Advanced Design of Steel Structures
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Lecture - 07
Material properties - 2

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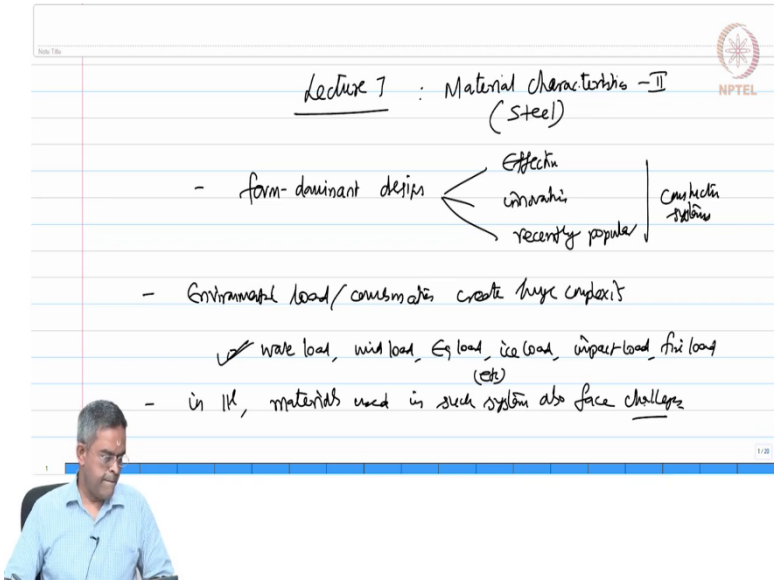

Friends, welcome to the 7th lecture on advanced field design course. This lecture is again going to focus on Material characteristics. We are going to again emphasize on steel as a construction material as per our engineering choice. So, we learnt about something off form dominant design, which is quite effective via innovative and recently popular in construction systems.

We already said that form dominant design or form dominant approach is not a new one, but arches, cable stage bridges, large span structural systems using thin shell members were all in practice for years and years. We are now formally trying to understand how this can be helpful in alleviating the applied loads on the system and we are now going away from a conventional approach of strength-based design to geometric based design.

So, the material chosen for this purpose should support the challenges what the structural system shall encounter and what are those characteristics which makes steel as special that is

the focus. So, we understand now environmental loads and their combinations create huge complexity in design.

For example, wave load, wind load, earthquake load, ice load, impact load, fire load, etcetera, are few examples which can get combined as the worst and rare events to cause huge complexities on the structural members. So, when we say this that form dominant design is able to sustain this combination successfully in parallel materials used in such systems also face challenges.

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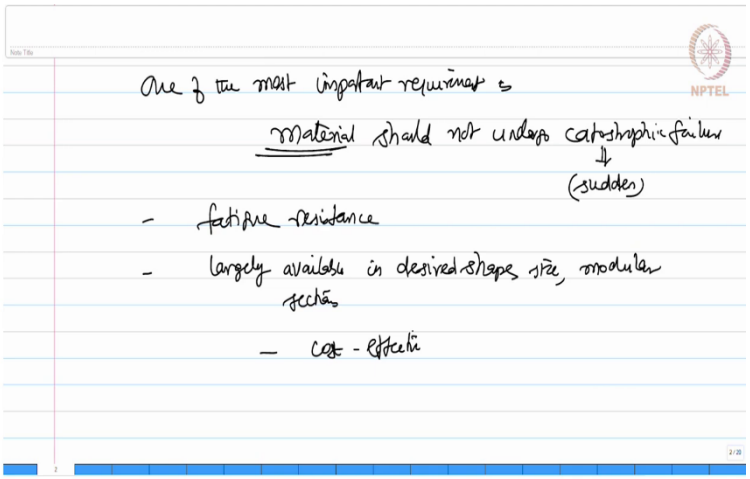

So, one of the most important requirement is that material should not fail or should not undergo catastrophic failure. Please re-emphasize the statement, I am talking about the material failure not the structure. Material should not undergo a catastrophic failure. Catastrophic in sense to make it very simple it should not initiate a sudden failure that is the foremost.

The other requirements could be it should possess a good fatigue resistance, then it should be it should be largely available in desired shape, size, modular sections, apart from being cost effective. We are looking for these kind of objectives when we choose materials for construction.

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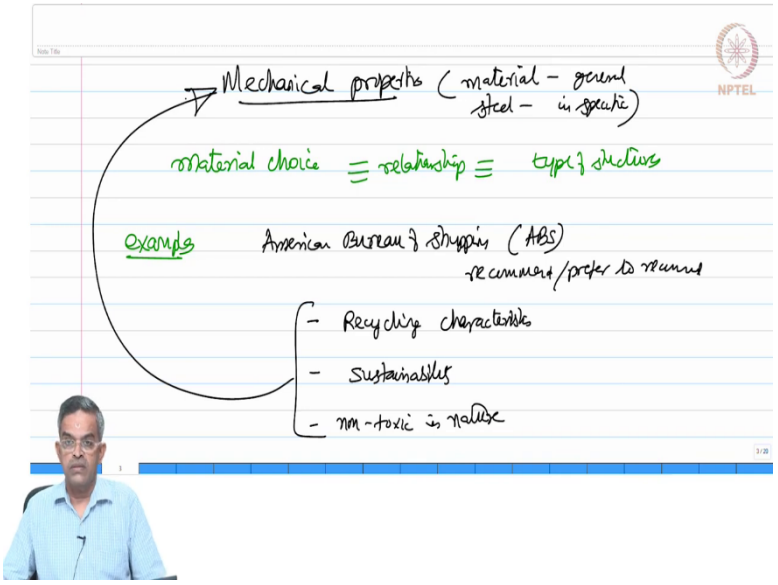

So, let us try to pay attention on the mechanical properties of the material, in general and steel in specific. We must agree on a common statement that, material choice has a very strong relationship with type of structure. You cannot apply a common material to all types of structures because the functional requirement of varieties of structures are different.

Therefore, the material choice has got a very strong relationship, one to one correspondence to the type of structure you are going to design, we can give some example. According to American Bureau of Shipping, which will popularly called as ADS which is one of the important guideline of governing design in United states, recommend prefer to recommend.

The following characteristics for design of structures in marine environment recycling, sustainability and nontoxic in nature in addition to the classical mechanical properties which are essentially required for a material to use as a structural material. We cannot overcome though those properties. They anyway exist. They are in addition to that, these are in addition to that.

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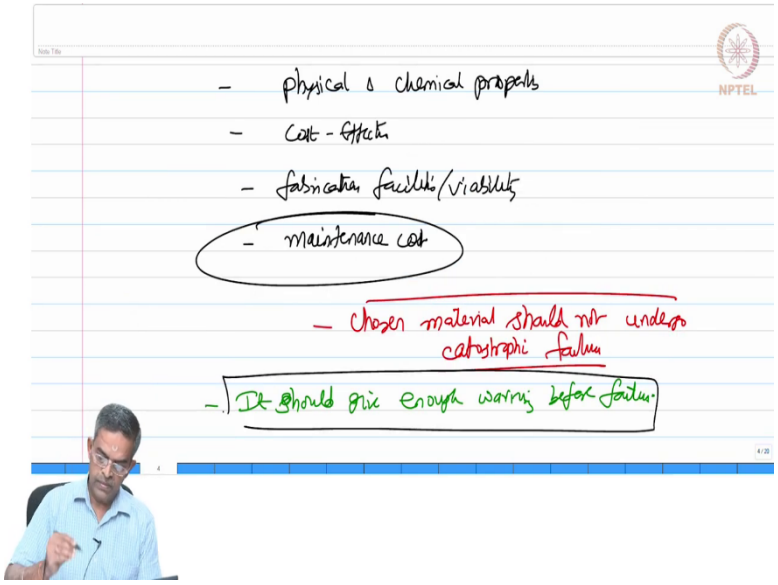

Further they also emphasize on physical and chemical properties, cost effective, fabrication facilities and their viability of fabrication and of course, most importantly the maintenance cost. In addition, the chosen material let us emphasize this again, should not possess or should not undergo catastrophic failure. That is an important statement. Then what does it do?

It should give enough warning before failure. Friends, one may wonder that how material can give warning. Structural system gives warning as per the design we know we can recollect them.

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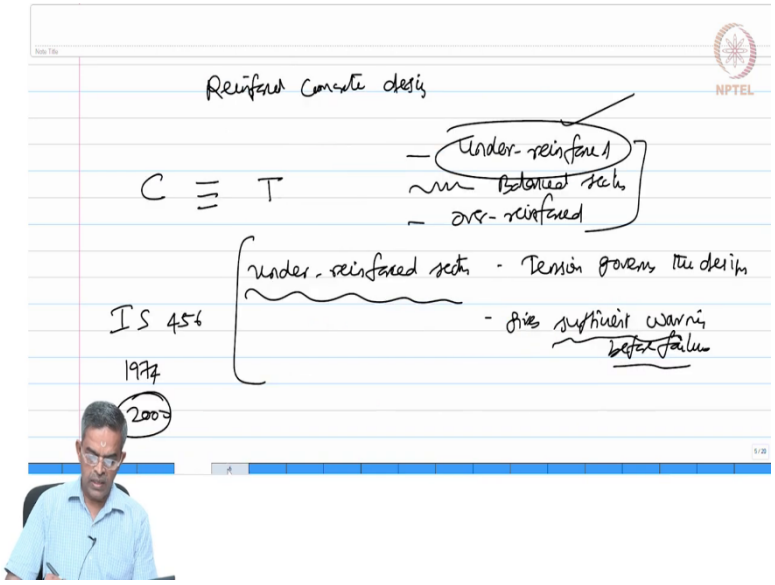

When you talk about reinforced concrete design, we hear something called under reinforced sections, we also have something called over reinforced sections and we have an hypothetical case which is called a balanced section. So, the principle in this hall the three is if C stands for the total compressive force acting on the cross section and T stands for the total tensile force acting on the cross section, for a balance section they should be identically equal, for a balance section identically equal.

But we prefer to design an under reinforced section considering that under reinforced sections where tension governs the design gives sufficient warning before it fails. This was the design philosophy what we had in Indian Code 456 right from 1974 till even 2000 year of revision.

So, I agree that the design can emphasize that it should give sufficient warning, it does not talk about the material is the choice of the section understand that. But what I am emphasizing here is the material should give warning that is what we are looking at. So, it is we are looking at different philosophy.

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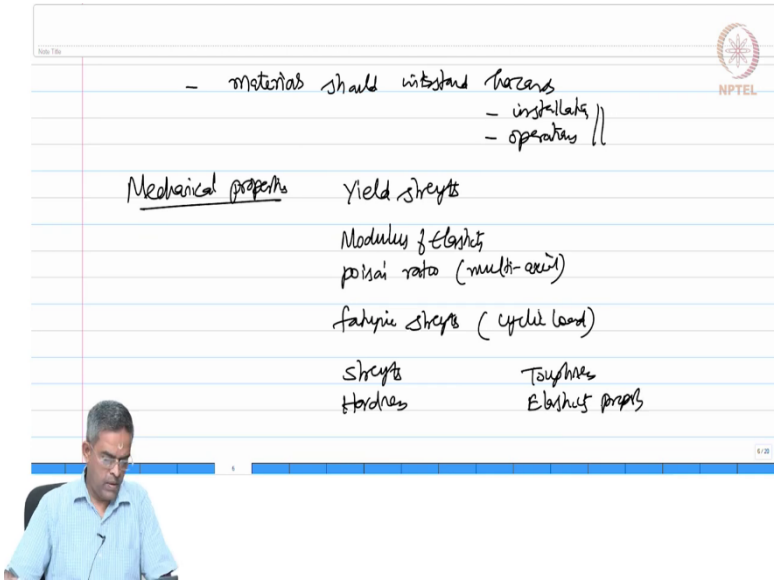

Furthermore, materials should withstand hazards that R is during installation and operations. Under this context what are those mechanical properties which are important? These are the requirements. Let us say which mechanical properties reflect this requirements, let us see them. Yield strength, modulus of elasticity, Poisson's ratio.

Because this is important for multi axial loading systems which is very common, fatigue performance or fatigue strength, because this is important for cyclic loads which is also necessary in the present case. We look for strength of the material, we look for hardness of the material, we look for toughness of the material, we also look for elasticity property of the material.

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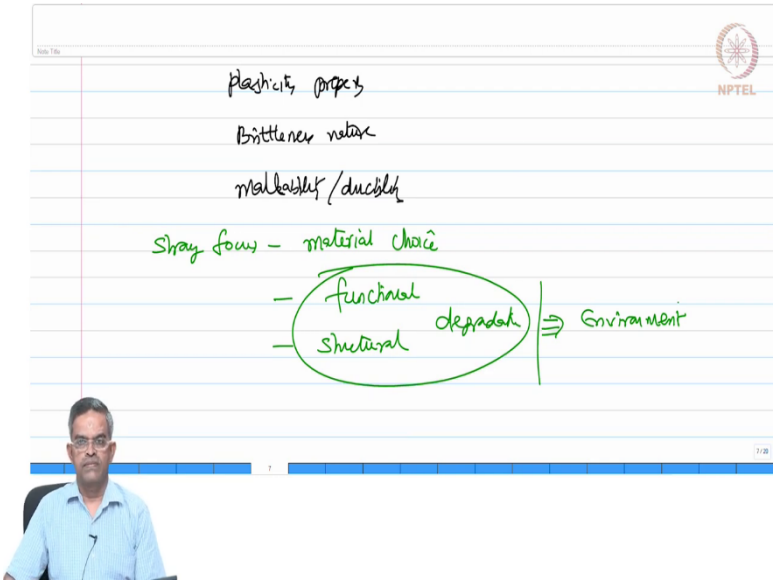

We look for plasticity property of the material, we also check the brittleness nature of the material and we also be sure the material should have enough malleability and of course, ductility. So, these properties listed will help us to choose a variety of materials available in the literature so that they can be sufficiently placed in the structure to encounter the forces acting on the member.

So now, if you ask me a general question, what should be the strong focus in material choice? The strong focus in material choice is the functional and structural degradation. So, the material what we choose should not functionally and structurally degrade as ages of the structure.

So, this can be checked with respect to the environment. So, we are now looking for a system which can sustain the forces with the help of geometric complacency. In addition to that the material should also support the system to sustain them in the given environment, without undergoing functional and structural degradation.

At any point of time the material should not expose and initiate a catastrophic failure, it should give sufficient warning before it fails.

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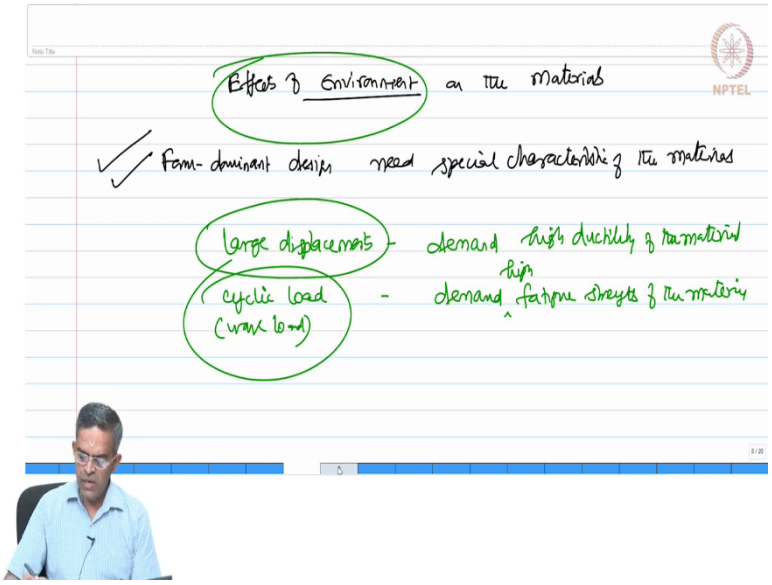

Having said this when we talk about the interaction of environment on the material, let us see now, what are the effects of environment on the materials. We have already agreed upon one fact that form dominant design requires special characteristic materials, we already said that. We already agreed that form dominant designs need special characteristics of the materials. We already agreed this.

So, now large displacements which are a common feature in this kind of compliant structures or form dominant structural systems, demand, high ductility of the material. Cyclic loads acting on the structure which arise from the environment for example, wave load is a cyclic load. There is a possibility of reversal of wave loads in terms of its direction amplitude and both. They demand fatigue strength of the material high fatigue strength of the material.

So, friends please see we are trying to relate the effect of environment and material this is from the environment, this is from the form dominant compliancy of the structural system design.

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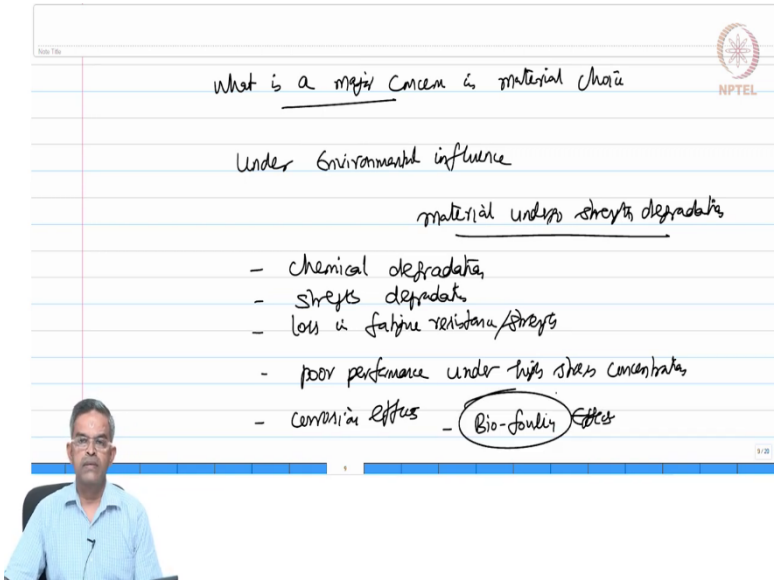

So, if you ask me a question what is one of the major concerns in materials? One of the major concerns in the material choice in environmental approach or environmental influence, let us put it like this. Under environmental influence, materials undergo strength degradation.

So, let us quickly see what are those degradations. They undergo chemical degradation, strength degradation, loss in fatigue resistance or fatigue strength, poor performance under high stress concentration, corrosion and of course, bio fouling. Is one of the major concern the recent trend of Environmental Protection Act that the material used in marine environment specifically should be bio friendly.

So, bio fouling effects are a major concern when you want to choose a material for construction or repair or even painting of let us say ships, offshore, structures etcetera, the material choice is to be done very carefully.

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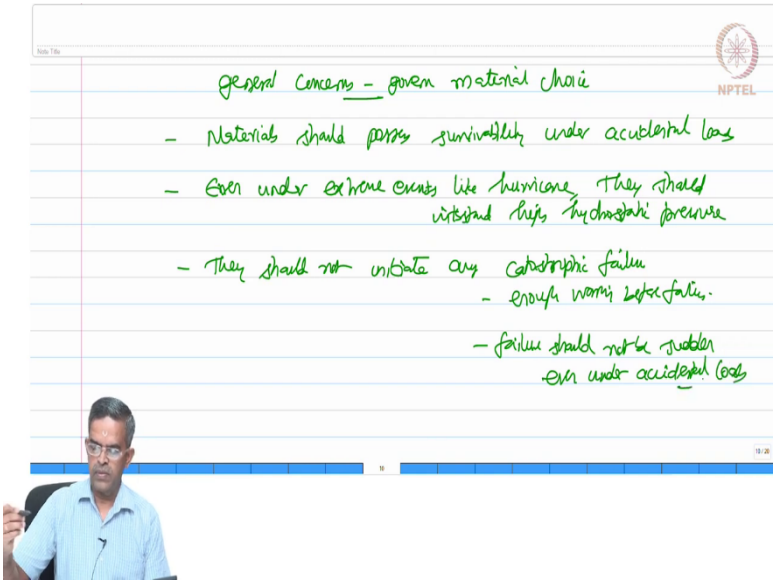

In addition to that, what are other general concerns that govern the material choice? The other concerns are material should possess survivability under accidental loads. Even under extreme cases like hurricane they should be able to withstand very high hydrostatic pressure. They should not initiate any catastrophic failure. It should give enough warning before failure. The failure should not be sudden even under accidental loads.

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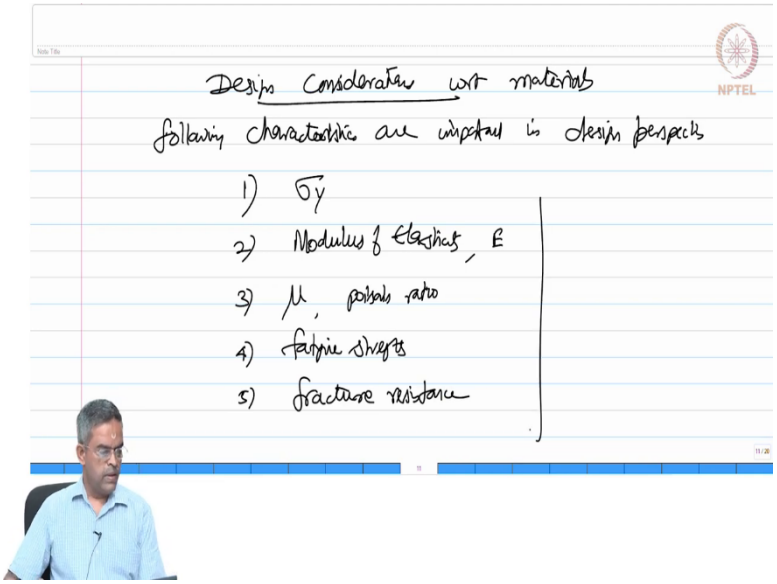

Now, let us focus on the design considerations with respect to materials. We have looked upon the environmental considerations on materials, now we look into the design

consideration on materials. Following properties of the material or following characteristics are important in design perspective.

1 the yield strength of the material, 2 Modulus of elasticity, 3 Poisson's ratio, 4 fatigue strength of the material and 5 fracture resistance of the material. In general, if you ask me a question, how this is handled in design.

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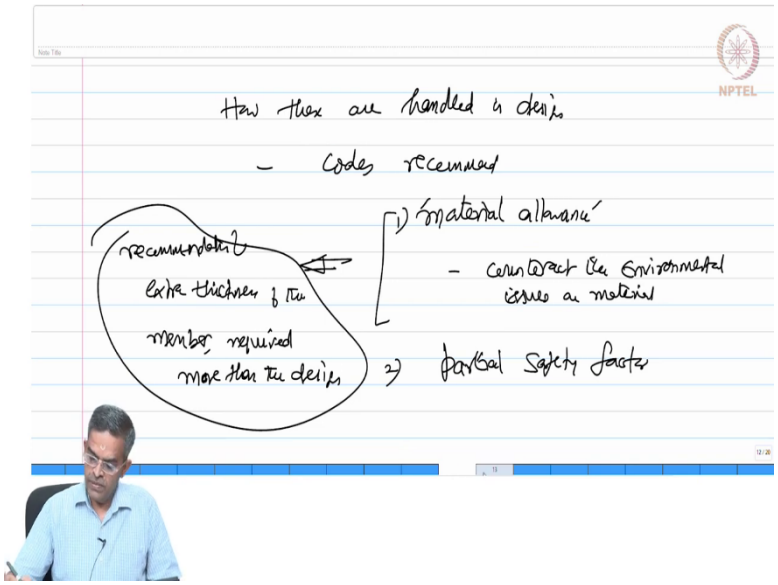

How these are handled in design? Codes handle them slightly in a different manner. Codes recommend material allowance, which can encounter or which can counteract the environmental issues on materials. Let us quickly ask a question what is material relevance. Material relevance is actually recommendation of extra thickness of the member, required more than the design.

This is one way of doing it. One way of doing it is material relevance. The second way of doing it is of course, we all know that you can recollect them that is in procedure. We use what is called partial safety factor to take care of these effects in the design. This is not new we have been doing this. Friends, let us come to an important segment of understanding now.

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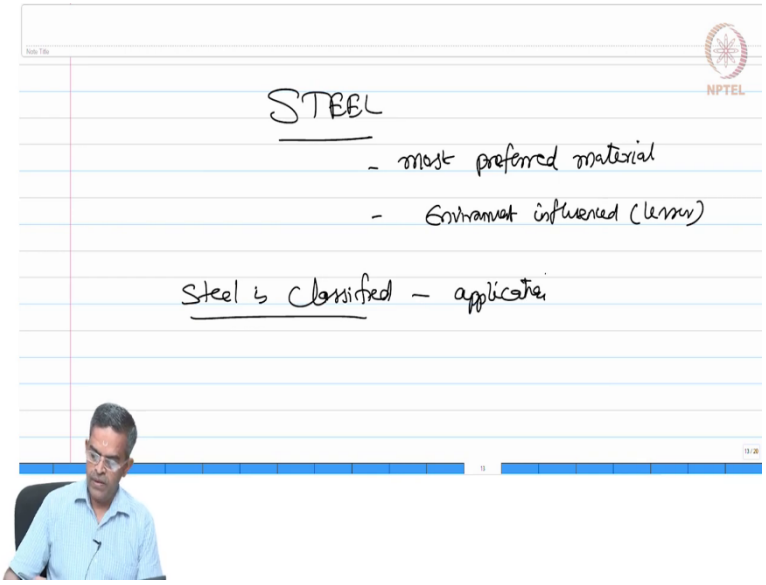

If steel is taken as the most preferred material for engineering construction for engineering construction and it is also accepted to be environmentally influenced in a lesser manner then interestingly steel is classified according to its application.

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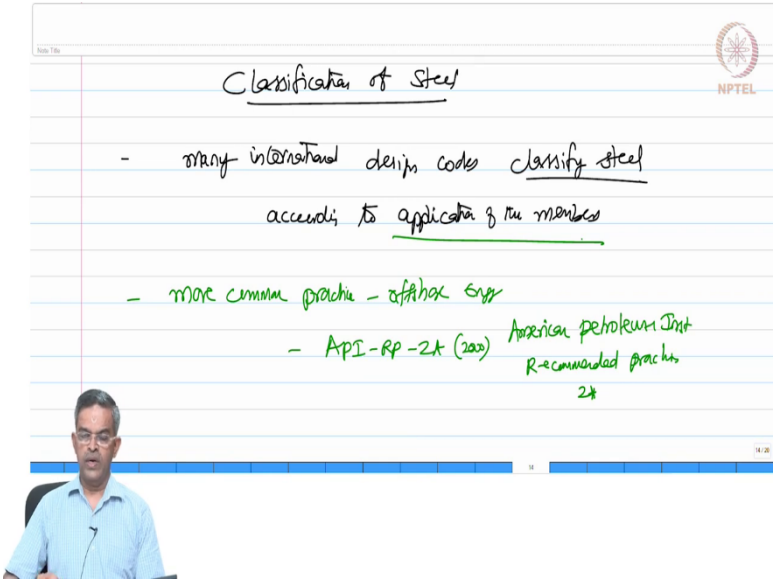

So, now let us see classification of steel. Friends, all codes do not do this. Major codes major design codes around the world do this classification. I will give you the name of the codes slightly the end of this lecture, but major international codes and Indian Code also do this classification. Let us first understand how this classification is done.

First let us try to learn that many international codes design codes, classify steel according to application of the members. To be very interesting this is more common practice in offshore engineering. And I am sure in land-based structures this application or classification is not common, but this is very common in offshore engineering.

For example, API-RP-2A American Petroleum Institute-Recommended Practice-2A the year of revision 2000. Classify steel for various applications of offshore structural members. For example, what should be the material or classification of steel for piles, what should be the classification of steel for bracing and patterns, what should be the classification of steel for the top deck for the hull of the vessels, propellers of the vessel and ships, etcetera.

It is very very interesting and they do in depth classification depending upon the application perspective of the material. Probably for many of you this may be the first time to know really the steel is classified based on application. So, far we have been learning only on conventional steel Fe 250, Fe 300, Fe 450, Fe 550 etcetera, where we learn only the focus of classification based on strength or yield strength.

There are many varieties of classification friends. international codes are very advanced in this perspective. So, this course will help you to get an insight of this which is one of the important objectives of this course actually. So, let us see how this classification is done.

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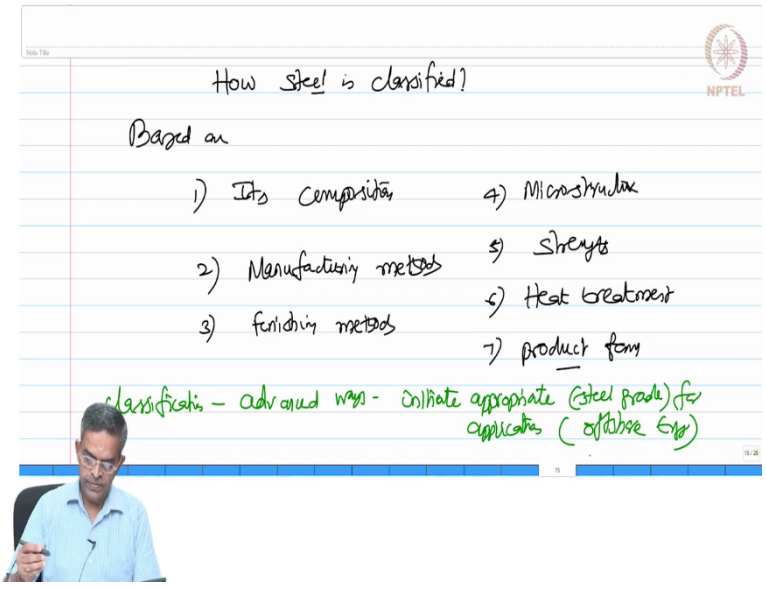

So, now, let us ask a question, how steel is classified. Steel is classified based on its composition, its manufacturing methods, finishing methods, microstructure, strength, heat treatment, product form. So, one can say that classification of steel is one of the advanced ways to initiate appropriate material. That is appropriate steel grade for application and this is a very common feature in offshore engineering.

Let us quickly elaborate them and see how they are really classified, let us take one by one.

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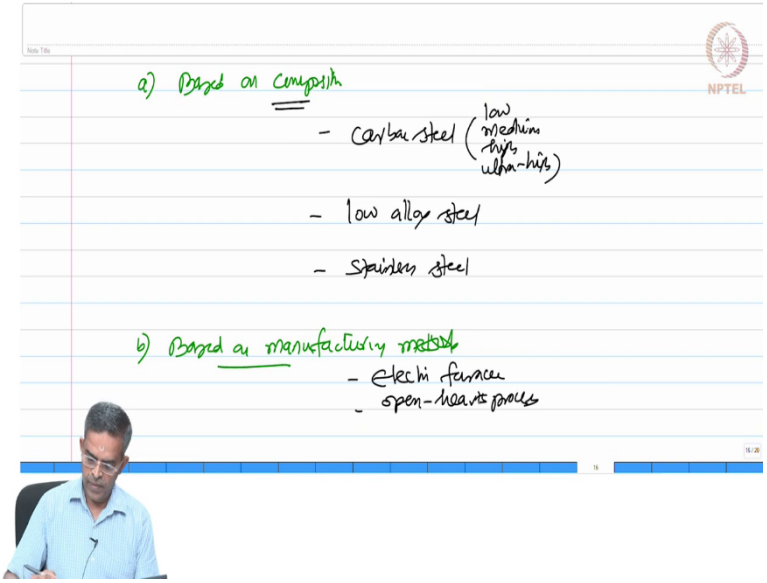

Let us say based on composition how they are classified. Based on composition it is classified as, carbon steel. The moment I say carbon steel I have again a variety; low, medium, high and ultra-high. Low alloy steel and stainless steel, these are based on their composition. Now based on the manufacturing methods, they are classified as electric furnace steel and open-hearth process steel.

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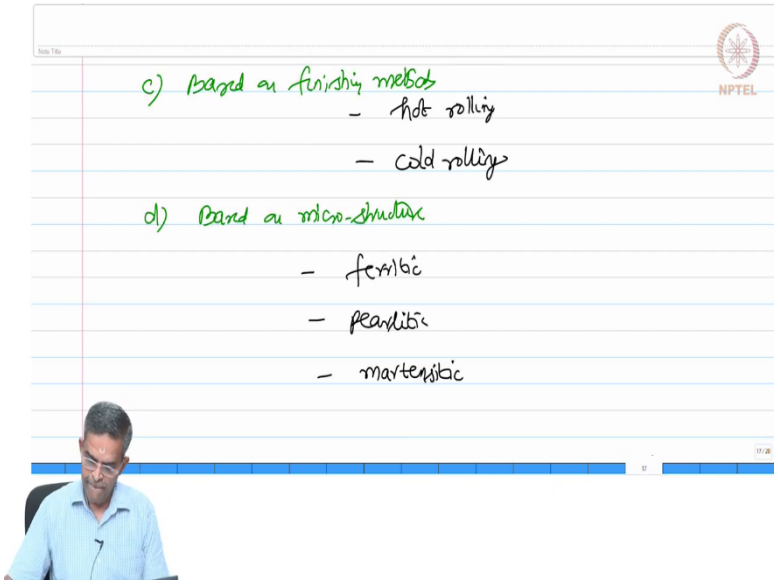

Based on the finishing methods, they are classified as hot rolling, cold rolling. Now based on micro structure, they are classified as ferritic, pearlitic and martensitic.

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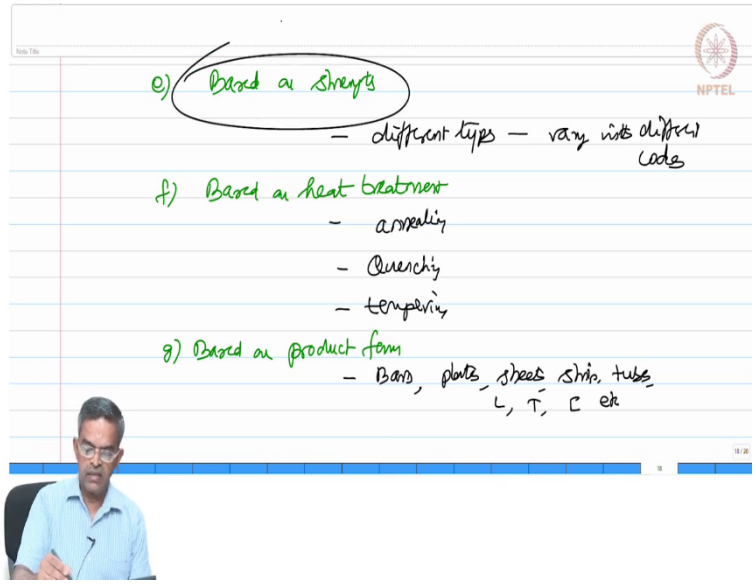

Based on strength, they are classified as different types and they vary with different codes. I will come to that slightly later. They are also classified based on heat treatment, as annealing, quenching, tempering. Based on product forms, they are classified as bars, plates, sheets, strips, tubes, L section, T section, channel section, etcetera. Friends, let us pay more attention towards how the classification of steel is based on strength more in detail.

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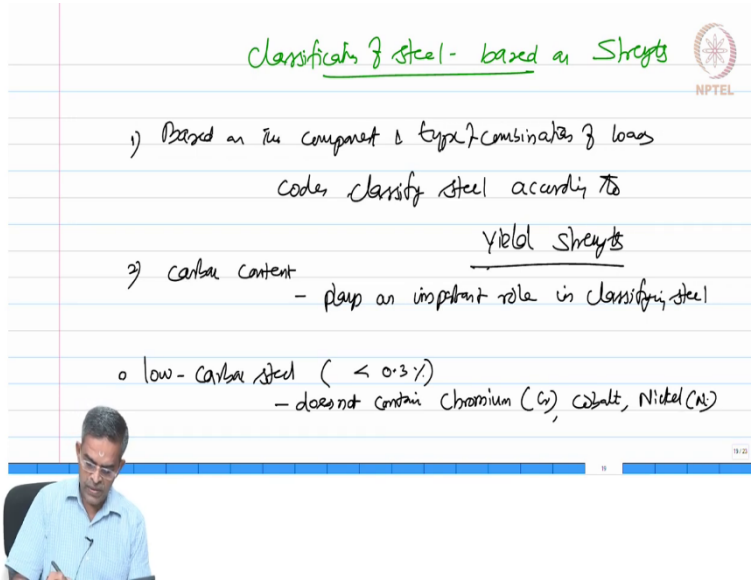

Let us say classification of steel based on strength. Now, before we look into the classification directly let us see what would be those factors which will help the code to classify steel based on strength, because strength is actually a load dependent phenomena. Strength is the capacity to withstand the applied load that is how the basic definition goes in mechanics.

So, we have to look into the factors which will help us to classify steel based on strength. The strength is actually not a single independent parameter or characteristic of material. It depends on the application of load on the material stress state and so on and so forth. So, based on the component and type of combination of loads codes classify steel according to yield strength.

2, carbon content present in steel composition plays a very important role in classifying steel. You may ask you a question, carbon being a chemical composition how does it relate to strength? Carbon content governs the strength of steel my friends. So, therefore, carbon content in the chemical composition helps to classify steel based on strength. For example, low carbon steel which has carbon lesser than 0.3% and it does not contain other elements like chromium, cobalt, nickel etcetera. It classifies this way.

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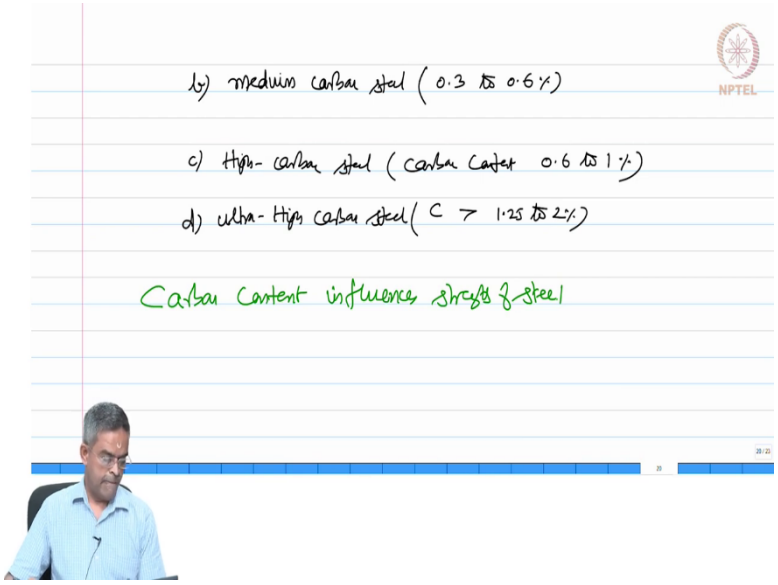

Second: Medium carbon steel, where the carbon content varies from 0.3 to 0.6 % carbon content, high carbon steel, where the carbon content varies from 0.6 to 1 % and ultra-high carbon steel, where the carbon content exceeds 1.25 to 2%. So, we have learnt an important statement here that, carbon content influences strength of steel because under the classification of strength carbon content is being identified. So, let us see in detail about this.

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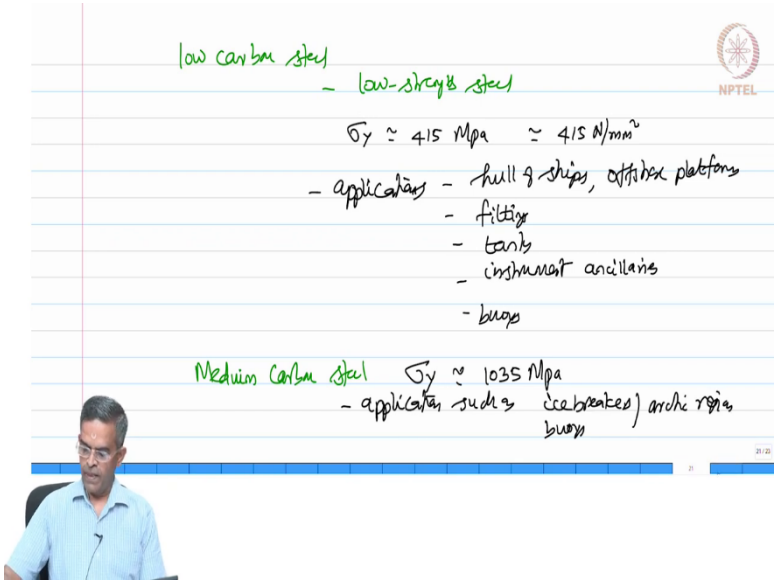

Low carbon steel is also referred as low strength steel, which has got yield strength is about 415 Mpa which is as same as 415 newton per mm square. Now it has got specific

applications. We already said that steel is classified based on applications, the applications recommended by the code or hull of ships and platforms offshore. Platforms, fittings, tanks, instrument ancillaries, and of course, buoys.

Medium carbon steel has got yield strength. It is about 1035 Mpa. This is recommended for fabrication of ice breakers and buoys in arctic region.

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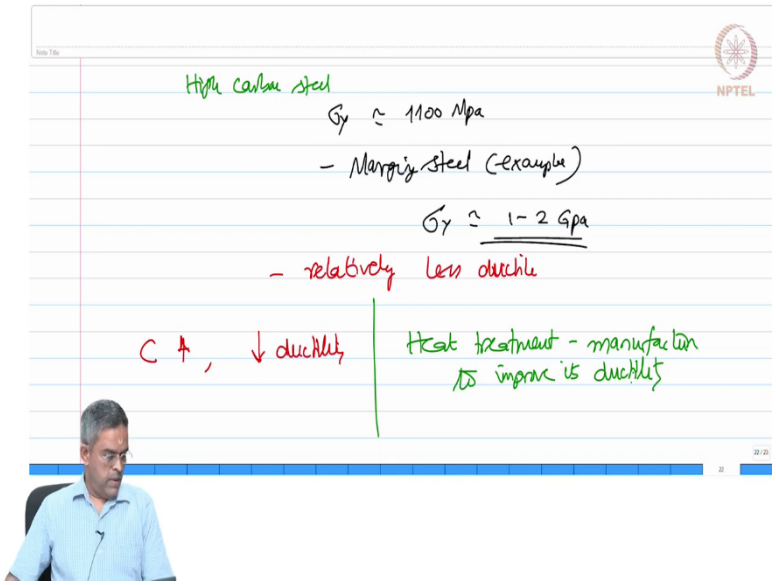

High carbon steel has an yield strength about 1100 Mpa. A classical example of this steel is maraging steel is an example. Maraging steel has σ_y about 1 to 2 Gpa. There is an issue with this kind of steel. High carbon steel is relatively less ductile compared to other steel.

It means, increase in carbon content decreases the ductility. So, what they do? To overcome this problem, they do heat treatment during manufacturing to improve its ductility.

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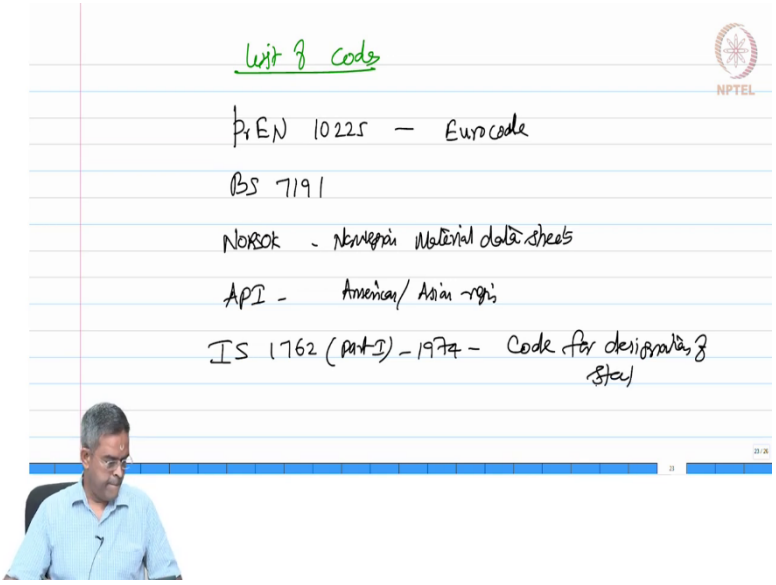

So, as I said a varieties of codes help in classifying steel. The list of codes which does classification of steel as I discussed just then are as follows. One is Euro Code 10225, Euro code for design of structures. British Standard 7191, then NORSOK which is a Norwegian material data sheet used for design of ships and offshore structure.

And of course, American Petroleum Institute used in America and Asian regions and of course, IS 1762 Part-I; the Indian Code 1974 which is the code for designation of steel.

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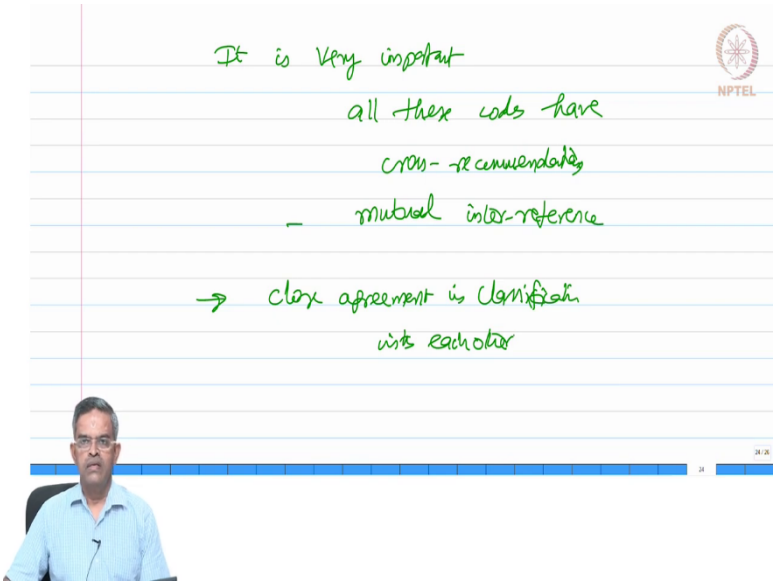

Friends it is very important that we learn to know all these codes have cross recommendations. What does it mean? It means that they have mutual inter-reference. So, the final summary is they have a close agreement in classification with each other. So, when a specific code classifies steel based on strength, the other code does not deviate much from this classification. They mutually agree closely on this.

And we are very proud that we are also advanced in this front and our Indian Code also helps to identify classification of steel based on very explicit parameters. I am sure how many of you would have gone through this course in the design classes. So, I think it is now high time for us to really understand update our advanced knowledge in design of steel structures and this course is certainly going to help you in that front.

I am sure that you are enjoying the new contents discussed in these lectures the way in which they have been discussed I am following a very simple classroom model, I am using a white board and I am writing and speaking and explaining and deriving all equations line by line, which I will practice in the entire lecturing of this particular course.

Whenever there is an example, we will also help you to use MATLAB codes. So, I will intuit a good level of confidence and a very strong understanding and therefore, love for this particular course of NPTEL.

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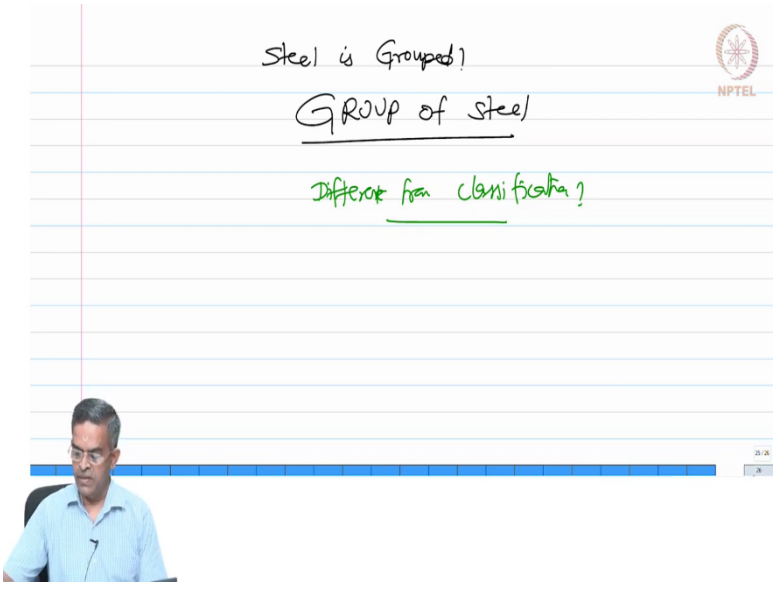

So, having said this we will also now talk about how steel is grouped. So, steel is also grouped. This is different from classification. Please understand grouping of steel is different from classification. How they are different, how they are grouped, we will see in the next lecture.

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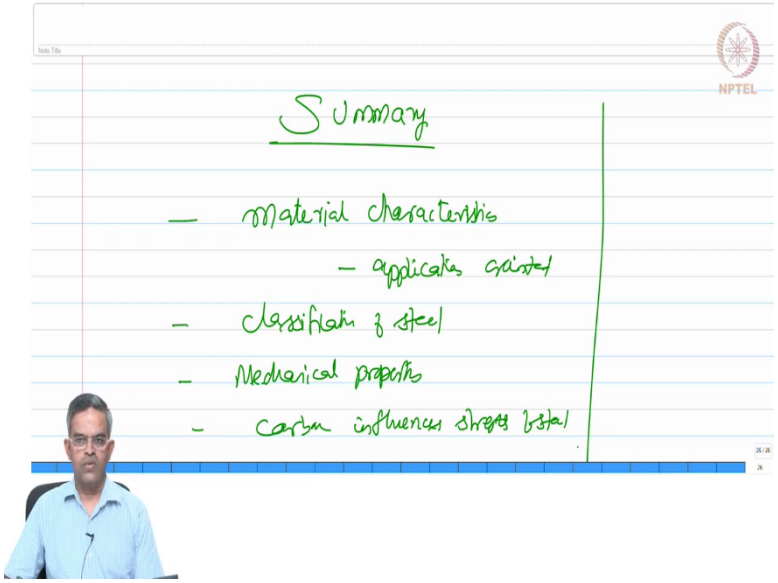

So, in this lecture as a summary we have learnt various material characteristics, which are application oriented which help us to choose steel for construction purposes. Two, we have also learnt how steel is classified. We have also learned what are those important mechanical properties that are useful to choose steel in the design perspective. We have also learnt how carbon influences strength of steel.

So, friends we will continue this in the next lecture and talk more about their material characteristics at normal and elevated temperatures and we will learn more about the material selection as recommended by Indian and international codes.

Thank you very much. Have a good day, bye.