Advanced Marine Structures

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Lecture - 15
Partial Safety Factor

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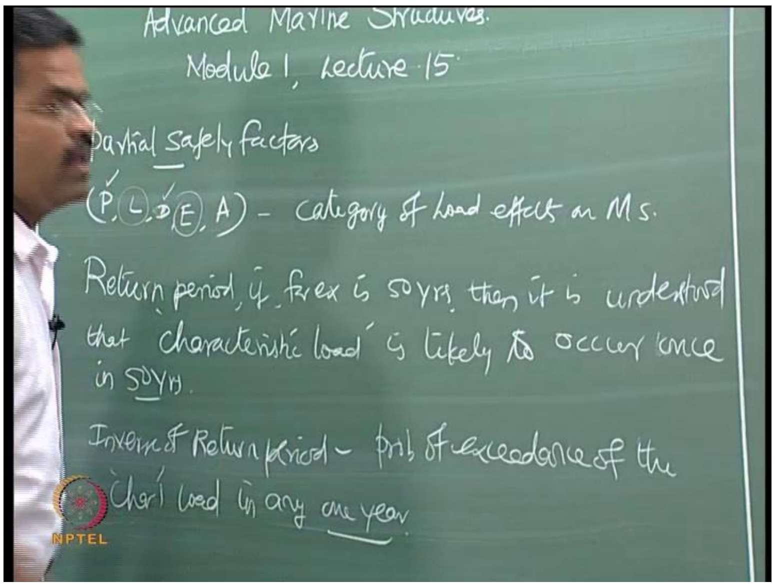

So in the last lecture, we discussed about the load effects on marine structures. We also discussed something about the partial safety factors. So we said the load is categorized by depending upon the effects on structures as a permanent load P, variable load live load L, then the deformation load D,then the environmental load E, and the accident load A. These are all basically the category of loads or I should say load effects on marine structures; out of which we discussed about what should be the characteristic value of P, what is the variation?Because P is almost more or less determined to the higher level of accuracy.

Live load has a difficulty, so we said on what format and what structure you want to apply; pick up the correctslope depending upon that.As far as the deformation load is concerned we look for the maximum value of the characteristic component of the load,and we were discussing about the environmental load; we had discussed about return period. So we said return period if for example is let us say 50 years, then it is understood that the characteristic load is likely to occur once in 50 years; that is the main.Inverse of return period will give you the probability of exceedanceof the load or I should say the characteristic load in any one year.

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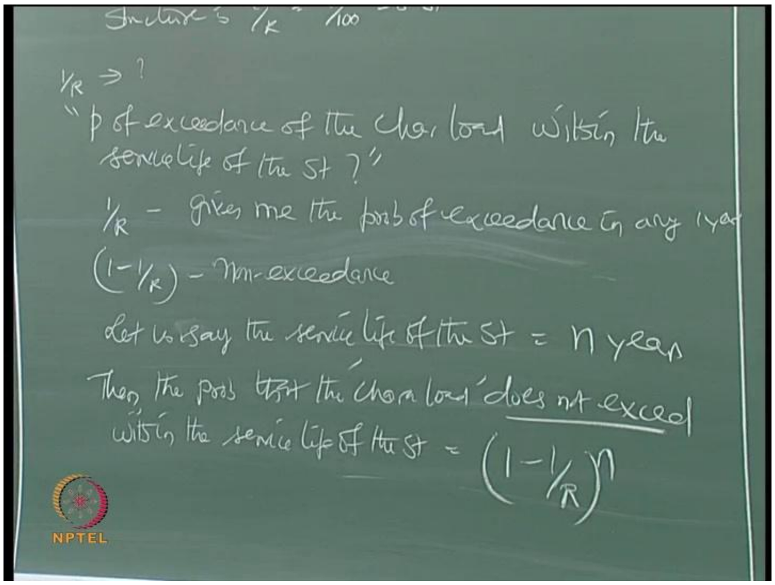

Let us say for example for wind load I have a return period as 100 years. So, I can quickly say the probability of exceedance of the wind load acting on the marine structure is 1 by R which is 1 by 100 which is 0.01; that is the probability. So,99 percent it will not exceed;1 percent, that is 0.01 may exceed the value. So,that can be very clearly understood that what is the meaning of this? Now let us quickly see what is the interest as far as the load effects on marine structure are concerned in the design part? Clearly understand the statement; the inverse of return period gives me an understanding of probability of exceedance of the characteristics load in any one year.What I am interested is not this. What I am interested is, what is the probability of exceedance of the characteristic load within the service life of the structure.

I am interested in this statement actually.I want to know this because that is my design component. I want to know this; what is my exceedance or what is my probability of exceedanceof this characteristic load within the service life of the structure. So, we have already seen that 1 by R gives me the probability of exceedance in any one year. So, this gives me in any one year. So, I should say 1 minus 1 by R will give me the probability of non-exceedance of this;non-exceedance in any one year. I am looking for the non-exceedance or probability of exceedance in service life. Let us say the service life of the structure is n years. Then the probability that thecharacteristic load does not exceed within the service life of the structure can be written as 1 minus 1 by R to the power n, but what I am interested?I am interested in probability of exceedance in service life; what I have got is non-exceedance in the service life.

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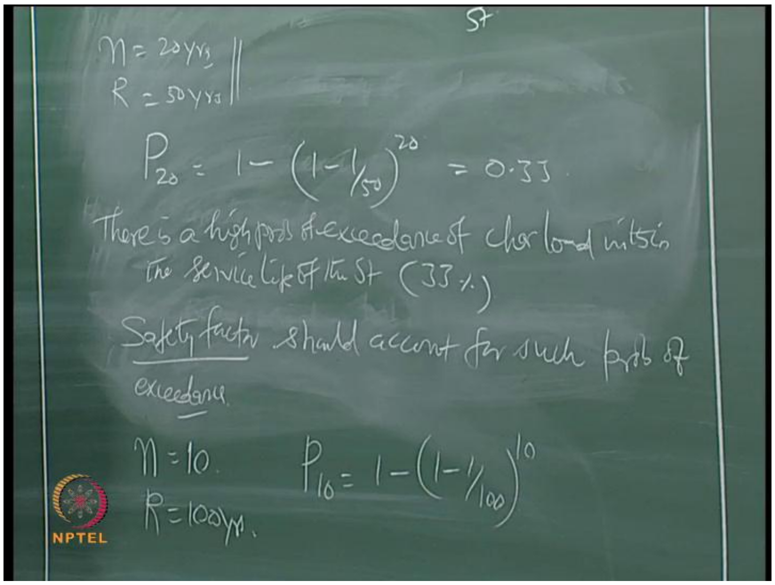

So I should say probability of exceedanceof the characteristic load within the service life should be1 minus 1 minus 1 by R to the power n. So, this will give me probability of exceedance of the characteristic look within the service lifeof the structure. Let us take an example. Let us say n is 20 years and return period is 50 years.Let us see what is the probability? So probability of exceedance in 20 years is 1 minus 1 by 50 of 20. Can you find out this value?You should come with the calculator form next class onwards because you are doing numerical; you need not go look at my face.

How much is this?

Student: 0.33 sir yeah;

so what does it mean?There is a high probability of exceedance of the characteristic load within the service life so that the percentage is very high.So a safety factor should account for such probabilities of exceedance. Just for understanding let us compare let the service life be 10 years and return period is 100years. What do you mean by 100 years?The characteristic load will get repeated or will reoccur at least once in 100 years. So, a very long time; service life is 10 years. Can we calculate p 10that is 9percent. So what does it mean?

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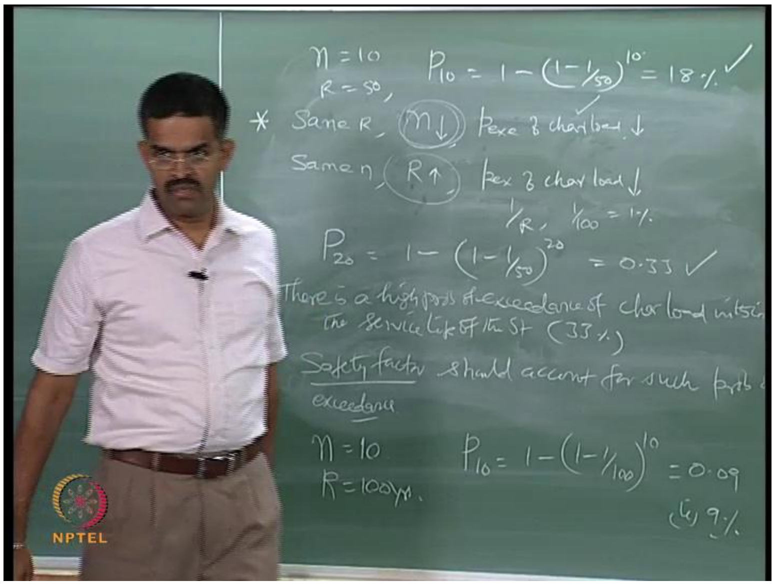

To make it more illustrative I will keep n as 10 but R as 50; same return period but service life is reduced, let us see what happens.Let us compare the answer of this with the terms first.Write the inference. I will remove this. The following inferences can be quickly drawn from these two examples as I have shown here. For the same return period, if the service life is reduced, probability of exceedance of characteristic load is reduced. For the same service life I am comparing this with this. If return period is increased, probability of exceedance of characteristic load is reduced. What we want is this statement. I do not want that the characteristic load should exceed; that is my desire in the design.The probability of exceedance of characteristic load should be as minimum as possible. I can do this in two ways. Again reduce the service life of the structure or increase the return period of the load.

Now what is the effect in the design? If you want to calculate a load whose return period is very large, what does it mean?1 by R is the probability of exceedance of this load in any one year. It means only 1 percent. Your load should be calculated accurately because the magnitude of the, so called, characteristic load should not be exceeded in any year by 1 percent. It means your accuracy should be very, very high. If you are not able to compute for certain class of loads that level of accuracy; for example earthquake loads, for example ice loads cannot calculate, then it is always better design the structure for a lower service life when you have got high variability in the return pages.It is because of this reason primarily offshore structureor marine structures are reduced for the service life. Now once we increase the service life for the same return period; same return period increase the service life.You have design it for 10 years; you are retaining the platform for 10 more years. So, increase the service life; you are encountering a higher probability of exceedance of the lower. So, that is dangerous. Let us remove this.

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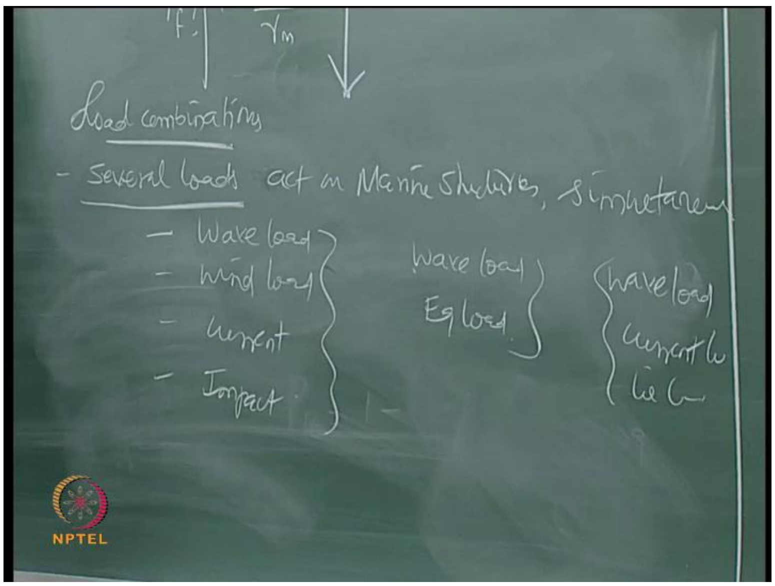

We have one more class of load; that is called accidental load which is A class loads accidental loads. They are caused because of collision,explosion of fire, dropped objects; object may fall from the crane hook because of some mismanagement during operation and causes impact loads; it is accidental loads. Now we need to identify the characteristic load for such accidental loads.So, the characteristic load depends on the type of investigation you are doing and the method of operation, investigation. You are looking closely for any possibility of failure of the structure under explosion. You are looking for any possibility of exceedance of accident loads during collision in the impact of ships or any vessels in the platform. So, you can pick up the characteristic load accordingly depending upon what investigation you want to do. So, there is no rule what multiplier you must use for the loads.I think you all agree for the load it is multiplier; for this strength it is denominator.

So, we are reducing the strength increasing the load; that is the philosophy what you are doing in the design. We have a load; we multiply by some number, increase the load. We have a material, account for some variability, decrease the strength. Combine them, do the design; that is called ultimate load design or ultimate limit state. Now let us talk about load combinations. As we all agree several loads act on marine structures simultaneously.We can give examples; wave load,wind load, current, impact.We can also say wave load, earthquake load; we can also say wave load, current load, ice load. So, there are several loads which combine together to act on marine structures.Now, what are those factors which will lead to difficulties in assessing this combination?

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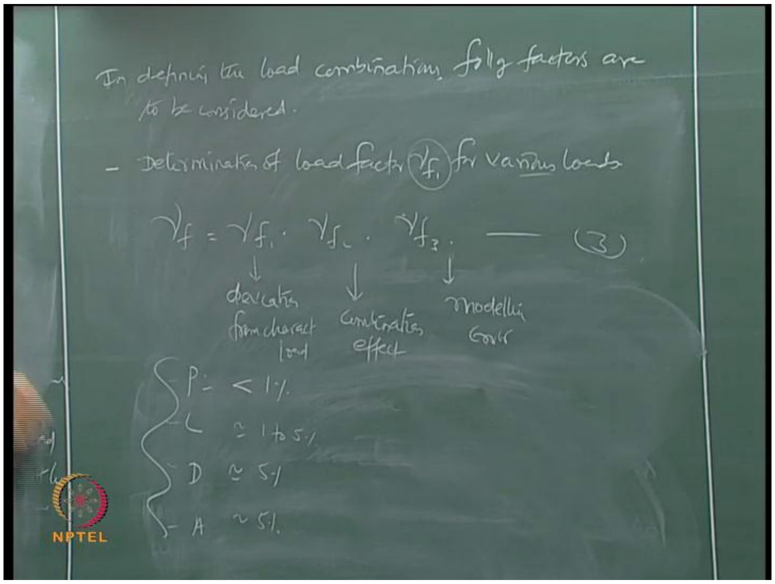

In defining the load combination we have following difficulties. First difficulty is the determination of load factor gamma f 1 for various loads. Just now we saw gamma f has got three components gamma f 1,gamma f 2 and gamma f 3; that is what we have seen in the last lecture. What is gamma f 1 addressing at? See gamma f which is the safety factor for load has got partial safety factor which are not explicitly told and shown in many of the international codes. It is very difficult to assess them. What we said is gamma f 1, gamma f 2and gamma f 3. This I think probably it was equation number, I think it is 3.So, gamma f 1 was addressing what are those parameters which were addressing gamma f 1. Sorry, deviation from characteristic load; that is the deviation.

What do you mean by characteristic load? The load should not exceed 95 percent of its possibility. Whatever you say the value the magnitude may be 1000 kilo Newton within the return period of that load 100 kilo Newton load should be acting. The variation cannot be more than 5 percent;95 percent it is correct,5 percent error; that is what characteristic load is.What is the deviation?Gamma f will take care of that; is it 5 percent, is it 3 percent, is it 1 percent,0.1 percent because a p category load that is permanent loads will have a very less deviation because they are calculated with a very high accuracy. Some international codes say for example Eurocodes say that the variation cannot be more than 2 percent or 2.235 percent.So, what is that variation or what is that deviation? Gamma f 2 talks about the combination factor and gamma3; sorry, gamma f 3 talks about the modeling error.

So,the very difficulty is to determine the load factor gamma f1 for various loads; just now I said p can have an accuracy of a very high order. So, p can have a deviation less than 1 percent;we are just guessing, where as live load can have a variation from 1 percent to 5 percent large variation and we just now said the deformation loads will have the maximum variation of 5 percentand so on. Accidental loads will have the maximum variation of 5 percent and so on. So, it is very difficult to fix what deviation your load will have; why? Because all of them are acting together; that is the problem here. We are talking about the combination effect.So, it is very difficult to address which deviation you can associate with what kind of load when they are compared.

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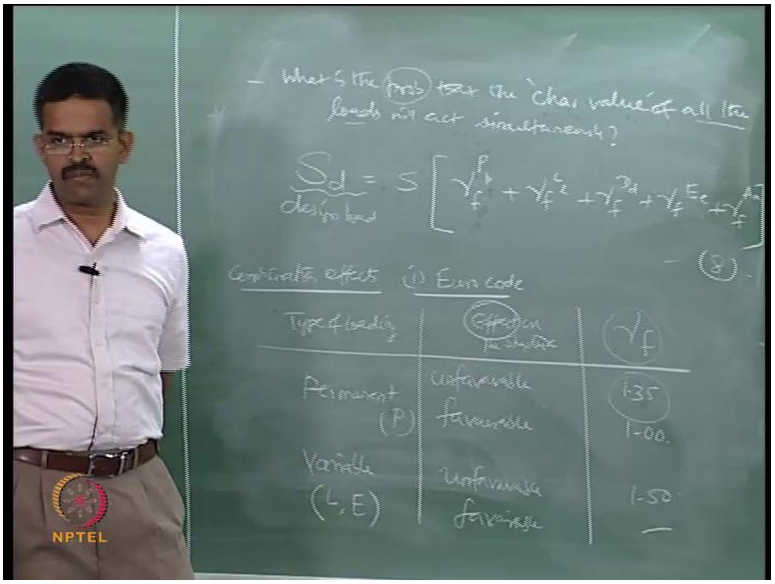

The second difficulty is what is the probability that the characteristic value of all the loads will act simultaneously?That is again a catch. See characteristic load we already understood what it is. What is the probability that the characteristic value of all the loads will act simultaneously. So, this is also not computable. It is very difficult. Therefore for design we can say the combination can be given by a simple expression which is s ofgamma f1 or let us say gamma f P for p gamma f L for l gamma f D for d gamma f E for e and gamma f A for a, equation number eight.Gamma f is the factor; p or the capital p is addressing the factor associated with f 1, small p is the factor associated with the combined effect of characteristic value acting together; that is pand so on and so forth.If you know this multiply this factor with load, you will get a design load; hypothetically that is the equation. If you know this combination effect multiply that factor with your load applied on the structure, you will get what is called the design; this is the design load. This is as far as the f 1 is concerned.

Now of course certain codes give you some adviceon this combination effects; we will talk about that.The combination effects are advised in different codes in different manner. Let us quickly see them here. If we look at Eurocode,I am looking for type of loading,the effect on the structure and gamma f recommended value.So, we say permanentand variable; permanent load we already know, it is a p class loading.We already know this whereas variable loads are actually addressing the L class loading and environmental loads; L is the live load and E is the environmental category of the load. It is called variable loading.If you want to look for most unfavorable effect, if you are designing the structure for the most unfavorable effect then use gamma f at 1.35. If you are looking for a favorable effecton the structure, then design this with gamma f of 1.0. For the variable loads we are looking for most unfavorable effect designing with 1.5and for favorable there is no recommendation given in the Eurocode.

So, you will now agree looking at the load combination to some extent, they have been explicit in addressing what should be the value for Pand what should be the value for LandE, etc in the codes.You can see that here; they are starting working out.But still I would say that this number is a combined effect of two things. What are the two things? One, what is the deviation of each one of them causing favorable or unfavorableeffect on the structure and what is the probability that the characteristic value of these loads will occur simultaneously; addressing these two factors together Eurocodehas advised the effect on the structure. Remember thisis a very important part; I am not talking about the effect of loading, I am talking about what are the consequences of this load on the structure; that is y I said load effects.If you want to get most unfavorable effect use this combination or this multiplier; if you want you get a favorable effect use this combination and so on and so forth.That is what the euro code says.

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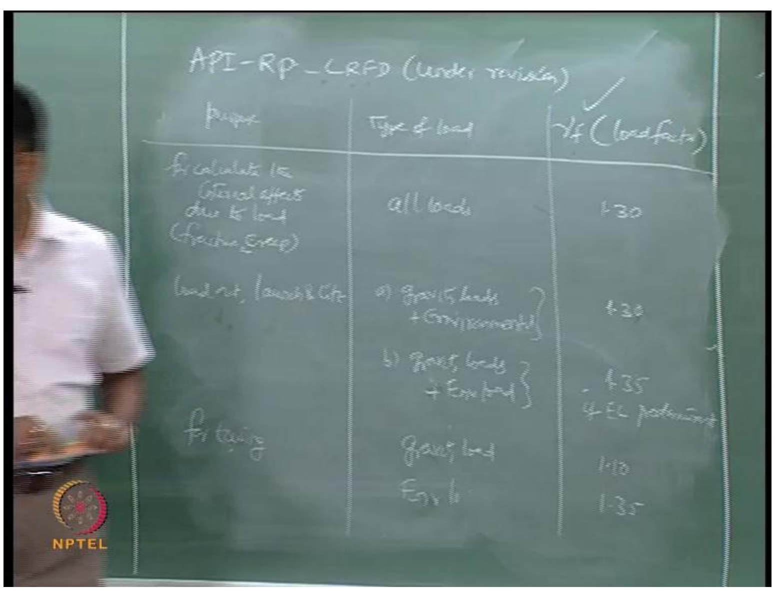

API-RP, there is a code by name LRFD Low resistant factor design. This code is now under revision; Ishould write it here but still never the less there is no harm in knowing what the code suggested, it is under revision now. This code says define gamma f for purpose of loading; it is a different category. It says what is the purpose? I should say the purpose not the load,then type of load, then of course the load factor. He is using a different symbol; I am using it for my convenience. The symbol used for load factor and API is different from gammahere but I am using it for my convenience. I can even write here load factor. You want to calculate the internal effects on the structure due to loads. Can you give me any one classical example of internal effect of structure on members due to load; any one example, fracture, creep; I mean these are examples internally, deformation; itcan be anyexample. For all loads use the factor of 1.3.

If you want to do it for load out, I think you understand what is the load out; load out is the term of phase of installation in jacket platform; that is called load out. Launch and lift; if you are looking for these purposes because you should design the structural system during erectionand construction loads also. If you are looking for this as your purpose, then for gravity loads plus environmental loads use the factor of 1.30. The other option is for a combination of gravity loads and environmental, you can also use the value of 1.35, if environmental loads are predominant than gravity loads. For example complain structures; for towing depending upon the purpose. For gravity loads use the value of 1.10;for environmental loads use the value of1.35. This is the order what API recommends for load factor depending upon what is the purpose you are looking at the design.

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Let us see what DNVdoes. If you look at DNV code offshore standard DNV-OS-C101;OS stands for offshore standards, C stands for the category 101. They say the combination of loads are directly addressed for different load categories P L E Dand A. I think I do not have to elaborate them; you already know these categories. This is permanent load, live load, environmental load, deformation load, accident load. If you are looking for an ordinary operation, this can be 1.3, this can be1.3,0.7, 1; you need not have to consider accident loads at all. If you are looking for extreme conditions, then also you need not have to consider this because the structure should be designed in for accident loads explicitly.

So, now we have seen different factors affecting the ultimate load design in terms of load estimates, in terms of material strength. There’s a very important combination or very important aspect which affects the material strength which will see now and it is nothing but the composition of the material. Mostly we use steel but steel has got variety of composition while manufacturing steel. What are those effects, number one? Number two, what is the effect of shape and size on your gamma m factors. We are looking at the factors effecting thesafety factorsor safety estimates in my material strength.

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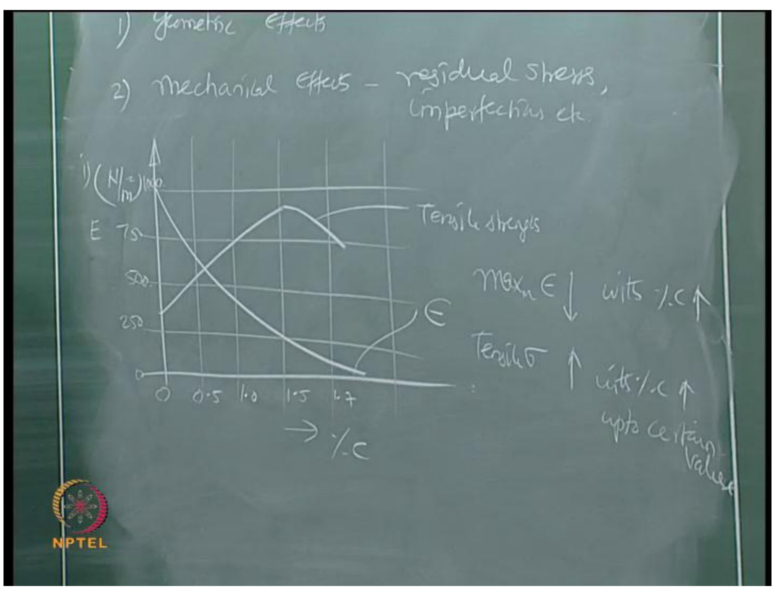

So, we are talking about the fabrication factors affecting gamma m material strength actually. So, there are globally two aspects which can be addressed in this heading; one is what we call geometric effects, other is what we call mechanical effects. Mechanical effects means residual or residual strength or residual stresses, imperfections, etc. Let us see few of them; we are not looking into all properties which will affect the strength. We will look at the carbon content; that is one of the important aspects in steel. So, if we look at the percentage carbon content I am looking for percentage carbon. This is my elongation epsilon.

I think you should say this as Young's modulus not epsilon. Let us, say, start from zero; let us say 0.5, 1, 1.5and 1.7 whereasthis is of course0,250, 500, 750 and 1000. I am talking about the variation of tensile strength; you will see that the tensile strength keeps on increasing with increase in percentage of carbon content till 1.5, then drips offthis tensile strength. If we look at the maximum elongation of the steel, it decreases with increase in carbon content. So, this is elongation. So, one can see here maximum elongation decreases with percentage carbon increase;tensile strengthincreases with percentage carbon increases up to certain value after which it drops.

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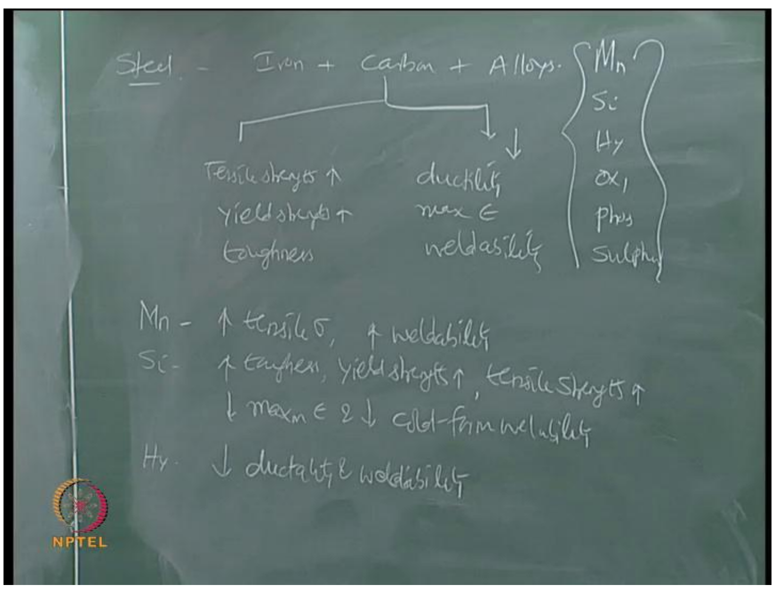

If you look at the composition of steel and their components which will contribute to the factors affecting the strength, let us divide this into iron, carbon and other alloys.So, the alloys can be manganese, silicon, hydrogen, oxygen, phosphorus, sulphur. Carbonincreasestensile strength, yield strength and toughness whereas decreases ductility, maximum elongation as just now you saw and weldability or the welding characteristics are decreased with the increase in carbon. Whereas manganese increases tensile strength, increases weldability; silicon increases toughness, yield strength and tensile strength whereas decreases maximum strain and decreases cold formweldability. When it is hot, then it is different.Hydrogendecreases ductility and weldablity.

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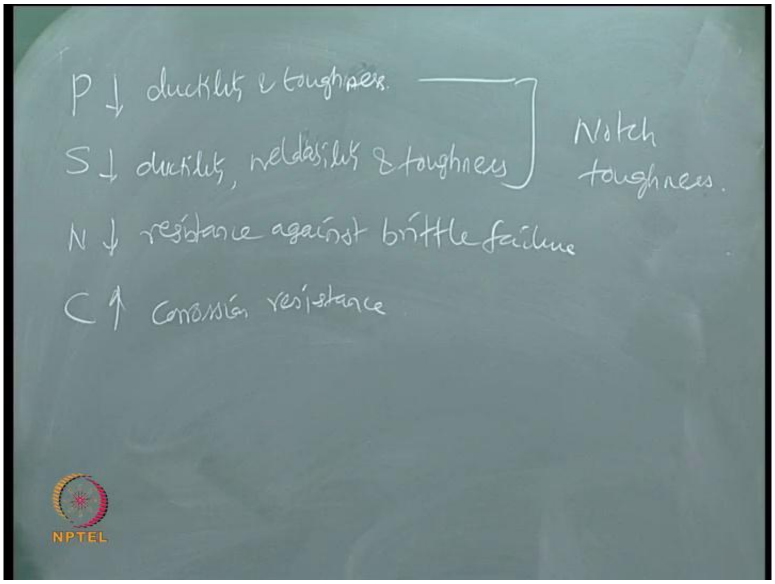

Phosphorus decreases toughness and ductility; sulphur decreases ductility,weldability and of course toughness. I think when we talk about toughness; you understand that talking about the Notch toughness;that is how we measure toughness. Nitrogen decreases the resistance against brittle failure; it means it promotes brittle failure. Carbon increases of course the corrosion resistance.

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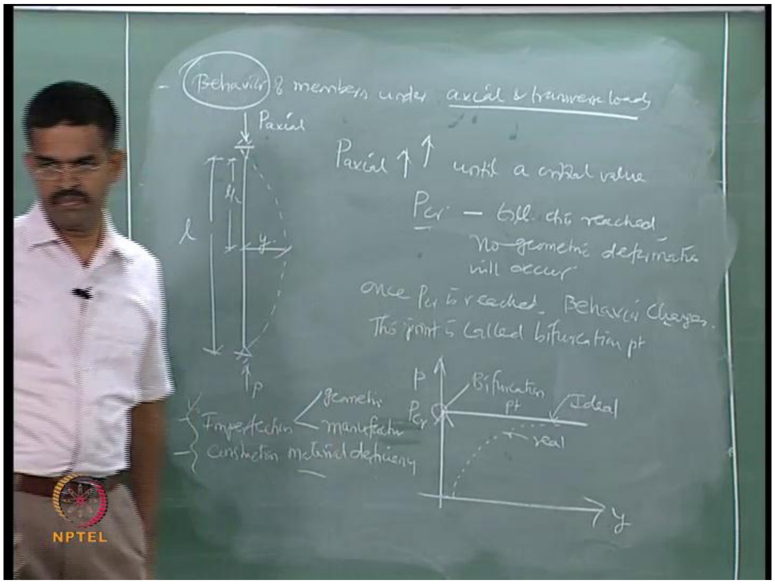

The last component which affects the strength of material; the last component which affects the strength of materialwhich accounts for variability in ultimate load design is the type of loading or i should say behavior of members under axial and transverse loads. It is behavior of the member itself. It is a very important factor which affects gamma here. To understand or explain this, we will take a very simple example. We will take a steel column both ends hinged and apply a pure axial load to this column.The column will start buckling will have a maximum deformation y at its centre.The load carrying capacity of the column will keep on increasing until a critical value which we call as p critical. How to identify a p critical value?p critical value is that value till this is reached; no geometric deformation will occur once this value is reached, the behavior changes.

This point is called bifurcation point. I can try to plot this bifurcation point graphically like this. Let us say and try to plot p verses y; p that is the load carrying capacity of the column versus its y value which is having a permanent deformation. So, primarily as you keep on applying the load there is no y which is distinctly seen and we keep on getting a higher and higher value until this reaches what we call P c r. After it reaches at P c r, it will undergo a very large deflection; it is an ideal case. This point is what we call bifurcation point. It is an ideal situation. Now because of the presence of the alloy elements, what we just now saw, this behavior will not be occurring. We land up in a slightly different behavior which has initial deformation and then this is what we call the real behavior. The real behavior is actually due to the presence of alloy elements in the material. So, there are many reasons why the real behavior is different from that of the ideal behavior.

There can be imperfections, there can be deficiency in construction material, imperfections can be geometric; what do you mean by geometric? The load applied is not purely axial; that is called geometric imperfection. The imperfection can even be manufacturing;what do you mean by manufacturing? The member is not vertical; it is not purely vertical. There is a defect in the manufacturing itself and so on. So, the presences of imperfections and the deficiency construction material affects the behavior under different loads axial, what we have seen here, which are also account for partial reduction in strength of the material which should be considered in the ultimate load design in gamma m. It is not only the material property; the way in which the members behave under axial as I have seen here will also affect the gamma m computationin your ultimate load design methodology. In additionlet us see what is the effect on the behavior of the member under transverse loads.

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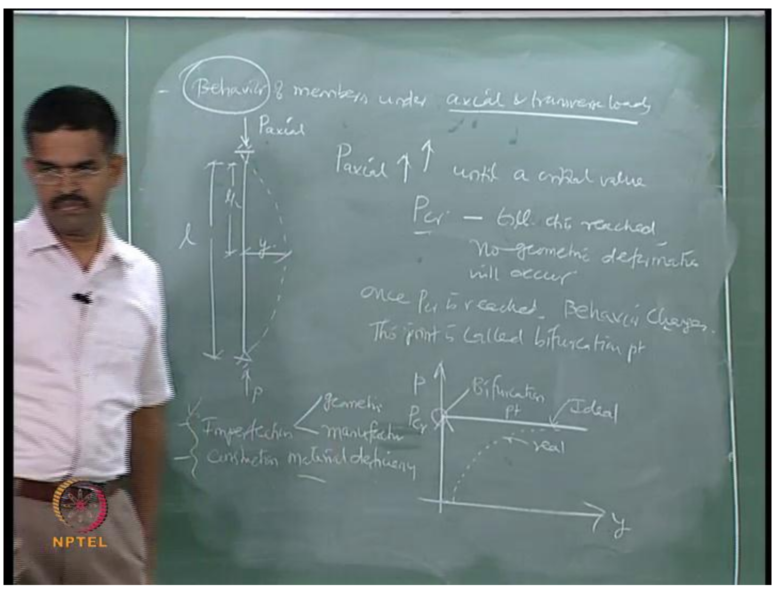

This is main plate. These are my stiffeners;I am putting them at any equal spacing which I call them as l s which is the spacing of the stiffeners and applying vertical loadand so on.I am applying vertical load.Now the basic problem with this kind of arrangement which is a common arrangement in marine structures; you can see I can give a very classic example of this.Whenever we got reinforce concrete jetties or even steel plate jetties which are facing the water load; this is my water site hydrodynamic loading coming on the facing of the jetty. Instead of constructing asingle plate to resist the hydrodynamic loading,I will have to give stiffness in between thinking that this stiffening arrangement will try to protect this main plate from the lateral load in addition to the self weight which is the gravity load acting on the structure. Because the jetty has to have a deck and the deck will have a load; that is what I am indicating here and there will be lateral load also because of hydrodynamic action because of the waves.

In such cases l s plays a very important role. If l is very high, if the spacing of the stiffness is very high, this will cause the local buckling of the plate; the plate will start bucklingand bend between the stiffness. So, because of the electoral load acting at this point very high intensity evenstiffness will also buckle. You may wonder that how the behavior of the plate and the stiffness will affect gamma m. Now gamma m is the uncertainty which is accounted for the material strength variation in the design.Thinking hypothetically thematerial is no geometric imperfection, no manufacturing defect and no variation in its yield strength,Young’s modulus, etc;just by arrangement of the number like this, some loading will be preloaded, some behavior will be preloaded which will cause reduction in load carrying capacity.

You would have designed it for an axial strength of x kilo Newton; before receiving it kilo Newton at the bifurcation point, the structure or the member will buckle and x kilo Newton will be y which will be lesser than x, much lesser than x. It means there will be a precluding of buckling before bending happens or before crushing happens. This arrangement has caused this failure because it is actually subjected to the behavior of the structureunder a load combination. So, we are looking at the load combination; we wanted to seewhat could be the worst scenario at which the load can be combined along with the material strength toattain the maximum safety in my design. So, hypothetically material gamma m is not only related to material; it is also related to behavior of the member under load combination. So, it is a very complex phenomenon.

You would say that I want to design a member for a pureaxial load depending upon the slenderness effect of the member; that is r by y value, r is the radius of gyration and y is the thickness, r by y value or l by d value. Depending upon the slenderness ratio of the member before it reaches the critical point or the bifurcation point in your p y curve,the member will start buckling. So,this will cause reduction in P c r; that is why in ideal behavior you see this difference.So, this difference not only comes from geometric imperfection, not only comes from material imperfection or material deficiency, not only comes from contribution of different constituents in the material but also comes from behavior of the member under the combination of loads.So, it is not the question of only material to be seen separately, only load to be seen separately,then combine them to see the safety factor; it is not that.So, it is important that we will discuss it in the next lecture.So, we will talk about plastic design in the next lecture.