Structural Reliability
Prof. Baidurya Bhattacharya
Department of Civil Engineering
Indian Institute of Technology-Kharagpur

Lecture-236
Reliability Based Design Code Development (Part-03)

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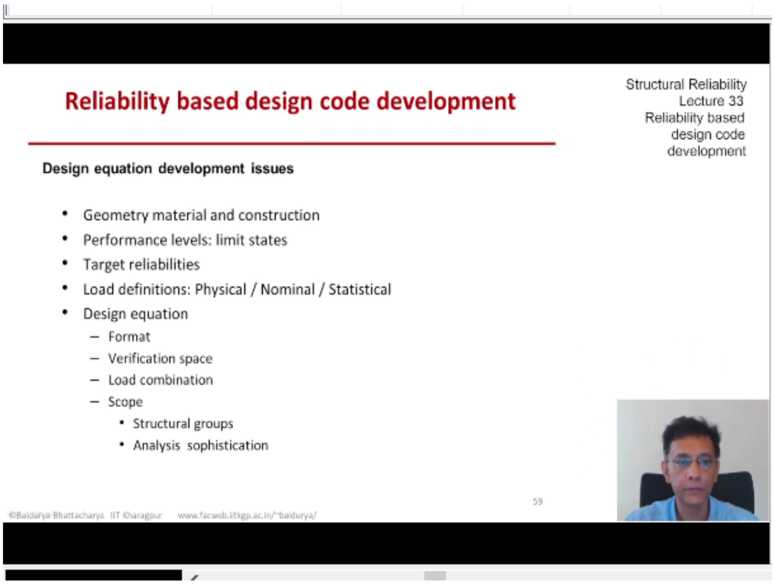

We now describe the general method for deriving reliability based partial safety factors used in design but I would like to emphasize what I have said before that a design standard is much more than just some design equations, it is a collection of wisdom and experience from successful performance that have accumulated over generations. So, we are not going to look at all those aspects of course we are just looking at this very narrow issue of partial safety factor to be used in design equations and how we can derive them at least the principle behind them.

There are also many issues and again we should not trivialize them and I have listed a few here that the design obviously is governed by and has to be consistent with the geometry of the structure or the member, the materials to be used and construction method, construction technique. Obviously, we have been talking about this what are the limit states, how the limit states are defined, what is the underlying mechanics, what are the target reliabilities?

We still have not talked about how they are derived; how we know what is safe or how safe is safe enough. So, that is also a major consideration which we are living out for today then how our loads are defined or we taking a physical definition or we talking about nominal loads or we talking about statistical description. So, these things have to be clearly understood and separated.

The design equation itself what format, there are many equivalent formats but each will have different outcomes. So, we must understand, we must decide unambiguously what the verification space is it in terms of stress or strain or moments or forces etcetera. So, we need to be able to make sure that aspect is well defined, which load combinations, which ones are relevant.

They have a direct bearing both on the limit state and the design equation and then what sort of structural member or is this design equation going to be valid for and then coupled with that is what sort of analysis both probabilistic analysis and mechanical analysis should be ensured in order for the design equation to be valid for the structure of the member being desired.

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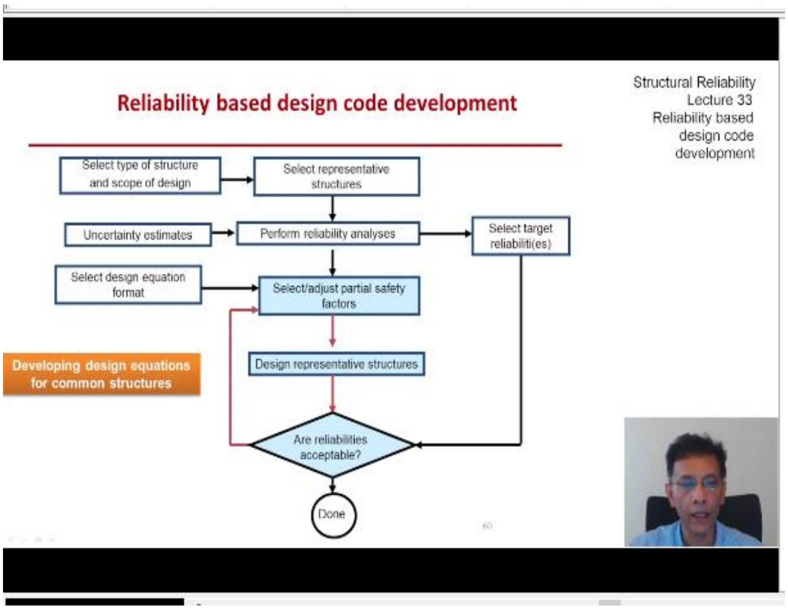

Now that said let us describe the steps that can be followed in general for developing design equations for common structures. Again we are talking about structures members with whom we have enough experience and at least we know what works and what does not work and we have a clear understanding of what constitutes satisfactory performance and what does not. So, clearly we want to derive a design equation that is valid for a number of structures in various design situations provided they are of the same type of course.

So, we decide on the type of the structure and then on the scope of the design. Then we carefully select representative structures from this type that cover the entire range of design situations that we are interested in. Following this we could perform what is known as a calibration exercise if we do not have an independent knowledge of what reliability we should aim for when we derive this new design equation.

So, part of that calibration exercise we perform reliability analysis on these representative structures store them and based on that analysis which also requires all the uncertainty information we decide on what target reliability or target reliabilities we should go for in our new design equation. And then we start a loop after we know the design equation format which depends on the scope of design that we already discussed. Then we start this loop of tweaking or optimizing the partial safety factors.

So, with the design equation format given we have a trial and then we design those same representative structures that you see on the top box and then the reliability that we get we compare with the target reliabilities which were either obtained by calibration or other more direct means. And then if those are acceptable then we are fine otherwise we keep adjusting and that is the optimization loop until we are happy with the outcome, all the optimization constraints have been satisfied.

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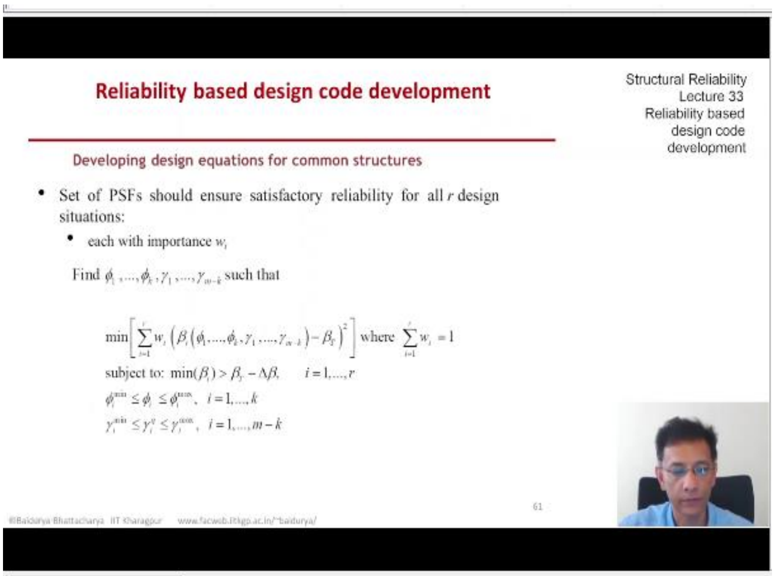

Now focusing on these PSFs, so this is what we want the set of PSFs should ensure satisfactory reliability for all the r design situations, by design situations we mean the either different element groups, different loading configurations etcetera. In our cable example it was basically possible values of the W n over Q n. So, each of these design situations are of them has their own importance.

So, if we have to see how well our design equation is doing we might weighted that with the importance factors there. So, the mathematical statement is find the partial set factors phi's and the gammas such that a certain error is minimized. So, the error is the weighted deviations. So, i find beta i for design situation i or element group i and then take the deviation from the ideal target square that and weight that with the importance factor.

And it is sensible to say that the weights are normalized so they sum to 1. So, that is our objective function, minimize the weighted sum squared error. And then obviously we could put constraints and that comes from our level of comfort, our engineering judgment. So, it could be that whatever optimal solution we get we will not let any single beta go below the target over a certain amount.

So, we could fix delta beta and no beta i should be less than delta beta below beta target. We could put more restrictions on the phi’s and the gammas and obviously they should be non-negative but for the phi type factors we can say that we do not like them to be more than 1 because their strength type factors and we do not want them to be more than 1 since we would like to reduce the strength in design.

So and then the loads we could likewise say that we do not want to be less than 1 this should be at least 1 and that agrees with our intuition that load factors should amplify the loads. And then obviously if these 2 limits are both equal then we are essentially fixing the value of phi or gamma at a particular number and that is also quite acceptable if we want a load factor or a set of load factors coming from some other document which are well researched and well accepted.

Then we have no reason or no scope to optimize them, we have to choose them as the r, we have to take them as the r. So, for those we could fix their values, so gamma min and gamma max will be the same number. So and obviously this sort of error which is the weighted sum squared it does not have to be that way we could give an unsymmetrical weight to higher values versus lower values.

And there are many options, but the principle is the same. With this now let us go through a problem involving the load and resistance factors for the design equation of a ship hull girder or ship hull girders.