Textile Product Design and Development
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Lecture – 08
Significance of Fibre Properties

We will discuss the significance of fibre properties for product development or product design. What is the role of the properties of the fibre in relation to the development of a product? Knowing what sort of fibre can be chosen to develop a particular product is important. Hence, understanding the fibre properties and their possible influence on the property of the final product is essential.

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The fibre properties are broadly classified as dimensional or surface geometrical properties, mechanical properties, absorption properties, electrical properties, thermal properties and chemical properties. What are these properties? How do the properties differ for different types of fibres, and what could be the role? What are the properties that fall under each category, such as the dimensional or surface-related properties of a fibre? So, it is important to know how the properties differ for different fibre types.

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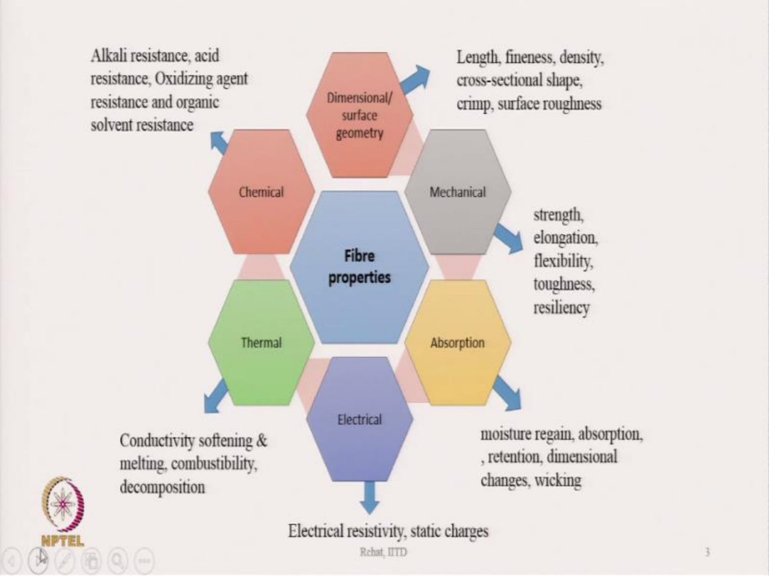

What are the properties that come under the dimensional or surface-related properties of a fibre? These are length, fineness, density, cross-sectional shape, crimp, and surface roughness, which are related to the dimensions of the fibre. The frictional properties of fibre could also be included, which is another surface property. Though it is not related to their dimensional properties, it is related to the surface phenomena. The other properties related to mechanical properties of fibre are related to strength, elongation, flexibility, toughness, and resiliency. Absorption property refers to properties related to moisture regain or moisture content, water absorption within the fibre, then retention of water by a fibre, wicking phenomena, and dimensional changes like swelling. In some cases, the fibres may swell, especially in diameter; hence, swelling is important in many stages.

The electrical properties of the fibre are electrical resistivity and static charge generation. Thermal properties could be classified as conductivity, softening and melting, combustibility, decomposition, or behaviour under sun rays. Chemical properties are resistance to alkali, acid and oxidising agents, and organic solvents. These properties must be understood when selecting the fibres for performing properties for a given product.

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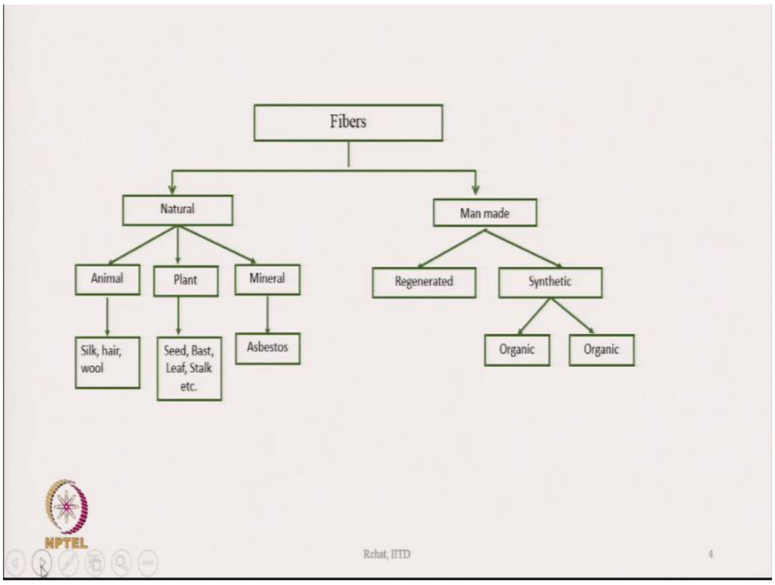

The fibres are broadly classified into two types: natural and man-made. Natural fibres are further classified according to their origins, such as animal, plant, and mineral sources. These fibres are the products of nature. Another group of man-made fibres has two categories: regenerated and synthetic. Synthetic fibres have two varieties: organic fibres and inorganic fibres. Among many raw materials available to us, we must decide which fibre we should choose for a given application. The natural fibres and their properties are fixed. We do not have much control over their property; whatever nature produces, we must accept it because we cannot engineer the properties in natural fibres.

Meanwhile, with man-made fibres, there is some scope for us to engineer the property. So, that is the advantage we have in the case of synthetic fibres: that properties can be engineered to some extent, whereas for natural fibres, we have no control over whatever nature produces, and whatever properties are there, we must accept it. We must make a very clever choice in terms of choosing a fibre for a particular type of application.

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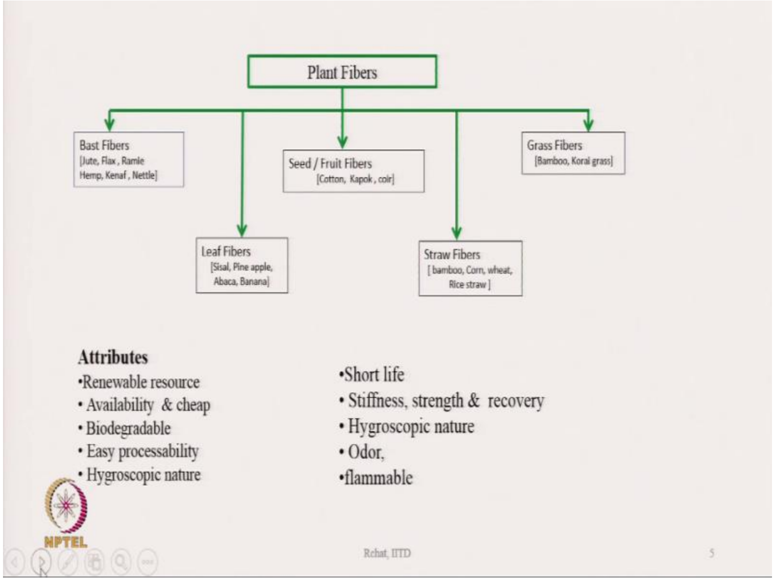

The plant fibre varieties are further classified based on bast, leaf, seed, straw, and grass. The main advantage of natural fibre is that it is obtained from renewable resources. It is also available and less costly. The other biggest advantage is that they are biodegradable, and processability is also considerably easier. They are hygroscopic in nature, which means they have the capability to absorb moisture. Besides these advantages, they possess certain disadvantages as well.

The fibre properties, namely stiffness, strength, and recovery properties, are comparatively lower than those of synthetic fibres. Not all the natural fibres are very stiff. Exceptional cases are cotton, wool, and silk, which are not stiff. However, bast fibres such as hemp, kenaf, and flax are very stiff and are high-modulus fibres in the natural fibre variety. As they are of natural origin, they have some odour and are generally flammable. These are the certain limitations of natural origin fibres.

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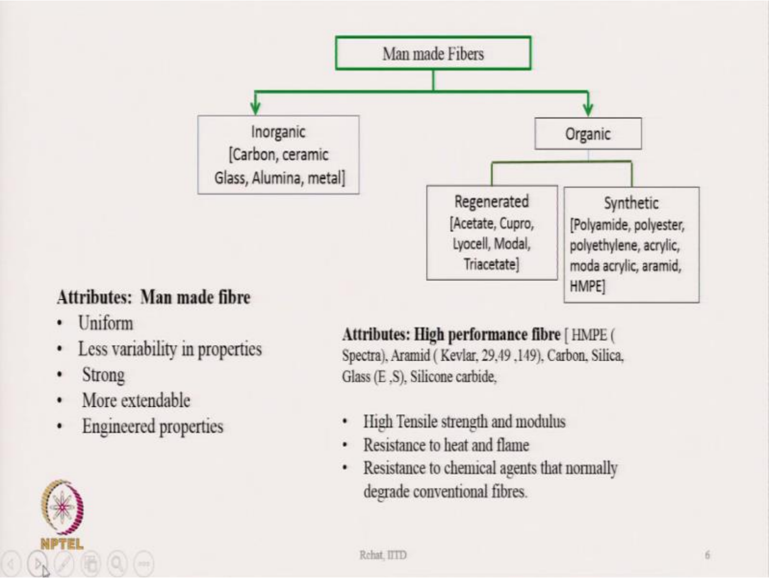

Under the man-made fibres category, the fibres are classified as organic and inorganic fibres origin. Carbon, ceramic, glass, alumina, and metals come under the category of inorganic fibres. Fibres regenerated from wood pulp, or acetate, cupro, lyocell, modal, and triacetate, are some examples of regenerated organic fibres. Synthetic polymer fibres are polyamide, polyester, polyethylene, acrylic, modacrylic, aramid, and HMPE. All synthetic fibres are produced under very controlled conditions; therefore, their diameter and properties are generally more uniform. So, their properties have less variability.

Synthetic fibres are stronger than natural fibres, and some synthetic fibres are also highly extendable. The properties of synthetic fibres can be engineered based on the requirement. High-performance fibres are engineered for specific applications. These fibres are not suitable for apparel but are suitable for high temperatures or high-stress environments. For example, high-modulus polyethylene (spectra), aramid fibres, carbon fibre, silica, glass, silicon carbon carbide. These fibres are engineered for high tensile strength and modulus and are suitable for high-stress applications. So, these fibres are also used in composite applications as they are resistant to heat and flame and to chemicals which normally degrade conventional fibres.

So, these are the attributes of the man-made fibres. Conventional manmade fibres are suitable for clothing products, whereas high-performance fibres are not suitable for clothing at all, but they are suitable for other applications. As stated, products made from high-performance fibres must face very high temperatures or high-stress applications.

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The other variety of synthetic fibres is speciality fibres. These fibres have selected performance properties such as dyeability, adhesion, absorbency, conductivity, flame retardancy, response to external stimuli, or special surface characteristics. The group of fibres can be engineered to special properties, so they are known as speciality fibres. So, they can absorb much more liquid because of some modification that we carry out on these fibres, or we can have conductive polymers or fibres that can conduct electricity, or we can also modify fibres to make them flame retardant. These fibre properties are either obtained by using additives such as colourants, flame retardants, conducting fillers, antistatic compounds, etc., during the spinning process or by modifying the surface using chemical finishes for specific properties such as hydrophilicity, high absorbency, low friction, plasma treatment, etc.,

The surface property of the fibres can be changed or modified by the special spinning process to produce different cross-sectional types, such as bicomponent fibres, microfibres, and nanofibres. As stated, the three different methods used to produce speciality fibres are either by using additives, modifying the fibre surface, or through a special spinning process. We can change many properties of the fibre through these methods. So, as designers, we must be aware of the type of material available to us to create a much better product.

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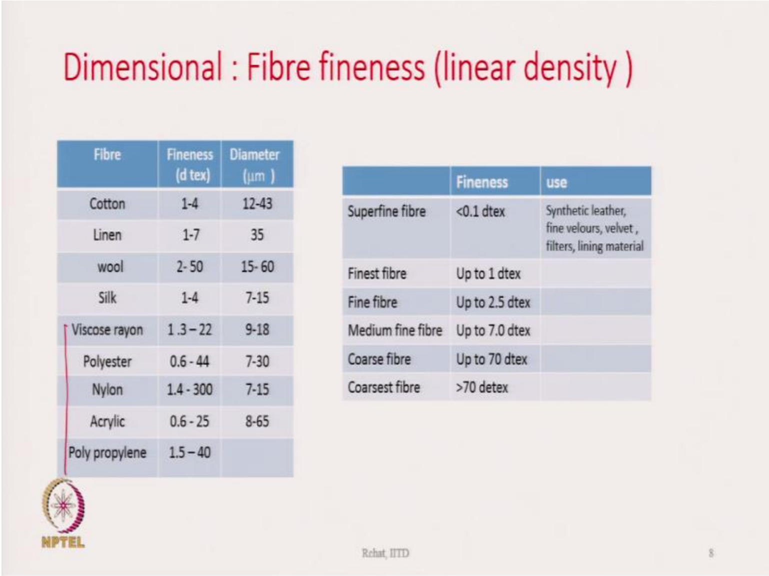

The next discussion could be about the various attributes of the fibres and their possible role or significance. The first parameter is fibre fineness or linear density of the fibre. The fibre fineness values of some fibres are listed in the table on the slide for cotton, linen, wool, silk, viscose rayon, polyester, nylon, acrylic, and polypropylene. The corresponding diameter in microns of all the fibres is also given. On the right-hand side table, fibres are classified into superfine fibres, finest fibre, fine fibre, medium fine fibre, coarse fibre, and coarsest fibre based on their fineness values.

Among this, the proper fineness must be chosen for the product intended to be designed. The fineness of natural fibre is limited as it is obtained from nature because whatever nature produces, we must accept it. For example, the fineness of cotton ranges between 1 to 4 decitex, linen ranges between 1 to 7 decitex, and wool ranges between 2 to 50 decitex. In the case of synthetic fibres, fineness can be produced based on our requirements as the process is under our control. So, in summary, we can produce a specific fineness for our requirement with manmade fibres, but that sort of control is not there for natural fibres.

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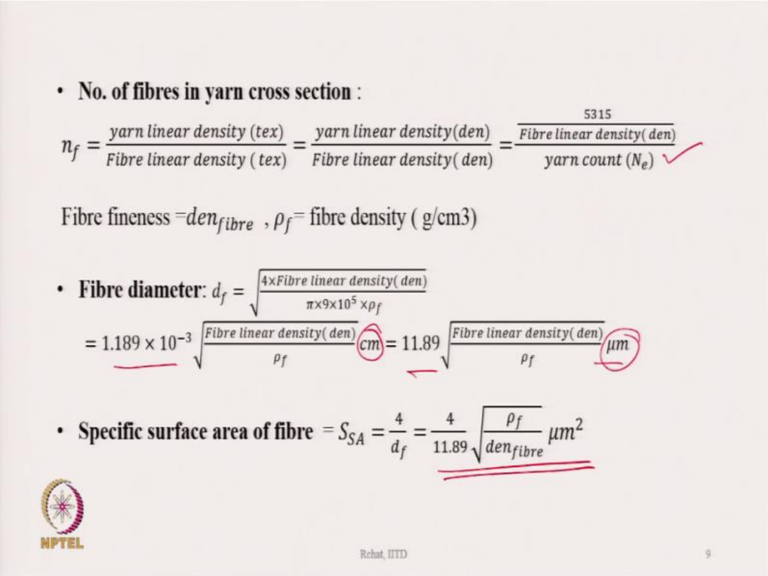

Next, we must understand the role of fibre fineness on certain properties. There are certain formulas stated in the slide that could help the designer to make specific calculations. If we want to calculate the number of fibres in the cross-section, a formula is given to determine the same on the slide. A formula is also given on the slide for calculating the fibre diameter from the fibre fineness value. The formulas are provided to calculate the fibre diameter in centimetre units as well as micrometre units, and we can find out that if we change the fineness in terms of denier, what could be the diameter of the fibre. The formula for the specific surface area of the fibre is also stated. These formulas help identify specific parameters needed while designing a product.

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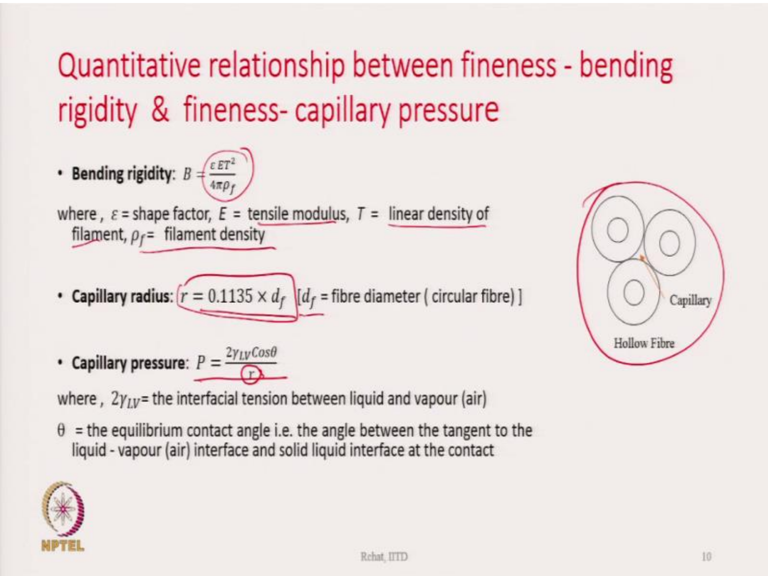

The quantitative relationship between fineness-bending rigidity and fineness-capillary pressure is stated on the slide. One of the significant fibre properties affected by fineness is bending rigidity. Bending rigidity 'B' is a function of shape factor (ε), tensile modulus (E), Filament or fibre linear density (T) and filament or fibre density (ρ_f). The fibre linear density 'T' is represented in the square term, meaning that the bending rigidity increases disproportionately with an increase in the linear density of the fibre. For example, if the fibre with a linear density of 2 denier is increased to 4 denier, bending increases by 4^2 times, i.e., 16 times. There is a massive increase in bending rigidity as linear density increases. So, a slight change in linear density makes the fibre flexible, which increases the flexibility of yarn, fabric and garment. So, in this way, the flexibility or bending rigidity of the fibre is connected to its fineness.

The other important thing, which is essential in some cases, is the capillary radius. We all know that in some situations, the product is going to absorb liquid, maybe it is going to absorb sweat if it is a wearable material or product, or it can also absorb liquid for some other technical applications; when we have swab, or we have some other product if we want to absorb some liquid, like baby diaper and incontinence pads. So, their capillary radius is important for absorbing the liquid. The capillary radius depends on the diameter of the fibre. The formula for capillary radius is '$r = 0.1135 \times d_f$', where 'd_f' is the diameter of the fibre, which in turn is related to the linear density of the fibre.

The capillary pressure is defined by the Laplace equation, '$P = \frac{2\gamma_{LV} \cos\theta}{r}$'. From this equation, the increase in capillary radius 'r' which is in the denominator, reduces the capillary pressure 'P'. From this formula, we also try to understand the relevance of fibre fineness and the significance of fineness in terms of affecting the absorption properties. In the yarn structure, the capillary channels are formed when the circular fibres touch each other, i.e., through the close packing of fibres. In this case, the capillary radius is related to the fibre diameter by '$r = 0.1135 \times d_f$', as stated earlier. However, this is not valid for nonwovens. In the case of non-wovens, the capillary channel radius formed is much larger than the above-stated equation, as the fibres are arranged in random order.

However, in actual cases, if the fibres are not touching each other, the value of 'r' is much larger than what we expect as per the given equation. In the equation of capillary pressure, 'r' is in the denominator, which indicates that if 'r' increases, capillary pressure reduces and viceversa. In summary, the liquid transport through fibrous materials depends upon the capillary pressure generated in the structure, which in turn depends on the capillary radius formed by the fibres. The capillary radius formed by the fibres depends upon their fineness. Additionally, fibre packing also decides the capillary pressure generation. So, fibre fineness and fibre packing arrangement decide the liquid transport through the fibrous assembly.

Therefore, fibre fineness affects the capillary radius formed within the structure as well as the bending rigidity of the fibre. So, fibre fineness has its own effect on product performance depending on the type of product that we are designing.

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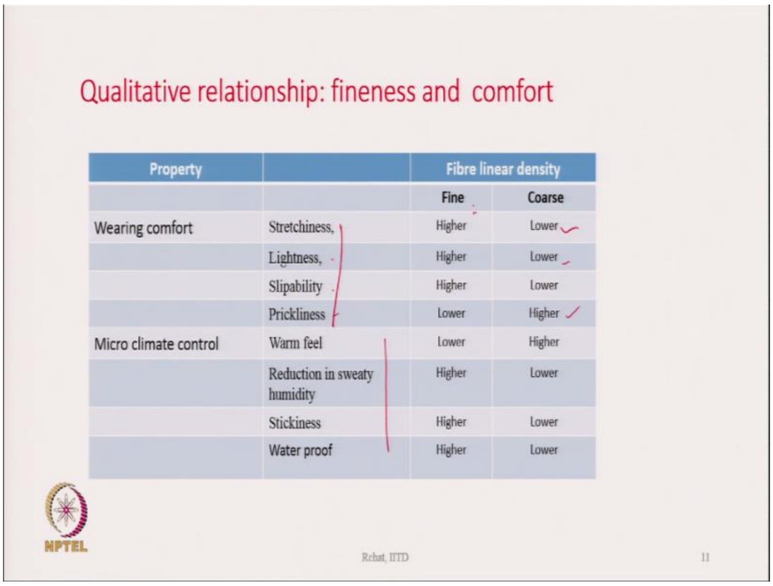

Fibre linear density significantly influences properties such as wearing comfort and microclimate control. Wearing comfort depends on stretchiness, lightness, slipability, prickliness, etc., which gives comfort to the wearer. The microclimate control depends on a warm feeling, reduction in sweaty humidity, stickiness, and waterproofness. If coarser fibre is used instead of finer fibre, stretchiness, lightness, and slipability get reduced, and prickliness increases, i.e., prickliness increases for an increase in fibre diameter, i.e., prickle sensation increases as the fibre diameter is large. So, the properties of the product or the fabric are on the left-hand side, and the effect of the fineness of the fibre is represented in the table on the right-hand side of the slide.

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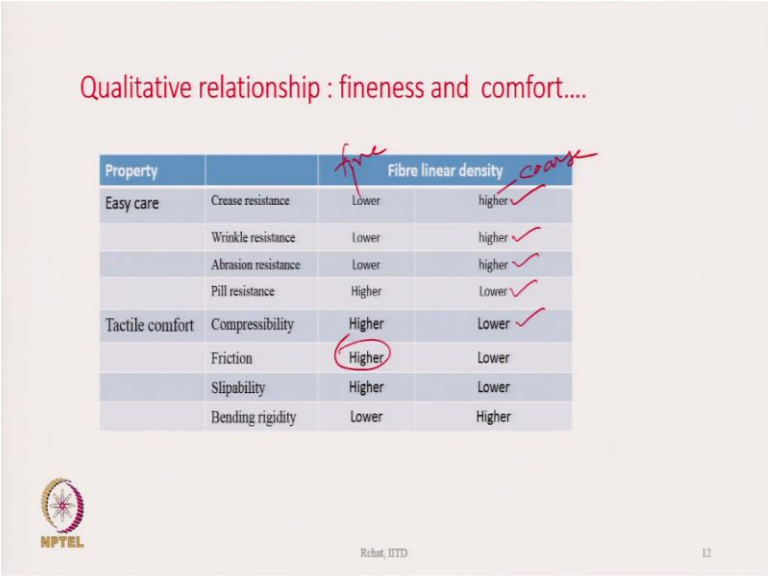

Fibre linear density plays a role in easy-care properties and tactile comfort. Whenever the fabric or the product gets creased, we need to remove the crease from the product by certain methods. So, in such cases, anti-crease treatments are given to the products. Fibre linear density affects the crease resistance of the products. Whenever the fabric or the product gets creased, ironing is required to remove these creases. To avoid this, if the coarser fibres are used, crease, wrinkle, and abrasion resistance will be higher, but pill resistance will be reduced. The other important property could be tactile comfort. It is the sensation that we get when we touch a fabric or when we wear a fabric. If coarser fibre is used, compressibility will be lower because coarser fibre has high bending rigidity. So, it gives quite a harsh and stiff feel as softness is reduced. Hence, the compression property is reduced, and more force is required to compress it. So, the compressibility of fabric reduces.

Friction property is also affected by the fineness of the fibre. If finer fibres are used, friction increases because it increases the surface area of contact. Since the specific surface area of the fibre is a function of its fineness, fabric friction increases. In some products, coarseness of the fibre is required, but in some cases, fibre coarseness may be detrimental. So, the choice of fibre depends on the nature of the product design. For example, for clothing material for babies, very fine fibres are chosen to incorporate softness into the fabric. Also, one can consider fibre, which is skin-friendly, like fine cotton, viscose rayon or polynosic fibres, which are also soft and fine.

We can also think of mixing it with polyester fibre. However, we must think of fibres which are intrinsically soft, and then we can play with the fineness of the fibre. If we choose finer fibres, the product will be very soft, as the yarn made from the finer fibre will be soft. So, once we choose the fibre, we choose the fineness of the fibre. Then, we should consider whether we should go for some twisting in the yarn. How much twist should be inserted if we need to provide the twist to the yarn? The twist also influences the softness of the products. Low-twisted yarns are used to produce softer products. The next consideration is the type of fabric that should be made. So, what is the role of fabric construction on softness? Should we go for a woven material, or should we go for a knitted material that is soft?

So, when a particular product attribute needs to be incorporated into it, there are so many options available to us. We must always keep in mind that the option always starts with the raw material, and then, for each stage of production, certain parameters may also have a role. Like, the yarn may have a role, the fabric construction also has a role, and the type of fabric also may have a role. Finally, finishing techniques may also play a role. So, at every stage of product preparation, there is a possibility of influencing the final attributes of the products that we want to impart.

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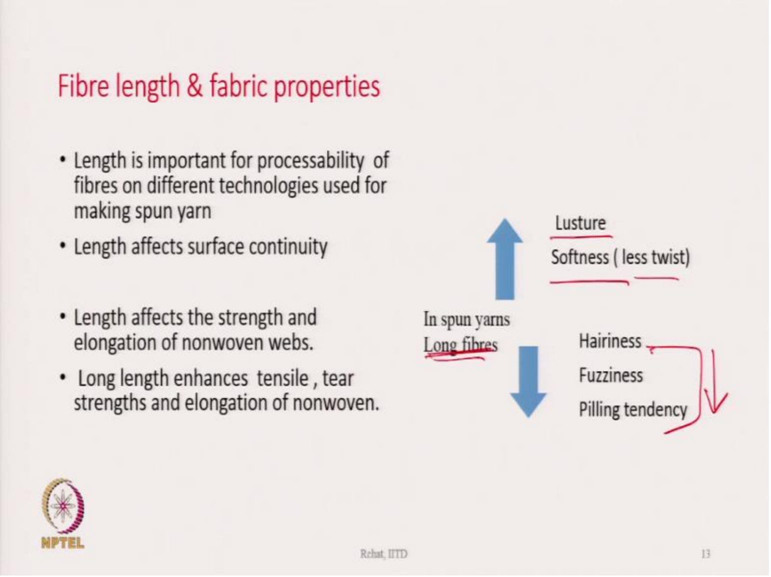

The next discussion is about the importance of fibre length and its role in product design. What is the role of length in the product design? The fibre length properties are significant from the processability perspective in the machines, especially yarn manufacturing machines. Very short fibres are difficult to process in certain technologies. The other thing is the surface continuity. The longer the fibres, the more the surface continuity. For example, when comparing one inch length fibre, the two inch length fibre has more surface continuity. If filament yarn is used, the surface is completely continuous, as the filaments have no break.

The fibre length can also affect the strength and elongation properties of nonwoven products. In nonwoven production, yarns are not used, and there is no concept of twisting to impart strength. So, which parameter affects the strength and elongation of the nonwoven products? There, the role of length of the fibre is very important. Generally, using long length fibres enhances the tensile and tear strength and elongation of nonwoven products. The other thing is that lustre and softness increase with spun yarns having long fibres. How does softness improve? The softness improves because using long fibres requires fewer twists.

So, when the twist is less, the yarn packing is less; therefore, the yarn has a soft feel, resulting in a softer fabric feel. Lustre is another thing that also improves with long fibres because hairiness reduces, as presented in the slide. So, in the case of cotton fibres, these three properties are reduced, i.e., hairiness, fuzziness, and pilling tendency, as it is longer and finer. The shorter fibres are always coarser. In synthetic fibres, length can be controlled during production. These are the effects of fibre length on product quality.

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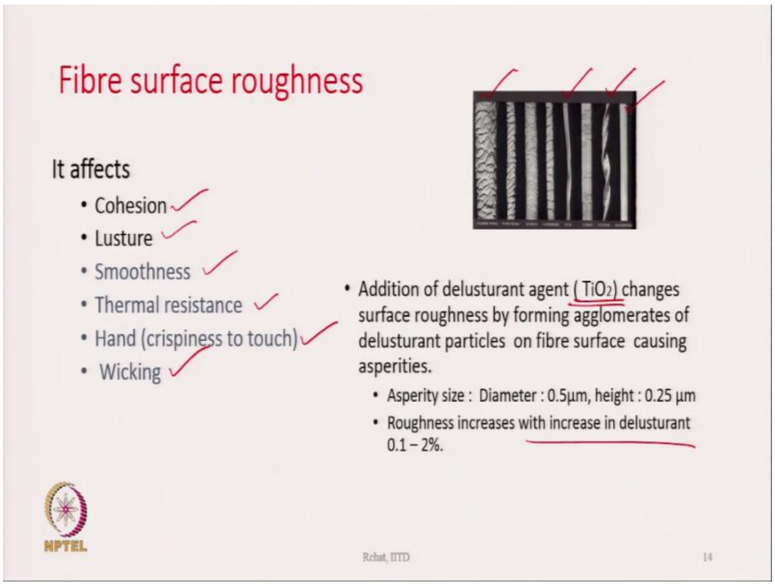

The other aspect is the surface roughness of fibre. SEM images of a longitudinal view of some fibres are displayed on the slide. The types of fibres shown are cotton, silk, wool, polyester, cashmere and alpaca. Among all the fibres, polyester is smooth like a glass rod. Cotton fibre does not have a round cross-section. While observing the cross-section under the microscope, cotton fibres have a kidney bean type of cross-section and twisted configurations along their length. The single fibres of cotton follow a kind of helical configuration. Wool fibre has a lot of scales on its surface, which makes a rough surface. Because different fibres have different surfaces, the surface properties of yarn and fabric are also affected.

What fabric properties are affected by the surface roughness of the fibre? Surface roughness of the fibre affects cohesion between fibres, lustre of the yarn or fabrics, smoothness of the fabric, thermal resistance, hand value and wicking. Sometimes, we intentionally roughen the surface of fibres like polyester, especially when the surface is too smooth and creates an excessive lustrous effect. Highly lustrous fabrics are often not preferred by many people, so to reduce the lustre, surface roughening is done. How do we impart the surface roughness to the smooth fibre surface?

The simplest way is to add TiO_2. If we add TiO_2, the surface of the polyester fibre turns rough, and therefore, the lustre value of the fabric is reduced to the required level. Besides, we all know that TiO_2 also helps enhance the life of a product exposed to the sun. TiO_2 is deliberately added with some fibres also to protect the products from UV rays of the sun. So, in that way, TiO_2 also helps the product to be UV protected. At the same time, it makes the surface a bit rough as stated earlier. So, if we want roughness but do not want a very slippery surface, and we want a surface which is not too lustrous, then we add TiO_2, i.e., titanium dioxide.

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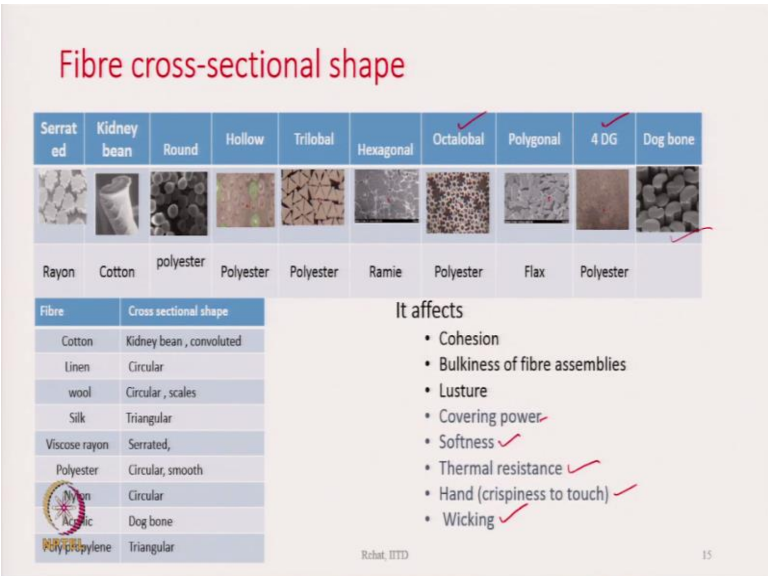

The various types of cross-sectional shapes of the fibre are presented on the slide. Viscose rayon fibres have serrated cross-sections, kidney bean shaped for cotton, round, hollow, trilobal, hexagonal, octalobal, polygonal, 4 DG, and dog bone types shapes are also represented. Is the cross-sectional shape important or not? Yes, It is important; therefore, we discuss what properties can be affected by the cross-sectional shape. The cross-sectional shape of fibre significantly impacts various properties, and different fibre shapes are represented in the table.

One of the primary properties influenced by cross-sectional shape is cohesion. Bulkiness is another property affected by cross-section. The product must be bulky to enhance the insulation value or make it very soft. Bulkiness also affects other properties, like covering power, where a bulkier yarn provides better coverage in the fabric. In addition to bulk, the cross-sectional shape influences the lustre of the fibre. Other important properties affected by cross-sectional shape include softness, thermal resistance, hand (how the fabric feels), and wicking (the ability to transport moisture).

Some fibres have a higher wicking rate, such as 4 DG fibre and octagonal polyester fibre. These fibres are designed to enhance the wicking property of the yarns or the fabrics made out of them. So, the cross-sectional shape of the 4 DG and octalobal fibres are such that we have produced micro channels on the surface of the fibres. Microchannels at the surface cause fast liquid transport, which is one of the reasons why we have used certain types of cross-sectional shapes. Natural fibres also have different types of shapes, which are controlled by nature, but in the case of synthetic fibres, various types of shapes can be made or engineered depending on the need.

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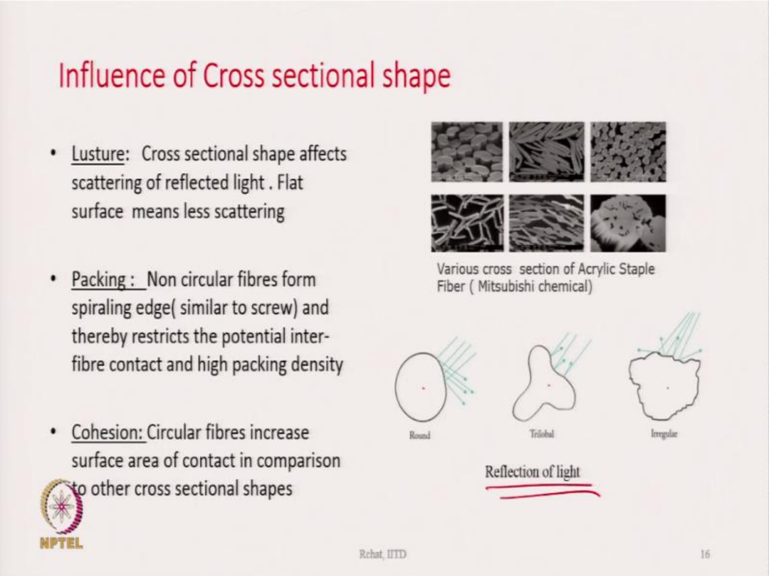

The properties affected by the cross-sectional shape of a material are numerous, and one of the key ones is luster. The luster of the material depends on the reflection of light, as shown on the slide. So, light reflection on three different cross-sections is compared on the slide and how the light rays reflect after falling on it. When light falls on the surface of the material and if it gets scattered, the luster decreases. Among the three different types of fibre cross-sections shown in the slide, irregularly shaped fibres scatter more light, resulting in low lustre. On the other hand, round-shaped fibres also scatter light but less than irregular shapes.

Trilobal fibres scatter less light, making them more reflective, which means that a flat surface reflects more light directly back to our eyes. So, it is the main reason that the trilobal shape fibre becomes more lustrous. Next, the packing density of fibres is vital in deciding the luster of the product. Non-circular fibres form spiral edges like screws and thereby restrict the potential inter-fibre contact and result in lower packing density. In contrast, circular fibres pack much more efficiently. When pressure is applied to a bundle of circular fibres, they fit together more closely, leading to higher overall packing density.

Circular cross-section fibres encourage packing, so they are preferred for producing fine and thinner yarn. On the other hand, non-circular fibres discourage packing. If yarn with higher porosity is needed, then predominantly non-circular fibres are chosen. Circular fibres enhance cohesion by increasing the surface area in contact with neighbouring fibres in comparison to noncircular fibres. In contrast, non-circular fibres have less surface area contact, which reduces cohesion and makes the fibres less likely to bond strongly.

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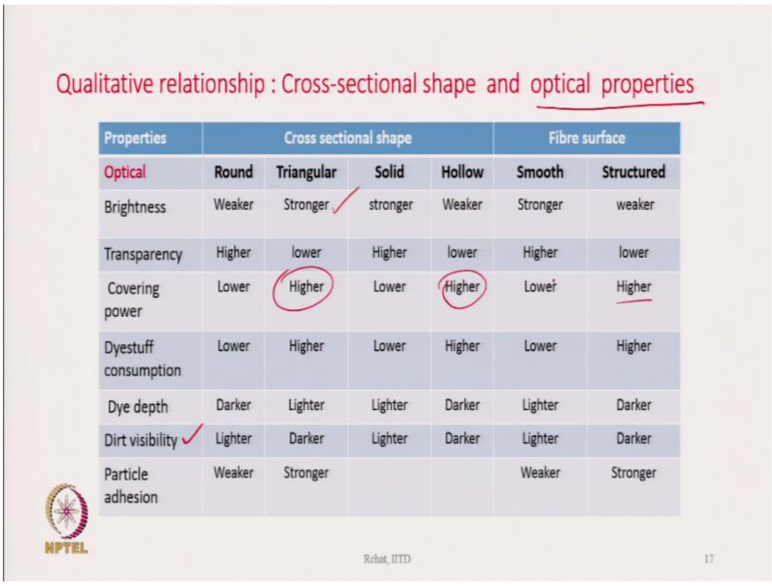

The table illustrates how different cross-sectional shapes of fibres influence various optical properties in a qualitative manner. Further, the table also illustrates the effect of surface characteristics of fibres on their optical properties. The optical properties include brightness, transparency, covering power, dyestuff consumption, dye depth, dirt visibility and particle adhesion. Dirt visibility is very important for carpets. So, particle adhesion depends upon the product type and specific attributes we need; the fibre is chosen depending on the product type and the specific attributes we need.

For example, brightness is weaker with round-shaped fibres but stronger with triangular fibres, and covering power is higher with hollow and triangular fibres. Hollow fibres mean because of hollowness, the overall diameter of the fibres is higher. Hollow fibres are larger in diameter when the denier is the same as that of solid fibres because there is a hollowness at the centre. The properties and their effects are listed in the table. These tables help choose the right type of shape or the surface characteristics of the fibre.

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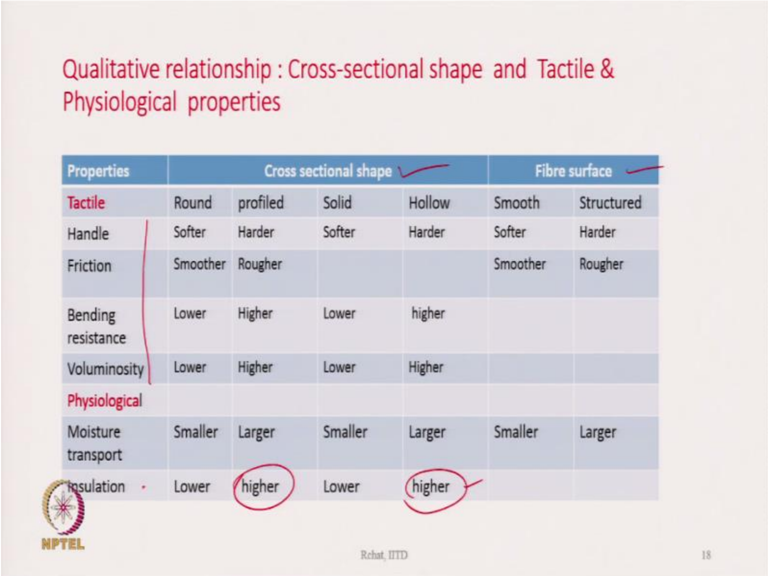

Similarly, the influence of fibre cross-sectional shape on the tactile and physiological properties of the products is listed on the slide. The tactile properties include handle, friction, bending resistance and voluminosity. The physiological properties include moisture transport and insulation characteristics. Insulation properties are higher with hollow fibres. Why? because the hollow fibres have air-filled void space at their centre. As stated, the void space at the centre entraps more air within the structure.

It is well-known that air is a very good insulator, so the insulation of products made from hollow fibres is higher than that of solid ones. All profiled fibres give higher insulation because they are not packed in a compact manner, and therefore, there are a lot of voids between the fibres in the structure. Hence, a lot of air will be trapped, so insulation will be needed. So, these are the different properties, and their effects are represented in the table.

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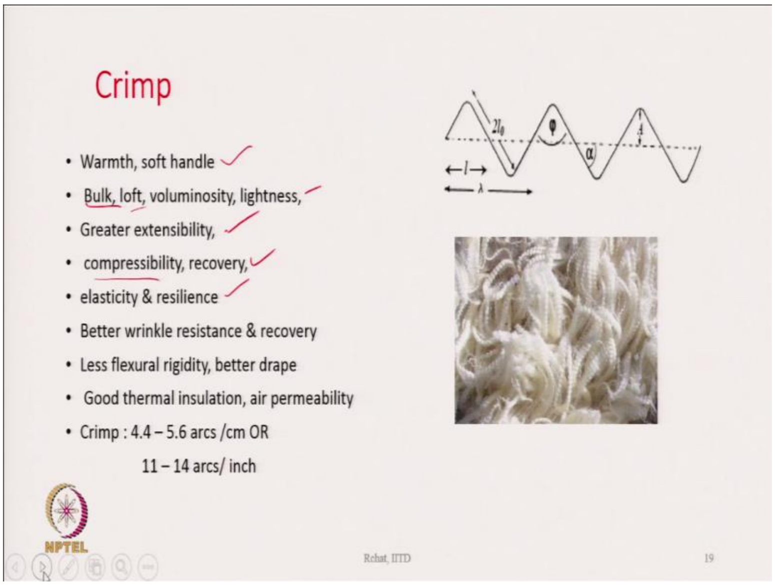

Next is the importance of crimp and its role in product design. Is there any role of fibre crimp in product design? Yes, crimp also has a certain role to play. Some natural fibres possess inherent crimp in their structure. An example is wool fibre; interestingly, it has a 3D crimp. Besides wool, cotton fibres also possess crimp inherently. So, crimpiness is important because it facilitates entanglement between the fibres, ultimately enhancing cohesion between them. Crimp is one of the desirable properties of fibre when processed on specific machines. Without a crimp, the fibres have no cohesion, and they are difficult to process in yarn manufacturing machines.

For example, the crimp helps the fibres to be integrated with the web in the carding machine and also helps in withstanding the tension draft applied to them in subsequent processing. Crimp is intentionally imparted to manmade fibre so that it can be processed easily on different machines, especially carding machines. The crimp imparts warmth and soft handle properties to the product. Crimps in fibres cause difficulty in packing, and therefore, more voids will be present. These voids increase the bulk and loft characteristics, contributing to the warmth and insulation of the product.

The crimp in the fibres keeps them away from each other, enhancing the extensibility of the fabric. Crimped fibres improve the compressibility and recovery of a fibre bundle, making the bulk more compressible and recoverable as well. This is especially important in products like carpets, where compressibility and recovery are the key performance indicators. In summary, the crimped configuration of fibres enhances elasticity and resilience, providing better wrinkle resistance, lower flexural rigidity, improved drape, and good thermal insulation to the products.

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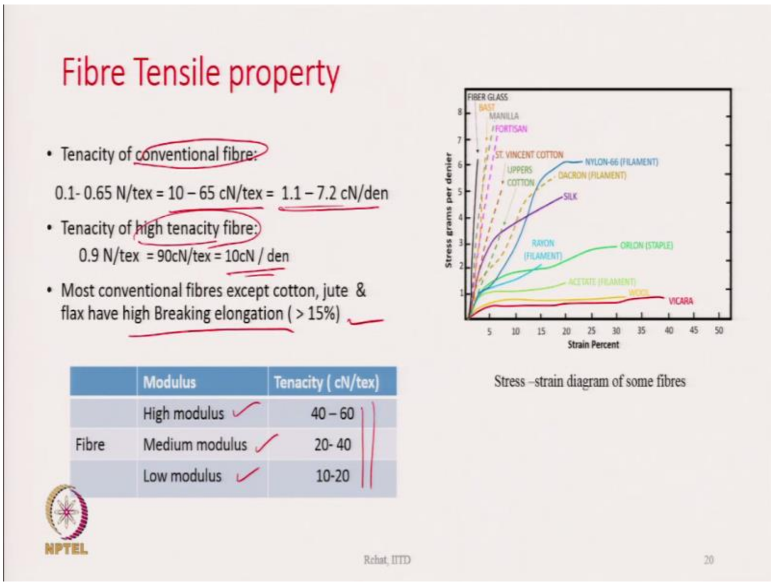

Fibre tensile property is an essential consideration in any product design. Typical stress-strain diagrams of some fibres are given on the right-hand side of the slide. The tenacity value shown here is expressed in terms of either cN/tex or cN/den. The tenacity of conventional fibres is in the range of 1.1 to 7.2 cN/den. The tenacity of high-tenacity fibres may be around 10 cN/den. Most conventional fibres except cotton, jute and flax have very high breaking elongations. Elongation of cotton is 7 to 8%, wool is 2% to 3% and flax is 2%. So, these fibres have less elongation or less extension, but other fibres natural fibres are more extensible, generally more than 15%.

The modulus of fibre is also very important. Fibres are also classified depending on modulus as low, medium and high modulus fibres. High modulus fibre has a tenacity of 40 to 60 cN/tex; medium modulus fibre has a tenacity range of 20 to 40 cN/tex; and low modulus fibre will have a tenacity range of 10 to 20 cN/tex. From the above discussion, it can be inferred that the modulus and tenacity are correlated. The higher the modulus, the higher the tenacity of the fibre.

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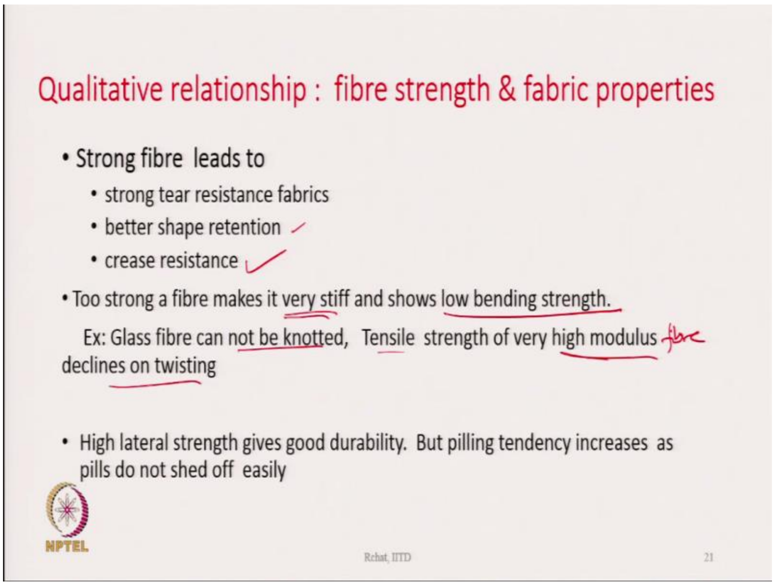

Quantitative relationship between fibre and fabric strength: strong fibre leads to strong tear resistance of the fabric. The fibre and fabric strengths are connected very straightforwardly, i.e., if we want to produce a strong fabric, we must choose a strong fibre. Shape retention property and fibre strength are also correlated well because as the fibres are strong, they do not extend easily, and hence, they have better shape retention. Stronger fibre shows better crease resistance. But if the fibre is too strong, it is very stiff and shows low bending strength.

When they are subjected to bending deformation, they may break easily. For example, glass fibre is very strong. However, it cannot be knotted. All fibres with extremely high modulus strength decline fast on twisting because the fibre follows a helical path. Twisting causes the fibre to follow a helical path, and the fibres will be twisted on their axis, which makes them weak. Generally, high-modulus fibres used in given applications are never twisted or given only a low number of twists.

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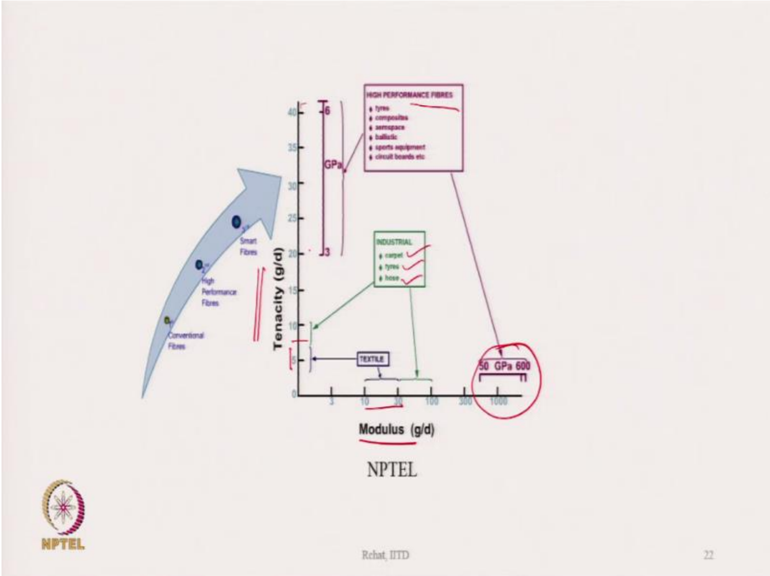

This diagram given on the slide illustrates the modulus and tenacity of the fibres with respect to their applications. Textile fibres intended for apparel use have a tenacity value close to 5 ± 2 g/den and a modulus of 10 to 30 g/den. Most of the textile fibres are utilized for apparel and consumer purposes only. Later, people developed fibres for specific industrial applications, like carpets, tyre cords or hoses, and their tenacity level increased to 7 to 10 g/den and modulus between 30 to 100 g/den.

Then, high-performance fibres came into the market with a tenacity range of 20 to above 40 g/den, and their modulus ranges between 50 to 600 GPa. So, high-performance fibres have very high modulus and high tenacity, whereas textile fibres for apparel use have a very low modulus and low tenacity.

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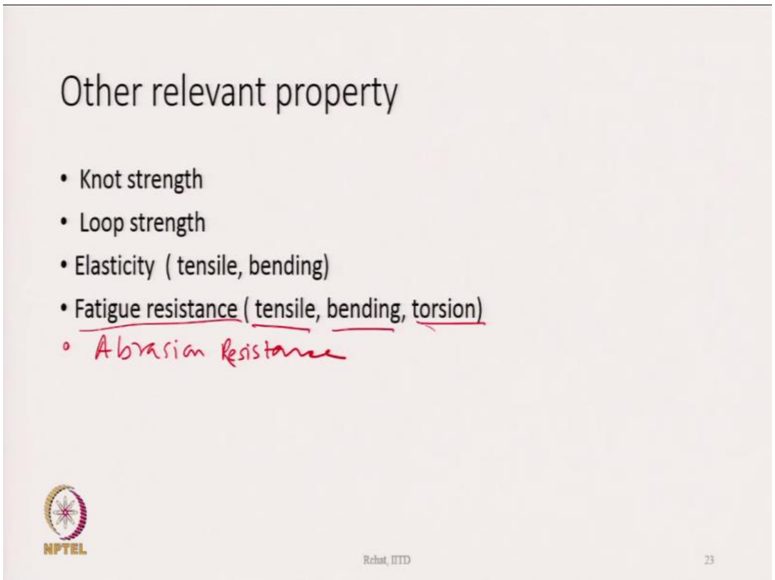

Other important properties of the fibres are the knot strength of the fibre, loop strength, and elasticity, i.e., during the application of tensile and bending stresses. How much is recovery property? How much has it recovered if we subject a fibre to tensile deformation? If I subject it to bending deformation, how much is recovery? These are very important from the application perspective. Similarly, fatigue resistance is also important when it is subjected to tensile, bending or torsional stresses.

For example, in a car tyre, the tyre cord is repeatedly subjected to tension, and tension goes high and becomes low in a cyclic manner. Also, depending on the continuous contact point of the tyre with the road, it is subjected to tensile fatigue. Another example of tensile fatigue could be hauling rope. Another important property that is not mentioned on the list is abrasion resistance. In some cases, the loop strength is very important; for example, in applications like sewing thread, the loop strength is vital as the yarn undergoes cyclic load. So, there are so many properties of the fibre that are also important, and we must have a creative data bank of the properties of the fibres and keep it ready to be used by a designer.

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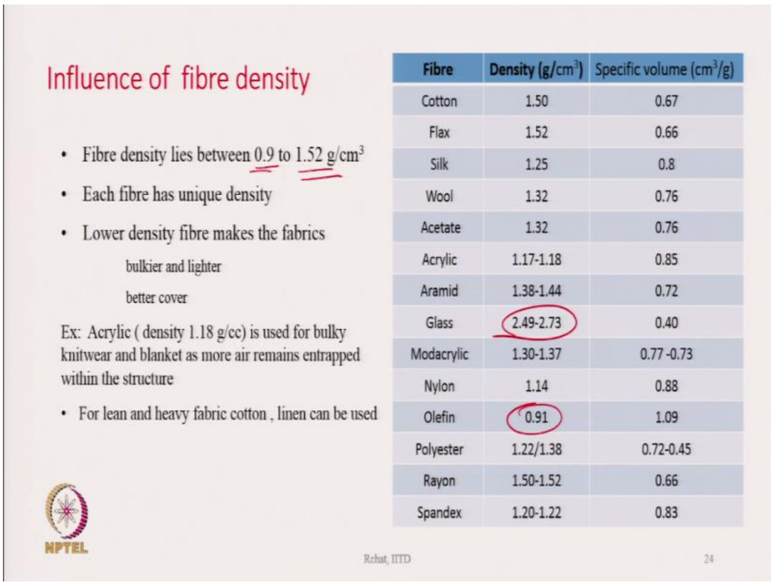

The next discussion is on the influence of fibre density on the product characteristics. The table shows the density value of different fibres. The fibres with the least density are olefin, polypropylene, and polyethylene. A density of less than one means they can float in water and will not sink. So, in some cases, if you want a product that has to float on water, this is the fibre for that, provided it satisfies other requirements. Some fibres have very high density. For example, glass fibre has a high density of 2.49 to 2.73 g/cm^3. Generally, most textile fibres will have a density ranging from 0.9 to 1.52.

The lower-density fibre makes the fabric bulkier and lighter, giving a better cover factor. For example, low-density fibres must be chosen to reduce the weight of the uniform for soldiers. Acrylic is used for bulky knitwear and blankets as more air remains trapped within the structure, and acrylic is also very light. So, the pullover looks bulky but is very light at the same time because it uses a low-density fibre. However, cotton or linen can be used for lean and heavy fabric.