Geotechnical Earthquake Engineering
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Module - 7
Lecture - 27
Seismic Hazard Analysis (Contd…)

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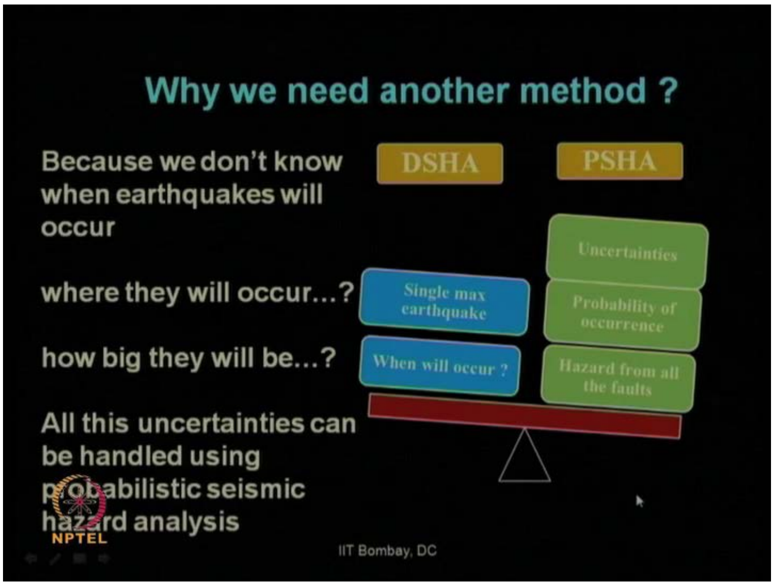

Let us start our today's lecture for this NPTEL video course on Geotechnical Earthquake Engineering. We are going through the module number 7, which is seismic hazard analysis. A quick recap what we have learnt in our previous lecture; let us see. We have seen the short comings of deterministic seismic hazard analysis and that leads to the requirement of another method which is nothing but probabilistic seismic hazard analysis, because in this case we take care of all the uncertainties involved in the earthquake event to estimate the hazard for a particular location or region or site.

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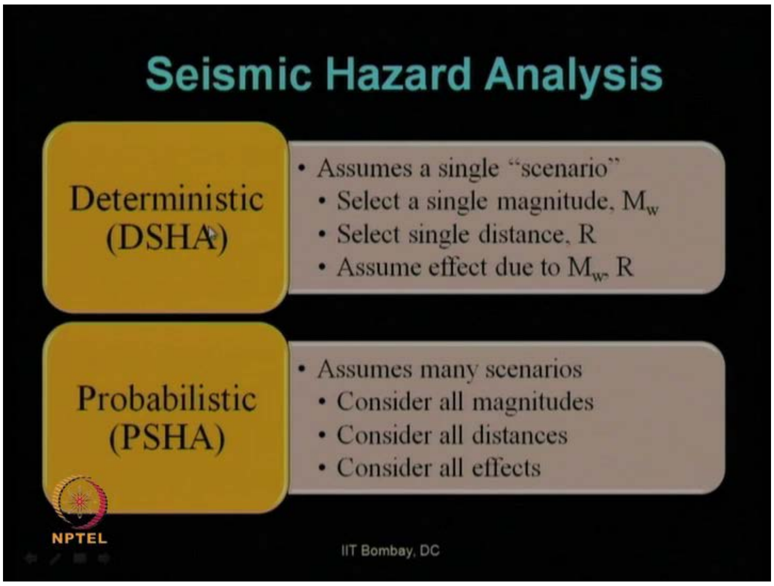

So, we have major characteristics of deterministic seismic hazard analysis like, here only a single magnitude that is the M max we consider, single distance R min we consider, and we assume the effect of this M max and R min to estimate the DSHA. Whereas, in probabilistic seismic hazard analysis, we consider all the magnitudes involved, all the distances involved and all the effects involved; that is the probability or uncertainty involved in the event is completely taken care of.

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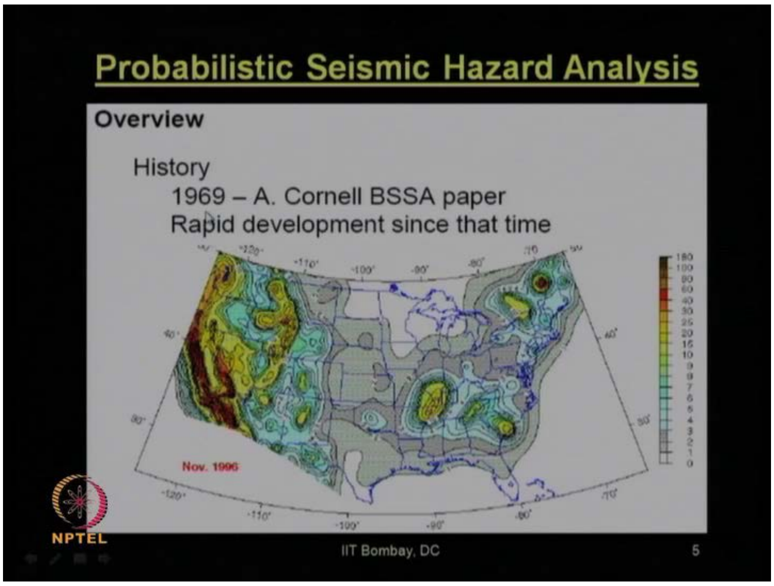

First 1969 Cornell through Bulletin of Seismological Society of America BSSA paper, first introduced this concept of Probabilistic Seismic Hazard Analysis or PSHA. Since then there is a rapid growth in this area of PSHA and still it is continuing today.

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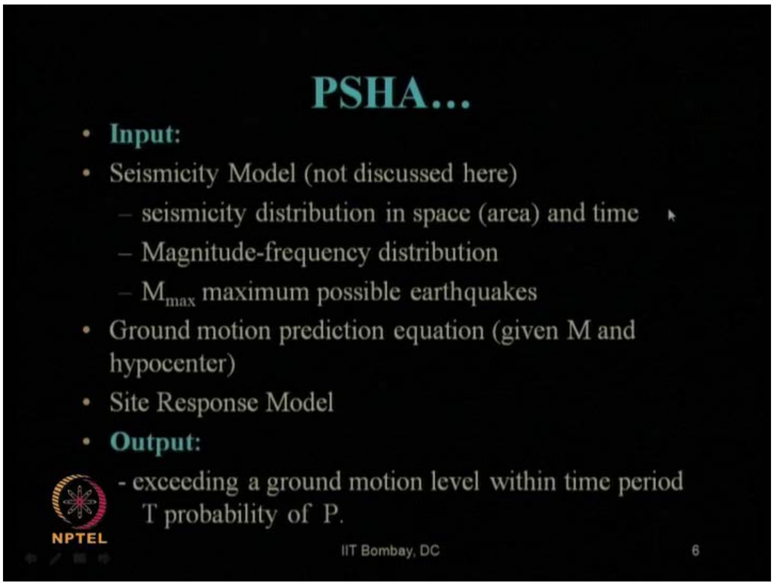

So, in PSHA we have learnt already the input data like: Seismicity model. then seismicity distribution in the space and time; magnitude frequency distribution M max maximum possible earthquakes; ground motion prediction equation or GMPEs which are nothing but attenuation relationships in terms of M and hypocenter, and site response model. And finally, we will get the output that is the event of exceeding a ground motion level within a time period of T with a probability of P; that is what we get as an output.

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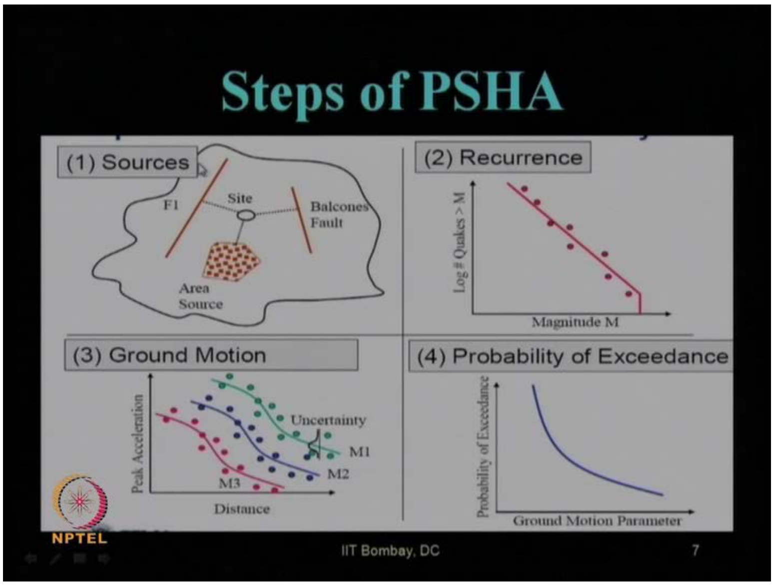

So, the four major steps of PSHA, which we have already seen; these are first to identify the sources, all the sources and from the site; then the recurrence number of earthquakes greater than a sustained event with respect to the earthquake magnitude. Then the ground motion prediction equation GMPE is based on the uncertainty involved in all the relationship, and finally to obtain the probability of exceedance of a particular event for a given ground motion parameter.

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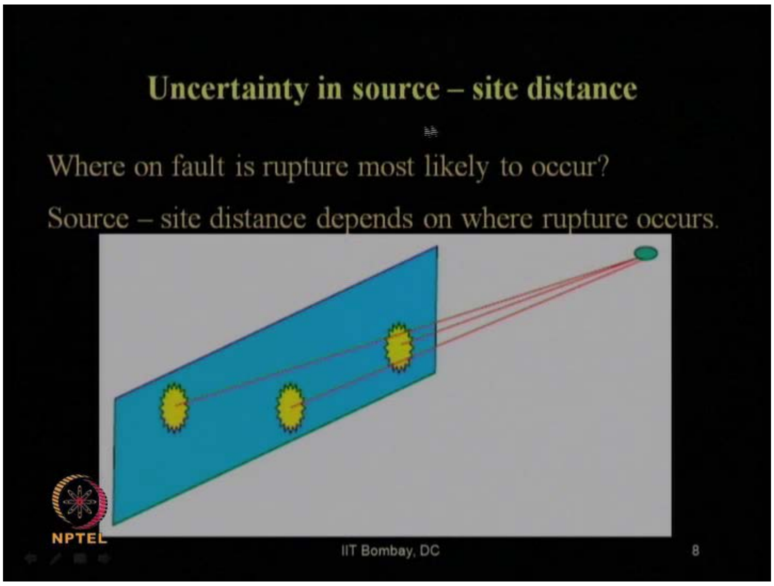

Then we have seen the uncertainty involved in the source to site distance; that is, we can have various source to site distances if the fault or the rapture is of a large area, of course, or large length like this.

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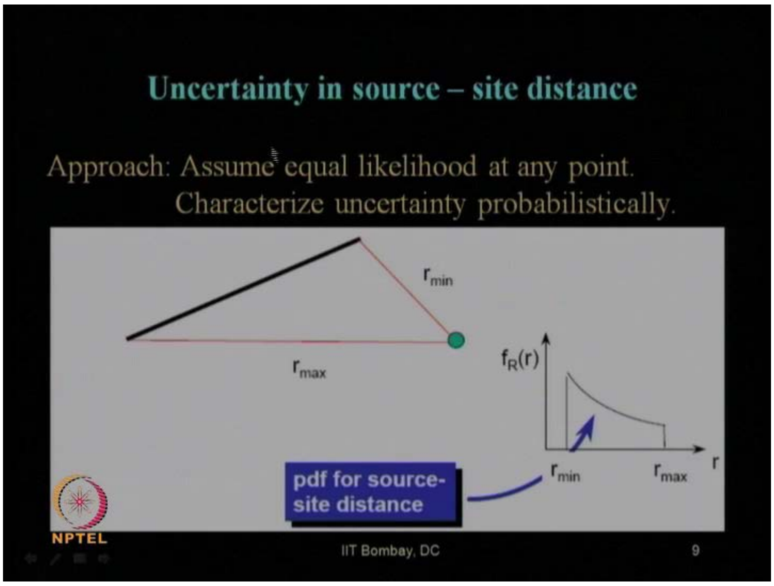

So, what is the mode of considering this uncertainty? We can find out r minimum, r maximum and all other r that is the distance from site to the source and find out the probability distribution function through the process of histogram for that r.

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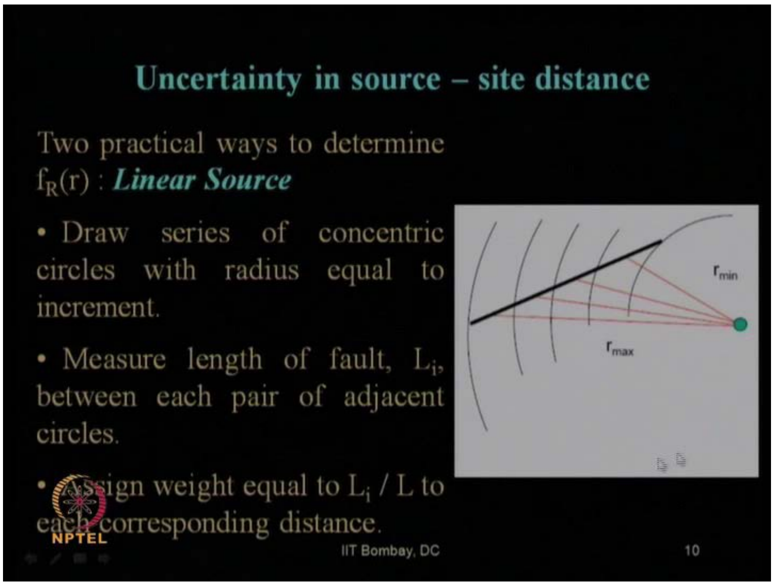

Then we have seen how to proceed with that, suppose if we have a linear source like this.

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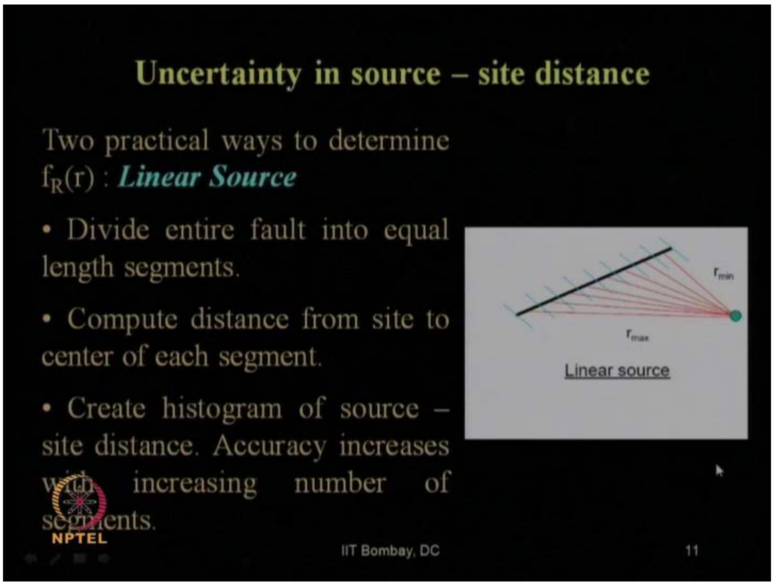

Then, we can divide that linear source into a number of segments by either using the concentric circle approach or by using the equal increment approach in the or equality approach in the segment of the linear source.

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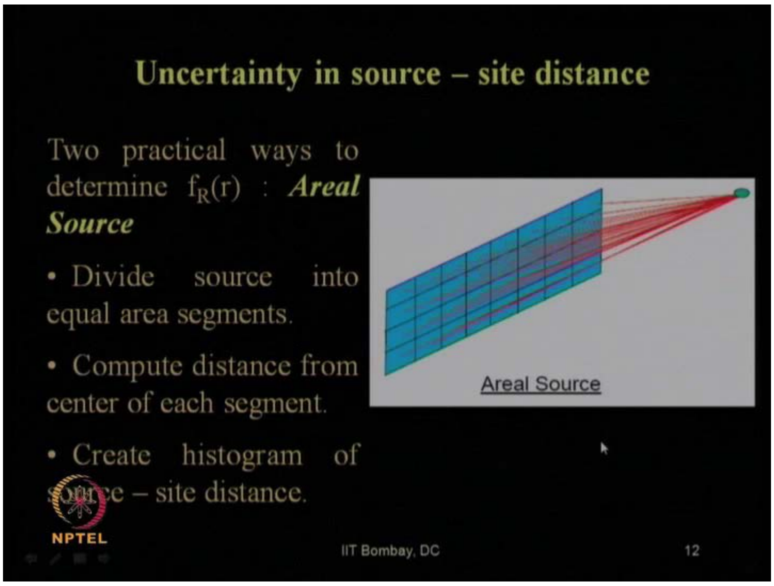

And then find out individual distances which will give us finally that probability distribution of distance versus that probability of occurrence. Similarly, for areal source also we sub divide the area into number of small segments.

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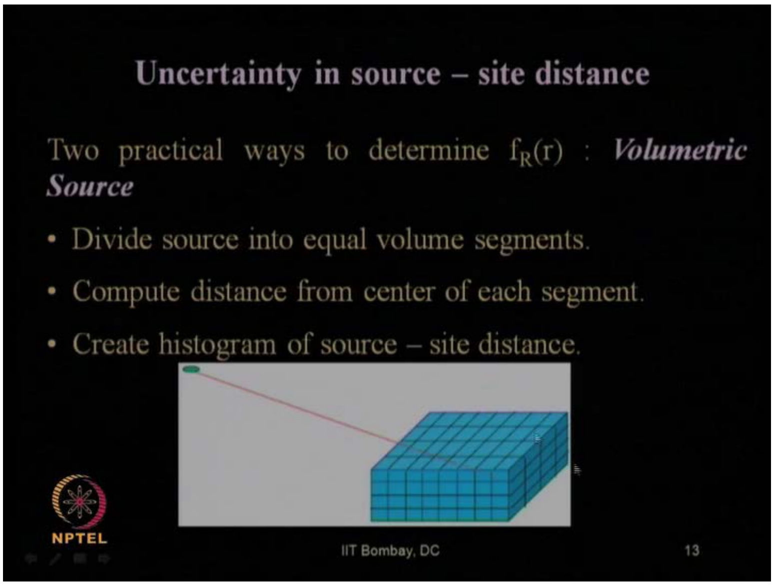

And for volume also we divide it into number of small segments.

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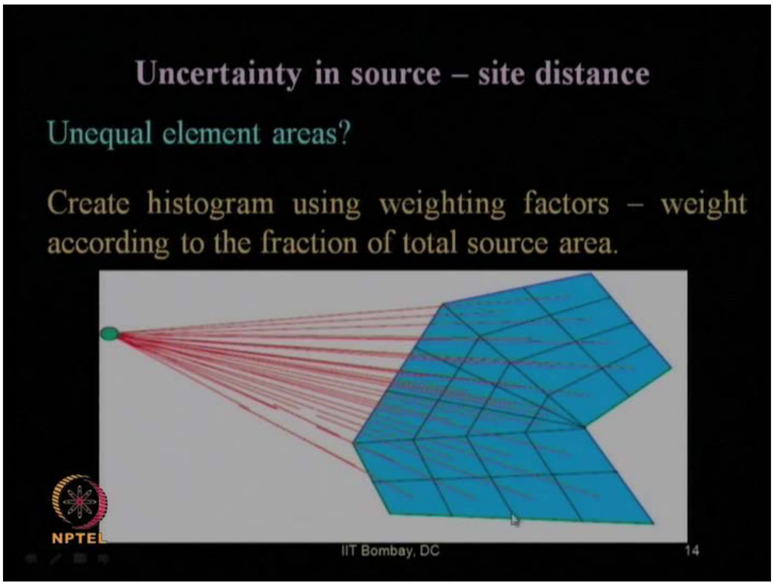

If we have unequal source that also we have seen. We can divide them in unequal areas and all the distances, we can correlate to them while calculating the histogram using the weight factor of each of them.

Suppose this area is a 1 compare to total area of a, say a 1 by a will be weighting factor to this distance. Then similarly, suppose this is a 10, say a 10 by a will be corresponding weighting factor to this distance. Like that we can find out the histogram putting the weighting factor also.

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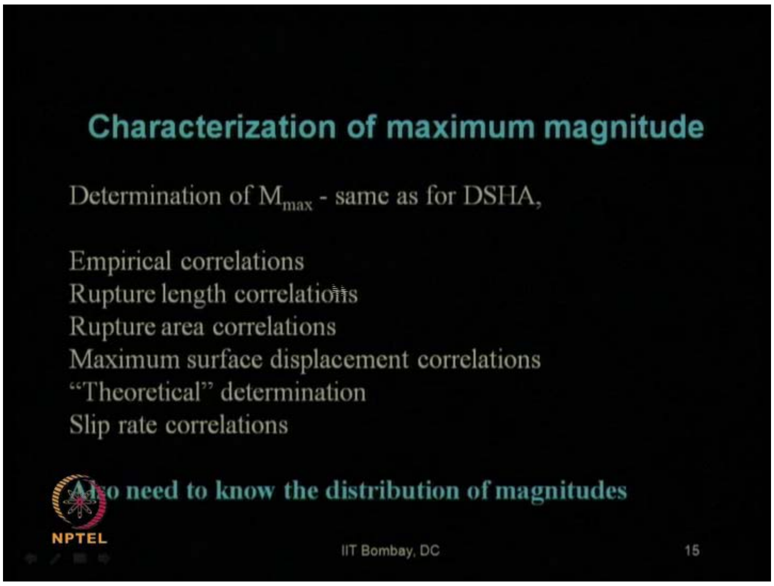

Next, we have seen how to characterize the maximum magnitude. It is similar to that DSHA process, either using all those empirical relationships like with respect to length area or surface displacement of fault or the theoretical determination through the seismic moment concept or the slip rate correlations process.

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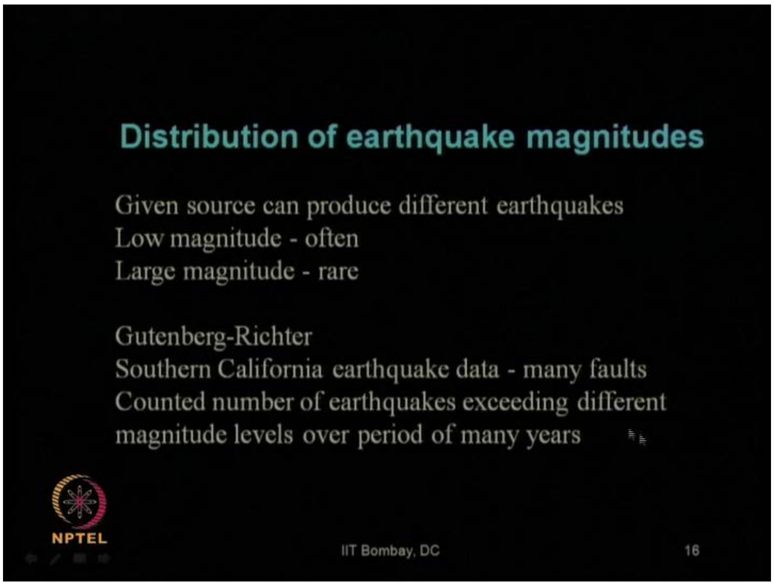

And we often found that the distribution is such that earthquake occurrence of low magnitude will be quite often and large magnitude will be very rare.

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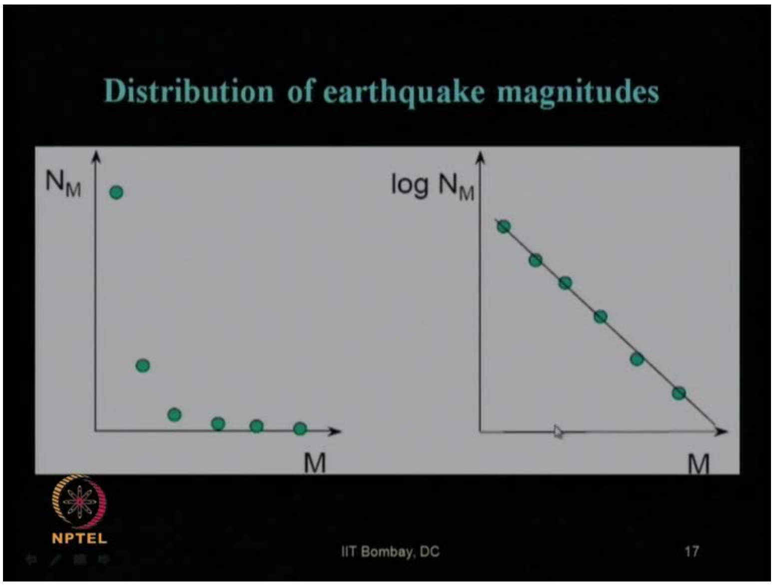

So, based on that, Gutenberg-Richter proposed some earthquake recurrence model which will look like this. That is, if we take any earthquake event at a particular region, this is number of occurrence of an earthquake of magnitude scale x-axis; this is the normal scale; it will follow some distribution like this which in the log scale of this number of event and normal scale of this magnitude will look like this linear relationship. (Refer Slide Time: 11:36).

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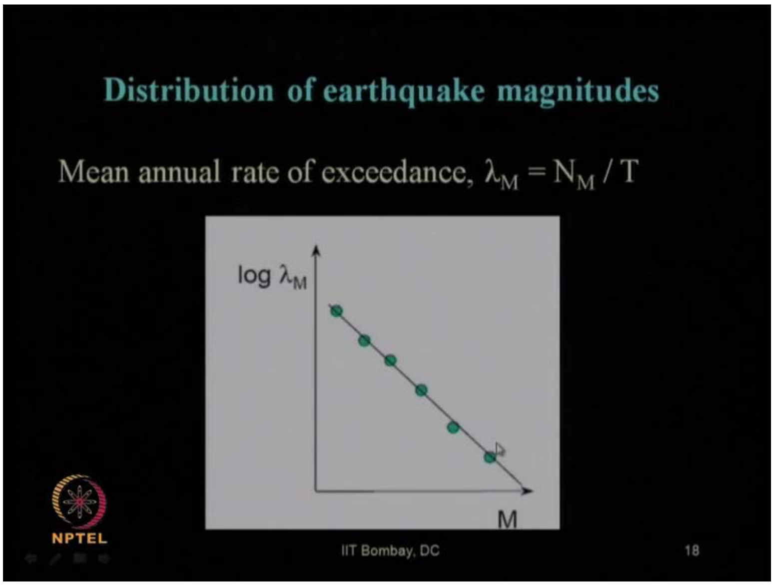

It has been proposed by Gutenberg and Richter through this concept of mean annual exceedance, which is nothing but number of that event divided by over the time T.

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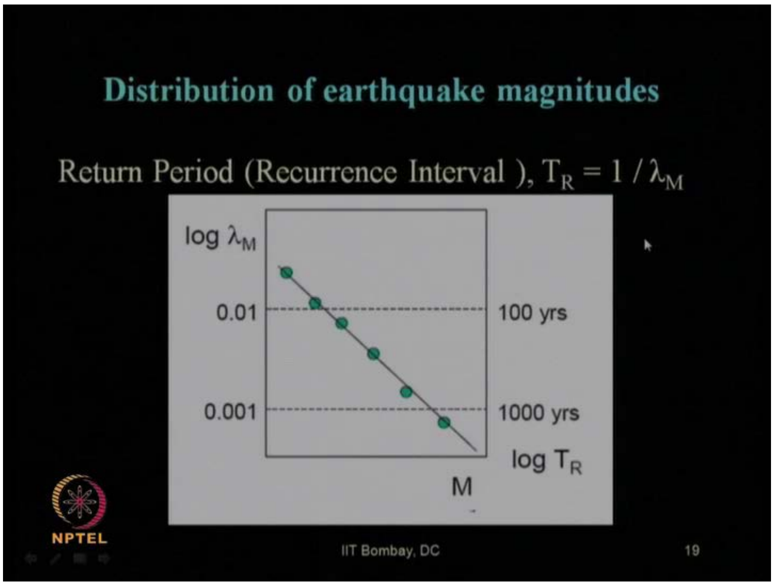

So, the recurrence interval is nothing but inverse of mean annual exceedance. So, if we plot log of lambda in this axis, the inverse will be log of T R increasing order in the reverse direction of that lambda m, but still they will follow this relationship.

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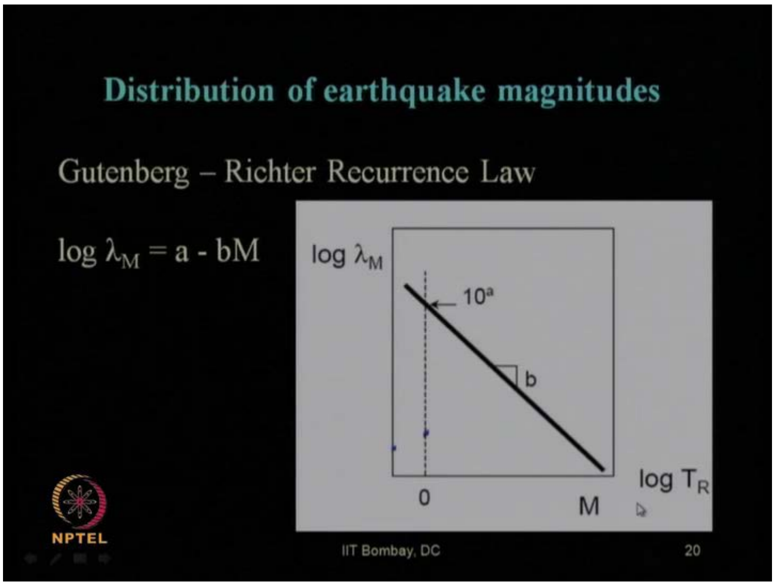

Hence, Gutenberg-Richter law for this kind of earthquake data will look like log of lambda M equals to a minus bM where a is nothing but the intercept on this axis at M equals to 0 with the value of 10 to the power a from here and b is nothing but the slope of this line, this recurrence law. So, this a and b coefficients need to be obtained for various regions based on the collected historical earthquake data.

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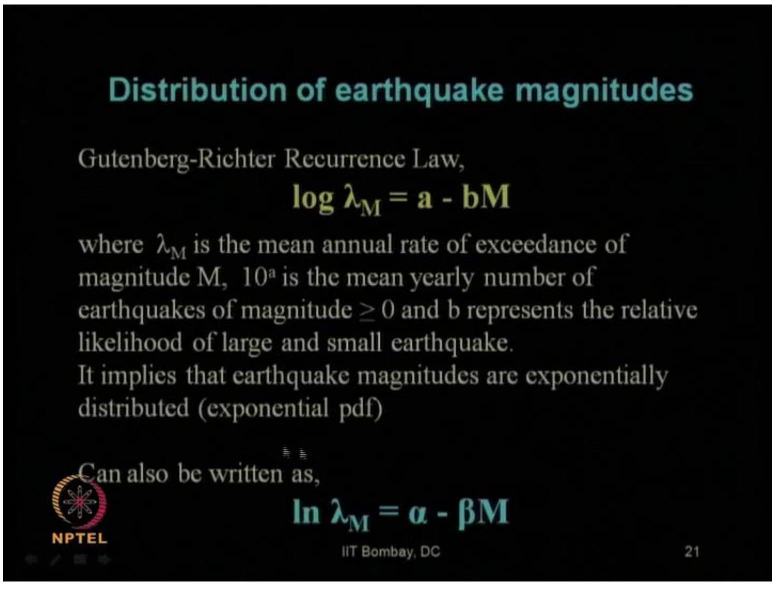

So, Gutenberg Richter law can further be expressed in terms of natural logarithm like this; in terms of alpha or beta where alpha and beta is nothing but conversion from the log to the base 10 to natural log through this process.

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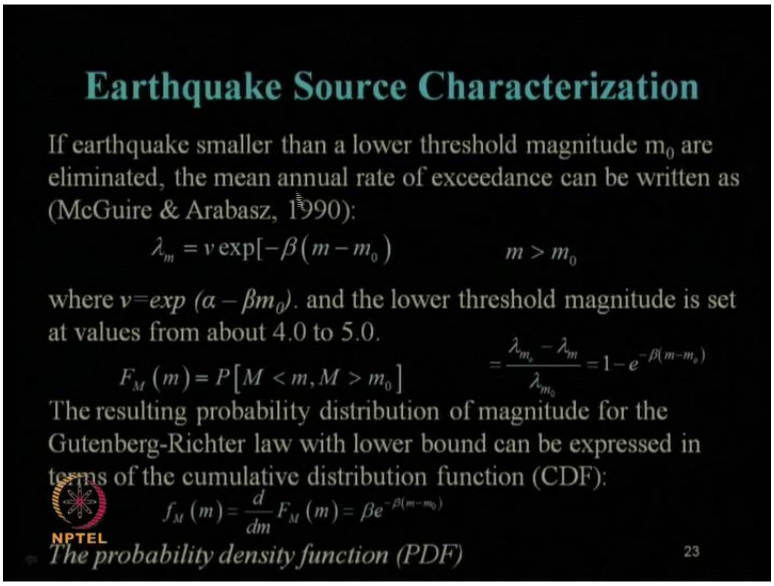

The earthquake is expressed in terms of a lower threshold magnitude m naught above below which we engineers are not interested. So, that is why there is a lower boundary. Hence, the lambda m has been expressed by this expression, as proposed by McGuire and Arabasz in 1990.

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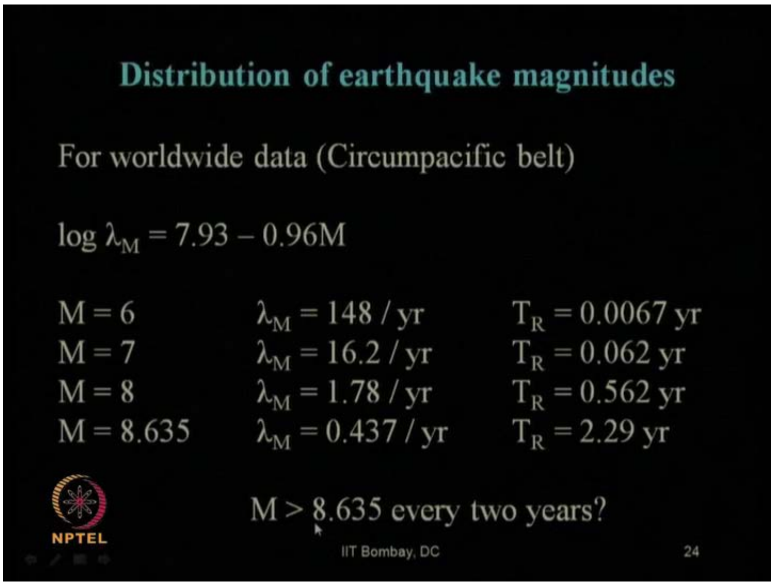

Now, the probability distribution function can be expressed like this. If we look for an example of worldwide data of circumpacific belt, the equation is proposed like this. We will get, for various magnitude of M, we can obtain what are their recurrence interval like T R. We can easily calculate, but this also we are not pretty sure whether it is giving the correct result or not, behind certain value like as it is shown over here. So, we have to select upper bound also up to which this equation is valid or applicable.

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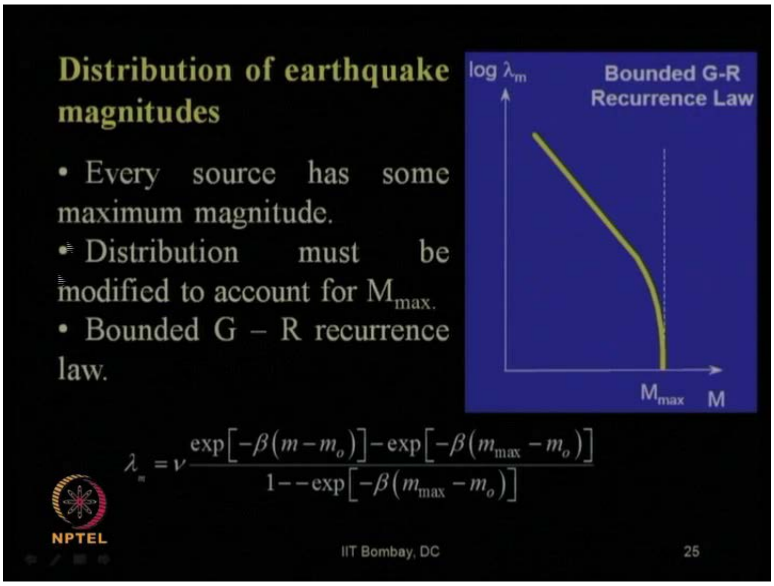

So, to know the validity of the or applicability of that equation, we have to bound it up to a maximum value of M, M max for that region whatever maximum value was accounted for from the known earthquake data. So, that is known as bounded Gutenberg Richter recurrence law. Hence the equation will change to not only with the threshold value of m naught, but also with respect to this m max.

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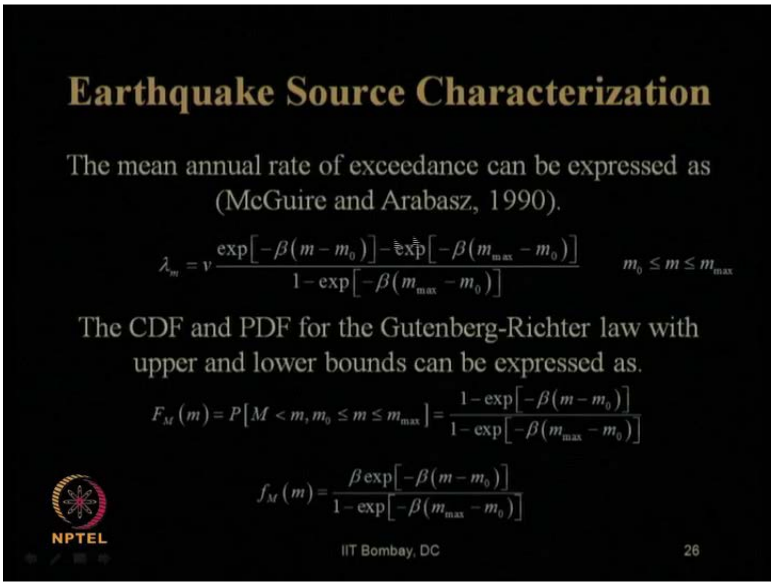

So, hence the modified magnitude McGuire and Arabasz equation of mean annual exceedance rate is given by this. Hence, the probability distribution function is given by this expression considering both maximum and minimum; that means, your magnitude should lie between these two ranges of threshold value of minimum and maximum value of this one.

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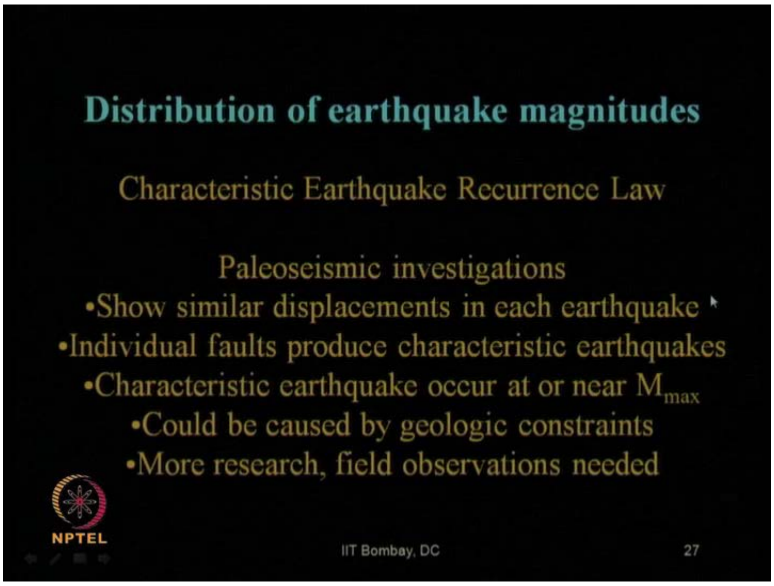

Then, we have seen for distribution of earthquake magnitude we require all these characteristics of earthquake recurrence law to arrive at all these informations are necessary.

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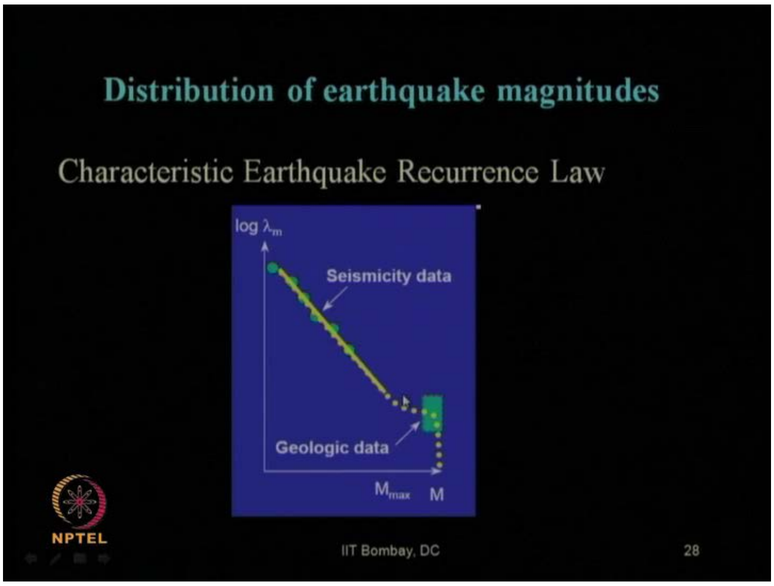

Hence, the seismicity data and geologic data everything can be clubbed together to obtain a characteristics earthquake recurrence law for a particular region.

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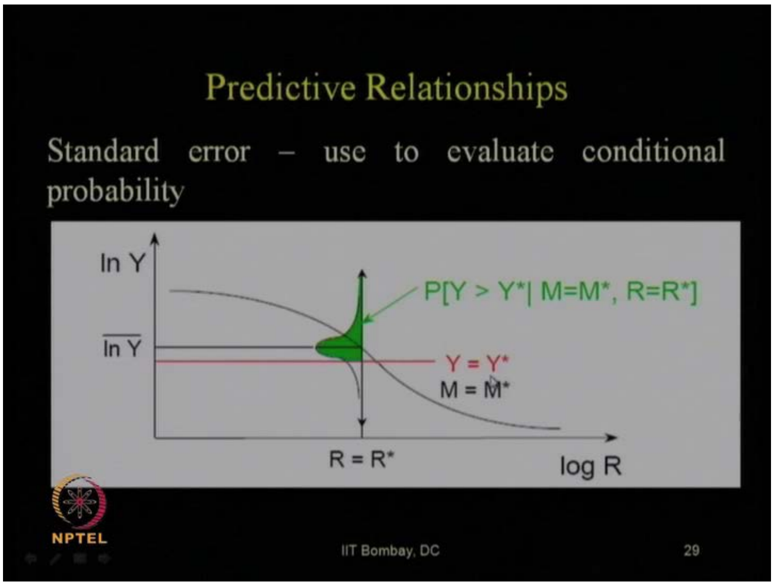

Also for the predictive relationship, we should know the conditional probability considering the standard error involved in the attenuation relationship like this for a given value of M equals to M star and R equals to R star.

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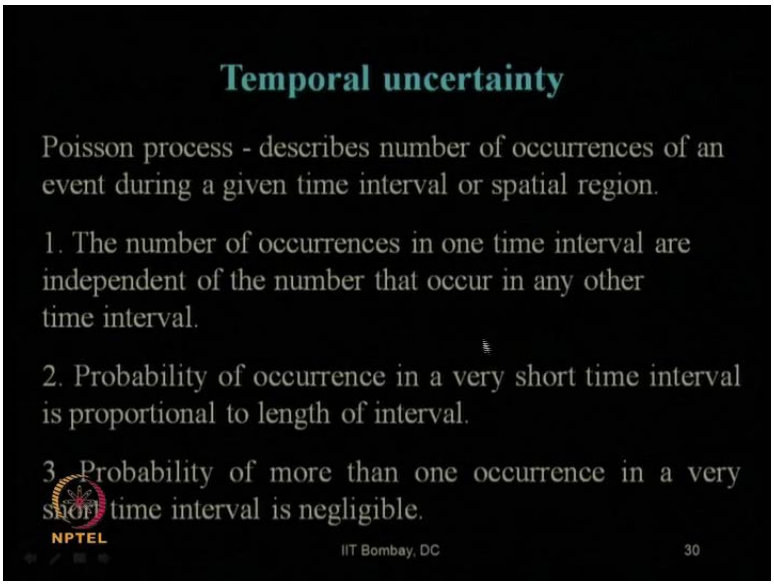

Now, for the temporal uncertainty in terms of time event, how to take care of that temporal uncertainty? Through the Poisson's Model probability distribution which is expressed in this form.

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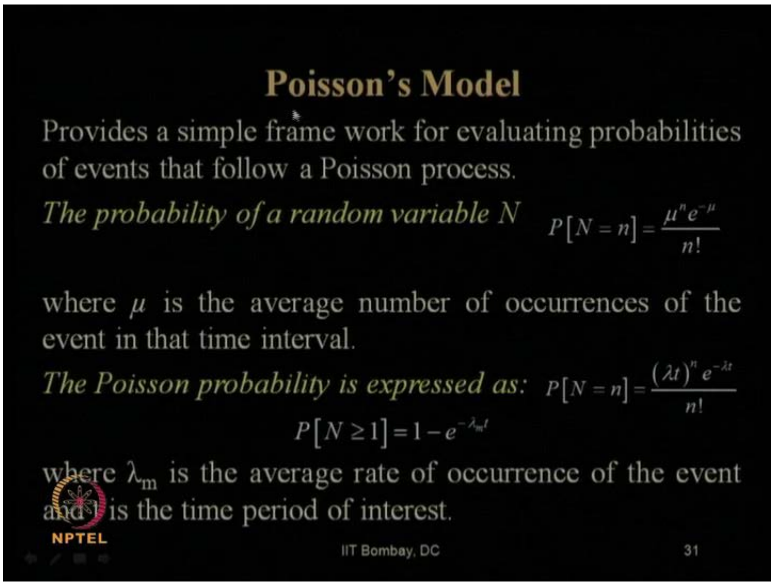

So, if we say occurrence of an event at least once, is nothing but N greater than equals to 1 will be 1 minus e to the power minus of lambda m t using this Poisson's relationship.

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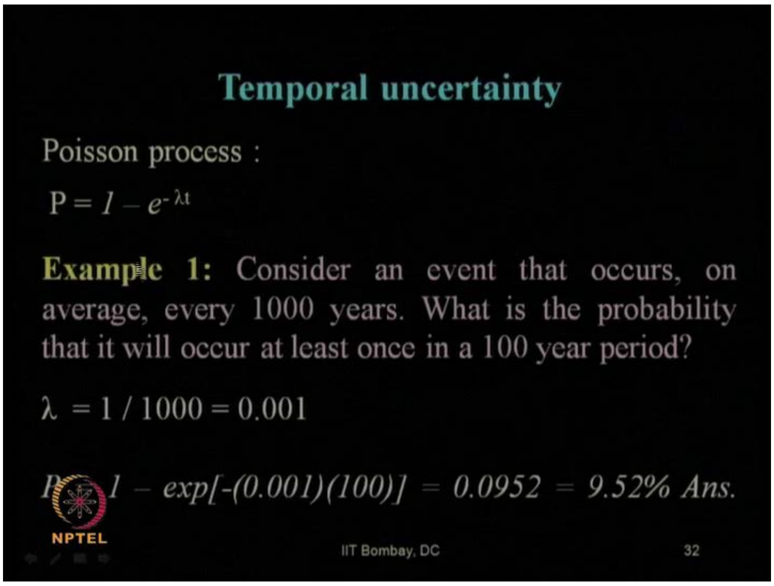

So, we have seen in the previous lecture, through example process of that at least once occurrence of that event using this Poisson's probability distribution equation that what is the occurrence suppose an event occurs once in 1000 years on an average; then lambda will be 1 by 1000; so occurrence of that event at least once in 100 years will be like this. it can be computed which comes out to be 9.52 percent.

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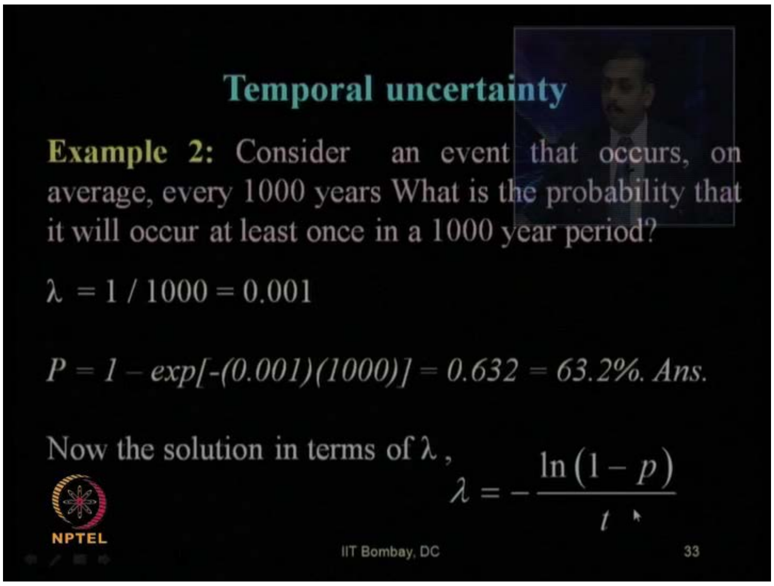

But the same problem that is occurrence of at least once in 1000 years probability is not 100 percent, what the lay man will generally say, but it will be 63.2 percent.

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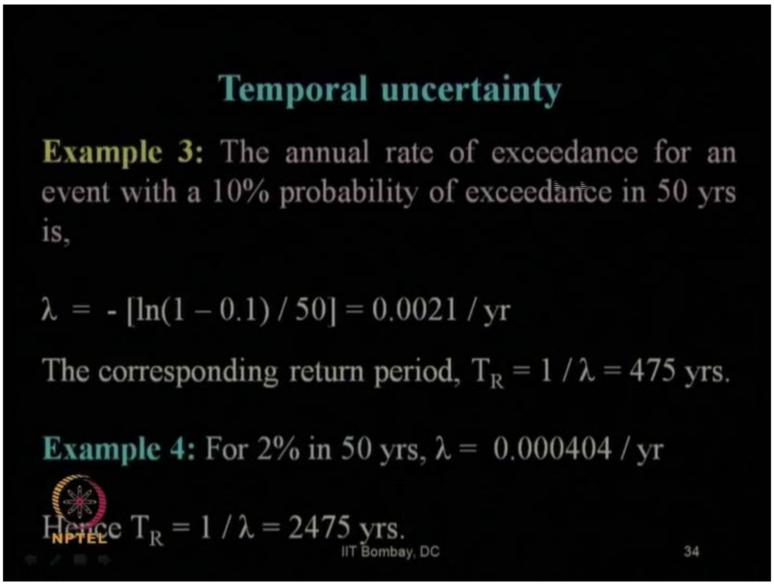

Now, expressing this lambda in terms of this probability P, we will get what is the annual rate of exceedance or the corresponding return period for a 10 percent probability of exceedance in 50 years time. So, that gives us 475 years of return period. The same thing which 2 percent probability of occurrence of earthquake in 50 years time will give us the return period of 2475. And these things, we have mentioned the use for our practical design of any structure in earthquake prone areas depending on its importance; that is whether we considered then earthquake event to be occurring in the return period of 2475, that is with less probability of occurrence for an event or with a little higher probability of occurrence with a lesser return period.

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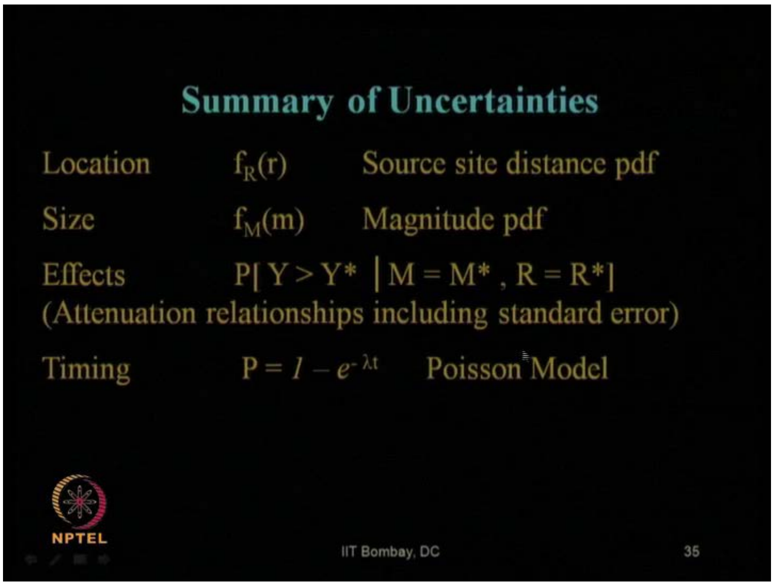

So, with that, we have summarized in the previous lecture that all the four types of uncertainties involved are with respect to location. That is site to source distance; then with respect to size, the magnitude probability distribution function; with respect to effect, considering the standard error in the attenuation relationship and with respect to timing based on the Poisson’s model.

Now, in today’s lecture, we should look how to combine this all the uncertainties involved for an earthquake event together because these are not independent event; all these uncertainties occurred together. So, we need to look at the conditional probability or the dependency of one event over the other; one uncertainty over the other.

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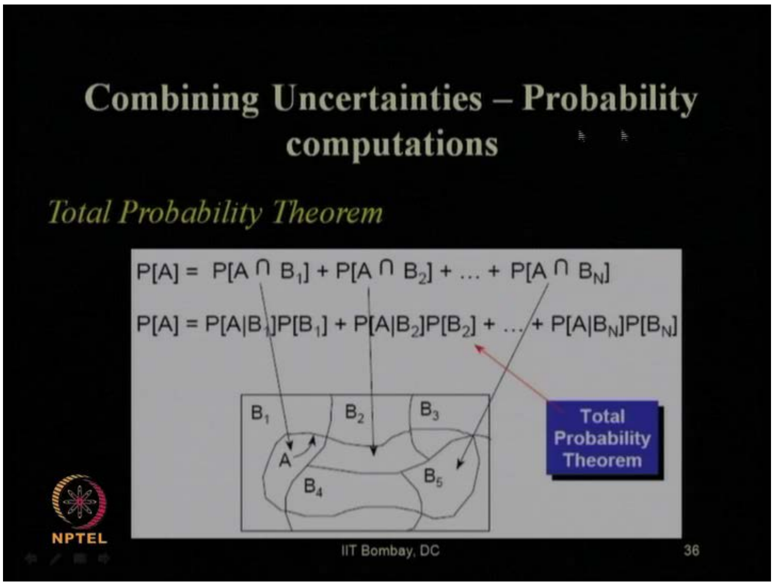

So, let us look at this - combining uncertainties probability computations. Now, we are starting combing all these uncertainties using the probability theorem. So, what is the total probability theorem? It gives us the idea. This is the… from any basic probability theorem, we all know that probability of occurrence of an event A will be nothing but suppose if this is the domain, the total probability theorem says us that it will be probability of occurrence of A intersection one event B 1, this is B 1 another event probability of occurrence of A intersection B 2 this is B 2 like that up to probability of occurrence of A intersection of B N which is nothing but it will be probability of occurrence of A is nothing but probability of occurrence of A for a given B 1 multiplied with probability of occurrence of that event B 1. And probability of occurrence of A for a given B 2 multiplied with probability of occurrence of that B 2 and so on up to n numbers of events.

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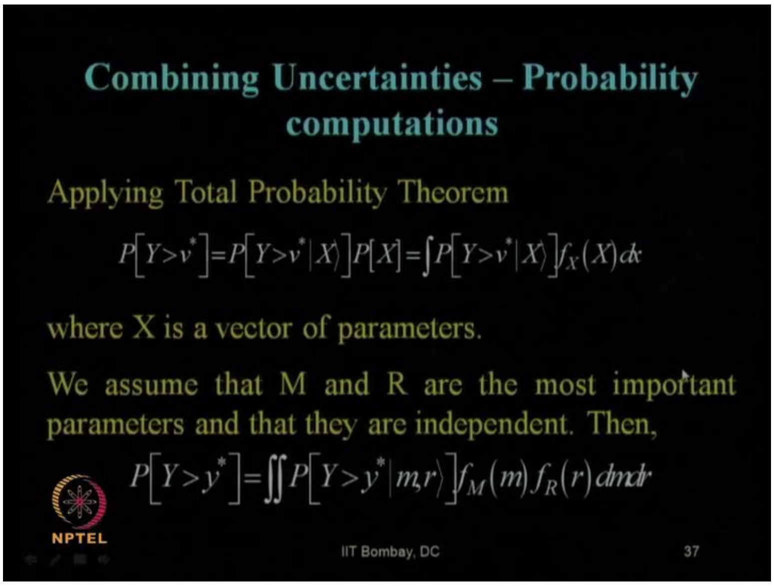

So, applying this total probability theorem, what we can write? That probability of occurrence of any Y, that parameter hazard parameter which we are going to compute, greater than some value say nu star will be given by probability of occurrence of that Y greater than nu star for a given X multiplied with probability of occurrence of that event X for entire ranges of X; that means, it has to integrate all these probability distribution functions of X. So, X is nothing but is a vector of parameters which is nothing but all the uncertainties involved; that is, for a given uncertainty, this is the value. So, for all the uncertainties, you can get the value. So, we assume that M and R are the most important parameters. So, let us say among all the uncertainties, let us say, M and R are the most important parameters.

So, we need to find out the dependency of them in this form; that is probability of occurrence of one particular parameter or event greater than some y star will be given as double integration of probability of occurrence of that for a given value of M and R, multiplied with probability distribution function of that M and probability distribution function of that R, which are coming from the uncertainties involved in magnitude and uncertainties involved in the distance. So, like that we can compute the probability of conditional probability or combining probability together. Clear?

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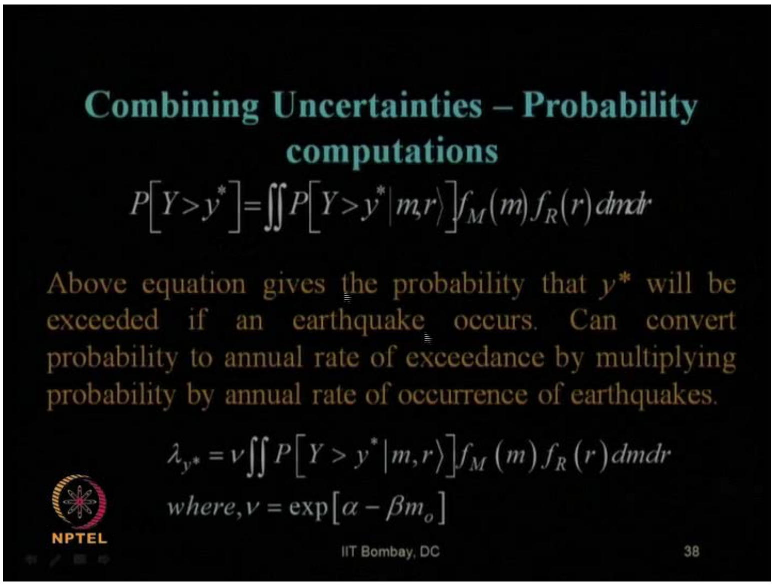

So, again we are writing the same thing. In the above equation it gives the probability that y star is the given value. It will be exceeded if an earthquake occurs. That is, we are suppose interested to know about a hazard that at a site Peak Ground Acceleration occurrence will be more than 0.3 g; let us say we are interested; so probability we need to find out that occurrence of that earthquake PGA greater than 0.3 g for all those given conditions of probability; that is magnitude uncertainty is taken care of, distance uncertainty is taken care of, source to site distance then we can find out the combined probability.

So, it can convert the probability to annual rate of exceedance by multiplying the probability by annual rate of occurrence of earthquake; that means, lambda of y star can be computed in this fashion as well nu times of this one, this probability where this nu is nothing but that e to the power alpha minus beta m naught.

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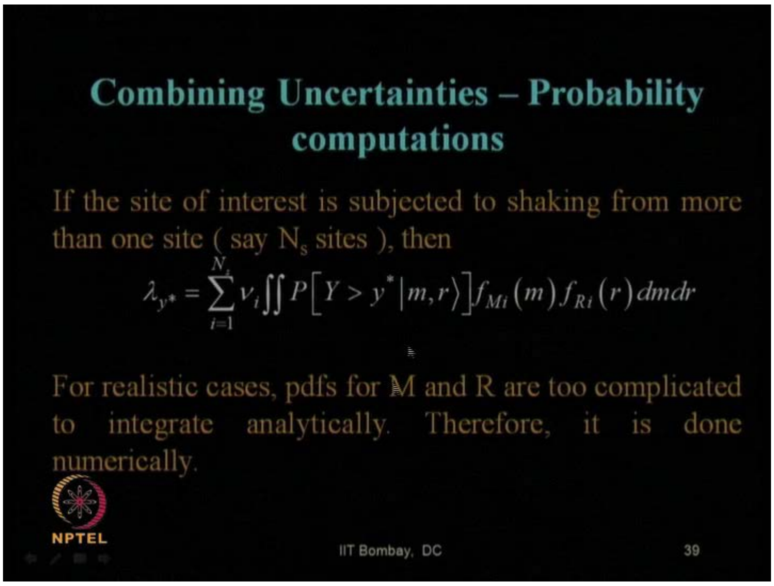

Now, if the site of interest is subjected to shaking from more than one site that is N S numbers of site, that is there is an influence of one site from another site; then what it should be? You should consider while obtaining that lambda Y mean value of exceedance of y star. You should consider all the effects coming from all the sites; that is, sum of i ranges from 1 t o N S of summation of all these integration of the probability. So, for realistic cases, probability distribution function for m and r are too complicated to integrate analytically. So, what we do? We do it numerically; that is, we do not integrate analytically like this, but we do integrate them numerically. We will discuss that very soon through examples also.

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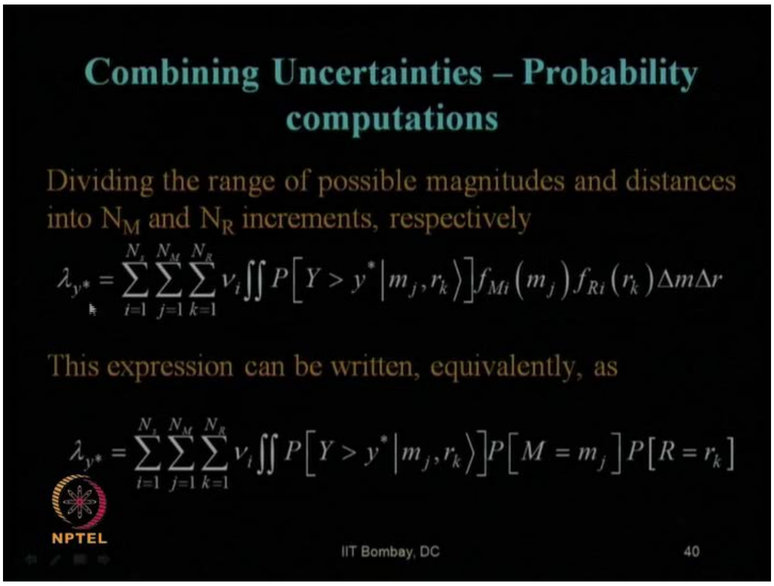

So, now, dividing the range of possible magnitudes and distances into N M and N R increments; that is instead of doing as I said, instead of doing this analytical integration, now we are doing the numerical integration. So, for numerical integration, we are dividing that M ranges, whatever range it is expanding, that range we are taking are sub dividing into N M; like this is number of sites; similarly number of magnitudes also we are dividing and number of source distance also we are dividing to N R. That is what it says; it should take the shape like this when we are doing the numerical integration.

So, this is numerical integration sum of i equals to 1 to N S; sum of j equals to 1 to N M; that is we have taken care of the integration of the moment function or moment uncertainty; sum of k equals to 1 to N R we have taken care of the uncertainty due to the distance. If v of i integrate of this entire thing delta m delta r which gives us for a given value of probability of M equals m j because this is ranging over j; this R equals to r k because this is ranging over k; this probability individual we have to find out. That will give us the final value of this lambda y which we are interested to.

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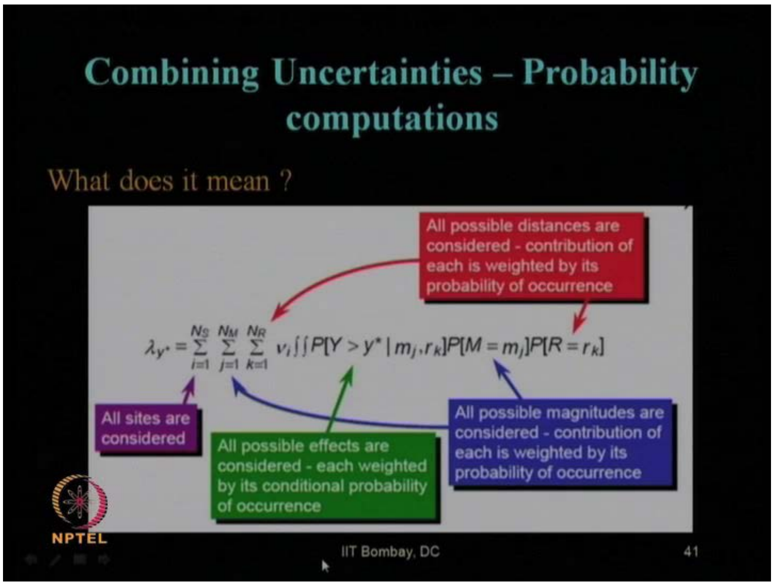

Now, what does it mean? Let us look at it very carefully. So, we have already mentioned lambda y star; that mean annual rate of exceedance of a particular value, say 0.3 g of PGA is expressed in this equation; by this equation it is expressed combining all the uncertainties; that is, we have taken care of what are the uncertainties, number of sites, number of earthquake magnitudes and number of distances.

So, what all of them are mentioning over here? Let us go one by one. This one, I ranging from 1 to N S refer to all sites are considered. What is the next term? This j equals to 1 to N M refers to this blue color box let us see, all possible magnitudes are considered; that is contribution of each is weighted by its probability of occurrence; that is, none of the magnitude we are neglecting; we are taking all magnitudes within that threshold value of magnitude and the maximum value of magnitude, right.

What we have discussed through that McGuire equation, that this is the probability distribution function M should be within m naught and M max. So, all the magnitudes with their weighting factor; why the weighting factor comes into picture because depending on their number of occurrences; of course, it will come into picture. That is taken care of in this term.

What is the next term? k equals to 1 to N R takes care. Let us look at this red box. All possible distances are considered in this probability; that is, contribution of each is waited by its probability of occurrence. The distance probability also we have seen, like dividing the distances in terms of r min r max and all other distances from site to source, whether it is linear volumetric or areal or unequal length.

So, combing them, we get all the information. So, this term takes care of all possible effects are considered; that is each weighted by its conditional probability of occurrence. This takes care of your for a given value of m j for a given value of r k; that is what it says probability of occurrence of that event of Y greater than Y star for a given m j for a given r k; that is the combining uncertainties.

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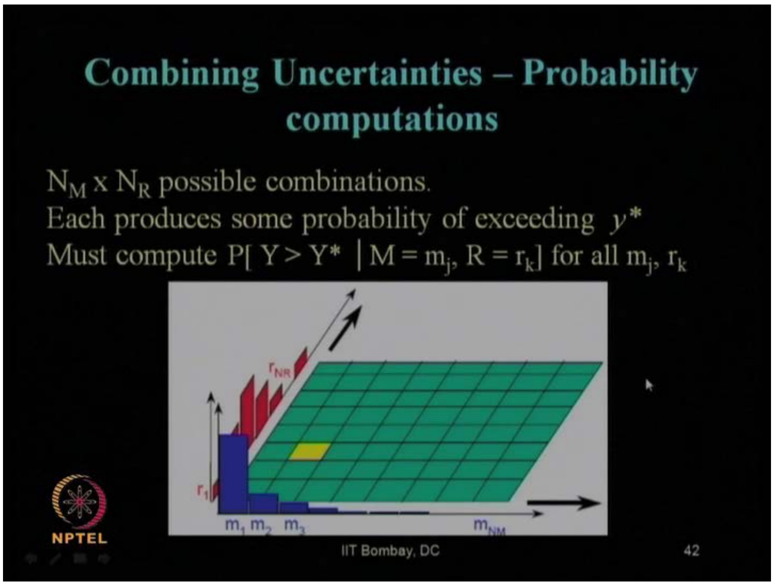

Now, how to understand it more easily or in a better fashion? Let us say, when we are doing the numerical integration, what we have done? We have divided it basically into a number of segments of N M segments and N R segments.

So, we have to look into that two dimensional boxes or systems where N M cross N R possible all combinations has to be taken care of. So, each produces some probability of exceedance say Y star and we need to must compare this probability of occurrence of that even Y greater than Y star for a given value of M equals to m j and R equals to r k for all values of m j and r k.

So, suppose this axis talks about all the probability distribution function in terms of magnitude and this axis gives us all the probability distribution functions in terms of distances. So, we have different histograms for different magnitudes like m 1, m 2, m 3 like that; obviously, the lower magnitude will have more number of occurrences; less one will have higher magnitude will have less number of occurrences; like this the histograms will come into picture. Similarly, for the distances also we can get the histograms like this taking the weighing factor. Now, each of them which one contributes say m 2 to say r 3? This value will be the combined probability. Like that, each of these boxes we have to take care of when we are considering this combining of the uncertainties to calculate the probability of occurrence of that event greater than Y star. Clear?

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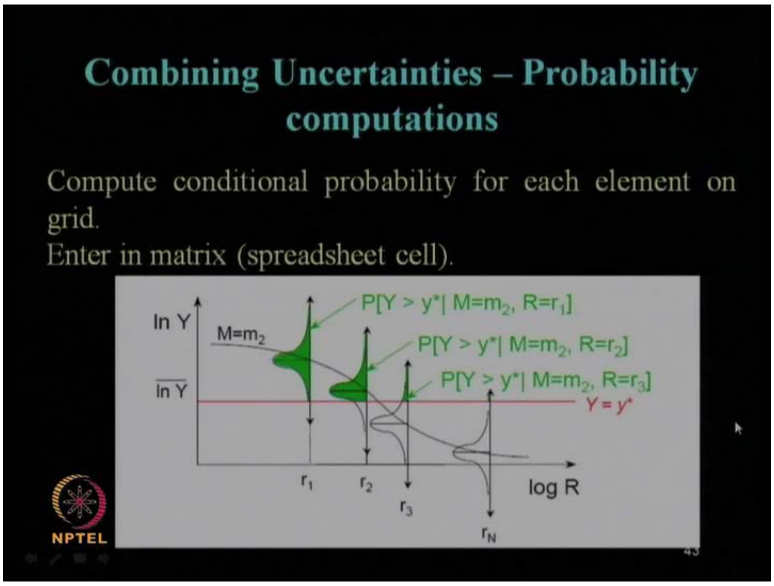

So, to compute this conditional probability for each element on that grid, just now as we have mentioned, this grid and enter that in a matrix; that is, in terms of spread sheet or in terms of cell; that is what value of that probability you are getting in terms of each of this cell will give you some values. Then we have to combine them to get the total probability. So, now, we are considering the effect of that attenuation relationship. Say, for M equals to m 2, this is your attenuation relationship.

You will have for different magnitude different attenuation relationship; now it is not a single one; like in deterministic seismic hazard analysis, we have taken this M equals to M max, but here we are considering all magnitudes; remember m 1, m 2, m 3 for each of the source. So, here you are getting this mean value, let us say, Y equals to y star about which we are interested to know. So, more than that, at various distances that is these are distance probability r 1, r 2, r 3, each of them will have some kind of standard error.

Now, from that probability distribution function above that value of Y greater than y star, for a given value of M equals to m 2 with a condition of R equals r 1 is this green color shaded value, where I am showing now. Whereas, for probability of Y greater than y star for a given M equals to same m 2, but R changes to r 2 will be this shaded portion.; whereas, for probability of occurrence of an event greater than that y star, for a given value of M equals to m 2 and R equals to r 3 will be this shaded portion (Refer Slide Time: 26:56); similarly for 4, 5 and so on.

So, like that, all these will give us the probability of occurrence of an event for a given M equals to m 2 for all values of Rs; that means, if we look at the grid, for m 2 all values of R these are the boxes your taking care of, got it?, in the numerical integration. Similarly, you can do it in the other way. For a particular R, for various M; you can do that for a given R. Now, you will have different attenuation relationship. This is for M equals to m 2; you will have M equals m 1, M equals to m 3, M equals to m n, and for each of them we will have a probability distribution function; that also you need to consider.

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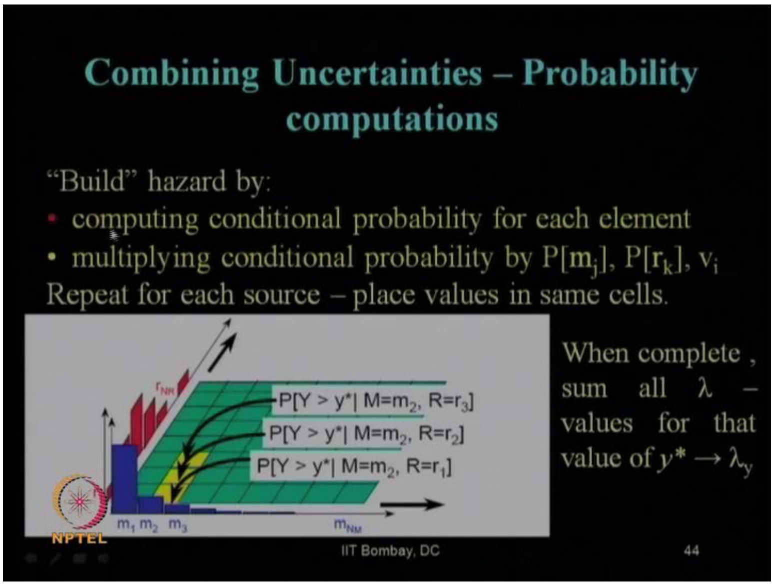

So, that is why, as we have just now mentioned, each of them will give you the hazard by computing this conditional probability for each of the element; that is, for R equals to r 1 with m 2; R equals to r 2 with m 2; R equals to r 3 with m 3; these are the boxes where we are getting that conditional probability. Clear? Now, you have to repeat this process for each source and value that place their values in the same cell. So, when it is complete, then sum of all of them will give you that lambda value.

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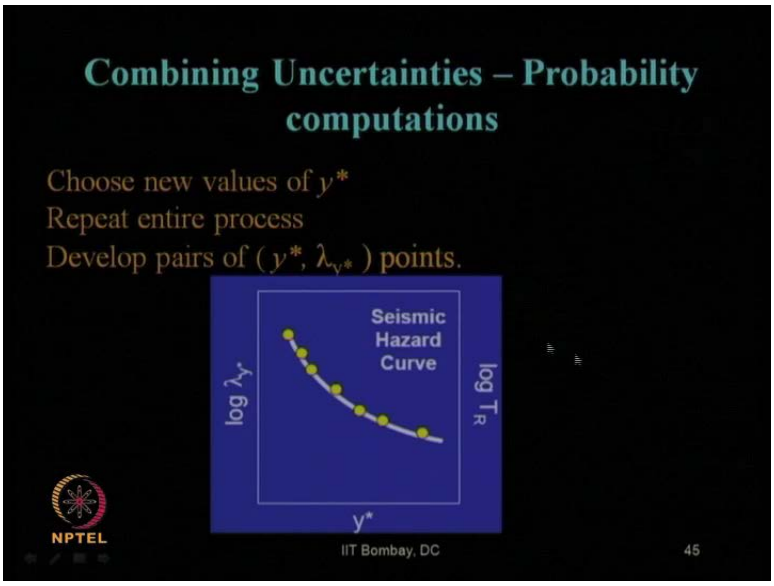

Now, we need to choose a new value of y star for repeating the entire process; is it not? because to find out your conditional probability, you need to go for another set of pairs of y star to develop another curve. See, each of this log of lambda y versus y star will give you final seismic hazard curve. Like earlier in deterministic seismic hazard analysis, we got it in terms of a single value. Here, in probabilistic seismic hazard analysis what you are getting? You should get that log of lambda y star and on the other side it can be log of T R in the reverse direction and that particular value of y star.

So, this one single point you are getting by doing all these analysis. By combining all these things, you are getting only one value corresponding to y star. Let us say, it is 0.3 g. We have to repeat it for another value say 0.4 g also. Like that, if you can generate this, the combined thing will give you the seismic hazard curve in that fashion. So, it is an iterative process of doing the probability of occurrence. So, that is why most of the time you cannot do it in hand; actually, you have to use some computer programming to repeat this process of probability distribution and do this process and compute the seismic hazard curve.

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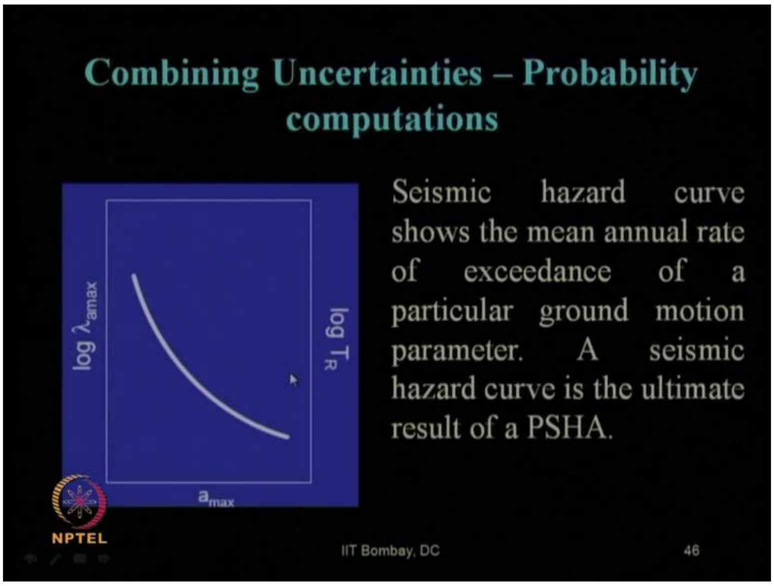

Now, how we use this seismic hazard curve? Let us see, so seismic hazard curve, it shows the mean annual rate of exceedance of a particular ground motion parameter. So, a seismic hazard curve is the ultimate result of this probabilistic seismic hazard analysis. As I have said, this is the ultimate output what you get from a probabilistic seismic hazard analysis.

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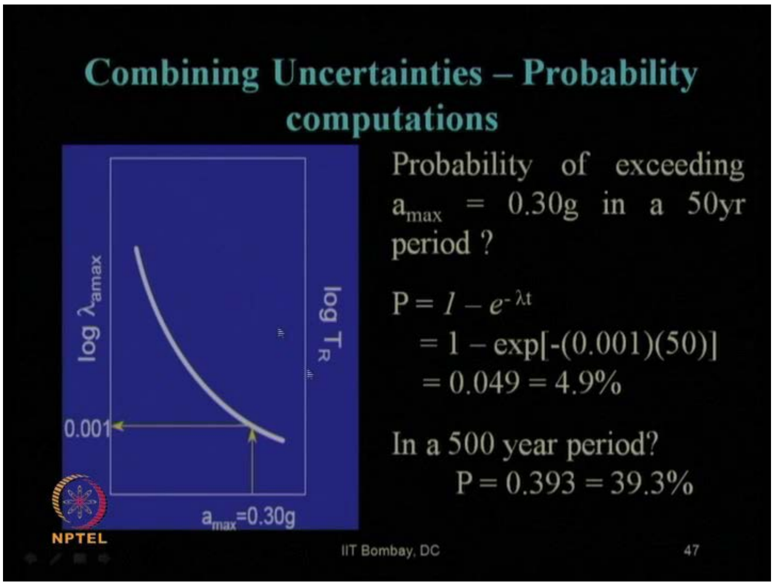

Now, if I want to use that, let us see how we can use it. So, say, let us want to know probability of exceeding a max value of 0.3g in a 50 year period from a given probabilistic seismic hazard curve. Suppose we have derived this seismic hazard curve for a region. Now, how to use it for our design? What is the use of that result? That result is used in this fashion. We want to know the probability of exceeding value of a max of 0.3 g.

So, in that probabilistic seismic hazard curve which is known to us, we should go to a value of corresponding to 0.3g. Now, drop that in this curve, get the value of lambda which you are getting from this curve. Clear? Use that value of lambda in this; now, the time related uncertainty event. Use that lambda from a probabilistic seismic hazard analysis curve. You put it here. Now, you are interested to know in 50 years span of time what is the probability of occurrence exceeding that 0.3 g. So, put that T equals 50 over here; probability comes out to be say 4.9 percent; very low probability.

Whereas, if the same result if you want to know for a 500 year of period, you will get 39.3 percent for the same result because this value remains same; only the T changes in this equation. So, if you solve, you will get 39 percent. So, it will obviously have a higher probability when your time scale is changing or increasing to 500 years. So, that depends on what is your design life of your structure. So, that is the way we use the probabilistic seismic hazard curve for our seismic design. Are you clear now where we use this probabilistic seismic hazard curve?

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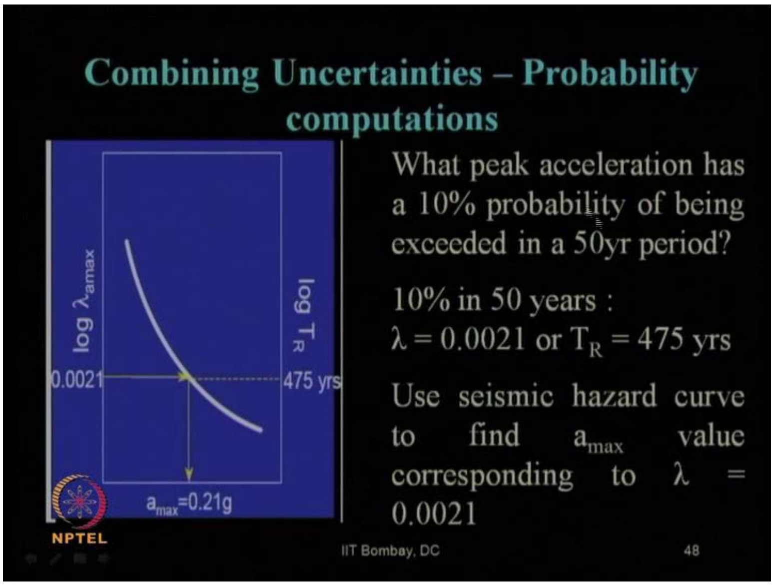

Now, let us see the application in another direction that is what peak acceleration has a 10 percent probability of being exceeded in a 50 year period will occur? This is the other way of looking at or using the probabilistic seismic hazard curve. What it says? For your structure, suppose you want to consider 10 percent of probability of occurrence of an event in the year of 50 years scale. We have decided to go for that. You want to know, what is the value of peak acceleration or what is the value of the design acceleration you should use. So, this is more realistic use of probabilistic seismic hazard in practice of design. Now, 10 percent in 50 years, how you will get?

For a particular region, you have already this seismic hazard curve developed. So, go to that curve corresponding to your 10 percent probability in 50 year. What it corresponds to T R? It is 475 or lambda value of 0.0021; that already we have seen in our example using that Poisson's distribution; is it not? It is known to us already. So, in that curve, you look for lambda value of 0.0021or T R value of point T R value of 475 years.

So, draw that line; where it intersects the curve, drop it from there; whatever value of a max you are getting, that is your design. Suppose, here you are getting the value of a max equals to 0.21 g, that means, corresponding to 10 percent probability in 50 years scale will be the peak acceleration should be considered 0.21 g. So, when with this much percentage of probability in 50 years scale you want to design your structure, you have to take peak acceleration for design as 0.1 g. Is it clear how we make use of this probabilistic seismic hazard curve in our practical design procedure?

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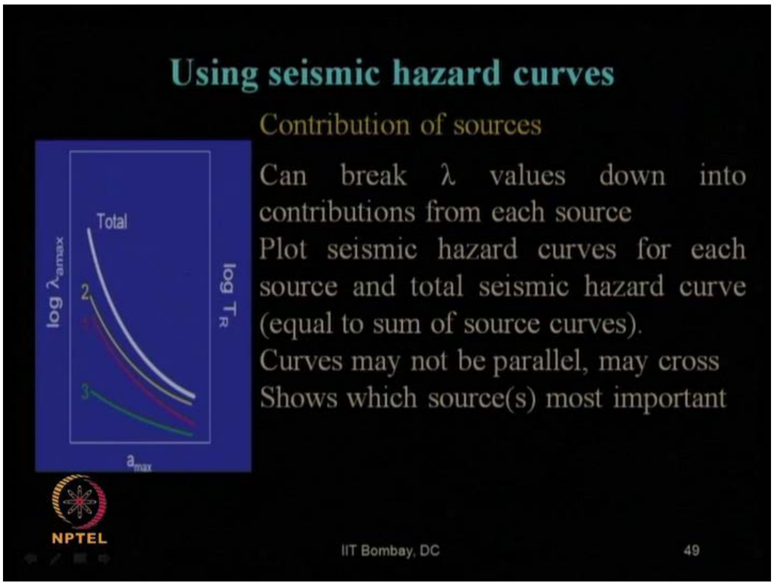

Now, we were talking about contributions from various sources. Like when we talk about contributions for various sources, we have to use various seismic curves. So, we can break that lambda value down into the contributions for each source; that is, this is the combined or total curve which we have obtained considering combined probability that up to n s sources.

Now, if you want to know individual source, how they affect your seismic hazard curve, suppose geologist or seismologist gave you an information, say source one is more active in recent past hundred years period of time, whereas, let us say, source 3 and 2 are not so active in last 100 years of time; so you should always look into not only the total probabilistic seismic hazard analysis curve, but also the individual source representation; that means, instead of considering all the sources, if you break them or if you consider the each one of them, each one of them will something come like this: say source one is coming like this, source two coming like this, source three coming like this (Refer Slide Time: 36:26)

So, in this probabilistic seismic hazard analysis, you have taken care of only magnitude and distance probability, not the source probability; got it? So, can break that lambda values down into the contributions from each sources and plot that seismic hazard curve for each source and the total seismic hazard curve equal to sum of these source curves and curves need not be parallel, quite obvious; may cross each other; it shows that which source is most important. There is suppose, if crosses cris-crosses some other, obviously, that will show significance or importance of that particular source compared to the other source. Clear?

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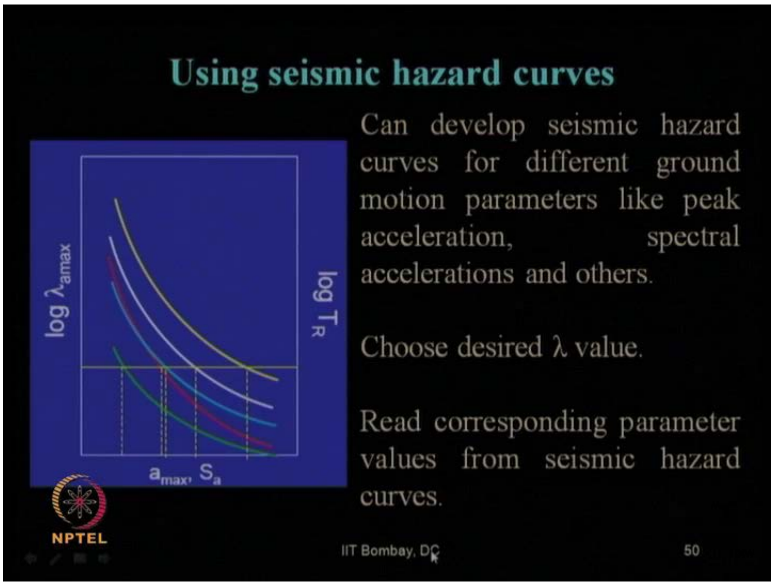

So, let us look at here, I,n an example can develop the seismic hazard curve for different ground motion parameters. Like this lambda value we can generate for a given y star. We have mentioned that y can be PGA, it can be spectral acceleration, it can be spectral velocity like anything. So, that is what it is mentioned. You can generate it for peak acceleration, spectral acceleration or any other parameter. Now, choose a desired value of lambda to be used and read the corresponding parameter values from the seismic hazard curves.

So, one of them will be the total curve and others will be individual value. From that, you can get a max value, if you are talking about your value as peak acceleration. You can get S a value which is spectral acceleration if you are talking about or you are deriving your peak seismic, you are deriving probabilistic seismic hazard analysis curve in terms of spectral acceleration.

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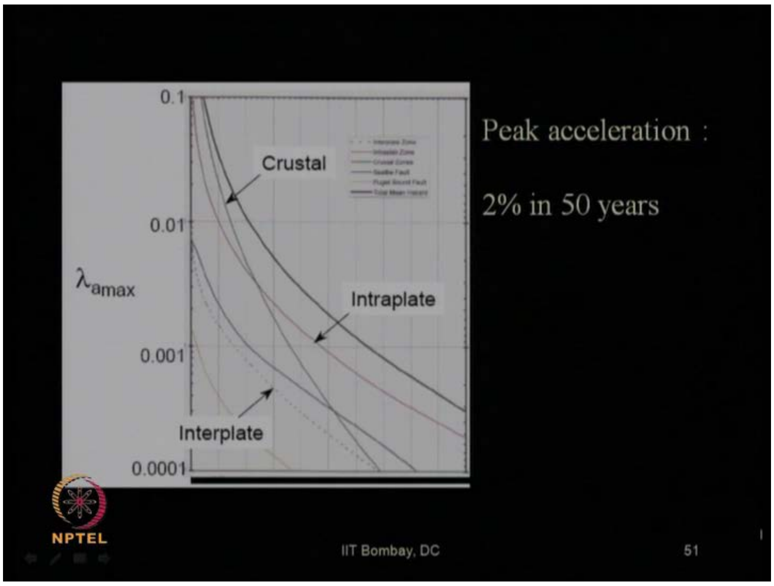

Now, peak acceleration: One example is shown over here. Say 2 percent in 50 years time for different sources like, if it is inter-plate event, say this is the curve; if it is a intra-plate event say this is the curve; if it is a crustal event, this is the curve. Like that, we have mentioned. For different sources, you can identify different curves and you can always say which for a particular region which curve is more predominant depending on criss crossing nature of them, which one is the higher value of your design value of that a max or S a like that.

Like for example, how do we know for peninsular India it is not the inter-plate, it is intra-plate? From this probabilistic seismic hazard curve only we know that. Clear? This is the way you can find it out it easily, for a particular region which source or which type of source dominates; whether it is fault movement or classical movement. If it is a plate movement, what type of plate movement, and all those. Clear?

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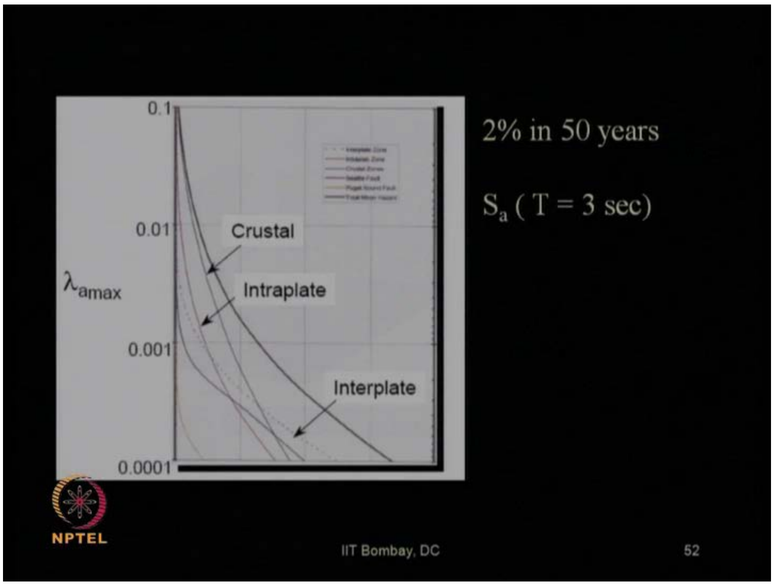

Similarly, in terms of S a also, that is when you are talking about spectral acceleration, you can find it out for a given natural period. It can be or estimated for say T equals to 3 seconds. It can be estimated for another time period also. Why this time period is important because that relates to your super structure or whatever structure you are going to develop or construct. Based on their natural period, your design value of S a will get guided. Clear? And corresponding probabilistic seismic hazard analysis curve you have to take care of.

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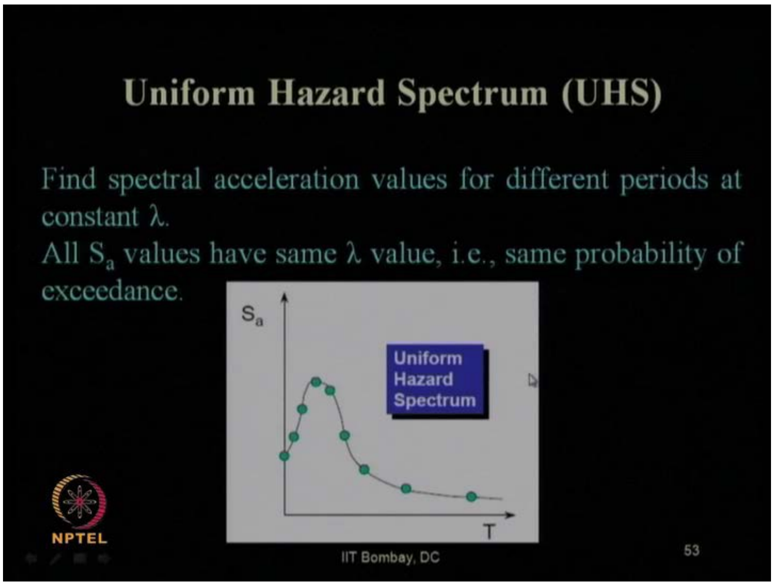

Next is uniform hazard spectra or in short we call them as UHS. UHS, it will look like typically like this; that is, it is plot of this spectral acceleration versus natural period T, like this. So, find the spectral acceleration values for different periods at the constant value of lambda and for all S a values, have the same lambda value that is same probability of exceedance. With the same probability of exceedance, you have to find it out this uniform hazard spectrum.

What does it mean? That means, suppose, if we want to consider 2 percent of probability in 50 years of time with a return period of 2475 years, we will get one uniform hazard spectrum. If we want to take 10 percent of probability of exceedance in 50 years of time, that is return period of 475 years, we will get another uniform hazard spectrum curve. Clear? So, different uniform hazard spectrum curve or UHS we will get corresponding to different probability of exceedance. And accordingly, based on your importance of the structure you can select which S a by T curve or UHS curve you should use or design clear.

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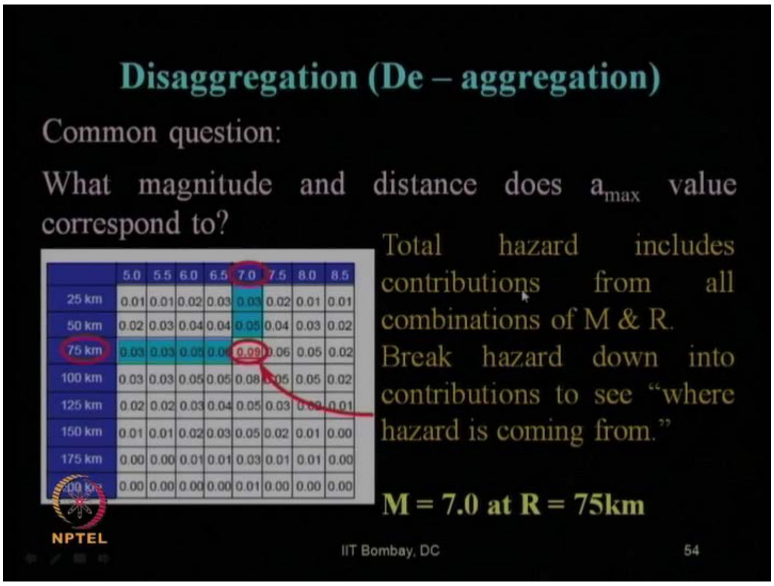

Now, let us come to another sub topic which is known as disaggregation or it is also called de-aggregation. Now, common question comes, arises like, what magnitude and distance does that a max value corresponds to? That is, when you got your answer here, like we have mentioned from a probabilistic seismic hazard analysis curve, you are getting for your design value of some value of a max, which you can use for your design.

Now, you you are interested to know that this value arises from which source and which magnitude mostly, mostly why? Because obviously it is having effect from all sources and all magnitudes, but there is a weighing factor. So, which one dominates? - That we are interested to know. So, what we need to do we need to de-aggregate or disintegrate these results further to go back and look for which magnitude is more influential, which distance is more influential for this maximum value of for our design.

Why it is necessary? Suppose if we can avoid or hetro of it in some way or disintegrate or can make a kind of isolation from that source, that will be very good. That is the need for using this concept of de-aggregation and disaggregation. So, let us look at here, disaggregation. So, total hazard, it includes contributions from all combinations of M and R; already we have mentioned that, but we can break that hazard down into contributions to see where from that majority coming from. So, suppose that chosen value or design value comes out to be 0.09; so if we disintegrate in terms of distance, in terms of magnitude, we will automatically say that grid comes from corresponding to 75 and 7 magnitude, as shown over here. The different values are of there, as you can see, and among these we have taken only the maximum one; already we have chosen the maximum one. So, now, we are disintegrating that. We are looking at different distances and different magnitudes, what are their contributions? This found that major contribution comes from this distance and this magnitude. So, this will be dominating when we disintegrate our data.

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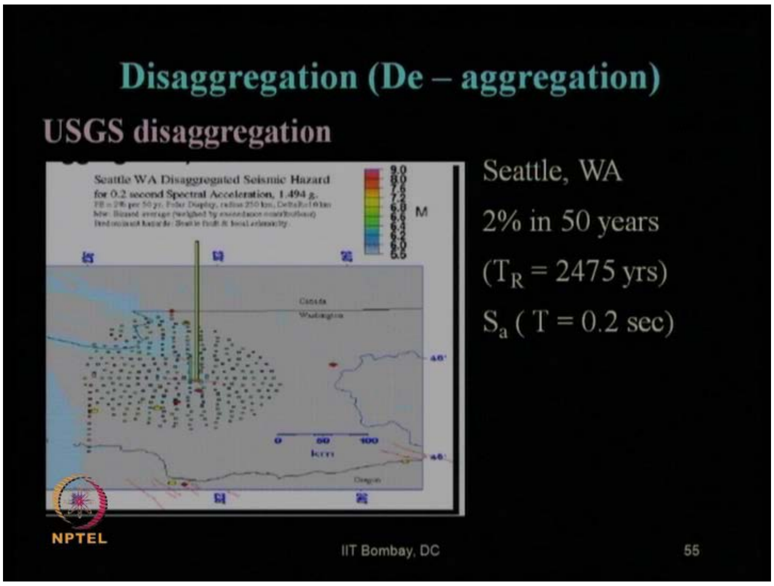

So, in that fashion, if you want to use the USGS site, USGS site immediately or little after that any earthquake, they disintegrate and give in their site, for all various earthquakes for various regions, the disintegration data so that it identifies which source actually dominated. It may happen that, during a major earthquake not only one source was involved; many multiple number of sources were involved. Now, which was the major source? To identify that major source, disintegration process can be very useful.

So, here, one example is shown over here. You can see this is for Seattle in Washington in US with 2 percent of probability in 50 years of time that is with respect to return period of 2475 years with spectral acceleration corresponding to time period of 0.2 seconds that is lower time period. You can see the disintegration of various magnitudes.

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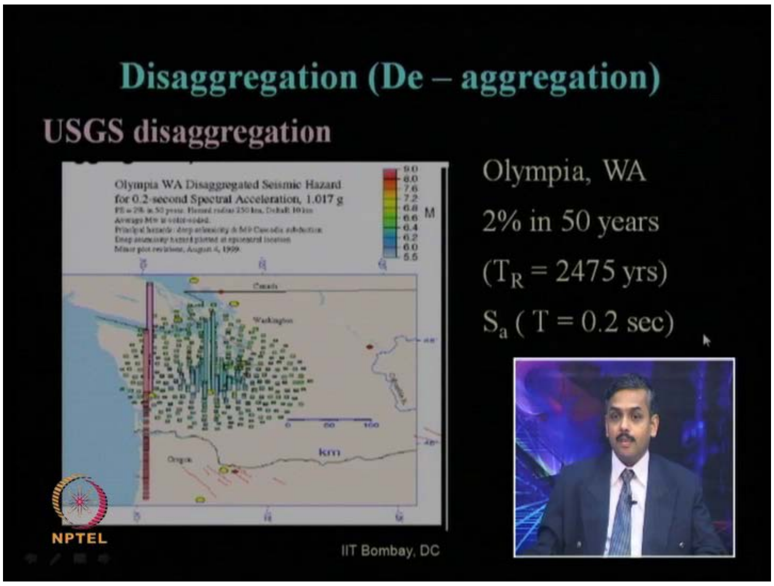

Similarly, for another region like Olympia in Washington only you can see different histograms. Can you see over here? So, various histogram values are already given in this; that is again for same T R value, same S a corresponding to T a value of 0.2 seconds.

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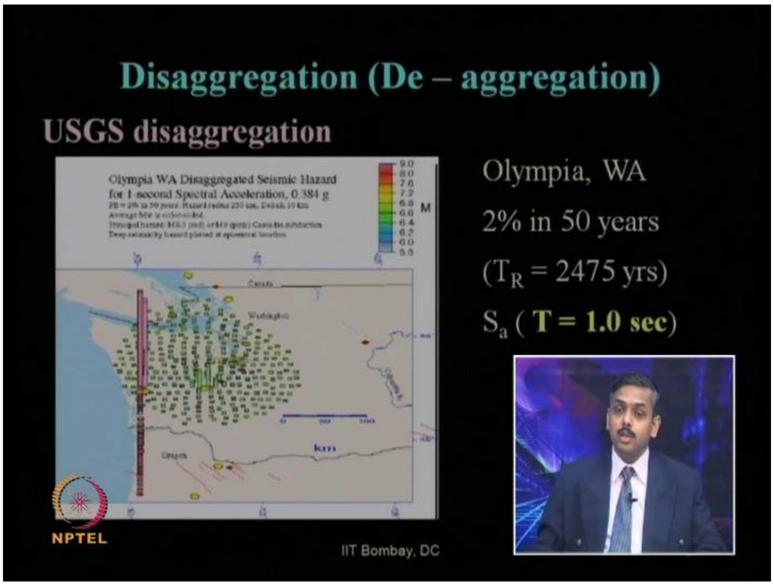

Same location, but for another natural period: Look at here, once again, higher value of time period. Why we are interested about different time period because it depends on in that locality what type of buildings are there. Generally in a thumb rule we will see that later; number of story of a building divided by 10 is considered as in a thumb rule, I am telling it again, as the natural period of a building.

Suppose, if we are talking about 20 story building 20 divided by 10 will be 2 seconds. So, 2 seconds is the natural time period for a 20 story building, typically. I am saying again; it is typically not exact. Exact time period, how to obtain it? We will see later on in another sub topic. So, typically T equals to 1 second will denote a 10 story building; whereas, T equals to 0.2 seconds will denote just a two story building. That means this disintegration will give information about which earthquake or which source and which distance is more effective for effecting the shallow buildings or shallow structures or low raised structures. Whereas, this disintegration data will give us the information that which source and which site are important to consider for a tall story building or high raised structure. Can you see the use of them? Clear?

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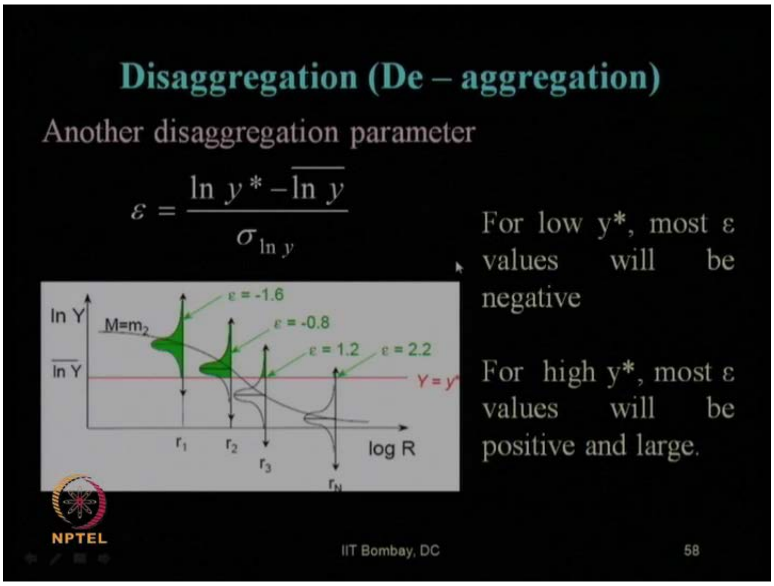

Now, another disintegration parameter by which we can estimate it mathematically considering this effect of this attenuation: Suppose we have these values, how to obtain this value of epsilon that is the standard error, error is nothing but area under the curve as I have already mentioned. How to estimate that? It is nothing but ln of y star; that value minus of ln of y bar; that average divided by whatever is the standard error involved in that reggration analysis; that will give you the standard error. So, for low value of y star mostly this standard error or disintegration values will be negative, as you can see over here.

If you select y star value pretty low, obviously, these values will be negative and if it is above this, then it will come positive; quite obvious. For high values, mostly these are positive and large. Clear?

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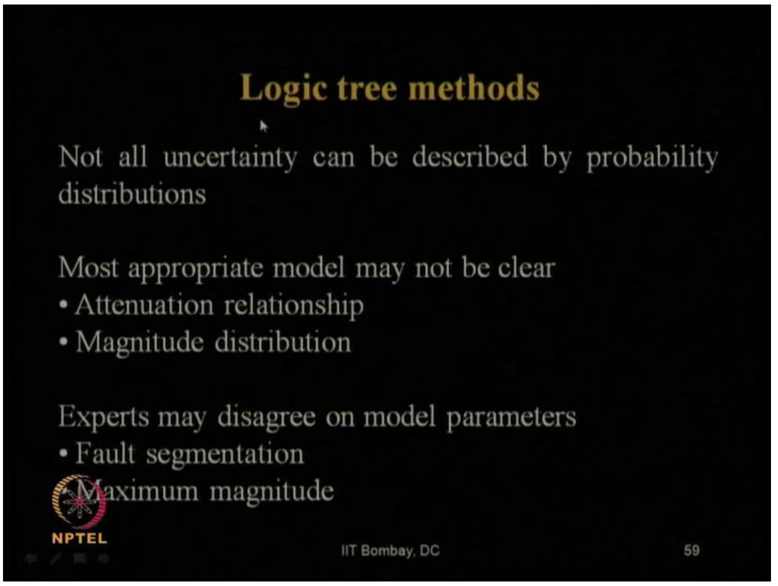

Now, let us come to another sub topic which is important, which is known as logic tree methods. What is this logic tree methods?

Now, we have talked about various uncertainties; majorly four uncertainties involved while comparing this probabilistic seismic hazard analysis. Now, all these uncertainties are not equally important. Am I right? There can be different importance of different uncertainty involved in the process. So, we have to find out that most appropriate model which may not be clear about the attenuation relationship and magnitude distribution because the effect which we are considering through attenuation relationship, we do not know which model is most appropriate because various attenuation relationships may be available for a particular region. Like for example, for India, for northeast India, also for Himalayan region of India we have already learnt that there are several attenuation relationships proposed by various researchers.

Now, which one is most correct and which one is least correct, we do not know. So, we have to give different importance based on the experience and expertise. That will give us this concept of logic tree to consider uncertainties. Similarly, for the magnitude distribution also, how the magnitude is distributed is also depends on what model you are considering; which equation you are using; whether it is a empirical relation of wells and coppersmith or whether it is a seismic moment calculation or whether it is a plate tectonic movement based relationship; all are empirical relations. So, there also you have uncertainties involved.

Now, which model you should give more priority, which one least priority, you do not know. That consideration comes through this logic tree method. Similarly, expert may disagree on the model parameters also; like fault segmentation; also, the maximum magnitude. There will be always different school of opinions or different thoughts like different expert will tell, okay, this attenuation relation is good; another expert will say no, this attenuation relation is good; another expert will say no my attenuation relationship is good. So, how to propose a better or realistic or mathematically more correct relationship or seismic hazard value? That is why this logic tree comes into picture.

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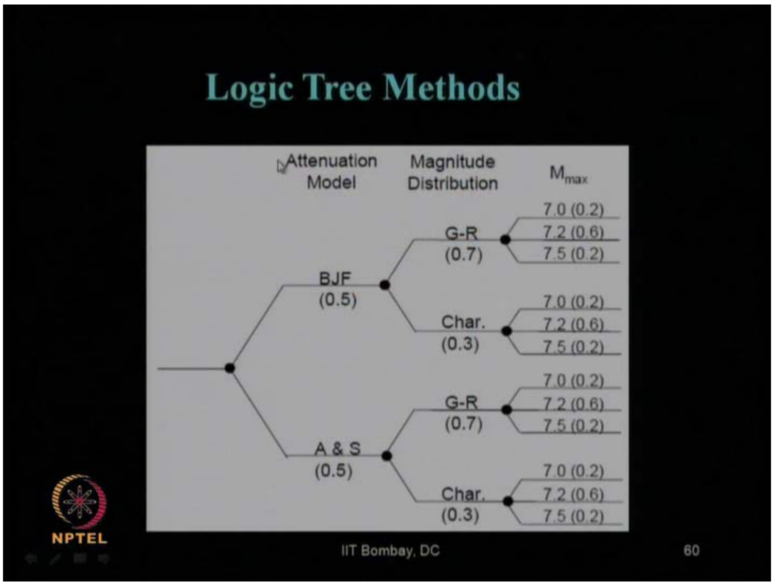

So, let us look at this. Suppose when we are computing we have various attenuation models. Some example is given: BJF model, A and S model. Let us give equal weightage to them. Let us say, we do not want to go any controversy that this is more correct this is less correct; let us give equal weightage. Now, within them you can use different magnitude distribution. One can use Gutenberg-Richter magnitude distribution; one can use some other characteristics earthquake magnitude distribution. Now, based on your experience you can give different weightage. Let us say Gutenberg-Richter magnitude distribution relation or recurrence relation is more correct. Let us say 70 percent weightage is given to that and 30 percent weightage is given to characteristic. It depends on the engineers, of course.

Similarly, for another model, now when you are computing M max value, you can see for different values you will get different weighing factors: 0.2, 0.6, 0.2. Here also different values, here also different values.

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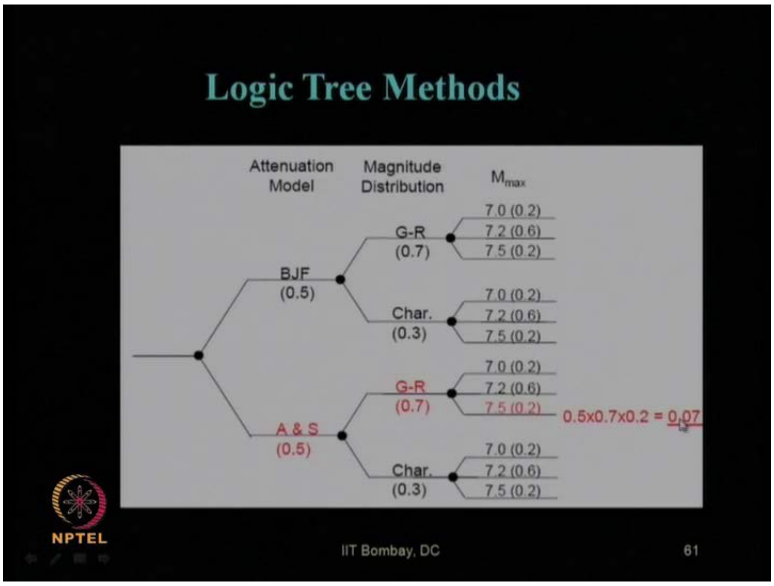

How these values are arrived at? You can see the example over here. Suppose we are going through this channel, this model we have selected. Let us say, we have selected Gutenberg-Richter model. Then for M max 7.5, it is coming 0.5 times 0.7 times 0.2. So, going factor or weight factor you should consider as 0.07 when you are using this logic tree influence in your probabilistic seismic hazard calculation.

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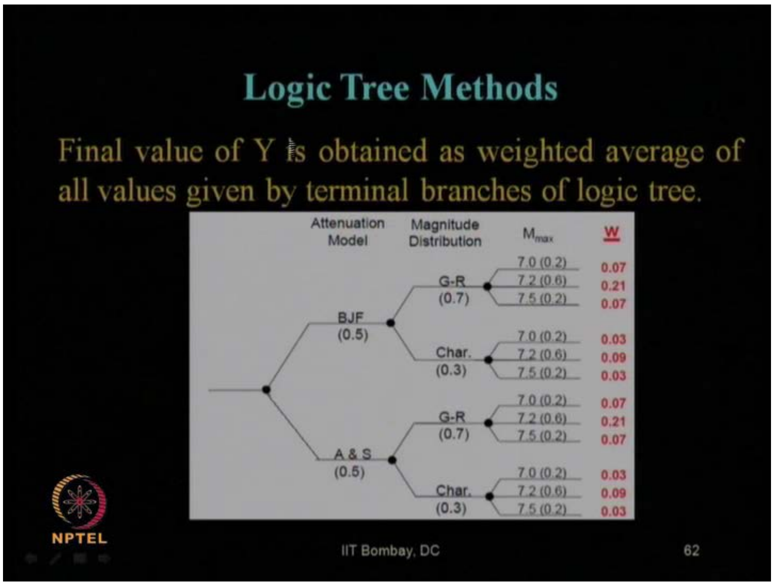

So, final value of that Y or the design parameter which is obtained as weighted average will give all the values in the terminal branches. So, this W is nothing but weight factor. That is if you go through this model, this equation, this value, weighing factor is 0.07. If you go through this model, this equation, this magnitude, your weighing factor is 0.21. Like that different values you are already obtaining going through different attenuation model, different magnitude distribution, different magnitude values. Fine. So, by using this logic tree weighing factors, finally you can get the value of your final Y in the probabilistic seismic hazard distribution. Fine. With this, we have come to the end of today’s lecture. We will continue further in our next lecture.