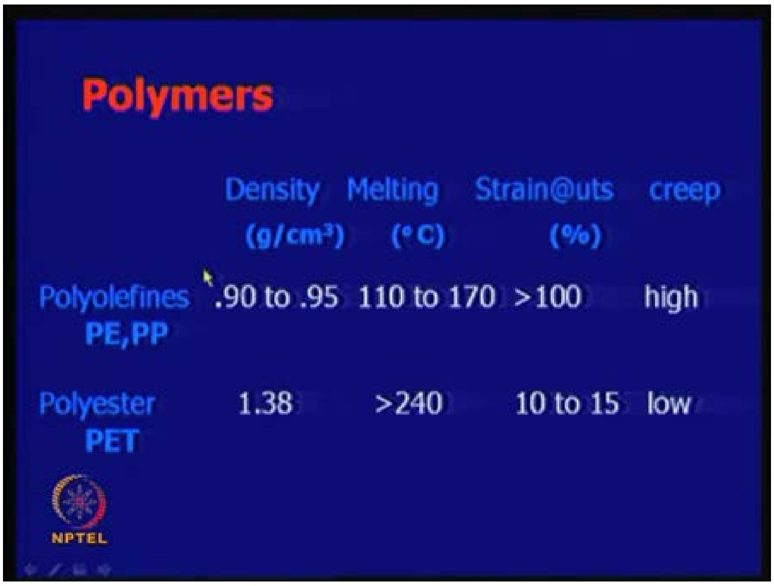

And, another information that we need to have is that, as I just mentioned, these are all the polymeric materials which are the, you know, which has, which are combined together by CH bonds, like carbon-hydrogen bonds. It is a molecular chain of carbon and hydrogen bonds, and depending on the manufacturing process, we will see that they can have a different properties like, say for example, if I say Polyethylene and Polypropylene, we say that they belong to this family of Polyolefin.

And, their densities are 0.90 to 0.95; the melting point is 110 to 170 degrees and strain at ultimate tensile strength is about, you know, they are stretchable like, you know, for example, you take a geotextile, it can have a, very strain could be little higher, creep also could be higher.

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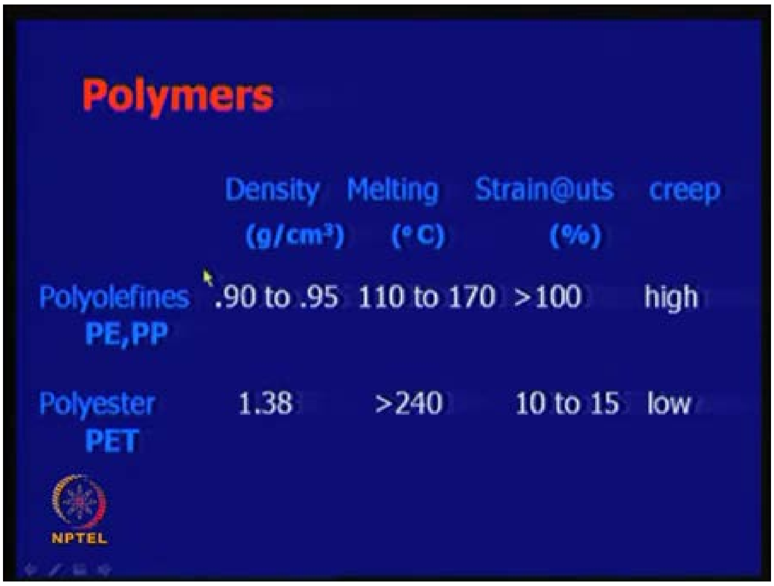

And, some Polyester materials, they are little; the specific gravity is higher and the density is higher; the melting point is also higher than the tensile strength. You can get a 10 to 15 percent like, you know; say for example, you take a stiffer material, it will reach the ultimate tensile strength in a very fast manner, and also the creep could be low. So, for example, in some applications, we do not want lot of creep and so, this is very important that we should also choose the materials in a proper sense. So, one should ask, what type of polymer you have in a particular Geotextile.

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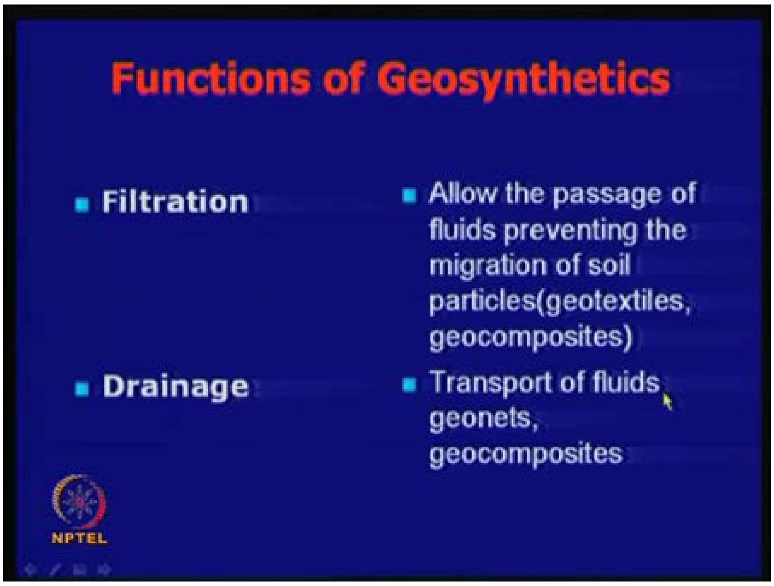

Then, functions: we have seen that a couple of functions are there, which are like, say for example, if I say filtration, it only allows the passage of fluids, preventing the migration of soil particles. So, we have a geotextiles, geotextiles and geocomposites here. Then, the drainage transport of fluids like, say for example, this, this is a geonet composite, then filtration is just a geotextile or a geocomposite can be used. And, separation; separation is nothing but it just prevents mixing of two different soils or materials using geotextiles, geotextiles or Geocomponents.

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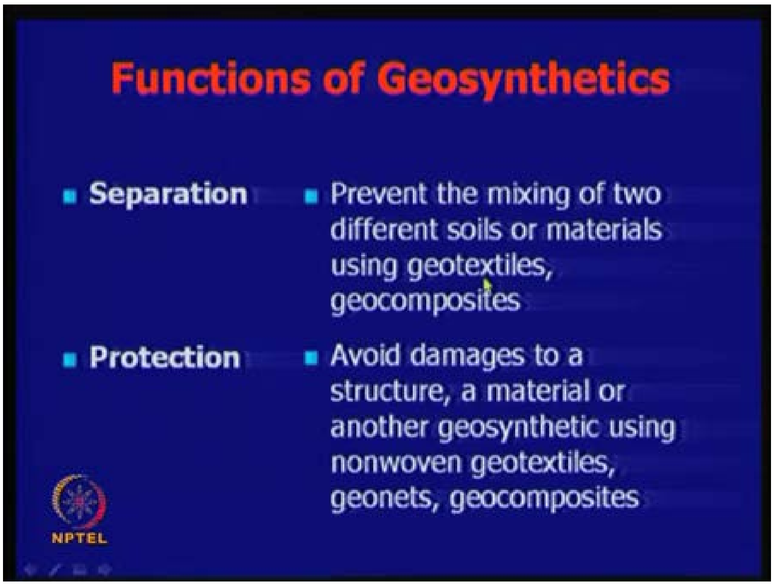

You can do this by any material which can be used for separation; essentially, geotextile is used, because it is much cheaper and prevents the mixing of both the materials.

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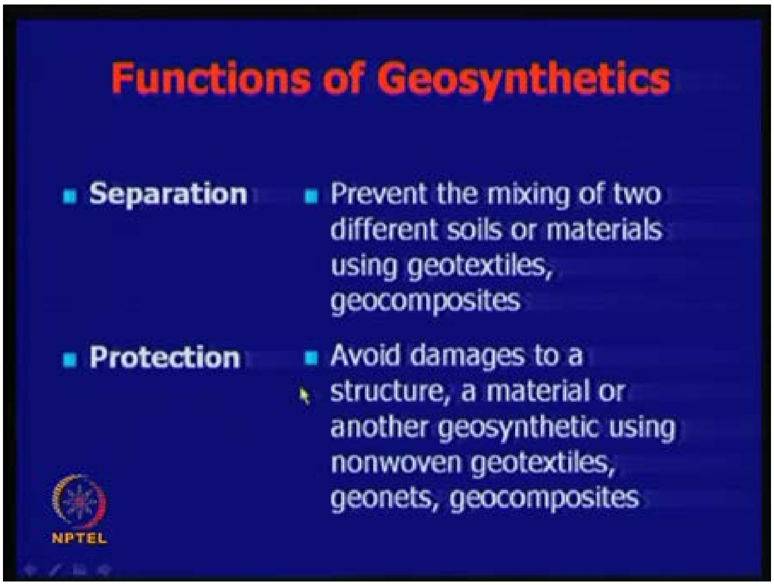

Then, you also have to protect. So, protection layers are there; say for example, if you take landfills, you would like to avoid damages to a structure or a material or another geosynthetic. Say for example, geomembrane is there, and then if the geomembrane gets punctured, then it cannot provide that impermeability characteristic which is required from it. So, what you do is that, you put some sort of geo, like a cushioning material, which is called a geotextile, which can be used to protect it or you can put a layer of sand and again put a layer of geotextile; because, that is also useful. So, it is useful to protect some materials which can get otherwise damaged.

Say for example, it could be any geocomposite, so, you can prevent it by any means, so that, it is protected. Particularly, in landfills, if some damage occurs in landfills or geosynthetic products, it is very difficult to repair them. So, it is very difficult to repair in some places in like landfills where the geosynthetic materials are about, say 30 meters or 50 meters deep.

And already the layers are inside and it is very difficult to remove any of them or repair them. So, what we do is that, we try to take utmost precaution in trying to put some more layers, addition layers as protective measures.

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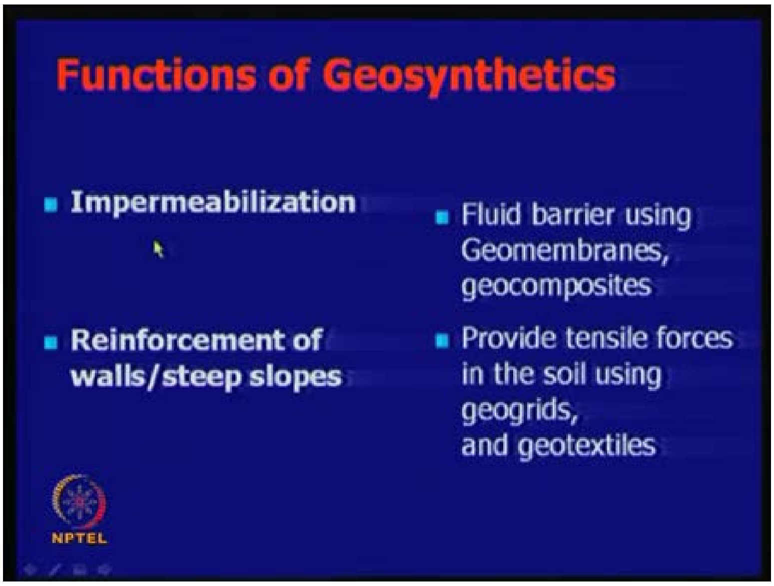

Then, as I just said, impermeable member is an important member of this family. Particularly, in the form of geomembranes, we would like to see that the water is not allowed in some cases. Say for example, leachate; leachate, it percolates in the landfill, it should just go to some nearby leachate collection system and should drain off; it should not go down and then contaminate the ground water. So, we use for the minimization of probability, we use geomembranes, we use like, you know, we say that they are either geocomposites or Geomembranes; they are essentially fluid barriers.

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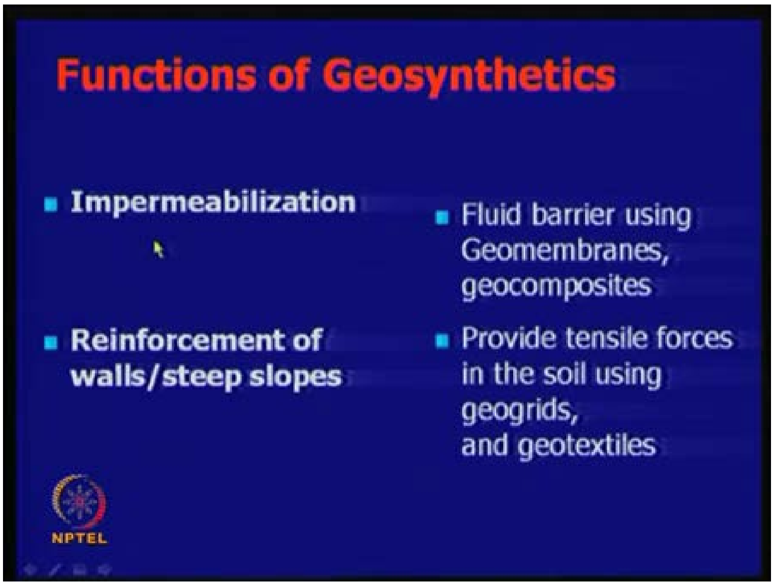

Then, very important thing is Reinforcement of walls and slopes. This is actually, of course, it provides tensile forces in soil using geogrids and geotextiles. Of course, this is a bi-oriented geogrid, and we will see in some of them, mono-oriented is also possible

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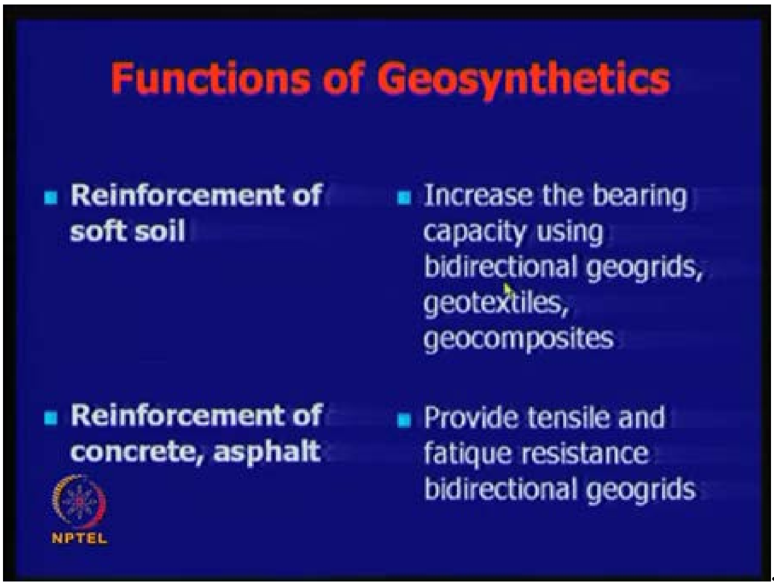

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So, Reinforcement of soft soil: it increases the bearing capacities in bi-directional geogrids, which are like this, or even it can be like this; where you have a bi-directional geogrid can be used, this also can be used. It is called some product secure grid, which is a quite a very good material .

And so, in some, even you can use a geocomposites, because, you need also a drainage at the bottom. So, you have a geotextile as well as geogrid and it can also be used for Reinforcement of concrete and Asphalt roads. Because, the fatigue resistance is very important in the payments like, both fatigue and tensile resistance like, can be provided using the geogrids. Say for example, the pavements crack because of the fatigue and rutting.

Two criteria are there, failure criteria. Both can be designed to see that these failures will not occur; and, if you use a geosynthetic material, how does it reduce both fatigue. Fatigue is nothing, but the accumulation of strain because of the repeated action of traffic. And, rutting is the formation of depressions or permanent deformations which can be avoided using this geogrids or geotextiles; geotextiles are there; some any of this members.

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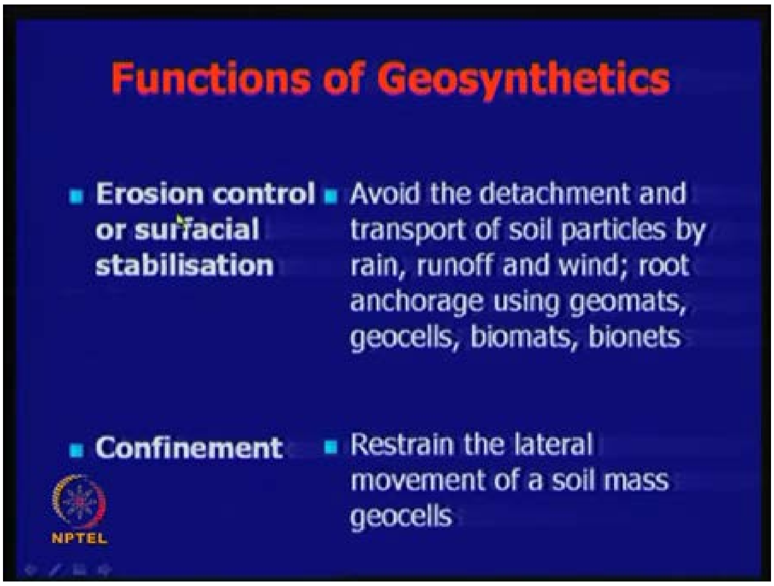

Then, another important application of the function is Erosion control of surfacial stabilization or surfacial stabilization. Actually, in many of the slopes, detachment of the soil particles is an important problem because of the rain and run off and other issues. So, we tried to anchorage them using geomats, geocells or biomats and bionets. One can use a lot of jute coir; say for example, geotextile material is here, jute geotextile material, one can use some of these material that you have here, all the geotextile material; one can use quite very well. In many of those applications, geotextile materials are here. So, this is all natural materials. The advantage is that, once vegetation grows, and then forms a layer of erosion control, then these materials can go off. But still, you have a nice soil cover.

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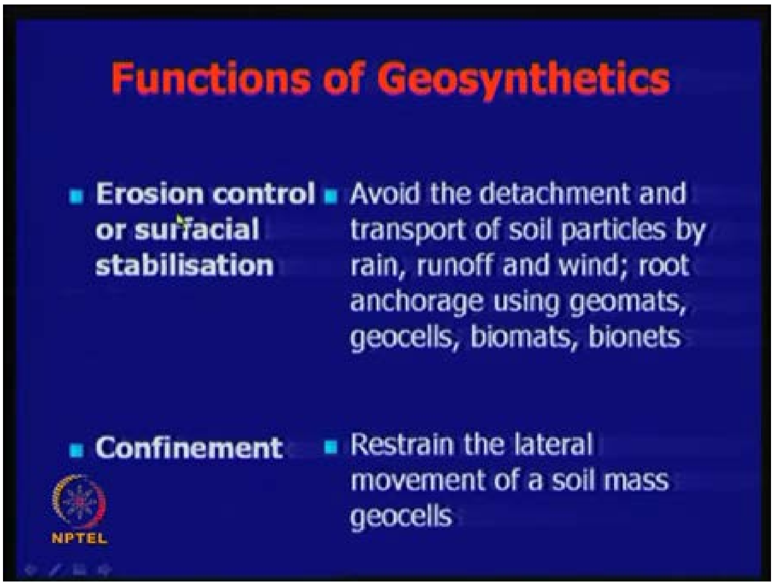

Then, another important thing is what is called Confinement. The Reinforcement also provides some sort of confinement. Nowadays, you have a geocells which are very good, which can provide good confinement.

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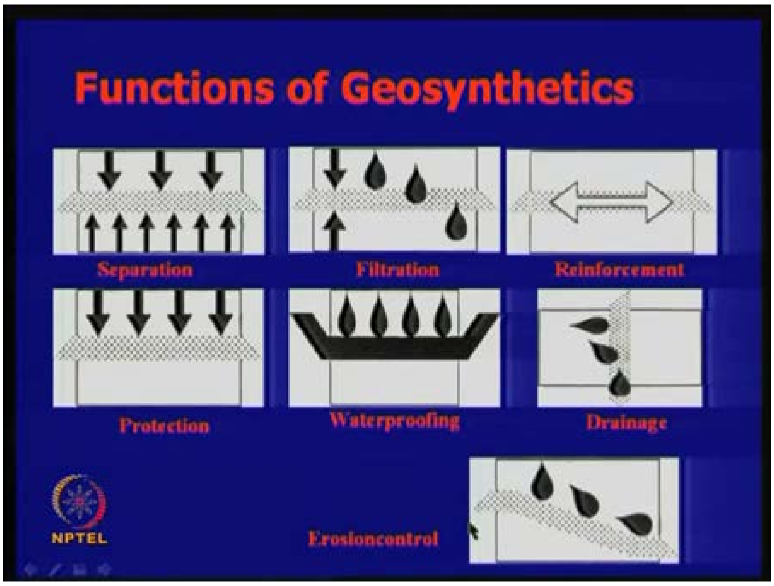

So, actually, the notation is like this, you know; there is, we have what is called International Geosynthetics Society, in which they have identified a proper notation for each function. Like, say for example you have a separation function, it will be like this;

you have a material like this, this is a separation function like, this is one thing; it acts as a separate layer.

Then, filtration means, it allows only water to go out of the material. Then, this is Reinforcement; you know, like tensile force is applied in the Reinforcement, like tension is applied. Then, this is a protection layer like, you know, it does not allow the bottom it will look damaged. Then, water proofing like a geomembrane; Geomembrane, it just collects water, then drainage.

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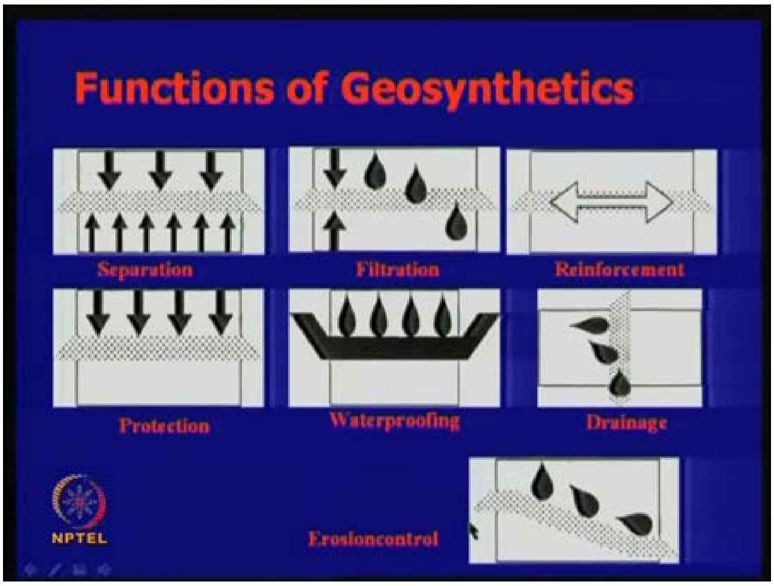

You can see that the water particles go out of this; say for example, you have a retaining wall, next to that you need to provide drainage, so you have a nice system like that. And, the drainage is nicely allowed and then the drain water gets collected at the bottom of the retaining wall. Then, erosion control, as I just mentioned, this will just nicely collect all the water without slope getting eroded; the slope should not get eroded. And, if the slope gets eroded, then it is a serious stability issue. And, if you have a geotextile or a proper riprap, you know; normally, the convention solution is to provide a riprap and the riprap prevents; if you have a geotextile as well, prevents the erosion problem.

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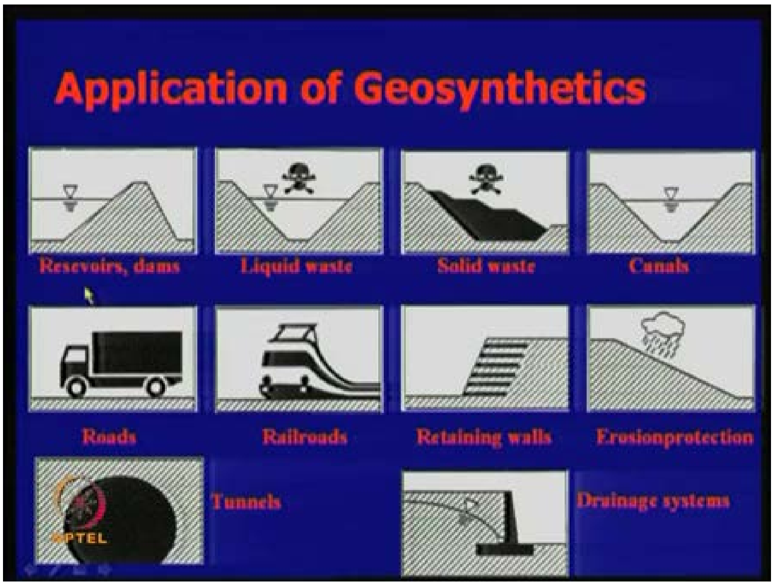

Then, the applications are too many. Like, it can be used in dams, reservoirs, and it can be used in liquid waste, solid waste, canal linings, then road network, railways, retaining walls like as I just mentioned. You can have a retaining wall system with reinforced earth. Then, erosion protection: even in tunnels, it can be done as drainage systems also.

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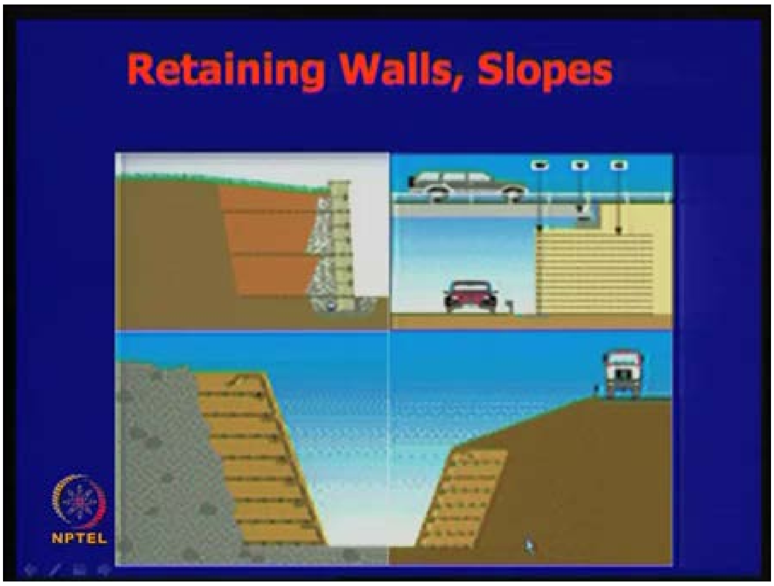

These are all some examples that we will see where... See, this is for the reinforced earth wall; you have a layer of geo; see, this is a backfill; this is a, this is actually we call it a backfill. This is a wall fill; wall fill means, the wall, the fill that is next to the wall. Then, this is a drainage material, and this is Reinforcement, and this is a facing element. This is one typical application, that one can have this is in the case of bridge apartment, where you have lot of applications like this, where, you know, you have a 6 to 7 meters is required as a grid separator.

And, if you have a reinforced earth wall like this, it is going to be very cost-effective; and, fortunately in Indian conditions, people have realized that this is very useful. And, it is very fast as well as cheaper; people have been using this technology very well for the past twenty years in India. Then, this is a case of a reinforced slope in which, you know, you can construct the slope to about 70 degrees, which is not otherwise possible by soil soils alone; you can see that this is an another type of example and this can also, it is also a reinforced slope .

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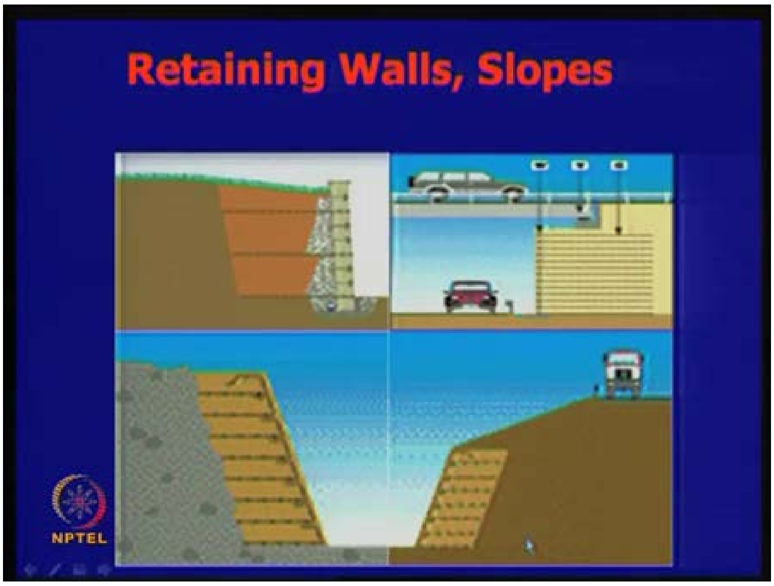

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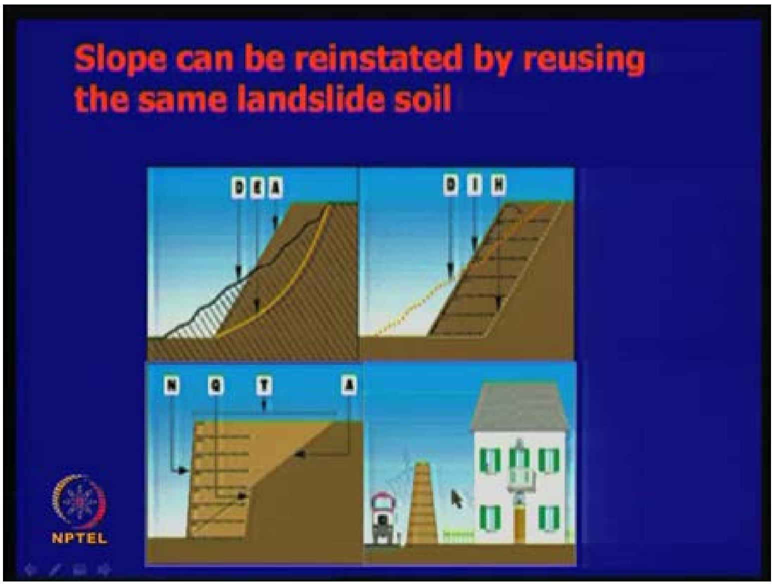

Then, soil can be reinstated by reusing the same material. Sometimes, if this is a slip that occurred in the case of slope failure, this is actually the failure surface, you can really repair that using a same filled material; put a geogrid properly. You know, the one can repair it in some sense very well using the same material and also using geogrids. So here, there was a problem of stability and then it collapsed. Here, we do not have the problem of stability, because reinforcement prevents that formation of failure surface; we have a failure surface like this, but that is not there.

If you have a Geogrid Reinforcement, then this is some extension where you would like to widen the roads like, you can see that you want to increase, the right of way, like you know; this, say for example, may be 4 meters is available, you would like it to be 10 meters or something like that, this is possible. These types of applications are too many in hilly areas. In fact, there was a 42 meter high wall construction, which have listed about sometime back, where to provide access to the hilly areas and to provide facilities for a the traffic; that is, visiting that area, they have made this sort of wide roads and also parking places in some places.

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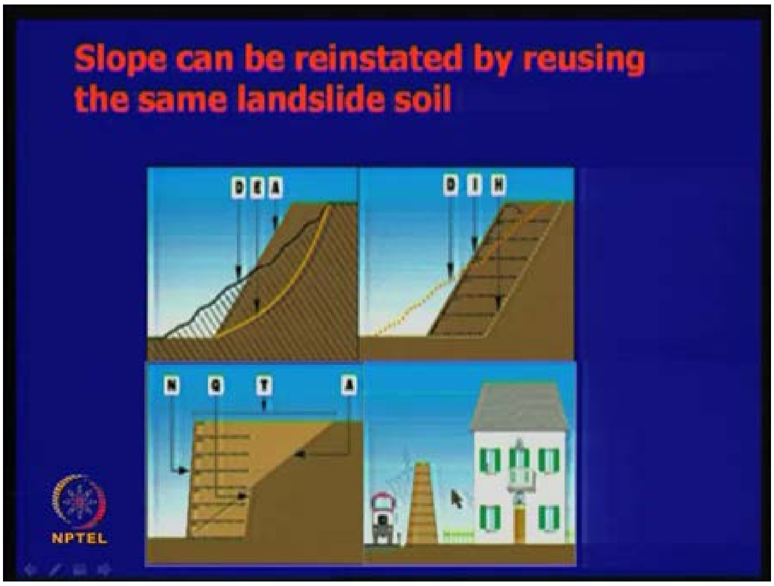

This is about noise barriers, which is again, you know, you have a residential locality here, and then you have a lot of noise nowadays coming from the highways when the speeds are of very high order, like more than 150 kilometers per hour, then it creates a lot of noise. So, you have a noise barrier system as well here, designed.

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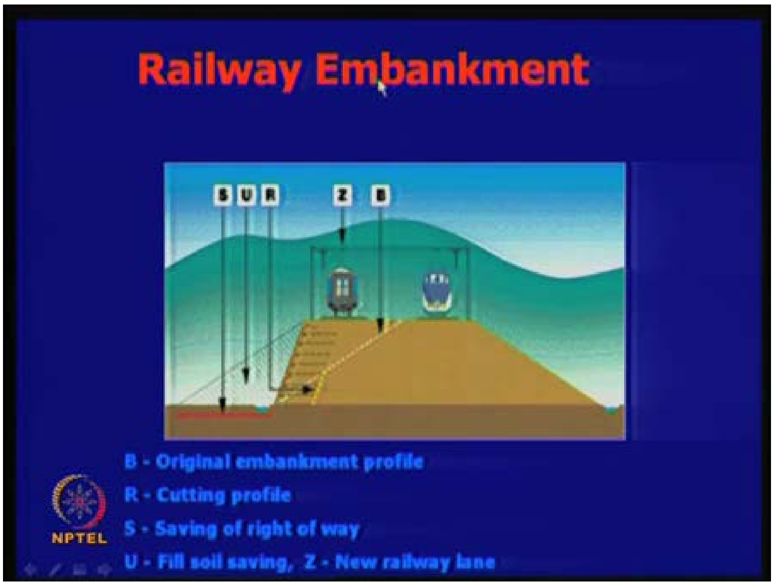

This is another example where, in the case of railway embankments, the earth ore can be saved. If you are able to construct the slope in this manner, using the RU wall, reinforced earth soil technique, reinforced soil technique, you are able to save this much of soil; and it is going to be much more stable as well. So, essentially, you can design some of these things in a very comfortable way; this is in a highway embankment.

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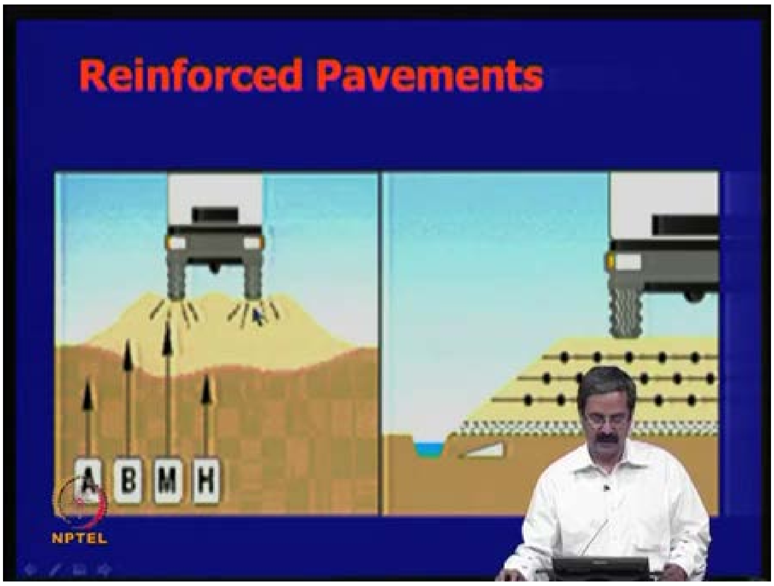

You can see that the area of cross sections, so much could be saved in the case of pavements; that is what I was telling. That it is possible to have rutting failures as well as, rutting failure means deformation failures and as well as fatigue failures, which are because of the repeated application of loads. Both can be seen that you have a higher resistance with this geogrid material; and you also have a drainage here, you can just have a geotextile here, then the drainage is there. So, all the problems that the road has, whether the sub grade is poor, then this material is poor, the loads are high; all could be handled by a proper combination of geogrids and geotextiles.

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This is some place where they are trying to, try this to separate, separation function, of course, as I just mentioned. It has been using quite extensively.

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Then, you can also have Separation plus Reinforcement also in some applications.

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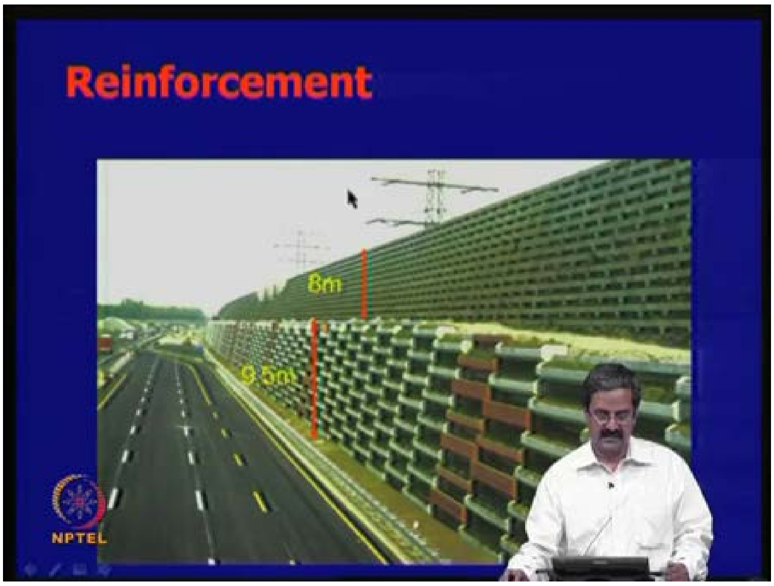

This is a high wall, you know, you can have 9.5 meters high wall; again, a 8 meter high wall. In fact, the total height in this case is about 17.5 meters. And, if you want to really conventionally go for this type of the, this like 17.5 meters, you should only go for counterfort retaining wall, which is very expensive. Like, if you want to go for 17.5 meters retaining wall, the base would could be about 0.3 h; like, which is about 4 to 5 meters. And then again, you know it is a very, the concrete quantity will be very high, steel quantity will be very high. But here, you have a simple Reinforcement, which is just horizontally acting; and then, you have a backfill, you have a facing like this; that is it. I mean, it will be very cheap, may be 30 to 40 percent cheaper when compared to regular retaining wall.

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So, this is how it looks like at the top where, you know, you just try to take this material filter, filter cloth.

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So, this is a close view of that material and this is the same view.

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Reinforcement, in the case of roads, it can be done like this; where you have a granular sub-base material, you know; you have a sub-base material, and then you properly cover it and put a geogrid like what you have here. And, put the backfill soil or whatever is the sub grade material, sub-base material, and then role that, and then you have a very good properties.

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It is another interesting application we are familiar with this are all, you know, fiber, you know; this is actually the Reinforcement. If the force of application is like this, this is the

Reinforcement; there is a friction between the soil and reinforcement. This is in the opposite direction. So, the force is being resisted by this Reinforcement you have. So, the soil, the friction between the soil and Reinforcement is acting in the opposite direction.

So, once you provide this length and spacing of that, then there is no problem at all. So, what you have is that, what this is, we call it a profiled reinforced soil. But in some places, like you can add fibers to the soil and then that also leads to cohesion, you can add lot of waste materials to soils and they increase cohesion.

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This is one case, what is called Texsol. In France, where earth wall, the wall was constructed with just this material alone; like they used a lot of material like this, then since it has good cohesion, it will not collapse; it will, the height, it can retain about 5 to 6 meters easily. So, that is much cheaper than going for these types of materials also. So, because, you know, the people have been exploring different methods of using these fibers and reinforced soils and all that.

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This is a reinforced earth wall, like you can have facing here and all that.

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This is actually a lining and drainage applications here; what are you trying to do is that, capping of an old waste dump. Waste dump, say for example, now in India also we have lot of waste dumps. The count is not easy you know; there are so many waste dumps and we should see that the odors, the gases or whatever is that, the problem because of that should not be to the nearby public.

So, people have to cap it, means, they have to close it. So, this is what people used. They closed the capping of an old dump with something very needs to be done systematically, because it leads to lot of problems. It should not, the old dump should not lead to pollution, both air pollution as well as water pollution.

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This is actually an erosion control mat here, you know; one can have a geotextile coir material and all that. This you can see that, as a slope is very nicely finished.

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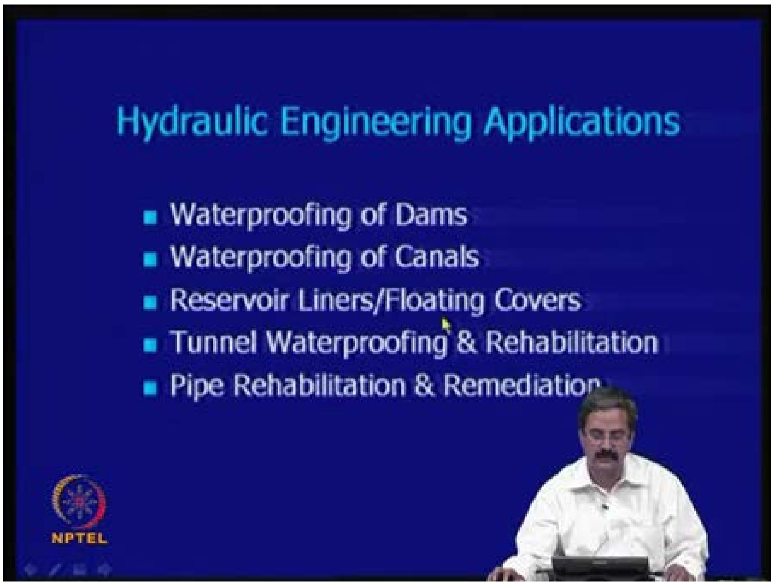

So, some more applications that I would like to mention, hydraulic engineering applications. Actually, we covered some applications in the previous class. So, water proofing of dams is very important; water proofing of canals, reservoir liners and floating covers, tunnel waterproofing and rehabilitation, pipe rehabilitation. Even these are all the, like one can say that in many of these applications, we had different types like, you know, transportation applications are there just for roads alone; for landfills only we have applications. We have even hydraulic applications, even structural engineering applications, whereas I just mentioned Geomembranes can be used for water proofing.

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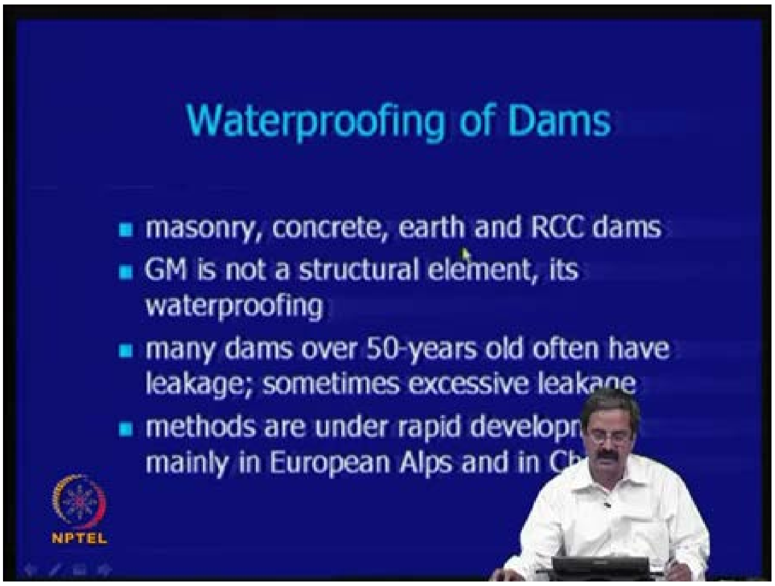

So, in the case of water proofing, like normally masonry, concrete and earth dams are used; and so, for which if you want to have water proofing, you need to have good geomembrane. So, it is, it is for water proofing that we provide. And particularly, there are many dams which are old like, say for example, fifty years, they have lot of leakage and sometimes excessive leakage.

In fact, even in India we have many problems, many dams that have this leakage problem, from the upstream and all that, you know; what happens? You are expecting that the dam stores water, but then if there is seepage, then it cannot store water. So, sometimes, it can be even excessive leakage. So, there are many methods that people have tried. In fact, it has been done in some places in Maharashtra, some places in Tamilnadu, where they used the Geomembranes to rehabilitate old dams.

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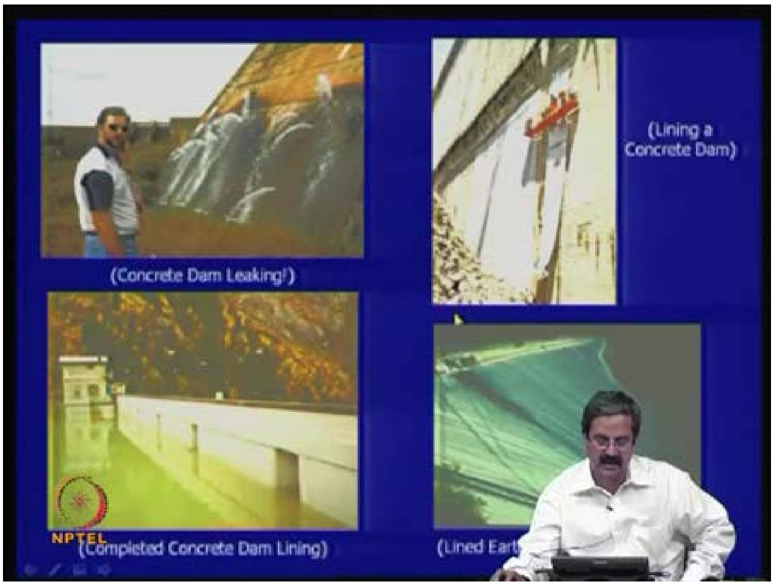

Let this is be a typical example. It is a, you know, a upstream face of the dam starts leaking. So, normally you should not find any water flow here, like this; that is wrong. So, what you do is that, you put a geomembrane, geomembrane like this lining of a concrete dam, you know; you can put some sort of geomembranes here, see that it is not there and the water is not permeated. So, this is the typical figure. Again, then, like this is another one lined earth dam, say, actually in some earth dams, we provide riprap. So, before the riprap, you can provide a geomembrane, geomembrane to see that there is no leakage.

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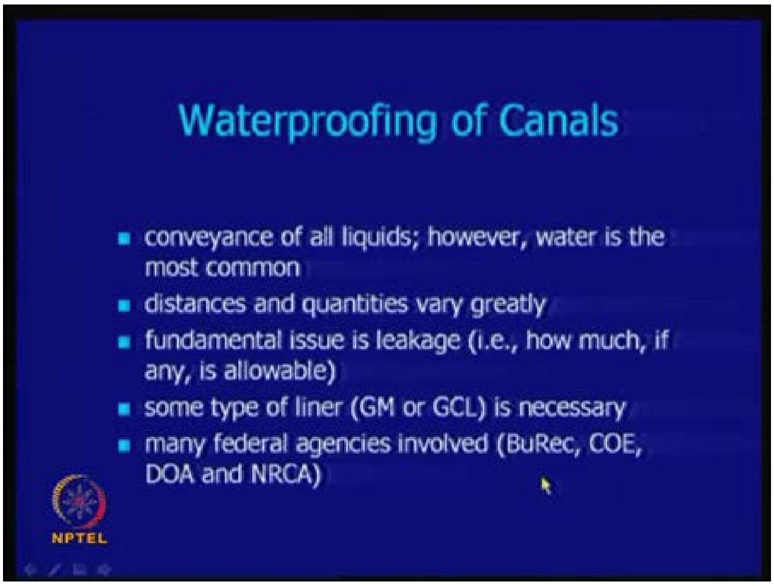

Then, water proofing of canals. Actually, in many of the places in India, at least we have we have what you call in many of the water supply and for irrigation and all that, for drinking and all, for particularly irrigation canals instead of the canals. And they have lot of quantities going through them; and, if there is a problem of seepage, then it is very significant. Like, you know, say for example, if 20 to 30 percent is through the leakage, then it is going to be very risky.

So, we need to have some sort type of liner, which is a Geomembrane, Geomembrane or a GCL. And, there are many agencies, even in India they are they are doing it like this, it is a simple example. Lining a canal before soil, covering like, you know, you can see that this is the geomembrane; this is the one they are trying to do.

This is a site; actually, this is a liner. So, you can see here more clearly, that you have a geomembrane, geomembrane liner here; then you can see here, sometimes, you know, they are very durable actually. Geomembrane canal lined after eighteen years, you know, canal liner; it is a life is about more than eighteen years. And, after the liner or liner, if somebody sees the flow like this, it could be, you know, there is no leakage. What it means is that, so, in many of the situations are there in Indian conditions, one should be able to use the geomembranes very well, like even it is possible to line canals which have lot of, you know, see water flow already.

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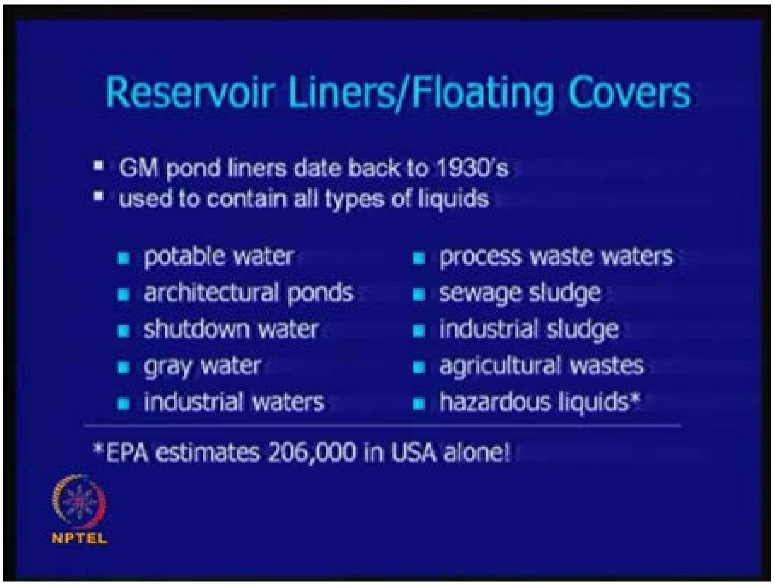

So, people have methods of doing this lining, the geomembrane; geomembrane lining is very essential, it has been useful for storing of tank. Even the tanks actually, are like ponds; then, whatever is waste water, that you have sewage sludge agricultural products and hazardous liquids and all that.

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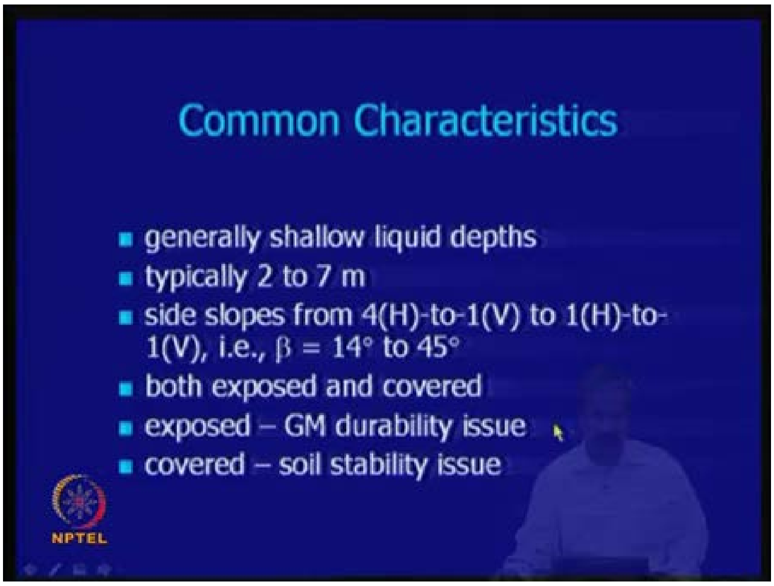

And the advantage here is that we have, is that there are some issues that we have here; that the liquid depths are there in the slopes are, there they should not have.

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Say for example, this is potable water, which is stored. And then, the potable water should not be a leaking; so, you need to have a geomembrane, geomembrane for that. Then, see, the thing is that you should be very careful; as I just mentioned earlier, the friction between the soil and geomembrane, geomembrane could be very low. So, it leads to some sort of a, you know, it floats like if there is no, like, if there is because of slightest pressure, it can get lifted up.

So, one should be very careful; and so, that is the reason we what we have the what is called floating failures will be there; like floating GM cover. I mean the geomembrane, geomembrane should not get you know, formations like this; that is one important worry in geomembranes.

They have been very effective, but then, if there are some air gaps, and all that it just gets lifted up, then there is a problem here. Also, one where see this, everything is a geomembrane, geomembrane area. But then, in some places, it got huge GM bags transporting potable water. So, this is one type.

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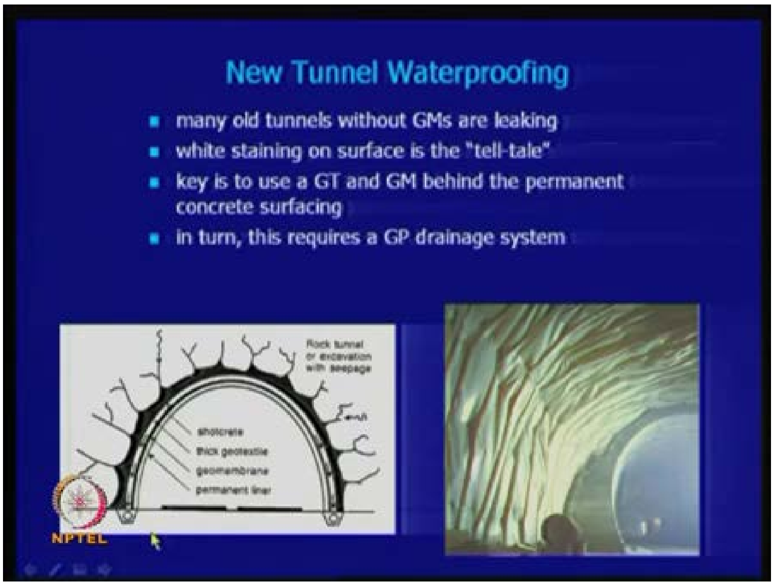

So, there are many issues that one can have even in tunnels; like, say for example, you know, you go to north-east and other places, where they are trying to put railway lines through tunnels and a lot of leakage is there in tunnels; it is very difficult to handle. See, you are trying to construct the tunnel and then the water starts slipping; it is very difficult to handle. So, what we do is that, we have a system like that, where you have a, you know, shotcrete first; you put some shotcrete means nothing, but cement plus concrete.

Then, you have a thick geotextile, you have a geomembrane, geomembrane you have a permanent liner. So, you can have an arrangement like this, which can be... Then, you collect all the water, you know, like this; say, whatever is the seepage water that can come here, there is a geotextile that one knows it is provided. So, take all that water through this geotextile, and also this sort of drains, and do not allow this water to go on this highway. Say for example, this could be a train, train track. So, one can see that such problems can be avoided using these geomembranes.

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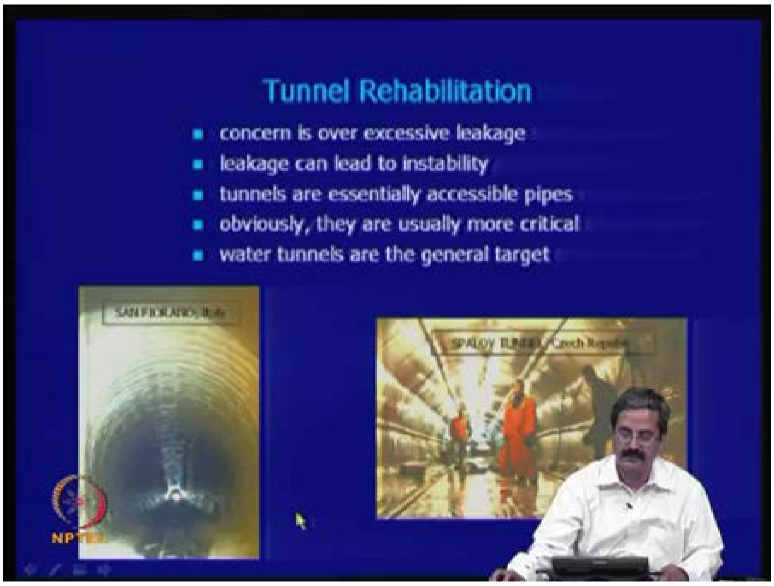

Even in some places, you know, tunnel rehabilitation like, you know; say for example, in some places, you cannot use the tunnels because of the excessive leakage, and leakage also leads to instability. So, then, what we do is that, this sort of, see this is a typical case; then they try to put a layer of geomembrane, geomembrane and all that. There is a systematic design here; so, these tunnels are whether it is for the water supply or for whatever purpose we have, we can rehabilitate.

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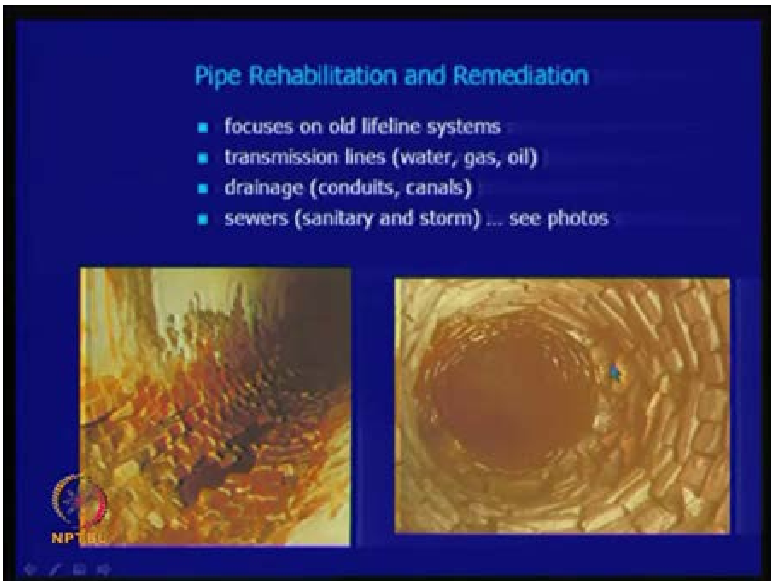

This is another example: pipe line rehabilitation. In fact, in the olden days, people were having cement pipes, you know, for carrying water or even they could be lined, you know, with bricks and all that, like this. You know, they were, if you expect them that they can carry water, it is not possible. What happens is that, all the water gets lost in seepage and other things and even this whole area gets damaged.

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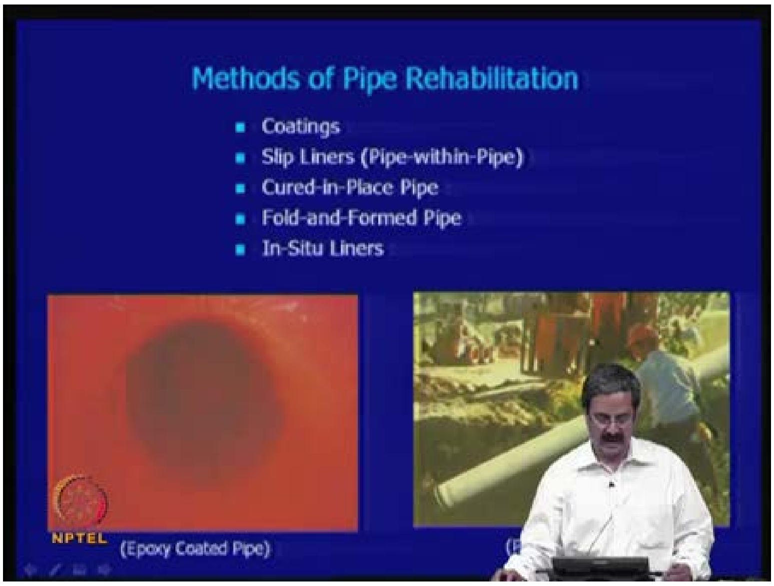

So, what we do is that, we try to line them with some; you have coatings, you have slip liners, you have curing in place and there are in-situ liners, like this pipe within pipe. So, there are so many techniques that one have, one can have. And so, now, I would like to show, how these materials like fibers and tapes are all made.

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Say for example, you know, you have a number of companies of production of this plastic material; it is called polypropylene fibers. For example, in this case, like you know, you have a thin fibers on this material here, very thin materials here, fibers; thin fibers like, you know, what I saw here, like they are all thin fibers. You can see that they are all very thin fibers.

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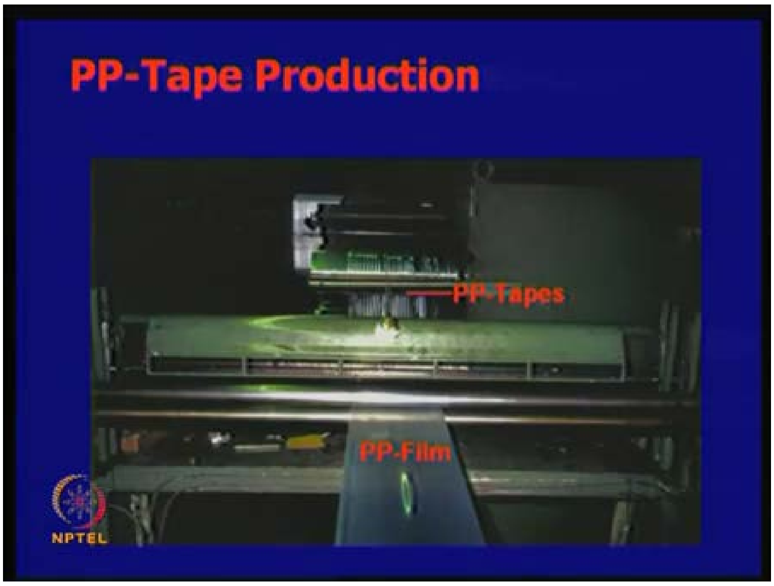

So, they are all... So, this is about fibers; even you can have a material like tape, you know, for a thick material, which can be, you know, in the form of like this. And so, like whatever we have, either a geotextile or something, one can have a, one that goes to that. What you see in the black color is something that is little later. So, you push the material and then it comes like this; then, you have, as I just mentioned, different types of weaving; like again, you know, you have a typical, say for example, we are used to this weaving industry in India, where they do this weaving of sarees and other things. Here, same thing; weaving is done, machines using machines where you have all the fibers stitching in a woven form.

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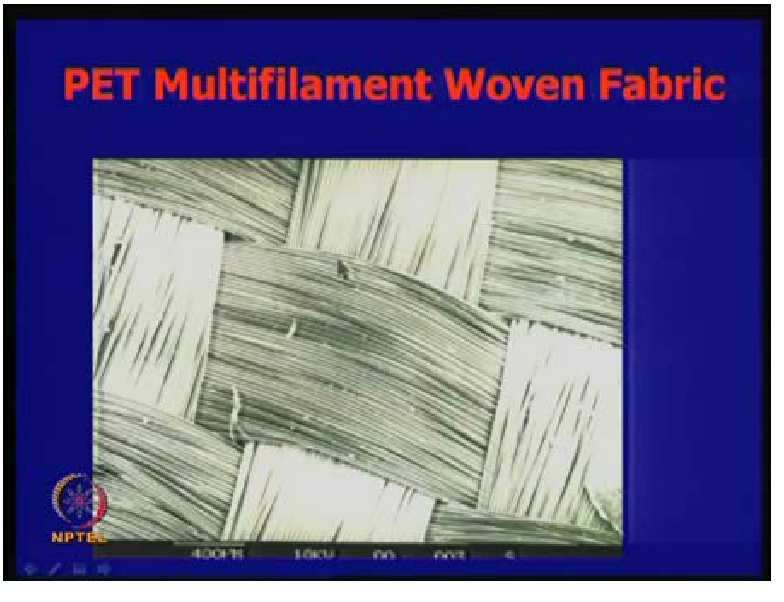

And it is not single, you know, multifilament. Actually, see, there it could be single filament, one; and then, it could be multifilament weaving. See, you can see that; it is a big one.

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Then, this is again a polyethylene; again a woven fabric here, you can just see that again, one more type, you know. You are looking at a very micro-level examination; then only it is possible.

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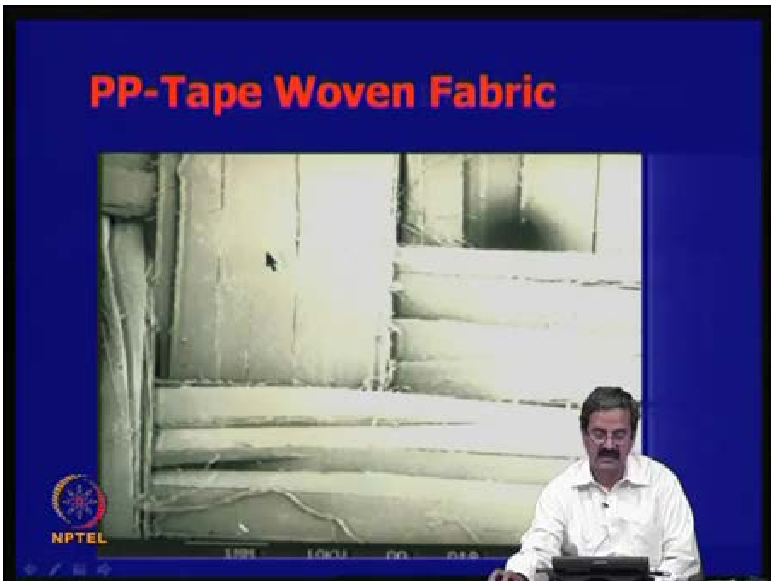

You do not see that in a naked eye; some of these arrangements, you have to look at it very carefully using a microscope. And, you will be able to see some of these differences in indentation and all that.

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This is again one more type.

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This is monofilament like, you know, single filaments, and they are all woven together. So, that is about geotextiles.

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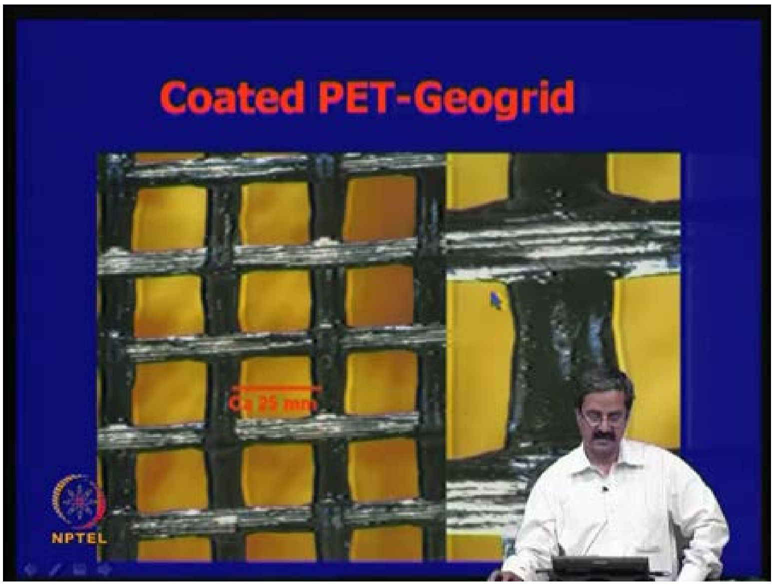

Geogrid is like this, is one type.

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These are laser-welded, it could be like this, you know, the welding technology has improved so much; you have x-ray welded. So, these are all some materials; because, see the thing is the advantage of the Geogrid is that, in the case of geotextile, when you provide, earthquake force is acting or any lateral force is acting; this will be like this.

The resisting force is only because of the friction between the geotextile and the soil. But in the case of a Geogrid, there is a small extra length here, which is called, some thicker one that provides a bearing resistance. So, a little thicker here. So, like this, a number of materials are there; they are all, they provide a bearing resistance in addition to skin friction or the frictional resistance here. So, this is a much more efficient.

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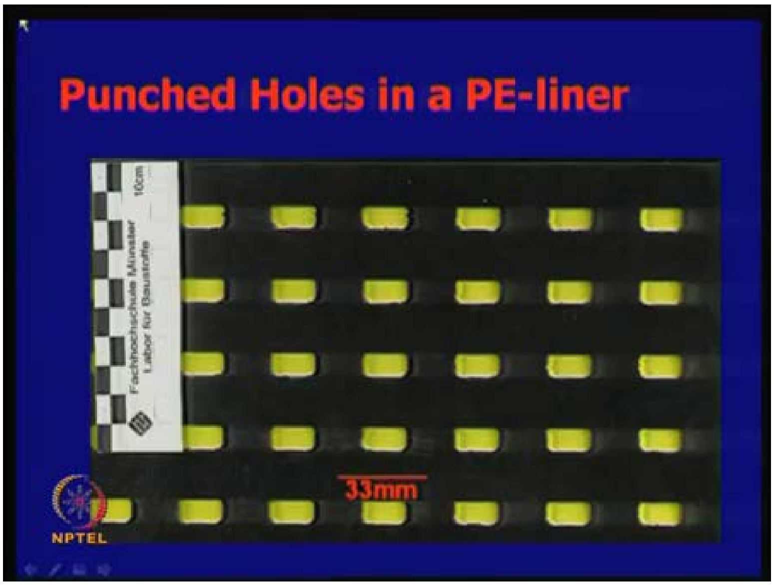

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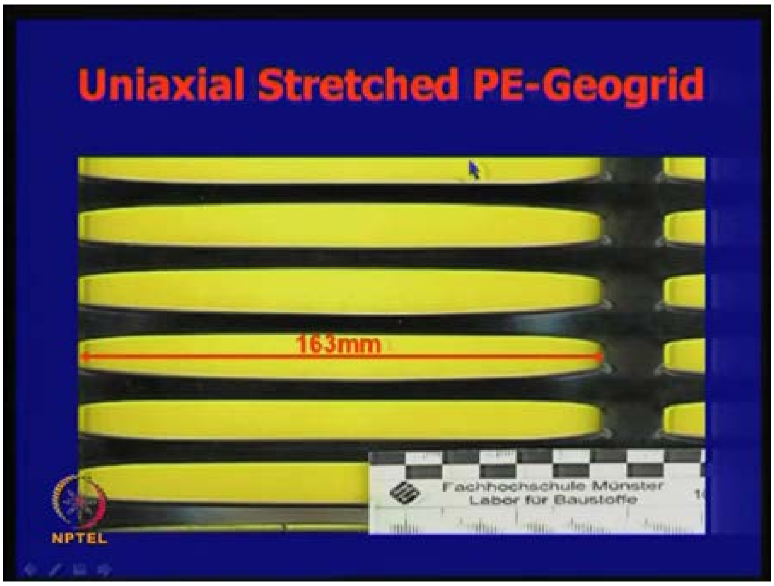

So, one can do a punching of the holes, the member to get this done. This is what I was just mentioning. In the case of geogrids, you have uniaxial members, and this is useful for RU wall applications. Actually, some of these slides, I must thank my friends from

Germany, like Landeskog and Bansal Bayan, you know, who have supplied some of these photos and some of these materials; doctor, captain and doctor (( )) .

They are able to get a lot of equipment and a lot of experimental facilities. They have, they are doing their, I mean, they have done excellent work in Geosynthetics, and I was in their Organization for one year in Germany. And I collected lot of information when I was there; and now, I am using some of these materials for representation of this in this lecture.

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This is what I just said. It is a geogrid, biaxial and knitted structure is one thing; you can see that it is like some knitting.

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So, Non-woven production: So, wovens are one thing where you weave around and then get that; what is nonwovens? Non-wovens, again you should get this here, again there are a couple of important points we should know. What is a fiber composition? What is the basic material there? Then it forms a fleece of oriented fibers and multiple layers of fleece for desired MUA. MUA means mass per unit area. Actually, this mass per unit area is an important property required in the case of non-wovens, where, see mass per unit, say for example, we know the paper, you know; we say its 80 GSM; 80 grams per square meter.

Or you take a silk saree, you say, about 1, 200 GSM; means, it is quite, it denotes a quality of the material like, you know, you are having a very good density of paper or any of the cloth material. Then, it shows that it is, it could be much stronger, durable and all that. So, here also we try to characterize some of these nonwovens using this term called MUA, which is nothing but mass per unit area; we measure it also.

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So, what we do is that we bond them mechanically or thermally; either you use a heat or mechanical bonding is done to get a product like, you know...

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So, this is all, you know, in one place. See these materials stacked in one place. In fact, I visited one of the plants in Luxemburg; it is called Dupont plant, in which people have lot of, you know, Geogrids. Geosynthetics are all manufactured there.

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So, these are all some materials that are stacked here.

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You can see that Staple Fiber Nonwovens, you know, orientation of fibers is something that they are doing; here, some processing is being done.

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Then, fleece of oriented fibers like, you know, when you just rotate in these high speeds and all that, you know, and then stitch it; and then, you know, join them together, they have a material like this which are formed.

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Then, this is all like this. Then, it becomes like this; this is all, you know. Remember, that they are all plastics polymer compounds.

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Then, there, some lot of conveyor belts, and there are lot of mechanical processing is done.

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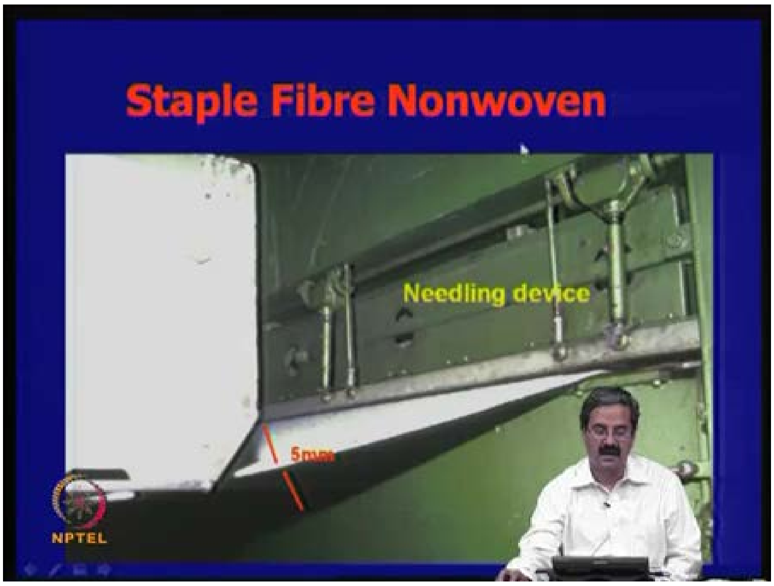

And, needling device; sometimes needling device is also there you know.

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This is one needling device. So, needle punched, nonwovens needle punched: actually, this is another one where, you know, this again one technique that we used. And, you have to see that this, at a very close examination like, you know, very micro-level examination, you will see things like this. But in the gross sense, actually, I do not have here. Yeah, I think this one. So, we have some material which are nonwovens; nonwovens plus heat bonded.

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If you just look at micro-level, the possibility is that it looks like this.

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Again, one more close view of the same thing; then you also have extruded mats.

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Like, again random drain core, you know. Say for example, as I just mentioned of our pre-fabricated vertical drains, we need to have drainage core, you know; like we have a geotextile as well as a geofilter.

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So, this is a drain core you know. You can see that we have a drain core also here, at the center like, this is a drain core. So, this is an either side, you have a geotextile. Some of these materials also can be manufactured in this manner.

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Some important characteristics one should remember was that, you need to have some mechanical properties, understanding them. You should also understand that, say for example, mechanical properties means strength and stiffness. Strength is nothing but, you know, as I just mentioned, that the ultimate tensile strength. Say for example, you take this material and test it, you have its short term tensile strength, you know. So, for example, immediately the material is manufactured, and then, you know, it is ready for delivery and testing and all that.

So, you have a mechanical, I mean short term testing, where you have to get its ultimate tensile strength and also stiffness. The mechanical properties, tensiles there are. So, so many we have like, it is, we will see some of them in a detailed way. Say for example, it is apart from strength and stiffness, it performs the other properties like, size like, say for example, apparent opening size of the geotextile, you know. The geotextile allows water, but how do characterize the opening size of this? Tt is called apparent opening size.

Say, that comes in the hydraulic properties; so, there is also short term and long term. Actually many of these materials, we need to have understand that there are two considerations here. One is a short term stability and long term stability. Like, you should be able to work immediately as soon as you apply. It should be done long term also. Say for example, if you are using for ten years or twenty years or thirty years, the mechanical property should be very good. Say for example, if I using a geogrid in a particular application and then they will; design life is thirty years.

So, I should design, I should know what its tensile strength is, at the end of thirty years. So, we have some methods to calculate; if you know the tensile strength, now what should be its tensile strength after thirty years? Based on testing, like people have done some durability studies or long term testing based on that, we have some correction factors like, say for example, you know, based on the time and the temperature. Even they see, because, many of them are polymeric materials; they have a temperature corrections also. Like, higher is the temperature, higher will be the creep; as a creep is there, definitely the tensile strength will come down.

So, if it is in an application which needs a long term applications of, say thirty years in a hot climate, may be you have a laboratory strength of, say for example, 50 kilonewton per meter. For this value, 50 should be divided by, say 1.3; because of temperature is 1.4. Because of something like, you know; temperature is one thing, then time duration is another one.

The third one is mechanical damage. Say for example, you may have it in the field, but then you install it in the field, we should just see that there is a damage factor also considered. So, all these things, we need and we calculate these mechanical properties as well as hydraulic properties. Hydraulic properties, as I just mentioned, it is just the apparent opening size and even the permeability. Actually, permeability, we call it, see for example, in some of these materials, thickness also plays a role.

If the higher is the thickness, higher is the flow. So, we use a term called permittivity. Permittivity is nothing but the permeability divided by the thickness of the material. So, if you know k divided by t, then we have that permittivity. Then, we also have what is called transmissivity. Like in the sense, like the filtration or permeability is required in this line, but the drainage, how much of water can be through this, this material can take.

It is called transmissivity, and it is nothing but k into the thickness. We call that, as that important parameter is again, you know, for drainage that is required; for the filtration, we need permittivity. We try to say in terms of the permittivity; and for drainage, we say in terms of the transmissivity. And, in both cases, we need the thickness; because, thickness is an important variable in many of these things.

Then, durability studies: durability studies are like, you know, as I said, many of these chemical materials, they are all temperature-dependents; installation conditions, aggressive chemical environment could be there. So, if there is some lot of chemical industry is there, one should use proper factors; it should not get damaged. Actually, what it, what we are essentially looking for is that, like this material should have its required tensile strength. Whatever is the condition you have, design, say for example, 50 kilonewton per meter is this number, but in design, you will get a number, that is what is required, is may be 10 kilo newton per meter.

So, you have a factor of about 50 by 10, a factor of 5, which can take care of its life. I mean the life of the structure, the damage; and then all other issues, one should calculate in that. And, same thing in permeability also; like, you know, clogging is one simple thing that can occur in permeability; like, if there is a clogging, then what happens? There is no water flow, and permeability is going to be quite low.

So, what we do is that, we try to account for that. So, we shall try to provide extra thickness of this material, extra opening or, you know, you try to say a, take a bigger size than what you got; what do you got now? Say for example, you get a 0.8 mm size because of some calculation. So, go for 1 mm size of that material, you know, something rather. So, essentially, some of these characteristics are quite important and one should see that they are all incorporated in design; this is a typical example.

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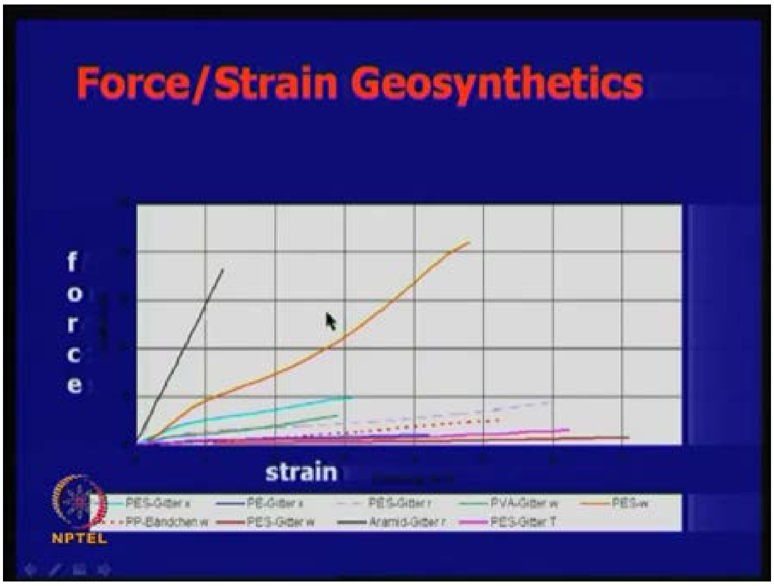

Like, see, as I just mentioned, many of these materials have time-dependent response. Say for example, some, of course, the x-axis is not very clear and y-axis is the force; and, see, some can be very stiff, some can be very, you know, the tensile they can go for long strains, and then they cannot; some materials cannot. They reach the ultimate value in a short span; the ultimate value, you can reach in a short like, you know, very fast.

Whereas in some materials, it can take time; see, it is a very interesting thing, that depending on the type of application, you can have both. This type of products, say for example, I had one case where the holding of stones is an important criteria. Like, you know, if I put a geotextile, you have a geotextile and it should hold a stone like, you know, say for example, riprap. Riprap is placed on a geotextile; geotextile is there, and then that material can really sag; I do not have any problem.

You know, if it can expand, this geotextile can expand, I do not have any problem. Why? Because, it should not get punctured, it should not yield; that is the only thing it can get; little this thing. It is not an important criterion; but as long as it does not crack and hold that, what is that? What is the stone pitching or that pebbles? It is alright for me, but in some other applications, it should be very stiff also like this; like so. Stiffness is, you know, if it is somewhat steeper curves, stress strain curves are the force verses strain curves are given by this.

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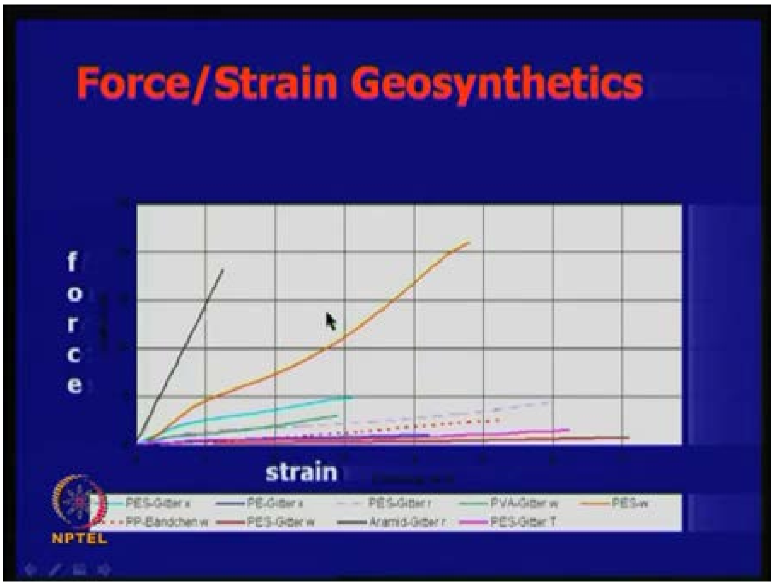

And, if it is flat also, is like, you know. Because, what happens? The flat ones are, you know, the materials that are stiffer are little expansive compared to the ones that have a lesser stiffness; that is one thing, and because of the manufacturing process and all that. So, these are all some properties.

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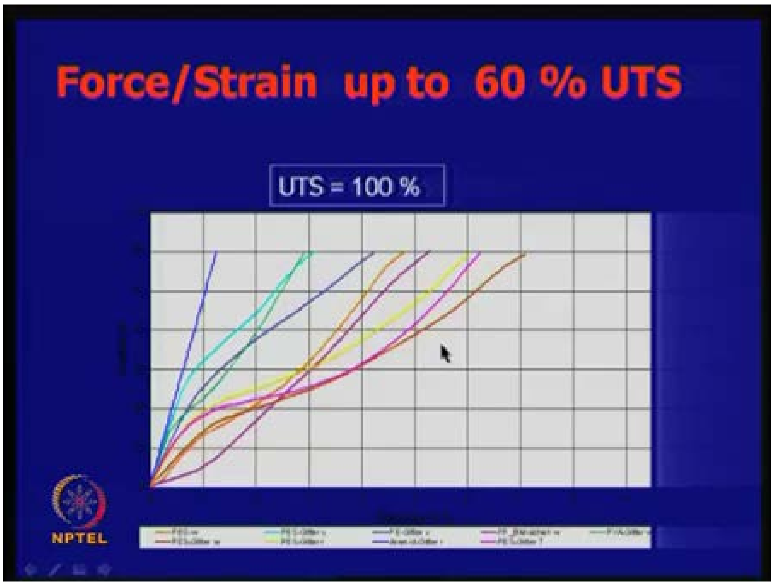

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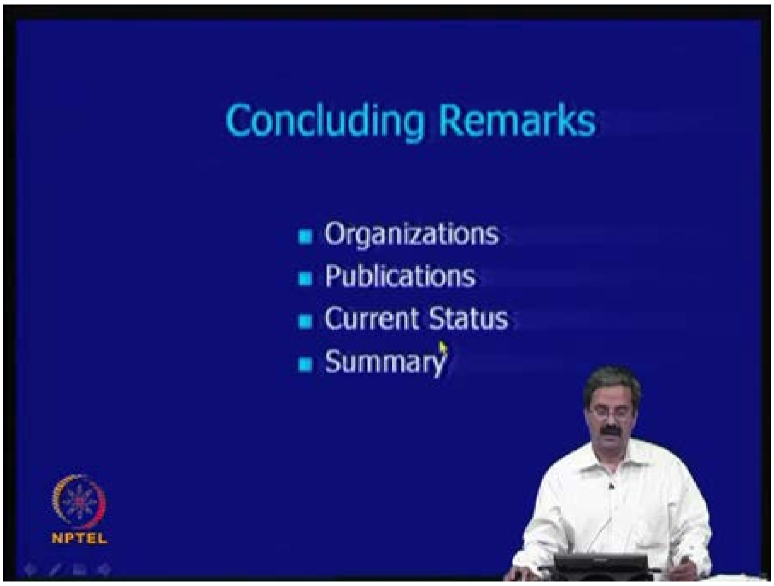

Ultimate tensile strength: these are again, they can have a relationship like this. What I want to just say is that, the geosynthetics families have materials, have a number of supporting organizations. In fact, so many Organizations, Indian International Geosynthetics Society is one; and then we have so many publications; we have journals on this area. Say for example, Geosynthetics and Geomembranes is one, Geosynthetic International is one; and there are so many. And, it has been quite extensively used in many of the ground improvement problems.

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As I just mentioned, Geosynthetic Institute is one International Geosynthetics Society. Then, Geosynthetics Materials Association International Standards Organization, like ISO standard, then ASTM International. In fact, there are so many standards also here nowadays. Because, these materials have all testing standards and some materials are, you know, the thing is that, we have what is called ISO. ISO standards, say for example, ASTM standards are also there. In America, the ASTM standards are popular; and in Europe, they are EN standards, EN. So, then ISO standards are also there for Geosynthetics and you also have various guidelines developed and proposed by these institutes.

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International Geosynthetics Society is quite useful in many of the applications. Actually, if you do not use this material properly, again this is useless. So, to us, this technique is properly to the use; this product properly, you should know its technique and its properties. So, to have its properties, you have to have standards and to see that they are properly implemented; you need to have the technical guidelines. See, this some of the organizations, some companies, they give lot of manufacturing guidelines. Say for example, this is, these are all geotextiles, geotextiles coir, geotextiles; geotextiles from the jute company.

So, they also gave, what are the specifications we have and what are the properties of each material. Like, say for example, non-woven geotextile; what are its properties? It is given; then, the other one was that, say, you can take any other commercial geotextile where, you know, say for example; there are in so many companies in India and abroad. Not less than, may be thirty to fifty companies, where they come up with their own catalog and products like this are given and their properties are given very clearly and how to use that in the field is also given. All the designs are also tentatively given, but then, you have to cross check with your calculations and actual field conditions. Because, the forces at the which are acting in a field, you need to understand and then use this material, whether it is a drainage, whether it is a lateral force, and all that one should do it properly.

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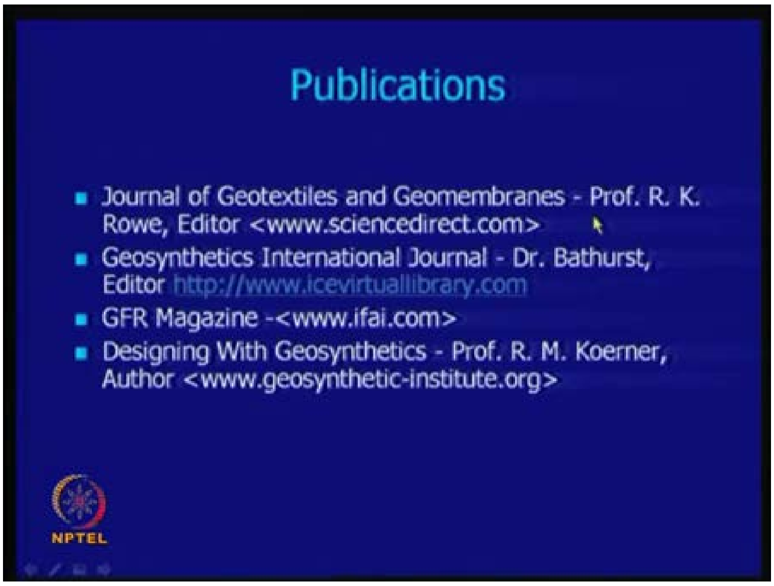

Then, the publications like, you know, lot of research is going on in this area you know. The thing is that, there is so much work and research, like it is a very innovative thing you know. As I just mentioned in the beginning, that civil engineering has soil concrete and steel; now, you have an other material geotextile or geosynthetic materials which can be used to construct roads or anything, right? So, you have a good journal like Journal of Geotextiles; Geotextiles, Geomembranes and Geosynthetics International Journal, then GFR magazine. There is also a standard book, Designing with Geosynthetics, by professor Koerner. And, of course, there are also many books which, in fact, are available which are generally based on the work that is reported in some of these papers.

The other one was that, we have even Ground Improvement journal; that is another important thing, Ground Engineering Journal; in fact, that is all they are all given by this is in LCR publication. Geotextiles, Geotextiles and Geomembranes; this is a it is called IC, Institute of Civil Engineers Publication. Then, you have ground improvement; there are so many journals one can have and they are very useful.

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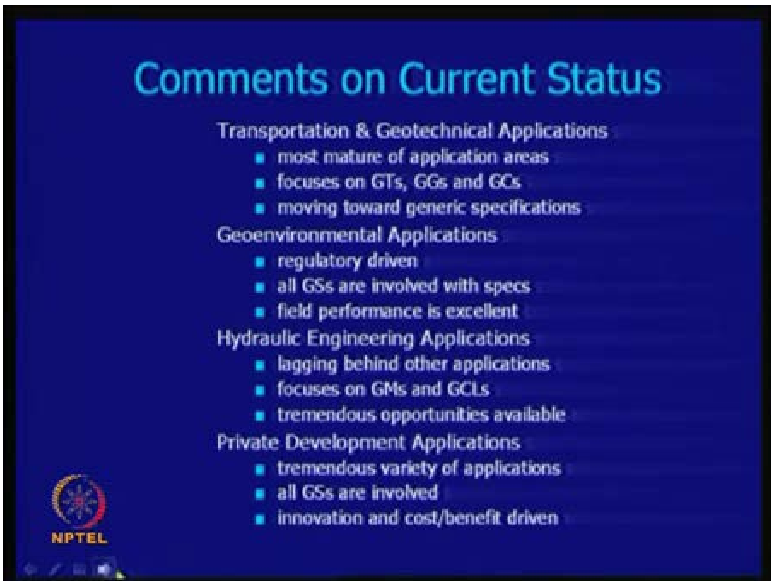

So, the scenario for the Geosynthetic family is that they are quite useful in transportation of applications. They are very much useful in Geo-environmental applications. And, they are moving towards hydraulics, hydraulic engineering applications. See, in the sense here, some more important thing is that, in the transportation, geo-technical applications, people have been able to understand that these materials are useful; and they are moving towards generic specifications. In general, you know, what could be that, and the geo-environmental applications, they have; there, they are all regulatory driven; driven as I just mentioned. Even government of India, say for example, Government of India also has rules on how to construct landfills in India using Geomembranes.

And, all these materials involved with some specifications and their field performance has been very good. Because, if you do not use them, we know see, we see the contamination immediately. So, field performance has been very good hydraulic engineering is, it needs a lot of inputs, much more inputs, but it has been picking up very well and it has a lot of opportunities. In fact, the other day only, I was just trying to design 35 meter high wall behind back waters of Nagarjunasagar water, where the water flow is so high. And, if use a conventional retaining wall, it could be very expensive. As I said, you have to design for water pressures as well, as the height itself is high, so much as 35 meters. So, when I just used a Gavient type Geosynthetic and type of all, it was quite effective; not less than 40 percent, it was cheaper.

So, actually, it was costing 5 lakh rupees per meter length, and including the height and whatever. So, now, it is reduced to about 2 and half to 3 lakhs, which is about, you know, quite cheaper compared to what they had initially. And, the opportunity is for private development applications. In fact, these geosynthetic materials are so useful, but, I know some people who are using it for water proofing in their houses like private development. There are so many apartment complexes nowadays, coming up; they want quick solutions faster; they do not want to have problems facing them and all that.

So, In fact, I know many apartment complexes who are using, say for example, Geomembranes for, you know... Suppose, they have a swimming pool in their developmental area, they need to go for geomembrane; they may go for Geogrid. So, apart from the work in the public sector, there is so much encouragement and application in the private areas also.

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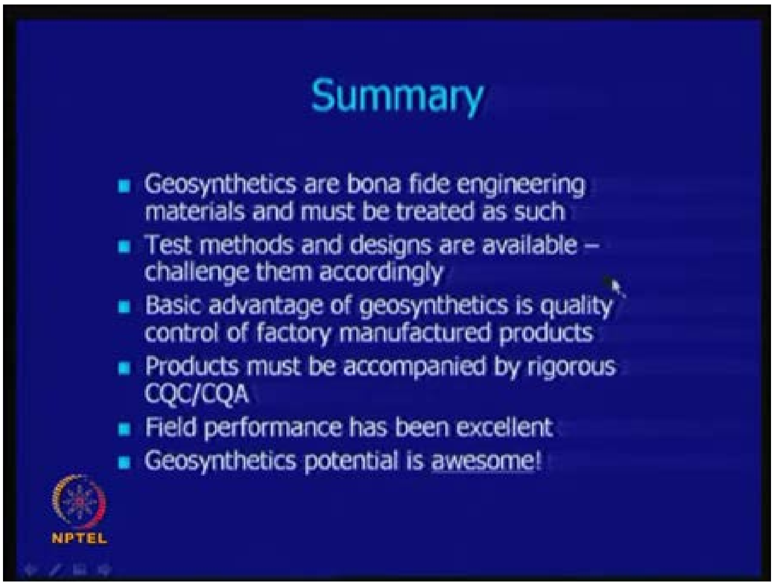

So, what I want to say is that, this Geosynthetics are bonafide engineering materials, and must be treated as such; you have testing methods and designs that are available. And the only thing is that, you should understand them properly and design them properly. The basic advantage of the Geosynthetic materials is that, there is its quality control products like, you know; they are all ISO certificated. You know, they have each product an ISO certificate, which is, you know, not easy to get.

And, they are also in a... Once you do in a field here, also you can test those samples also. So, they are all supported by rigorous quality-control programs, if field performance has been excellent. In fact, there are facts the RU walls are been constructed now about thirty, forty years. Now, see the first RU wall about may be, twenty five years back it is constructed; they are doing well.

Geomembranes: In fact, they are used in 1958 in one of the dam projects; 1958, it is used about more than fifty years; so, their prediction and their performance has been excellent. In fact, there are so many applications that imagination is the only limit here. So, people have been able to use it, you know; the thing is that, if you are really serious about using these materials, one can, you know; they are very, you know, you have to be a little more aggressive in thinking as well as take advantage of these products. Your challenge is to take advantage of these materials and get number one; the design has to be very good. Then, its analysis has to be, you know, you must be doubly sure that, yes it works for you, provided you install it. So, your property should be very sure that all of them are there. So, it is only thing is that, one should take advantage of this, and of course, people have been doing it.

So, I am sure that in the subsequent classes, we will be dealing with some of these materials and their applications. Thank you.