Structural Reliability
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Lecture –243
Target Reliabilities (Part - 06)

We continue with the last topic of our course on structural reliability in the previous lecture we saw how target reliabilities appear as constraints in the design optimization process and how their values should be tied to the consequence of limit state violation. We also saw that in the absence of good real life failure based statistics on the one hand and our inability of modelling real life failures on the other.

The target reliability values can be inferred from existing successful designs. The first generations of reliability based codes were actually calibrated on this principle. But they suffer from a couple of problems as we discussed. The traditional design codes which were used for this calibration exercise they have evolved over decades of successful use and they have imbibed various experiences and wisdoms from the practitioners.

So, the implicit reliabilities are not necessarily uniform for the same limit states across different load combinations and different materials and using those same implicit reliabilities in the new design codes have the potential of perpetuating a sub-optimal design. At the same time the idea that the acceptable limit state probability must above all be tied to the consequence of failure it kept exerting a strong pull on the minds of the investigators.

So, beginning the 1990s as the community gained confidence from the development of the first generation reliability-based codes we see the first movements away from calibration towards more rational or first principles based approaches.

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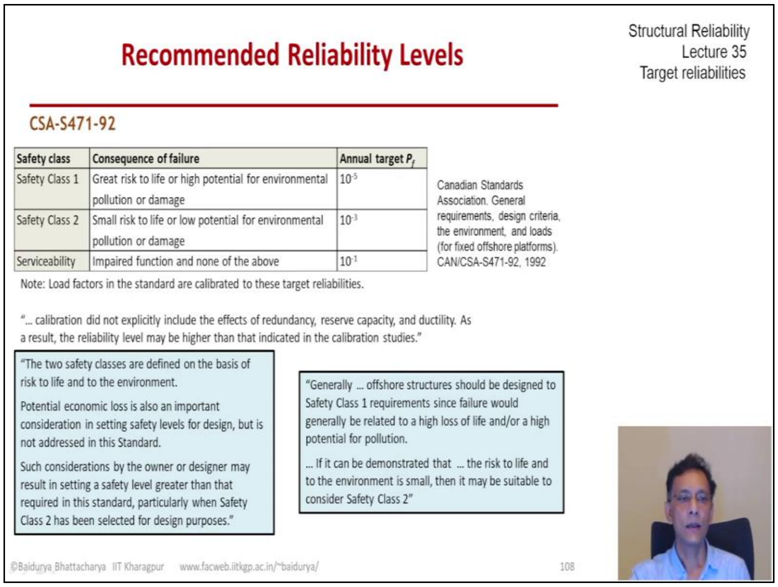

One of the earliest examples in this effort was the Canadian standard CSA S-471 of 1992 that was a group of standards for the design of fixed offshore platforms. So, here we see one of the first efforts to bring in explicitly the consequence of failure in reliability based design standard um. So, let us go through this table carefull. So, two safety classes have been defined one and two and along with the limited serviceability the definition of these two safety classes are like this that those structures that belong to safety class 1 their failure pose great risk to life and the environment.

And those that belong to safety class 2 their failure pose a small risk to life and the environment. Now before we find out what the annual target Pf is let us noting the focus on risk to life and environment. So, and that is actually significant because it is after all a national standard and the clear focus is on life safety and public health. The annual target Pf is of the order of the -5 and 10 to the -3 and then 10 -1 in serviceability the important point to note about these numbers is that these are not in terms of beta.

So, this is also a deliberate move away from the indirect reliability index measure of structural safety and a clear explicit measure in terms of probability. Now let us look at some more statements from this design code and let us see what the thinking process was. So, the both these two safety classes as we just said are defined on the basis of life safety and environmental safety and then although potential economic loss can be a driver.

But this design code is clearly stating that it is not concerned with that or it is outside its scope that economic consideration is not part of this set of criteria the focus is again on life safety and public health. It could be that if one wanted to bring in economic considerations in some cases especially in class 2 structures one might end up with a safety level, level greater than what is given here but that would be a decision for the owners and operators.

So, we also see a certain amount of increased participation being expected on the part of the designer. The designer is no longer asked to passively implement the design rules and that is actually a common feature on these more and more modern as we will see codes that use reliability and performance based approaches. Continuing so, it is what the code is saying is that it is it expects most of these offer structures to be designed to or be considered in safety class one.

So, that is the default case. So this code is deliberately being conservative and it is the choice to consider a structure to belong to safety class 2 has to be done actively. So, if only it can be shown that the structure has low failure consequence to life and public health then only it is permissible to consider as a safety class two structure. So, again the onus is on the designer and owner if it can be demonstrated that.

So, that is actually a very potent statement. Now in spite of this in these first moves away from the calibration based standards this code did not give up or did not move completely away from calibration based on these target reliabilities two sets of load factors were calibrated. So, this code still used in part the approach to calibration but not to older standards but to these new target reliabilities the code also says that this is mainly a component based approach.

So, any benefit coming from systems effects are not included and which can only be helpful and increase the actual reliability.

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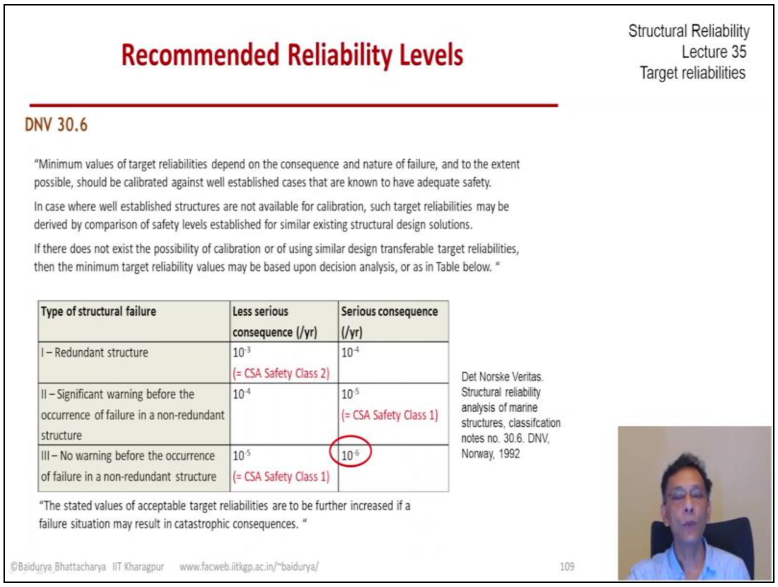

The next example that we will see is also from the same year 1992 and this is a Norwegian standard DNV 30.6 on again on marine structures. So, this has some similarities with the Canadian standard but a certain interesting differences as well. So, let us take a look at those. So, let us read this important statement the minimum values of target reliabilities depend on the consequence and nature of failure.

So, not only consequence but nature of failure is brought in and to the extent possible should be calibrated. So, this early efforts are still a little hesitant to move away from calibration and it is the idea is to first try out calibration and if it fails then to try out more direct and more first principles based approaches. So, the next statement is going to make it clearer that when calibration is not possible then one could look at similar structures and compare the safety levels of those structures and even when even if that is not possible.

So, it is just not possible to do either a comparison or calibration then only the minimum target reliabilities in this code may be adopted. So, now let us see how DNV handled not only the consequence but the nature of failure. So, what we see here is there the last two columns have consequence less serious and serious consequences but then the nature of failure is brought in as an additional degree of freedom the whether the structure is redundant or not and whether warning is available or not.

So, there are three possibilities there the structure is redundant. So, that is the best type of case to be and then if the structure is non-redundant but significant warning is available then that is still okay and then if the structure is non-redundant and no warning is available then that is the most dangerous situation and the and the target failure probabilities or acceptable failure probabilities per year reflect those numbers those considerations.

So, the numbers are 10 to the -3 for the safest case all the way up to 10 to the -5 for the least safe case for the less serious and 10 to the -4 to 10 to -6 for the serious consequence. So, here we see certain interesting features is that we have not only this new degree of freedom that we considered about the availability of warning or not but we also see that there are certain matches with the CSA numbers for example the safety class 2 matches with redundant structure less serious consequence.

And the safety class 1 matches with non-redundant significant warning serious consequence as well as non-redundant no warning less serious consequence what is interesting is there is an even higher level of safety specified and a full order of magnitude higher than the CSA standard. And again we see the thinking leading to conservatism that these can be further reduced these acceptable failure probabilities can be further reduced if the consequences are even more severe.