Characterization of Construction Materials
Prof. Manu Santhanam
Department of Civil Engineering
Indian Institute of Technology - Madras

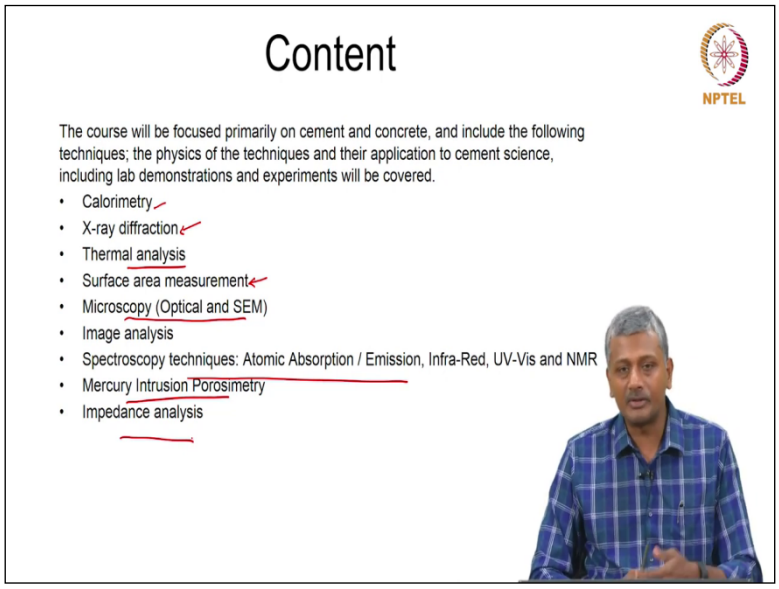
Lecture 1
Characterization of Construction Materials An Introduction Part 1

Hello everybody and welcome to this course on characterization of construction materials. In this course you will learn the science behind several techniques that are applied to try and understand the structure and properties of different types of materials. And the emphasis will be on learning what aspects of the structure that had discovered through these techniques and how are they connected to the actual structural performance of the materials.

So, in this talk we will just give a brief introduction to what this course contains and what is expected from you at the end of this course what will you actually be learning and what will be your skills at the end of this course. So, the instructors for this course I am Manu Santhanam and my colleague Dr. Piyush Chaunsali who will talk to you in just a minute. Both of us are faculty members at the department of civil engineering at IIT Madras.

And you have our email addresses here in case you have specific queries regarding the content and regarding concrete research in general you are welcome to write to us of course you will also be dealing with teaching assistants for this course through the web portal through which you have actually registered for this course. But anyway in case you have other questions and queries related to concrete research in general you can always write to us at the same email address.

(Refer Slide Time: 01:36)



So, what is the objective of this course and why are we here the idea is to introduce students who are taking this course to the characterization of construction materials and their behaviour. The primary viewpoint is to develop an understanding of the mechanisms that govern the performance of these materials. And in the course of this subject you will actually be learning several different types of construction materials based techniques which are primarily focused a lot the the lectures will primarily be focused a lot on cement and concrete although we will also throw in some examples from other construction materials.

As far as possible we will supplement the theory that you learn in class with experiments that can be shown demonstrated to you in the laboratory. And we will also have specific experiments which can be shown to actually see how the data can be assessed and looked at in detail to actually provide some explanations for the behaviour observed in the macro scales. So, these are the different techniques that we will be doing in this course.

The first one is calorimetry which primarily applies to the study of cements, what we try to understand with calorimetry is how cements react. What are the rates of reaction of the cement different cement types and what are the rate controlling factors especially when you have different types of additives that you are adding to the cementations mixtures. What are the rate controlling factors.

And how can actually these be studied through an assessment of the heat release characteristics during the reaction of the cement with water. The next major technique that you will be talking about is x-ray diffraction. Now this is again a very sophisticated technique and it is highly

useful in the study of construction materials not just cement and concrete but also other types of construction materials. Primarily x-ray diffraction addresses the crystalline phases that are found in different types of materials.

And how we can actually identify the different types of phases that are present and also quantify them using different types of methodologies. The next set of lectures will be on thermal analysis now thermal analysis is something that many of us have actually done in real life we would have always prepared mixtures of two different materials and then remove the water from the mixture to actually get a phase that is completely different.

So, that is basically thermal analysis when you heat something over a range of temperatures and study the changes in the material as the temperature changes that basically similar analysis. And you will be learning the details of what are the different types of methods available within thermal analysis and how they can be applied to the study of construction materials. The next topic would be surface area measurement and surface area measurement is very important for the point of view of materials.

Because we are dealing with different size scales of materials we are talking about cement we are talking about aggregate we are talking about fillers we are talking about very fine, micro-fine additives that we are adding to the concrete mixtures. And so we have to get an assessment of the fineness of these materials because that has a direct connotation on the reactivity of these materials. Microscopy is a tool that is applied probably in all branches of material studies.

And in cement and concrete optical and scanning electron microscopy have a very large range of applications. And what we will be talking about here is how deep we can go to the microstructure of these materials and try and relate that to the micro structural characteristics. Image analysis naturally follows microscopy because ultimately to get information about the material you need to interpret the images that you collect from the microscopic techniques.

And so image analysis will focus on how we can actually interpret these micro graphs or other pictures that we are getting from the microscopic investigations. Then we have spectroscopy actually if you look at it all the study is coming to the same overall segment of spectroscopy. But here we are talking about certain techniques that are specifically applying to the study of the scattering or absorption of electromagnetic radiation.

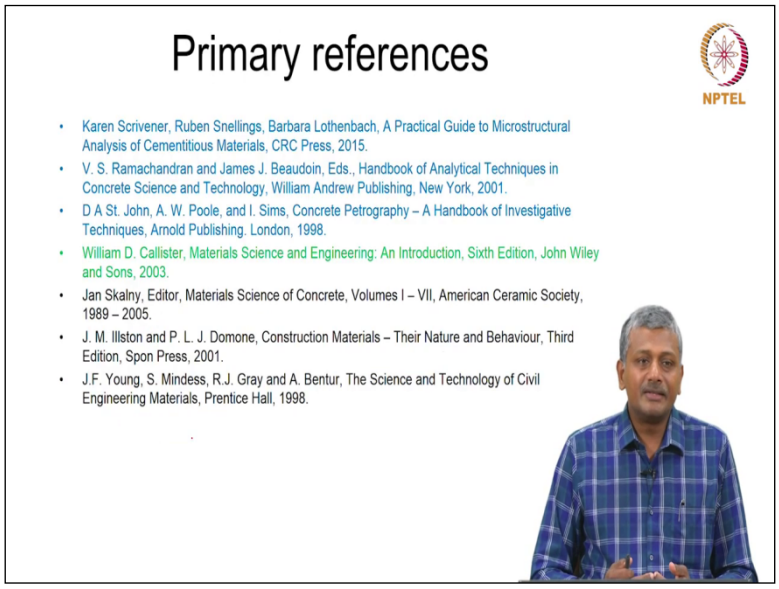
So, we have atomic absorption or emission which basically looks at using visible light and ultraviolet light and then you have infrared spectroscopy which deals with infrared electromagnetic radiation. UV visible spectroscopy again is the same range as the atomic absorption we are talking about visible and ultraviolet light. And then you have NMR basically which is radio waves. So, analysis of materials with radio waves and that is NMR or nuclear magnetic resonance.

This will be followed by an assessment of how we can use porosimetry techniques to determine pore structure of porous materials primarily we are dealing with bricks we are dealing with cement, concrete and so on. And how we actually can assess the size of the pores that are available in these materials and how these pores are connected to each other and that is basically the basis of mercury intrusion porosimetry.

And finally we will have will round off this segment or this course with a discussion on impedance analysis. Now impedance is a very interesting technique application of electrical impedance to study the properties of construction materials that is a very useful non-destructive technique which can give you a lot of different types of assessment about the material characteristics. And you will see later that the range of applications that impedance can have can cover different types of materials like cement concrete, soils and so on.

And you will see the kind of investigations that we talk about and the range of applications that are available for this technique. So, this is basically the overall scope of the content that we are going to be covering.

(Refer Slide Time: 07:20)



Of course the content is so broad or so wide that you cannot really find all of it in one textbook. So, what we have here are some primary references that you can have or you can refer to, to get an understanding of the content in these different aspects that I just talked different types of techniques that I just talked about. But one of the foremost references as far as cementitious materials is concerned is this first one by Scrivener, Snellings and Lothenbach it is actually called A Practical Guide to MicroStructural Analysis of Cementitious Materials.

And much of the lectures you will see will have content that is quite similar or based on the techniques that have been discussed in this textbook. Now this book is of course quite expensive to purchase there is an online edition which is a little bit cheaper than the hard bound copy. But for what it is worth what the content that we will provide from this course should have most of the techniques and their physics enough information will be there for you.

So, that you do not truly need a textbook for the course. But if you do have a chance to purchase any book regarding characterization this would be the one that we had prescribed for you. The second book by Rama Chandra and Beaudoin that is based on handbook of analytical techniques in concrete Science and Technology, again a very good book but it was written quite some time back. So, some of the applications may be a little bit old right now.

Many more interesting methodologies and techniques I have actually come across since the time that this book was written. So, that is what that was 2001 and I am calling it old because this subject of characterization has been evolving significantly in the last decade or two. The book by St. John Poole and Sims although I have given the link to a 1998 edition a newer

Edition is also available of this book those of you who are very in arrested in microscopy this is an absolute Bible to have because it is got amazing images.

It covers the microscopy of concrete to a large detail especially optical microscopy and the kind of images and examples provided in this book are really amazing. So, it is really worth having but again very expensive book to actually purchase. So, again if you find references in papers and in websites for this book, make sure that you always have those because the examples covered in this book are excellent.

The other books that we have provided here the one which is titled material science and engineering it is by William Callister which is a basic text book required to understand the material structure the properties of materials on from an atomic scale. So, that is a textbook that most metallurgy or material science students would use in their first couple of years to really build their fundamentals.

So while it does not directly apply to construction materials the basis of understanding atomic structure the types of bonding in materials and the kind of crystal structures that materials can actually have is very important from the viewpoint of understanding construction materials also as a whole. So, if you really want to get back to understanding things from the very basic constituents of the materials this book is an absolute must-have and it is available for fairly affordable price.

There are Indian editions also available and you can find them in most bookstores it is actually an excellent book to have. The other three books are the which we have included in the last they are all related to actually study of civil engineering materials and concrete. Primarily concrete and other civil engineeringmaterials so these are very specific to civil engineering material studies but they do not really cover the techniques of characterization that we will be talking about in this course.

They talk a little bit more about the macro properties that you are commonly used to measuring in your laboratory studies.

(Refer Slide Time: 11:16)

There are ofcourse tons of web sources available which will give you excellent information on characterization. In fact you will see that many of our lectures are peppered examples that we have taken from various web sources because these days the content that is available on the internet is tremendous and you can actually find content probably that is equivalent to a textbook in many of these websites.

And the advantage of a website is or you can also get content that is over and above what you can actually find in standard textbook because there is no limitation in the space that you need to have for putting stuff on the website. So, one of the very good references is this site from UK basically it talks about very many types of physical techniques and physics and chemistry related processes and how those can be understood by application of different types of characterization techniques.

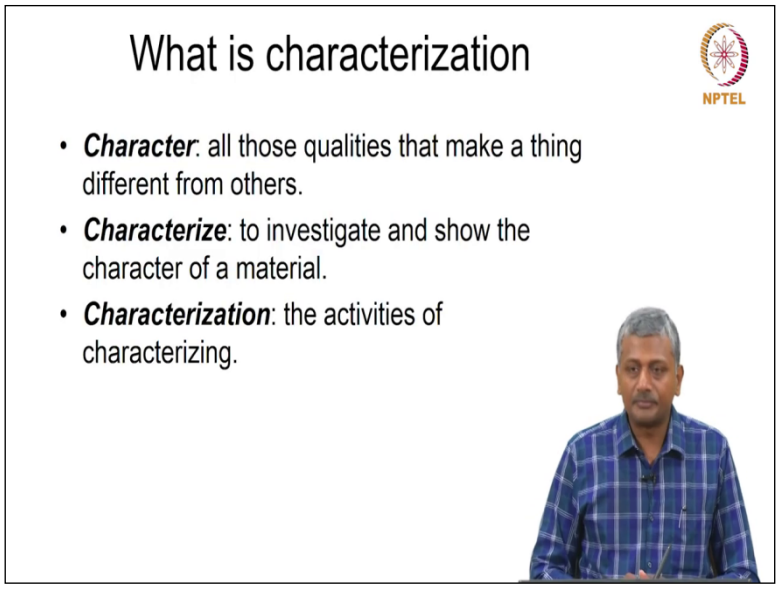
So there is a lot of information given in this and there is also this website from Florida State University in the US which has several different techniques that are explained to a large detail and they also have very interesting animations and tools for improving your learning that you can actually get from these websites. And of course always you have to list Wikipedia is one of the major references because these days you can find anything under the Sun refer to an Wikipedia.

One of the good things about Wikipedia is most of the articles are also referenced you can actually get very good references from the Wikipedia article itself. And then you can look at those references to develop your understanding further. So, Wikipedia is a very well written

most of the times of course in some cases you may find that the pages have not been properly reviewed they are just some paper some pages have been just put by different authors they have not properly been reviewed.

But most of their pages on material signs and characterization have been properly reviewed and properly referenced so you can actually get excellent information from Wikipedia also as far as material science is concerned. But of course you must realize that the Wikipedia pages on characterization are not specifically addressing construction materials but they are applicable to all different types of materials.

(Refer Slide Time: 13:31)

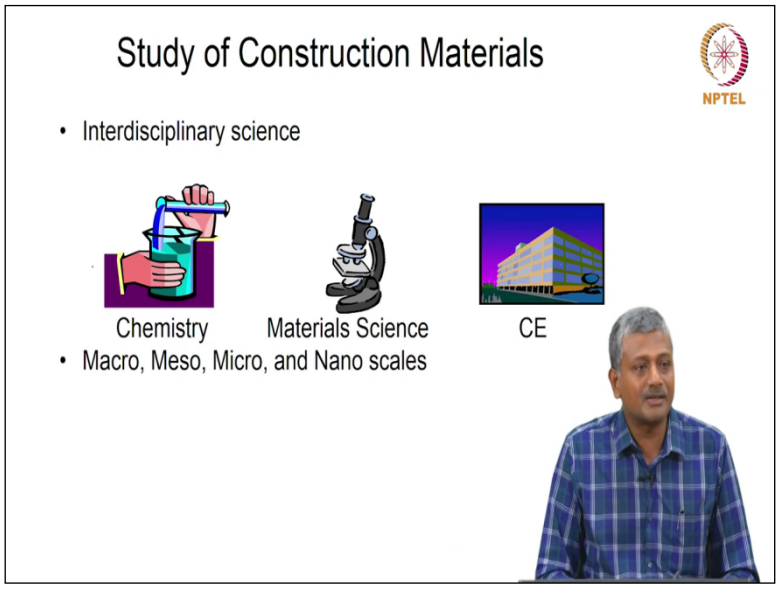


So, having looked at what this course entails and what are the different sources from which you can get information on this course lets talk a little bit about what characterization actually means. Of course you all know very well that character defines a person or defines an object. So, any quality that makes one thing different from others is basically the character of the material and to characterize means we are just investigating and showing the characteristics of the material and characterization is nothing but the activities of characterizing.

So if you had to characterize a human you probably would be characterizing first of all from the gender if the human a male or a female. Within a person you will actually again look for specific characteristics that you can actually give. I am not talking about the intangible characteristics which you do not know about until you actually know the person well enough. I am talking more about the tangible characteristics like the height and weight of a person the colour of the skin.

All these are easy to characterize and that is basically what we are looking at as far as material characterization is also concerned. We want to characterize these aspects to try and understand how these materials behave from the small to the largest scales.

(Refer Slide Time: 14:45)



Now of course you must all know that as far as construction materials are concerned previously we never looked at it in the way that we are looking at it today. Previously or what we were just looking at is how do we actually design with these materials to fulfill the needs of the structure. So, we were mostly in the civil engineering domain and applying the material directly to the study of the structure.

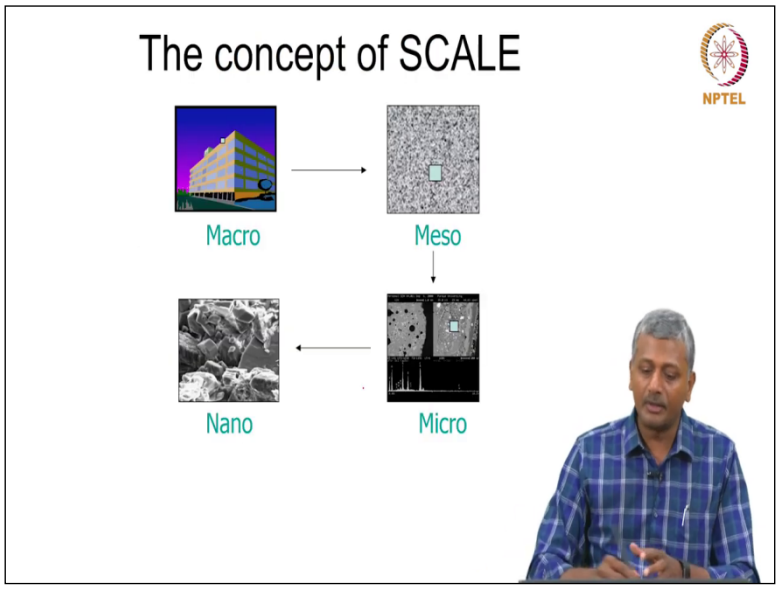
But slowly we realized that unless you really get down to the basic understanding of how this material behaves on the smallest scales for that you need obviously material science and chemistry related studies also only then you can really fulfill the understanding or complete the understanding of this material. And the primary challenge as far as construction material studies or understanding of the behaviour is concerned.

Is how do we link these scale understandings which are developed from your chemistry and material science approaches to the understanding of this material as a component of a large structural system. One of the primary aspects that we already come across here the challenges that we already come across here is the fact that we are talking about chemistry and material science which are performed at very small scales.

So we are looking at extremely small samples of materials that we are investigating. But here in the civil engineering domain we are talking about very large objects. So, how do we reduce those large objects to the small size scales and that is again one of the challenges that we talked about during the discussion on different types of techniques. As to how we can actually get relevant information from the smallest scale to get an understanding of the behaviour of the structure level.

So, of course we can keep on extending different types of scales but for the most part we are dealing with four different scales one is macro which is the performance of the material in the structure. We have meso which means that when we test your concrete specimens in the laboratory.

(Refer Slide Time: 16:34)



Like a concrete cube or a cylinder so that is basically a meso scale. If you go of step further down I am just taking an example of concrete you could apply this to any other construction material also. When you go down to the micro scale what we are looking at is how the paste and the aggregate that make up the concrete are connected to each other. What are the different phase distributions that you find of the paste and the aggregate.

And then finally when you get to nano scale you can characterize the type of hydration products that are forming in the paste when cement reacts with water. You can really get down to a much smaller scale than what we started off when concrete was used in a structural component. So, there are various degrees of studies possible it all depends on what we exactly want to learn about the material.

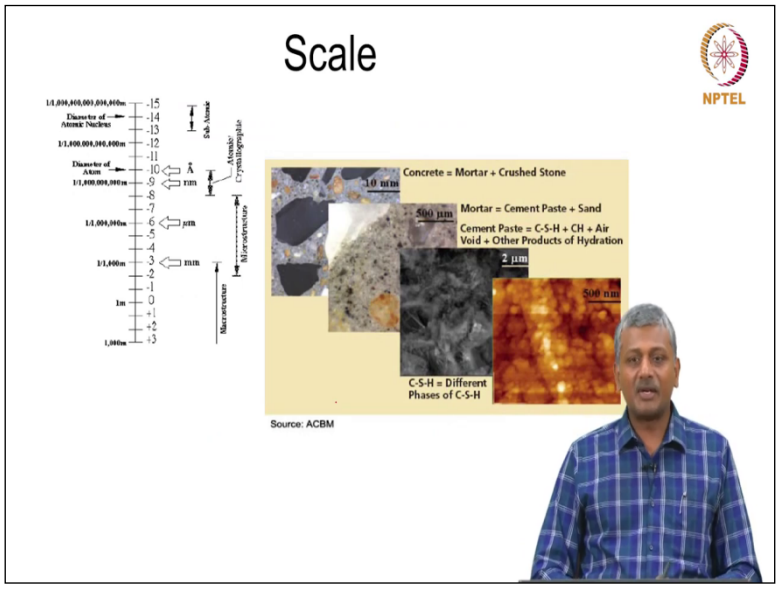
In some cases I do not really need to go here I do not sometimes I may not need to go to the micro scale even sometimes my answers I may be able to get at the micro scale. For example you are doing a design of a concrete you are doing a mix design for concrete. Why would you want to understand how the paste and aggregate phases are distributed in this concrete. You would get the answer directly by measuring the compressive strength on a micro scale using your cube or cylinder specimens.

But if you try to explain why the strength of the concrete obtained in one lab is different from the other your answers may not be that obvious at the macro scales or meso scale. You might have to come down to the scale of how this concrete was actually mixed what was the paste phase to separate out from the aggregate phase. Did the aggregates get distributed uniformly in the concrete.

So all those answers you will not get until you start coming down to the micro and sometimes to the nano scales depending upon the kind of information that you need and the details that are actually needed to support your evidence. So, again you do not have to decide to do smaller scale investigations until it is absolutely necessary. Why do I say that a lot of time is spent in doing investigations and second is cost.

The more sophisticated the investigation the greater is the time spent the greater is the cost. And the more is the difficulty in trying to add to completely relate the material characteristics at different scales. So, deeper you go in understanding the material the more difficulty you will have in explaining it now it sounds contradictory but ultimately that is what you learn from the different techniques that we talked about in this course.

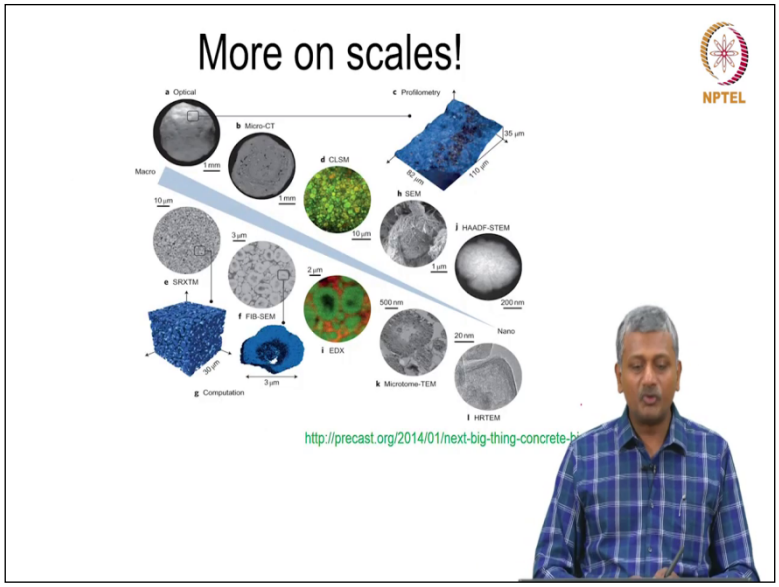
(Refer Slide Time: 19:03)



again I have just given you an example of the scale here so concrete we are talking about the meso scale. When you go down to mortar again you are still at meso scale but you have come down one step lower in terms of the particle sizes. But then you are coming to CSH and trying to understand the different phases of CSH that is probably seen in a micro scale. And if you come down further still you can do atomic force microscopy and address even the texture of the CSH and that can tell you things about different types of CSH and what their characteristics are on a nano scale.

So we are talking about very different scales here and again to completely understand how these scales are related you will have to definitely understand the physics of the technique and how it can be applied to the study of these materials.

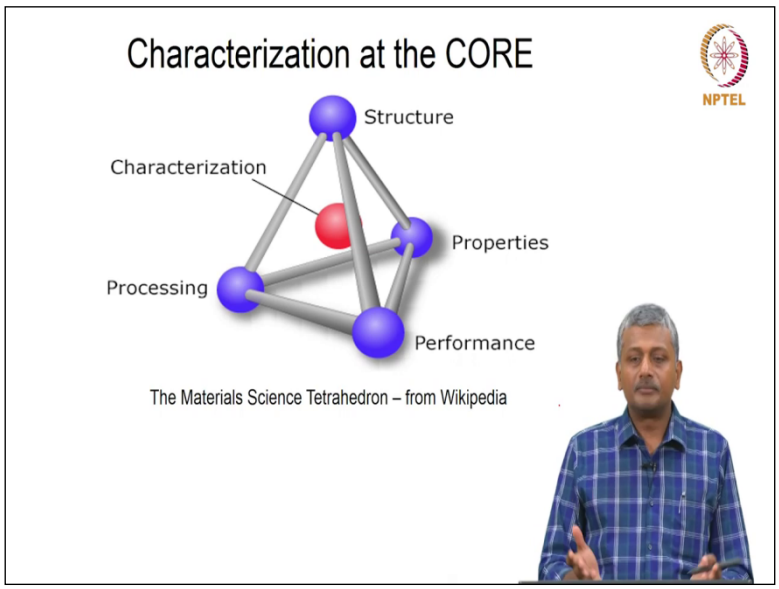
(Refer Slide Time: 19:51)



Again we can take this discussion of scales for any number of materials. But here again there is an example from concrete. So, what type of processes are applied at different types of scales so you have here you have optical microscopy Micro computed tomography using x-rays and then you have SEM and scanning tunnelling microscopy and high resolution transmission electron microscopy.

So, you can actually keep getting more and more sophistication into your techniques and try and investigate material characteristics from the largest to the smallest of scales. But again our work does not end there we have to tie up the information obtained at different scales to put a story that is convergent on all the scales.

(Refer Slide Time: 20:39)



So, I would like to end my part of this lecture by saying that characterization lies at the core of everything that we study about materials. So, if you would like to understand the structure you need to characterize you need to understand properties or performance is still need to characterize and based upon your understanding of the structure and the properties if you have to fine-tune the processes to produce a material that has a slightly different structure.

Again for that you need the characterization to be done. So characterization is at the core of this material science tetrahedron again it is again obtained from Wikipedia but this is there you can probably find this information in most material science textbooks. So, let me stop and I request now my colleague Dr. Piyush to continue with this talk further. And he will talk about how characterization can be applied to the study of different types of processes and techniques, thank you.