Basic construction materials
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Lecture 02
Introduction to Construction Materials - Part 2

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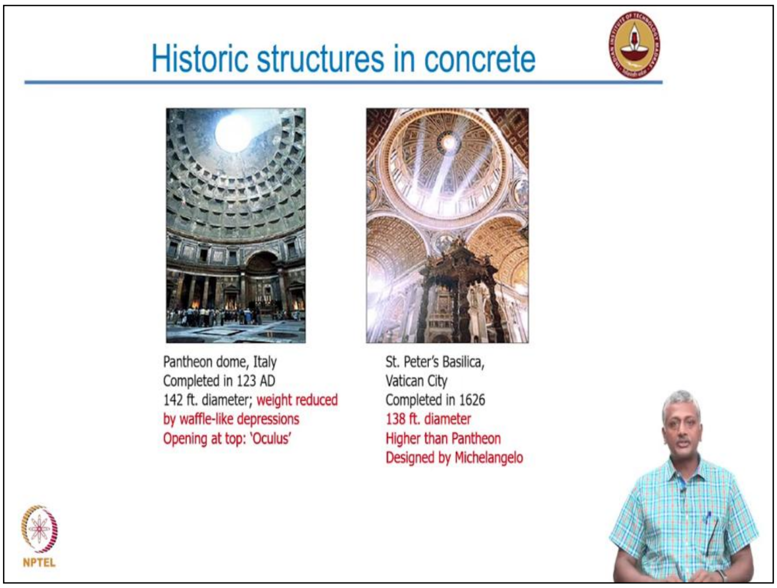

Some iconic structures, historic structures in concrete, I don't know many of you may have seen this in various pictures and various books. This is the pantheon dome in Italy. This was made with concrete but of course it was not using cement as we know it today. The cement that was used at that time may have been a mixture of lime and some pozzolanic material.

So, this is a dome structure. The entire concrete is in compression. In arches and domes, you only get compression and so you can easily use concrete or stone in those cases, because concrete and stone which are otherwise very poor in tension will never feel tension in this kind of a structure. So that's why many of the older structures that are still standing in spite of all the earthquakes in Italy are basically the ones which have arches and domes.

Now this is again Saint Peter's Basilica in Vatican City, which was a lot more recent. This pantheon dome is 123 AD whereas saint peter's basilica is 1626 AD. So it's about 400 years back, but still it is magnificent structure. It is still standing without much problems.

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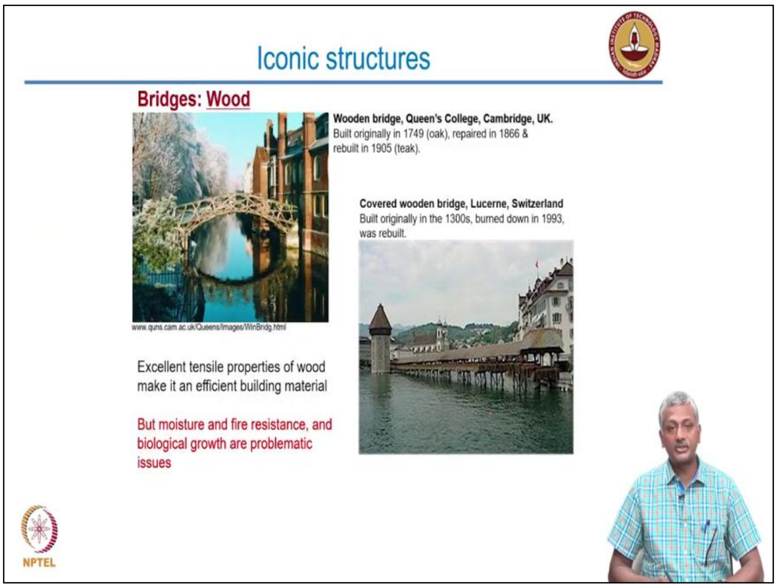

Iconic structures in wood - there are many bridges around the around the world which are really beautiful to look at and very efficient because wood is a material that is highly efficient in construction. Wood can give you excellent properties both in compression and tension. And because it can work very well as a tensile material, you can build entire structures with just wood. In many of the western countries, people build their own homes. They just go to a market and buy wood and come back. They have good training in carpentry and all that and they actually do the design of the entire superstructure on their own. They only get concrete and stone for the foundation, fill it up and then they do the entire structure on the top on their own. People build their own house. That's because wood is such an easy material to build with, if you have understood the basics of carpentry and jointing you can do a very good job with wood for construction.

Only problem with wood is obviously moisture, fire resistance. Moisture can damage the wood and change its property significantly, if you have not seasoned it well enough it will start warping and changing its shape.

Fire resistance is an obvious problem with wood and of course biological growth. You will have easy biological growth and also wood can give place to all these insects like termites, which will end up totally degrading the quality of the material.

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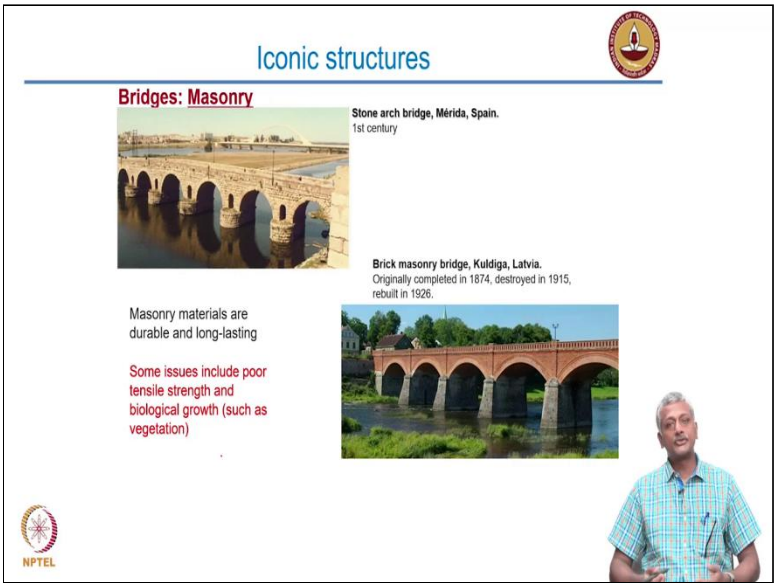

Masonry of course as I said, it is highly durable and it lasts for a very long time. Some very good examples are given here from different parts of the world. Some issues obviously include poor tensile stress. And masonry also can have biological growth; sometimes vegetation. In some old buildings which are made with brick or stone masonry, you may start seeing that not just algae but full scale plants and shrubs are growing through these structures. That's because of the porosity and the kind of environment that is provided by the brick.

Brick is essentially made with clay. Silica and alumina is in plenty. So if you have the porosity and the water availability, plants can grow quite easily on masonry structures. So, this biological growth is a common problem in masonry structures.

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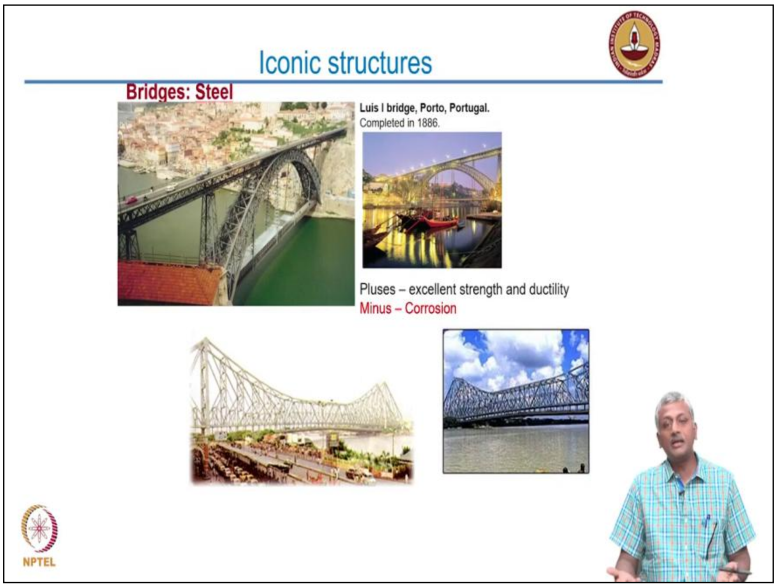

Steel - many of our old Railway bridges are completely made with steel. Many of the world's tallest skyscrapers are also made with steel. Of course not the tallest one, I will come to that in just a minute. So, excellent strength and ductility of steel make it a very good material for construction. Ductility means steel has the capability of deforming significantly before it actually fails. In structures, we want to design structures that are durable and ductile.

We want them to be ductile because any indication of failure should be slow and long, so that people realize that there is something wrong going on and get to safety before the building collapses. If you build a structure which is brittle, it will collapse suddenly and that will lead to loss of life. So again, I don’t have to ask you to guess what structure is being shown here, this is the iconic Howrah Bridge in Calcutta.

One of the minuses obviously is the corrosion of the steel. So steel is basically Fe with some carbon. It has to go back to its original state. How is it found in natural state? It is found as an oxide, either Fe_2O_3 (Hematite) or Fe_3O_4 (Magnetite). So, steel has to go back to its oxide state because of which it will corrode eventually. So all the efforts in steel construction are usually towards not just providing strength and stability; that’s the first thing obviously structural engineers do, but then you also need to provide protection mechanisms to ensure that the steel has a prolonged life against corrosion.

You may have also heard that the World Trade Centre that collapsed in the 2001 bombing or the plane crashing into the towers in 2001. The structural collapse happened because the structure was a steel structure. The structural collapse basically got aggravated and the structure disintegrated primarily because of steel component.

The main load carrying structure was all steel. So if you have a fire, that will very quickly reduce the properties like strength and elastic modulus of the steel and it starts crumbling. If it had been a concrete structure, it may have withstood a very long time and more people may have been saved. Anyway that’s only a moot point, we don’t know.

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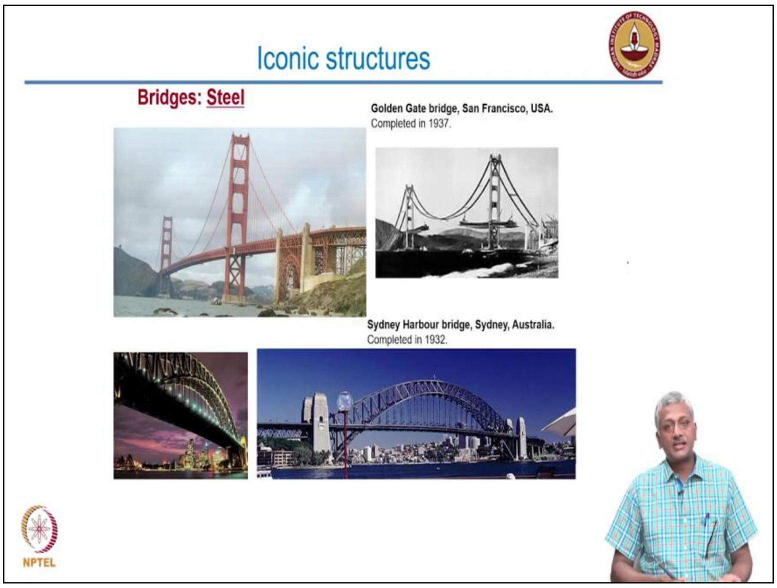

There are several bridges in steel obviously, which are iconic. Again, no prizes for guessing this bridge here, this is the golden gate bridge. This is a very interesting bridge here, again a suspension bridge looks similar to golden gate, but you see that it's broken. If you do a Google search, you will come across this bridge called Tacoma Narrows Bridge. Tacoma narrows bridge, a very interesting bridge that failed because of very high wind forces.

And of course, in Sydney you have the Sydney harbour bridge, which is again an iconic steel structure.

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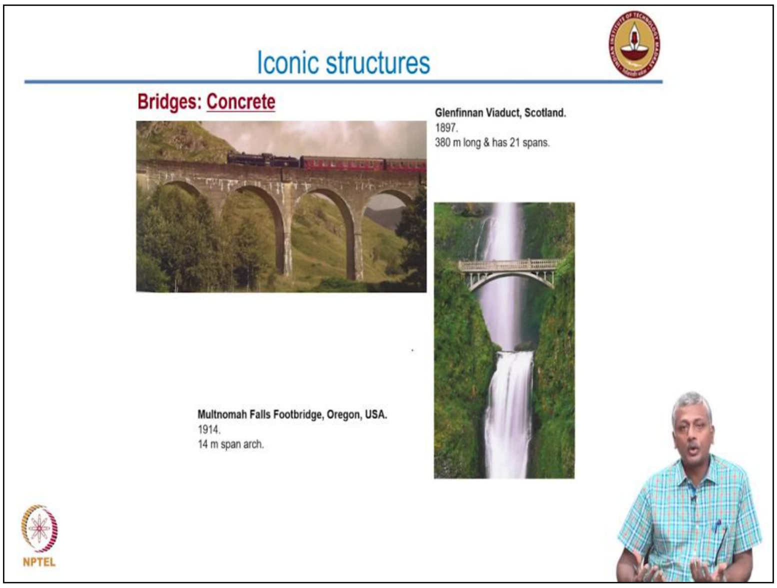

As far as concrete bridges are concerned, they are found all over the world. This one, you may recognize this bridge from the movie harry potter. This was one of the scenes where the Hogwarts express basically going towards the Hogwarts school. It goes and crosses across this bridge. This is called the Glenfinnan Viaduct in Scotland. And look at this very interesting footbridge in a very scenic location. These are all concrete bridges.

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Concrete, of course I mean reinforced concrete. These are not plain concrete but these are reinforced concrete bridges. This is the very interesting bridge in Meghalaya, which is at a very high level. Again this is a Confederation bridge in Canada, which goes across the sea for a long distance.

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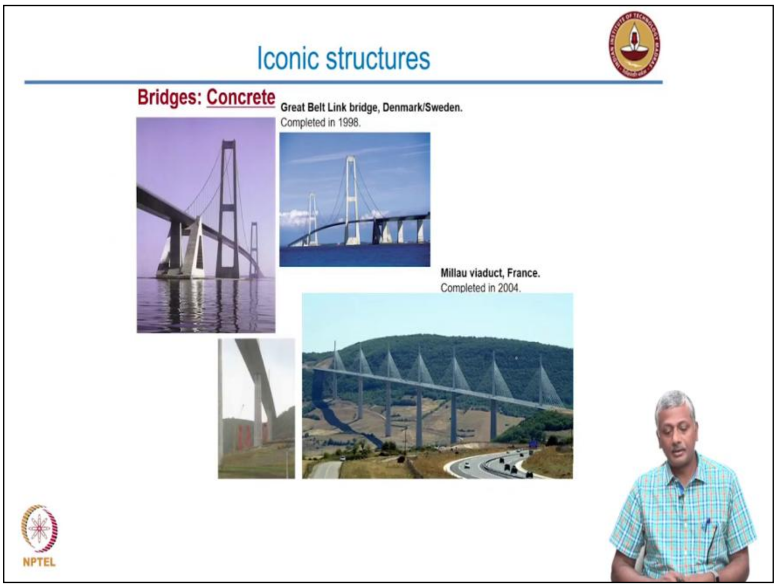

Great Belt Link between Denmark and Sweden basically connected with the reinforced concrete bridge. And again one of the iconic structures of the modern construction era is the Millau Viaduct in France.

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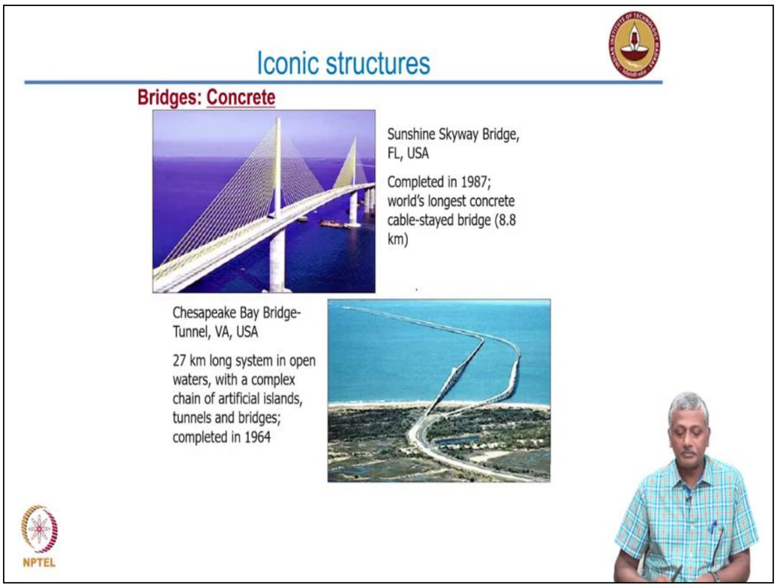

There are several other examples like the Sunshine Skyway Bridge which is shown here and this Chesapeake Bay Bridge tunnel. This structure is partly a bridge and then becomes a tunnel and then comes out again as a bridge.

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Composite structures are today being used quite extensively in making bridges and pipes. This is example of a concrete pipe where carbon shells are filled with lightweight concrete and even used as girder sometimes. Girder is basically a beam. You can see here, glass fiber reinforced polymer deck. All the cavities indicate that the weight of the structure has been reduced because the ribs themselves are strong enough to actually bear the load.

And this example is of a storm water channel bridge made with a composite structure out of this glass fiber reinforced concrete polymer deck. So composites basically work on the synergy that you get from different combinations of materials.

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Wood buildings of course are all over the world. In India also you can find quite a few examples. These are examples from Kerala and Tamilnadu.

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Stone masonry - common examples are, you have your buildings made with stone masonry like the Qutab Minar. Buildings made of concrete - lot of examples are there, the Petronas twin towers in Kuala Lumpur, iconic landmark from the world.

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Burj Khalifa, everybody knows about this now. In 2010, it was unveiled as the tallest building in the world. Interestingly it has a concrete up to about 600 meters and the remaining part of about 228 meters is in steel. The interesting fact is that, the concrete part which is up to 600 meters costs less than the steel part that is forming only the last 228 meters. So you can just imagine the kind of impact in terms of material cost. It is lesser for the concrete part that is in the 600 meters below. And this is actually a steel frame building, Sears tower in Chicago, a very famous building.

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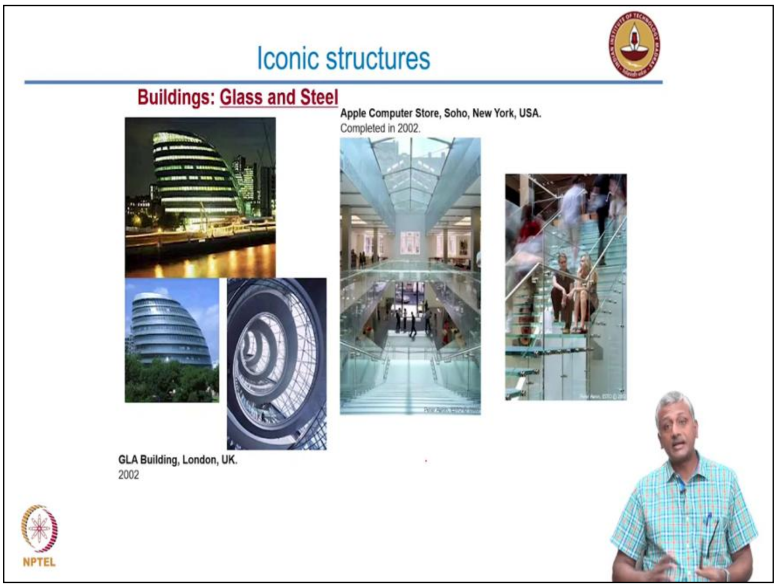

As I already said, the Empire State building is in steel. The World Trade Center twin towers in New York that were brought down by Osama Bin Laden's planes crashing into them, they were also seal structures.

Modern buildings also use a lot of glass along with steel. You can see the intelligent use of glass to provide a good quality aesthetic appearance. And this is what I was talking about. Here of course, you have glass and steel combined to make a nice structure but sometimes what we have in India are regular reinforced concrete structures, which are simply cladded with glass. So those are not really the same as composite sort of a construction.

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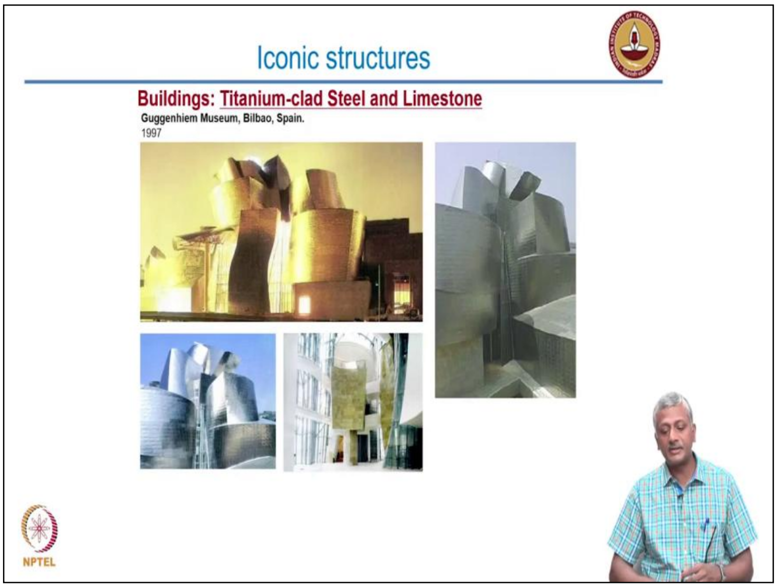

Here, this is a titanium-clad steel and limestone, which has been used in the Guggenhiem Museum. Again it is an iconic structure, many of you may recognize it from the pictures that are shown here.

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Dams made of concrete are all over the world, most popular one being the Hoover dam and the Aswan dam in Egypt.

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I have shown you examples of several structures. There are obvious reasons why some materials made it to these structures, why they were used there and so on. But as far as how we think about the usage of materials in future, what are some of the things that we need to start thinking about?

One is the dwindling resources. We want to make a lot of structures with concrete. Concrete utilizes a lot of cement, stone and sand. Where do we get these quantities of stone and sand that are required to produce the concrete? How do we produce so much cement? Cement depends a lot on limestone and we have to find that out if limestone is available in such quantities or not. We have to conserve the existing resources and start using alternative materials to reduce the impact or the burden on the earth, where we are mining for these resources. Because we are changing geology significantly by mining the resources, we are adversely impacting the environment.

In some cases like the choice of materials like concrete, we have heterogeneity in the material. We have materials which are combining different sizes. Cement is a powder, stone and sand are particles that are of different sizes. We are combining all these in a matrix with water and this becomes a composite. And because of this, we get heterogeneity and unpredictability in terms of the performance. So that is something of a challenge and material scientists or concrete technologists have to learn as to how to mitigate these challenges.

Now we want to increase life span of materials and also service life the structures. And we have to use suitable models that can do this, because we can’t keep testing materials all the time. After we get sufficient experience and confidence in the tests that we have carried out on materials, we need to have suitable models to describe their behaviour in real practice.

And finally as I said, as modern engineers we always need to choose sustainable options. Many of you may have come across the term green rating for a building. If you look at some buildings, they would have said outside the building that this is a LEED rated building, this is a Gold rated building from LEED. LEED is an agency that certifies buildings for their sustainability impact.

Now, very often there are lot of components that go into making the sustainable option. And one of the component is the choice of a good quality material as well as material that is having a good benefit to cost ratio, not just in terms of economy, but also in terms of the environmental impact.

So all that needs to be considered and calculated to really formulate an opinion; whether the option that you are considering, whether it be a material or a process or a technology or a structure, is it sustainable or not.

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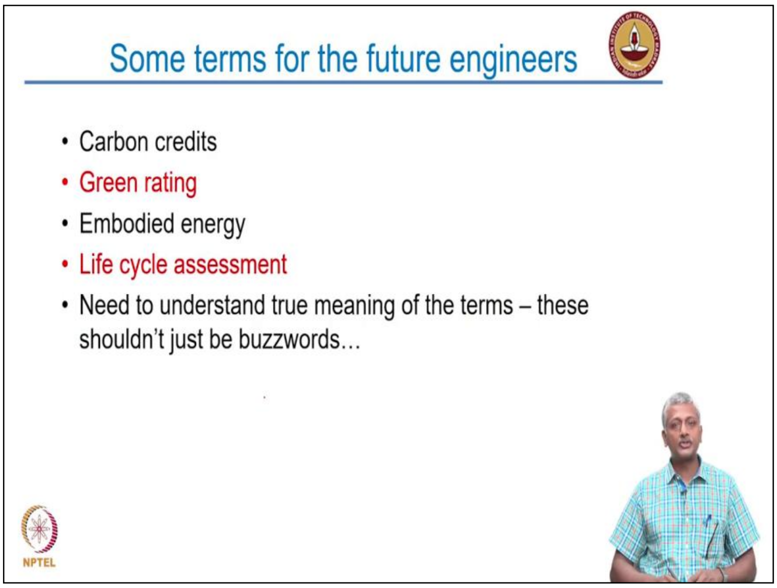

As future engineers, you may have to use some of these terms quite frequently. Carbon credits, this is a term that you come across quite often today or Carbon tax in some cases. A technology that evolves less carbon dioxide and less energy essentially gets carbon credits.

The technology that is poor in terms of carbon dioxide emission will be taxed heavily. So that is a carbon tax.

Green rating, I already talked about. Most buildings today have green ratings which they get from different certifying agencies. Essentially this rating is dependent upon, how the choice of materials and the technologies for construction have led to a low energy in the building as well as a low CO_2 emission.

If you do a Google search for Net-zero energy buildings, you will find a lot of very interesting examples. What is Net-zero energy building? That means a building that has consumed so much energy to be brought up and will consume so much energy during its life cycle. But at the same time, the same building is capable of producing an equivalent amount of energy over its entire life cycle. That means the usage and production of the energy cancel out. So that is a net zero energy building concept.

Embodied energy is again a concept that you will come across very often today. It basically talks about what amount of energy it took to actually bring the material to the current state in which it is servicing in a given structure.

Life cycle assessment is again a common term you hear today. Life cycle assessment deals with assessing, how over the entire life cycle of the material or the structure your impact will be on the environment, on the economy and on the society.

So, as good engineers you have to understand the true meaning of these terms. These are not just buzzwords that you use, putting in your resumes and so on. That is not the idea. The idea is to be good engineers to make decisions that will impact the earth in a positive way. You have to understand the true meaning of these terms.

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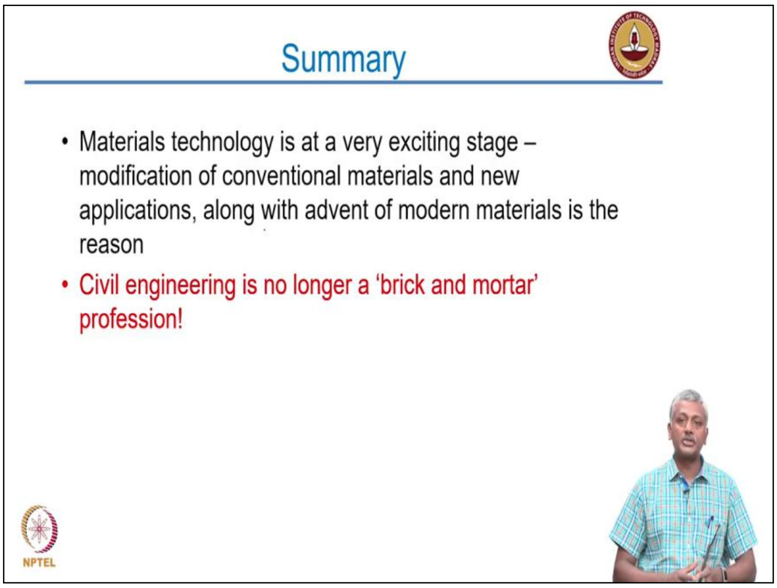

So, with that we come to the end of the introductory part. I will just quickly summarize what I talked about. I said materials technology today is at a very exciting stage, we are talking about a completely different perspective with which we actually see these materials. We looked at conventional materials that are getting modified for different applications and with the advent of modern materials we are able to now combine characteristics, which previously were not achievable with conventional materials.

In summary, civil engineering is no longer a brick and mortar profession. There are several challenges which are going to consume a lot of time of high quality engineers all over the world and you should be one of them too. So with those words of an introduction, let me talk about what the learning objectives are in this particular course.

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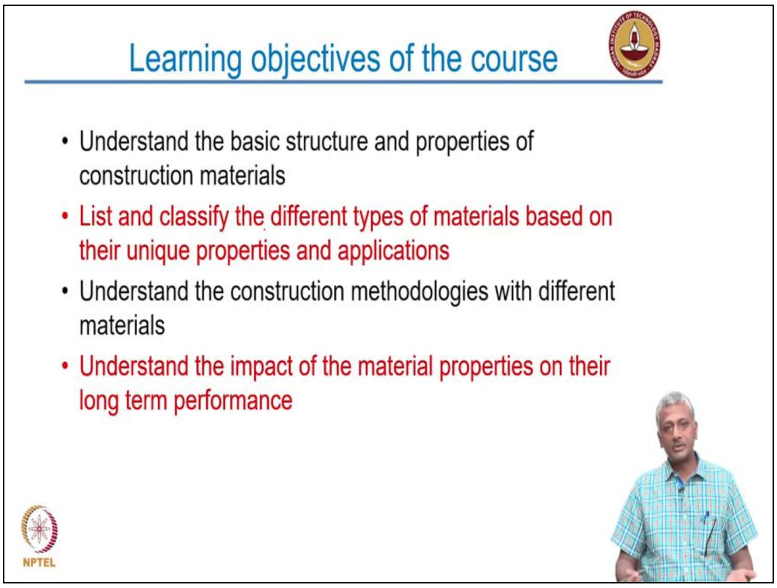

So this course is about construction materials. The first and foremost objective is obviously to understand the basic structure and properties of construction materials. We have to be able to also list and classify the different types of materials based upon their unique properties and applications. We will also look at construction methodologies with these materials, understand the construction methodologies with different materials.

So how do you actually build out of masonry? What kind of arrangements do you have for the blocks? How do you build with reinforced concrete? How do you build with prestressed concrete and so on.

Then finally, understanding the impact of material properties on their long-term performance. How does the choice of a certain type of ingredient affect the way that the material will behave in the long term and how will it affect the overall life of the structure. So that's something also we will talk about in this course.

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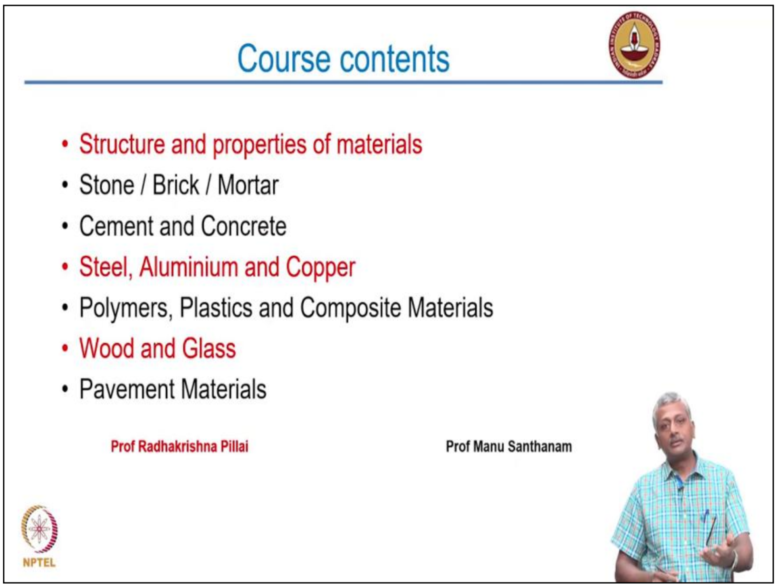

So just to give you the idea of course content, we have the next few lectures will be by Dr. Radhakrishna Pillai on structure and properties of materials. Then from my side, I will talk first about stone, brick and mortar, essentially masonry materials and then I will talk about cement and concrete. This will be followed again by Dr. Pillai, talking about steel, aluminium and copper. And I will then talk about polymers, plastics and composite materials.

The last two segments, one is by Dr. Pillai on wood and glass and then the final segment will be on pavement materials, essentially I will talk more about bituminous concrete and I will also briefly touch upon the use of cement concrete for pavements.

I hope that this course will be extremely useful to you. As I said, it builds the fundamental foundation on which you are going to be moving forward with the higher level courses in civil engineering, thank you.