Technical Textiles

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Lecture - 03
Textile Reinforced Composites

Hello, everyone, now we will start the specific area of technical textiles. So we will start with fibre reinforced composites.

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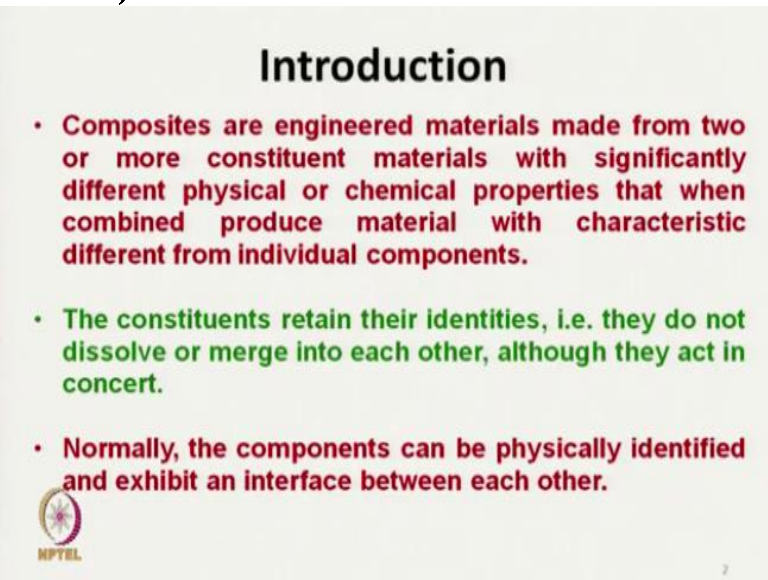

Now, first we will try to understand the term composite. The composites are engineered materials made from 2 or more constituent materials with significantly different physical or chemical properties that when combined produce a material with different characteristics which are different from individual components. Another characteristics of composites are this characteristics is that this individual components they will retain their own identity.

That means, they do not dissolve, they do not merge into each other, although they act together. Like if we dissolve salt into water. Although salt is one component, water is another component but once it is dissolved, the saltwater is not composite, that means this individual component has to retain their own identity they should be separable even at the composite stage. So, this normally these components can be physically identified and exhibit and interface between each other.

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So, now why should we bother about composite? Why should we use composite? When we have individual components, we can very well use this individual components. The composites are important because they can be very strong and stiff, yet very light in weight. So, if we need very strong or very stiff lighter material, then composite is the answer. The ratio of strength to weight and stiffness to weight are several times greater than the common engineering material like steel and aluminum.

That means, where we need strength, but at the same time we have to reduce the mass there composite is the only answer. Fatigue properties are generally better than common engineering material that means where the loads are being applied repeatedly, composites are useful in those areas. Toughness of composites are greater, composite can be designed that do not corrode like steel. That means, we can eliminate steel, where steel can corrode in those areas by composite.

And we can design composite which will not corrode and possible to achieve a combination of properties which is not attainable with metals, ceramics or polymers alone. So, if we need light weight and strong or light weight and elastic material or strong and elastic material, so combination of properties we can achieve by using composites.

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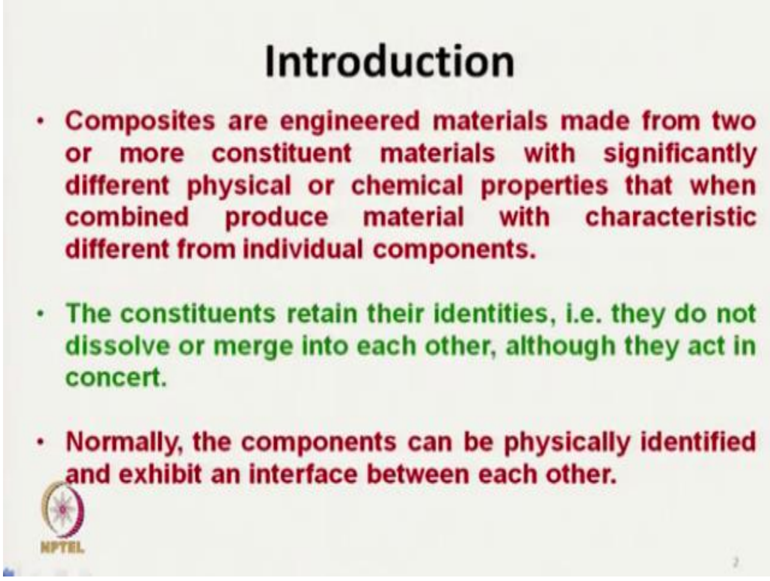

So, these are the engineered material made from 2 or more constituent materials with significantly different physical and chemical characteristics, this part I have already discussed, they are able to retain the identity, individual components.

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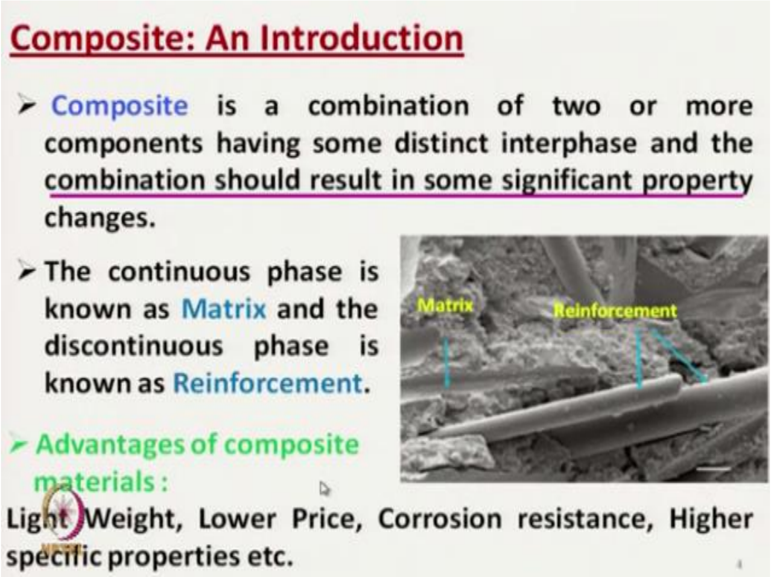

It is a combination of 2 or more components having some distinct interface. The combinations should result some significant property change. Now if we see this picture, in composite, we have basically 2 main components or phases. One phase is known as continuous phase and another phases is discontinuous phase, the continuous phase is known as matrix and discontinuous phase is reinforcement. And this reinforcement phase is used for enhancing the strength.

And this matrix is actually used for holding the reinforcement and transferring the load. So, the main advantages of composite materials are lightweight, lower in price, corrosion resistance, higher specific properties like higher specific strength, higher specific modulus. Specific properties means the strength per unit mass. Now, you must understand why is it called continuous phase? The matrix is called continuous phase, means matrix is holding the reinforcement component.

And there is no discontinuity; matrix is join throughout the structure. But this reinforcement it is a discontinuous phase and load is being transferred through the matrix.

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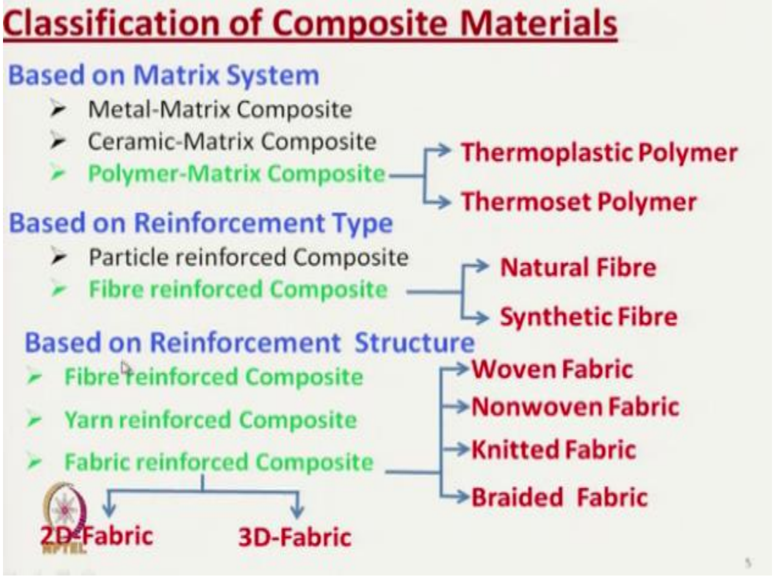

So, if we try to classify the composite materials, we can classify based on matrix or based on the reinforcement. The classifications based on matrix systems are of 3 types the metal matrix composite, ceramic matrix composite and polymer matrix composite. Metal matrix composites are where metals are used as matrix component continuous phase ceramics matrix. Ceramics are used in as continuous phase and polymers are used as continuous phase in polymer matrix composite.

And polymer matrix composites are again subdivided into 2 classes. One is thermoplastic polymer another is thermoset polymers. I will discuss the advantages and disadvantages of all this type of composites. Based on reinforcement type, there are basically 2 types of reinforcement, particle reinforcement composite and fibre reinforcement composite. The fibre reinforcement composites are again subdivided into 2 types.

One is natural fibre reinforcement another is synthetic fibre reinforcement. Particles reinforcements are also subdivided into different classes, I will discuss and based on reinforcement structure, we can also classify the composite. In textile reinforced composite, it is classified based on fibre reinforced composite, yarn reinforced composite and fabric reinforced composite. If the reinforcing materials are of loose fibre form then we call it as fibre reinforced composite.

If it is in yarn form, it will be yarn reinforced composite and if it is fabric form that is fabric reinforced composite and in application we use all 3 types of composites. Fabric reinforced composites are again subdivided depending on the type of structure like woven fabric, nonwoven fabric, knitted fabric and braided fabric. So, we get composite, we can manufacture composite from all these types of fabrics and the woven fabrics are, as far as matter of fact, fabrics can be again subdivided based on the dimension.

If it is 2D fabric and the composite made of 2D fabric, 2 dimensional fabric it is a 2D composite 2D fabric composite. In fact, 2D composite means it does not mean that it does not have the third dimension where the thickness component is very small, like normal woven fabric or single layer woven fabric it is called 2D fabric. And for some specific applications, we sometimes use 3 dimensional fabrics.

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And if we see the broad market broad applications in transportation application, construction, marine, corrosion resistant application, consumer goods application, electrical and electronic industry application, appliances application aircraft defense there are many areas where we can use composites.

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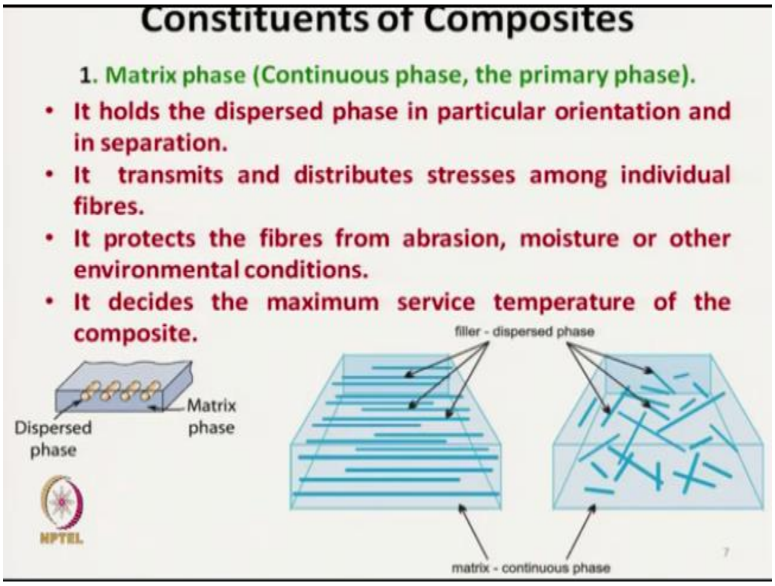

Now, I will discuss little detail the constituents of composite. As I mentioned, there are 2 phases one is matrix phase and another is reinforcement phase. In the matrix phase which is continuous in nature, and it is a primary phase, without this matrix phase, we cannot have composite which is basically holding the disperse phase or discontinuous phase. So, it holds the disperse phase in particular orientation and in separation.

So, it is very important the disperse phase if it is not separated, if they are clustered, then we will not call them as composite, because the disperse phase between the disperse phase the matrix has to be there, matrix cannot be discontinuous, matrix has to penetrate between the disperse phase. For our discussion here suppose it is a fibre reinforced composite between the fibres, the composite has to penetrate.

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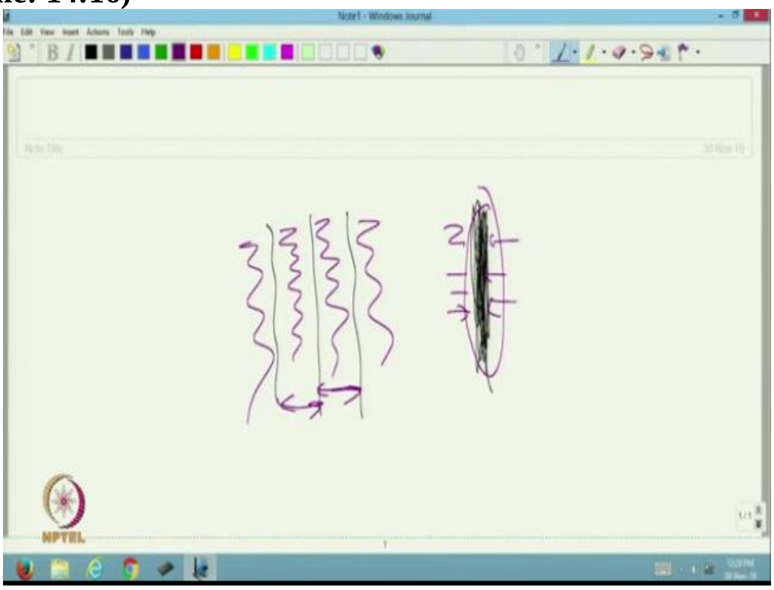

Like these are the reinforced phase or discontinuous phase, between these phases we have to have matrix. Matrix has to separate out this discontinuous phase. If the fibres are closely packed and where matrix cannot penetrate, then we will not call it is as composite. In composite the matrix has to hold the dispersed phase in separation then this matrix transmits and distributes stress among the individual fibres that is which is dispersed phase.

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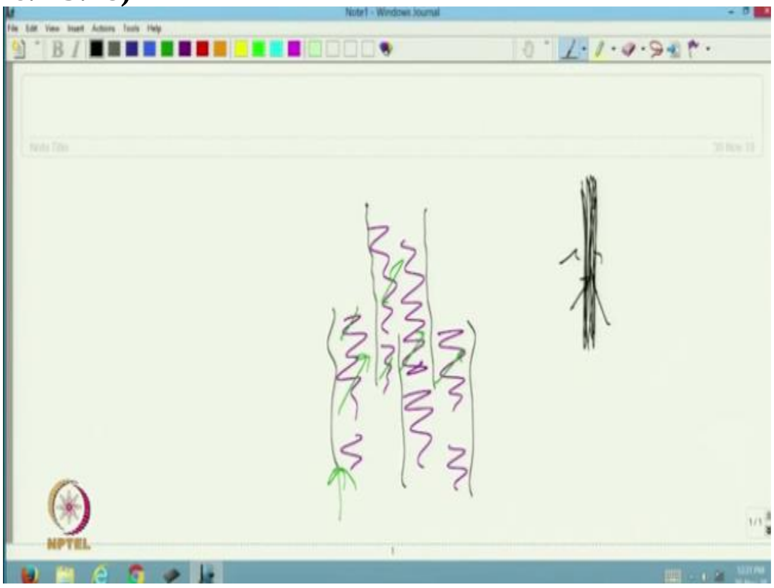

Like this is fibre these are the fibres discontinuous phase. Now when matrix is coming in between, these are the matrix in purple color. Now, the load carried by this fibre suppose load it is being loaded through the matrix the load will get distributed. If the matrix is not there in between the fibres then the load distribution will not take place. So, it transmits and distributes the stresses among individual fibres. Another important function of matrix is that it does not allow the reinforcement material like fibres to get exposed.

It protects the fibre from abrasion, moisture and other environmental condition. Matrix generally covers this reinforcement material. So, any abrasion it is actually it is faced by the matrix material, it allows the fibres to be protected, which is actually strength bearing component. And the matrix decides the maximum service temperature of the composite, which is very important because the melting point of matrix, if we talk about the thermoplastic matrix that is important.

It is not important that the reinforcing fibre is of very high melting point. That is actually not important, because if matrix melts, then composite will disintegrate. So basically, the maximum service temperature is decided not by the reinforcement fibre, but by the matrix component. So, you can see the fibres can be dispersed in oriented fashion or in random fashion. That depends on the requirement, we can, will discuss in detail.

So, if it is oriented in a one particular direction, the strength in that particular axial direction that direction will be high, because the orientations of fibres are in that direction. So, here if it is X axis, so X axis strength of matrix will be much higher than the strength in Y axis where the orientation of fibres are not there here the strength will be carried mainly by the matrix which is lower in tensile characteristics. But on the other hand, if the matrix is actually dispersing the fibres in random orientation.

So, that this fibres are oriented in random oriented there, we can see the load bearing capacity in both X and Y axis multi direction will be almost uniform.

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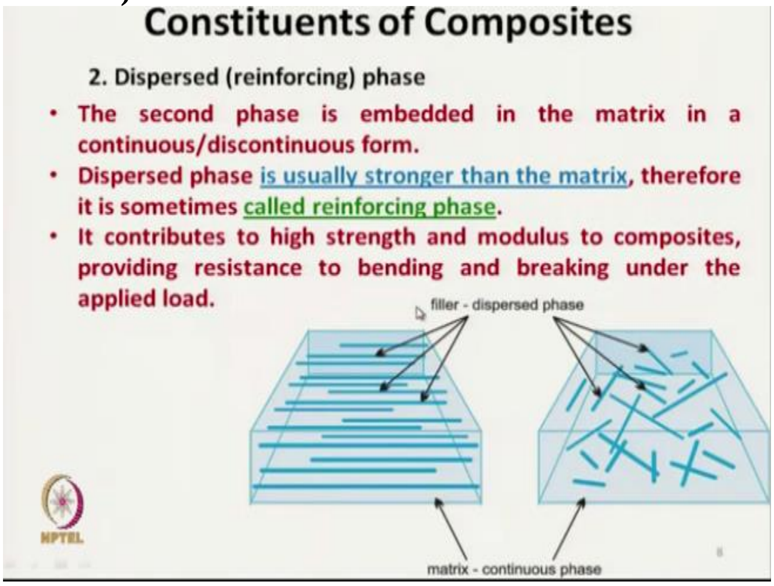

And next is that constituent is that the dispersed phase, as I have already mentioned. This phase is embedded in the matrix in either continuous or discontinuous form depending on the application, we may select whether we should go for continuous form or discontinuous form. And this dispersed phase, which is known as the reinforcing phase, is usually stronger than the matrix phase, it contributes to the strength of the matrix strength and modulus of the composite, provide resistance to bending and breaking under applied load. So, this provides the mainly the reinforcement.

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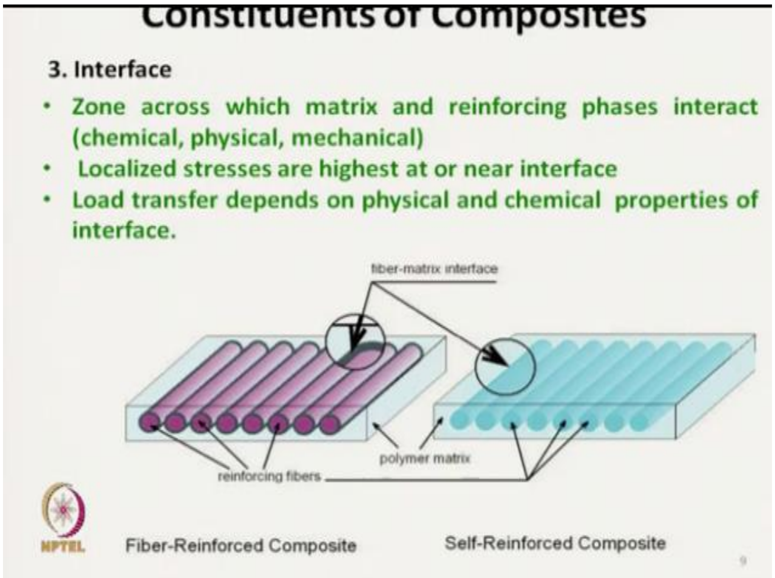

Apart from these 2 phases, that is matrix and reinforcement, there is another important phase which is interface. There has to be one interface between matrix and reinforcement, the zone across which matrix and reinforcing phase interact, it is called interface. This interaction maybe chemical interaction, may be physical interaction or may be mechanical interaction. But there has to be one interface they cannot mix and the localized stresses are highest at or near this interface.

Because through this interface the reinforcing material is transmitting the stress to the matrix and from the matrix to the reinforcement again, the load transfer depends on physical and mechanical properties of the interface.

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So, apart from the synthetic composites, manmade composite there are examples of natural composites. So, natural biological materials are often made of at least 2 constituents and the strong and stiff component is embedded in a soft matrix, like wood is made of fibrous chain of cellulose molecule in a matrix of lignin, this is example of natural composite where lignin is matrix and the fibre fibrous chain is reinforcing material.

On the other end bones and teeth are hard inorganic crystal in a matrix of tough organic constituent called collagen, here collagen is actually acting as a matrix and inorganic crystals are reinforcing material. Now, we will try to understand why do we need to read replace metals by fibre reinforced composites?

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Metals	Fibre Reinforced Composites
Lower strength to weight ratio and modulus to weight ratio as compared to composites	Higher strength to weight ratio and modulus to weight ratio as compared to metals
Fatigue strength and fatigue damage tolerance are inferior to composites	Fatigue strength and fatigue damage tolerance are superior to metals
Metals have isotropic properties	Composites have anisotropic properties , higher properties when load is applied along the reinforcement direction and lower properties at different angles to direction of reinforcement.
Designing of metals is easier	Designing of composites is difficult due to anisotropy in the properties.
Metals exhibit yield point and plastic deformation	Composites are mostly elastic in tensile stress-strain characteristics
Failure in metals is catastrophic	Composites exhibit a gradual deterioration in properties

So, if we see the difference between metals and fibre reinforced composite, we will understand the need of replacement of fibre reinforced metals by fibre reinforced composites. Now, the metals are lower strength to weight ratio that is lower specific strength and modulus to weight ratio as compared to composite. So, and on the other hand fibre reinforced composites are higher strength to weight ratio and modulus to weight ratio as compared to composite.

Now, we need composite, we need to replace metal where we need lighter weight with high strength and high modulus application, like aircrafts even for automobile body we need composite to reduce the mass. Fatigue strength and fatigue damage tolerance are inferior to composite in case of metal. So where we need higher fatigue strength and fatigue damage so, we must use composite. Metals have isotropic properties which is good in some sense.

But there are applications where we need characteristics in a particular anisotropic direction, particular direction strength in a particular direction we do not need the strength in other direction like composite have anisotropic property we can definitely make composite of isotropic properties also. Higher properties when load is applied along the reinforcement direction and lower properties at different angle. So, if we need strength in a particular direction we have to select composite and orient the composite that reinforcement direction.

Designing of metal is easier and designing of composite is difficult due to anisotropy in properties. So, metals are still used in many areas because of designing that it is easier to design the metal. Metal exhibits yield point and plastic deformation, whereas composites are mostly elastic in tensile stress strain characteristics. Now, we have to decide if we do not need permanent deformation like many applications are there where loads after removal of load, the structure has to come back to their original position.

There we have to use composite, not metal, metal failures are catastrophic. So, it can fail immediately. But composites are gradual that fails that it exhibits gradual deterioration in property. So, we can replace composite when we detect the deterioration in properties.

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Metals	Fibre Reinforced Composites
Coefficient of thermal expansion is higher for metals , so poor dimensional stability.	Coefficient of thermal expansion is lower for composites, so better dimensional stability over a wide range of temperature.
High electrical conductivity for metals	Low electrical conductivity for fibre reinforced composites.
High thermal conductivity.	Lower
Low vibrational energy absorption	High internal damping i.e more vibrational energy absorption and low transfer of noise and vibration to neighboring structures
Corroding behavior	Non-corroding behavior

Metals have higher thermal expansion and poor thermal dimensional stability. So, the applications where we do not need the thermal expansion we need better stability. So, we should use fibre reinforced composite in those places for high melt high temperature applications. Metals are having higher electrical conductivity the applications where electrical insulation is required we must use composite material, we must replace metal with the composite higher thermal conductivity.

Composite has lower thermal conductivity. Now, this is important the shock absorption behavior of metal is low, so low vibration energy absorption. Whereas for composites higher internal damping characteristics is there that is more vibrational energy absorption and low transfer of noise and vibration to the neighboring structure. This is important basically for vehicle application cars and automobile application, in those applications if we use metal in case of collision, the type of shock the driver or people inside the vehicle will actually experience is much higher than if the body is made of composite.

It will absorb the vibration shock and corrosion behavior is main concern for metal application and composites are having generally non-corrosive in nature. So, if we understand this difference between metals and fibre reinforced composites clearly and then we can gradually replace the metal with the fibre reinforced composite.

And at this point we must understand we cannot 100% replace the metal, but gradually we can replace where the danger of catastrophic breakage or then the very high load bearing is not there. Like we cannot immediately replace the metallic bridge by composite. There are other engineering aspects we have to see, but there are many areas where we can replace the metal with the composite.

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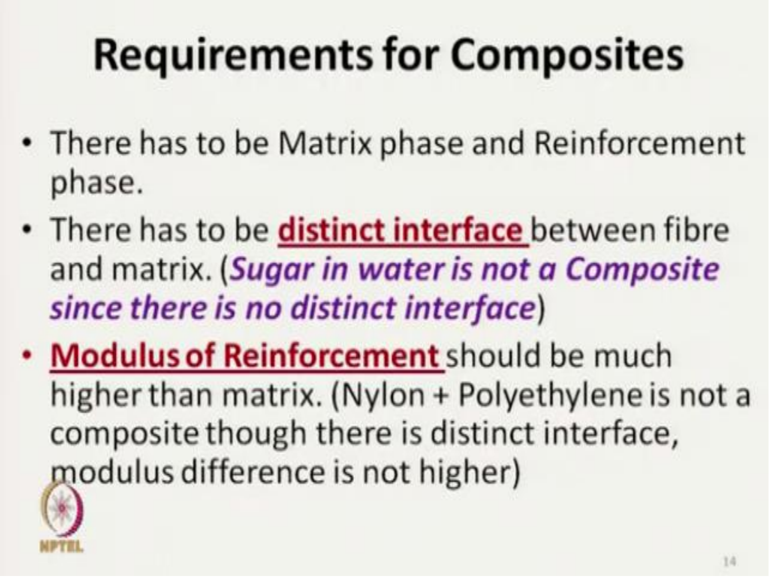

As it has already been mentioned that may basic requirements of composites are 2 phases mainly matrix phase and reinforcement phase and distinct interface. So, sugar in water is not composite, because there is no interface, interface has to be there, although sugar molecules are there and water molecules are there, but there is no interface, modulus of reinforcement should be much higher than matrix.

So, there has to be difference in modulus. If the 2 components matrix and reinforcement they are having very close nature as per as modulus is concerned, then it will not form a composite. Like nylon and polythene is not a composite, though there is a distinct interface because modulus difference is not too high. So, if we try to develop composite, we must first decide the difference in that reinforcement modulus. So, modulus of matrix should be much lower than the reinforcement.

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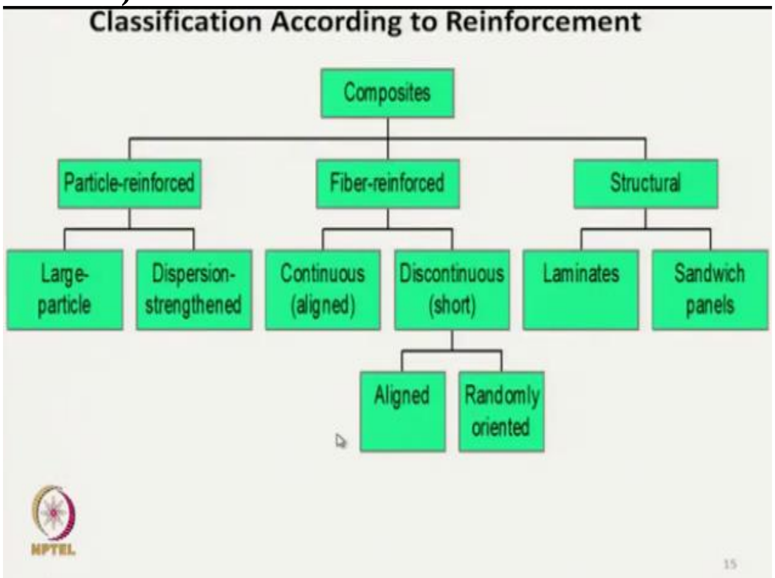

Now, coming to the classification of composite, according to the reinforcement, composites are classified in 3 categories, one is fibre particle reinforcement, then fibre reinforcement and then structural reinforcement. Particle reinforcements are classified again into 2 categories one is large particle and this dispersion strength, so larger particles are not in disperse condition, but smaller particles are in disperse condition.

Fibre reinforcement are of 2 types one is continuous which is aligned fibre and discontinuous short fibres. Short fibres are also of 2 types aligned and randomly oriented. So, this alignment and orientation we can control depending on the property requirement. And structural reinforcement, one is laminated structural reinforcement another is sandwiched panels.

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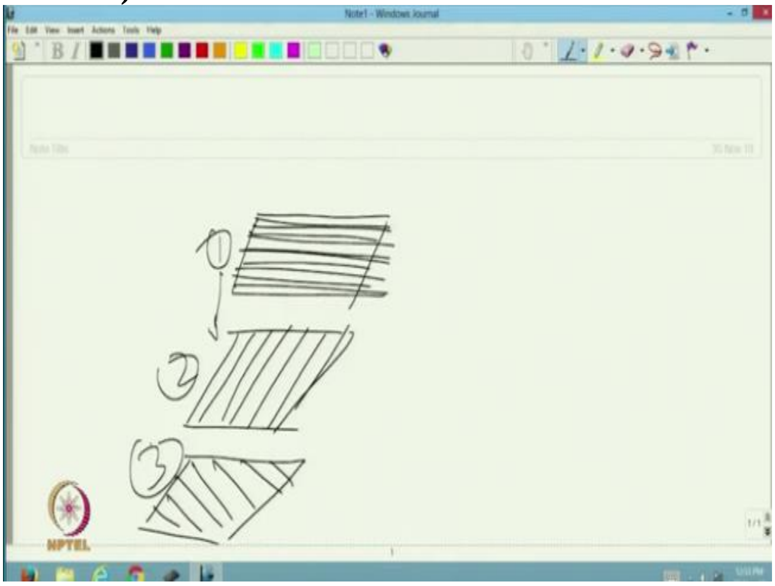

Sandwich panel means suppose we have one layer of, this is one panel of reinforcing material aligned to this, next panel alignment in this direction, another panel if we take alignment in this direction and if we sandwich we will get a sandwiched structure of composite where we can expect the strength or modulus in multi direction. So, depending on our requirement, we can use the sandwiched panel or number of panel can also be varied

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And the classification according to matrix are, metal matrix composite as I have already mentioned, this metal matrix composites are basically here matrix components are metal. And here in metal matrix the reinforcement maybe ceramics or maybe carbon components like cemented carbides and other cements as well as aluminum or magnesium reinforced by strong high steel fibres. So, this may be in particle form or maybe in fibre form. So, but here matrix are in metal.

Where we use ceramics as matrix, it is a ceramic matrix composite. It is not very common, but still it is used for specific application like aluminum oxide and silicon carbide are the materials that can be embedded with fibres for improved properties. So, these are the ceramic materials and their properties are improved by incorporation of fibre. And polymer matrix composite, so, the matrix where polymers are used as matrix those are called polymer matrix composites.

And polymer matrix composites are basically 2 types one is thermosetting polymer which are most widely used polymer, this resins are commonly mixed with fibre reinforcement. I will discuss the advantages of this thermosetting resins; they have their own disadvantage also. Another polymer matrix material is thermoplastic material; they overcome the disadvantages of thermosets.

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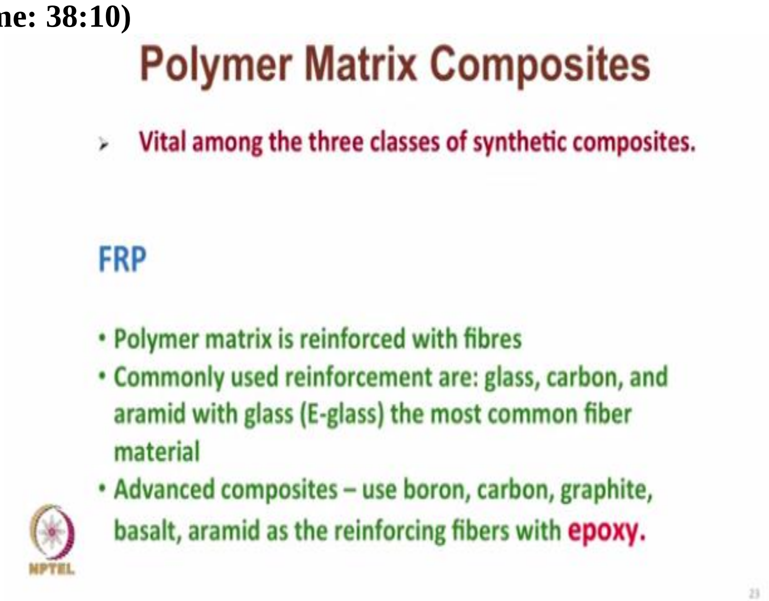

So, the polymer matrix composites, the most important of the 3 classes of synthetic composites like metal matrix composites, ceramic matrix composites and polymer matrix composite. Among these polymer matrix composites are most important, we can call it as fibre reinforced polymer or most closely identified with the term composites. FRP, fibre reinforced polymer, it is a composite material consisting of a polymer matrix embedded with high strength fibre.

So, where we use polymer as matrix we call it polymer matrix composite. The principle fibre materials are glass, carbon, kevlar. These are the commonly used fibres in polymer matrix composite, glass is very widely used fibre in polymer matrix composite. Advanced composites use boron, carbon, kevlar as reinforcing fibre with epoxy as the common matrix polymer.

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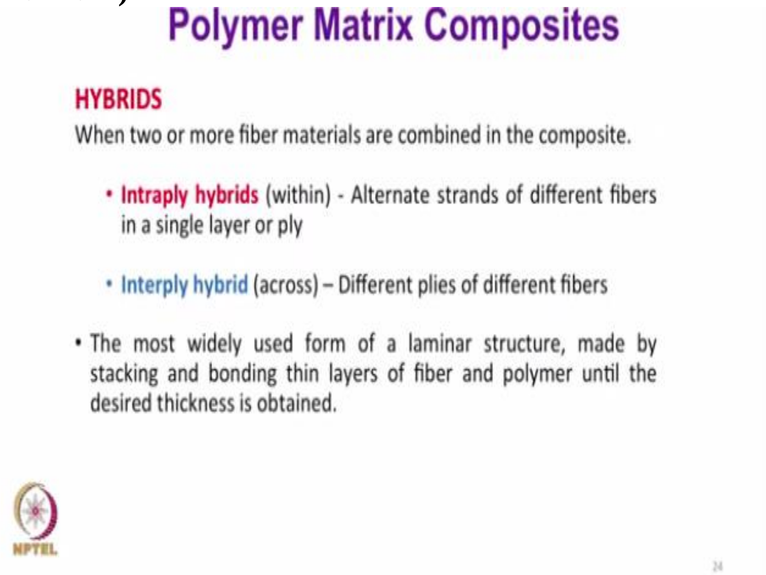

So, the polymer matrix hybrids are also used when 2 or more fibre materials are combined in the composites depending on our requirement, we can use 2 or more fibre materials. These are actually placed in different ways. Depending on their placement we can subdivide these hybrid polymer matrix composites, intraply hybrids and the interply hybrids, within an interply hybrids across, within means alternate strands of fibres in a single layer or a single ply that is called within and here across means different plies of different fibres.

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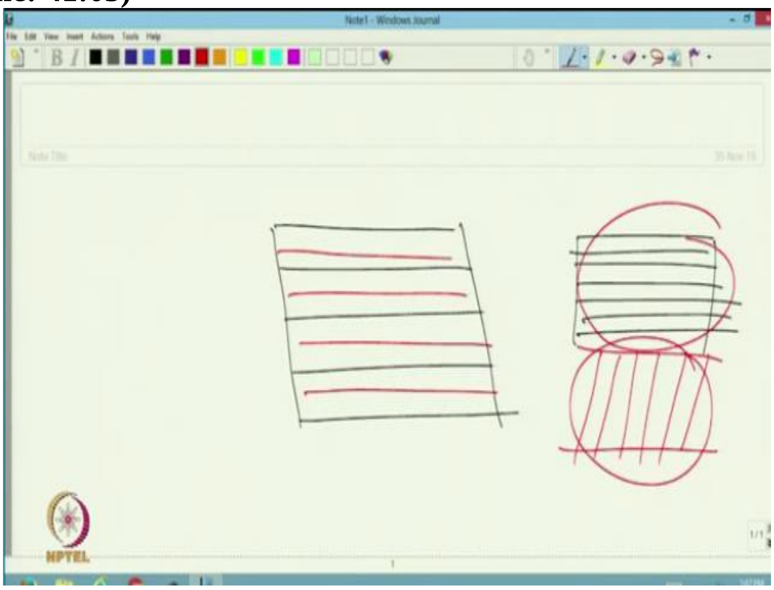

Now if we try to see the reinforcing fibres suppose this is fibre 1, this is fibre 2 and this is forming 1, say panel reinforcing panel this is called within, but if we try to have this is 1 panel another panel this type, so this 2 panels if we mix or in different angles then it will be called the between. So intraply hybrids within alternate strands of different fibres in a single layer, so this is single layer or ply and here at the different plies, the most widely used form of laminar structure. So these are the laminar structure were stacking different layers of fibres to form certain thickness desired thickness.

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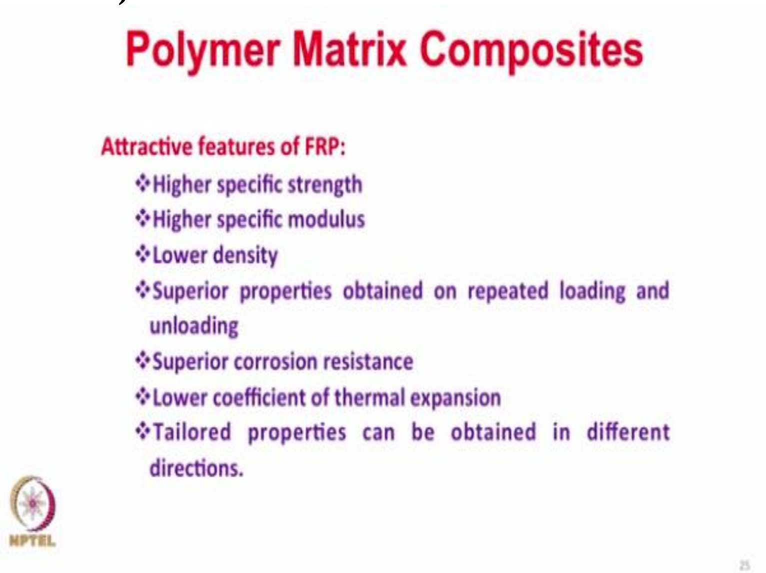

The main attractive features of polymer matrix composites are high strength to weight ratio, so it is a very light as compared to other matrix high modulus to weight ratio low specific gravity, good fatigue strength, good corrosion resistance, although the polymers are soluble in various chemicals. So we must keep in mind. Normally this chemicals are very specific chemicals and we should we must avoid this chemicals when we use polymer matrix composite.

Low thermal expansion leading to good thermal dimensional stability, significant anisotropy in property so these are the attractive features of polymer matrix composites which leads which actually the driving force of being that polymer matrix composite these are the reasons for which polymer matrix composites are use now a days widely.

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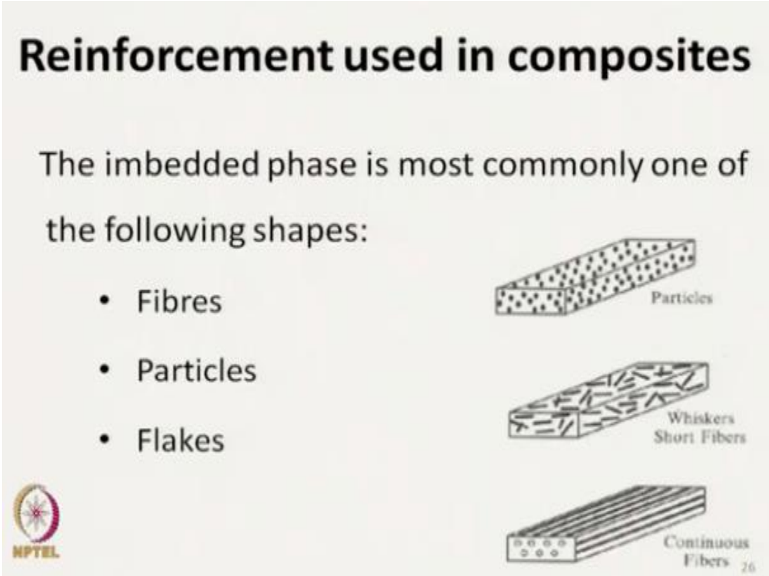

So the reinforcement used in composites are of basically 3 types fibres, particles and flakes. So these are the 3 different types of reinforcement used in composites. Earlier we have used the matrix and now it is reinforcement.

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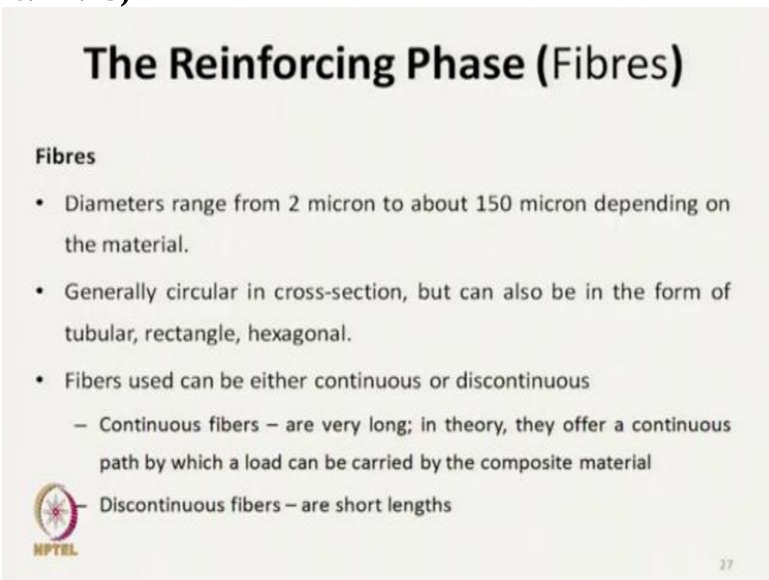

The reinforcing fibre phase that is reinforcing phase that fibre reinforcement this we will discuss in detailed in the next class. Till then thank you.