Offshore structures under special loads including Fire resistance

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Module – 03
Fire Resistance
Lecture – 52
Design Approach- I

Friends, in this lecture we will discuss about various design approaches which are commonly used for fire resistant design of buildings. We will apply them try to discuss these approaches as applicable in suitability of these approaches for offshore structural design as well.

So please recollect, in the last lectures, set of lectures we said that offshore structures are dealing with exploration of highly flammable mixtures therefore, risk presence in offshore systems because of fire and explosion due to these hydrocarbon exploration process or inhabitable. The whole idea of the fire resistance design should be leading towards minimizing the consequences of the risk. You will not be able to mitigate the probability of occurrence of these accidents because these accidents are because of falls or because of complexities that arise in the chemical process of exploration production processing and storage.

Therefore we will not be able to identify and control the probability of occurrences of these accidents. The fire resistant design as a whole will and should lead towards minimizing the consequences in case of in his explosion occurs. So, risk is of course, handling the consequences also one important part. In the last set of lectures we saw how fire and explosion can be leading towards disasters consequences which can be controlled and brought down to an acceptable level which is referred as ALARP level in offshore design.

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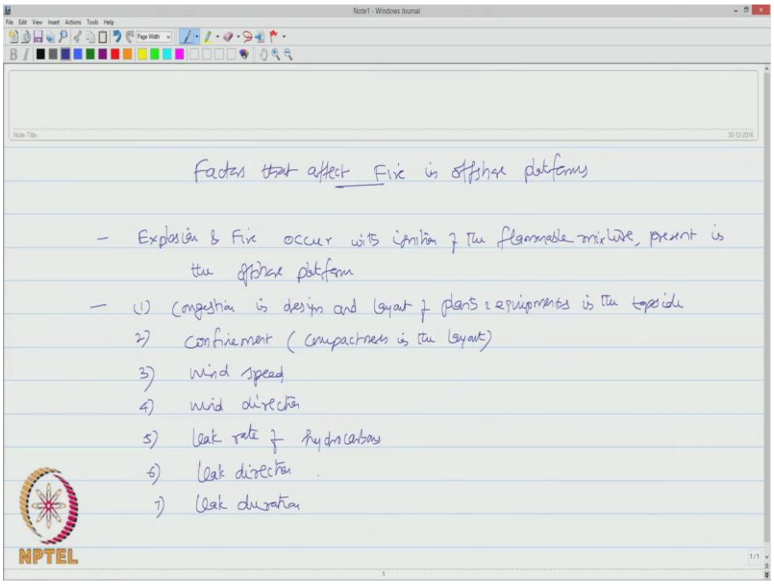

After understanding the types of fire which can happen in offshore platforms, let us talk about the factors that affect fire in offshore platforms. There are many factors responsible for fire and explosion occurrence in offshore platforms. We now know that explosion and fire occurs with ignition of the flammable mixture present in the offshore platform. Various factors lead to the fire and offshore platforms, the foremost factor is congestion in design and layout of plants and equipments in the top side.

The second factor should be referred to the confinement, what we say as compactness in the layout. In fact, that is one of the important factors which leads to fire, wind speed, wind direction, leak rate of hydrocarbons and gas leak direction, leak duration, leak position.

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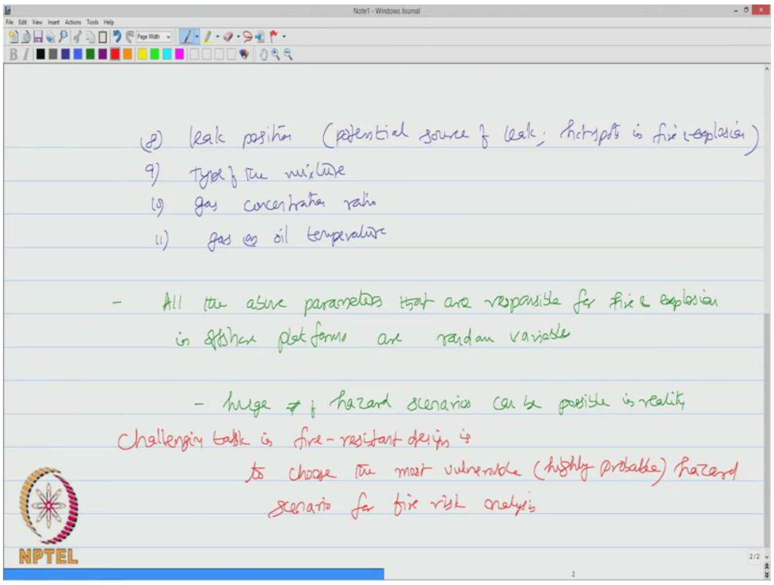

Let us say the potential source of leak or otherwise called as hotspots in fire and explosion, type of the mixture and gas concentration ratio gas or oil temperature. Looking at these factors which are going to influence fire accidents occurrence in offshore platforms, we have learnt very important lesson from this saying that all the above parameters that are responsible for fire and explosion in offshore platforms are random variables.

Therefore a huge number of hazard scenarios can be possible in reality. Hence the most challenging task in fire resistant design is to chose the most vulnerable or let us say highly probable hazard scenario for fire risk analysis, so that is the most challenging task.

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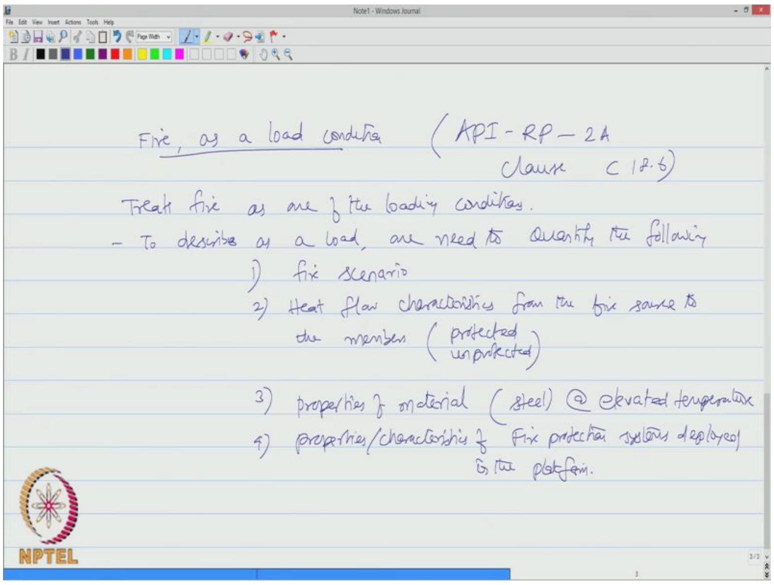

If you look at fire as a load condition, international course guide us in treating fire as one of the loads, one can look at API RP 2 A clause C 18.6 to be very specific. International coral procedure treats fire as one of the loading conditions, so to describe fire as a load one need to quantify the following.

One; one has to identify the fire scenario; second one should need to quantify the heat flow characteristics from the fire source to the members. The members sometimes may be protected, it can be unprotected. Three we need to also know properties of material by and large it is steel at elevated temperatures, we have discussed about this in detail in the previous lectures and fourth could be we should also know what are the various properties and characteristics of fire protection systems deployed in the platform.

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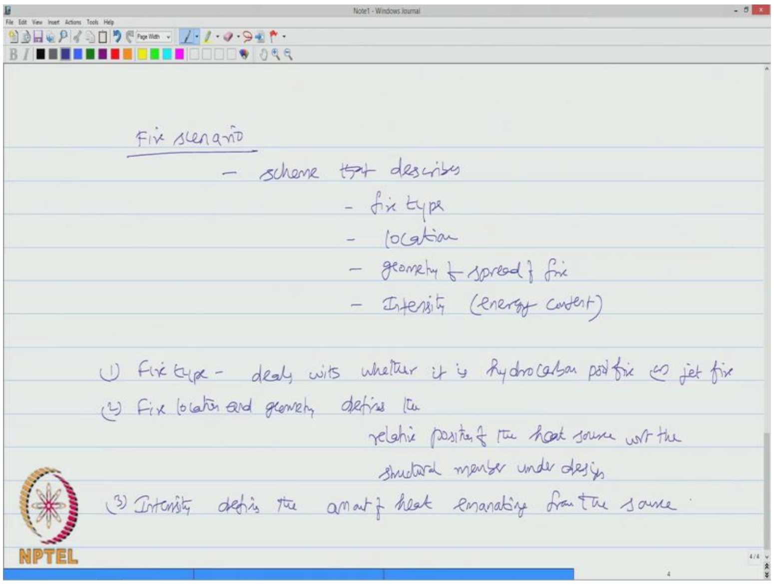

Let us quickly talk about what is called as a fire scenario, fire scenario is a scheme that describes fire type, location, geometry of spread of fire and of course, intensity which talks about the energy content, out of this, fire type deals with whether the fire, whether it is a hydrocarbon pool fire or a jet fire. Fire location and geometry defines the relative position of the heat source with respect to the structural member under design. Intensity defines the amount of heat emanating from the source.

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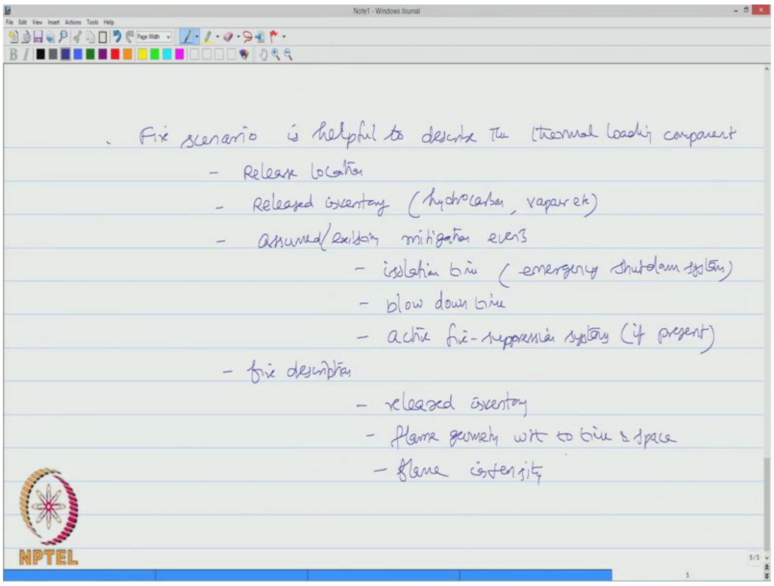

So, fire scenario is helpful to describe the thermal loading component, he talks about the release location, the released inventory whether it is hydrocarbon vapor etcetera. It also deals with the assumed or existing mitigation events like isolation time, in case when people use emergency shutdown systems. It also talks about blow down time; it also talks about some active fire suppression systems if they are in place. It also deals with fire description like the released inventory, flame geometry with respect to time and space.

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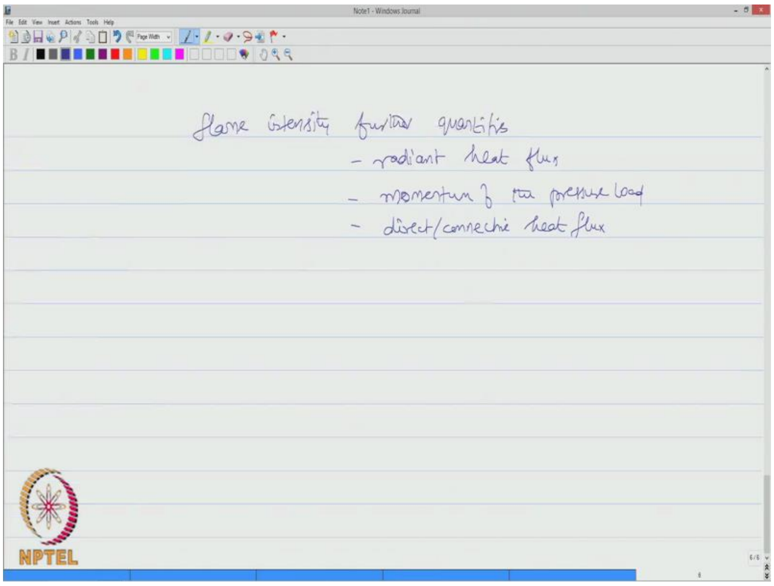

Flame intensity further quantifies the radiant heat flux, momentum of the pressure load and direct or connective heat flux.

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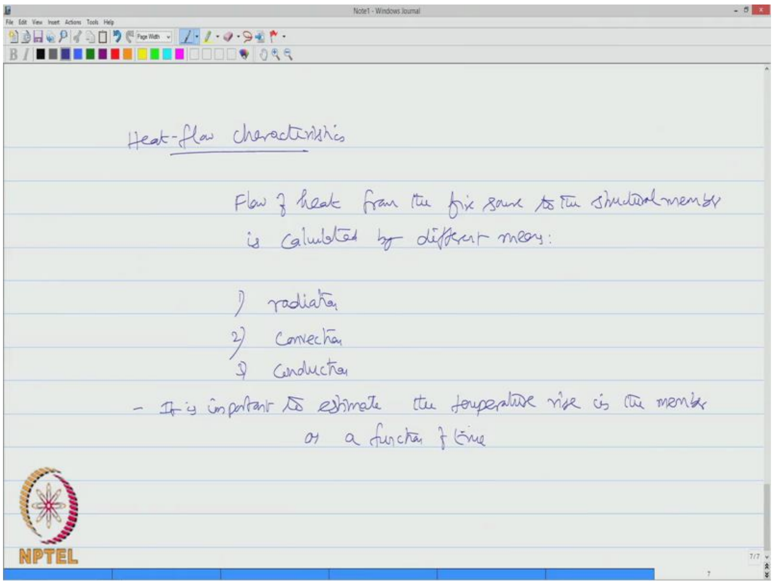

Let us now talk about some of the heat flow characteristics which are important to ascertain the design approach. Flow of heat from the fire source to the structural member is calculated by different ways. One; it can be as radiation, it can be convection and it can be conduction, it is important to estimate the temperature rise in the member as function of time.

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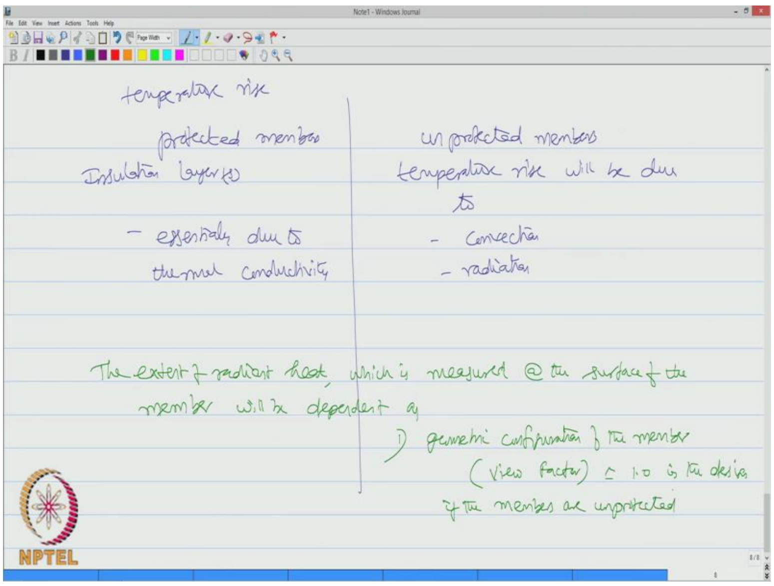

Let us talk about the temperature rise in protected and unprotected members; obviously, in protected members there will be insulation layer, there can be even insulation layers.

Therefore, the temperature rise in protected members will be essentially due to thermal conductivity, whereas an unprotected members; temperature rise will be due to convection and radiation.

So, friends the extent of radiant heat which is measured at the surface of the member will be dependent on the geometric configuration of the member, which is otherwise in design called as view factor. Generally the view factor is used as 1.0 in the design, if the members are unprotected.

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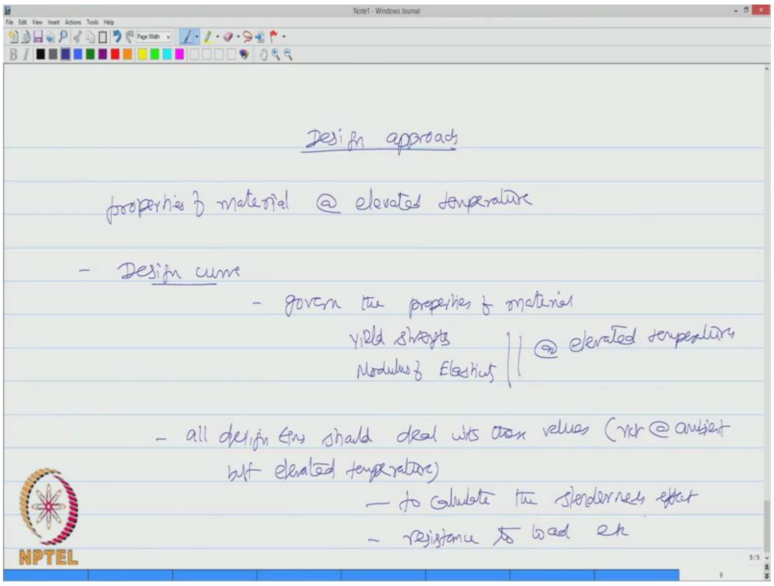

When we talk about design approach, we need to essentially understand the properties of material at elevated temperature, so we need to look at what is called a design curve. The design curve should govern the properties of material like yield strength, modulus of elasticity at elevated temperatures and all design equations should deal with these values not at ambient temperature, but at elevated temperature to calculate the slenderness effect, resistance to load etcetera.

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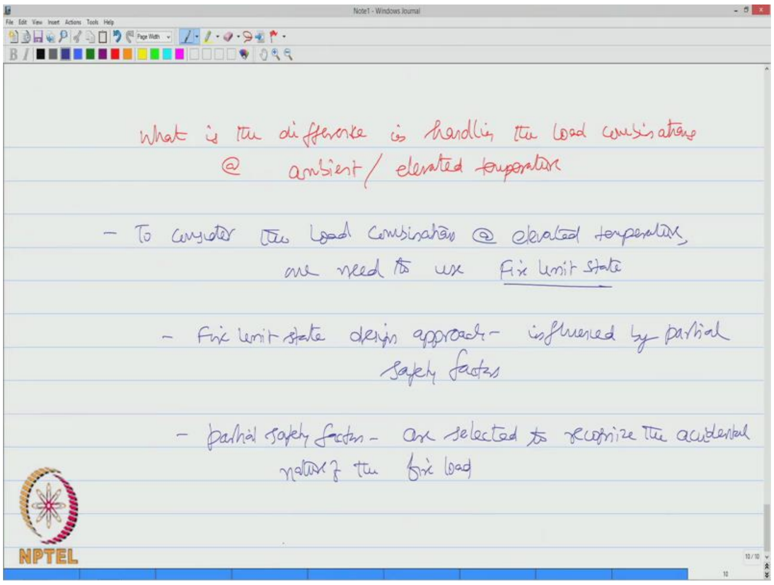

Now the interesting part is; what is the difference in handling the load combinations at ambient temperature and elevated temperature. So, the question is to consider the load combinations at elevated temperature, we need to use fire limit state.

Fire limit state design approach is influenced by use of partial safety factors, these partial safety factors are selected to recognize the accidental nature of the fire load. So, the philosophy should be to compute or assess temperature distribution within the structure.

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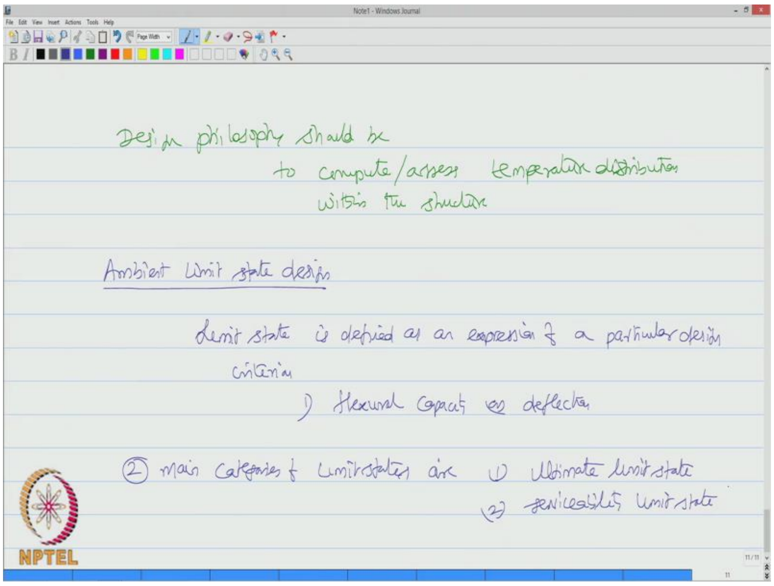

Let us quickly compare this with an ambient limit state design before we move on to understand fire limit state design. So, let us see what are the factors and what is the design analogy; in ambient limit state design generally if you look at a limit state, limit state is defined as an expression of a particular design criteria, for example it can be flexural capacity or deflection.

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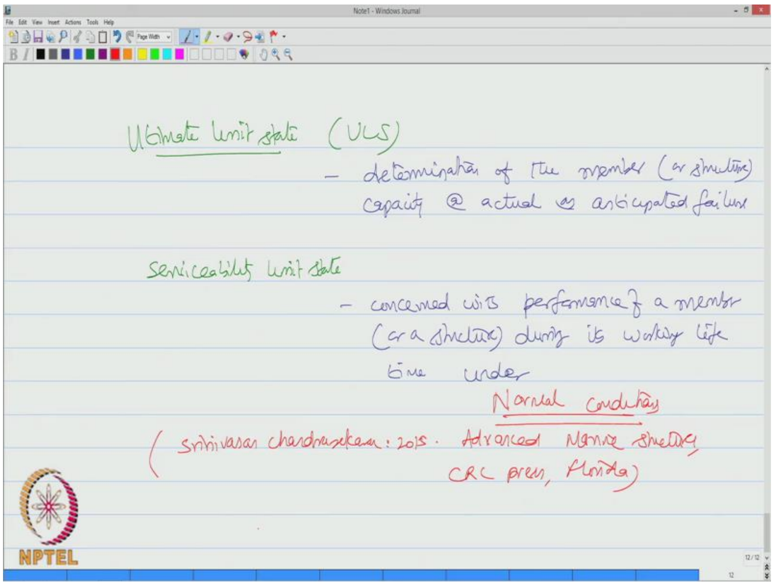

The two main categories of limit state design or limit states are one, ultimate limit state; two serviceability limit state. Ultimate limit state which is ULS deals with determination of the member capacity, member or structure capacity at actual or anticipated failure.

Whereas serviceability limit state is concerned with performance of a structure, of a member or a structure during its working lifetime under most importantly normal conditions. So, one can look into more details of this limit states by the book authored by me; Advanced Marine Structures CRC press, Florida, the details of reference are available in the reference list in the course end.

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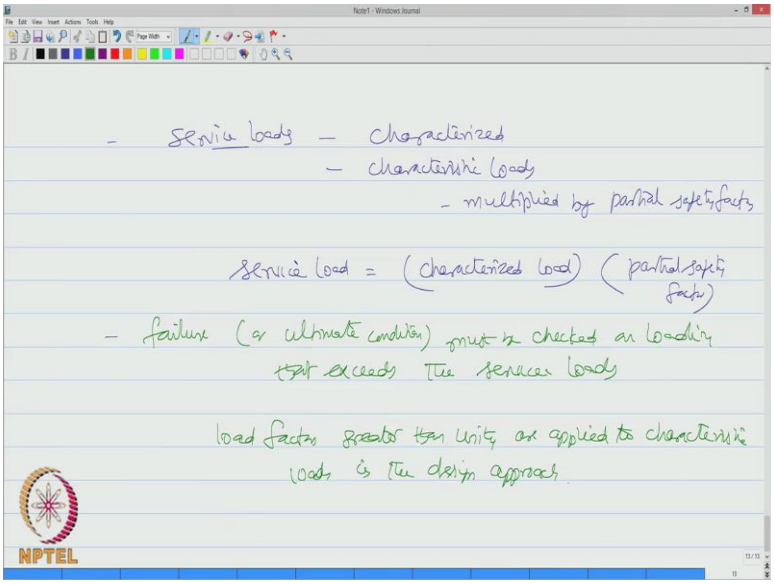

So, we understand that in the conventional limit state design at ambient temperature, we calculate what is called service loads. Service loads are generally characterized; they are called characteristic loads which are actually multiplied by partial safety factors. So, service load is actually characterized load, multiplied by a partial safety factor. Therefore, failure or let us say ultimate condition must be checked on loading that exceeds the service, that is the design philosophy in ultimate limit state design that is load factors greater than unity or applied to characteristic loads in the design approach.

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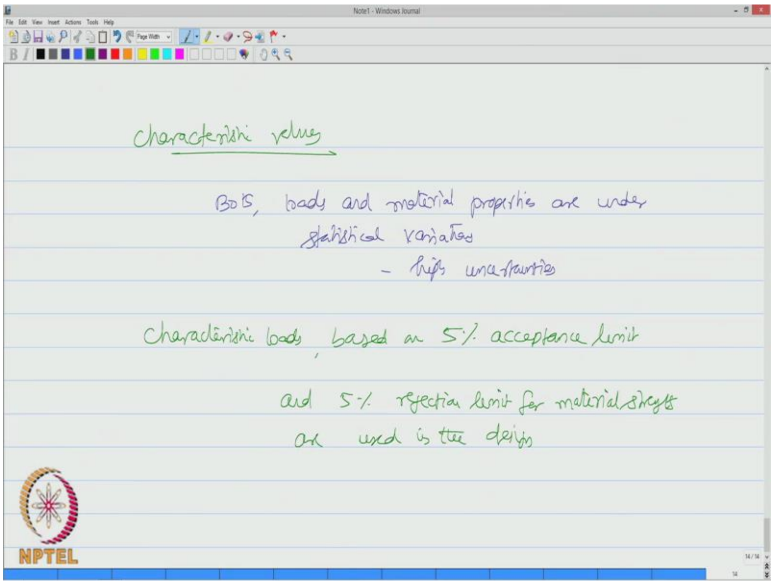

Once we talk about characteristic loads, let us say what is this characteristic values. Now both loads and material properties are under statistical variations, they are subjected to high uncertainties.

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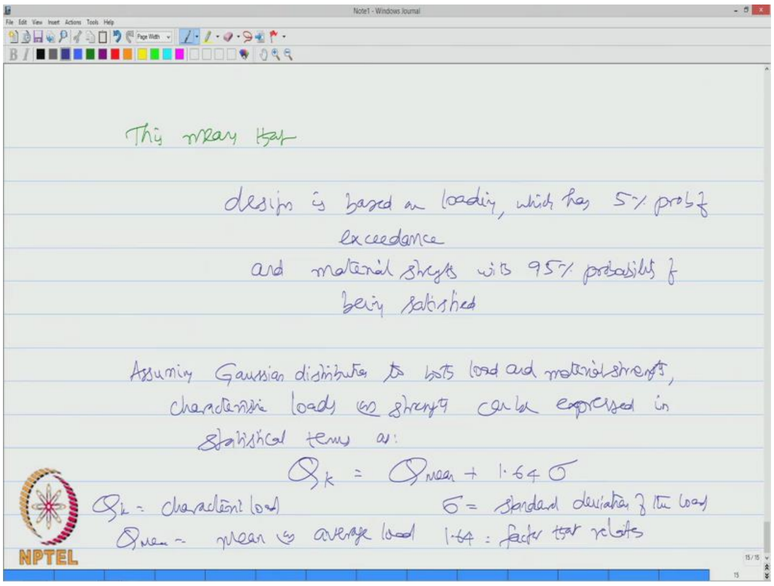

Therefore, characteristic loads based on 5 percent acceptance limit and 5 percents rejection limit for material strength are used in the design which means that design is actually based on loading which has 5 percent probability of exceedance and material strength with 95 percent probability of being satisfied, by assuming Gaussian distribution; to both load and material strength, characteristic loads or strength can be expressed in statistical terms as below.

Let us say quantity k which is the characteristic load can the mean value plus 1.64 sigma where Qk is the characteristic load and Q mean is the mean or average load and sigma is the standard deviation of the load and 1.64 is a factor that relates area under the Gaussian distribution curve to give a 5 percent limit.

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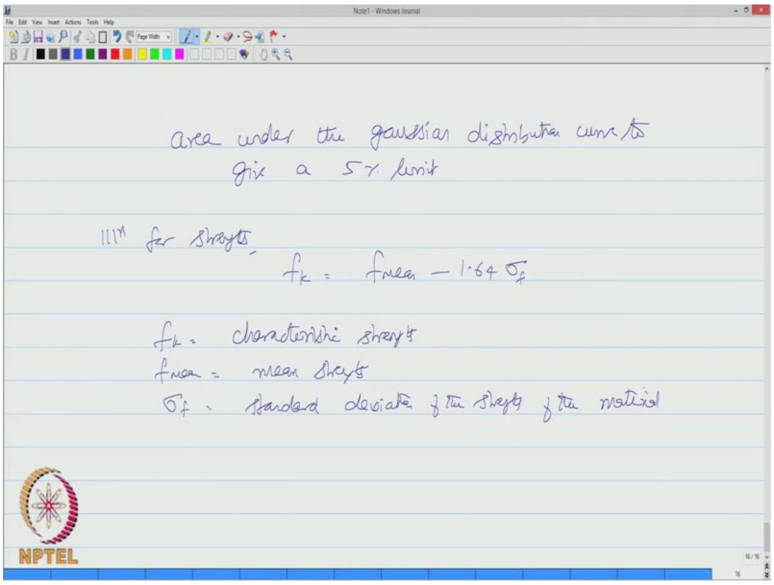

Similarly for strength fk can be f mean minus 1.64 sigma f; where fk can be the characteristic strength, f mean is the mean strength sigma f either standard deviation of the strength of the material.

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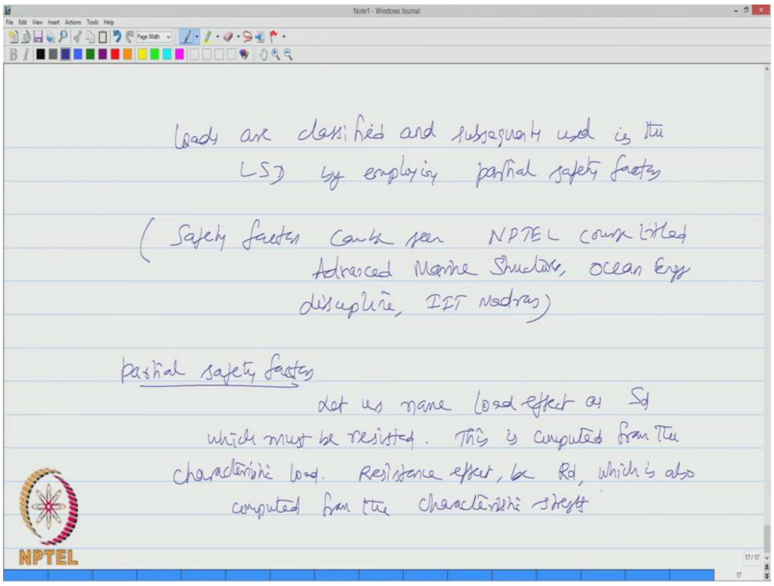

So, if we do agree that loads are classified and subsequently used in the limit state design by employing partial safety factors. More explanation on safety factors can be seen in NPTEL course titled; Advanced Marine Structures in the Ocean Engineering discipline offered by IIT Madras.

So, for convenience sake let us discuss very briefly the partial safety factors. Let us call, let us name the load effect as Sd; which must be resisted. This is computed from the characteristic load, the resistance effect be Rd which is also computed from the characteristic strength.

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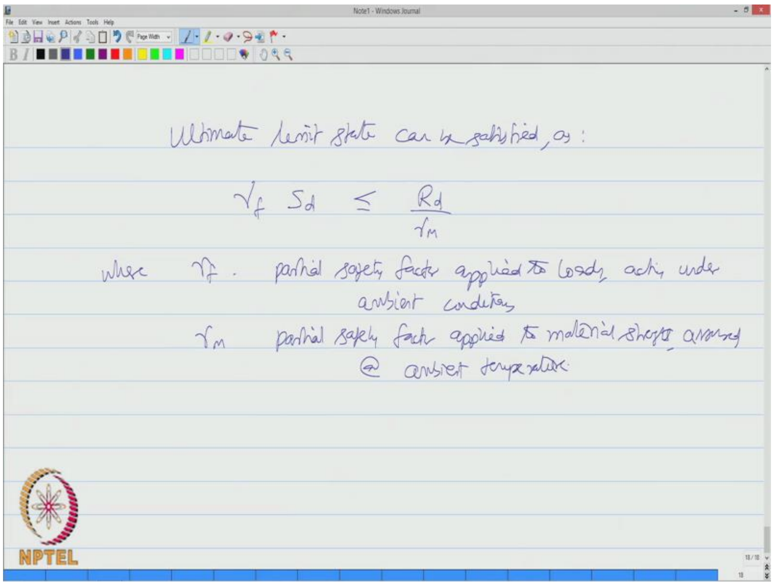

Then ultimate limit state can be satisfied as gamma f into Sd which will less than or equal to Rd by gamma m, where gamma f is the partial safety factor applied to loads acting under ambient conditions please note this and gamma m is partial safety factor applied to material strength, assessed at ambient temperature.

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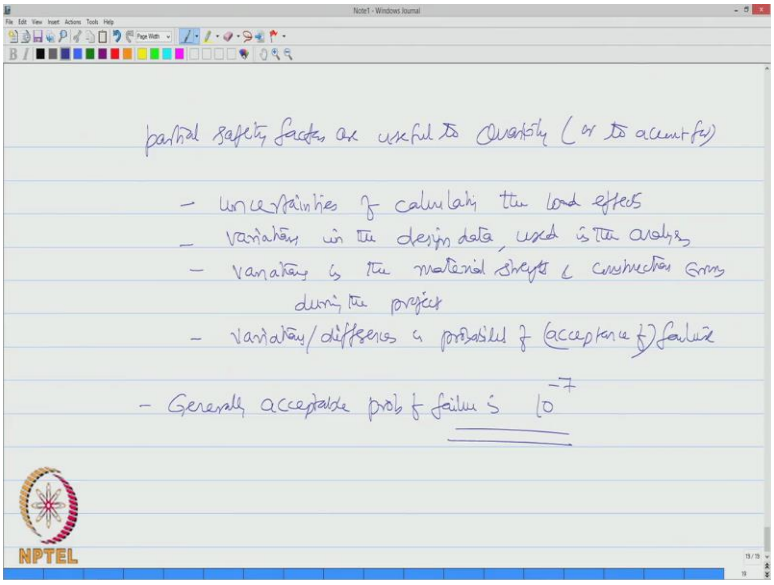

Partial safety factors are actually useful to quantify or to account for one uncertainties of calculating the load effects variations in the design data used in the analysis, variations in the material strength and construction errors during the project and account for variations or let us say differences in probability of acceptance of failure.

So, the generally acceptable probability of failure is 10 power minus 7, so such a low probability ensures that partial safety factor should be properly selected so that the design is delivering the serviceability and the strength requirements of the member to withstand the applied loads.

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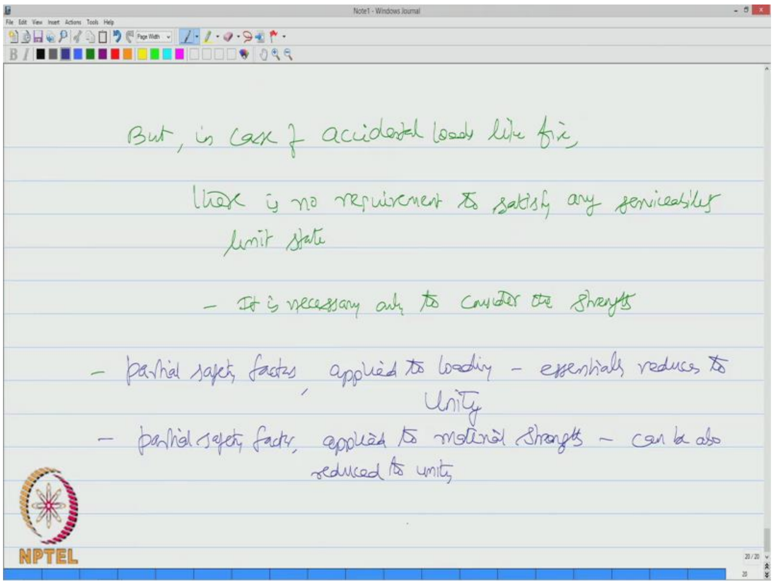

But in case of accidental loads like fire, there is no requirement to satisfy any serviceability limit state. It is necessary only to consider the strength. Therefore, partial safety factors which are applied to loading essentially reduces to unity; whereas partial safety factors applied to material strength can also be reduced to unity provided.

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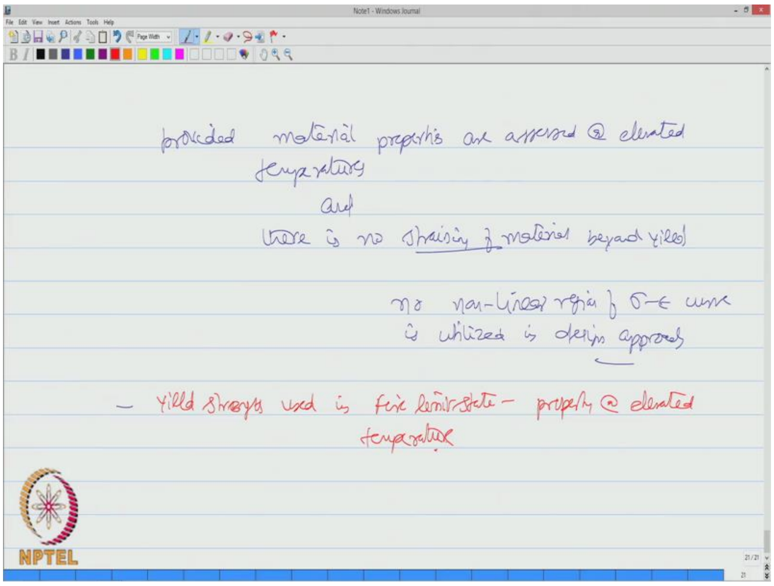

Material properties are assessed at elevated temperatures and there is no straining of material beyond yield that is no non-linear region of the stress strain curve is utilized in design, but please note that the yield strength used in fire limit state is related to property at elevated temperature.

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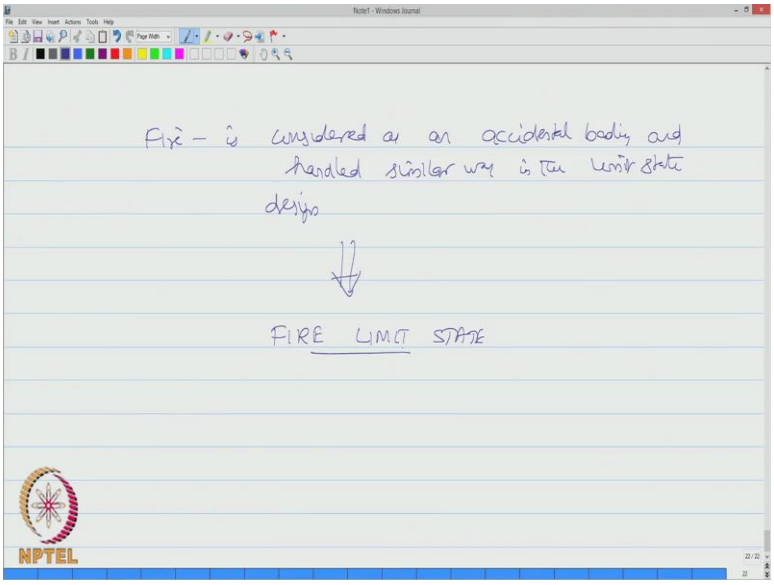

Therefore fire is considered as an accidental loading and handled similar way in the limit state design. So, let us extend the study of understanding to what we call fire limit state, which will discuss in the next lecture.

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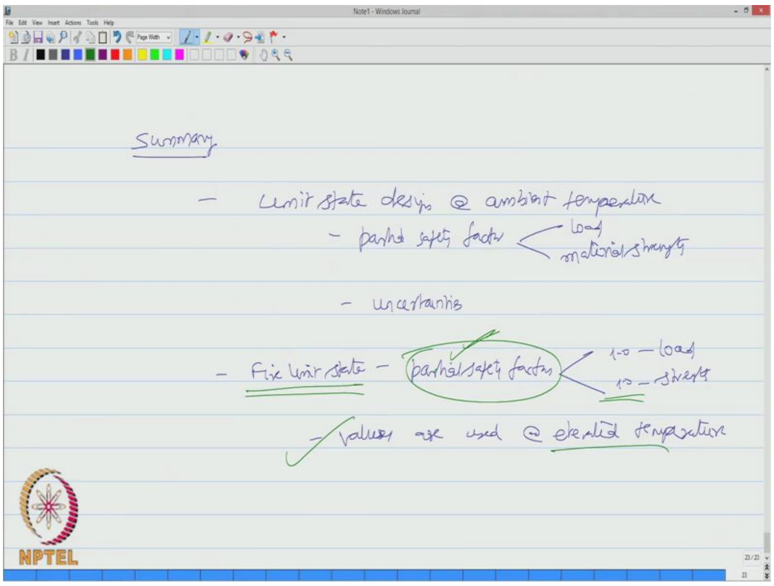

So, friends we understood that conventional limit state design at ambient temperature uses partial safety factors to both load and material strength. This only to account for various uncertainties whereas, the fire limit state can also be a similar procedure, but uses again partial safety factors which are closely reduced to 1.0 in both loads and strength but values are used at elevated temperatures.

On the other hand please note the partial safety factor used in fire limit state do not account for uncertainties that arise in material strength because of elevated temperatures that is very very important. We do not use the factor to account for reduction in strength at elevated temperature you must use the actual strength at elevated temperature in the design. Therefore, we can say that the partial safety factors in fire limit state more or less reduces to 1.0 whereas, still these partial safety factors an account for uncertainties in estimating the fire loads and characterizing the strength of the material at elevated temperatures but they do not account for variation in strength at elevated temperature which must be assess a prior to use this in the design approach.

Thank you very much.