Introduction to Composites

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Lecture – 03
Classification of Composite Materials

Hello, welcome to introduction to composites course. Today is the third day of the first week of this course. And till so far, we have been introducing and giving you some basic information about what are composites, and what are their different applications. What I plan to do today is to give you an overview of what different types of composites are there in the world. So, what I will be essentially doing is classifying composites based on different types of constituent. So, what we will discuss today is classification of composites.

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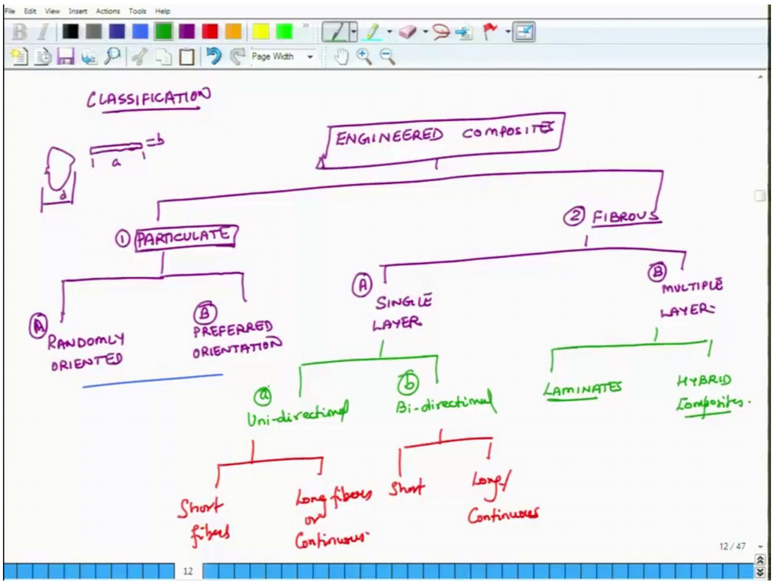

And when we are doing this, we are only going to address engineered or engineering composites. We are not going to worry about naturally a composite such as wood or bone or granite and things like that. So, will talk about we are going to do this classification in context of manmade composites.

So, we have engineered composites. And broadly speaking you have 2 types of composites. So, the first category is particulate composites. And the second category is fibrous composites. So, what is particulate composite? Particulate is a composite material which has a mixture of particles; for instance, cement for instance concrete which is a mixture of particles and cement. So, it has a mixture of particles, or you know some lumpy things and a matrix material in concrete that would be cement and sand. And in fibrous composite, you have fibers.

That is one constituent and other constituent would be some matrix material. So, that is there. And another way to explain this is what is particle, a particle is something which is not long. So, if you look at particle, this is not this dimension is not very large. It is aspect ratio or another way to look at it is aspect ratio take it is largest dimension and the smallest dimension the ratio of those 2, is not very large, but if you choose a fiber, it may be a short fiber or a long fiber.

This dimension the ratio of these 2 dimensions a and b is very large. So, particulate composite has a lot of particles bound together by some matrix and fibrous composites have fibers, and in fibers what is the definition of fiber that it has as a high length to diameter ratio. So, that is basic thing now. So, this is the first category of composites and this is the second category of composites; particulate and fibrous. Now let us look at different types of particulate composites.

So, a particulate composite can further be classified into 2 groups. So, the first group will be where particles are randomly oriented. For instance, in concrete all the particles or the pebbles they are not aligned in some particular direction. And then the other group would be directionally oriented, that is directionally oriented. Or it has a actually I will not call it directionally oriented, rather it has a preferred orientation.

So, that does not mean all the particles are in one particular direction. But broadly speaking there is one some direction to the orientation of particles. So, I will say preferred orientation. So, this is A, and this is B. This is A. So, 1 A is randomly oriented particulate composite, and 1 b is preferred orientation composite which is particulate in nature. Now let us talk a little bit about particulate composites.

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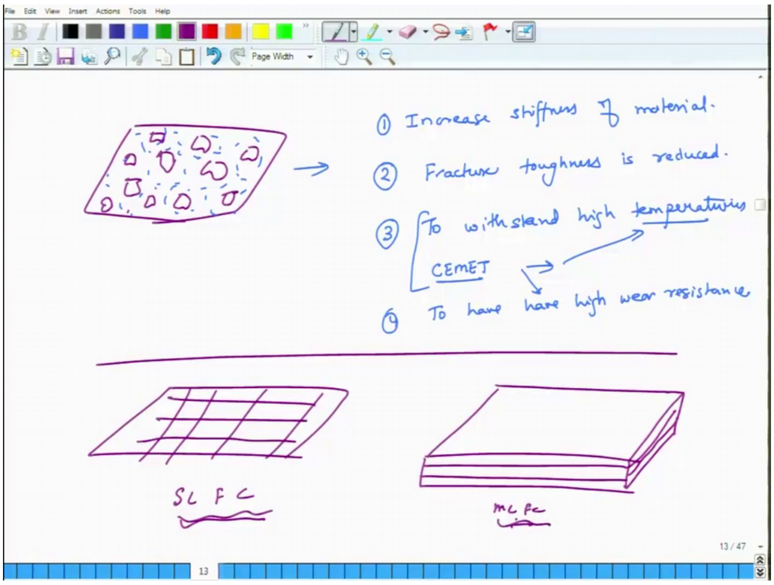

So, what is so, this is some randomly oriented composites. You know, particular composite it has these block here la lumpy particles. And then of course, as I said there is this matrix material. Why do we use them? One reason we use them is; if we want to increase the stiffness a stiffness of material. For instance if you take a slab of cement and put some compressive load on it, it will have some stiffness. But if you have a concrete if you inject it mix it with lot of these pebbles and particles, then it becomes significantly stiffer v significantly stiffer.

So, it can take much higher compressive loads. So, a lot of times, we if we have to increase the stiffness of the material we in mixed them with some particles. And these particles should be stiffer than the met that then the than the material the matrix material. Then only will it will increase the stiffness. The weak thing about or the not so good thing about particulate composites is that, they are fracture toughness is reduced (Refer Time: 07:46) to fracture easily, why? Because the bonds between the particle and the matrix is not very good, and those are the places where you have a probability of getting cracks developed much earlier. So, if you take one of these composites and try to bend it like this, it will try it will crack very easily along the play points where the matrix touches the particle at that interface.

So, that is one reason. There several applications where they are also used to in to with stand high temperatures, to withstand high temperatures. And one example of that we have already discussed this earlier, is called CEMET. It is called CEMET. Here you have particles of ceramics embedded in a matrix of metal. And these things have very high wear resistance and temperature resistance.

So, with to withstand high temperatures, and to have to have high wear resistance, CEMETs do both these things. They have temperature resistance and they also have wear resistance. So, this is some basic information about particulate composites. So, we are done with this. Next, let us look at fibrous composites. So now, fibrous composites again, they come in 2 varieties. 1 A and 2 A and 2 B.

So, 2 A would be single layer. And 2 B would be multiple layer. Now these so, what does this mean? In single layer composites, you have fibers. It is just one single layer. So, we can have a thin sheet, and maybe the fibers are oriented like this. Or there could be a case where fibers are oriented in both the directions. It all depends, but it just one single layer. So, this is a single layer fibrous composite, but then you can have another composite where there are several layers like these. And each layer may have a single layer of fibers, but then you can stick them together. And that is a multiple layer fibrous composite. So, this is multiple layer fibrous composite. This is one type of multiple layer fibrous composite.

Now, both these composites rely on fibers to increase the properties of the material. Now remember, I am not yet decided whether these fibers are long or short. They could be either, but here we rely on the fiber to make the thing either stronger or stripper or lighter and so on and so forth. So, that is the purpose. So, this this is about fibrous composites. Now these single layer composites, I can again break them into 2 categories. I can again break them into 2 categories. One is longitudinal orientation. What does that mean? That the fiber is aligned along the length of the composite, and the other one is bidirectional. Actually, maybe a better word would be unidirectional and here it is bidirectional. Excuse me, bidirectional.

So, this is A, and this is B. So, unidirectional composite which is fibrous and single layer that is 2 A a and this bidirectional is 2 A b.

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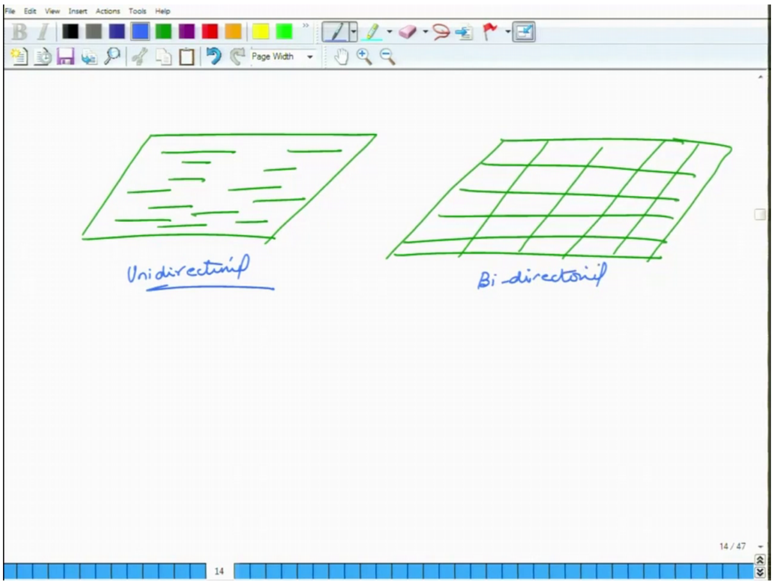

So, let us look at a picture. So, if you have these are all fibers, but they are not long and continuous. They may be short or long, but here this is unidirectional fibrous composite. An example of a bidirectional single layer composite, it will be something like this. A fibers in this direction. And you may also have fibers in this direction.

Very good example of a bidirectional single layer composite would be if you take a piece of this cloth. This cloth has fibers woven in both the directions. Where, woven like this and like that, right and you immerse it. In some epoxy and you bind it then you get a bidirectional single layer fibrous composite. So, this is bidirectional. And then you can further break these guys into short fibers and long fibers.

Same thing here, you can break them into short and long. As a lot of times we do not call them long fibers or we can also call them continuous fibers. So, we can here also we can call them either long fibers or continuous fibers. And later we will actually define, what is meant by long fiber or continuous fibers. What is the meaning of this in a mathematical sense? So, this is how single layer composites may be classified.

Now multiple layer composites we can further categorize them as laminates or why we can make them hybrid laminates, hybrid composites. Now what is a laminate? So, a laminate is when you have several layers of single layer composites, but so, maybe this is the first layer, this is the second layer, and you stick them like this may be the third layer is like this. And the 4th layer maybe in oriented in some other direction. So, all when you stick them together each layer by layer. The overall thing which is a combination of several layers is called a laminate.

So, single is called a lamina, and if you stick a lot of lamina or layers together then it is called a laminate. So, that is a laminate. And hybrid composites things become even more complicated. So, here in a laminate the fibers are only in the plane of the each layer. So, fibers may be running like this, or they may be running like this or both. But in hybrids the fibers may also be running in the thickness direction.

So, these are more complicated structures, they maybe hybrids like this. So, this is the overall classification of composite materials. Next what we will do is; we will start looking at some of the details of some of these things. So, one thing we have discussed in a lot of times I mean we have address to the talked about, is at a lot of these engineered composites have fibers and a matrix material, lot of these.

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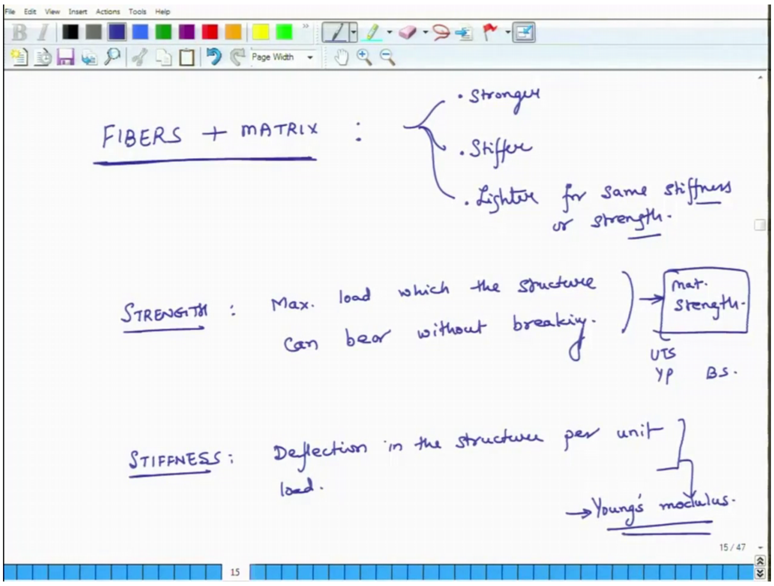

So, fibers composites are made up of mixtures of fibers and metrics materials. And the question is; why do we use fibers. Why do we use fibers? And the answer to that is we use these fibers in a lot of cases.

Either to make them stronger, and or to make them stiffer now these are 2 different work with 2 different meanings, and the third reason could be to make things lighter for the same stiffness or strength. So, you have want a structure to be having the same strength.

So, that it can be at the same amount of load. Let us say maybe the load carrying requirement is 20 thousand newtons.

I can make it from steel it can be heavy; I can make maybe the same structure. From composite it will be much lighter, several times lighter. But it may still be able to wear the same load. So, these are in general the big reasons. Either you have to make things stronger or stiffer or lighter without necessarily increasing the mask, you know even though you want the same stiffness or strength. Now before I discuss further sometimes be confuse between strength and stiffness.

So, let us get this clear what is the strength and what is stiffness. So, strength, what is the strength of a structure? It is the maximum load which the structure can bear without breaking. So, for example, there could be a bridge, you are designing a bridge. And you want to make sure that if you put one thousand tons of the load on the bridge. It should be able to survive it. And this load could be because a lot of trucks cars vehicles people and also the weight of the structure itself.

And it should be able to we are all this mass or all this weight and should not still break. So, that is known as the strength of the structure. That is known as the strength of the structure. Stiffness is somewhat different. So, but before we go to stiffness this strength is related.

It is related to materials strength. So, what would be material strength? Either it could be ultimate tensile strength for regular materials isotropic material such a steel or plastics. Either it could be ultimate tensile strength, or it could be the yield point, or it could be the shear strength or it could be the bending strength of the material right. So, this strength of the structure is related to material strength. So, what are so, it could be either ultimate tensile strength or yield point or bending strength and so on and so forth. Now stiffness is the deflection in the structure per unit load. That is what is stiffness. So, what does that mean? Suppose this is a pen, if I keep on bending it I apply some load here at some load it will break. That will be called the strength of this pen.

But that is not same as stiffness. A stiffness will be suppose I apply 5 newtons here, and 5 newtons here, and because of it there is a deflection of; let us say 2 millimeters, then I will call it that the stiffness of this structure is 5 divided by 2; that is, 2.5 newtons per millimeter. That is the stiffness of this structure. And the stiffness of the structure in general is very strongly related to what? Youngs modulus, now this is in context of regular materials like steel and glass and plastics.

In composites, there is something similar to young s modulus, but we do not call it young s modulus. So, but anyway it is related to young s modulus of the material. It also depends on geometry and shape of the structure. But it also strongly depends on the young s modulus. So, lot of times we get confused between strength and stiffness. If we have to makes things stronger, then we have to make sure that it has higher strength. If I have to make things stiffer, I have to make sure that it is young s modulus or modulus becomes larger.

It could be young s modulus or shear modulus, or bulk modulus, you know one of these things. So, when we use composites a lot of times fibrous composites, we either our trying to make things stronger. Or make things stiffer or make things lighter for the same stiffness or the strength. These are the 3 things. So, if I am trying to make things stronger then my focus will be to ensure that the material strength of the composite is high.

If I am trying to make things stiffer, then I have to make sure that the modulus the modulus of the composite should be as highest possible. And if I have to make things lighter, then I have to make sure that the density of the material should be as low as possible without reducing it is a strength or young modulus. So, this is the thing.

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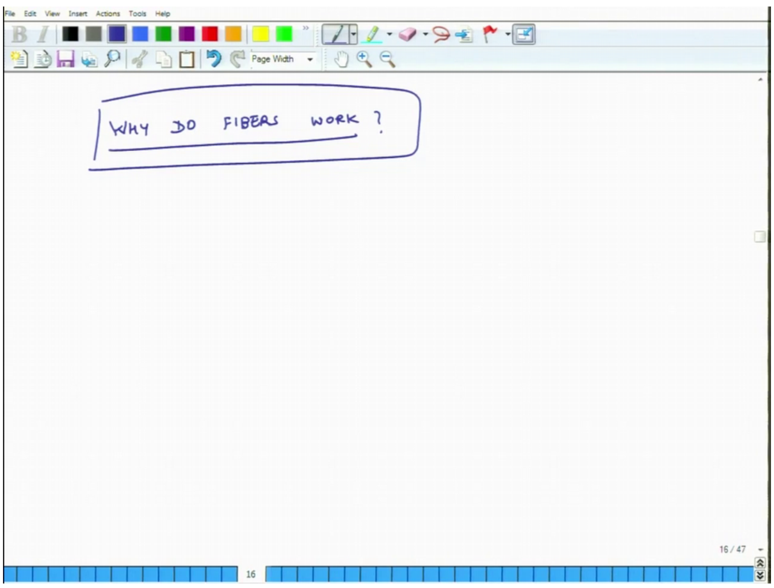

So, the next question is why do we use fibers, or rather why do fibers work. Because people have made a very large number of applications of fibrous composites, and there they do not use suppose for instance they in fibrous composites there could be glass fiber plus some matrix. So, you mix glass fiber and matrix and it helps you increase the either the string or the modulus or you can make things lighter. But if you do not use glass fiber and rather instead of that you use regular chunky glass you will not have success.

So, the question is why do fibers help us in making things lighter or a stiffer or stronger things. So, this is an important question. And this is something I wanted to post this to you what I would recommend is; you please go and explore it on the net or in the books, which you have been using and then tomorrow when we start the new lecture. We will come back to this question and we will try to understand why do fibers work, and regular materials in bulk face they do not give us the same advantages.

So, with this background I wanted to conclude our discussion for today. And I look forward to meeting you tomorrow. And till then have a great day, bye.