

Advanced Design of Steel Structures
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Lecture - 13
Design Methods - 2

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Lecture 13 — Design Methods - 2

Learn partial factors

$$\gamma_f \times S_p \leq \frac{\gamma_p}{\gamma_m}$$

(design load) (design strength)

design strength

So, friends, welcome to Lecture 13 of the course on Advanced Steel Design, in this lecture we are going to learn more about the Partial Factors. So, this lecture is also focusing on Design Methods. In the last lecture we said $\gamma_f S_p \leq \frac{\gamma_p}{\gamma_m}$. So, we call this as the design load and we call this as a design strength. whereas, the factors address the uncertainties which are arising from various sources as we discussed in the last lecture.

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γ_f - load
 γ_m - material strength

partial factors

Ex, load factor (γ_f)

$$\gamma_f = \gamma_{f1} \cdot \gamma_{f2} \cdot \gamma_{f3} \quad (1)$$

γ_{f1} - accounts for load deviation from the assigned characteristic value

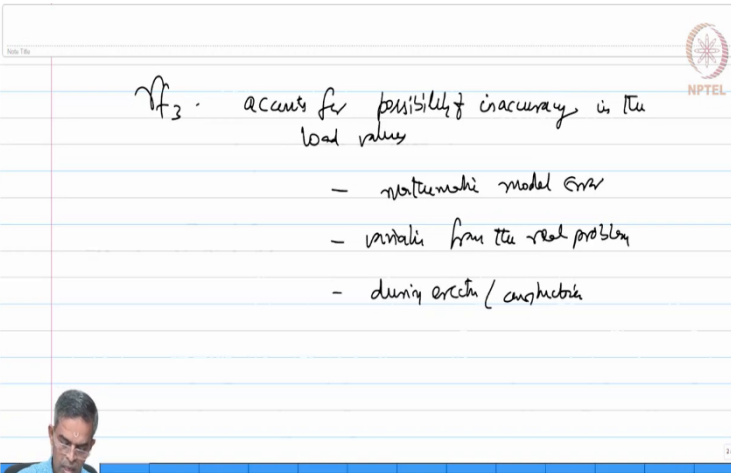
γ_{f2} - reduced probability that several independent loads appear together with the same characteristic value (load combination)

So, having said that the factors present in the load and the strength are going to take care of these uncertainties they are anyway addressed only as partial factors. So, let us take for example, the load factor which is γ_f , in the literature γ_f is actually a product of γ_{f1} , γ_{f2} , γ_{f3} . So, it has got three subdivisions let us see what are these three subdivisions address.

γ_{f1} accounts for load deviation from the assigned characteristic value. If you say the characteristic value is 5 percent the exceedance is only about 5 percent, but we exceeds beyond 5 percent what is that exceedance, beyond the characteristic value will be looked at γ_{f1} separately.

γ_{f2} will account for reduced probability that several independent loads appear together with the same characteristic value. When several loads with the same characteristic value appear together there can be reduced probability of that combination.


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γ_{f3} - accounts for possibility of inaccuracy in the load values

- mathematical model error
- variation from the real problem
- during erection / construction

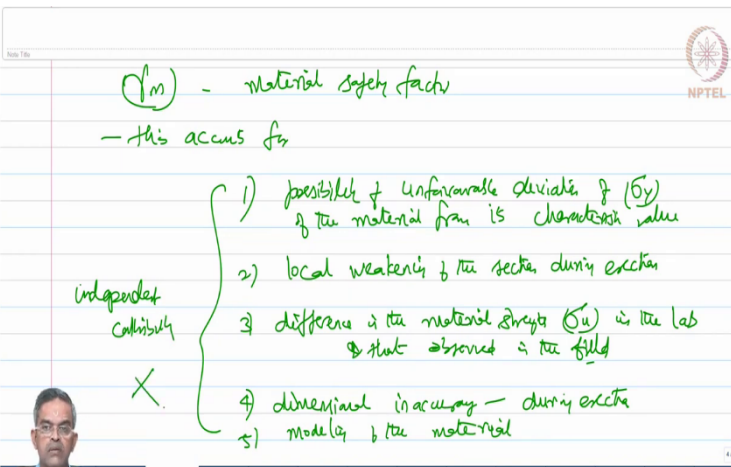
NPTEL



So, γ_{f2} looks for that, γ_{f3} accounts for possibility of inaccuracy in the load value arising from mathematical error or mathematical model error, variation from the real problem, problem arising during erection or construction etcetera. So, amongst these if you look at carefully γ_{f2} addresses the effect of load combination.

So, even within the partial safety factor of load itself there are three sub classifications.

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γ_m - material safety factor


- this accounts for

independent contribution

- 1) possibility of unfavourable deviation of σ_y of the material from its characteristic value
- 2) local weakness of the section during erection
- 3) difference in the material strength σ_u in the lab & that observed in the field
- 4) dimensional inaccuracy - during erection
- 5) modeling of the material

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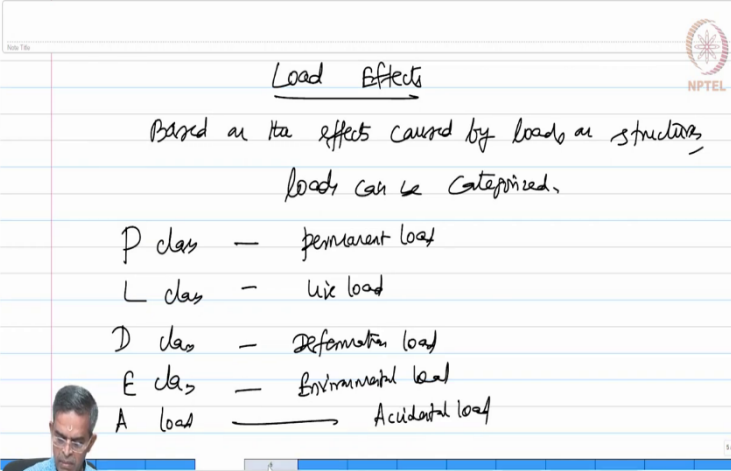


Similarly, if you look at γ_m , this accounts for possibility of unfavorable deviations of yield strength of the material from its characteristic value. There can be factors arising from local weakening of the section due to or during erection. There can be difference in the material strength for example, σ_u in the lab and that observed in the field.

So, in the field also you conduct experiments, you find out ultimate strength and Young's modulus in the field can compare those data directly with the manufactured supplier's data. So, there can be a variation and that difference is accounted in γ_m . Further there can be dimensional inaccuracy which can arise during erection. There can be also error in mathematical modeling of the material.

However, many codes do not distinguish these factors elaborately and do not give the percentage contribution of γ_m or γ_f from independent factors, they give a single combined number. So, for example, if γ_f is 1.5 and γ_m is 1.15 as in Indian codes, you will not come to know this 1.5 will be contribution from various sources. What is the effect of every factor on this γ ? You will not know these independent contributions, but they are together contributing to γ , we can only know that.

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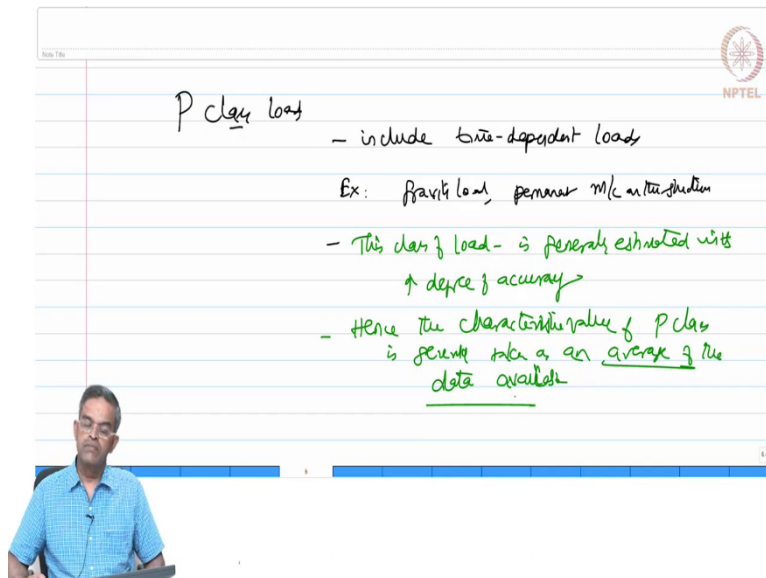


The slide contains handwritten text on a lined background. At the top right is the NPTEL logo. The title is 'Load Effects'. Below it, the text reads: 'Based on the effects caused by loads on structures, loads can be categorized.' This is followed by a list of load classes: 'P class - permanent load', 'L class - live load', 'D class - deformation load', 'E class - environmental load', and 'A class - accidental load'. In the bottom left corner, there is a small video inset showing a man in a blue shirt.

Let us now see something called load effects, see, what is the load effect? Based on the effects caused by the loads on structures loads can be categorized as P class load, L class load, D class load, E class load and A class load.

P class refers to permanent load, L class refers to live load, D class refers to deformation load, E class refers to environmental load and A class refers to accidental load.

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The slide displays handwritten notes on a lined background. The text is as follows:

P class load

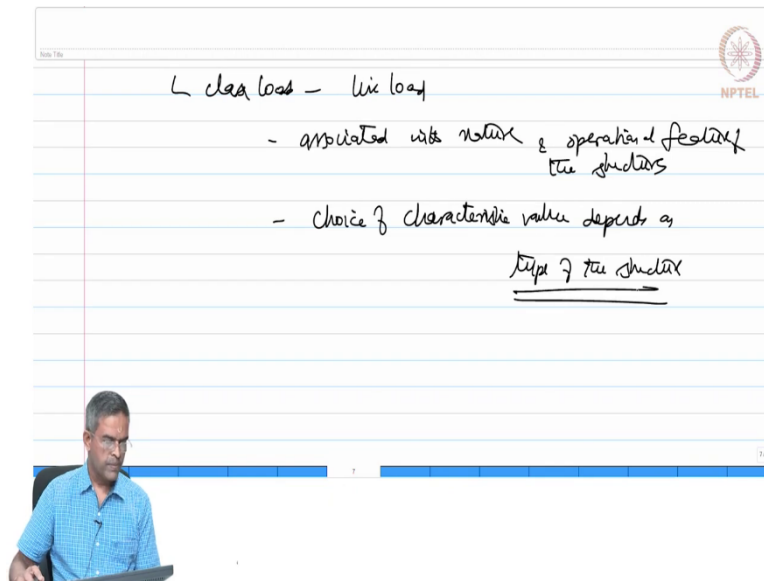
- include time-dependent loads
- Ex: gravity load, permanent m/c on the structure
- This class of load - is generally estimated with
↑ degree of accuracy
- Hence the characteristic value of P class
is generally taken as an average of the
data available

The NPTEL logo is visible in the top right corner of the slide. A small video inset of the presenter is located in the bottom left corner of the slide frame.

Let us see them slightly elaborate P class load, which are permanent load they include time dependent loads. Examples could be gravity load, weight of any permanent machinery on the structure and their variation over a period of time. So, the good thing about this class of load is this class of load is generally estimated with higher degree of accuracy.

Hence, the characteristic value of P class load is generally taken as an average of the data available and we can compute this with higher accuracy.

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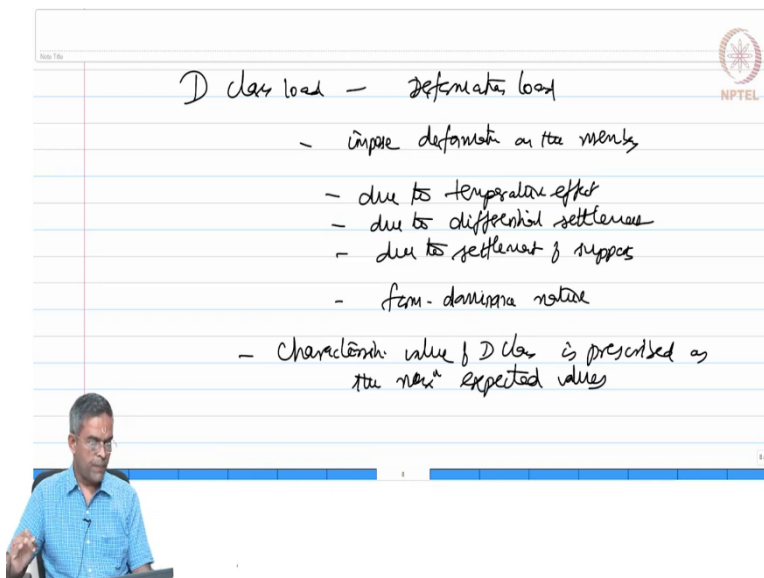


L class load - live load

- associated with nature & operational features of the structure
- choice of characteristic value depends on type of the structure

Let us come to L class load, L class load anywhere refers to live load, live load are associated with nature and operational features of the structure. That's why they are called live load. So, now, the choice of the characteristic value depends on type of the structure not on the type of the load.

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D class load - deformation load

- impose deformation on the members
- due to temperature effect
- due to differential settlement
- due to settlement of supports
- form-dominance nature
- Characteristic value of D class is prescribed as the max. expected values

When we talk about D class loads which refer to deformation loads, these loads are imposing the imposed deformation on the members. It may be due to temperature effect, due to differential settlement, due to settlement of supports, due to form dominance nature of the

structure. So, the characteristic value of D class is prescribed as the maximum expected values, it is an upper limit.

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E class - Environmental load

- accumulated - Environmental
 - wave load
 - wind load
 - current
 - G load

→ mean return period is the expected # of years between a seasonal max to occur

ex, If the return period is 50yr, it means that

If you come to the E class load which refers to environmental load, they are associated with loads arising from the environment. Examples could be wave load, wind load, load arising from current, and earthquake load etcetera. They are generally classified with the help of a term called mean return period.

Mean return period is defined as the expected number of years between a seasonal maximum to occur. For example, if the return period is 50 years.

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the characteristic load is expected to occur
only once in 50 yrs

Inverse of the return period

Prob that the characteristic value
will be exceeded in any one year
of its application

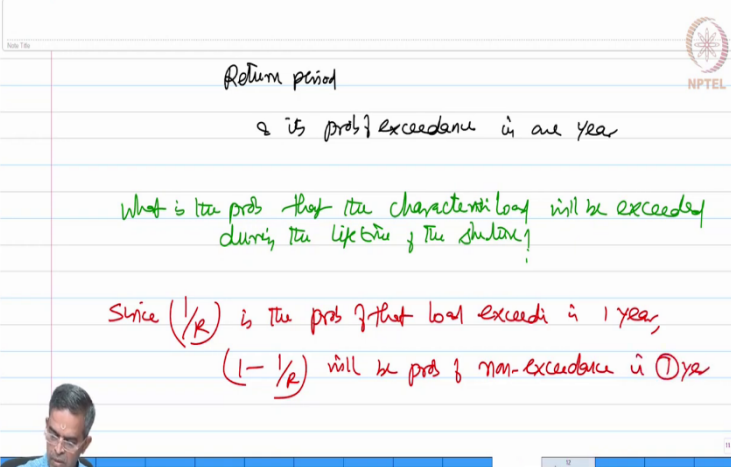
for ex. Return period of wind load = 100 yrs
Prob of wind load (characteristic value) will be exceeded in any one
year is 0.01 = 1% (circled)

It means that, it means that the characteristic load is expected to occur only once in 50 years that is the return period. Now, inverse of the return period is a very interesting parameter, this is the probability that the characteristic value will be exceeded in any one year of its application.

For example, if the return period of wind load is 100 years, inverse of this is going to be 0.11. So, we can now say that probability of the wind load that is the characteristic value will be exceeded in any one year is 0.01 which is nothing, but 1 by 100. So, 99 percent it will not exceed in any one year, but 1 percent there is a probability it may exceed. That is what the meaning of inverse return period.

Now, friends we have the return period which is expressed for the environmental loads we have seen the inverse of the time period also.


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Return period
is its prob of exceedance in one year

What is the prob that the characteristic load will be exceeded during the lifetime of the structure?

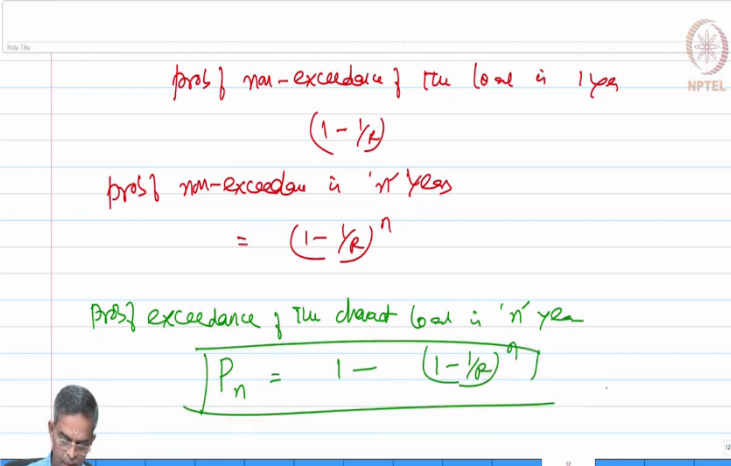
Since $(1/R)$ is the prob that load exceeds in 1 year,
 $(1 - 1/R)$ will be prob of non-exceedance in 1 year



Now, we have seen that return period and its probability of exceedance in one year. Now, what the question we want to know is; what is the probability that the characteristic load will be exceeded during the lifetime of the structure? What is the probability?

So, now, since 1 by R is the probability of that load exceeding in 1 year 1 minus 1 by R will the probability of non - exceedance in 1 year, is not.


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prob of non-exceedance of the load in 1 year
 $(1 - 1/R)$

prob of non-exceedance in 'n' years
 $= (1 - 1/R)^n$

Prob of exceedance of the charact load in 'n' year

$$P_n = 1 - (1 - 1/R)^n$$


So, the probability of non-exceedance of the load in 1 year is $1 - 1/R$, what is the probability of non-exceedance in n years will be $(1 - 1/R)^n$. Now, we are looking for what is the probability of exceedance of the characteristic load in n years.

So, I should say probability of exceedance in n years $1 - (1 - 1/R)^n$ to the power n right.

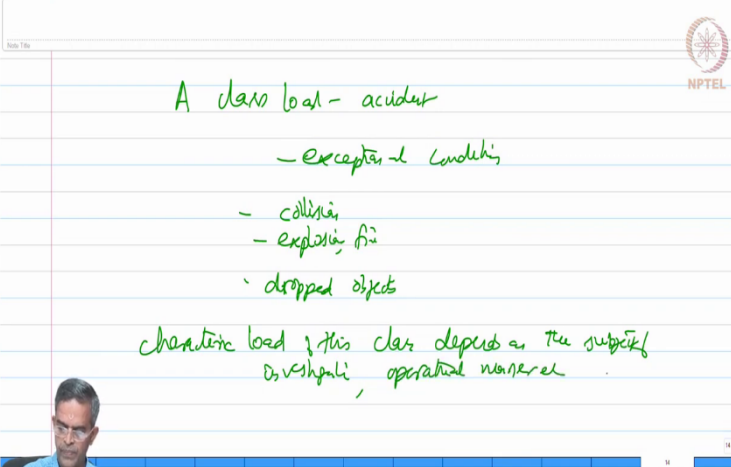
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$R = 50 \text{ yr}$
 $\text{Life time} = 20 \text{ yr}$
 prob of design load exceed at least once during the service life (20 yr) of the st
 $= P_{20} = 1 - (1 - 1/R)^n$
 $= 1 - (1 - 1/50)^{20} = 0.33$
 (P, n) are necessary

For example, if the return period is 50 years and the lifetime of the structure is 20 years we can now say the probability of design load exceeding at least once during the service life that is 20 years of the structure could be P_{20} which is $1 - (1 - 1/R)^n$ to the power n $1 - (1 - 1/50)^{20}$. So, it has got an exceedance of 33 percent, which is an alarming number.

So, it is interestingly friends, the return period is 50 years, service level 20, you may possibly think the exceedance will not happen at all see here it is about 33 percent. So, it is clear from the example that there is a chance of design load exceeding at least once in the service life is about 33 percent which is an alarming number. Therefore safety factors are important.


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A class load - accident

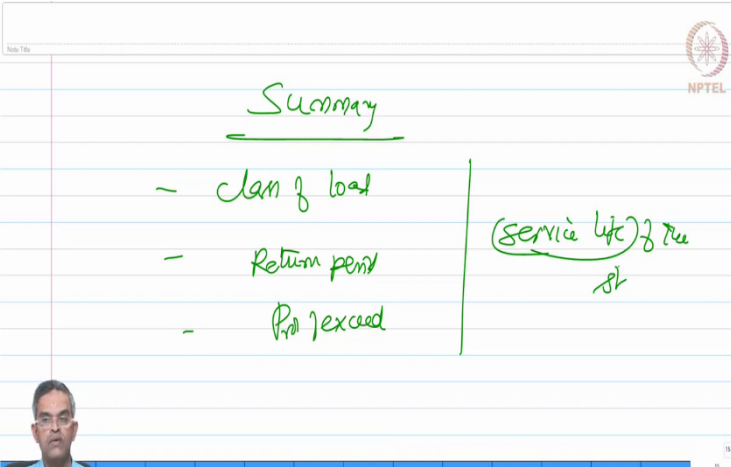
- exceptional loads
- collision
- explosion, fire
- dropped objects

Characteristic load of this class depends on the subject of investigation, operational manner etcetera.



The last one is an accident class loads A class load refers to accident class, these loads are exceptional cases, they arise when there is a collision, when there is an explosion or fire or there can be accidents caused due to dropped objects. Now, the characteristic load of the dropped objects or accidental load of this class depends on the subject of investigation and operational manner etcetera.


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Summary

- class of load
- Return period
- Prob exceed

(service life) of the str



So, friends in this lecture we have discussed about different class of loads, we have discussed about return period, we have discussed about the probability of exceedance of the return period and we have seen how the return period is connected to service life of the structure.

So, please revise these concepts and take many examples from the textbook, try to look into them, read research papers from various journals in this connection and update your knowledge and know how on these friends.

Thank you very much have a good day.