Advanced Design of Steel Structures
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Lecture - 02
Form-dominant design - II

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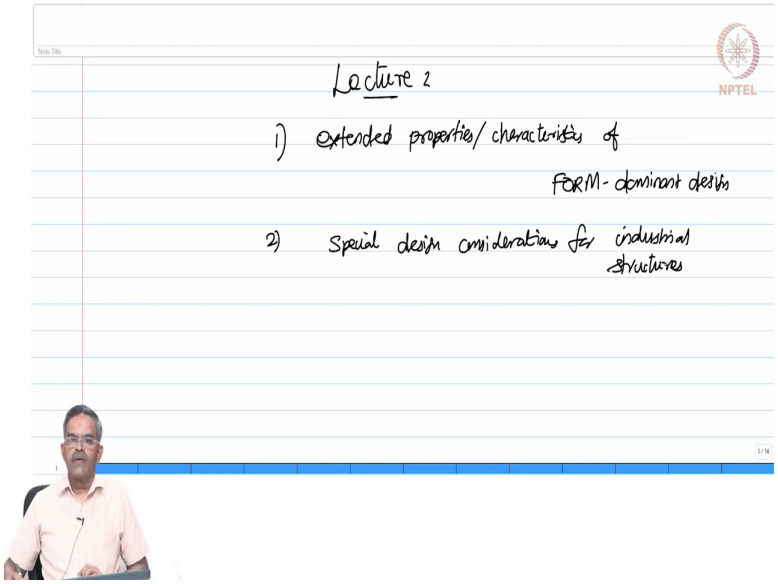

Friends, this is the second lecture in which we are going to discuss and learn some extended properties or characteristics of Form Dominant Design. Then, we will also see special design considerations for industrial structures.

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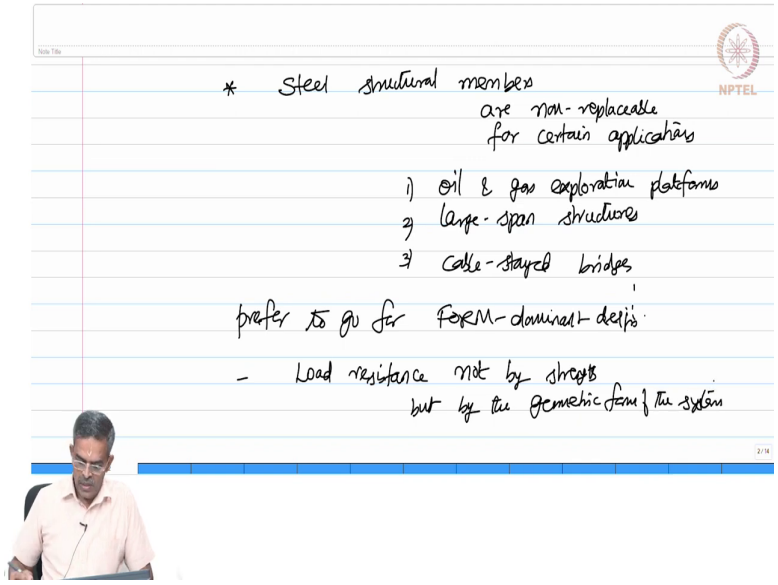

So, in the last lecture, we said steel structural components or non-replaceable, there is no replacement, there is no alternative on certain applications. We can give some classical examples, where steel structures are essentially important. We can see oil and gas exploration platforms, large-span structures, cable-stayed bridges and many more to add.

We said under these kind of special structural systems, we generally prefer to have FORM-dominant design. As explained earlier, form dominance is load resistance not by strength, but by the geometric form of the structural system.

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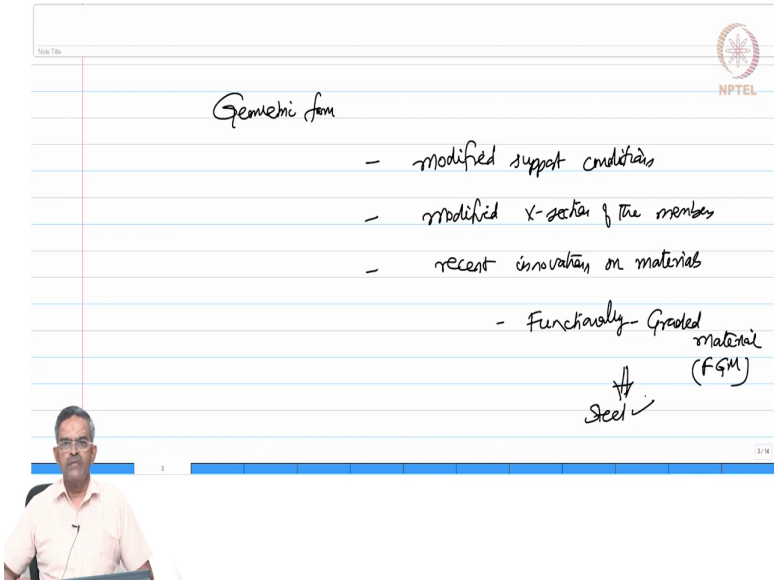

The moment we say geometric form, it can come from modified support conditions. Modified cross sectional properties and to some extent novelty in the material which come from recent innovations on materials. One classical and recent advantage which is applied to structural systems undergo large and extensive corrosion is functionally graded material.

So, in this course, we are also going to talk about what are FGMs; how are they manufactured; what are the combinations that make a functionally graded material and if it is manufactured on a lab scale, what are the explicit advantages this material possess in comparison to the classical structural steel as an engineering material.

So, we will compare this with steel and see what are explicit merits that prefer engineers to use FGM in the future in comparison to the so called non-replaceable engineering material for large industrial structures, which is currently steel. So, friends, when we draw our attention towards form dominant design, we are talking about the structural arrangement of members that is a structural geometry.

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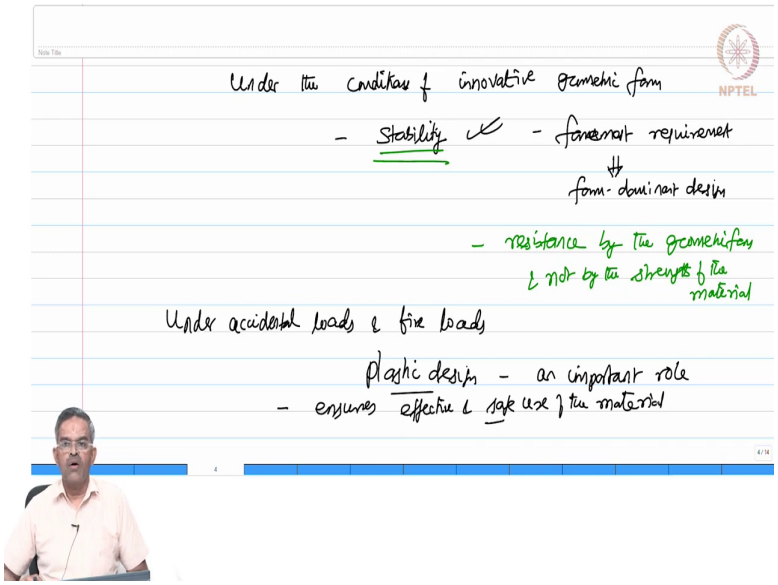

So, when we talk about an innovative geometric form, under the conditions of innovative geometric form. The foremost requirement for a structural system to function properly is its stability. So, stability becomes the foremost requirement. This is much more important when you talk about structural systems, where form dominant design is invoked.

So, friends, let us recollect form dominant design is resistance by the geometric form and not by the strength of the material. So, when the geometric form has got to resist the applied loads, apart from being innovative, it should satisfy the stability requirements first.

So, in this course, we have to also discuss about the stability of structural systems much in detail. In particular, under accidental loads and fire loads, plastic design plays a very important role. As we all know plastic design procedure effectively uses the cross sectional property of any material, of course using plastic design for composite materials like reinforced concrete is complicated.

Because the behavior of concrete and steel in a close agreement under the given load pattern is difficult to establish; whereas, steel as a structural material can be comfortably handled in plastic design which was done for the past 20-30 years. So, when steel structures are subjected to accidental loads and fire loads, plastic design plays a very important role in the design phenomena of these kind of structures.

Because plastic design apart from using effective cross section of the material, it also ensures effective and safe use of the material. So, friends, please note very carefully form dominant design is parallelly getting along with two objectives.

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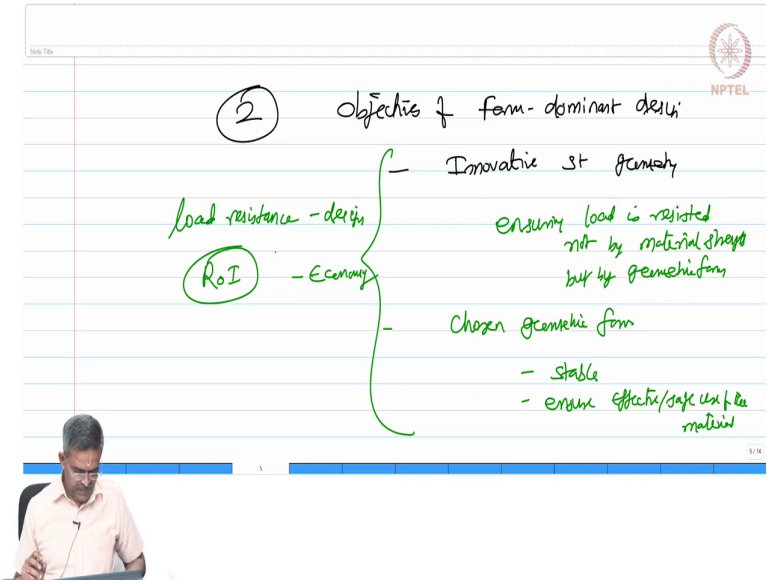

The first objective is innovative structural geometry and ensuring load is resisted not by material strength, but by the geometric form that being the first objective. The second

objective is the chosen geometric form should be stable; it should ensure effective and safe use of the material. So, you see in form dominant design, these two factors are circumscribed to each other. One is the load resistance which is the requirement of any design procedure; second is the economy which is return on investment.

We have already saw in the last lecture how because of rapid construction process steel enables a lot of advantages over other standard construction materials. Therefore, it empowers a quick return on investment. So, form dominant design is not only a design procedure, it also ensures economic use and safe use of the material. So, in form dominant design, we have to get along with the plastic design procedure which we will be discussing in this course in detail.

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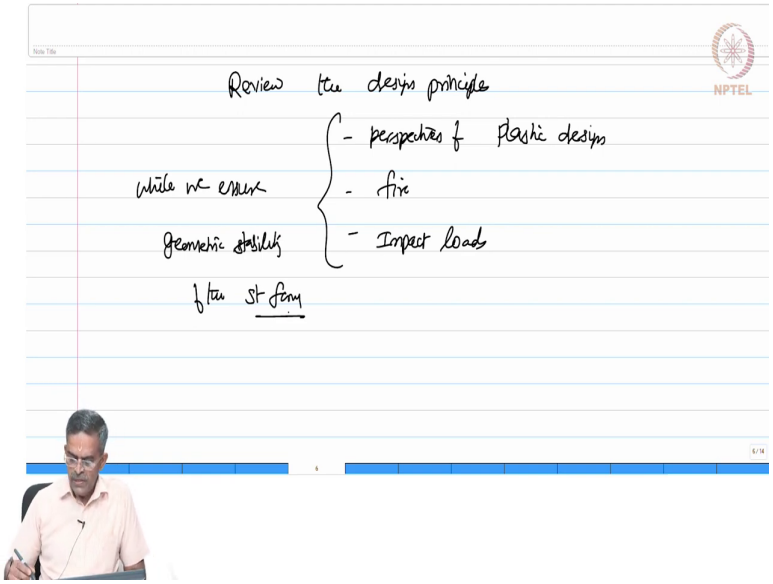

Having said this, we will then review the design principles in the perspectives of plastic design, design for fire, design under impact loads, while we ensure the geometric stability of the structural form.

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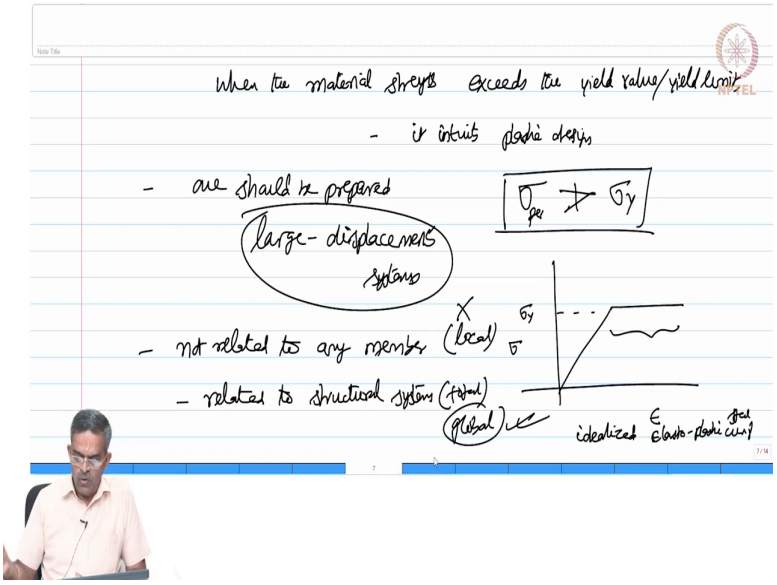

Friends, to make it very simple, when the material strength exceeds the yield value or the yield limit, then it intuits plastic design. Though in plastic design, the permissible stress cannot exceed the yield value. So, we can stress the material only up to the yield; but looking at the modified elastoplastic curve is an idealized elastoplastic curve of steel. Beyond yield, we allow large inelastic displacement.

So, friends, please note a very careful derived demerit of form dominant design. The derived demerit could be as it employs plastic design, one should be prepared a large displacement systems. I am not talking about large deformation. It is not related to any member individually, it is related to the structural system in total. So, we are not talking about any local deformations, we are talking about all the time global displacements. So, you would have got a clue at this time that how a form dominant design resist the load by geometry.

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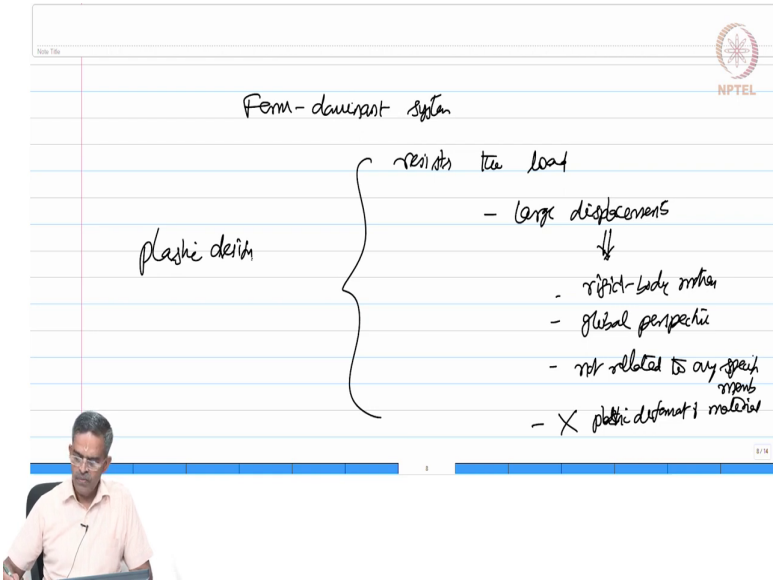

The answer could be the form dominant design or form dominant system primarily resist the load by undergoing large displacements. Please note these displacements are related to the rigid body motion of the system. It is on the global perspective. It is not related to any specific member and it is not certainly related to plastic deformation of any material.

So, the material is permitted to undergo inelastic deformation. With that permission available on board, the structure undergoes large global displacements to resist the loads. So, if this concept is clearly understood, then one can readily say plastic design procedure becomes an inherent requirement of form dominant design which is one of the advanced design procedures in steel structural systems.

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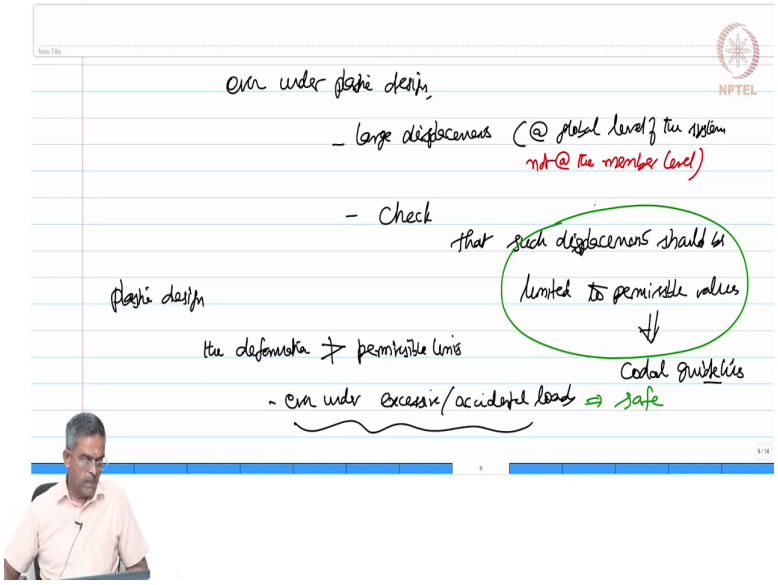

Having said this, one should then ensure even under plastic design, even under large displacements at the global level of the system, not at the member level ok; let us make it very clear. Even though the system is permitted to undergo large displacements; however, there should be a check that such displacements should be limited to permissible values. As usual being a designer, you could have guessed by this time who would be recommending these permissible values.

The permissible values generally come from the Codal guidelines. So, the plastic design which is chosen as one of the design procedures for form dominant design should ensure that the deformations should be within the permissive limits even under excessive or accidental loads. So, by ensuring this statement, one can very happily note that this design procedure is safe because it checks the displacement levels. Friends, when we talk about application problems or difficulties of these kind of form dominant design procedures to large industrial structures.

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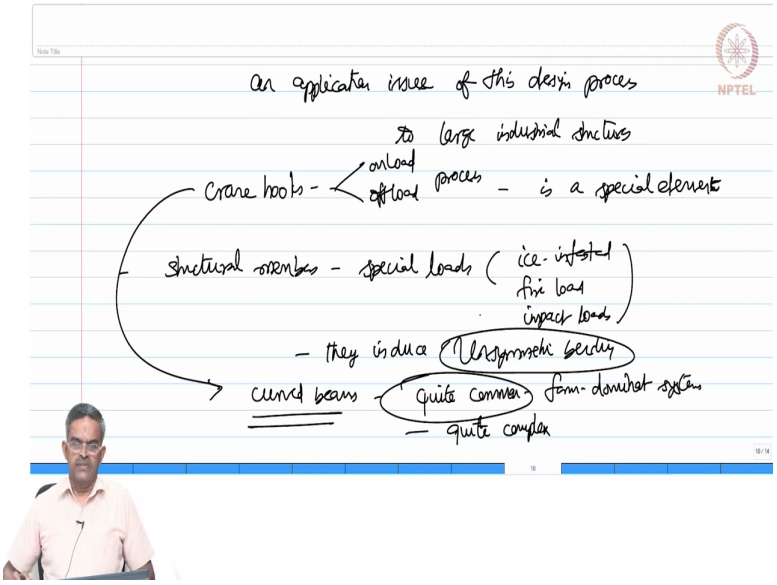

Let us talk about an application problem or an application issue of this design process to large industrial structures. You know in large industrial structures like factories, paper industry, oil and gas exploration platforms, submarines etcetera you will notice that crane hooks which are used for on-load and off-load process of the manufacturing and fabrication in industry is a special element is one of the special element.

Further, structural members will be subjected to special loads; as I said special loads, I am not covering the dead load, live load, impose load etcetera, even wind load is also considered as a special load. I talk about only ice infested loads, fire loads and impact loads as special loads.

When structural members will be encountering special loads, they induce unsymmetric bending. Further crane hooks or special elements because they are curved beams and curved beams are quite complex in design; but they are quite common in form dominant systems. I have given an example in the last lecture about arches. In form dominant systems, curved beams are quite common; but in design, they are quite complex.

So, in this course, we will try to discuss about the procedure for analyzing systems or members under unsymmetric bending. We will also discuss about the analysis of crane hooks or curved beams in general, its analysis procedure and the design procedures.

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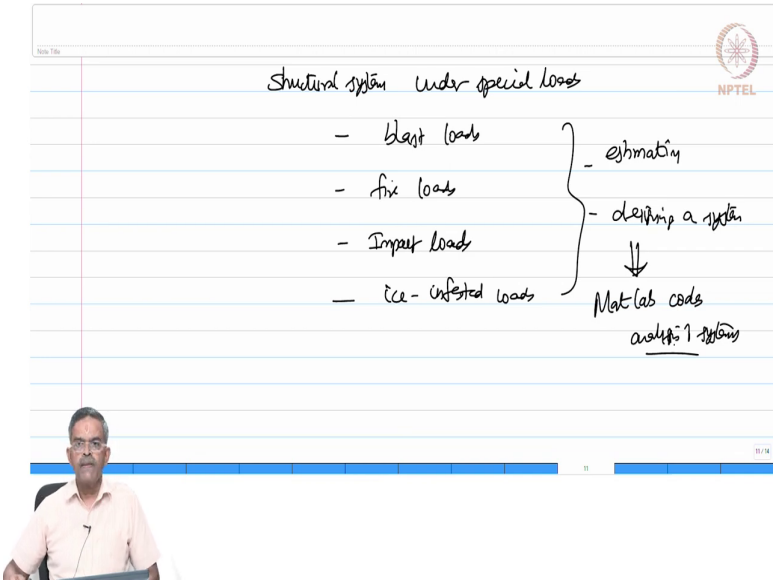

When we talk about structural systems under special loads, we need to pay attention to special loads like blast loads, fire loads and impact loads. In addition, we will also talk about ice infested loads because they are very useful for arctic structures and they are not commonly available in the literature.

So, we will talk about and give a overall comprehensive understanding of all these loads in terms of estimating them, in terms of designing a system under these loads and so and so forth, we will also give you the MATLAB codes for doing the analysis of systems subjected to these loads.

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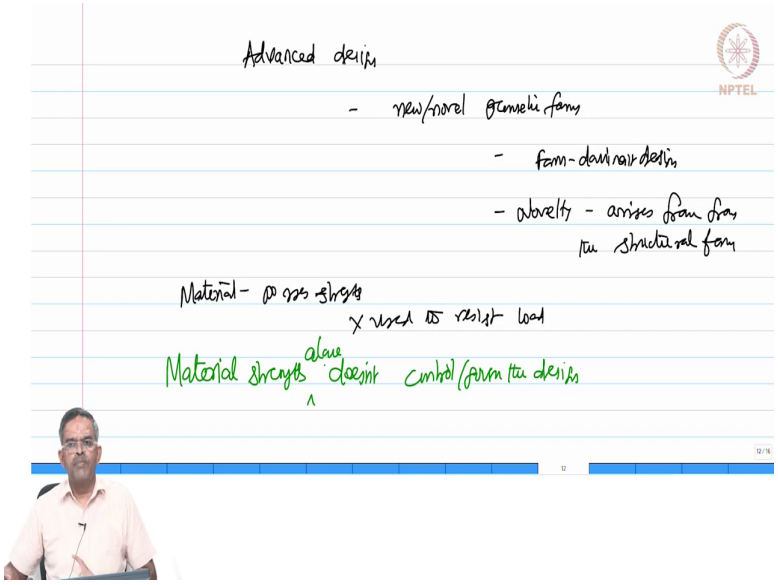

Having said this friends, when we talk about advanced design; when we talk about new or novel geometric form, we emphasize on the form dominant design. In form dominant design, we are repeatedly insisting that the structural system will encounter the loads and disperse these loads not using the material strength; but by its arrangement of structural members. So, the novelty comes from the geometric form .

So, there is a total deviation in the design philosophy. Now, materials though they possess strength; but not used to resist loads. So, therefore, material strength does not control or govern the design. In fact, I should say material strength alone does not govern the design. However, when we talk about steel for such complicated or advanced application, steel has got a very major problem of corrosion.

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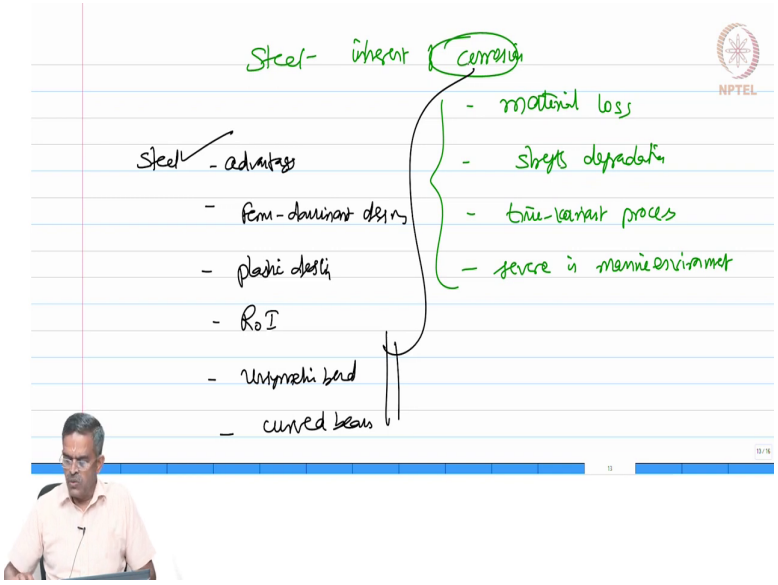

Steel has got an inherent problem of corrosion. So, corrosion as per the material science is material loss and we know a corroded element will have strength degradation and corrosion is a time variant process and it is severe in marine environment.

So, on one hand, we say steel has got many advantages; it is very good for form dominance, it is very comfortable to use plastic design, it has got very good return on investment, it can handle unsymmetric bending loads, it can also get fabricated for curved beams. But it has got a major demerit, it undergoes corrosion.

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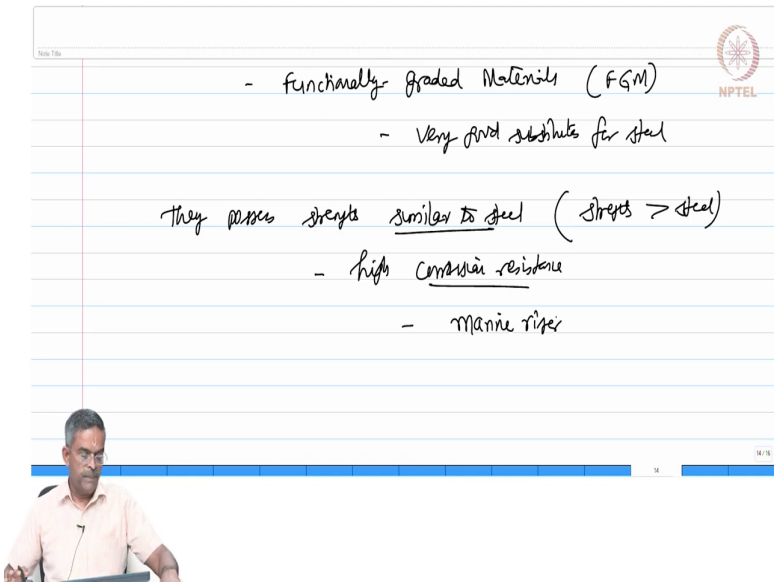

Now, to address this issue, the recent innovation happened in structural engineering is functionally graded materials, very commonly known as FGMs. So, they are very good substitutes for steel. They possess strength similar to steel. In fact, I will show you one application what we did in our lab to fabricate an FGM, it possess strength in fact, higher than steel. In addition to that, it has got a very high corrosion resistance compared to steel.

So, now, we have got an innovative material which is suitable to form dominant applications because one of the primary constituent of FGM is steel. While satisfying the form dominant requirements of the members, it also addresses the common problems what steel faces in special environments like marine environment, where corrosion is a major challenge.

So, we will talk about FGM in detail in this course and give you a very clear example application of an FGM for a marine riser, where corrosion is one of the serious problem, we still remains unaddressed in the modern engineering era.

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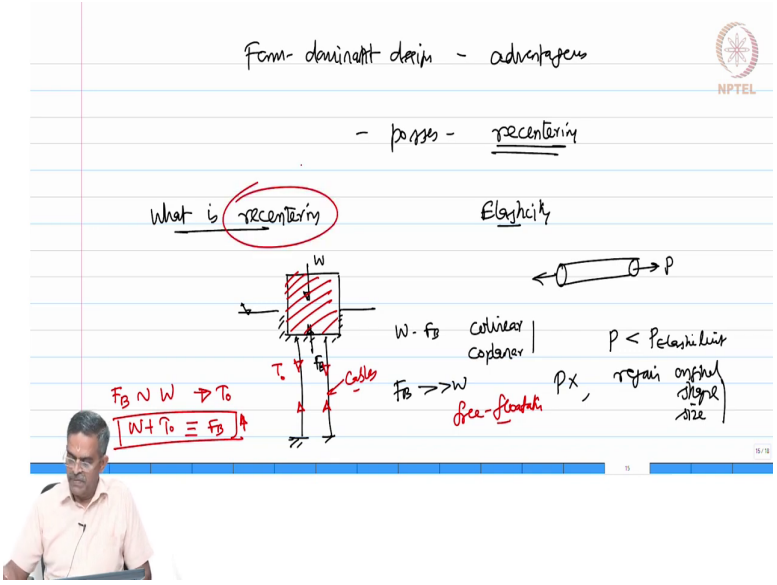

We have already said that form dominant design is advantageous, but they should possess a very important ability called recentering. Let us quickly see what is recentering. Before we understand what is recentering, let us talk about what is elasticity. Elasticity is the property of the material which enables it to regain its original shape and size upon removal of load.

A simple example could be a bar; pull the bar to some load P. If this load P as long as lesser than P elastic limit of the material upon removal of load, the member will regain its original

shape and size . That is what we are studied as elasticity. Let us apply this concept for systems undergoing large displacements which is a form dominant system.

So, let us take a body which is enabled to float. If this is my water level, the submerged volume of the members will impose buoyancy to the system. The weight of the system will any way act downward, the system is designed in such a manner that W and F_B will be co-linear, co-planar and act at the same point.

However, for form dominant design as I discussed in the last lecture, buoyancy will exceed the weight. So, that if buoyancy exceeds the weight, this body which is our structural system in terms of a rigid body model will have a free floatation characteristic. It will keep on freely floating.

To control this free motion of floatation, this has got to be held down by some cables which we call them as tethers which are nothing but axially stressed wires. If the tension in the cable is T_o, then the difference between buoyancy and W should be taken care of by this T_o.

Therefore, equation of static equilibrium for the system will be now $W + T_o = F_B$ ok because the left hand side acts downward, right hand side acts upward. Let us imagine a system of this order and try to explain what is recentering.

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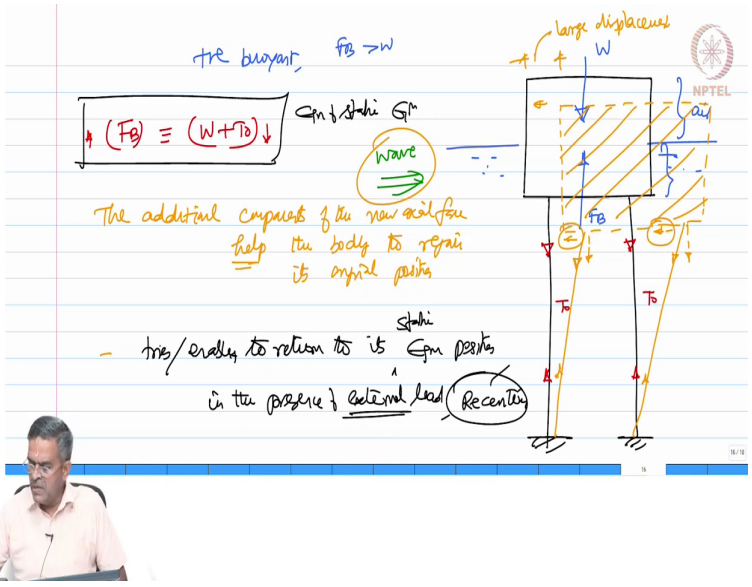

So, I have a body which is anchored to the seabed using cables. Let us say this is my water line. So, this portion is submerged; this portion is in air . The body has some weight. The submerged portion of the body will offer an upward force which is buoyancy force.

As per design, if the system has to be positive buoyant, then F_B will exceed W to compromise this. To adjust this difference, we will have tension in the cables. So, we now said the equation of static equilibrium for this problem could be F_B is equal to $W+T_o$ because this is acting downward; this will act upward.

Now, under this condition, let us say the system is imposed by a wave load which is horizontal. As the system is free to float, the system now assumes a new position. Under the new position, the system has undergone large displacement ok in the presence of waves; but please understand, the system will try to regain its original position automatically. See how?

Now, these cables will be in again tension, they will have a vertical and horizontal component. These horizontal components will try to bring this body back to the normal position. So, the additional components of the new axial force helps the body to regain its original position. I am saying it help; there is no guarantee, it will come back to the original position. But it tries. Now, in simple terms when such body, when such body tries or enables to return to its equilibrium position, let me very clear to its static equilibrium position because the equation of static equilibrium is this.

If the body possess a capability to return to its static equilibrium position in the presence of load, then we call that as recentering. So, recentering is the geometric ability of a structural system to return back to its static equilibrium position in the presence of external loads; whereas, elasticity is a material property. So, for form dominant design systems, we must ensure recentering ability.

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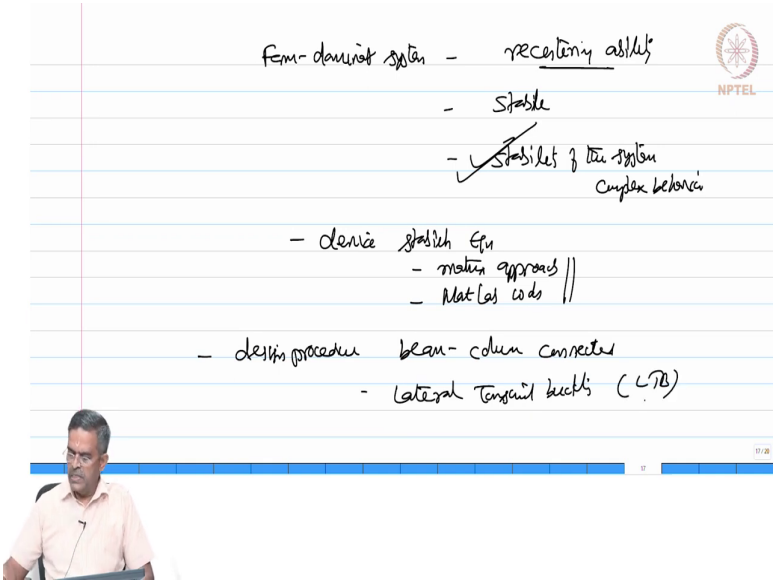

So, the form dominant design systems should ensure a good recentering ability, then only the system can sustain the loads acting from the environment. While doing so, the system should remain stable. Therefore, we must understand the stability of the system under such complex behavior. So, stability plays an important role in understanding advanced design of steel structures under form dominant design.

So, in this course, we will also help you to derive the stability equations using matrix approach. We will also give you the MATLAB codes to solve numerical examples of stability problems which is quite novel and very scarce in the present literature friends. It is not commonly available. In addition, we will also talk about the design procedures of beam column connections under Lateral Torsional Buckling. LTB is a big menace in structural systems of large span and cylinder systems.

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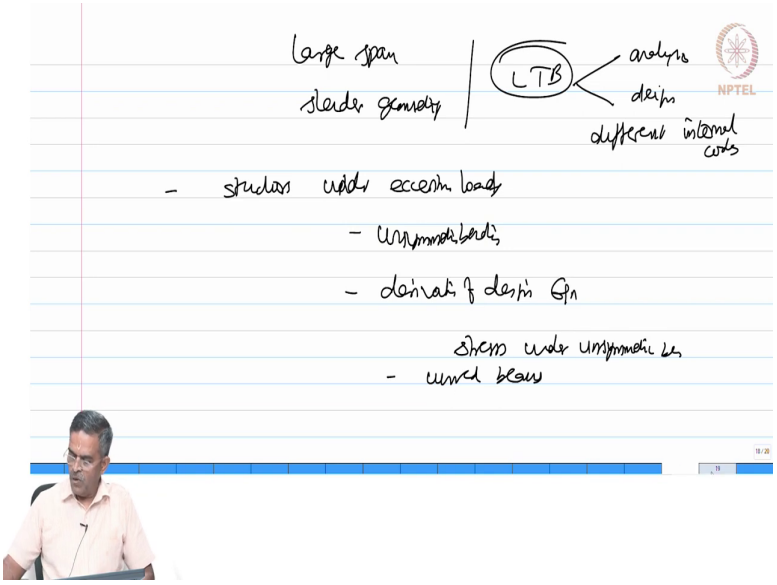

When we talk about a large span and slender geometry, then we have to also consider lateral torsional buckling. So, this course will help you to understand the lateral torsional buckling analysis and design. We will also do a design example using different international codes including Indian code for members under lateral torsional buckling in this course.

Furthermore, when we talk about structures under eccentric loads. These structural systems will undergo unsymmetric bending and one should have an idea how to do analysis under unsymmetric bending. So, we will talk about the derivations of design equations for estimating stresses under unsymmetric bending and also, under curved beams.

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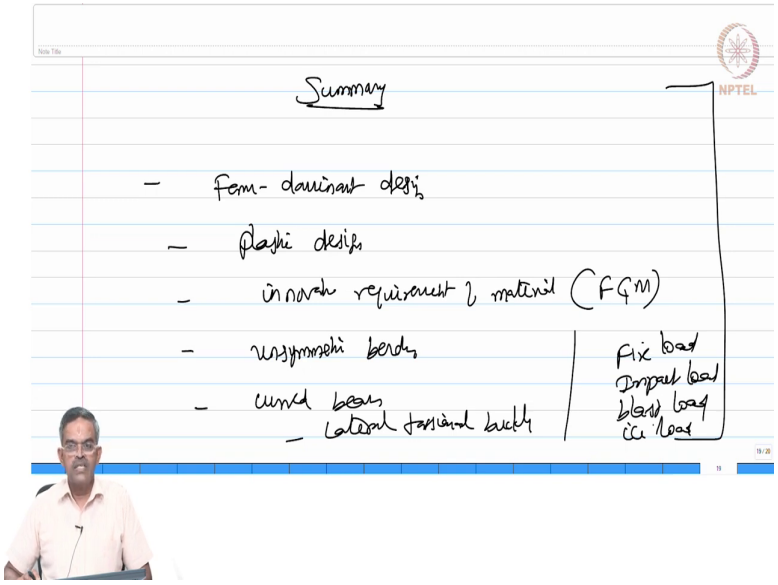

So, friends, in this lecture, what we have learnt? We have learnt more insight about form dominant design. We have understood the importance of plastic design. In this context, we clearly understood what will be the innovation requirement of material in the modern era. One classical application what we just mentioned is functionally graded materials and we are also interested to learn more about unsymmetric bending, curved beams, lateral torsional buckling; in addition to learning more on fire load, impact load, blast loads and ice loads.

So, this is what the promise what we made which will go through this course and the course will support you through and through using MATLAB programs solving lot of numerical. On the screen using MATLAB program and this programs will also available to you from the NPTEL link free to download and use them and the course has got a very strong set of reference books authored by me, on the same topics which are also published by publishers of international repute.

So, friends, you will I believe you will join hands with me in making this learning experience quite interesting, quite robust and of course, quite knowledgeable and learning.

Thank you. We will see in the next lecture, bye.