Advanced Composites
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Lecture - 01
Basics of Composite Materials

Hello, welcome to Advanced Composites MOOC course. Today is the start of this particular course, which is going to run over a period of 12 weeks. And I welcome all of you very warmly to this course. This is an advanced level course, in the sense, that whatever basics are required for this course as a prerequisite the those basics have already been covered in an introductory course, which was offered a few months back; and the name of that course was Introduction to Composite Materials.

Now, you may find the details of that particular course and all the lectures on YouTube as well as on the NPTEL site. So, if you feel a little uncomfortable, so that you may not be necessarily prepared for this course, then I would suggest that you please go back to that course, review all the contents learned stuff and before you start feeling uncomfortable in this course, so that is something about it.

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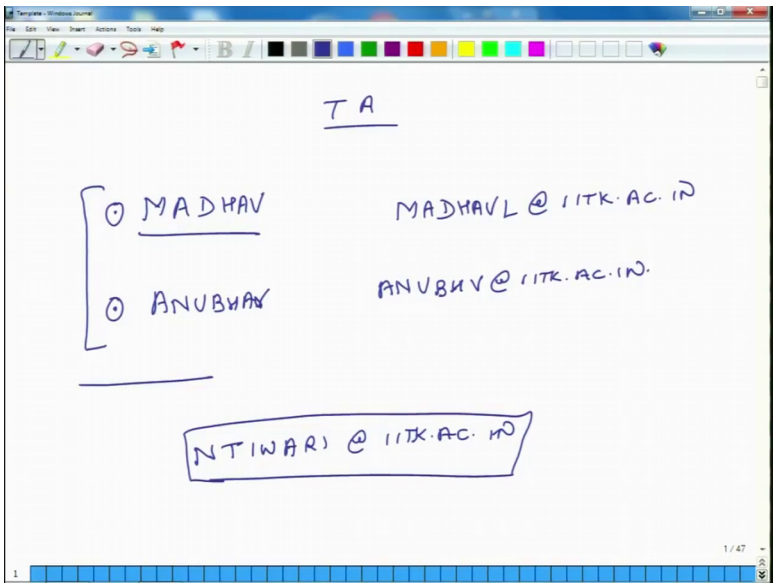

The other thing of what I will talk about is a little bit about logistics related to this course. So, as I said the course is going to run over a period of 12 weeks. In every week, what I will also be doing is I will be giving out an assignment and each assignment will

have several multiple choice questions. So, it would be expected for all the attendees of this course to do those assignments, some submit them back in time. All this can be done in an online method mode. And at the end of the course, there will be an examination. So, those of you who are interested in earning a certificate for this course, you can write that examination of once again that examination will also be multiple choice question type, MCQ type.

But both in assignments and MCQ, the fact that you have to do multiple choice questions does not necessarily mean that you will be able to answer all the questions right away. So, each several questions will be of a nature, where you may be expected to do some detailed calculations. So, as you move into this course, please be aware and please prepare for the assignments and in particular for the final exam in such a way that you internalize a lot of material which I am going to cover in this course.

So, this is how the course is going to run. Each lecture will be telecast, and it will be available on YouTube and NPTEL websites. And if you have questions at the end of each lecture, you can approach the teaching assistants for this course; the TAs, there are two TAs for this course. And I am going to give out their names as well as their contact details. So, first one is Madhav. So, this is about TAs and Madhav, his email address is MADHAVL at the rate IITK dot AC dot IN. So, you can ask him questions.

And then there is another teaching assistant and both of them will be helping me equally in this particular course. So, the other person is Anubhav and his email id is ANUBHV, so there is no A between H and V at the rate IITK dot AC dot IN. So, these are the two gentlemen whom you can approach if you have questions about the format about particular assignment related questions or in general concepts related to whatever I will be covering in this course.

And in case you are not satisfied by that then you can approach me as well. And my email addresses NTIWARI at the rate IITK dot AC dot IN, but I will suggest that it will be better if you approach these two gentlemen that two TAs, if you have any questions related to course. And in case they are not able to help you or resolve you your doubts or questions then please approach me, so that is about logistics.

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What will we cover in this course? So again, it is a 12 week course. And out of these 12 weeks, the first 3 weeks, we will be trying to very quickly capture the essence of whatever was taught in the introductory course so that people specially those people who did not get a chance to take the earlier course, they will have a good understanding of what were the basics and that will be a subway into this advanced level course.

So, first 3 weeks, we will be doing a very expressed review of whatever was discussed in introductory course on composites. And starting fourth week, we will be starting advanced level stuff, specifically in the fourth week what we will discusses how do composites fail, the laminated composites fail in a progressive manner. So, we will discuss in detail about the progressive failure theories related to composite materials.

And then in sixth fifth through twelfth weeks, we will be discussing in detail the mechanics of composite plates and for that we will be developing some differential equations. And those differential equations we will try to solve in context of different types of geometries both for static situations that is the plate is loaded statically as well as when the plate is loaded in a dynamic way.

So, we will learn how to find the buckling modes of these plates, how the plates vibrate and stuff like that, so that is what I plan to cover in the over in an overall sense in this particular course. And I hope you find this particular course enjoyable and a very

rewarding experience. So, with that we will proceed to start discussing some introductory stuff about composite materials.

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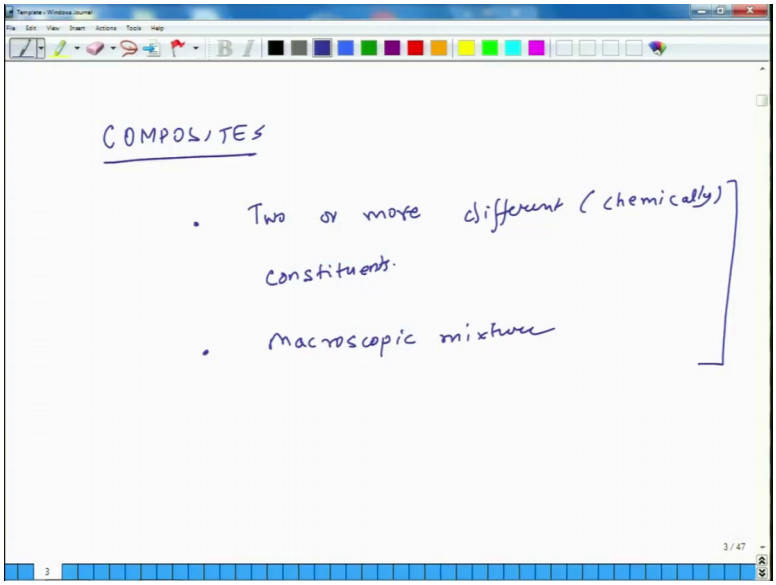

And the first thing very quickly we will like to review as to what are composites? So, what are composites? And as discussed in the earlier course composites we call anything; a composite if it meets certain criteria. So, one thing is that it has to have two or more chemically different constituents different and different by different I mean chemically constituents. So, this is one thing which a composite should have. And then these constituents, when we mix these, this should be a macroscopic mixture should be macroscopic mixture. So, anything any material solid material if it has two or more different chemical constituents and these constituents are mixed not at a micro or nano level, but at a macroscopic level, then the material is known as composite material.

So, for this reason, if I consider let us say an alloy, so an alloy for instance mild steel it has carbon, it has iron, it may have some other materials phosphorus and things like that and still it will not be considered a composite material even though it has several different chemical constituents. Just for the simple reason that these mixtures exist at micro level you know at very small fine level. So, an alloy will not be considered composite material, but examples of composite materials would be wood that is a natural material and it is also a composite material.

Another natural composite would be bone. Another natural composite would be some special rocks like granite, because when you cut a cross section of granite, you will see at macroscopic level you have different materials specifically quartz, feldspar and mica all mixed up together and bonded together. So, at a macro level these different mixtures exist and that is why granite will be valid composite material. So, these are some examples of naturally existing composites.

But then we also have artificial composites or manmade composites. And there is a huge variety of these manmade composites. A Very popular form of manmade composite would be fibre glass, where you have very small particles of glass in fibrous form, and they are randomly oriented and all of them are bonded together by some glue or a matrix material typically some polyester resin or epoxy, so that is a very commonly used composite material which is manmade in nature.

And then there are more expensive where composites for instance graphite epoxy composite, Kevlar epoxy composite and so on and so forth. So, this is what we imply by composites. And these composites especially the manmade ones human beings have found a very large number of applications for these composites. So, we use them in aerospace structures, in aerospace industry, in automobile industry, we use them as car body, parts, brake pads, drive shafts, fuel tanks, hoods, spoilers and so on and so forth.

Innova space structure we use these composites as parts in the door, nose of the aircraft, struts, trunnions, fairings, cowlings and so on and so forth, we used all these composites also in rockets and missiles, in the nose of the missile and several places and then also in satellites.

So, in aerospace systems, we use composites because they come out to be lighter, stronger, temperature you know more temperature resistant and smarter structures, and they also offer good amount of resistance to wear. So, that is one beer that is some of the reasons why they are used in aerospace industry.

And then we use these composites another big area is sports industry, because composites offer some very unique properties in terms of their lightness. So, they can be light, but simultaneously they could be very strong and tough. And you can design composites in a way so that they look nice and pretty. So, for purposes of lightness, strength, toughness, aesthetics and high damping properties, we use these composites in

a large number of sport related applications. For instance a lot of tennis rackets are made up of graphite epoxy composites. And then bicycles are again made up of graphite epoxy composites, and sometimes even parts of it are made from Kevlar, badminton rackets. Boats are a lot of times they are made from glass epoxy composites, hockey sticks, golf golf's, motorcycle parts and so on and so forth.

Another big area where composites are used is the transportation sector such as in railway coaches, bridges, ships, boats, dam's truck bodies and floors, recreational vehicles. And in these applications they are used because composites you can engineer them and you can engineer specific composites which are light. So, their density is less compared to metals and simultaneously they could be fairly strong, fairly stiff. And they could also absorb a lot of energy, so they would be tough and they offer very good damping properties.

And besides these things composites are also used in several other industries such as in biomedical sector, in consumer goods industry, agricultural equipments, heavy machinery, computers, healthcare products and so on and so forth so that is some basic information about different applications of composite materials. The next thing we will very quickly look at is how our composite materials classified.

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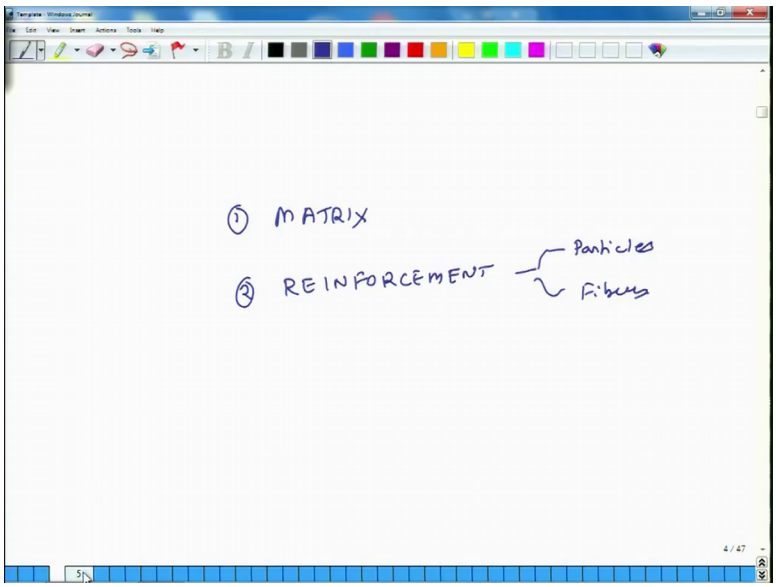

So, broadly speaking broadly speaking if you look at manmade composite material it has two primary constituents one is matrix and the other one is a reinforcement. So, matrix

could be typically a polyester, it could be epoxy, it could be peak, it could be nylon. So, a whole range of plastics, and thermal it could be a thermo set resin or a thermoplastic resin. But in this matrix material to make it stronger and stiffer, a lot of times you can introduce some reinforced in constituents. Now, these reinforcements could be either in form of small particles or they could be in form of fibres ok. So, so these reinforcement could be either in particles or it could be fibres, so that forms the basic two important categories of composites.

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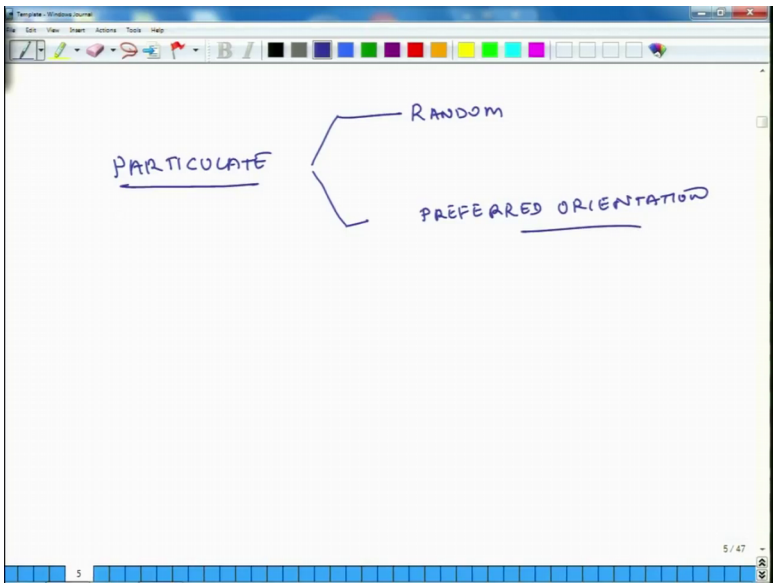

So, you have composites which are particulate, so these are particulate materials. An example of a particulate composite would be concrete. So, in concrete what do you have you have sand, you have cement. So, sand and cement act mixed together and they act as a matrix material, but then you also have pebbles right small pieces of stones so that is like your particulate matter, so that would be concrete. And you could have not only this particular matter in concrete sometimes you can also have steel bars steel bars. So, in that case it will be concrete with steel as well. So, you have particulate composites. And then the other degree is fibrous composites.

So, let us look at different types of particulate composites. So, particulate composites you can have two types; one is where the reinforcement is randomly oriented. So, concrete is a very good example, which concrete without steel bars that is a very good example of a particulate composite, where the reinforcing material is randomly oriented. And the other

one is where you have preferred orientation. So, these are two categories of particulate composites.

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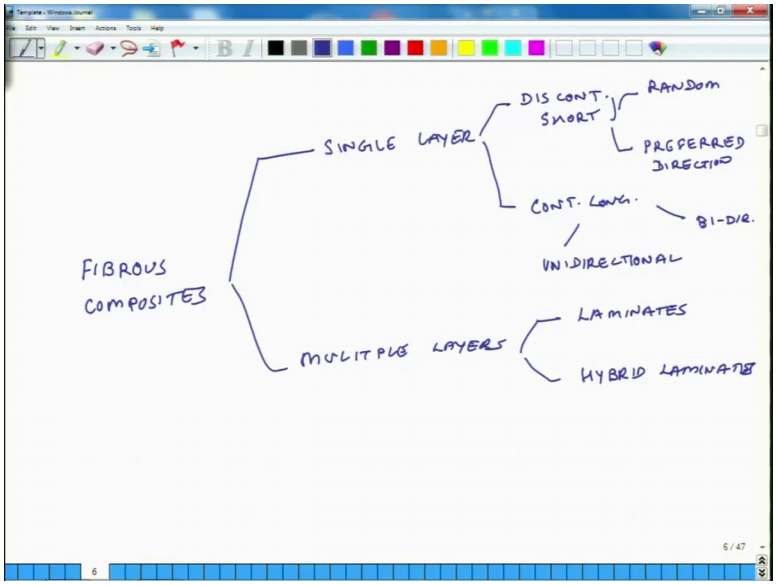

So, the next one, we will look at is composites which are fibrous. So, here the reinforcement is not small particles which are having different types of shapes, but very thin fibres so fibres. So, those are fibrous composites, fibrous composites ok. And these fibrous composites, you can have either single layer or you can have multiple layers.

So, what do you mean by a single layer? Fibrous composite, you can have just one single layer a sheet of composite and in which all the fibres are oriented in a particular direction, but there is no reason why you cannot have fibres oriented in different directions. So, you could have another situation where you have one layer let us say and in this case the fibres are oriented in 90 degree or 0 degree direction, then on top of that there is another layer where the fibres are oriented at 45 degree direction; and on top of that there could be fibres oriented at 90 degree direction, so that would be an example of a multiple layer fibrous composite.

And these single layer composites, we can further classify them into two. So, what are those two categories? The first one is discontinuous fibres. So, I am not going to write the whole thing this, but it is discontinuous short fibres. And the other one is continuous and long fibres. So, in discontinuous short fibres maybe the fibre are typically few millimetres long, but definitely they are not in tens of centimetres in length. But if we are

talking about continuous fibres, the length of these fibres could be really long and sometimes they may run along the entire length of the composite structure.

So, you have single layer composites first case where fibres are short and discontinuous; and the other one is long and discontinuous; and in short and discontinuous you can again have these fibres. So, the orientation of the fibres is random or they could be oriented in a preferred direction.

So, an example of randomly oriented fibre, single layer composite could be a lot of times in the case where you have a boat; and in that the body of the boat is made up of a single layer of randomly oriented fibre. An example of a preferred you know single layer composite with discontinuous short fibres would be sometimes in a lot of injection moulded parts where you have a plastic let us say nylon. And you are reinforcing that nylon with small glass fibres and as this glass fibre plus nylon in a molten state passes through a small nozzle, all the fibres tend to get aligned in the direction of the flow, so that would be an example of a single layer fibrous composite, where the fibres are discontinuous and short, but the orientation of the fibres is in a particular direction. So, they have a particular orientation.

And then we have continuous and long fibres. And again there you can have two different cases. So, either the fibres are unidirectional or they could be bidirectional. So, I am just abbreviating that. And then we have multiple layer composites. And here we can have either laminates and we can also have hybrid laminates ok, in multiple layer.

So, what was that mean? In laminates, there will be several layers of oriented fibres. And in each layer the orientation of the fibre may be different, but the material may be the same; but in hybrid laminates the material as well as the orientation of the fibres could vary along the thickness. So, this is an overview of how we go around classifying composites and this also concludes today's introductory lecture. And starting tomorrow we will start having taking a review of different types of fibres, composites, matrix materials, and very quickly we will review all these materials so that we get up to speed in the context of this particular course.

So, thank you and I look forward to seeing you tomorrow. Bye.