Advanced Design of Steel Structures

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Lecture - 62
Fire - resistant design - 1

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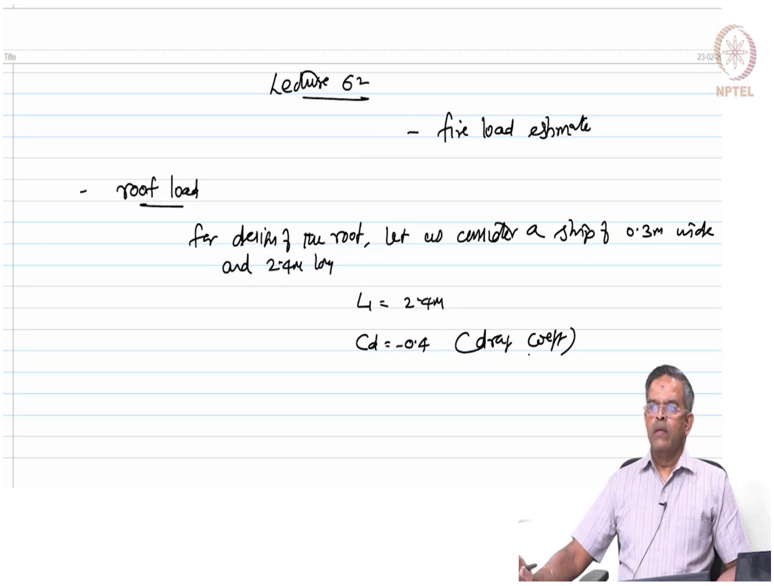

Friends, welcome to lecture 62, where we are going to talk about Fire Load Estimate. Before that, we will complete the numerical problem of blast load estimate on a rectangular building. We will continue with that.

So, we worked out previously the sidewall load, now let us work out the roof load for the problem. For design of roof, let us consider a strip of 0.3 meter wide and 2.4 meter long. So, let us take L_1 as 2.4 meter, and let the drag coefficient be 0.4 negative for the roof.

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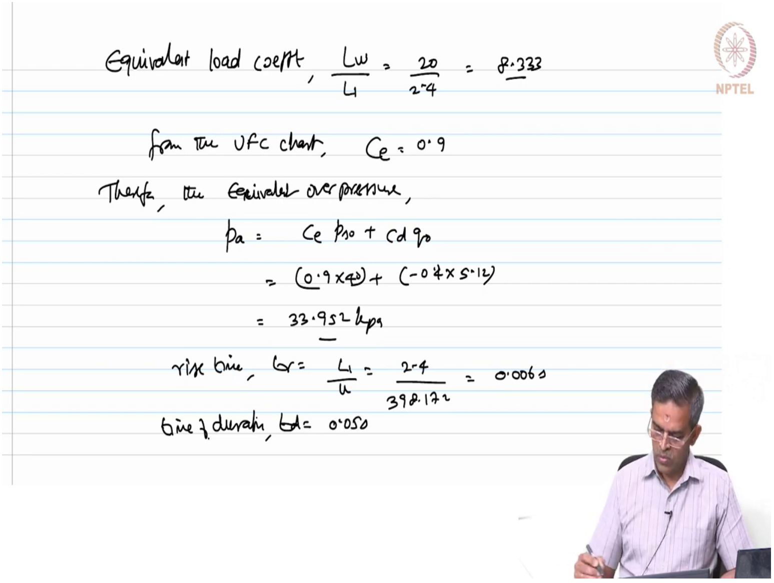

Equivalent load coefficient will be now equal to L_w/L_1 which is 20/2.4 which is 8.333. From the UFC chart, one can calculate C_e as 0.9. Therefore, the equivalent over pressure is given by $p_a = C_e p_{so} + C_d q_o$ which is (0.9 x 40) +(-0.4 x 5.12), that is what we had as q_o, which comes to be 33.952 kpa. The rise time for this, t_r will be L_1/u which is 2.4 by 398.172 which comes to 0.006 seconds. So, let us plot this. Further time of duration t_d is 0.05.

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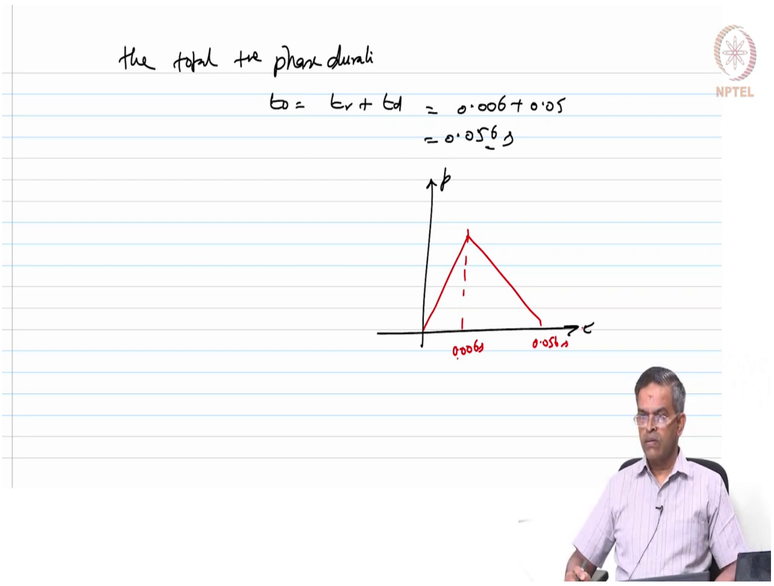

So, the total positive phase duration will be equal to t_r plus t_d which is 0.006 plus 0.05, 0.056 seconds. Let us plot this. So, this is 0.006 seconds, is the positive rise phase. This is 0.056 seconds.

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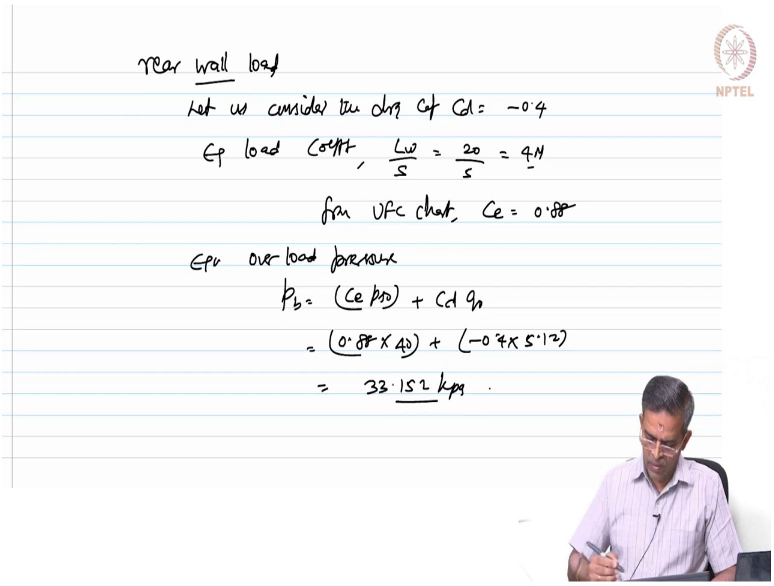

Let us look at the rear wall loading. Let us consider the drag coefficient C_d as -0.4. So, the equivalent load coefficient will be actually given by L_w/s which is 20 / 5 which is 4 meters. And from the UFC chart, one can find C_e as 0.88. So, the equivalent overload pressure is given by $p_a = C_e\, p_{so} + C_d\, q_o$ which will be (0.88 x 40) + (- 0.4 x 5.12) which will be 33.152 kilopascal.

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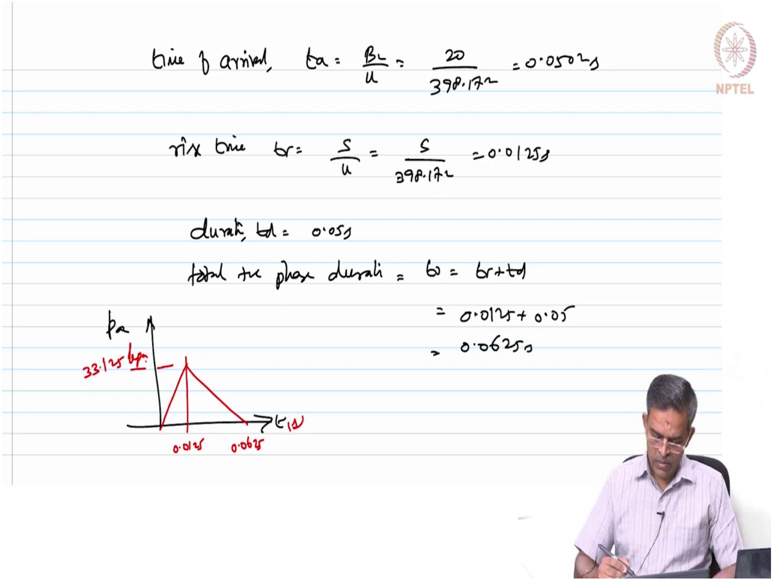

Time of arrival is t_a which is B_L/u which is 20/398.172 which is 0.0502 seconds. Now, the rise time of the positive phase t_r is given by S/u which is 5/398.172, which is 0.0125 seconds. Duration, t_d is 0.05 seconds.

Therefore, the total positive phase duration will equal to t naught which is t_r plus t_d which is 0.0125 plus 0.05 which is 0.0625 seconds, which can be plotted as t and p_a 0.0125, this is 0.0625, and this value is 33.125 kilopascal. So, friends, this example illustrated how to compute the blast loads on different segments of a rectangular building taken for the study using UFC code.

Now, let us discuss about estimate of fire loads on buildings.

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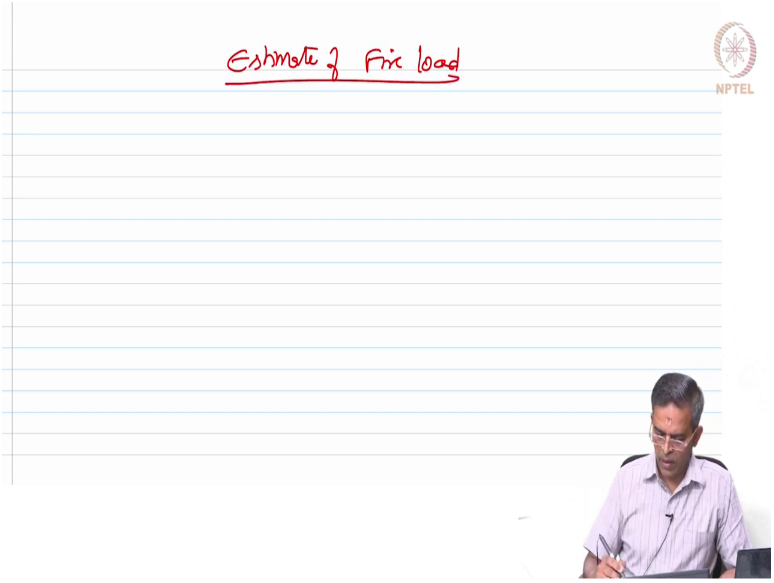

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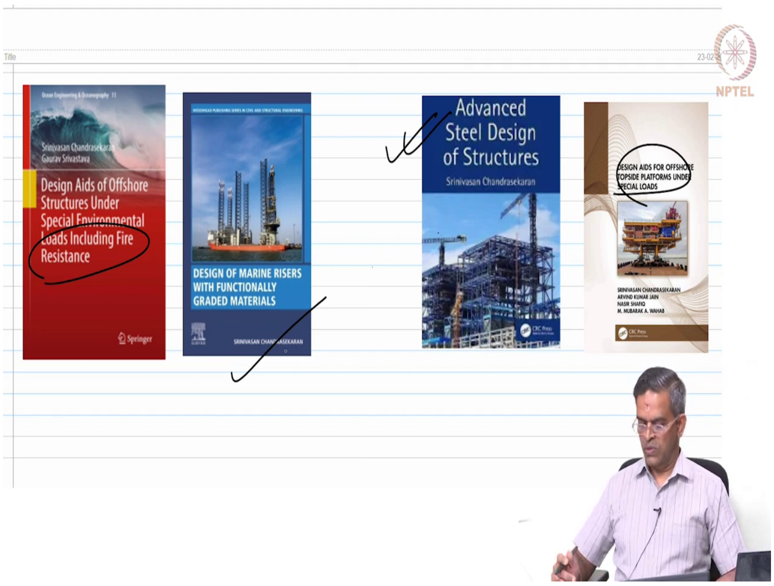

So, friends, now we will talk about fire loads. These are some interesting references which you would like to see back when you use fire load computation on structures. Design Aids of Offshore Structures Including Fire Resistance, this book covers concepts of fire-resistant design as well as the special loads. Please have a look at these textbooks, which are recommended for this course.

In addition, if you want to know about the properties of functionally graded material compared to steel, this is a very nice reference book which is recommended for this course.

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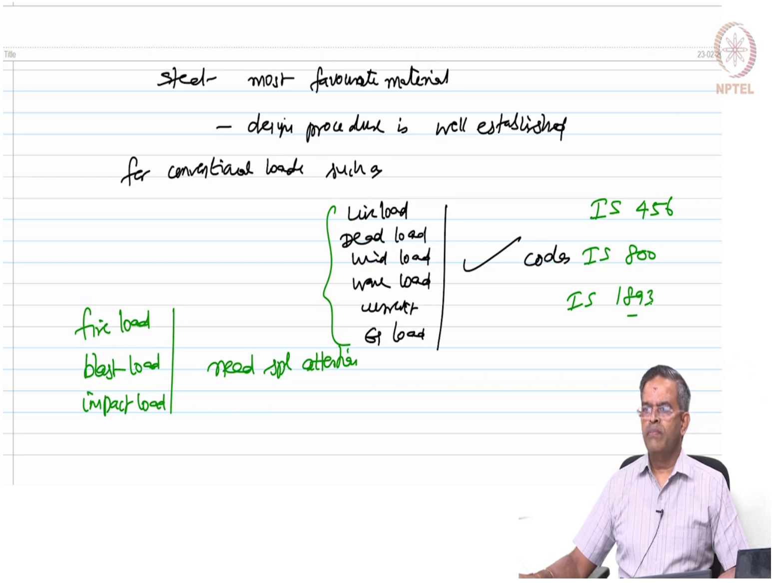

Now, let us say steel is the most favorite material for construction. The design procedure for steel structures is well laid and well established. For conventional loads such as live load, dead load, wind load, wave load, current and earthquake loads, we have recommendations given by the codes. But when you talk about fire load, blast load, impact load, etcetera, they need a special attention, and the analysis methods are different for them.

For example, there are varieties of Indian codes which discuss about the design procedures. For example, let us say, IS 456 this is for concrete structures, IS 800 for steel structures, IS 1893 for earthquake loads. But there are no explicit design procedures available and recommended by the codes for fire loads.

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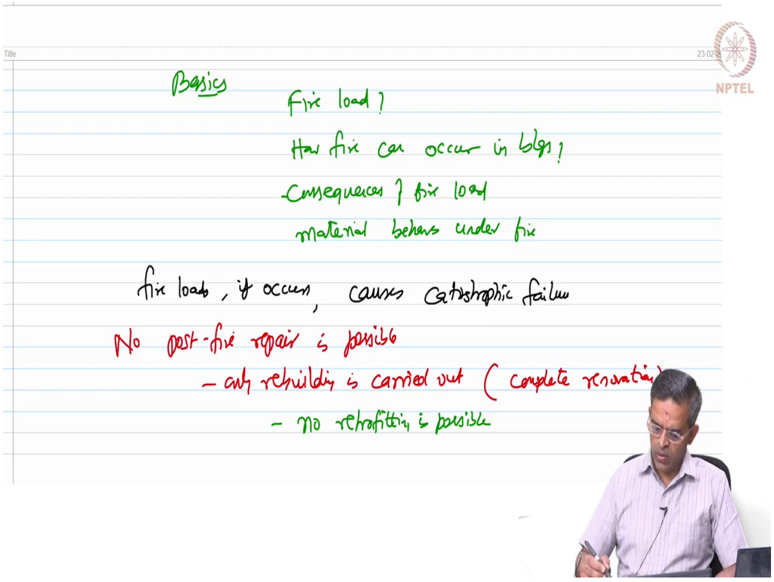

So, let us see what are the basics of fire load. So, we would like to learn, what is a fire load? How fire can occur in buildings? What are consequences of fire load? And how material behaves under fire? Because there are no special design and repair procedures of structures under post fire accidents. And the steel what we generally use for construction is a high carbon steel. So, there are issues related to these two concerns, so we need to address that.

But, one thing we need to realize is that, if fire loads occur, causes catastrophic damage, very importantly no post-fire repair is possible, only rebuilding is done, no repair, it is amounting to a complete renovation because fire causes a total devastation. Very importantly no retrofitting is possible for structures subjected to severe fire loads.

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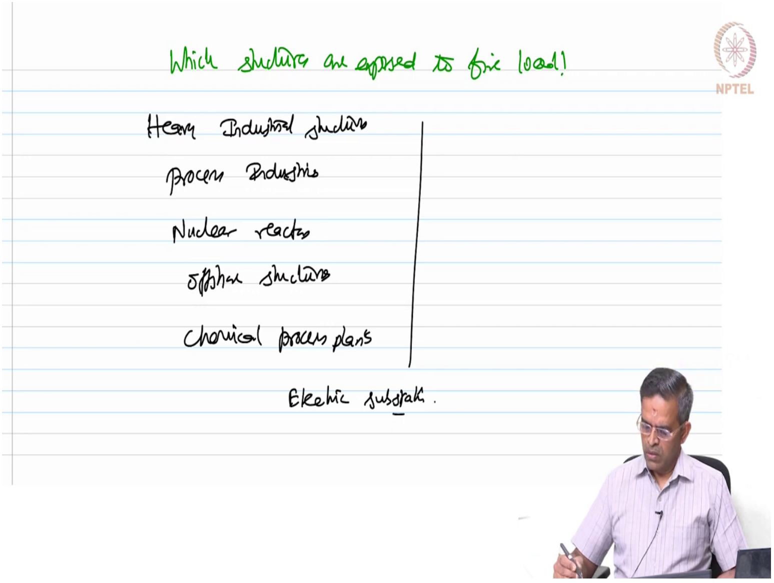

Having said this, let us ask a question which structures are exposed to fire loads? Do we have to design every building for a fire load? The answer is no. Heavy industrial structures, process industries, nuclear reactor power plants, offshore structures, chemical process plants, can cause fire. We can also include electric substations, because electric fire is an important aspect for design.

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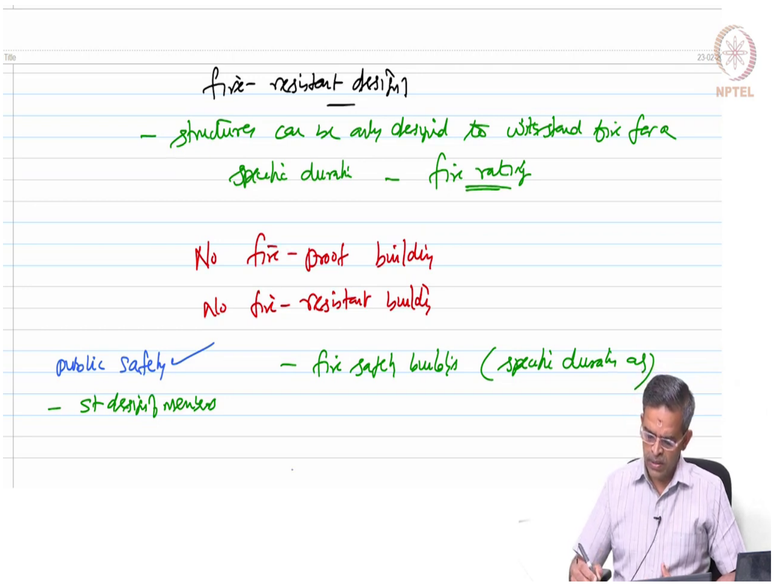

Now, let us talk about what do you understand by fire resistant design. Structures can be only designed to withstand fire for the specific duration. This is called fire rating. So, please understand friends, there is no fire proof building, there is no fire-resistant building, but there are fire safety buildings for a specific duration only.

Then, in that case, what is important in fire resistant design? Structural design of members for fire load is only secondary. The primary is public safety. The primary is public safety. Structural design of members for fire is necessary, but that is only a secondary case.

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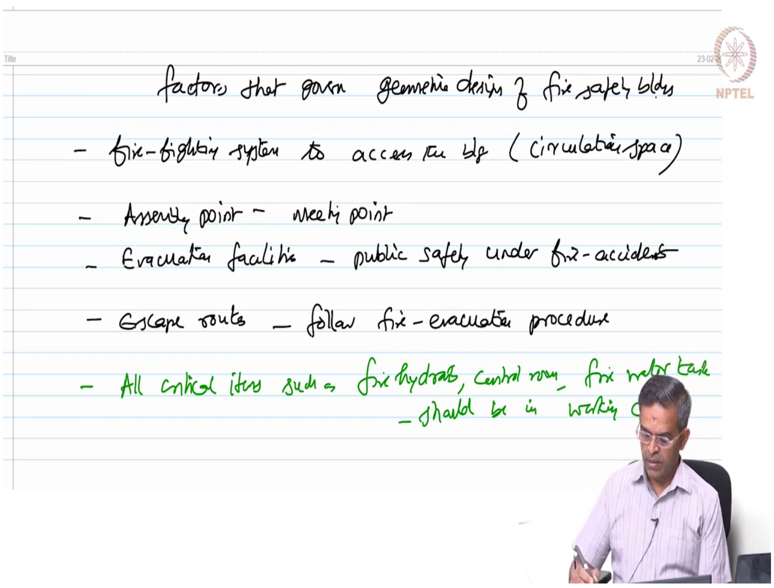

Now, let us see what are the factors that govern the geometric design of fire-resistant buildings. The first one is the firefighting system to access the building. That is the building should have enough circulation space around the building. The building should have something called a common assembly point, which is also otherwise called as meeting point which should be known to all the occupants of the building.

The building should have a very good evacuation facility. It should follow public safety under fire accidents. It should have well-lit escape routes; it should follow fire evacuation procedure as instructed by the course. Moreover, and most importantly, all critical items such as fire hydrants, control rooms, fire water tank, should be in proper working condition. It should be frequently inspected and certified for its proper working.

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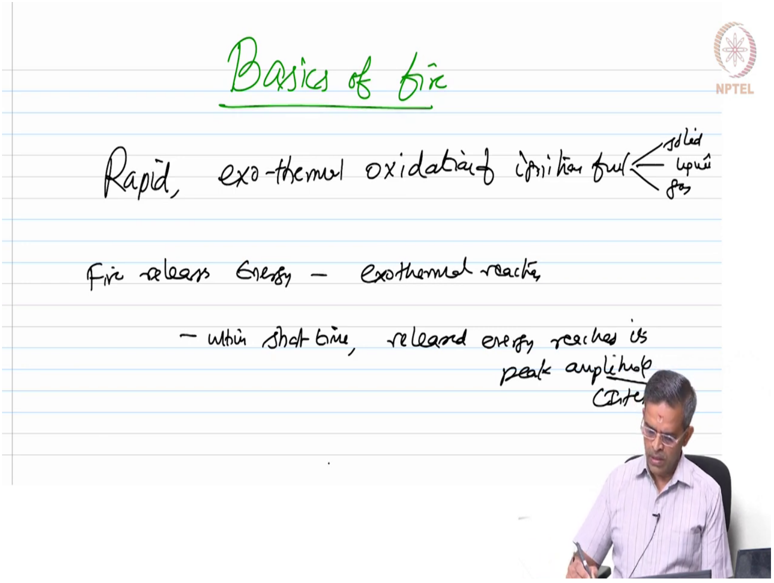

Let us quickly see some basics of fire. Friends, fire is a rapid exothermal oxidation of ignition fuel. The fuel can be in the form of solid, liquid or gas. Fire releases energy which is an exothermal reaction. Now, within short time, the released energy reaches its peak amplitude or peak intensity. That is the most serious concern as far as fire is concerned.

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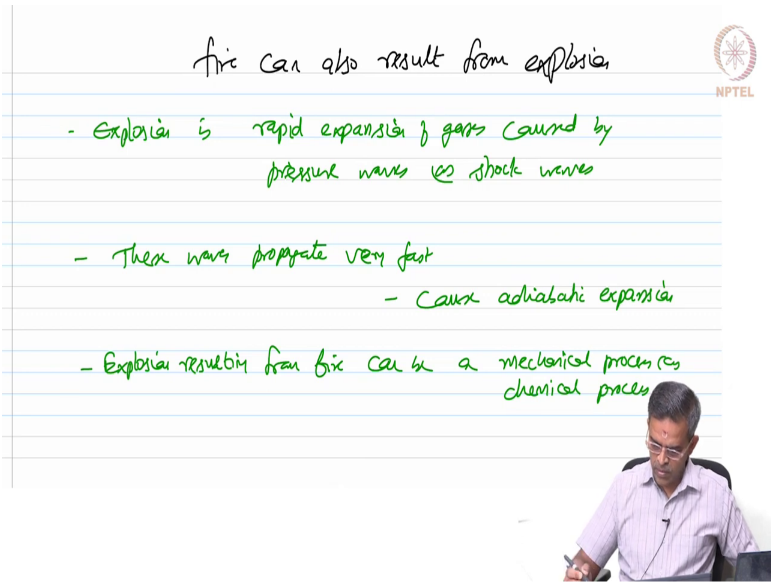

Fire can also result from explosion. Explosion is rapid expansion of gases caused by pressure waves or shockwaves. In the previous set of lectures, we understood how to calculate the shockwave and overpressure waves. A rapid expansion of gases caused by these waves can result in explosion.

The interesting part is these waves propagate very fast. In the numerical example you see that they were only in milliseconds. What is the concern of this? It can cause adiabatic expansion.

Explosion resulting from fire can be a mechanical process or a chemical process.

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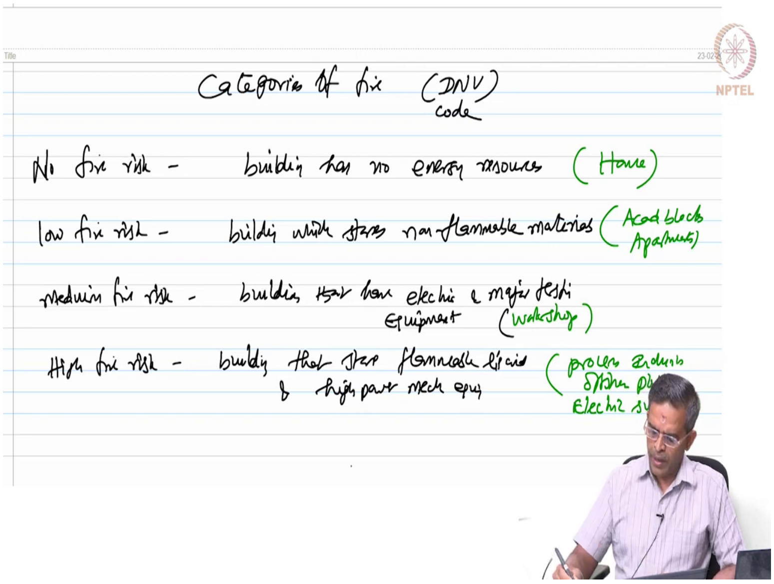

Let us see what are categories of fire as per DNV code. So, DNV code classifies fire as follows. No fire risk, so the building in that case has no energy resources to catch fire. The example could be home or house.

The next is low fire risk, this will occur in buildings which stores non-flammable materials. Examples of academic blocks, schools, colleges, apartments, which stores non-flammable materials.

Next could be medium fire risk, which is classified as buildings that has or that have electric and major testing equipment. For example, it can be workshop. Lastly, high fire risk, these can be buildings that stores flammable liquid. Example could be process industries, offshore platforms, as well as it also classifies and high-power mechanical equipment. So, in that case, I can also include electric substation.

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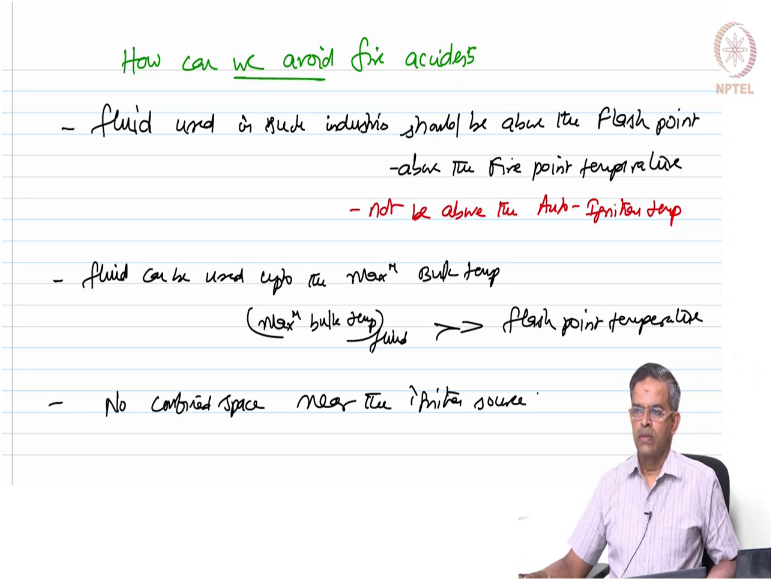

Let us ask a question how can we avoid fire accidents. The fluid used in such industries which are prone to fire should be above the flash point. It should be above the fire point temperature. It should not be above the auto ignition temperature.

Next, fluid can be used up to the maximum bulk temperature. So, the maximum bulk temperature of any fluid is always much higher than the flash point temperature. It is a common characteristic of a fluid. Finally, no confined space near the ignition source, it should be open from all sides.

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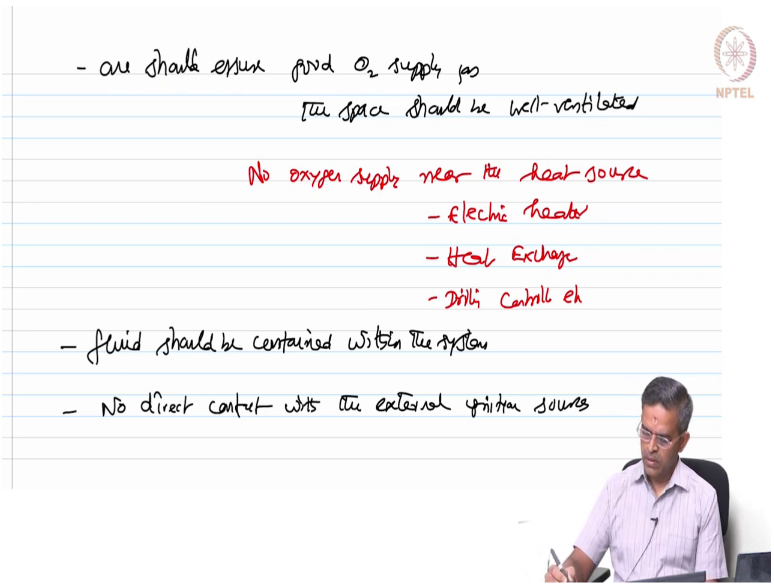

Further, one should ensure good oxygen supply or the space should be well-ventilated. But importantly no oxygen supply near the heat source, electric heater, the heat exchanger, the drilling controller. Further, fluid should be contained within the system. There should be no direct contact with the external ignition sources.

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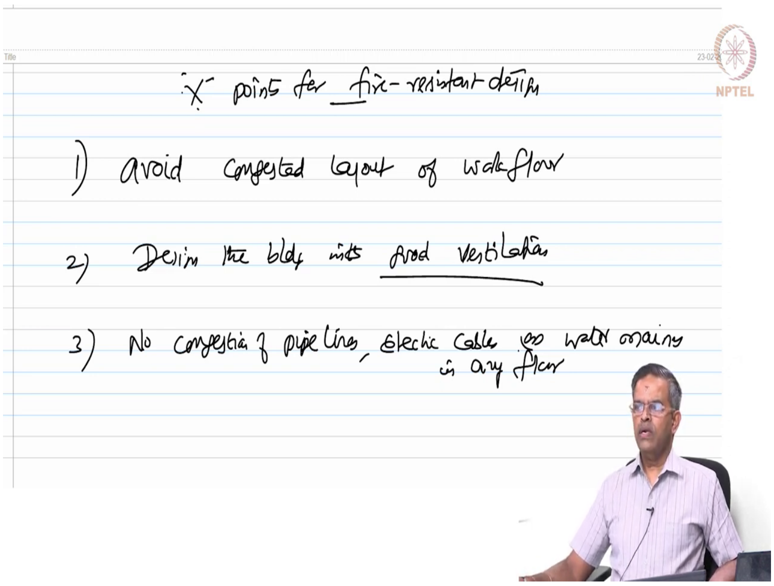

So, let us see some of the important points for fire resistant design.

Avoid congested layout of workflow.

Design the building with good ventilation.

There should be no congestion of pipelines, electric cables, or water mains in any floor.

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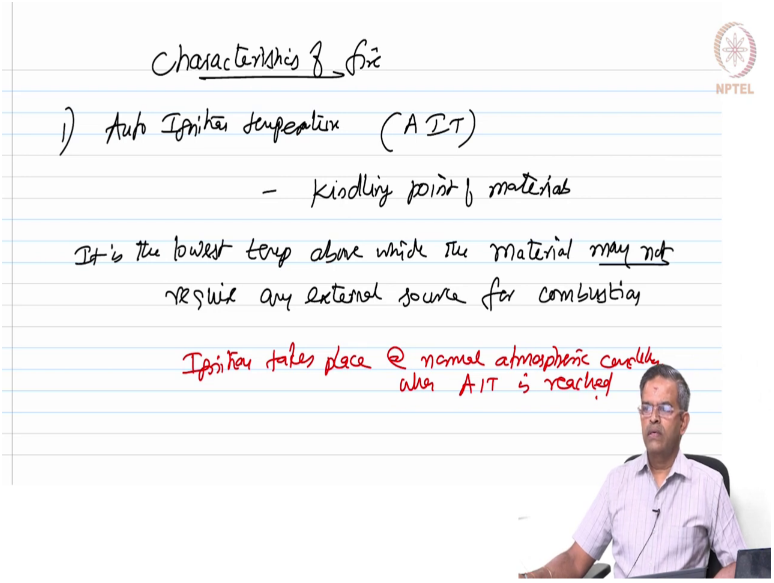

Now, let us see what are important characteristics of fire.

First one, Auto ignition temperature, AIT. It is also called as kindling point of materials. It is the lowest temperature above which the material may not require any external source for combustion. So, ignition takes place at normal atmospheric conditions when AIT of a fluid is reached.

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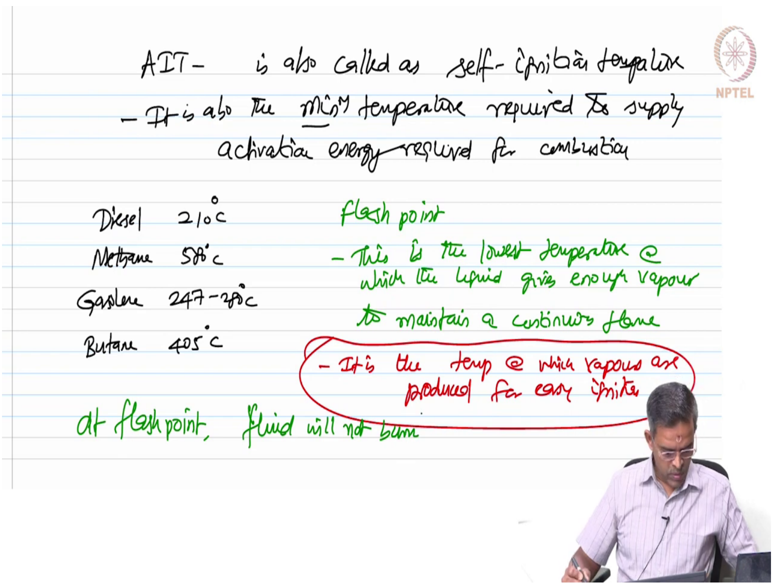

AIT is called also called as self-ignition temperature. It is also the minimum temperature require to supply activation energy required for combustion. Let us say for example, diesel has got 200 degrees Celsius, methane is 580 degrees Celsius, gasoline is in the range of 247 to 280, butane is about 405 degree Celsius.

Let us also look at something called a flashpoint. This is the lowest temperature at which the liquid gives enough vapour to maintain a continuous flame. It is not the temperature at which vapours are produced, for easy ignition. It is the temperature at which vapours are produced for easy ignition.

So, friends, an important point here is at flashpoint, fluid will not burn. That is important.

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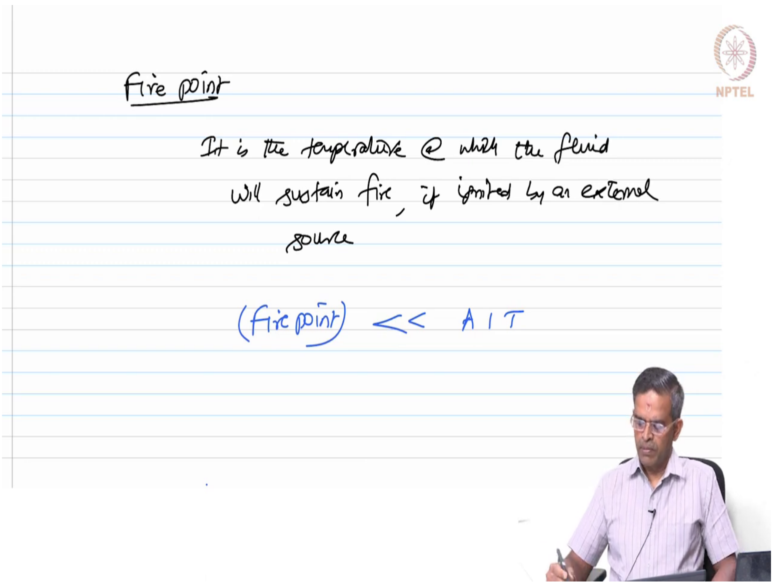

The next one is called as a fire point. It is a temperature at which the fluid will sustain fire, if ignited by an external source. But interestingly, fire point of a fluid is always much lesser than the auto ignition temperature. Since, we are writing about the fire-resistant design, let us talk quickly about fire protection systems as well for our understanding.

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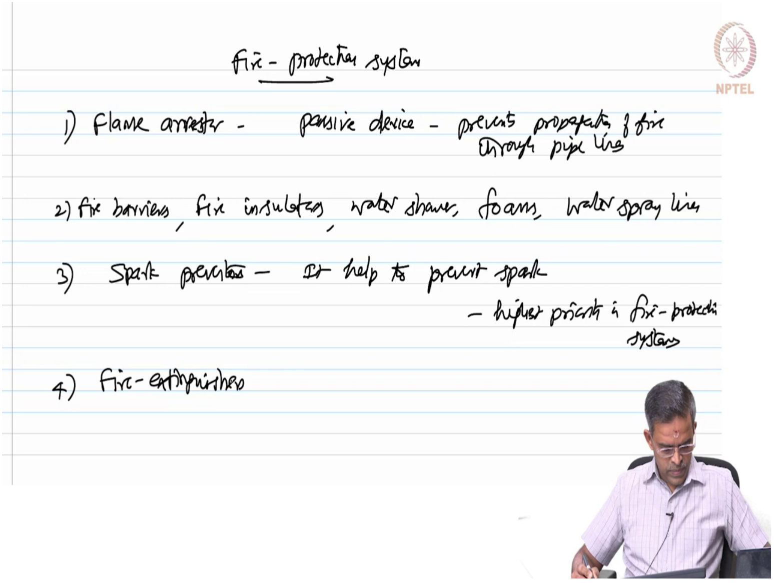

There are many fire protection systems available. One is called as the frame arrestor. Flame arrestor, it is a passive device which prevents propagation of fire through pipelines.

The second one is called fire barriers, fire insulators, water shower, foams, water spray lines etc. The third set of fire protection system involves spark preventers. It helps to prevent spark. This is one of the highest priorities in firefighting protection systems. Of course, the last one as we all know is fire extinguishers which are firefighting systems.

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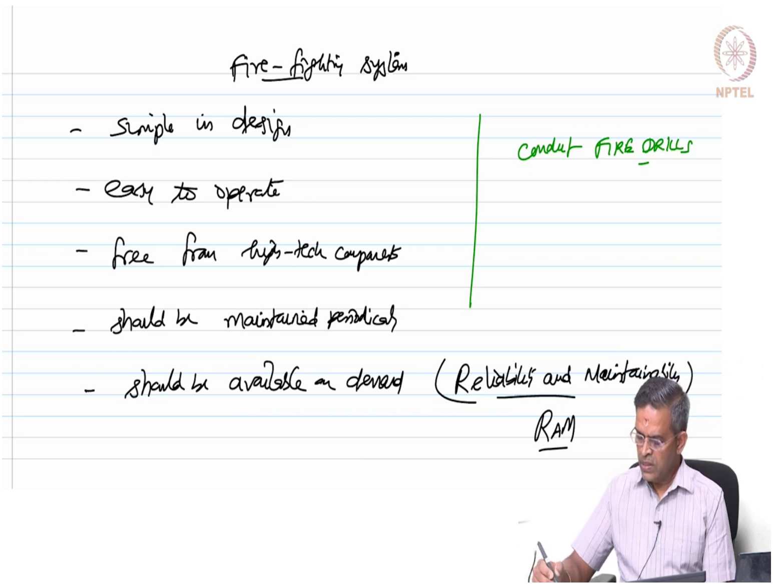

And let us have a brief look at the components of firefighting system. Firefighting system should be simple in design. It should be easy to operate. It should be free from high tech components. It should be maintained periodically. Most importantly, should be available on demand.

Friends, the recent research is now focusing on reliability and maintainability. So, you are looking for reliability and maintainability to check whether any specific system is reliable and available on demand. So, to ensure this, people conduct fire drills at periodic intervals in all industrial structural systems to ensure that the firefighting system is essentially works maintained in a proper manner.

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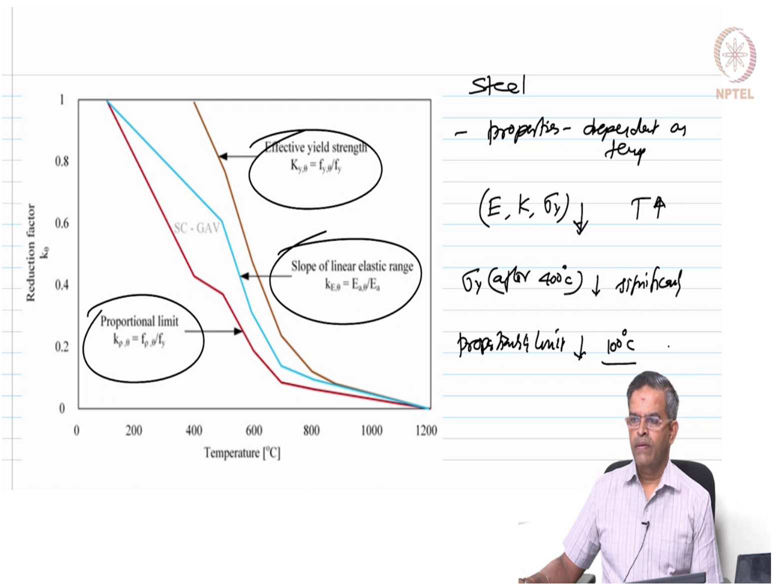

Now, friends as we understand, steel is seen as a very advantageous material. The curve on the screen shows the temperature is a reduction factor which is a strength reduction of steel. So, steel is the most preferred material, but steel has got properties which are dependent on temperature.

Look at the effective yield strength and proportional limit as well as the slope of linear elastic range. So, the yield strength, the stiffness, and modulus of elasticity, all decrease with increase in temperature. Especially, the yield strength after 400-degree Celsius decreases significantly.

The proportionality limit also decreases beyond 100 degree Celsius. So, the ductility characteristics, strength degradation, happens in steel as you proceed with the temperature.

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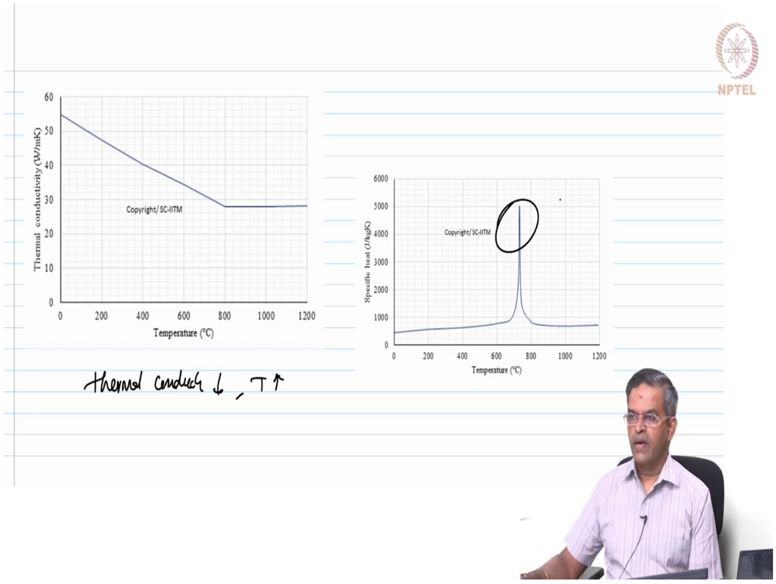

Furthermore, if you look at thermal conductivity of steel, it also decreases with increase in temperature beyond 800 degrees Celsius. It remains constant. Furthermore, the specific heat capacity of steel remains almost constant except at about 700 degrees Celsius, it reaches a specific peak where the specific heat capacity touches about 5000 joules per kg kelvin close to range of about 750 degrees Celsius in the temperature.

So, these properties of steel which were discussed in the earlier lectures are only helping you to re-brush the constant characteristics of steel with respect to time and temperature.

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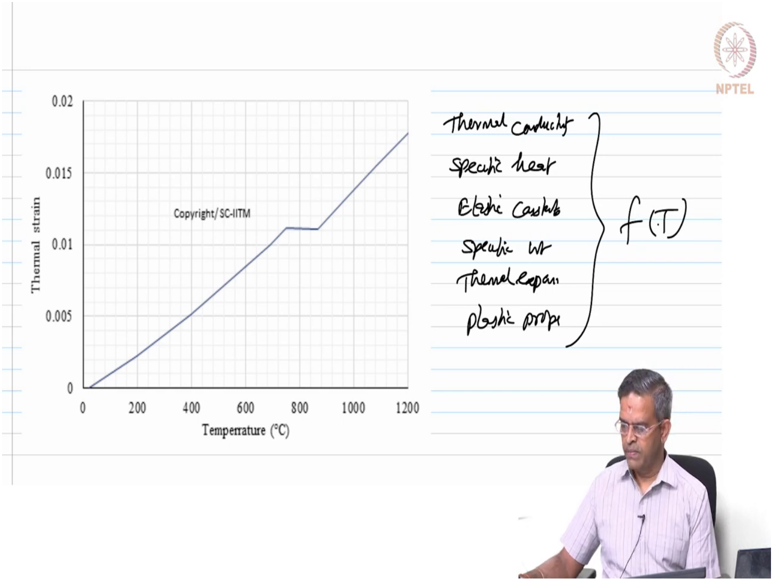

Furthermore, if we look at the thermal strain, it keeps on increasing with increase in temperature. So, therefore, friends, thermal conductivity, specific heat, elastic constants, specific weight, thermal expansion, and plastic properties of steel all become function of temperature.

So, when you are using steel for a fire-resistant design, where the fire is going to happen at a higher temperature because of explosion or hydrocarbon fire et. You got to be very careful in understanding the properties of steel which is being used for fire resistant design.

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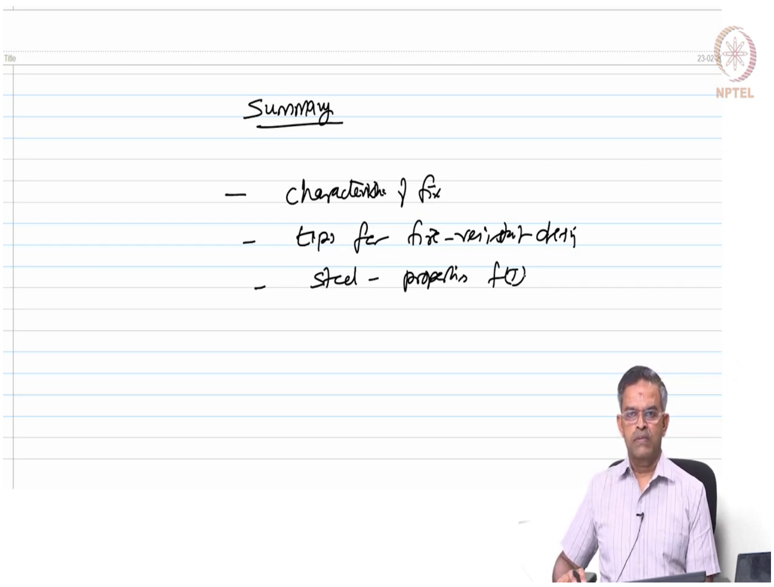

So, friends, in this lecture, we learnt about characteristics of fire. We learned briefly about tips for fire resistant design. We also completed a problem on blast loads analysis. And we learned that steel has got properties which are function of temperature. And one has got to be very careful, in using these properties appropriately in the design, if you are enabling fire resistant design of steel structures.

Thank you very much. And have a good day.