Technical Textiles
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Lecture - 16
Geotextiles

Hello everyone, so, our new topic is geotextiles so, geotextile is one of the members in the group geosynthetics.

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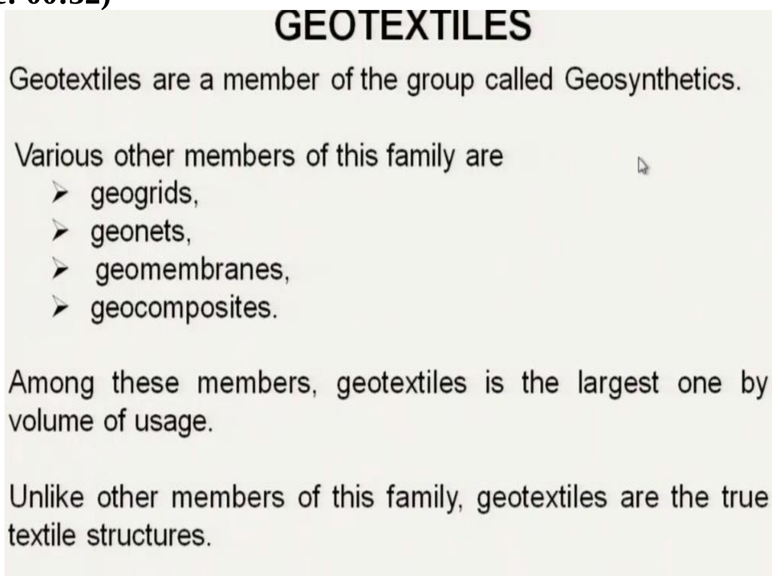

So, this is this geosynthetics, the other members are in addition to geotextiles are geogrids, geonets, geomembranes, geocomposites. So, these are basically made from synthetic materials and as far as geotextile is concerned, they are made from synthetic material as well as natural material natural fibres. So, if we see the application wise, the geotextile is the member where the usage are in large scale, unlike other members of this family, geotextile is true textile structure so where understanding of textile structure is extremely important.

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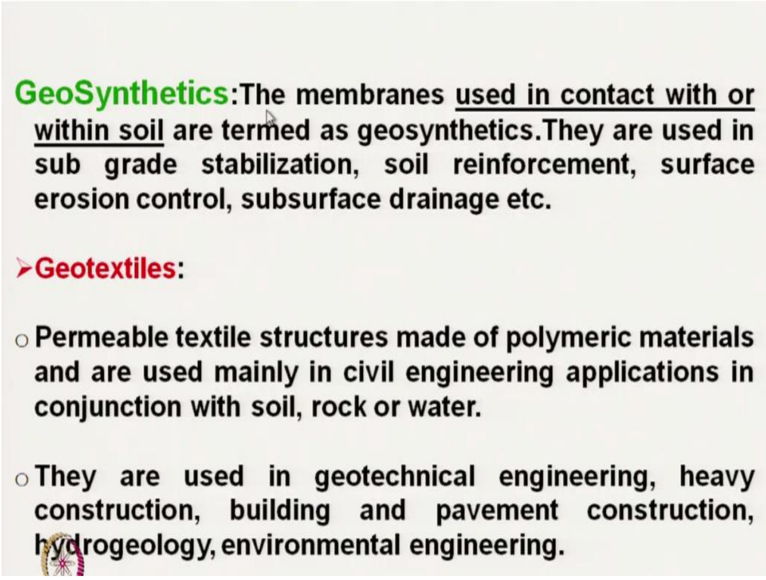

So, geosynthetics the membranes used in contact with soil that is why the term geo comes, they are used in subgrade stabilization, soil reinforcement, surface erosion control, surface damage or many other applications. So, these are the basic applications of geosynthetics. Here we will concentrate will focus on only geotextiles. So geotextiles the main advantage is that it is permeable. We can control the permeability of geotextile material.

So it is a permeable textile structure made of polymeric material and are used mainly in civil engineering application in conjunction with soil rock and water. So, if we use in conjunction with soil, rock and water then we can call this textile product as geotextiles. So they are used in geotechnical engineering, heavy construction, building and pavement construction, hydrology environmental engineering. So, these are the various areas where geotextiles can be used.

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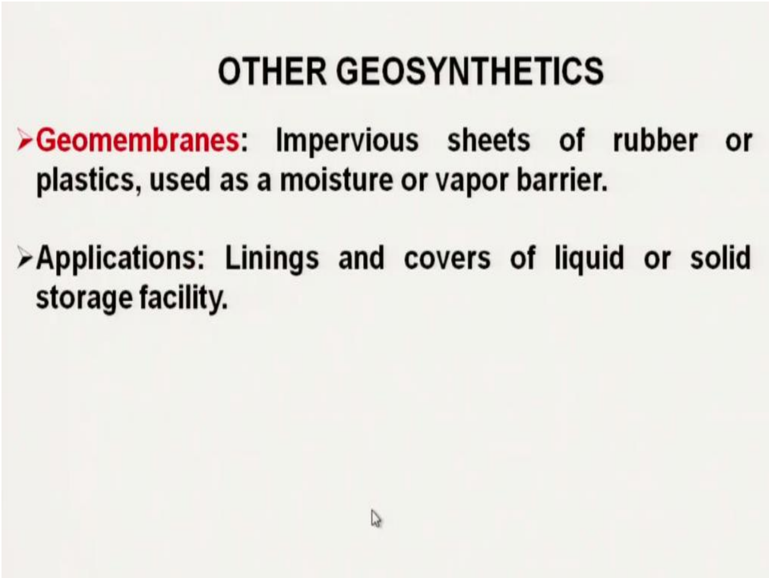

On the other hand geomembrane is nothing but it is a polymeric sheet impervious sheet used as liquid or vapor barrie,r like linings and cover of liquid solid storage facility. These are the applications, like landfill lining we may use geosynthetics to prevent seepage of maybe harmful fluid.

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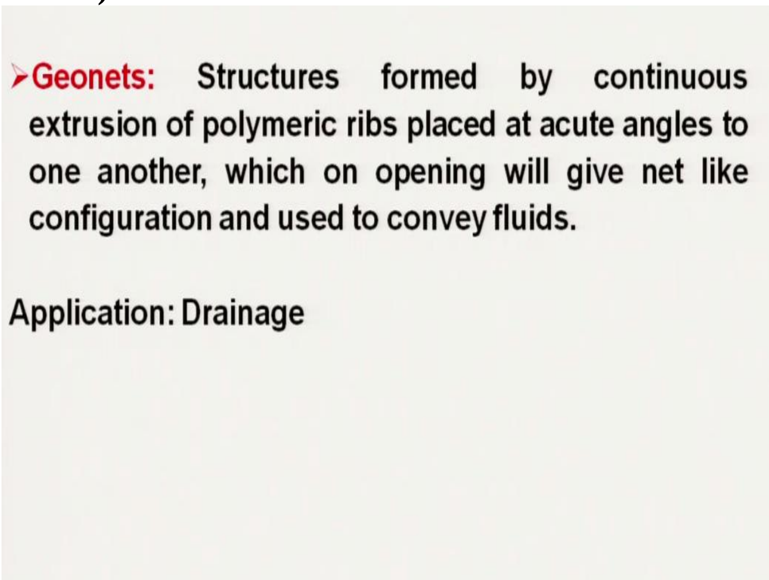

Geonets this structures formed by a continuous extrusion of polymeric ribs placed at an acute angle to one another which on opening will form a net like configuration and it is used to convey fluid. So, for drainage application, we sometimes use geonets.

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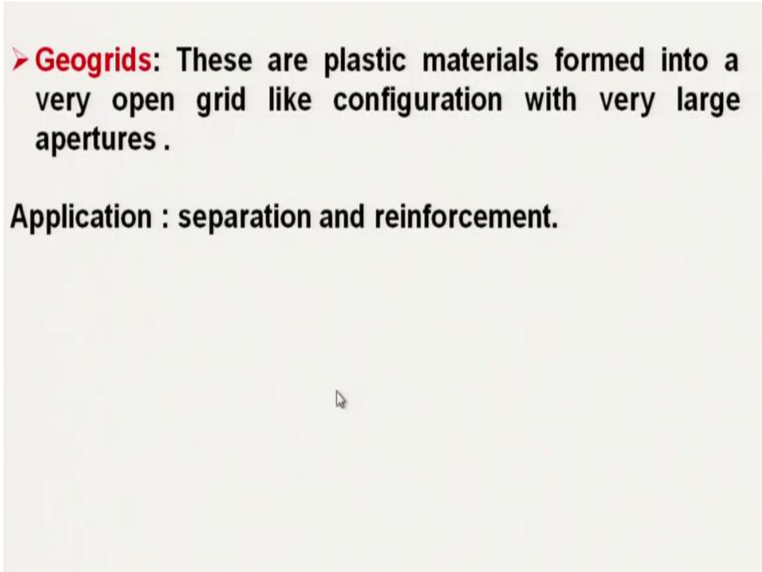

Geogrids are for reinforcement application or separation application. These are plastic materials formed into a very open grid like configuration with very large aperture. So, these are basically to retain the rocks in the inclined slope,

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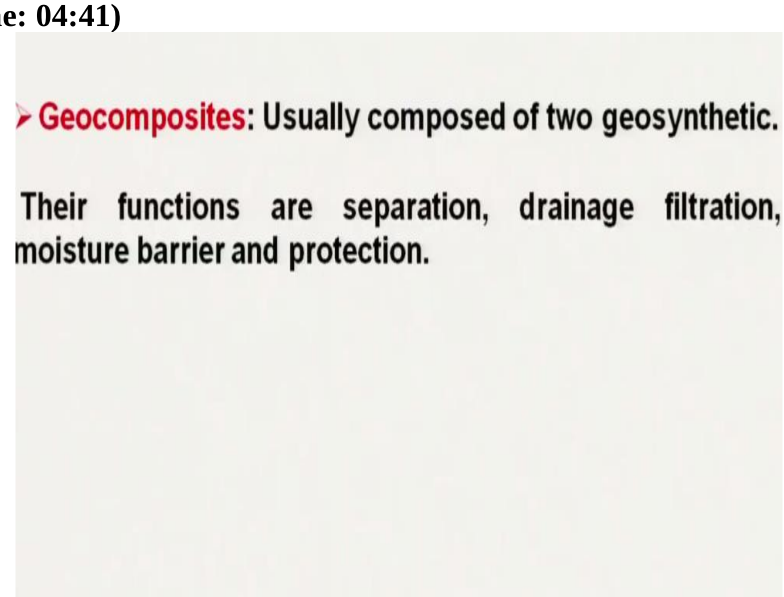

It is used for separation and reinforcement application and geocomposites are basically using more than one geosynthetics together to have multiple or enhanced function they are functions are basically separation drainage, filtration, moisture barrier, protection. So, if we require multiple function, we can use geocomposites.

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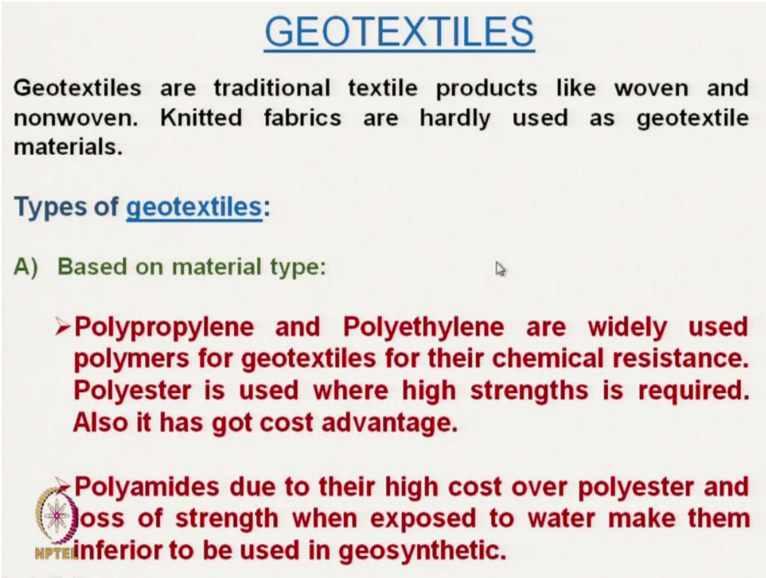

So, our focus as I have mentioned will be basically on geotextiles. So, this geotextiles can be woven and nonwoven although knitted geotextiles are hardly used, but some time for a specific application, warp knitted geotextiles are used. So, if we try to classify geotextile, we can classify geotextile fast based on the material used the raw materials like synthetic fibre or natural fibres synthetic geotextile, manmade geotextile or natural fibre geotextile and in manmade fibre,

We can use say polypropylene or polyethylene because they are widely used for geotextile due to their chemical inertness. The chemical resistance they are not easily affected by chemicals, sometime polyesters are also used due to their high strength, the main problem with polypropylene is lower strength. So, polyester is having higher strength and they have cost advantage also sometime we use polyamides for very special application.

But main problem with polyamides are their higher cost and also their strength drops when it is exposed to water. Because in geotextile, when it is always in contact with the soil rocks, definitely there will be interference with the water. So, that is why polyamides are hardly used, but for some application, where the abrasion resistance is important, because polyamide has got very high abrasion resistance.

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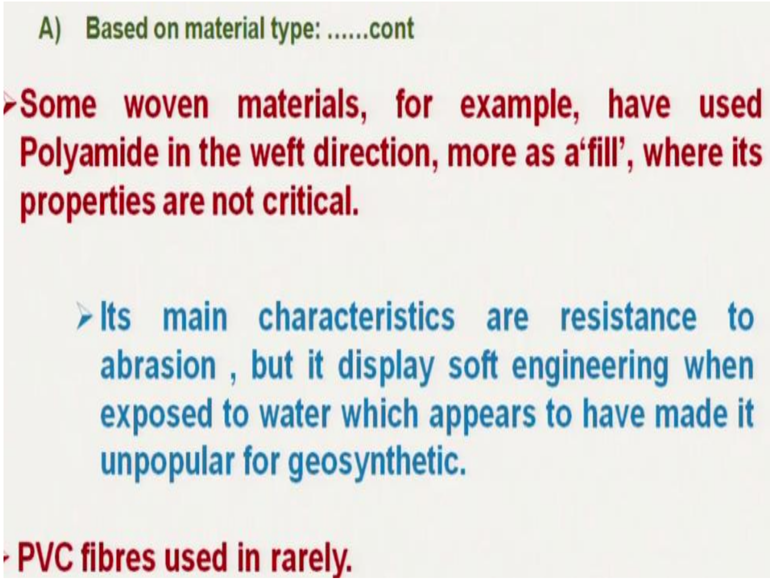

So, it is it can be used, PVC fibres are rarely used, it can also be classified based on the manufacturing technique. So, woven geotextile.

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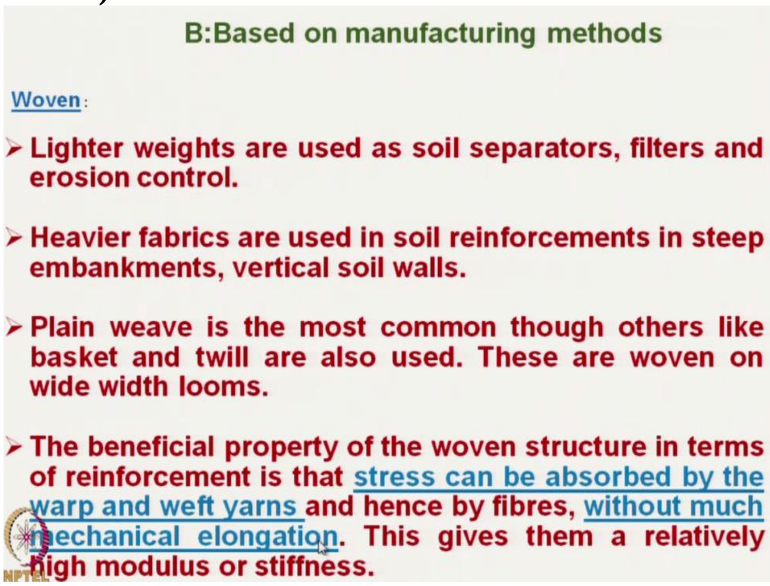

So, lighter weight are used for soil separation, filter and erosion control. Heavier fabrics are used for soil reinforcement and among the woven fabrics plain wover a plain weave structure is most commonly used, sometime basket and twill fabrics are used and this geotextiles woven geotextile are normally manufactured in wide width loom not like apparel, other normal fabrics. So, why do it looms are required.

So, their main advantage is that their stress can be absorbed in both warp and weft direction, because the yarns are in both directions. And another advantage is that their high modulus, higher stiffness which is essential because they can actually they can have a higher stress with less elongation.

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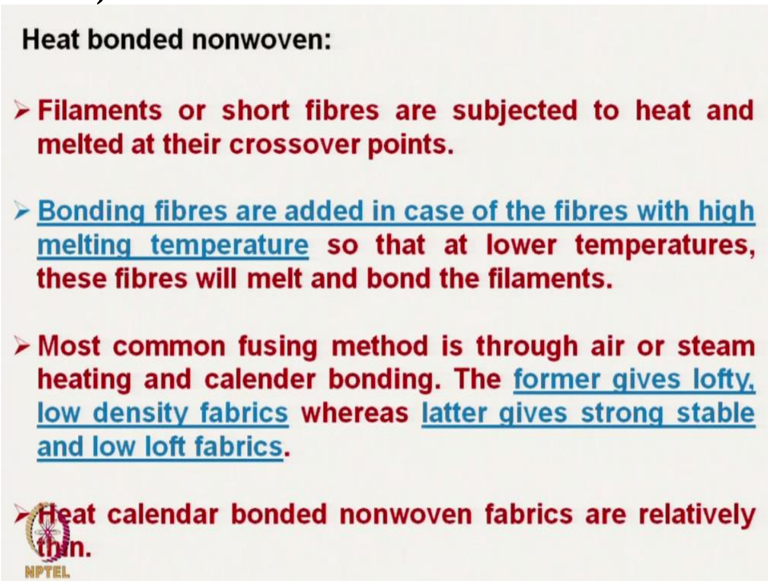

Sometimes heat bonded nonwovens are used. So, filaments or soft fibres are subject to heat and melted at their crossover points. So, these are the geotextiles with bonding fibres are also used where the melting point of fibres are very high. There we can use some bonding or fusing fibres like we want to use say polyester. These are the polyester.

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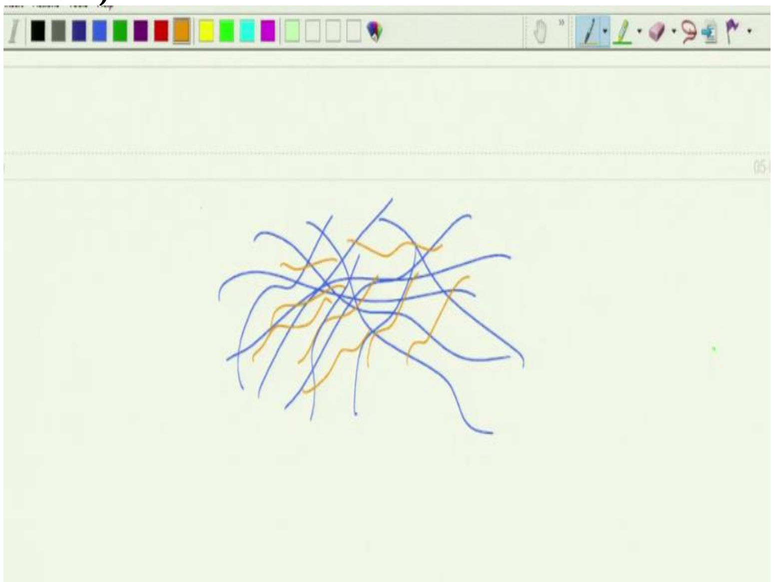

Polyester nonwovens polyester web but main drawback of polyester is that it has a high melting point. Here we can use some low melting point fibre with some proportion and during heat bonding, either calendaring or through air blowing hot air blowing these low melting point fibres melted and fused the stronger polyester fibre. So, bonding fibres are added in case of hybrids with high melting temperature.

So, that the, at lower temperature these fibres will melt and bond the filaments. Most common fusing method is through air or steam heating or sometime calendar bonding are used. Main problem with calendar bonding is that it will make the fabric stiff the porous structure will not remain there. But on the other hand through air or steam bonding gives the lofty structure, low density fabric and heat calendar bonded nonwovens are relatively thinner in dimension.

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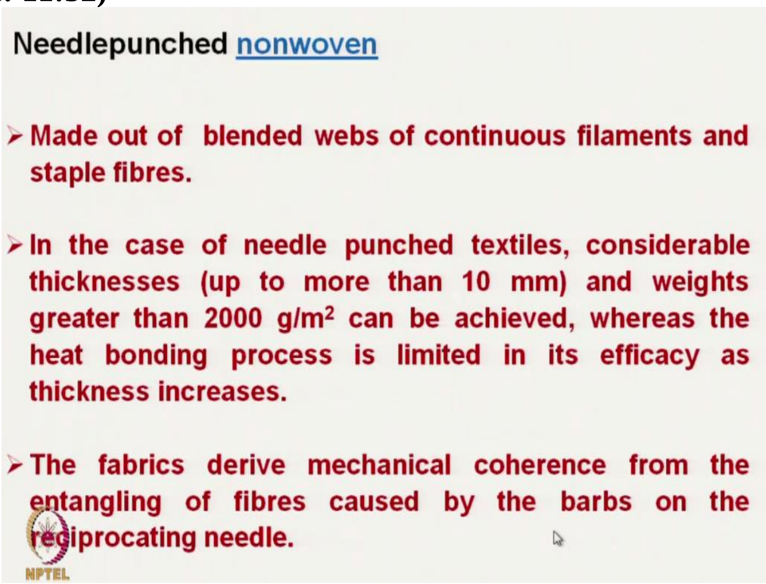

Another way of making nonwoven fabric that needle punched fabric, where using the barb needle the fabrics are bonded mechanically. We can use staple fibre or filaments continuous filaments for needle punching. In the case of needle punch textile, considerable thickness can be achieved. It can go up to 10 millimeter thickness depending on our requirement. The weight can be 2 kg per square meter, the fabric derived from mechanical coherence by entangling fibre using the barbed needles.

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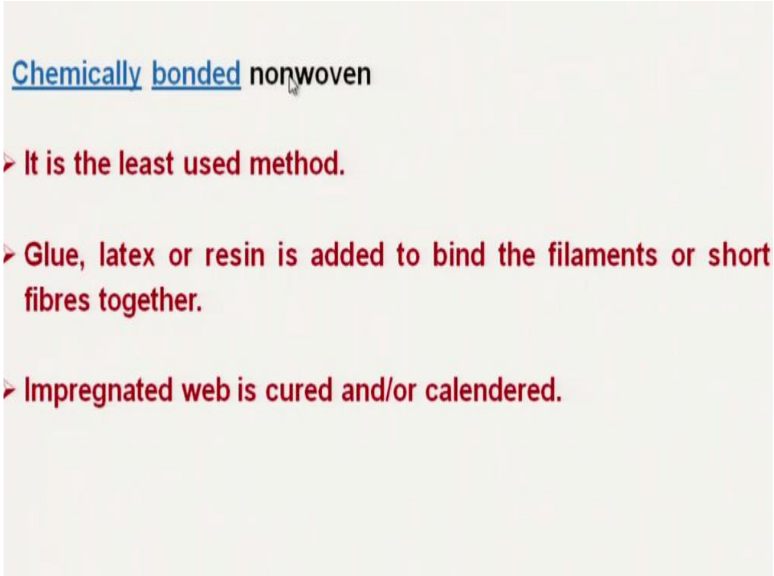

Next type of nonwoven fabrics are it is a chemically bonding nonwoven but chemical bonded nonwovens are hardly used in geotextile. So these fibres are bonded using the glue, resin.

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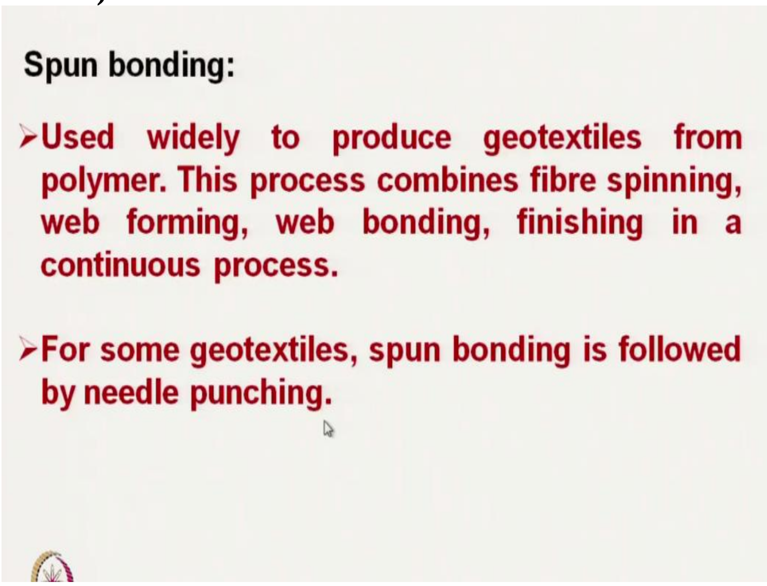

The technique of manufacturing nonwoven fabric using continuous filament is called spun bonding technique. It is used widely to produce geotextile from directly from polymer. This process combines fibre spinning, web forming, web bonding and finishing together. So all these processes, if we put together we will get the fabric directly from the polymer. So, spun bonding process where we can use both heat calendar or needle punching. If we use needle punching, we will get more, higher porous structure.

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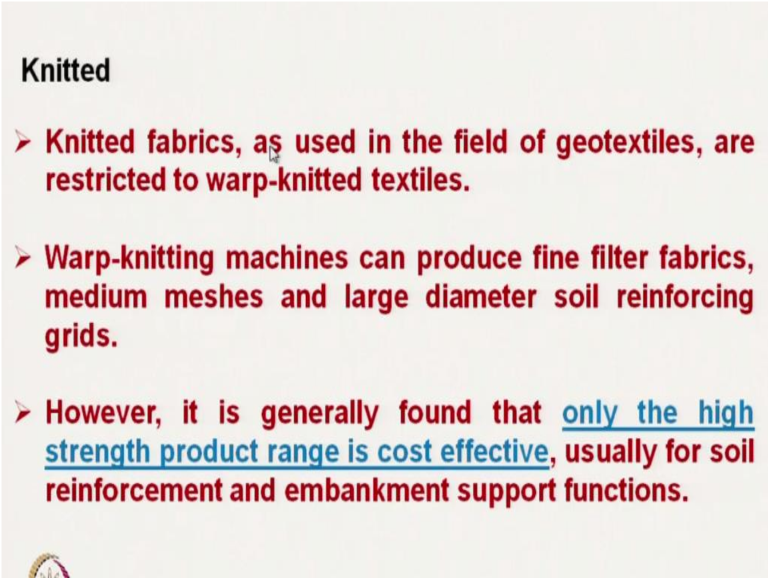

So knitted fabrics, as used in the field of geotextile are restricted to only warp knitted structure. As the warp knitted structures are expensive, only the high strength product range is used to where soil reinforcement, embankment support functions are needed, there we can use warp knitted structure.

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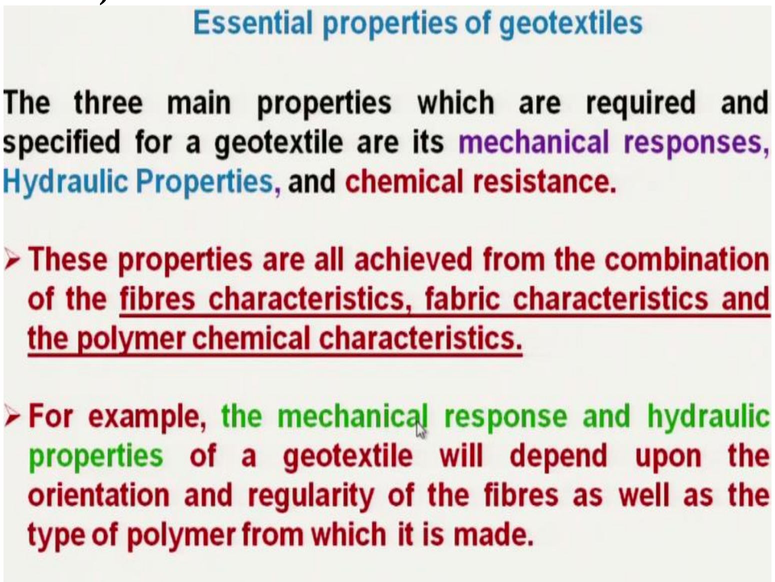

Now, coming to the properties the essential properties of geotextiles are basically classified into 3 categories. One is mechanical property, then hydraulic property and next is chemical resistance. All 3 properties are extremely important, they have to be balanced otherwise, performance of geotextiles will not be proper, like a fabric with very good mechanical response if it is not performing hydraulically properly or chemical resistance is poor then during use after a certain time this structure will be will collapse. So, that the geotextile will not be useful.

So, the properties these properties are all achieved from combination of fibre characteristics, fabric characteristics and the polymer chemical characteristics, like if we use polymer with say natural fibre polymer like jute its chemical resistance may not be that good. So for getting all these characteristics, we must consider the fibre characteristics so, diameter of fibre. So, fibre with lower diameter may get attacked by the microorganism present in the soil quickly due to their higher exposed area.

Like fabric characteristics, whether it is woven, nonwoven fabric, these characteristics will actually guide the hydraulic property, mechanical response. For example, the mechanical response and hydraulic properties of geotextiles will depend upon the orientation and regularity of fibre as well as the type of polymer from which it is made. If the fibre orientation is there in one direction, then mechanical response of the fabric in that direction will be different than the other direction. Let us try to see here, if we see the say nonwoven fabric.

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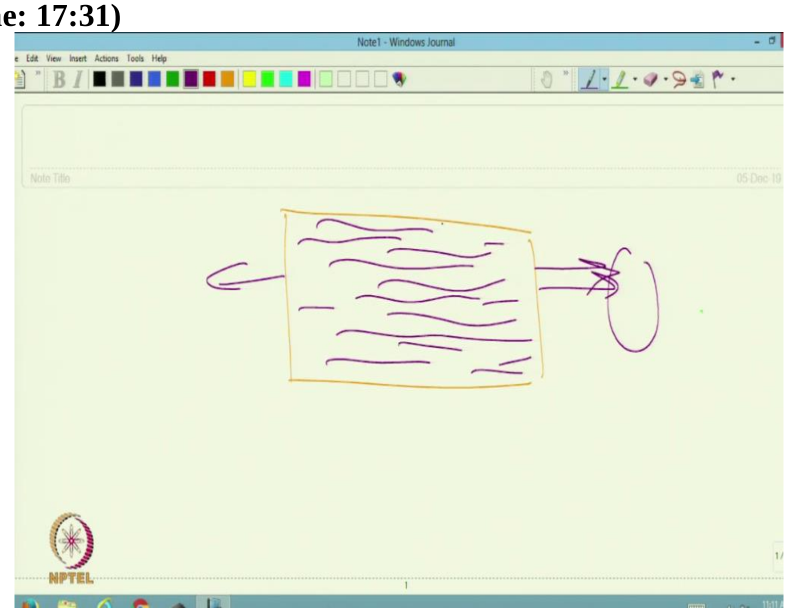

This is nonwoven fabric, we with fibres oriented in length direction. Mechanical the strength and modulus of fabric in this direction will be much higher than the cross plane direction.

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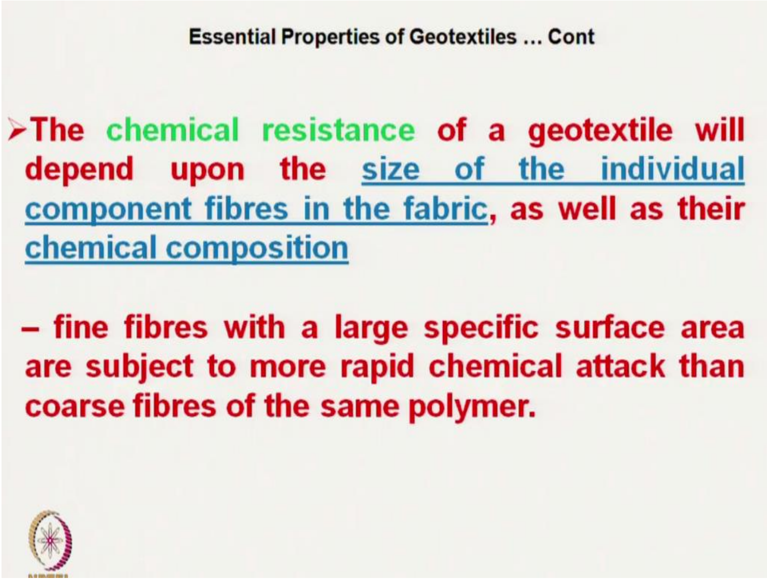

So, the chemical resistance of geotextile will depend upon the size of the individual component fibre in the fabric as well as the chemical composition. Like the polypropylene, as it is inert against most of the chemicals so, it will not be degraded quickly. On the other hand, if we use jute in geotextile, they are biodegradable they will decompose quickly. Similarly, the fibre diameter so, the finer fibre with larger specific surface area subject to more rapid chemical attack then coarser fine. So, we have to select the fibre accordingly.

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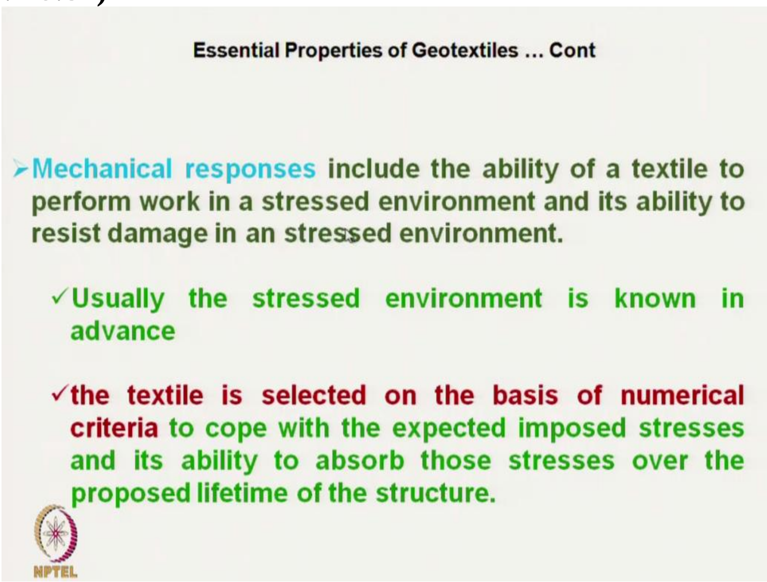

The mechanical response include the ability of a textile to perform work under stressed environment so because it has to resist the damage of the structure under stress, Usually the stressed environment is known as the known in the in advance. So, if we know the application we can predict the type of stress environment. Accordingly, we can select.

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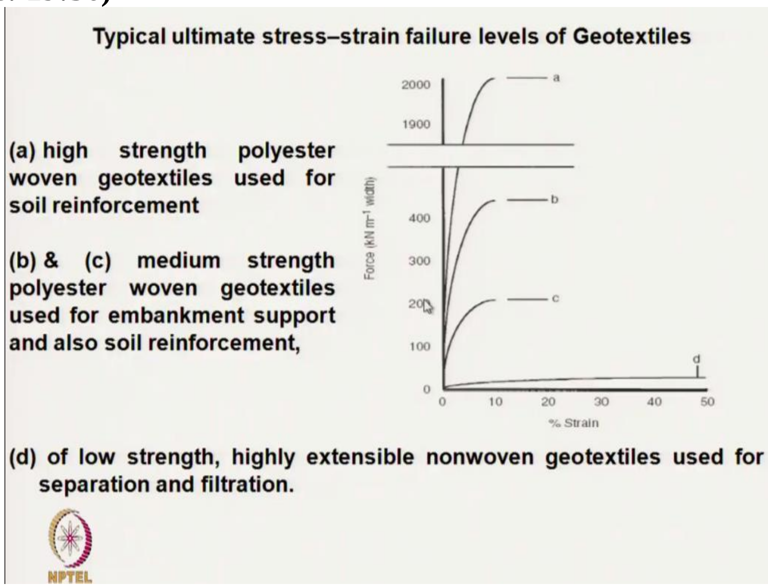

Like, for example, in this curve a here its high strength polyester, woven geotextiles are used for reinforcement. So, the application where we need reinforcement so, we know the stress condition we know the application in those applications will use high strength high modulus woven fabric, because in woven fabric here the modulus is high. So, it will not allow the structure to get deformed.

Similarly, medium strength we will use for different application and of low strength high extensibility nonwoven, geotextiles are used for separation and filtration application. So depending on the stress strain behavior, we can select the application we will not use nonwoven geotextile for high strength or high modulus application.

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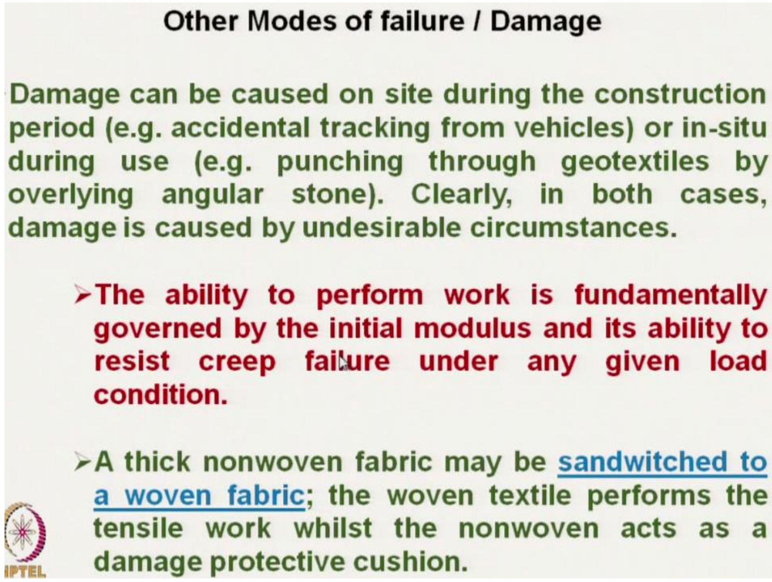

So, these are the different damages we have discussed which are predictable but there are other mode of failure, which we cannot predict. So, the damage can be caused in site during construction period also like accidental tracking from vehicles or in situ damage during punching by the angular stone. So, this punching may take place, but this type of damages may occur and we have to design our geotextiles accordingly.

The ability to perform work in is fundamentally governed by the initial modulus and its ability to resist creep failure under any given load. That means, we must have a clear idea about the initial modulus and its creep. Now, let us see the importance of initial modulus. The ultimate strength is not that important for geotextile construction. It is the initial modulus.

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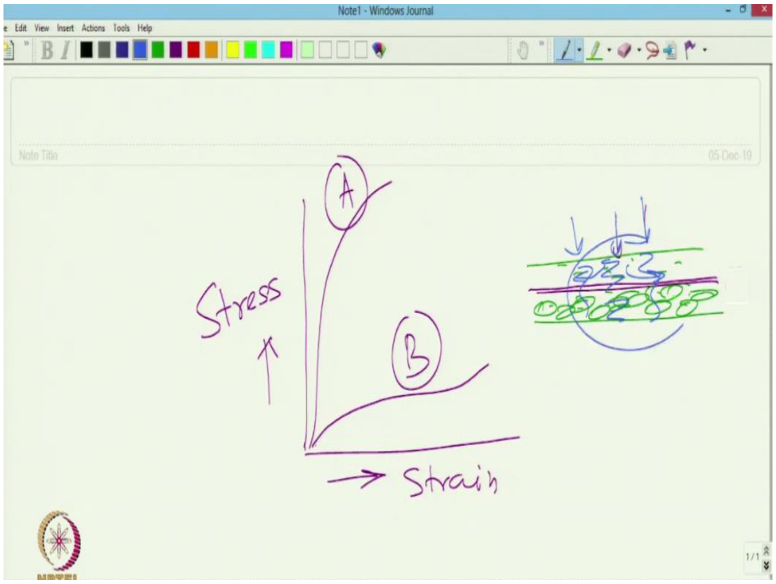

Initial modulus means this is one fabric and this another fabric, A and B, which one we should use for say reinforcement purpose or maybe geotextile stabilization purposes? So, this is the structure, soil structure. Now, we are using these are the some gravels and we are using geotextile for separation here. This is a geotextile. Now, here, if the initial modulus is low if we use B where the strain is high at lower stress upon loading here. So, once it is loaded this structure, the soft soil structure the soil structure will try to move out sideways.

If the extensibility of this geotextile is high then this total structure will get distorted. So, we must use geotextile A here to control the distortion and also the creep is another characteristics which is very important. Creep means at sustained load, how the material is getting extended. So, a thick nonwoven fabric may be sandwiched with woven fabric, the woven textile performs the tensile work whilst the nonwoven acts as damage protective cushion. So, this due to this type of damages by punching by stones, so, if we want to protect woven fabric, so, at the upper level we can use nonwoven. Which will have cushioning effect.

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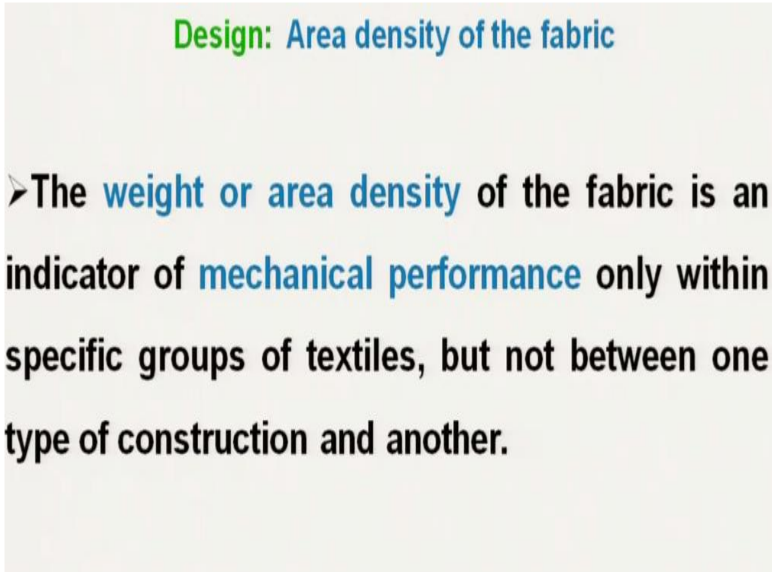

Now coming to design of geotextile, so design can be done based on mass per unit area that is area density or weight density. The area density of fabric is an indicator of mechanical performance only within a specific group of textiles but not between the different types of constructions, like for if we take say needle punch fabric, needle punch fabric if we use higher mass per unit area, higher area density.

That means higher the area density higher will be the mechanical performs higher with the strength, stress strain characteristics higher tensile strength will be there. But for same mass per unit area, if we take woven fabric, if we try to compare woven and nonwoven, then it will be totally misleading. So, if we take the mass per unit area as the design criteria, we must consider that this is only for the same similar type of material.

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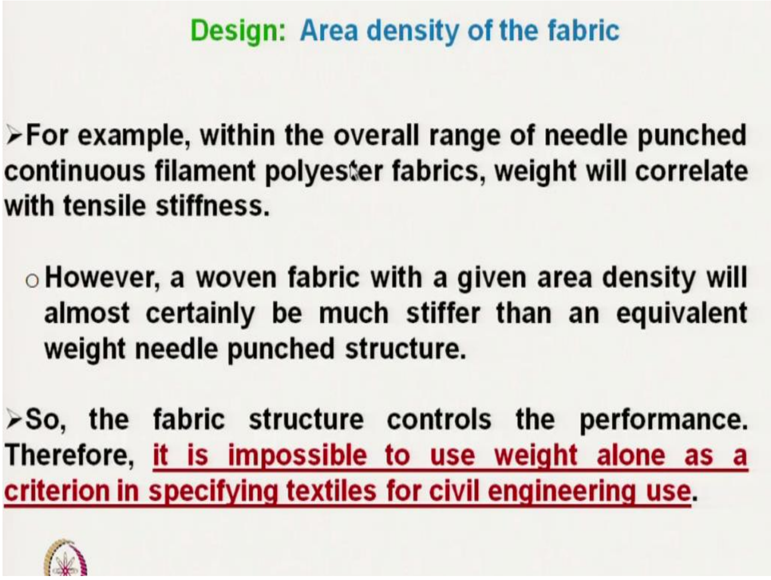

Like for example, within overall range of needle punched continuous filament polyester fabrics, weight will correlate with tensile stiffness. But if we try to compare with woven fabric, woven fabric is always stiffer than the needle punched fabric for sale mass per unit area. So, the fabric structure control, it controls the performance. So therefore, it is impossible to use weight alone as a criteria in specifying textile for civil engineering use.

So, we cannot say the x mass per unit area you can use for a particular application, for say, reinforcing application or soil stabilization application. Along with the mass per unit area, we must specify the structure of fabric, whether it is a nonwoven fabric or woven fabric, if it is nonwoven, whether it is a needle punched or heat bonded. So that information one must have along with the area density.

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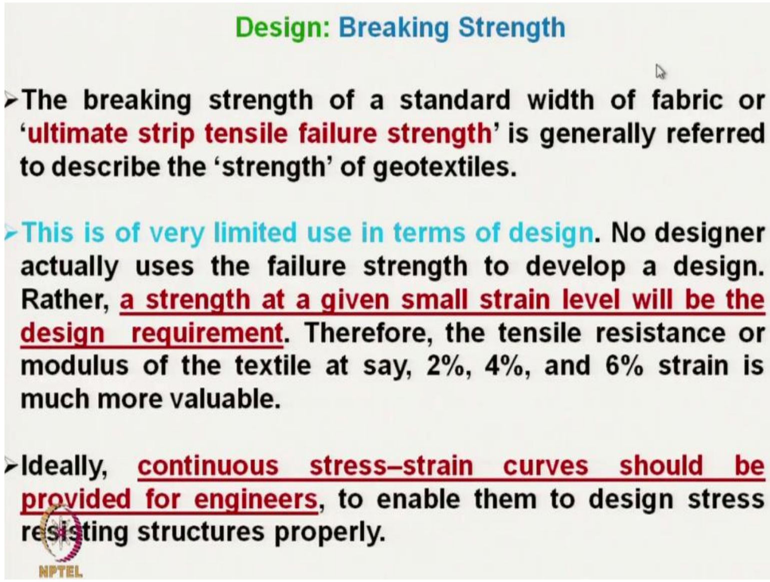

Next design criteria is that breaking strength. Although ultimate tensile failure strength is important, but it is not enough. I will give one example.

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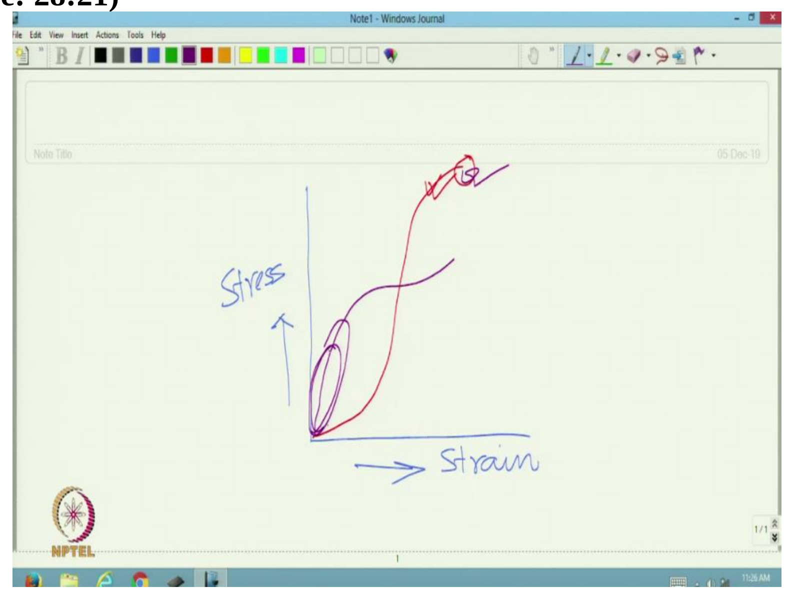

Normally, in actual application we never reach the final strength. You have two geotextiles this is really higher stiffness. Another one is that lower initial modulus but with higher strength. Now which one we have to select? If we select based on the, their breaking load or ultimate breaking strength, so we will select say this one. But as far as the modulus is concerned initial modulus is concerned, this one gives higher initial modulus, we never reach the stress condition ultimate up to the ultimate breaking strength.

So, our stress condition is limited to a lower level because we use very highest factor of safety. Therefore, we must know the elongation at lower load or at lower elongation at different elongation, what is the stress condition? So, ultimate breaking strength is not important. So, this is the ultimate failure strength is of very limited use in terms of design, we cannot use this breaking strength. So, no designer actually used the failure strength to develop a design.

So, if you have parameters ultimate strength you will not be able to design the structure based on geotextile, because it will be misleading, rather a strength at given small strain level will be the design requirement. So, at different level of strain smaller strain 2% 4% 6% strain these are more much more valuable. Ideally along with the breaking strength value continuous stress strain curves are required for the engineers to design the structure. So, we must provide the continuous stress strain curve for the geotextile.

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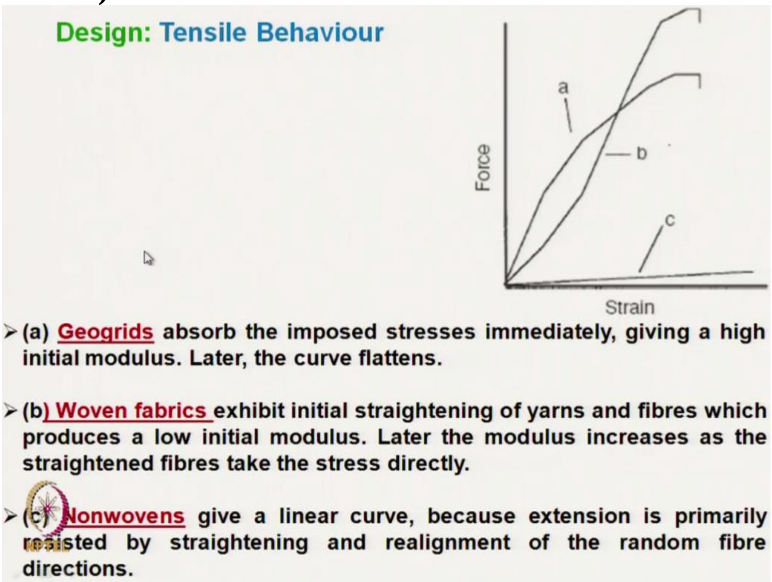

Here you can see the tensile behavior of geogrid A, woven fabric B and nonwoven fabric. So, it is not that we must always need the higher strength or higher modulus, depending on their stress strain characteristics we can use at different applications. This A curve is showing geogrids but we can use we can have woven fabric or different types of geotextiles this type of curve. So this is used to absorb the imposed stress immediately giving a high modulus and then curve flatten.

So where we do not need any deformation and at certain lower deformation, high stress is being imposed. So those applicants who use this type of geotextiles. Like in geogrid, we do not expect any higher strain during application, otherwise the total structure will collapse. The woven fabric exhibits initial straightening of yarn that is the crimp present that is why this type of behavior at lower load the strain is higher than the geogrid. But on the other hand, nonwoven is having very high extensibility due to their random fibre orientation.

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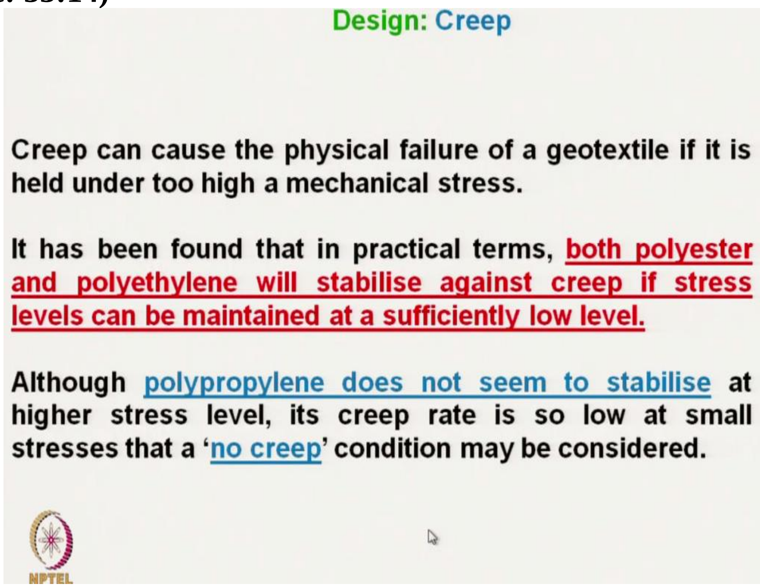

After tensile characteristics, next design parameter is that the creep, creep is characteristics which can result failure of the structure. So, it has been found that in practical term both polyester and polypropylene will stabilize against creep if the stress level is maintained at sufficiently low level. Although polyester and polypropylene at high level of load they show higher creep. But, if we maintain the stress level at low, there can be a situation of no creep condition that the polypropylene is used for stimulation, where level of stress is low.

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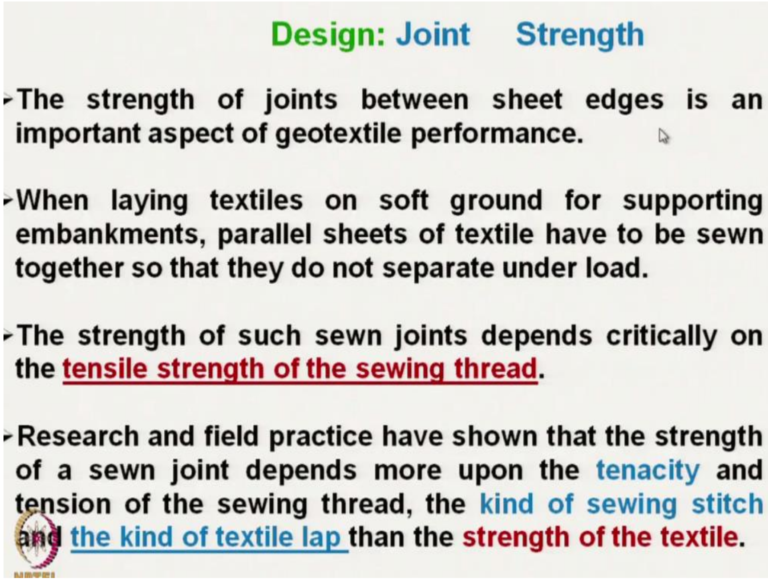

Next design criteria is that joint strength. Like stitching in our apparel we need to join the structure, join the geotextile. So, here its joining is typically done by swing by stitching and main failure it has been observed at the stitched portion. Because the strength of the swing thread, typically it is lower than the strength of geotextile. So, the stitching is the problem, the research and field trial have shown that the strength of a sewn joint depends on the tenacity and stress strain behavior of sewing thread and the kind of stitch and the kind of textile lap.

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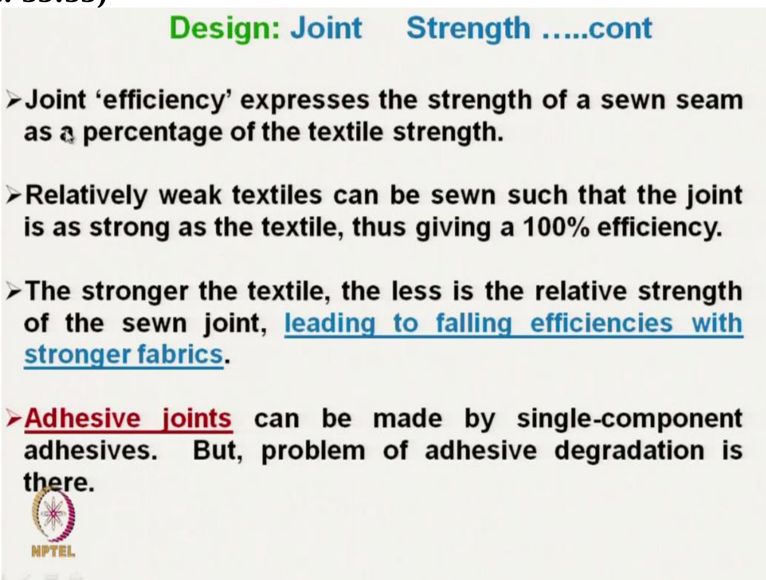

The joint efficiency expressed in terms of the strength of stitched portion to the total strength that the in terms of percentage. So, relatively weaker textile can be stitched such that the joint strength is typically 100%, the efficiency is 100%, the stronger the textile less the relative strength of stitch portion leading to failure of the structure. Sometimes adhesive joints are used, but the problem is that the degradation of adhesive takes place during the actual use.

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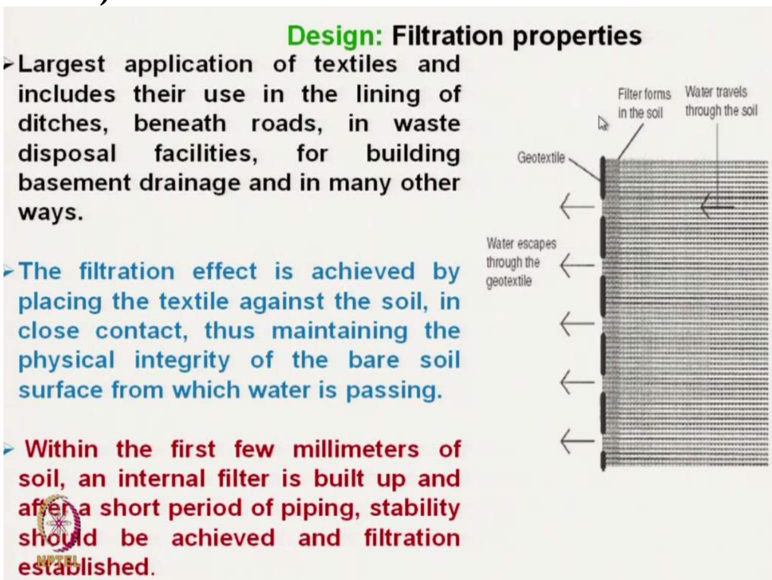

Next is that design criteria is that filtration. So, filtration is one of the most important filtration criteria, we have to select geotextile depending on the type of soil present. Here, this is the structure or the geotextile that soil structure is there geotextile is put here and what it should allow the water to pass through without allowing the soil particle loss, the main problem here is that the soil particle here it is of different size. Now, let us see here.

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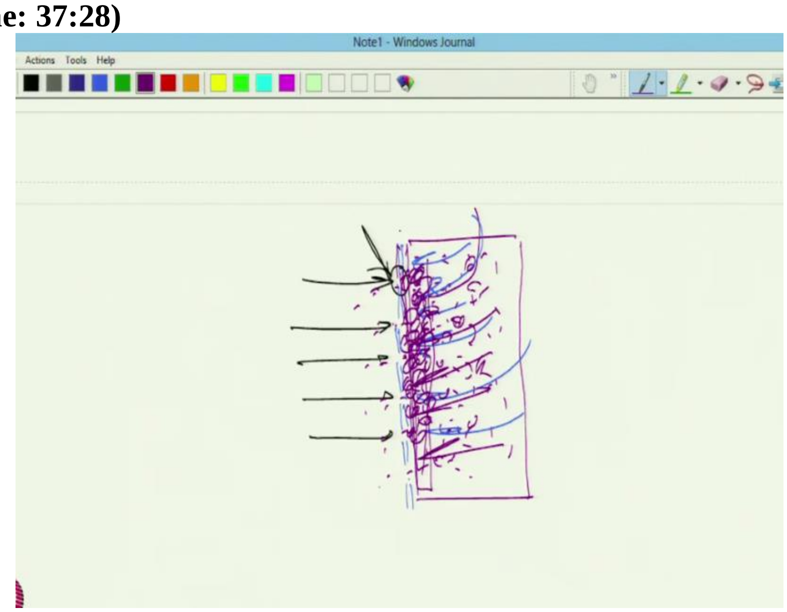

This is soil structure, soil of different size larger particles are there very small particles are also there. Now we are now putting geotextile here so, here this is the, these are the pores in the geotextile. Now, the problem here is that if we use the pore size of very small dimension or if we try to block suppose we are blocking the pore size pores to arrest the smaller soil particles then it is a problem. Because we have to allow the water, water to flow through. This is the water so that the structure remains dry but so at the same time, we should not allow the soil loss.

So, this is the contradictory requirement like in air filtration we have discussed surface filter like cake filtration, similar thing happens here. Initially what happened with this pore the smaller soil particle will come out after putting geotextile for few days you can see the soil particles of smaller size will keep coming. This is called piping, leaving the particles with larger diameter. Larger diameter particles are here and these are forming porous structure.

So, after that, after formation of this cake like a porous structure of particle then this will be porous structure and geotextile will act along with this porous structure and it will act as filter as well as it will allow the water to flow through. This total structure will be developed with the time. For filtration properties the largest application of textiles because filtration is the property which among the geosynthetics family geotextile can offer.

It includes their use of in the lining, of ditches, beneath the road, in waste disposal facility for base building basement drainage and many other applications. The filtration effect is achieved by placing the textile against the soil in close contact, thus maintaining the physical integrity of the bare soil surface from the water. So, this is the water here bare soil surface within first few millimeters of the soil and internal filter is built up.

This is the soil internal filter is built up with the time as I have already mentioned, and after a short period of piping initially piping will take place piping means the wastage the moving of the smaller particle through the geotextile and the structure stabilize and then after a certain time, this total porous structure this porous soil structure, the water flows without any loss of soil.

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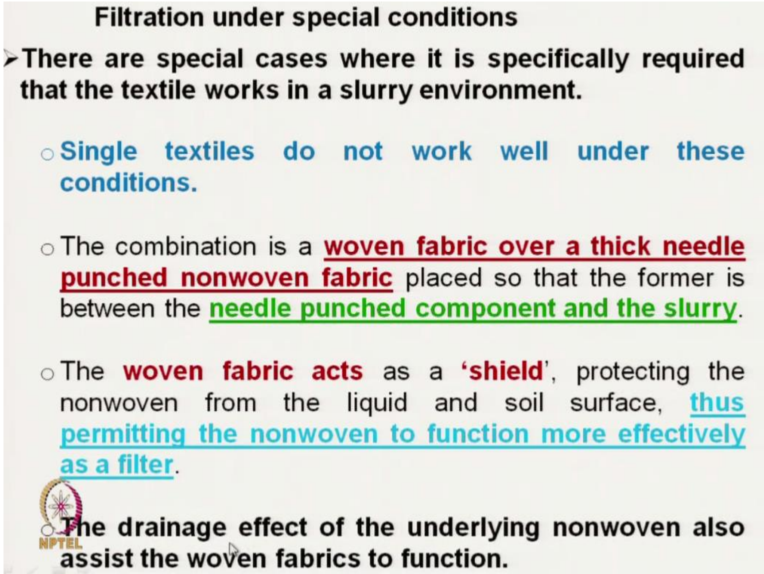

There are also some special cases for filtration or separation like slurry environment where single textile do not work under this condition. The combination of woven fabric over thick needle punched nonwoven is important because here needle punched others needle punched nonwoven will get clogged quickly. So, this woven fabric is placed over the needle punched component. So, this woven fabric is acting as a barrier between slurry and nonwoven needle punched fabric. In doing so, the drainage effect of underlying nonwoven is maintained.

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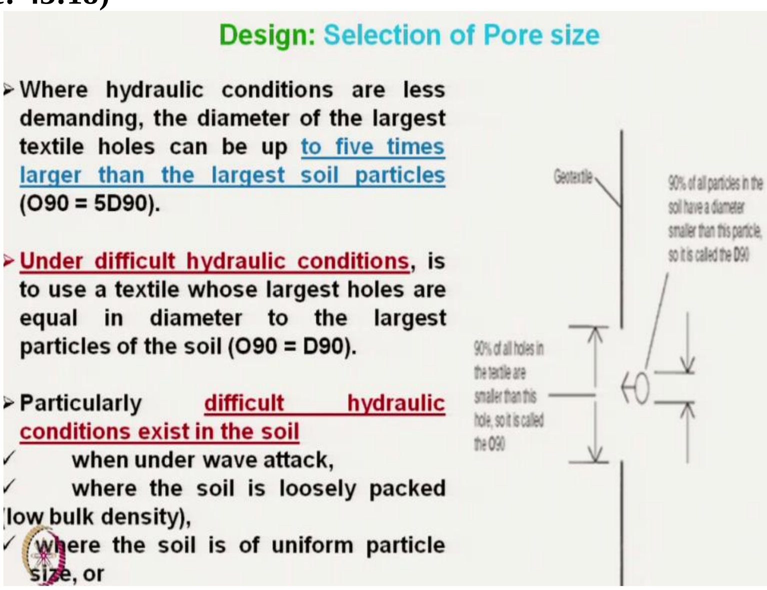

Another design criteria is that the selection of pore size. If we know the size of the soil then we have to select the pore size of geotextile. It is not that the pore size will be exactly the same as the soil particle size because it is not possible. So, the basic design criteria is that when the hydraulic conditions are less demanding that is streamline flow with lower motion, ok lower velocity the diameter of the largest textile holes.

Which is expressed in terms of O90 that means, O90 means, the 90% of the pores are of diameter less than this. Say O90 of say 1 millimeter means 90% of the pores are of 1 millimeter or less in diameter. Similarly, D90 means 90% of the particles are of diameter that D90 or less. So, at lower hydraulic condition the relationship between O90 and D90 is that we require very large diameter of pores.

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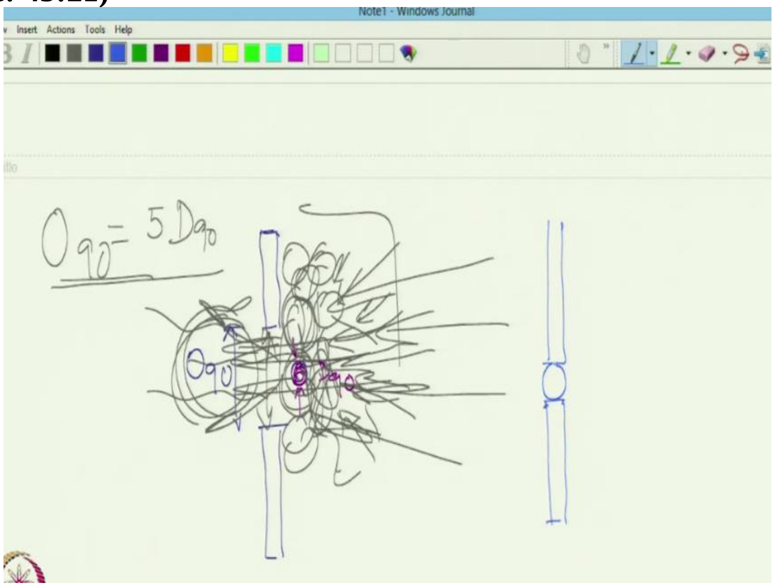

This is O90 and we have a particle of diameter this is D90. So, D90 means 90% of particles are of diameter less than this. So, as per the relationship here, O90 = 5 times of D90 that means this is 5 time more than this, the system here is that most of the particles we are allowing to pass through the hole, but gradually the larger particle larger than D90 will be will form certain structure. Here advantage that the hydraulic condition is not harsh that means, the liquid flow will be slower with lower pressure at as it is coming with a lower pressure.

In that case, we need to allow the water to flow easily. If we reduce the size then as the liquid pressure is less water pressure is less, so, it will start clogging the water logging will start. So, that is why for this type of application, we need higher pore size. But let us consider case suddenly the hydraulic condition has become harsh, this water is flowing at a very high condition there is a high wave condition, so, that they will give the structure this may create the structure the collapse.

So, in that case if we maintain this condition O90 = 5 times of D90, then there will be problem then what will happen this total all this soil particles will be washed out. So for harsh condition we have to select the lower pore size, that means O90 is approximately equal to D90 for harsh condition, where there is a wave and under difficult hydraulic condition it is used that O90 = D90. What are this conditions?

When there is under water wave, where the soil is loosely packed that means soil can individual soil can come out, but the soil is of uniform particle size so uniform particle size always create the less cohesion where the hydraulic gradient is high higher hydraulic pressure is there. So, as far as chemical resistance is concerned.

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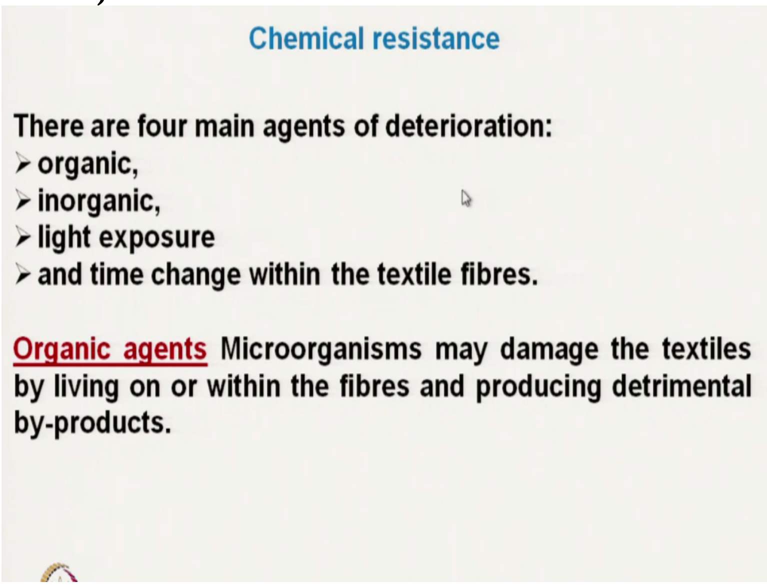

There are 4 main agents of deterioration organic inorganic light exposure and time with the time. The organic agents the microorganisms may damage the textile by living on or within the fibre.

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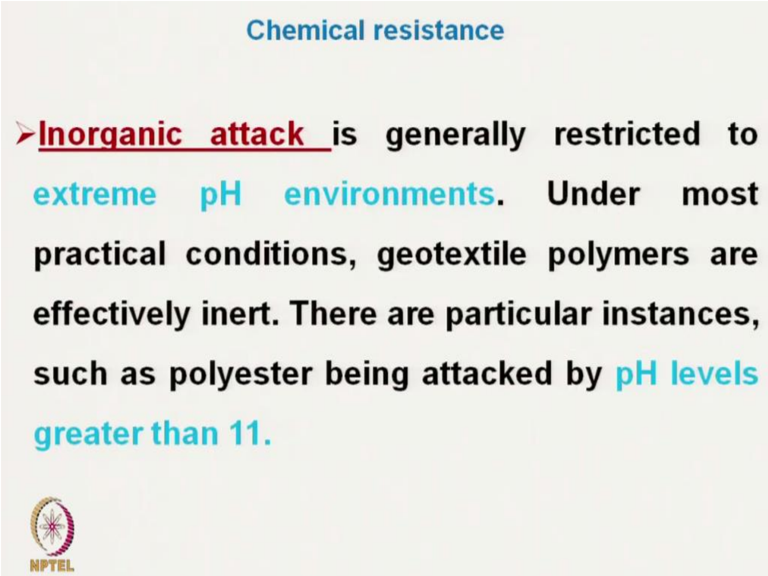

Inorganic attack is generally restricted to extreme pH environment. We may select the fibre accordingly so, polyester may attacked by the inorganic chemical of pH more than 11.

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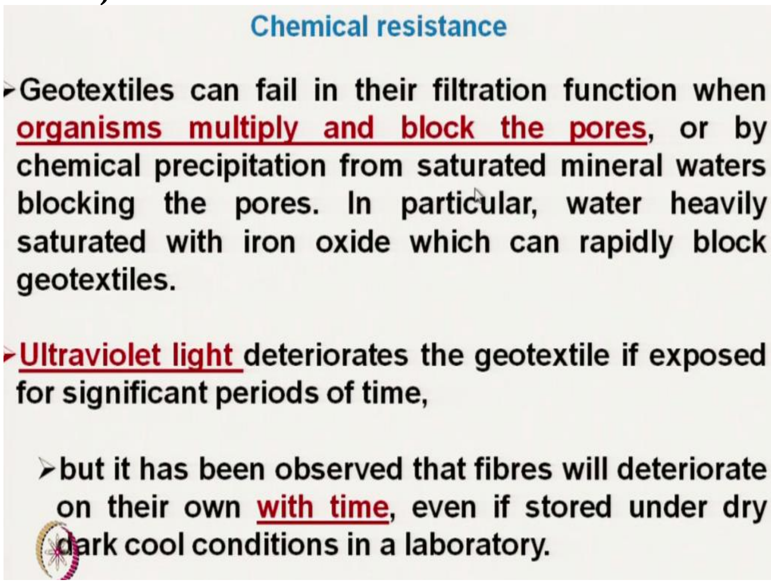

And some time the organisms may block the pores. So once they enter into the geotextile and they multiply and block the pores and ultimately they are reducing the filtration or drainage performance and also the saturation. Once the water is saturated with the iron oxide they may deposit inside the structure and block geotextiles. UV ray also deteriorates, so we should be careful when we use geotextile in exposed condition and it has also been observed even if we store geotextile in dark, cool condition it may sometime deteriorate and it is with the time.

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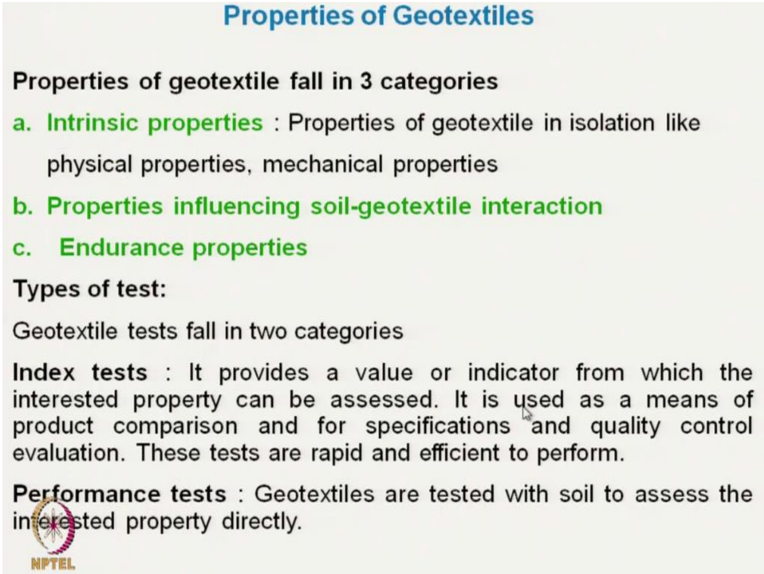

Next section we will discuss the properties of geotextiles and that we will discuss in next class. Till then thank you.