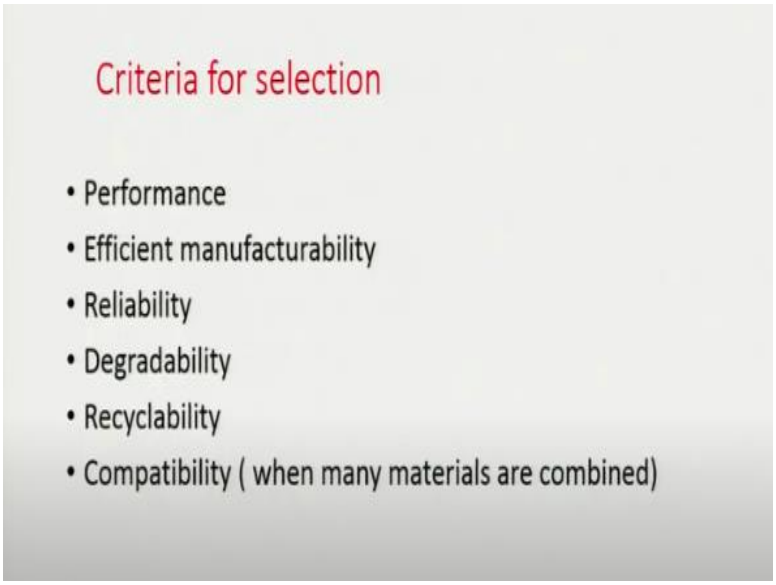
Textile Product Design and Development
Prof. R Chattopadhyay
Department of Textile and Fibre Engineering
Indian Institute of Technology - Delhi

Lecture - 06
Material Selection

So, we are going to discuss material selection for design activity.

(Refer Slide Time: 00:27)

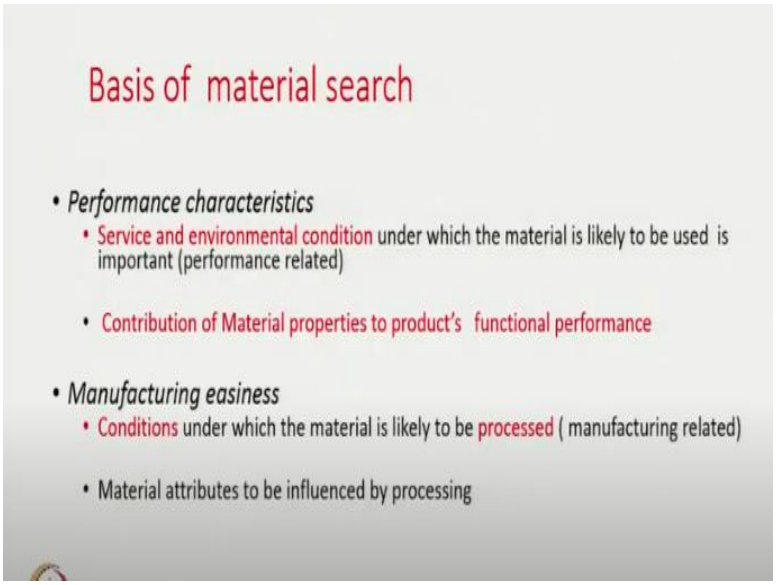


It is very important to select the right material for a given product. The criteria for material selection are listed in the slide. The first criterion is performance, i.e., the material must be able to meet the performance criteria decided for the needs of a product. The second criterion is the efficient manufacturability of the material, i.e., the material should be processed efficiently on the machines. It should not create too many problems during processing. In such cases, there could be a lot of waste generation of material, difficulty in managing the process, and a lot of defects. Therefore, the manufacturability of the material is also an important criterion.

The next criterion is reliability, i.e., performance reliability is also very important. There must be some reliability with respect to the level of performance we expect from that particular material. The next criterion is degradability. Because of today's environmental issues, the degradability of the material is also very important. The next criterion is recyclability, which is also related to environmental problems or issues. So,

recyclable materials are to be preferred. The last criterion is compatibility; sometimes, the material we prefer is not a single material but a composition of multiple materials. So, the materials must be compatible with each other. If the materials are not compatible, then there could be difficulty in their performance, difficulty in using them together, and manufacturing difficulties.

(Refer Slide Time: 04:02)

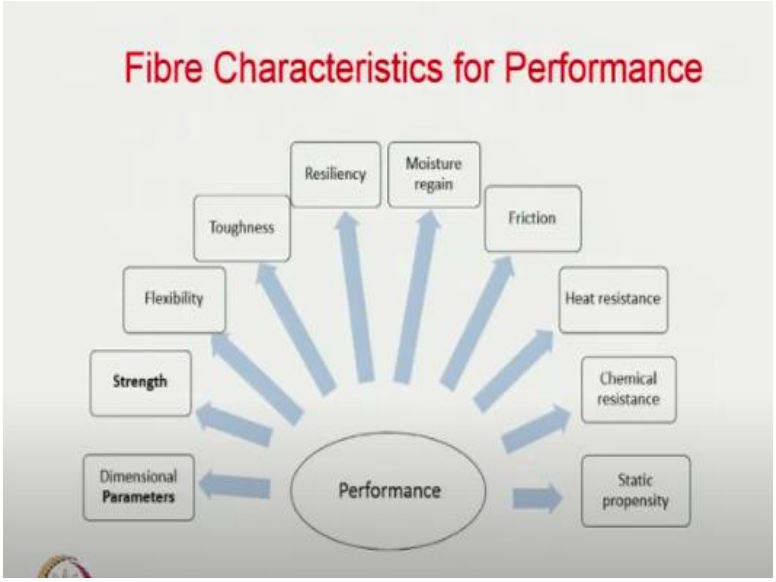


The basis of material search is discussed in this slide. The performance characteristics are the most important, and the performance of the material is also dependent on the service and environmental conditions under which the material is used. So, the service conditions and environmental conditions are known in advance for material selection. For example, the materials would be able to meet the requirements in such environmental conditions as sub-zero temperatures. The materials should not get brittle when the temperature goes below 0°C.

So, the products suitable at a temperature of 20°C, or 25°C, or 30 °C, may not be suitable when the temperature is below 0°C. So, the environmental conditions are different for various applications. The material properties observed in a laboratory situation may not be expected in environmental conditions as they may be completely different from the laboratory environments. So, environmental conditions are a very important consideration when selecting a material. The next consideration is the contribution of the material properties to the product's functional performance.

The properties of the material should be such that they meet the functional performance requirements of the product and make manufacturing easier. We must consider the condition under which the material is likely to be processed, the conditions to be maintained on the shop floor, and the technology needed to process these materials. The next consideration is material attributes that are also influenced by the processing. So, sometimes, the selected materials based on processing conditions may not be suitable from the point of view of processability. So, these aspects must be understood and studied before the selection of the material.

(Refer Slide Time: 07:20)



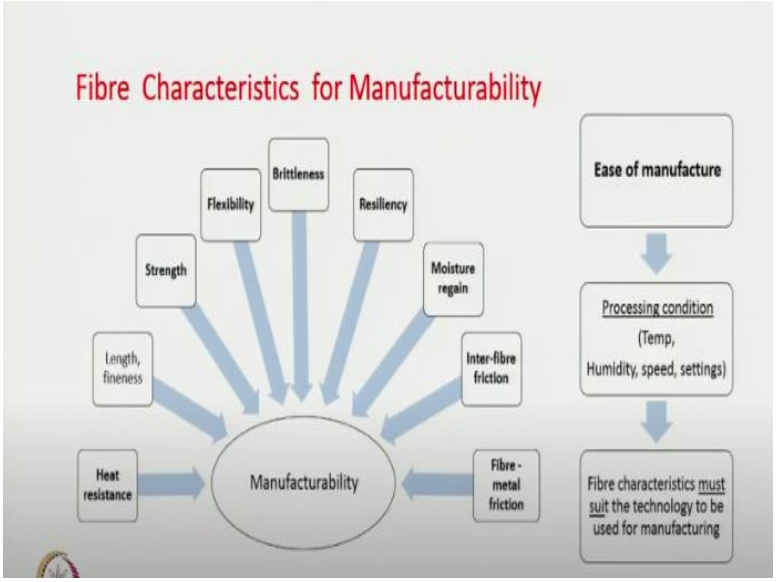
In this slide, various properties of the fibre material that decide the performance of the product are depicted. Different aspects of intrinsic fibre properties are involved in determining product performance. The dimensional parameters of the fibres have a significant role in product performance. The dimensional parameters include length, fineness, cross-sectional shape, hollowness and crimp. The next parameters are the mechanical properties of the fibre, where strength is important in such applications. In addition to strength, elongation, modulus, and toughness are important parameters.

The flexibility, bending rigidity, and resiliency of the fibre, i.e., how elastic the material is, also decides the product's performance. Other important parameters are moisture regain (indicating whether the material absorbs moisture), frictional properties, and heat resistance (indicating the thermal property of the fibre), i.e., the temperature at which the material melts or softens, and combustion properties. Similarly, chemical resistance

is another important property because the environmental conditions could be such that it must be used under an acidic or alkaline medium.

So, it is important to understand the chemical resistance of the material against different types of chemicals with which the material or the product may come into contact. Static propensity may also be important in some situations. In summary, the product performance depends on all the above properties. Therefore, we must have a databank of properties related to these properties for different types of fibres.

(Refer Slide Time: 10:05)



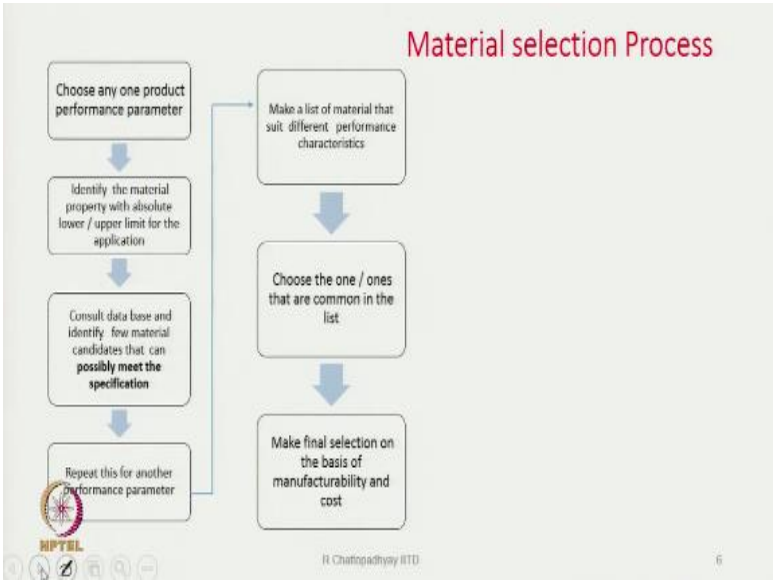
The next discussion is the characteristics of fibres from the point of view of manufacturability. From the manufacturing point of view, heat resistance is a significant property of fibres. Because when the material is being processed, the machine components get heated up due to a lot of friction. So, the temperature-resistant capability of fibres has a crucial role in manufacturability. Length and fineness are also important characteristics from the point of view of manufacturability. Strength is very important as the fibre should not rupture during processing. Therefore, both strength and brittleness are important.

Fibre flexibility is also important because it often gets bent or twisted during processing, so it must be flexible enough. Resiliency of fibres: during processing, a lot of stresses act on the fibres, which may change the dimension of the fibres. So, they should be able to return to the original dimensions; hence, resiliency is important.

Moisture regain, inter-fibre friction and fibre-to-metal friction are the relevant properties from the manufacturability point of view.

Therefore, ease of manufacture depends on processing conditions like temperature, humidity, speed, settings, etc., and the fibre characteristics must suit the technology to be used for manufacturing. In summary, we have to keep in mind that whatever fibres we choose, with the performance criteria in mind, we must consider the manufacturability of those fibres. How easy it is to process the fibres on different machines.

(Refer Slide Time: 12:27)



The material selection process flowchart is given in this slide. First, we choose any product performance parameter. Sometimes, the performance of a product may not be just one attribute; it may be multiple attributes. Identify the material property with absolute lower and upper limits for the applications. For example, the minimum strength requirement is very important so that it can meet the strength requirement of the product. So, we have to know what the upper limit is and what the lower limit could be.

Consult the database and identify a few material candidates that can possibly meet the specifications. Then, we must prepare a proper database of the properties of different fibres: natural fibres, synthetic fibres, and high-performance fibres. So, whatever new fibres are introduced in the market, their properties are maintained in the database. We

choose some candidates from the database; sometimes, the fibre may not just be one; it may be three or four fibres which will meet the criteria. Then, repeat the same procedure for another performance parameter.

For the first performance parameter, '*x*', '*y*', and '*z*' are three fibres. Then, we go to the second performance parameter and again see how many fibres could be there that will meet these criteria. So, in this way, we make a list of materials or fibres that suit different performance characteristics and then choose one or more from the list. Make a final selection based on manufacturability and cost because cost is also very important, and the fibres should be easily processable.

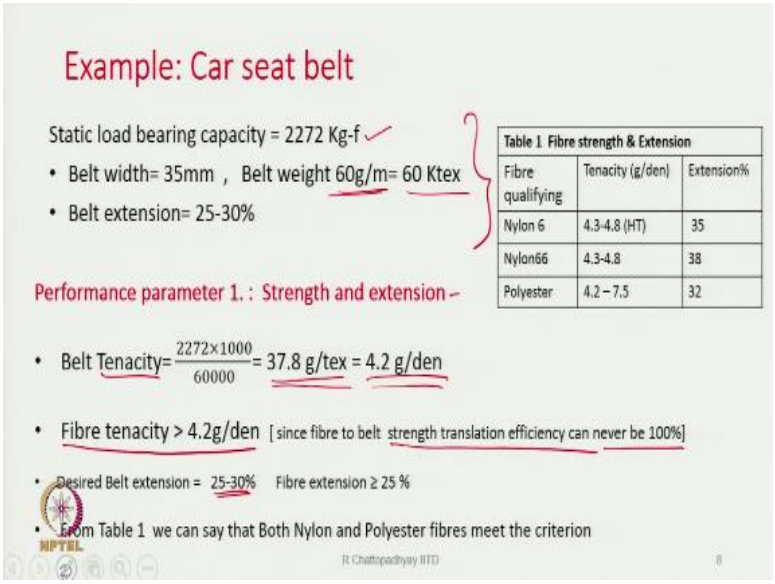
(Refer Slide Time: 15:16)

The other selection guidelines are usually strong and flexible fibres perform well in manufacturing. The properties of the selected material in the fabricated state may be different from its isolated state, i.e., whatever property that we observed when the material is tested in an isolated state in laboratory conditions, and where they are in the form of groups or interaction with another type of fibres, then the same performance or same property of the fibre may not be reflected. For example, micro-denier fibres are very good from the point of view of apparel products because they give very good drape and flexibility.

The micro-denier fibres are also very good for filtration because they create fine pores in the fibrous structure and can be used for wipe-cleaning applications. However, it

creates some manufacturing challenges like nep formation in carding, or easily damages because being very fine, they are weak as well. So, from the property point of view, they are suitable. But from the processing point of view, they may not be that suitable because of nep formation, and damage. So, nep formation spoils the appearance of the fabric. So, these sorts of situations may arise, and we have to make a proper choice of materials while keeping in mind all the aspects, such as performance and processability.

(Refer Slide Time: 18:02)



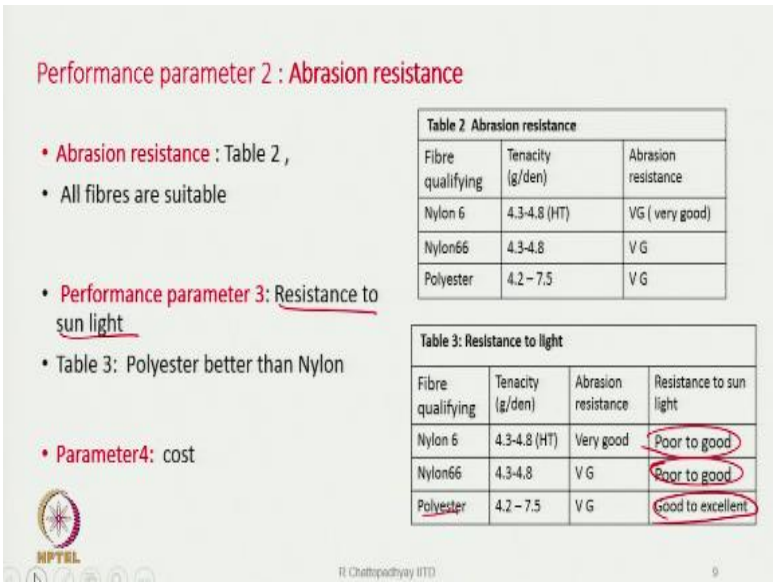
We try to understand an example. Let us say we have to design a car seat belt. Static load bearing capacity is 2272 kg-f, the belt width has to be 35 mm, and the belt weight is 60 g/m, which is 60 ktex. The other criterion is belt extension should be 25 to 30%. If this is the desired functionality in the product, then we have to find out which fibre could be selected to design the seat belt. So, from the point of view of performance parameter 1, we made a very simple calculation for an initial estimation of strength and extension.

The belt strength has already been given. From there, we can calculate the strength or tenacity of the belt in terms of g/tex or g/den. So, we divide the strength by the belt tex value to convert into g/tex and g/den, which are also known as the tenacity of the belt. The fibre tenacity must be more than the calculated value. So, we can immediately get an idea of the selection of fibres based on tenacity. Next, we can try to find the fibres that have a tenacity value greater than the calculated belt strength. The fibre tenacity should not be equal to or less than the calculated strength, and it must always be more

because the strength translation efficiency from fibre or the filament to the belt can never be 100%.

Therefore, selecting the fibres with a tenacity value of more than 4.2 g/den. Similarly, the belt extension should be around 25 to 30%, which means the fibre extension also should be close to this, not less than this. Now, if we observe the fibre databank where the fibre properties are listed, we can identify the suitable fibres. In Table 1, fibres like nylon 6, nylon 66, and polyester are given, which meet the criteria. Therefore, all of them will be suitable for manufacturing car seat belts.

(Refer Slide Time: 21:35)



The next criterion is abrasion resistance. The car seat belt must have good abrasion resistance. In Table 2, we can observe that the abrasion resistance values are not given in terms of numerical figures but in a qualitative manner. We can consult a lot of research papers to find out the quantitative values of the qualitative ranking of fibres. It is not necessary to initially proceed with the numerical values of various properties. If we have a table with us where the properties are given in terms of qualitative terms, then they can also be used as initial guidance.

Generally, all of the fibres listed in Table 2 are very good, and therefore, all of them will be suitable from the point of view of abrasion. The next criterion is resistance to sunlight because the car may be lying under the sun, and hence the sunlight may be falling on the belt, and therefore, the belt should not get damaged by the UV of the

sunlight. From the criterion of resistance to sunlight, we will see that polyester has good to excellent behaviour whereas nylons are poor to good. Therefore, from the performance criteria of resistance towards sunlight, we can say polyester is scoring over nylon.

The next significant criterion is the cost. We must analyse how much we are going to lose in terms of its performance and how much we gain in terms of cost if we choose materials like '*A*' or '*B*' or '*C*'. So, the cost will also always be a deciding factor when we decide on the right material. Sometimes, we may need to mix the material to obtain the required properties.

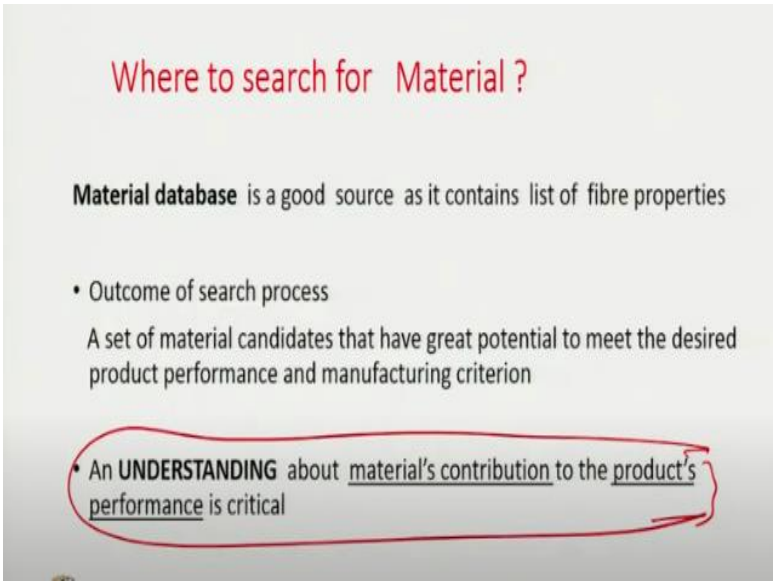
(Refer Slide Time: 24:39)

The other aspect is sometimes we can go for straightforward selections. In some situations, material selection becomes straightforward due to the limited options available for the appropriate material or the well-established performance of some raw materials in a particular product. An example is given on the slide. The choice becomes almost automatic, like cotton fibre for producing denim, which is such a well-established raw material for denim. So, we choose cotton material immediately if we want to design a new denim or a new type of fabric for denim.

Similarly, cotton is always used to produce towels which is also an established product. For wedding sarees or any ceremonial dress, silk has always been preferred and has been used for centuries. Then, for a shawl, very fine wool will be the right choice.

Today, other fibres are being used as raw material to produce the shawl. But when it comes to a very elegant-looking shawl or a very high-quality shawl, then very fine merino wool will be the right choice because there is a very good association between the property and the performance over so many years and therefore, the choice becomes almost automatic in nature.

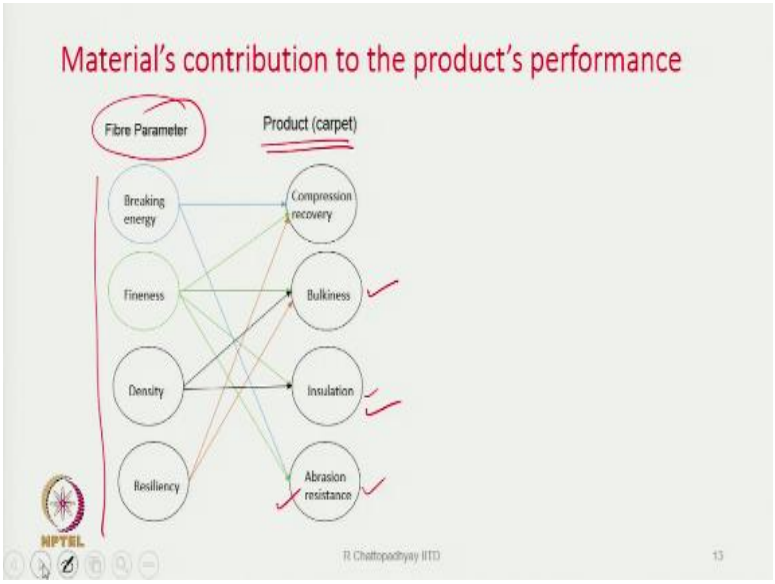
(Refer Slide Time: 26:32)



Where to search for material? The material database is a good source. So, we have to create a database of material, i.e., whatever the fibres and other materials we use, we must have a database containing all the properties. For example, we may need some adhesive to join the two fabrics, so we should also have a database of various adhesives. Similarly, for the other accessories we use for any product, we have to maintain a database of the materials used and their properties.

So, the outcome of the search process is a set of material candidates with great potential to meet the desired product performance and manufacturing criteria; therefore, understanding the material's contribution to product performance is very critical. So, to design any product, we must have a good understanding of the material's properties and the product's performance. Understanding the performance and properties of the product's basic element, whether fibre or yarn, is a must.

(Refer Slide Time: 28:19)



As an example, the material's contribution to the product performance is given in this slide. On the right-hand side, product parameters are given, and the product is a carpet. The fibre parameters are given on the left-hand side because we must be able to associate first, which requires real domain knowledge. As for a carpet, the important properties are compression recovery, bulkiness, insulation, and abrasion resistance. We have just stated only 4 properties. These properties of the product are related to fibre by arrows. The breaking energy of fibre is important for compression recovery and for abrasion resistance of the carpet.

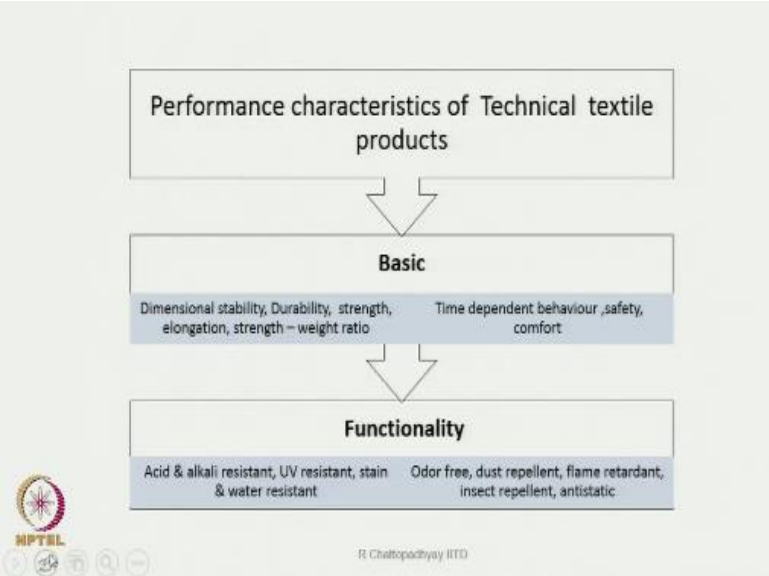
The fineness of fibre is very important for compression recovery, bulkiness, insulation, and abrasion resistance. The density of fibre can decide the bulkiness and insulation. The resiliency of fibre decides the bulkiness and compression recovery of the carpet. So, this kind of diagram easily relates the product's performance with the fibre's basic properties. Therefore, we can choose the right type of fibre, and the designer must have the capability to do so.

(Refer Slide Time: 30:41)

The outcome of the material selection could be a single material with desirable performance characteristics or two or more materials that can be mixed to get the desirable characteristics. So, many times, we blend the material. For example, polyester cotton blended shirts or polyester viscose blended materials. They are so common because one material does not suit us, and it does not give us a desirable performance. Therefore, we try to mix two different types of fibres. As fibres are converted to different structures, some of their characteristics can get altered in magnitude or their relative contribution to the end product properties.

Besides the material blending, different types of finishings also make it possible to obtain the desirable properties of the final product. We can make certain characteristics more visible, or some characteristics remain subdued. It is also possible that it depends upon the processing part of the material, where the fibre also can play a role.

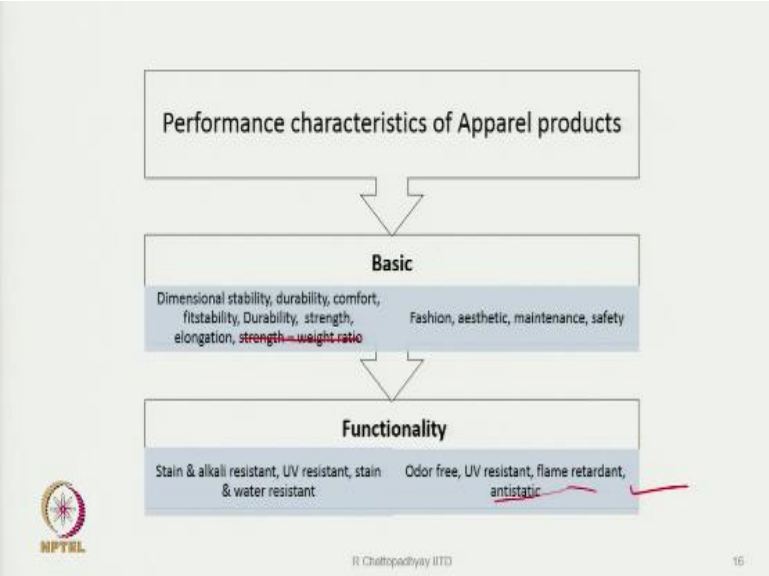
(Refer Slide Time: 32:44)



For example, let us take technical textile products. Technical textiles are a vast field, and many types of technical textiles are present, like geotextiles, medical textiles, and many other types of technical textiles. In general, the basic properties of technical textile products are dimensional stability, durability, strength, elongation, strength-weight ratio, and their time-dependent behaviour, safety, and comfort. These are the basic property of the technical textile fibres.

The functionality could be that it is acid and alkali-resistant, UV-resistant, stain-resistant, water-resistant, odour-free, dust-repellent, flame retardancy, insect-repellency, and antistatic behaviour are important functional requirements of many technical textile products. So, there are some basics which we have to meet, and there are some others which are also very important. So, we can classify the properties as basic and functional requirements.

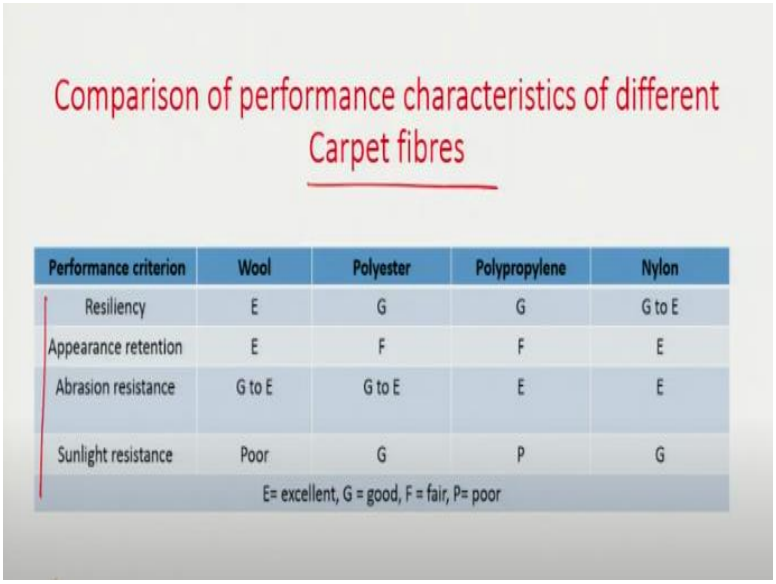
(Refer Slide Time: 34:18)



Similarly, for apparel products, generally, the basic requirements are dimensional stability, durability, comfort, fit, strength, elongation, and strength-weight ratio. The strength-weight ratio is not very important in the case of apparel products. However, aesthetics, maintenance, and safety are very important for fashion-related products. From a functionality point of view, stain and alkali resistance, UV resistance, stain, and water resistance are all important. We should not get even a watermark on apparel products like silk sarees because it is common that if we try to wash a silk saree with water, there will be a watermark if the water dries which spoils the appearance of the silk.

So, this could be a problem for very costly products. So, the appearance may get spoiled because of any kind of stain, not only from chemicals or even from water; stains could also be there. Similarly, it should sometimes be water-resistant, depending on the type of apparel we use. Odour-free, UV resistance, flame retardancy, and antistatic behaviour are important for apparel, depending upon end use. So, If we take a specific apparel, we can make another list of the basic properties we expect and other functional properties that we may need.

(Refer Slide Time: 36:25)



As an example, we are comparing the performance characteristics of different carpet fibres in this slide. Four fibres are shown in the table: wool, polyester, polypropylene, and nylon. These fibres are mostly used in carpets, and qualitative data in relation to their performance, i.e., resilience, appearance, retention, abrasion resistance and sunlight resistance are stated here in this table. There are qualitative values stated in terms of excellent, good, fair, and poor. From the table, one can observe that every fibre has some good characteristics and some inferior characteristics in comparison to others.

The carpets made from different fibres have their own merits and demerits, or sometimes we can mix them together to get certain properties which we expect from them. So, this kind of table can help us to choose the right material. With this, we close this particular discussion. From these aspects of discussion, it will be easy to make the initial selection process of fibres, and then one has to go for more detail. Okay, thank you.