Structural Reliability
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Lecture –250
Target Reliabilities and General Conclusions (Part - 03)

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Putting all these surveys together we find that society's attitude towards an individual's involuntary fatality risk if it is 10 to -3 per year it is clearly unacceptable. On the other end if it is 10 to minus 6 per year or less then it is acceptable it is okay and in between these two limits 10 to the -4 per year seems to be tolerable but barely so we would like it to be less now with these in mind we find that the general consensus that have developed around the world for acceptable risk of an individual fatality for a member of the public from building collapse should not be more than 10 to -5 per year.

And if possible should be closer to 10 to the -6 per year so that is what we find the acceptable standards. Now if you want more information I would refer you to these two papers now continuing with our earlier thought that building failure or structural failure does not necessarily lead to one potential fatality there could be multiple fatalities. So, it is instructive to see how investigators and agencies have handled that possibility.

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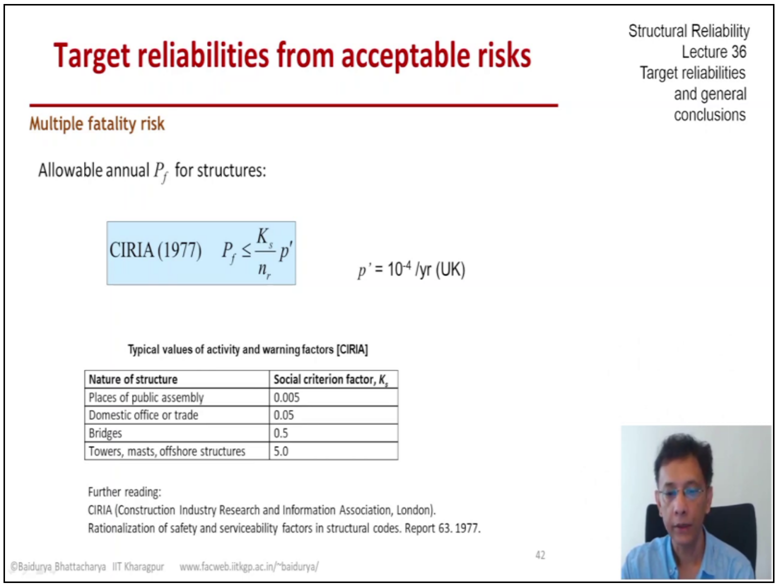

One of the earliest examples that we see in setting allowable annual target failure probabilities for structures came out of the UK in 1977 the CIRIA report it is instructive to see let us this equation and go term by term so the allowable P f is the product of three numbers so there is P prime which is the base rate and it's 10 to the -4 per year as we just discussed. Now this base rate can be adjusted by two numbers and one is K s in the numerator and n r is number of people at risk so number of potential lives lost.

So clearly what CIRIA have felt that it is a it is just proportional if more number of lives are lost then the single individual's fatality risk should be should be reduced exactly in that proportion. Now this number K s it depends on what sort of what sort of structures we have and whether the risk is voluntary or not so if it is an offshore structure for example it is quite likely that the person on board the offshore structure is a professional and has done so fully knowing the risk.

So, then the allowable P f can be multiplied by a factor of five on the other hand if it is a place of public assembly it is member of public for whom the risk would be involuntary. So then that number can be brought down by a factor of 0.005. So in effect we would have something like of the order of 10 to the -6 or less would be the allowable P f. So this way we see how a very early example tried to handle the possibility of multiple fatalities. A few years later we find another example coming out this is the reference of the CIRIA report.

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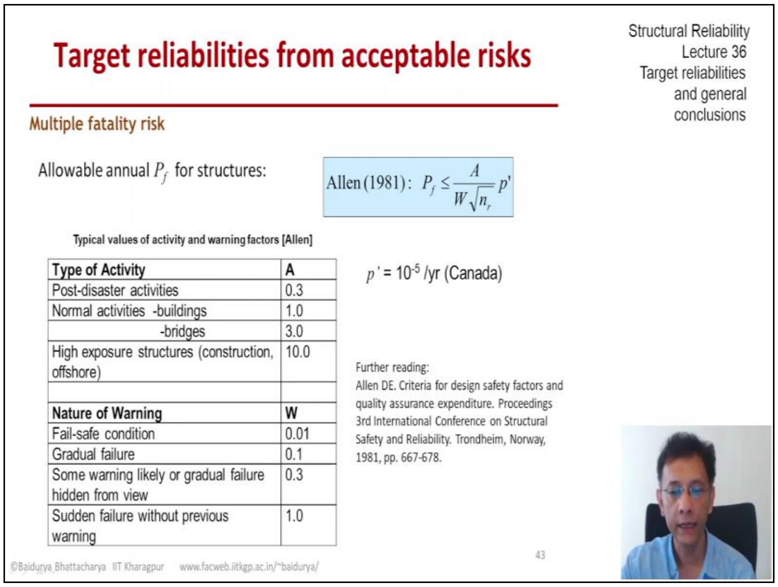

The next example came out of Canada and this is a paper by Allen and this is interesting this it has a different logic the P prime quantity is still there but there are three factors. Now multiplying P prime and the first thing we notice is the presence of square root of n r so here the allowable risk is not going down proportionately with number of life's loss but with the square root.

So it is kind of this model is insensitive to a larger number of deaths in one accident the other this P prime is 10 to the power -5 per year that's the base acceptable probability. But then we can see the different multipliers A in the numerator and W in the denominator. So let us take a look at a first. So if it is normal activity then we do not change P prime if it is high exposure. So, again if it is construction worker offshore work then it can be even increased by a factor of 10.

For bridges it is something between normal activity and high exposure so a takes care of the activity which in some sense looks at the voluntary or involuntary nature of the exposure the warning factor W in the denominator that would be one if there is no warning at all. So, it is complete sudden failure and we have seen these earlier when we were discussing all the design standards who are putting acceptable uh depending on consequence of failure.

So, if the failure is gradual or if complete fail-safe condition then the P f can actually be increased. So W can be less than one so it could be even 10 times more if there is adequate warning. So that is the sort of suggestion that came out of Alan's work. Almost two decades later let us go down go on to one example and this is now an international standard.

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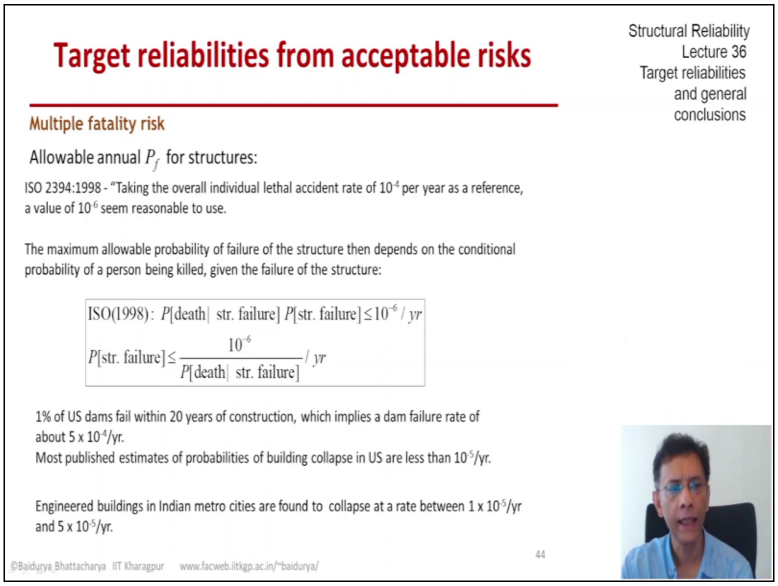

The ISO2394 of 1998, so let us read some of the texts from the standard carefully. So, clearly the 1998 edition of the standard says that 10 to the -4 per year of an individual's risk of death is acceptable and then 10 to -6 based on that 10 to -6 would be that from structure. So that would be limit they would like to put from failure of building structures. So expressing the failure as the product of two one conditional is so the death from structural failure is probability of death given structural failure times the structure fails the probability that the structure fails it should not be more than 10 to the -6 per year as they just stated.

And then the structural failure probabilities should be limited to 10 to minus 6 per year divided by the probability of death given the structure has failed. Now that could be obviously the worst case would be one so we would have 10 to -6 or somewhat higher if the failure of the structure does not necessarily lead to an occupants death. Let us compare some of the numbers now with what we observe in terms of building collapse frequency actually.

We have some estimates this number is from Ellingwood's paper the one that I just referred two or three slides back. So, most published estimates of building collapse would be found are found to be less than 10 to -5 per year in the US. In India I have found that for engineering buildings in metros the rate is a little higher it is between 1 to 5 times 10 to the -5 per year. So, that is what we have found from recent building collapses around the country.

So that gives an idea about what the structural failure should be according to ISO2394 1998 and what we typically observe around the world. Now let us see how ISO2394 handled the possibility of multiple fatalities.

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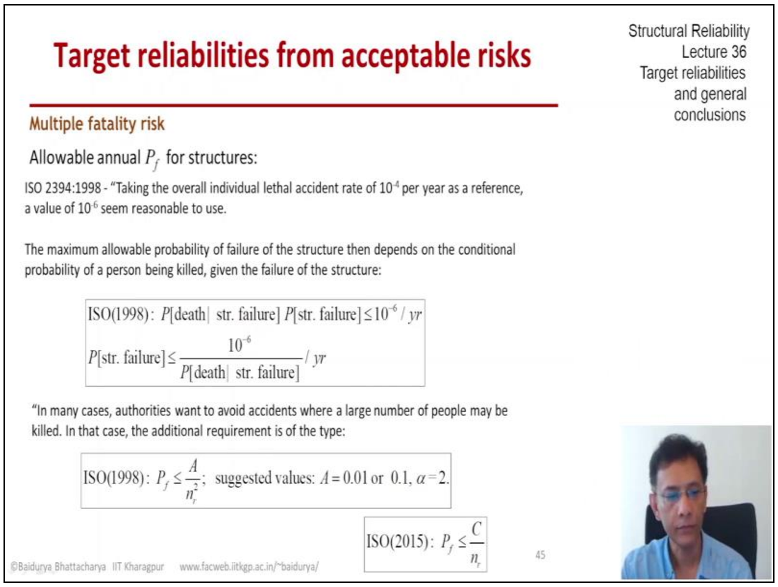

So, this statement is instructive that where a large number of people may be killed in that case the authorities would like to avoid such accidents and then the requirement that ISO2394 of 1998 suggests is that it should be proportional to 1 by n r squared in the denominator. So, if more number of people would be killed P f should be reduced disproportionately. So, more emphasis is given on the number of lives lost in a single event not proportional.

But n r to the power of 2 and then we see that so alpha is 2 in the in the denominator which is the exponent of n r and then that a value could be 0.01 or 0.1 those are just examples but it shows that P f would be further reduced so that would be the factor which we are going to use to set P f. Interestingly uh an economic based analysis in the next revision of 2394 actually changes that approach of alpha of 2 and brings back alpha to about 2 to 1 and that is what we will see later in this lecture.

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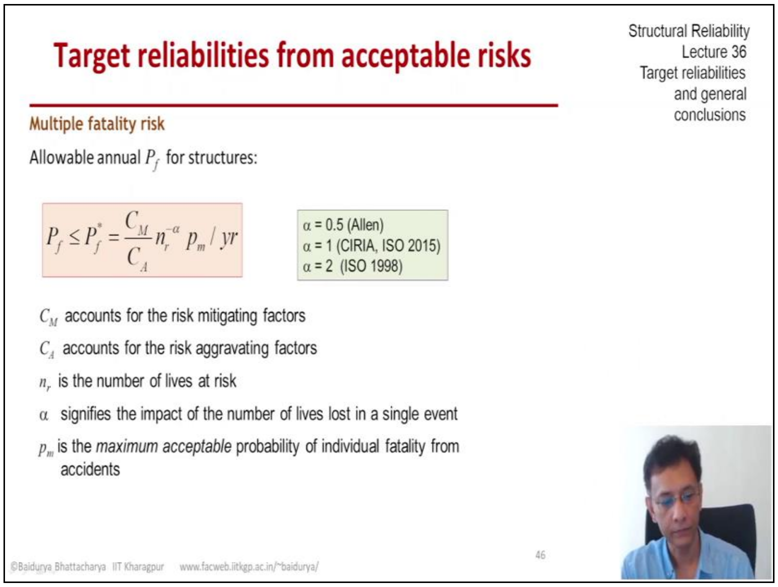

Putting all of this together it is seems that for multiple fatalities or with the possibility of multiple fatalities P f should be less than the number of lives at risk to the power of minus alpha and alpha depending on the investigator and the agency and their priorities could be one could be less than one could be more than one. And then there are factors which could increase this acceptable probability of failure if there are risk mitigating factors or they could further decrease this if the risk aggravating factors.

And then multiplying that is always the maximum acceptable failure probability which could be of the order of -4 per year or such depending on society's attitude towards such risks.