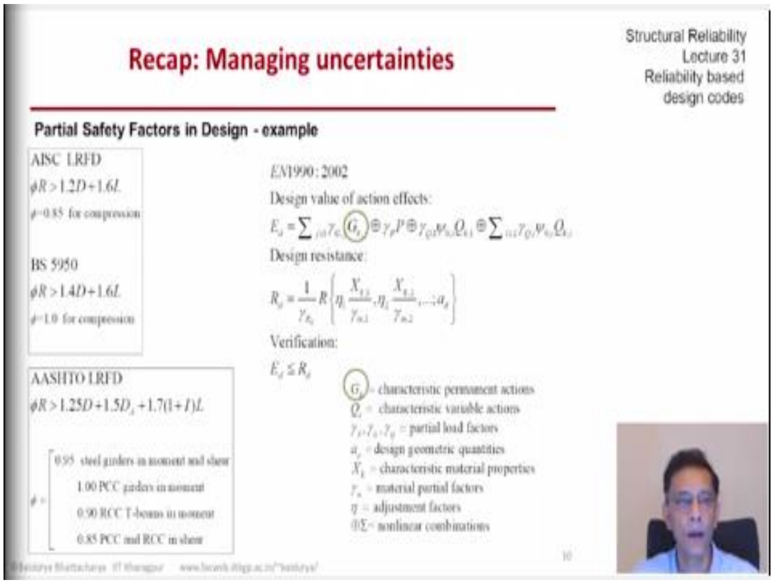
Structural Reliability
Prof. Baidurya Bhattacharya
Department of Civil Engineering
Indian Institute of Technology-Kharagpur

Lecture-229
Reliability Based Design Codes (Part-05)

(Refer Slide Time: 00:27)



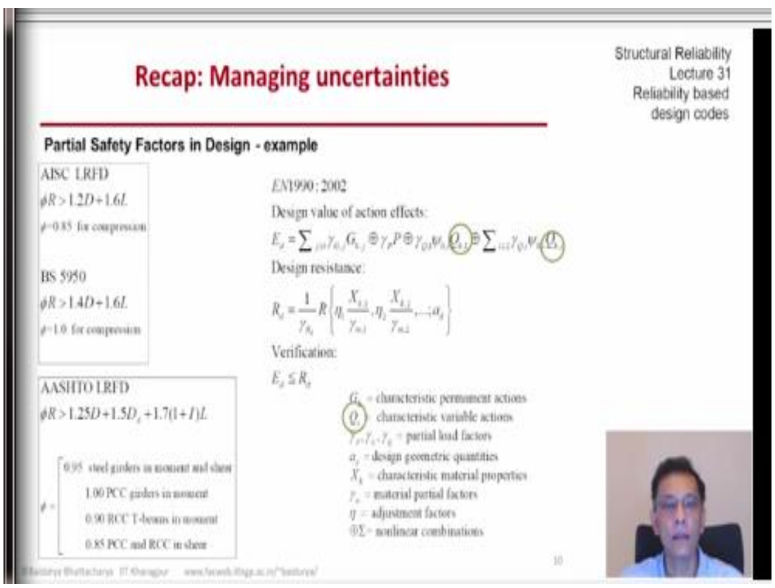
Broadly speaking structural design standards provide a comprehensive set of minimum expectations about the design process, minimum in the sense that the designer always has the option of going above and beyond these requirements. Now in addition to the equations or inequalities that must be satisfied with mathematical computations. There are many, more provisions in these standards that come from collective experience and history of successful performance.

We will not look at those but focus rather narrowly on the safety checking or design equation aspects of these design standards or design codes. We have 3 sets of examples here; this is from the AISC LRFD standard that I mentioned in the previous slide, you see that the factored strength phi times R has to be at least as great as the combined load effect of 1.2 times the nominal dead load and 1.6 times the nominal live load.

Now this is just one such equation there are quite a few of them depending on the failure mode and the load combination in question. You also see the corresponding British standard and then we have the AASHTO LRFD for highway bridges and you see some similar expression there. We have 2 kinds of dead loads and the live load has been multiplied by the impact factor I. One of the latest codes in this line is the structural Euro codes EN 1990 that was first published in 2002 then amended in 2005 and then 8 and 10.

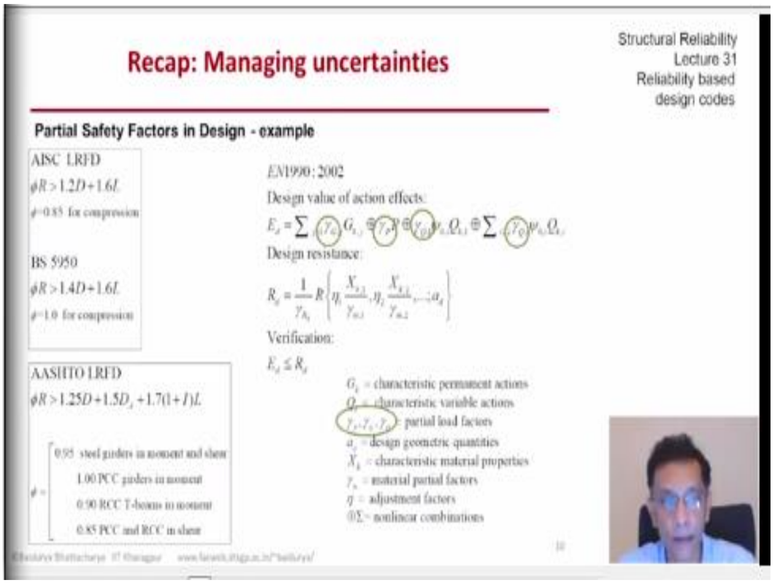
So, the design process or the design checking exercise looks something like this. So, let us go through this set of equations term by term. So, the design value of the action affects E d that needs to be compared with the design resistance R d. In the bottom right side you see all the quantities that need to be considered. So, let us take a look at them one by one, we have the characteristic value or the nominal value of the permanent actions.

(Refer Slide Time: 03:35)



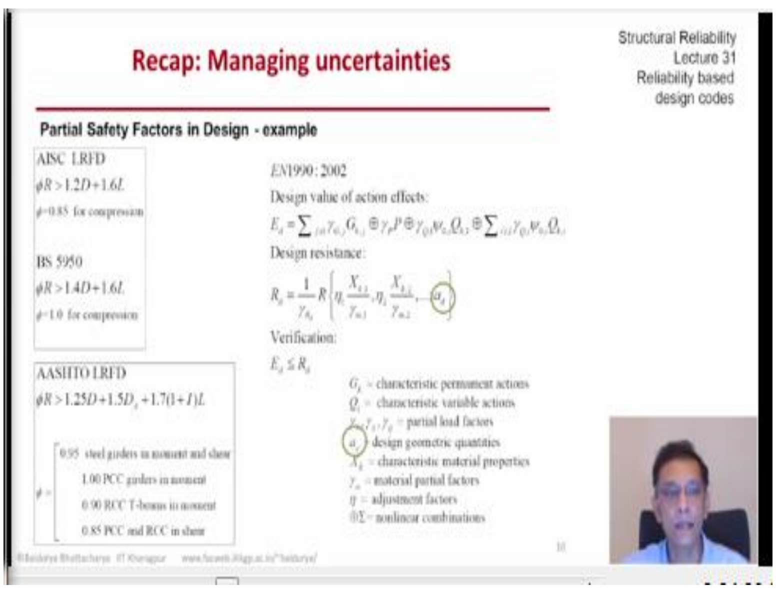
We have the nominal values of the variable actions the Qs.

(Refer Slide Time: 03:42)



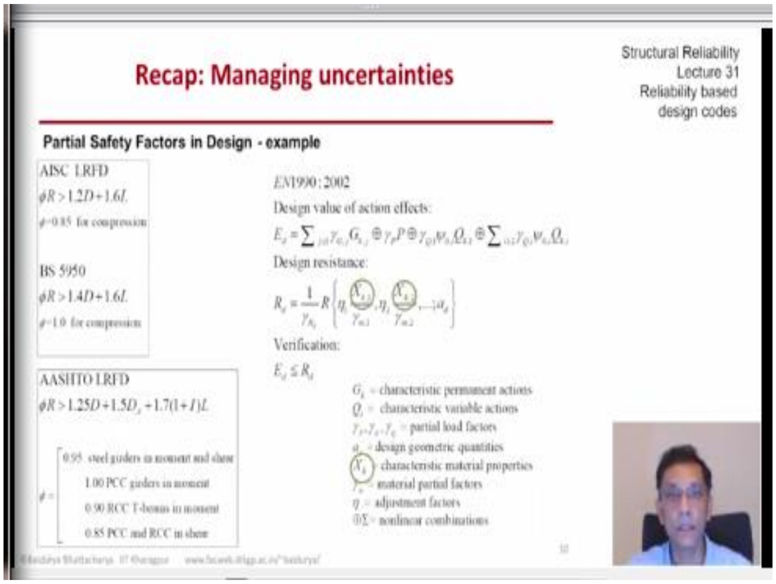
Then we have the partial load factor. So, all these loads, all these actions they need to be multiplied by those load factors and then they enter into the computations. And then the action effects or load effects are found out.

(Refer Slide Time: 04:05)



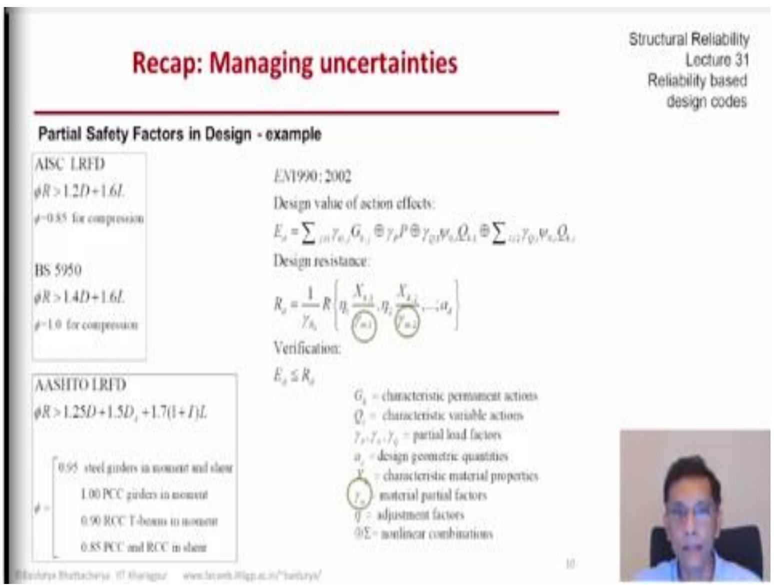
There are geometric quantities that define the resistance.

(Refer Slide Time: 04:10)



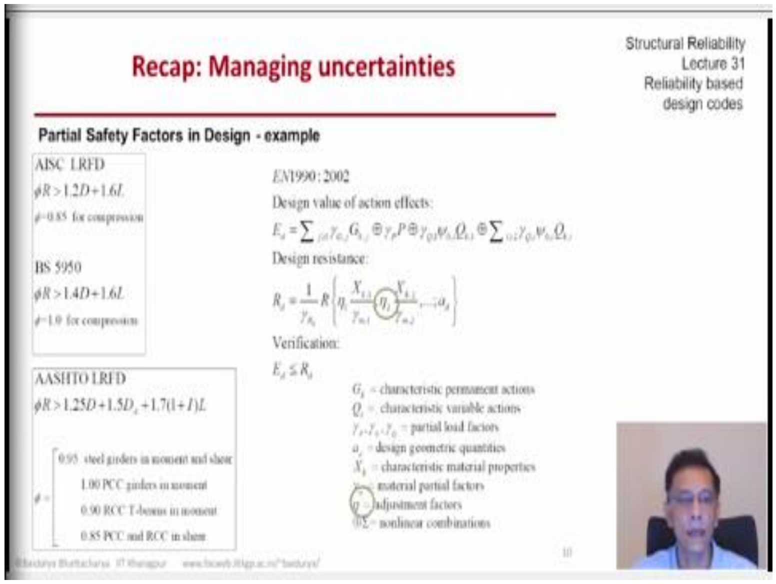
There are characteristic or nominal material properties that define the resistance.

(Refer Slide Time: 04:16)



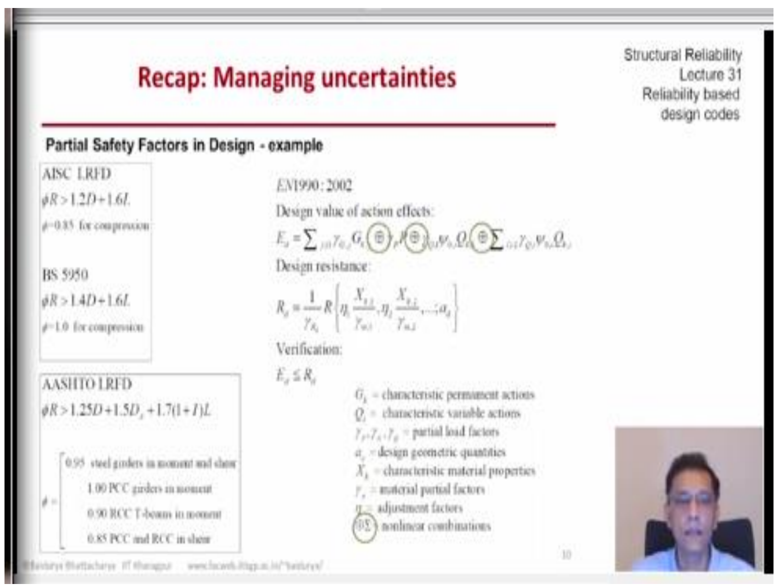
These are divided by material partial factors just like the load partial factors multiply the characteristic loads. The material partial factors divide the characteristic material properties because they are strength type.

(Refer Slide Time: 04:37)



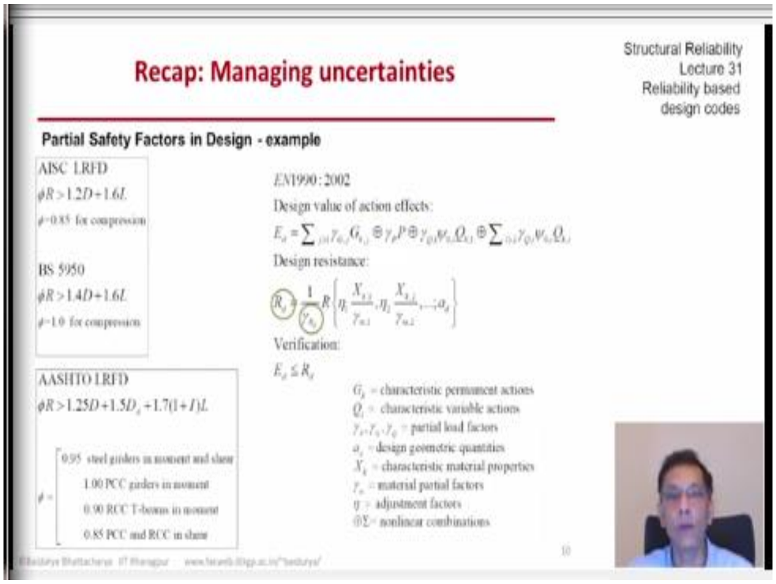
There are several adjustment factors eta 1, eta 2 and so on.

(Refer Slide Time: 04:42)



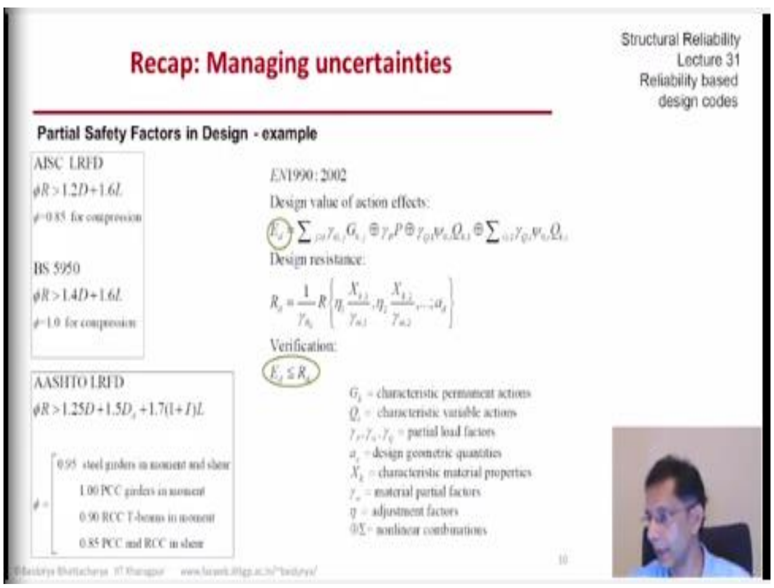
And then just to emphasize that all those pluses and sums are basically a non linear combinations if non linear effects are to be considered or if they are relevant.

(Refer Slide Time: 04:56)



Now you can also have an overall strength factor just like we have in the AISC LRFD AASHTO LRFD cases you can have another partial safety factor for the strength, so finally that gives us the design resistance.

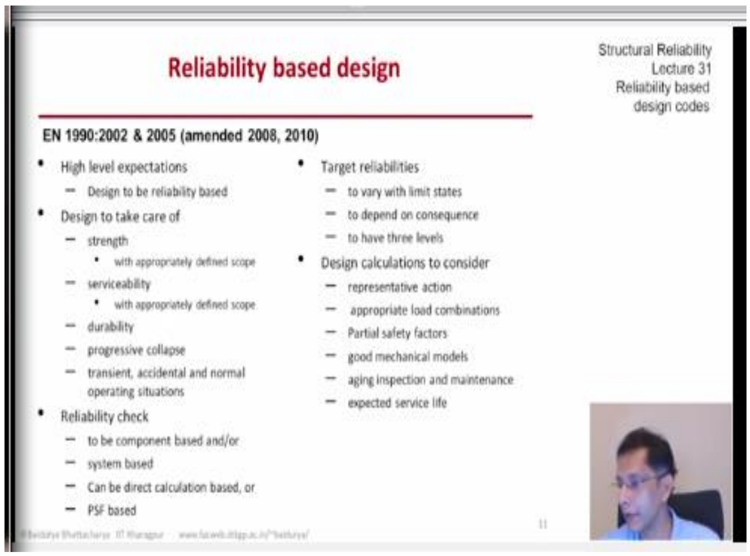
(Refer Slide Time: 05:20)



And then that needs to be compared with the design, action effect and as long as E d is less than or equal to R d that aspect of design has been satisfied. Now as we said in the previous slide, let us see how structural Euro codes being one of the latest and being very comprehensive. Approaches the design process and as I said it is reliability based, so what it tries to cover, what it is expectations are at least at the high level.

So, the next few slides I am going to go through the first 3 or so chapters from EN 1990 and pick out the important points or the important phrases that bring out the philosophy and the expectations of the structural EURO codes.

(Refer Slide Time: 06:23)



So, as we will see here I have just summarized before. As we will see in the next few slides that the first expectation is that the design has to be reliability based. And then we will pass out these important expectations that the design has to take care of the strength, aspect or the strength limit state as we will see. And with appropriately defined scope, the design has to take care of the serviceability limit state whose scope also needs to be appropriately defined, has to take care of durability has to take of progressive collapse.

We discussed that through 1 example at the very first lecture, the collapse of the Ronan point buildings. And then the design also has to take care of not only normal design situations, normal operating situations but transient and accidental situations as well. The reliability check and this is not the way that the code comes up chapter to chapter and section to section, but I have just tried to reorganize them to bring out the story nicely.

So, the reliability check has could either be component based or system based or both, it so happens that most of our design checks are still component based. The reliability check can be direct calculation based like actual reliability number is found out and that is checked against the target or minimum acceptable value or it can be indirect with the help of partial safety factors which is what we saw in the previous slide.

And then the target reliabilities those that must be satisfied at the minimum, they should vary with limit states because different limit states have different consequences of exceedance. And in particular 3 levels of such consequences have been specified. So, the designer has to see which consequence class their structure comes under. And then the design calculations which should be used to ensure this satisfaction of target reliability for each relevant limit state.

It should consider representative actions, so that is what we saw in the previous slide in going through those equations should use all appropriate load combinations, should use partial safety factors unless obviously the calculations are direct calculation based. It must use a good mechanical model. Aging, inspection, maintenance all these time dependent issues have to be considered in the design calculations as much the expected service life be.