Introduction to Engineering Seismologyles
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Lecture-64
Estimation of Hazard

So, Vanakam, so will continue our lecturer on Engineering seismology. So we almost came to the end of the course so today class we are going to talk about the different method of seismic hazard analysis and the typical calculation. So with this will be finishing our course so we have seen that the selection of the seismic study area, try to collect seismotectonic details like source, active fault and mapping them and prepare a seismotectonic map by considering the seismic study area radius based on the past earthquake.

We are also discussed about the seismicity data, homogenization and de-clustering of data and M max estimation and then followed by the distance. Ok how to take the minimum hazard calculation and recurrence ok so model development which is required for the PSHA analysis. And M max estimation also we discussed followed by the GMPs. Ok different ground motion prediction models available how to qualitatively you can take the GMPs.

Then how to select your GMPs considering the Quantitative approach ok log likelihood method, efficacy test. Ok once you have selected GMPs. The next part is estimating the hazard so, why we need to estimate hazard, basically.

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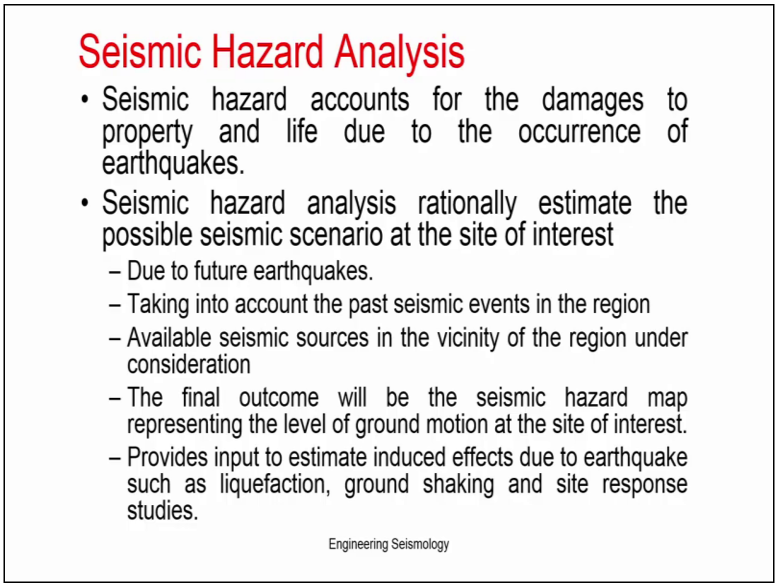

The seismic hazards account your damage of the property and life due to the occurrence of the earthquake. The seismic hazard analysis rationally estimate a possible seismic scenario at your site up interest due to the future earthquake taking into account of the past seismic event in the region available seismic sources in the vicinity region under consideration. The final outcome will be answered map representing the value of PGA of the site of interest or intensity.

If the risk assessment is record duration of the duration related parameters that provide input for estimating the different earthquake effects such as liquefaction, ground change, site response study that is also useful for designing the structures in the region.

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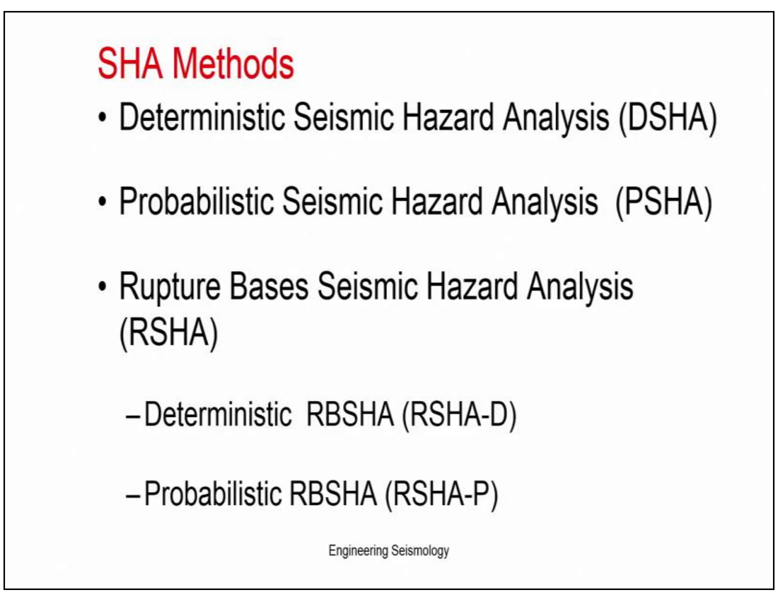

This hazard analysis actually as a 2 classical method one is the deterministic seismic hazard analysis and other problem stick seismic hazard analysis, which is called as a DSHA and PSHA. So, then we actually developed a new approach called rapture based seismic hazard analysis. Ok rupture base seismic hazard analysis, which can be done deterministic and probabilistic by considering a regional data that is a very important.

So this sometime does not talk about anything some of the parameters but here we will specify what is the parameter, how you should account regional variation in the hazard analysis that is the difference. So today class we are going to talk about all this method in detail. I will be showing a typical calculation for this as well as this PSHA procedure basically, you need a matlab based approach where you need to run a matlab code and understand a matlab code.

As I told you that our courses only to the plus two level, so we are not going to that PSHA analysis discussion, but if you are in an interesting and that we can help you if he approach us ok, but otherwise as per DSHA concerned rapture based one conventional one will be sufficient, a typical example also shown in this class.

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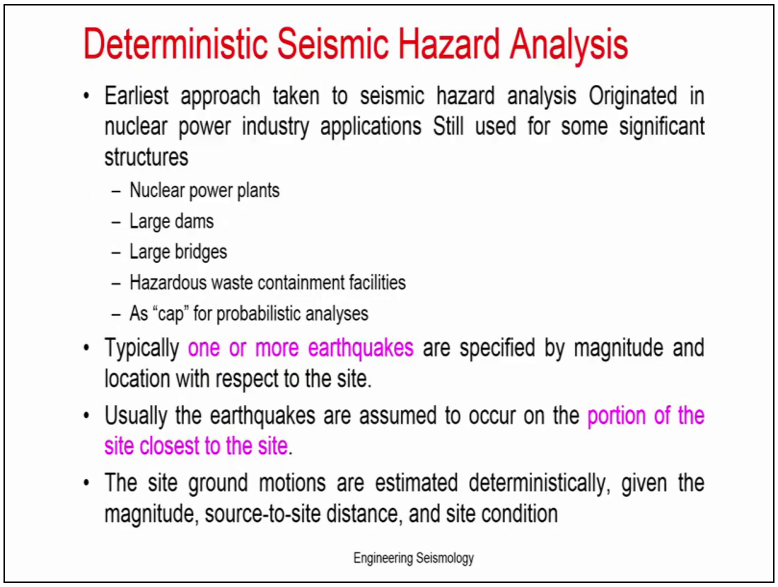

So we have seen that the DSHA ok approach the earliest approach where they developed the first. Where there are basically developed this for the nuclear power industry application but still it is being used for the very important structures like we need to a power plant, Dam, large bridges, hazardous waste containment, disposal sites and this gives the cap ok value for the PSHA. When you do PSHA where are you can cap means that DSHA result would be important. That means any region you should not only do one analysis. We should do both DSHA as well as PSHA.

Typically one or more earthquake are specified by a magnitude and location of the; to the site that is considered worst scenario earthquakes or critical earthquake for the site. You should the earthquake occur portion of the closest to the site. Portion of the source ok the distance will be closes to the site. The side ground motions are estimated deterministically by giving magnitude and source to distance and sidte condition.

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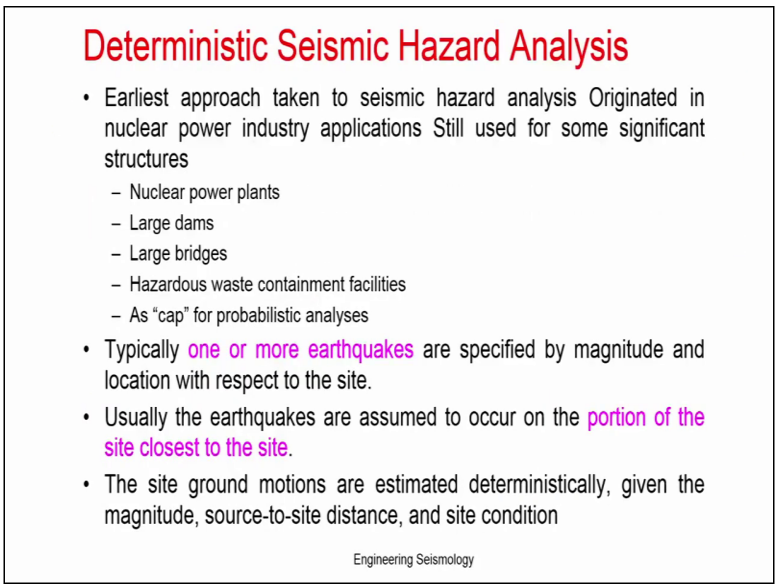

So since our analysis talk about only on the Bedrock level so there is no site condition one only talk about the magnitude and distance if the source parameters if the GMPs are included that as a this one. So, consider worst scenario earthquake for arriving the hazard value without considering the possibility of level of ground motion within the design of structures. He does not give the range of ground motion gives only one ground motion.

The event as to occur at the closest distance from the site accounts for the largest possible earthquake magnitude to be occurred on the fault. Ok. So basically they have to get account largest possible magnitude to the occurred on the fault. The result obtained are highly uneconomical because is the worst scenario. It may happen. It may not happen generally useful for the important structure where the safety of the structures is a prime important not the cost involved in the construction particularly dam, nuclear power plant and big bridge connecting two regions kind of things. Those are all; the place where the DSHA as to be adapted.

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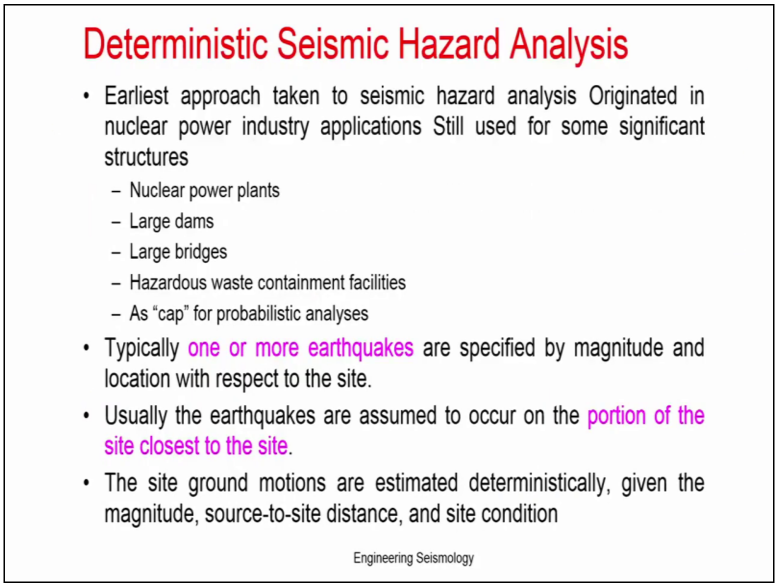

So the DHSA procedure classical textbook procedure; so this is your site ok that take a different source. Source 1, source 2, source 3 and different magnitudes reported on that and then they estimate the closest distance which is perpendicular to the site. Ok then they estimates the PGA variation with the given distance and then take, which were giving the highest value will be the controlling earthquake that is recommended for the design ok that magnitude and PGA value will be recommended as parameters for the design. So, this is a typical classical DSHA method.

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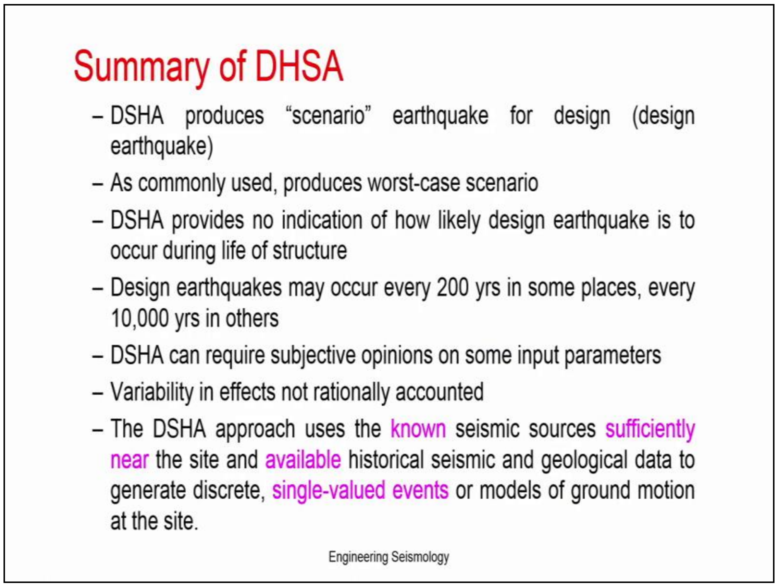

So here this like a scenario, if you do all the calculations we end up in the one earthquake for this scenario commonly used to produce worst case scenario DSHS provide no indication of how likely the design earthquake to occur at the lifetime of the structure. It may occur it may not occur but it is a worst scenario. So the design earthquake may occur every 200 years some places every 10000 years in others as we have seen that some of the places that earthquake are frequently occurring which is plate boundary region.

Some of the places that occurs once in a while, where is the interior of the plate or mid plate. So, that kind of interval considering the worst scenario will be that too much up investment. Ok the DSHA as a subjective opinion of some input parameters variability effect are not rationally accounted. DSHA approach uses the known seismic source sufficiently near to the site available in historic seismic record geological data to generate discrete single value even an model up from the site. Ok it is gives a single value from the known magnitude and the distance based on the available data.

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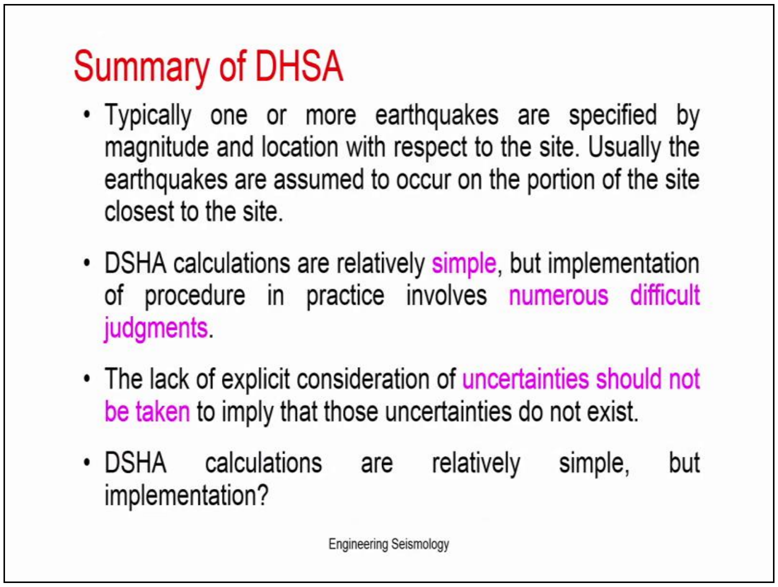

So the summary; you can make say that typically one or more earthquakes are specified by the magnitude and location with respect to the site. Usually earthquakes are assumed to occur on the portion of the site close to the site. DSHA check alterations are relatively simple but implementation of procedure in them practice involves number of difficult judgment. The lack of explicit reconsideration of uncertainty should not be taken to imply the; those uncertainly do not exist. DSHA calculations are relatively simple but implementation wise is very expensive.

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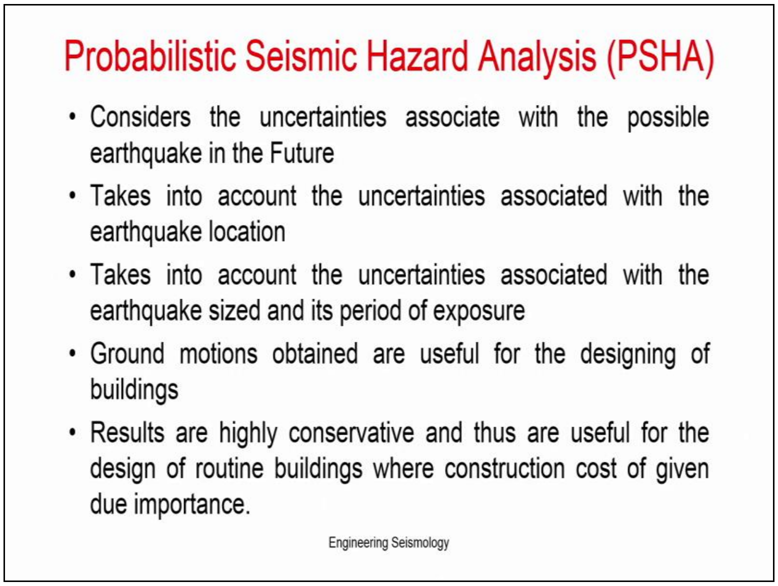

In order to overcome that the problematic seismic hazard analysis has been developed ok where they try to consider the uncertainty associated on the different parameters or the component of the hazard analysis and tried to quantify that uncertainty mathematically. So then they give by asking the owner how much risk you want to take. So I want to take 50% repeatability ok, so then 25% or based and that you will get hazard value ok how much risk you want to take.

Which you manage basically manages cost and risk you want to get out of this. This because of that this is more useful for the buildings. Because the building life is basically 50 years or 30 years or 10 years so depends on that you can take care. I want to take short structure more risk, ok with less risk and long structure. Something like a different combination can be worked out in the PSHA procedure.

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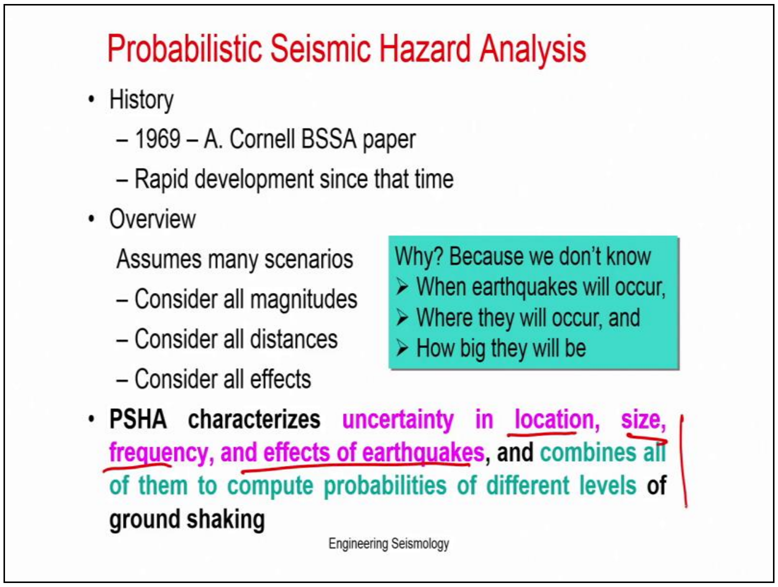

So, this was developed by Cornel in 1969 paper. So where he assumed that ok since we do not know where when and how the Earth was going to occur so that he assumed that all the possible magnitude all the possible distance all the possible effect of the earthquake. So that the PHSA characterize the uncertainty in the location and size frequency and effect of earthquake and combined all of them so to complete possibility of different level of ground shaking for the analysis.

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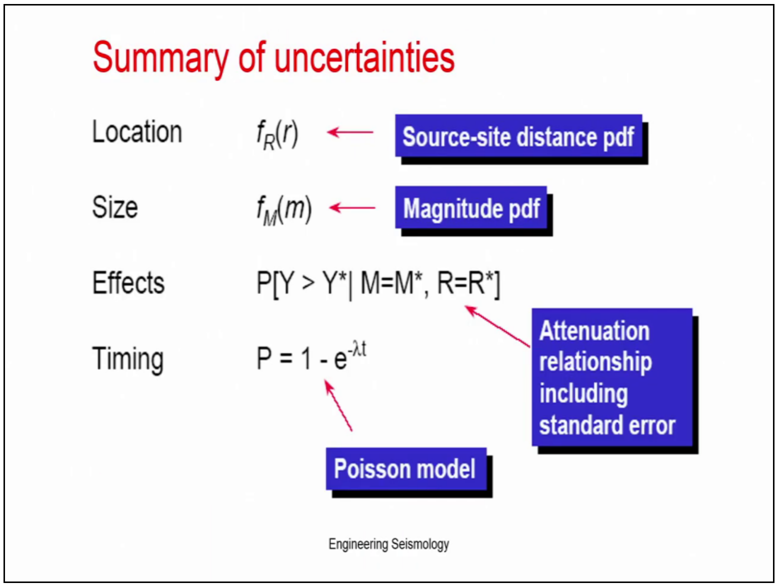

So the location is basically a distance ok site to source distance. So you take a probability density function of that the distance and size magnitude ok the minimum. maximum magnitude possible and consider all of them and their effect ok how this magnitude and distance combined in the GMPs peace and then how these values are varies, how the error term is there and then the time Poisson distribution model is used to account a time. So we will discuss these steps in detail one by one.

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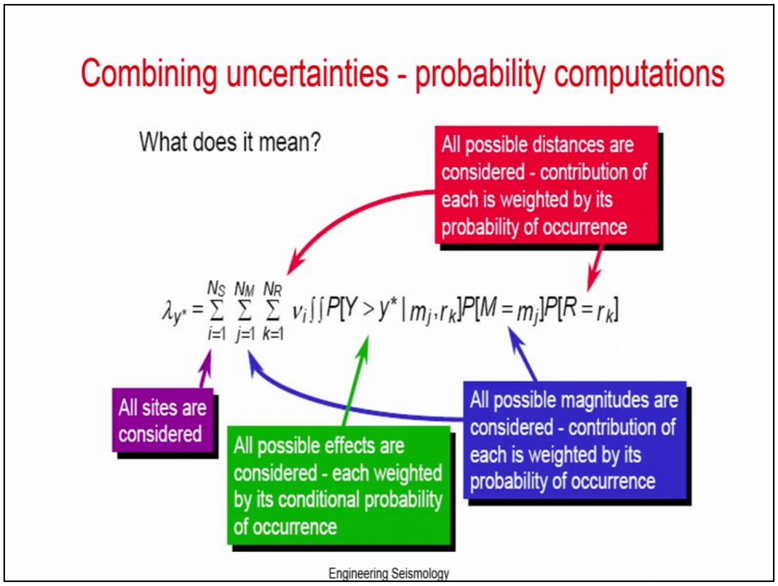

So this all this put together and then say that so the combining all the uncertainty of the; this one and each one and then combined like this and say that I can mean well, ok rate of accidents of particular PGA for the given probable exceedence.

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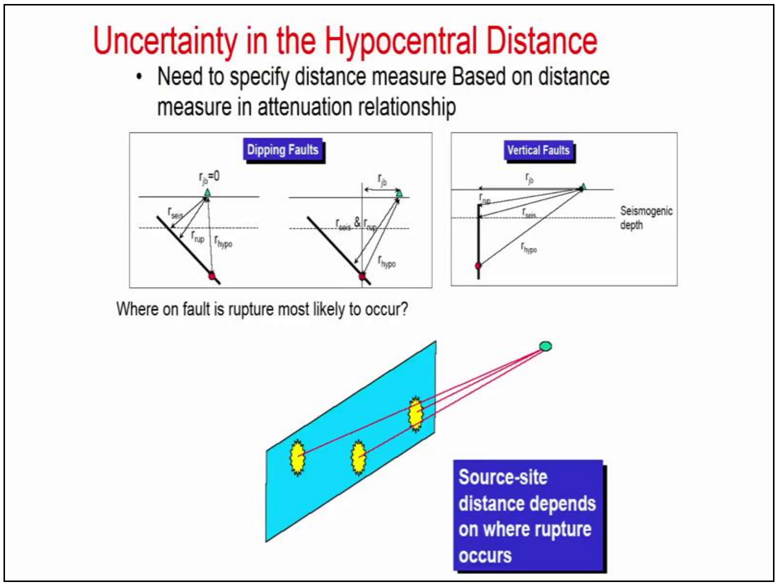

So that will be estimated that estimation will be done using the other loop. Ok. So like the repeatability of the sum of the step again and again and finally you are having a summation values by wearing the parameters for example, as I told you that the minimum and maximum distance they take minimum distance and then vary up to maximum distance each and every segment ok saying that my earthquake may occur here then here and then here and then here and then here and what is the probability density function of each one? And what is a possibility of occurring that is modeled in the probability density function.

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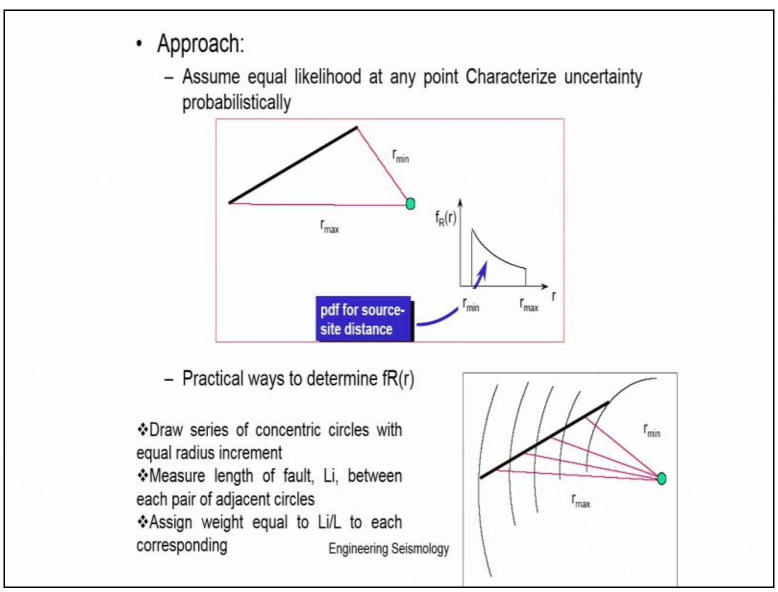

This basically so you will get a PDF of the distance like this using the functions with described in detail. Since some of our publications also we can see and you get a variation and if you have the Ariel source you will be taking as a grid different grid like this and how this grid distances are vary ok.

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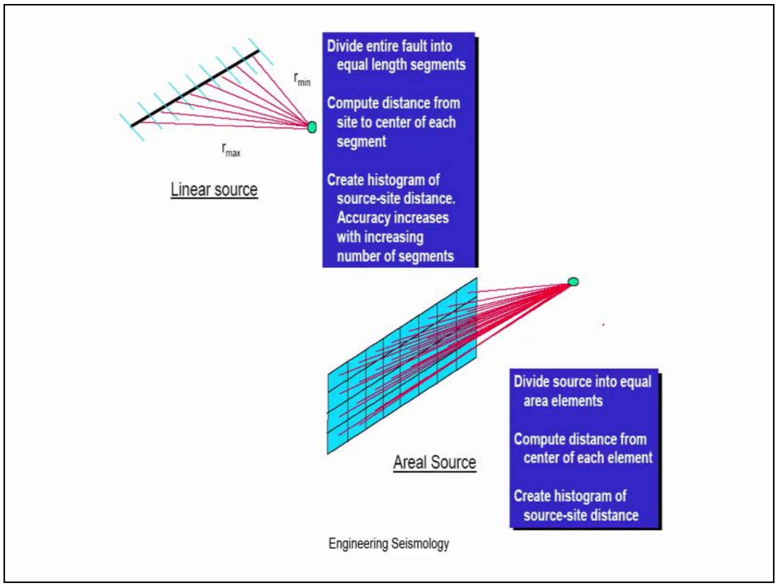

So, like that you can take and then you can get that this one, you can see the Arial source so how the centre is divided how the distance uncertainty associated with that. So linear source is very easy for Arial source we have to make it a square grid underestimate the probability density function.

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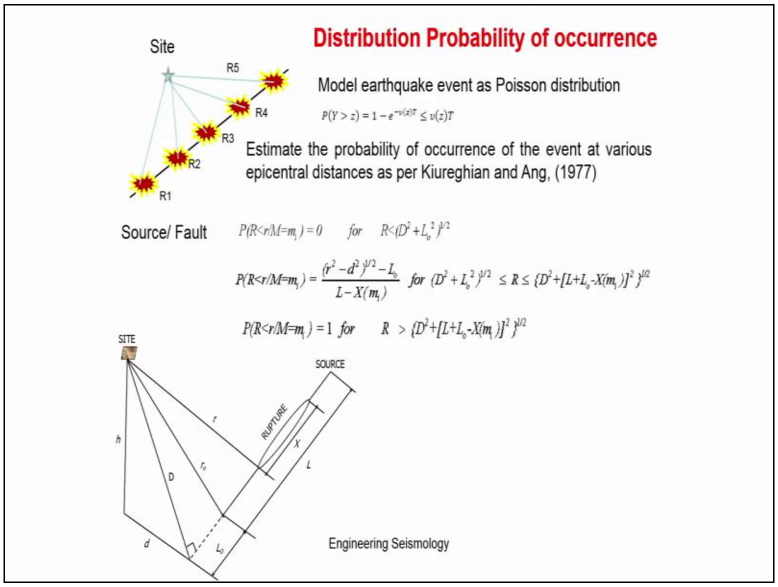

See basically which implies that a particular fault ok a smaller and bigger magnitude can take place at a different distance so each distance will be estimating what is a probability of occurrence so let us see that. So, this is the part is a ruptured length. So, this rapture length keep moving from this point to this point and what is the probability when it moves from different segment which is explained with the dimension given here in this equation.

So you are to model this and estimate this as per your site case that is not doing in the probability of occurrence of the distance ok probability of occurrence of the particular distance. So this is the typical probability distance for the given site.

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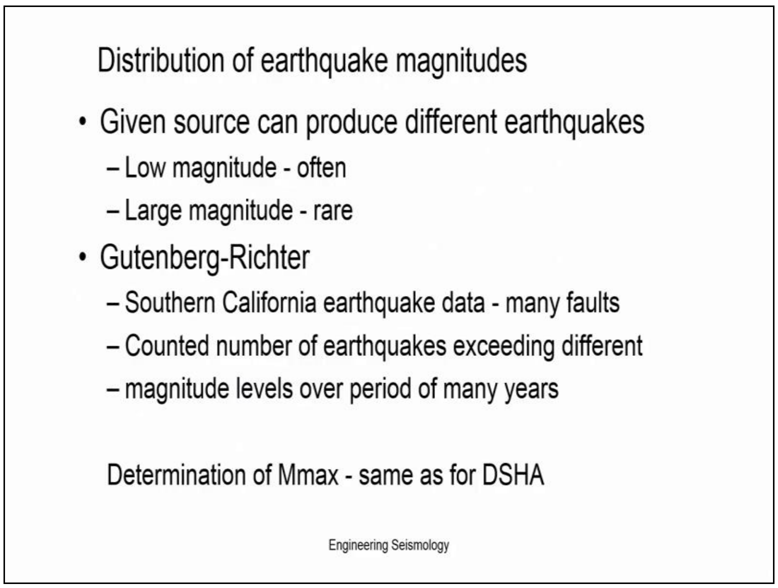

Ok so the next basically is the magnitude once a distance is given then the magnitude. So, the magnitude lower magnet, largest magnitude the largest will be the M max ok which is occurred based on that or you can estimate by any method and then take care Gutenberg-Richter relation because the repeatability of the magnitude depends upon the recurrence relation with the a, b parameters.

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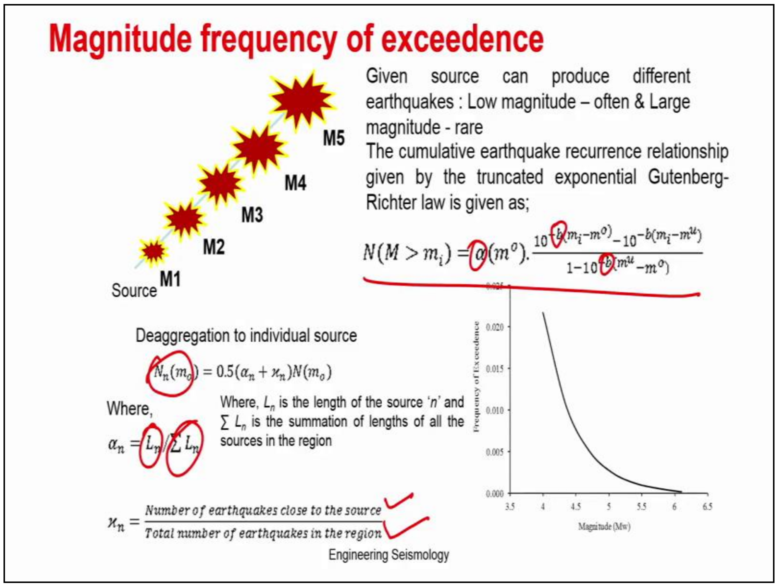

Combining both you can estimate a magnitude this one how small and big magnitude can be expected on the same location how the probability density function varies or the cumulative effect of this magnitude varies can be modelled using this equation. Here you can see that the Alpha ok and B value ok those are all the function of your Gutenberg-Richter relation and that is developed for the entire region a, b value which you can narrow down to the your particular source by doing a de-aggregation by considering your Length of the source total length of the source in the region.

Number of earthquake in the particular source and total number of earthquake this de-aggregation will help you to narrow down your recurrence model from regional or entire seismic study area to the particular source. So that is very important. So that will help you to get your magnitude uncertainty in the particular place. So this calculation has to be done in matlab kind of coding because it involves the large number of repeatability of the steps looping up steps that needs to be accounted in the proper calculation tool.

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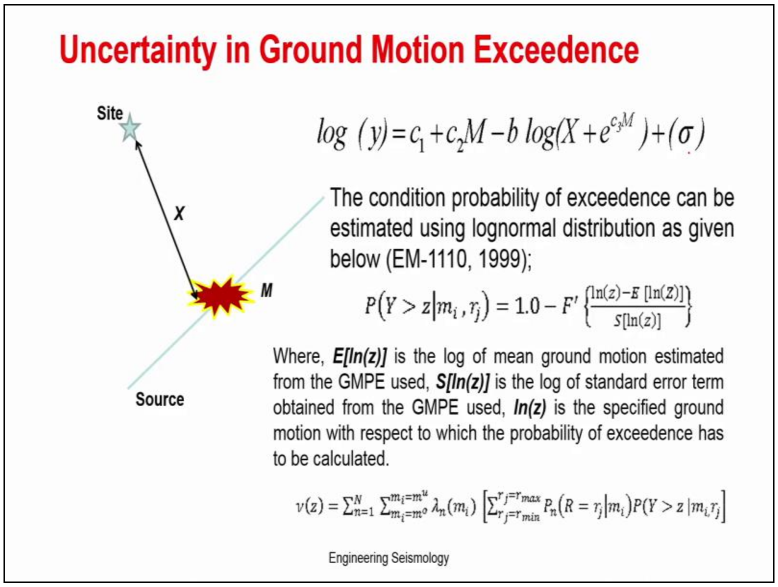

OK so the next once you have done with the magnitude and distance. Next you are going to use a particular ground motion prediction equation. How the ground motion prediction equations are reliable. What is the error associated with that? That uncertainty is estimated on using this kind of phenomena, for example different M and X combination will give you the GMP PGA that PGA may varies functionally with real value. Ok how the known value and the estimated value will varies with this combination. So that uncertainty is estimated using the predictive equations.

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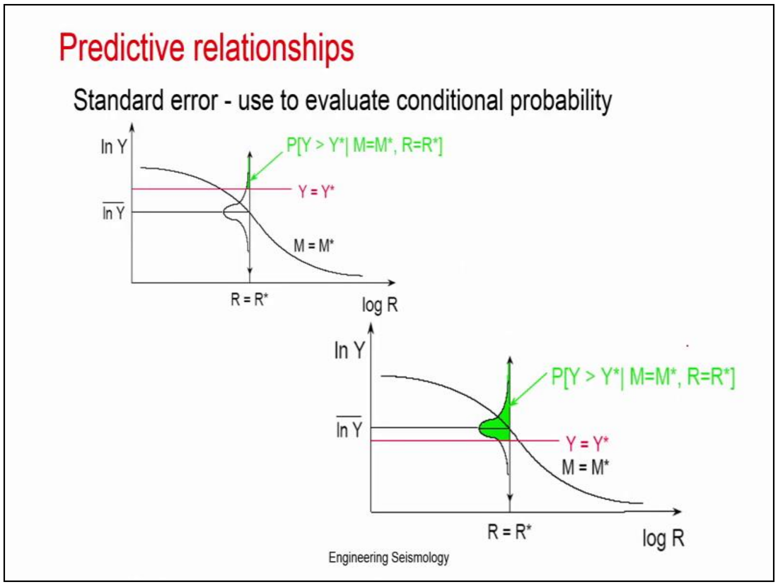

Ok. So like this, this has been modelled as you can see the combination of Y and this one is a what is the probability density function. So, similarly the Y are differently, so this uncertainty is modelled ok in the PSHA as a ground motion prediction equation uncertainty.

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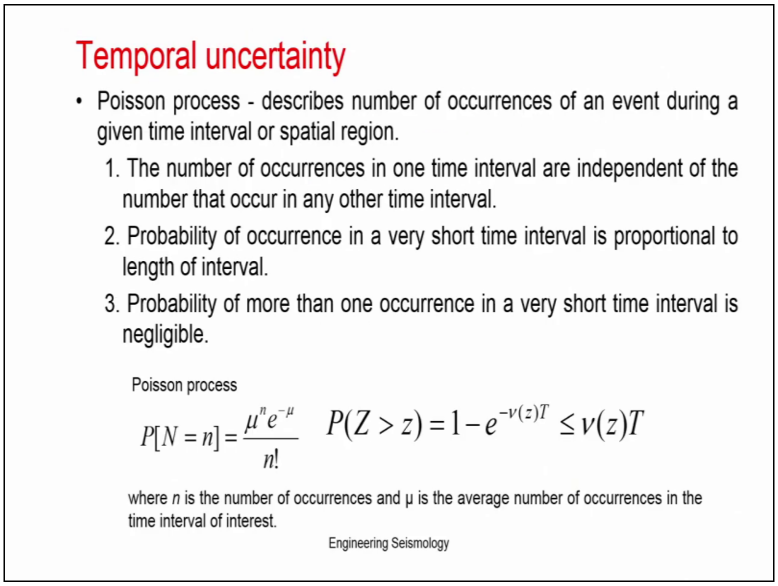

So, after this is the temporal uncertainty like a time. Ok. This time is as I told you that the Poisson model is used. Ok, the number of occurrence of one time interval are independent of the number of that occur at other time interval. Probability of occurrence is very short time interval proportional to the length of the interval the probability more than one occurrence at very short time interval is negligible. For example this is the Poisson process where you take that 1- cv Z by T, so that time T is actually is average number of occurrence time interval interest n is the number.

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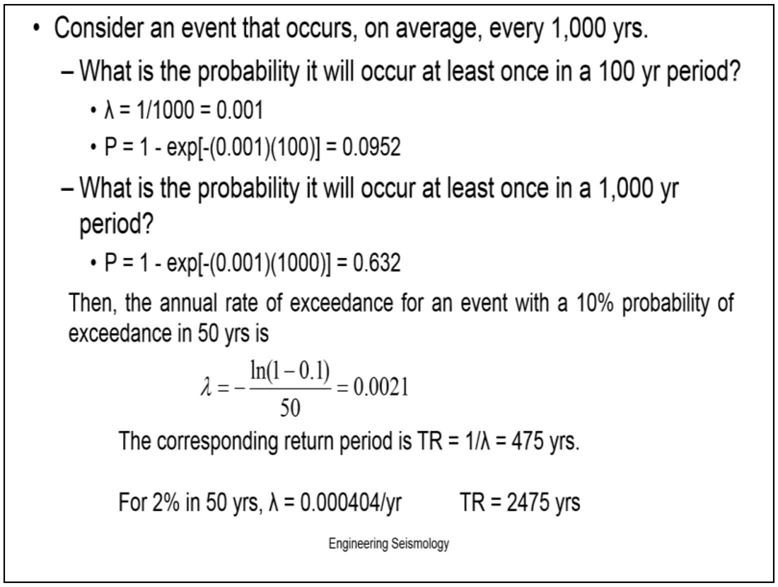

So you can take that you are typically how this probability works basically, What is the probability of occurrence of at least once in a 100 years as you consider a event which is occurring average of every 1000 years. So what is the probability of occurrence in 100 years? So, like Lambda is equal to 1 by 1000, which is 001, so the P is 1 - exponential of Lambda and T so that is what you are given here? So you can see that you get this, this is the probability of occurrence of in 100 years.

Similarly what is the probability of it will occur at least once in a 1000 years. We can see again same you can get, so even though it is once in a 100 years was occur. The probability of occurrence is actually is 0.63 the probabilistic based approach that is where they are incorporated. They do not give 100% weightage that they give the mathematically considering the structure. So here they also annual rate of exceedence and event with the 10% probability exceedence in 50 years this 50 years corresponding to the structure.

OK so the Lambda is equal to 1n of 1 minus the probability like this whatever and 50 you get this so the inverse of that is actually they where the return period. Like a 2% probability you get a 275 so that means the 10% probability if you take any event occurring on the 475 return period is accounted in your design for the period of 50 years structure will be there. So this typical calculation you can try to understand.

So similar way you can also workout for the 2% probability in 50 years completion. So this model ok all these models are combined here the temporal variation ok distance variation magnitude variation and GMP uncertainty is a combined together and finally the mean annual rate of exceedence is estimated with respect to different Period of the structure and different PGA value.

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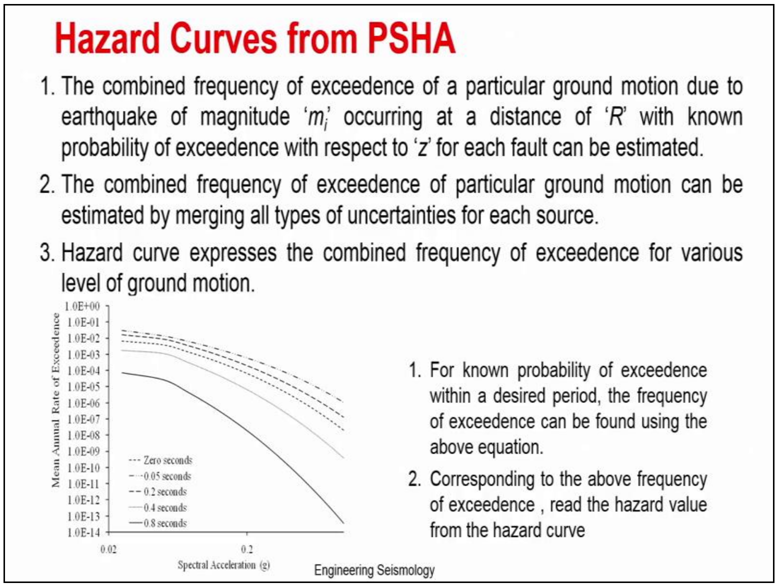

So, that is called as a hazard curve. So, the mean annual rate of incidence is plotted here with lateral acceleration like PGA of the difference source you can estimate and different period you can estimate considering the G evaluation. This typical curve is called as a hazard curve from the probabilistic seismic hazard analysis. So, this curve can be also estimated for the cumulative curve structure by considering this.

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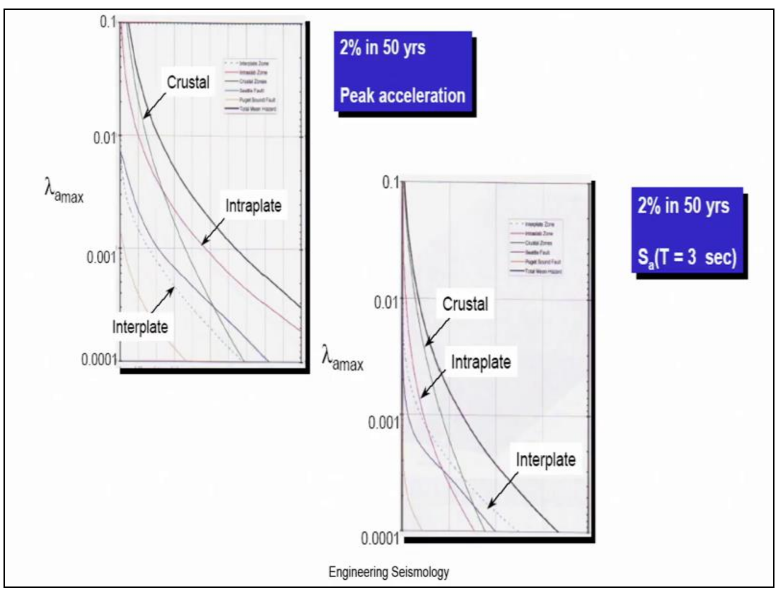

So this curve is actually as a different shape for a different region can see intraplate how it varies. Ok. So the interpolate, intraplate and then crystal you can see how this where is this the general trend observed. So, this is for the peak acceleration for the spectral acceleration at 3 seconds. You can see the shape difference. Ok. So this will give you that mean annual rate of exceedence. So the inverse of this is actually a return period ok you will know that what is the approximate return period of a G given value? Ok that will get on the right place on this one.

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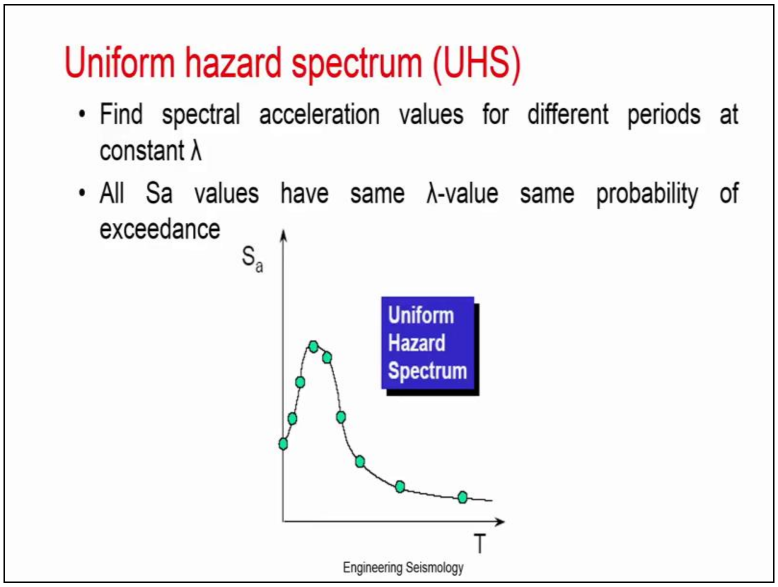

So if you estimate a given response spectrum for similar probability exceedence. Ok, so that means you keep your probability of exceedence Lambda value ok and their period of structure is same and try to estimate how the spectral response where is per the different period that is called as a uniform hazard spectrum. This uniform hazard spectrum similar to response spectrum but it is further given consent probability of exceedence. Ok that is the difference the response spectrum is the response of single degree structure for a given input motion.

Here the given constant probability of exceedence how the spectral acceleration varies that will get from the uniform hazard spectrum.

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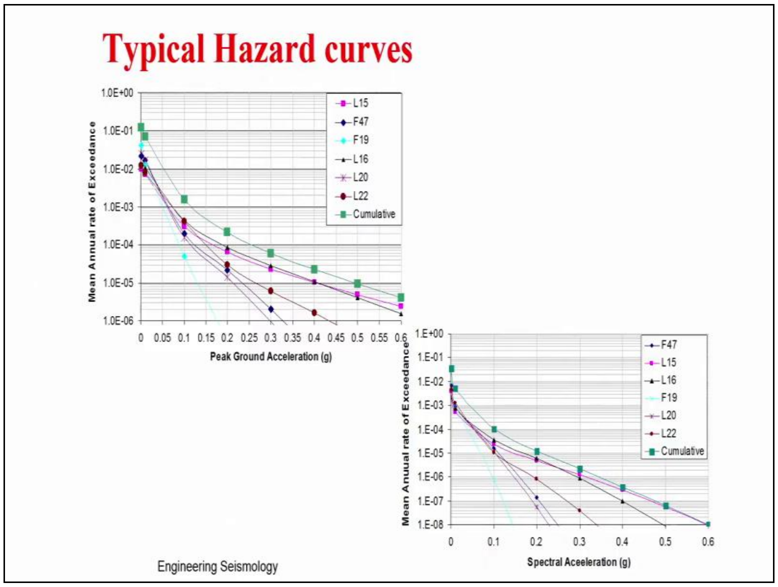

This can be done. Ok where you can see the typical hazard curve which we have developed for several project. The difference source you can see how that mean annual rate of exceedence and then the cumulative of the particular region. So, generally the cumulative will be taken and source if you take you can see that which source is giving more ok that understanding you can do with hazard analysis.

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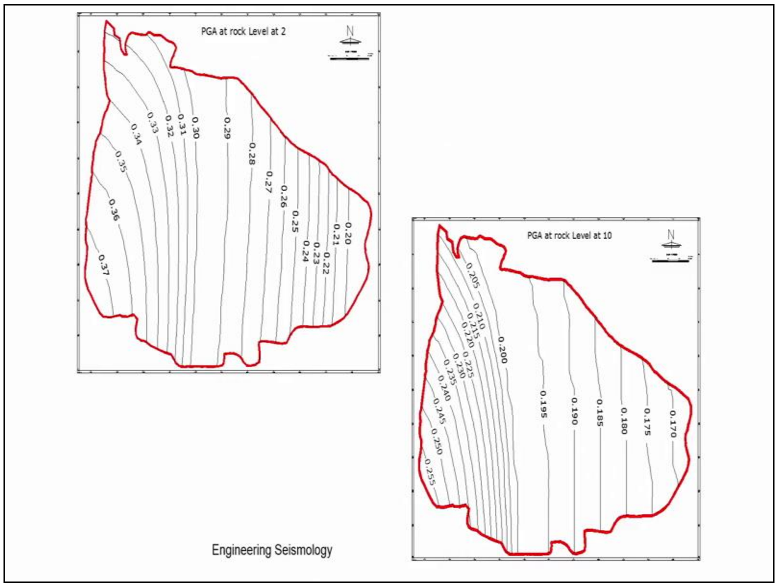

You can also estimate different area of the study area how the PGA varies this is typically 2% probability of exceedence. PGA at Bangalore 10% of exceedence in the 50 years you can see the difference. Generally 2% exceedence will have the higher value you can see the compared to the 10%.

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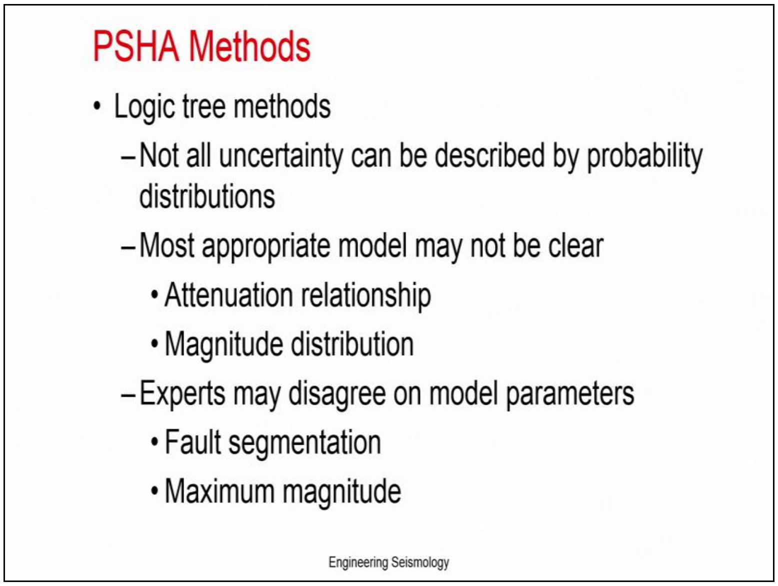

So this PSHA method also can be combined with different model ok you can use 11 value and do all of them 1 max 1 recurrence relation 1 GMP or you can do combine several recurrence relation ok several M max ok several GMP and by taking a logic tree approach. Ok not all the uncertainty can be described by probability distribution. Most appropriate model can be not clear so they can take a multiple model and weigh them accordingly and combined them.

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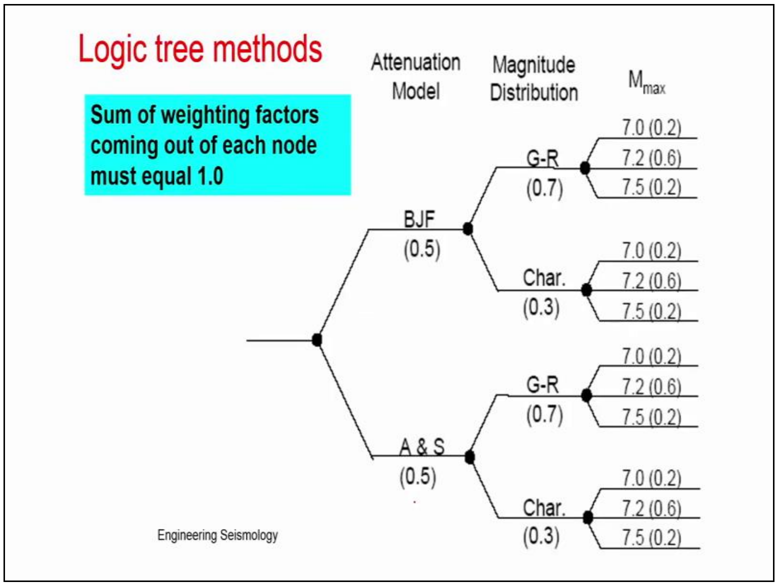

For example this is my final results I am going to expect where I have 2 attenuation model giving different weight. So equal weight have giving 2 GR equation 1 is a characteristic equation and another is the complete data equation and that weightage and different M max you can see like that.

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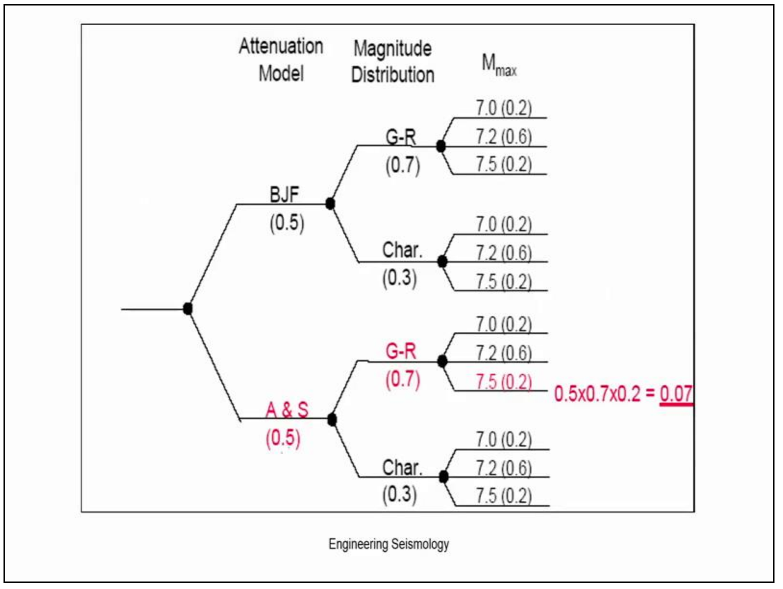

Then finally this combined one will be taken like you can see the weightage at the end the cumulative weightage should be the unity that what will say but you will try to account all the possibility uncertainty associated in this. So, that kind of analysis called as a logic tree probabilistic seismic hazard analysis.

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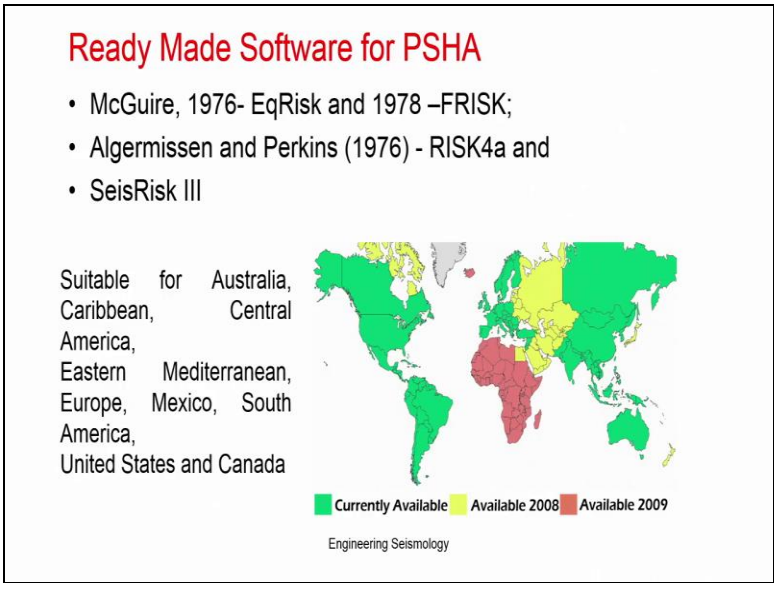

So, right now this as I told you that the writing of matlab code is not easy you need extra knowledge and skill. So, because of that there are some companies who made this program as a commercial program ok Eqrisk, McGuire and SeisRisk 3 package where they try to incorporate regional wise GMPs sources and model where you can get the hazard analysis from the package directly by understanding the what input you are giving. So that kinds of models also available commercially for seismic hazard analysis. So, that also can be tried ok.

So even though this model I said it is available. You can see that DSHA PSHA does not really account a regional variation. Ok because they did not specify. What is the seismic study area I should take which we felt we have seen that it is very important that they did not specify what M max should say. They did not specify what are the GMPs you should take? How to take? All those other generally they are given is a global step you can adapt anything. So that makes many time researcher what they do, based on their experience ok based on their knowledge, they end up using a known information to the input which give the some kind of output which is not more realistically suitable to that region.

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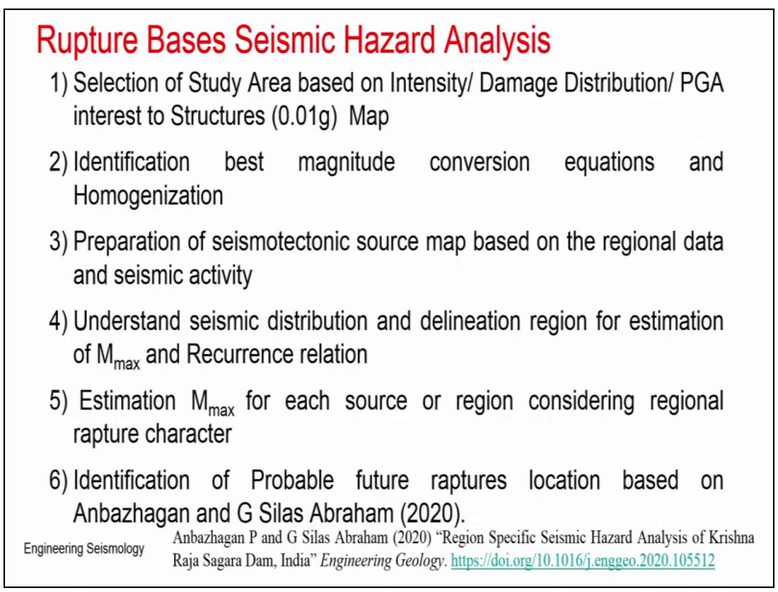

So, in order to overcome that we developed Rapture based seismic hazard analysis. So, the rupture based seismic hazard analysis, basically which take care of the each and every aspect of the hazard analysis by counting the proper regional input. So, one of them is selection of seismic study area. Ok. So what do you do? Basically you consider intensity damage distribution and then or PGA of the structure which is available in the region.

And then take that as a seismic study area map. Ok the distance so that is one regional input you can consider. Then once you are done that. You to identify the best magnitude conversion equation for the homogenation, so you can take a regional available data few, like we have said an LLH or similar kind of approach you can adopt and identify the magnitude conversion equation best and try to homogenize the catalogue.

Once you homogenize general catalogue and tried to process your seismotectonic map using the regional source and activity in the region. Once you are done that right to estimate M max and regional recurrence relation. So, these will basically all this original inputs are gone in this M max and recurrence relation will be more representing. So, M max of each source or region can be considered from the regional Rapture character, which I told you how you can have time that you can use.

So then identify a probable future Rapture location, this identification of the Probable feature Rapture locations are very important which is basically the conventionally they told that wherever M max is there you had increment and consider that for hazard analysis, but whenever there is no M max sufficiently you will be ignoring that source. In the regional rapture character method we give more weightage to the active location where there is a minor earthquake, but there is no big earthquake.

So, that is the difference. So that procedure and discussion because also find this journal paper which is a published very recently in the engineering geology.

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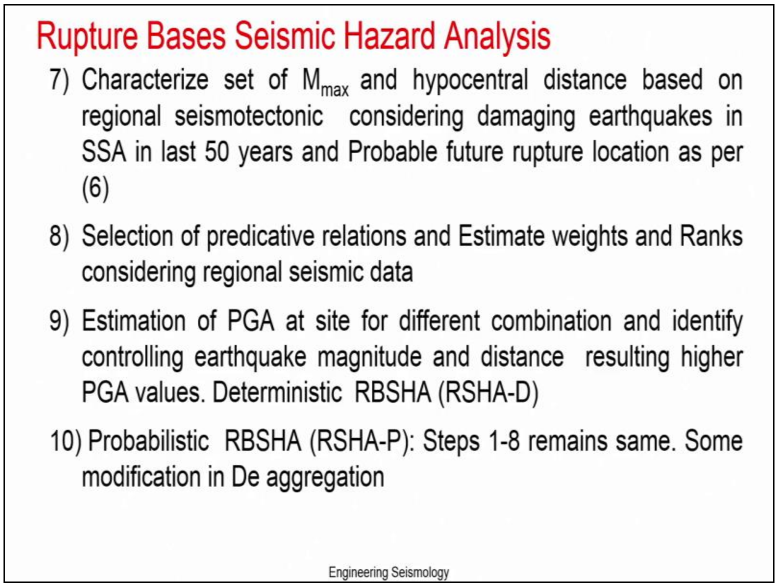

Once you are done that you try to characterize M max and hypocentral distance combination, so from the previous steps. Select a proper ground motion predictive equation and weigh them just made the weights and ranks based on the regional seismic data. That is the next step once you are done that you do PGA estimation. And from that you identify which source and M gives a more PGA that will be taken as a ruptured based seismic hazard analysis values.

So the probabilistic seismic hazard analysis of the rupture based approach remains same up to source one to I mean step 1 to 8, but however we change in the procedures of the de-aggregating the factor. For example in the conventional approach.

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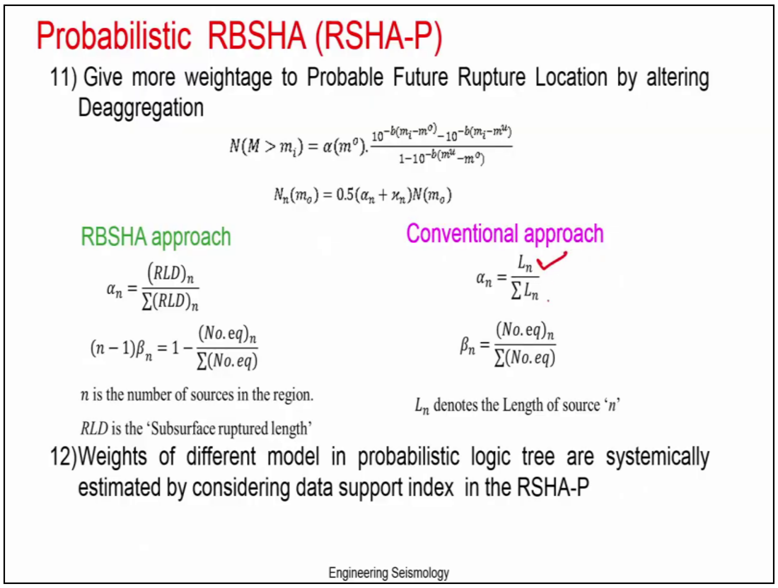

The alpha is consider L n and Sigma L n the length of the source and total length of the source in the RLD approach. We give RLD ruptured and total RLD of the region. So, this way this alpha this alpha's is different. So this Alpha will be followed by the ruptured based seismic hazard analysis probabilistic based approach and then the number of earthquake and then total number of earthquake this gives a more weightage for the already ruptured source or already earthquake location.

But here we are taking 1 minus of that so where it will give the weightage but less weightage but give more weightage to the where the number of earthquake is less. So that concept has been introduced here. So this is actually in the research and development stage, so we are published after DSHA PSHA we are writing a paper, but this practice I believe that it will be useful by the time you see this course maybe we might have published this work. You can also read that paper.

So, then that weight and rank difference will be incorporated in the PSHA and that PSHA become a RSHAP ok rapture based seismic hazard analysis in probabilistic way where you account and give more weightage to that non ruptured location. So, let us see how this calculation works for the typical DSHA case of the conventional approach and then rapture based DSHA approach.

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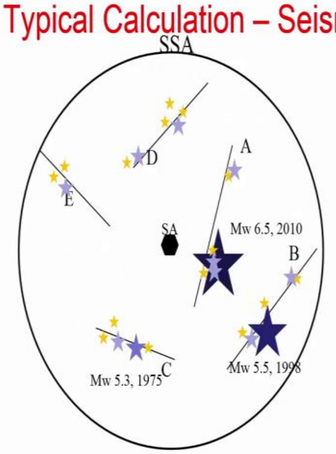
Typical Calculation – Seismotectonic Map



Source	Max Observe	No of EQ	Mmax by Increment
A	6.0	7	6.5
B	5.5	7	6.0
C	5.3	5	5.8
D	3.8	6	~~4.3~~
E	2.7	3	~~3.2~~

So let us take a area, ok this is my study area. So I have the five sources here. I am giving you the typical calculation. You do not exactly look at the size of the drawing and then estimation and all, only a typical incorporation here. So, this is my study area. This is my seismic study area so the conventional approach you do not worry about the seismic study area because there is no guideline.

But my rupture based approach we selected this based on the past seismic data in the region. Intensity map or RPG record, whatever so we have the five sources A, B, C, D, and E each source we have the different earthquake. So you have small earthquakes ok then medium earthquake and big earthquake in the each source. So, you can see that these are the small earthquake which is less than 4 generally ignored in the conventional approach.

So that means the source E and D may not accounted in hazard analysis. So the equation above 4 is 5.3 magnitudes 6.5 and 5.5 may be considered for hazard analysis in the conventional approach. We can see A B C observed maximum magnitude since it is less than 4 generally it is not counted. So, the next is actually your number of earthquake. So the number of earthquake basically associated with your PSHA procedure of rupture based analysis that we are taking that also to show how it varies.

For example A as many earthquake B as many earthquake, C as a many earthquake because this is from the past earthquake occurred. You can also see that period of 1998, 2010 and 1975. So, this is about the seismotectonic map and; try to understand how the data is there. We did homogenation conversion everything is now ready for hazard analysis.

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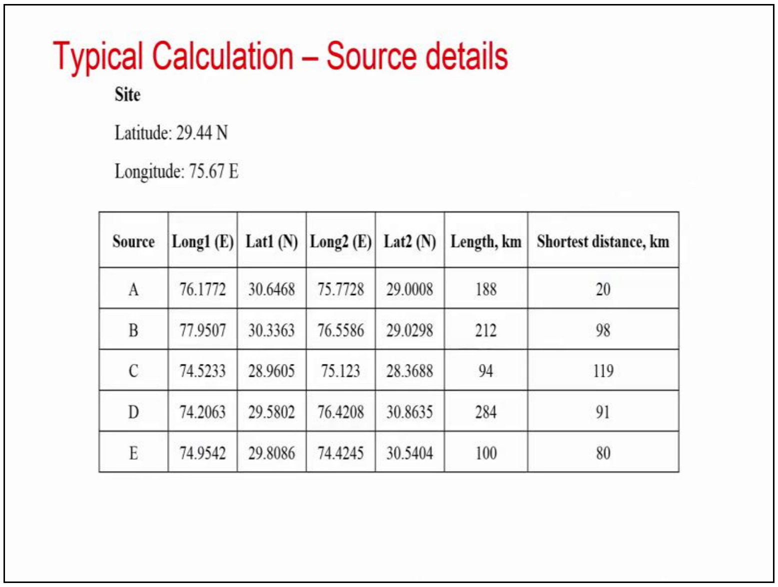

Typical Calculation – Source details

Site

Latitude: 29.44 N

Longitude: 75.67 E

Source	Long1 (E)	Lat1 (N)	Long2 (E)	Lat2 (N)	Length, km	Shortest distance, km
A	76.1772	30.6468	75.7728	29.0008	188	20
B	77.9507	30.3363	76.5586	29.0298	212	98
C	74.5233	28.9605	75.123	28.3688	94	119
D	74.2063	29.5802	76.4208	30.8635	284	91
E	74.9542	29.8086	74.4245	30.5404	100	80

So, then let us see the source and the length starting and end length and estimate a length and then the shortest distance to the site Ok using that this perpendicular line. You can estimate shortest distance to the site that has been also estimated using the Excel.

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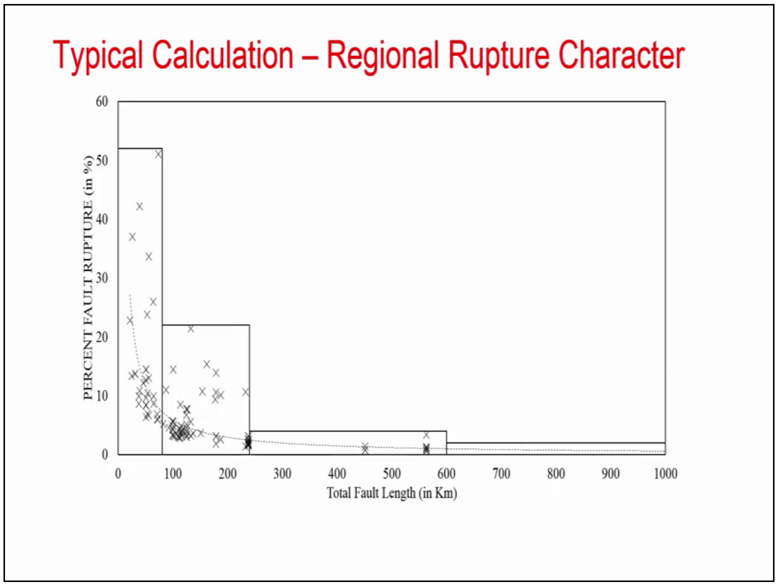

So, once you estimate that you need to establish a regional Rapture character. So you have seen how, the original rupture character is estimated. This is a typical plot of that not for our case. But you can see this the; estimation based on this give a M max segment, ok segment 1 segment 2 segment 3.

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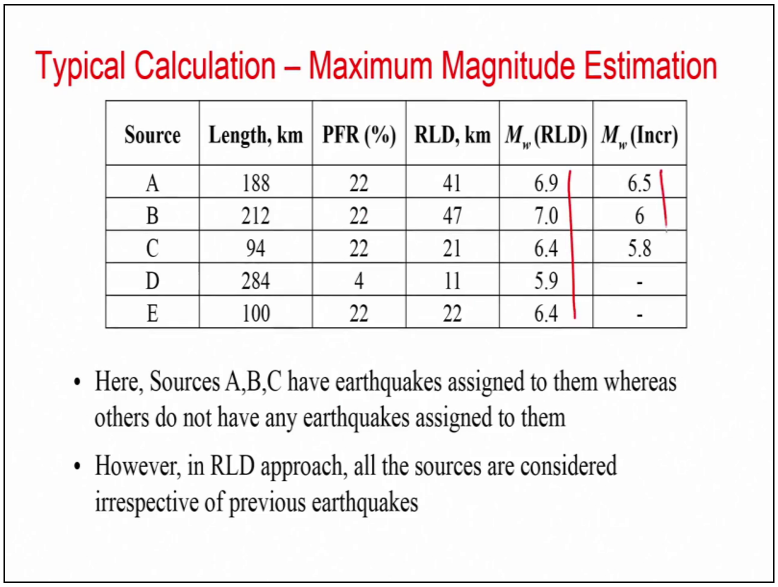

Typical Calculation – Maximum Magnitude Estimation

Source	Length, km	PFR (%)	RLD, km	M_w (RLD)	M_w (Incr)
A	188	22	41	6.9	6.5
B	212	22	47	7.0	6
C	94	22	21	6.4	5.8
D	284	4	11	5.9	-
E	100	22	22	6.4	-

- Here, Sources A,B,C have earthquakes assigned to them whereas others do not have any earthquakes assigned to them
- However, in RLD approach, all the sources are considered irrespective of previous earthquakes

So, by assuming this kind of relation you can estimate a probable rupture length and RLD and again convert that RLD to the MW you can see this is M max by increment method where you can see here. So this is the observed magnitude I add it 0.5 as M max from the increment meter. So this earthquake is the maximum magnitude as per the conversion procedure of DSHA but the revised M max is this one which is from the ruptured based analysis.

So now I have the M max I have the distance. Ok. I have to select a GMP. So, conventional what I will do. So this is actually the estimated M max at overlapped with seismotectonic map. You can see the difference. So this I will be using in the rupture based analysis. This is a conventional approach. So here I ignored these two source in the conventional approach because the magnitudes are less than 4.

But in rupture based analysis I do not ignore because there is a event and there is a source which indicate that there is a seismic potential there that it may Rapture in the future. So that is what beauty of the; this RSHS method. So this is typical plot of that.

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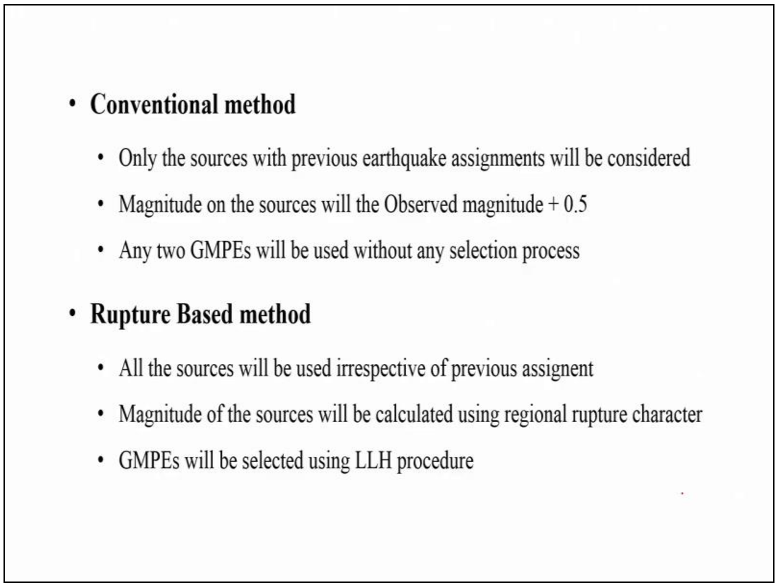

So, then we will now take a GMP is known to us and then try to estimate PGF.

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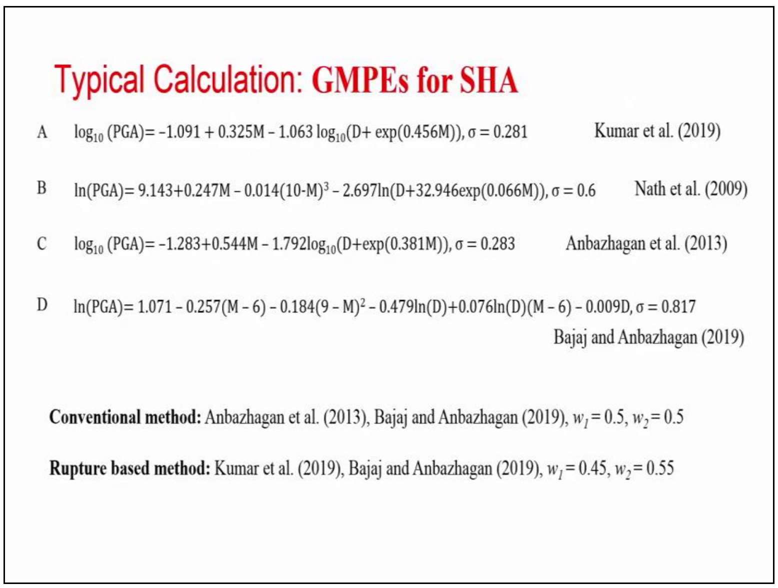

So as I told you that the 4 GMPs we have taken which we discussed in the ranking previously. So, that GMPs I have conventional method what I will do I will take whichever GMPs I felt it is more. For example; since I believe that my equations are good. So, I take both of them and give equal weightage to estimate hazard value. But if you do systematically and select the GMPs according to LLH approach basically you will be ending up with these 2 GMPs.

So which is only I recommend in the Rapture based seismic hazard analysis? Ok. So this is for the rupture based analysis.

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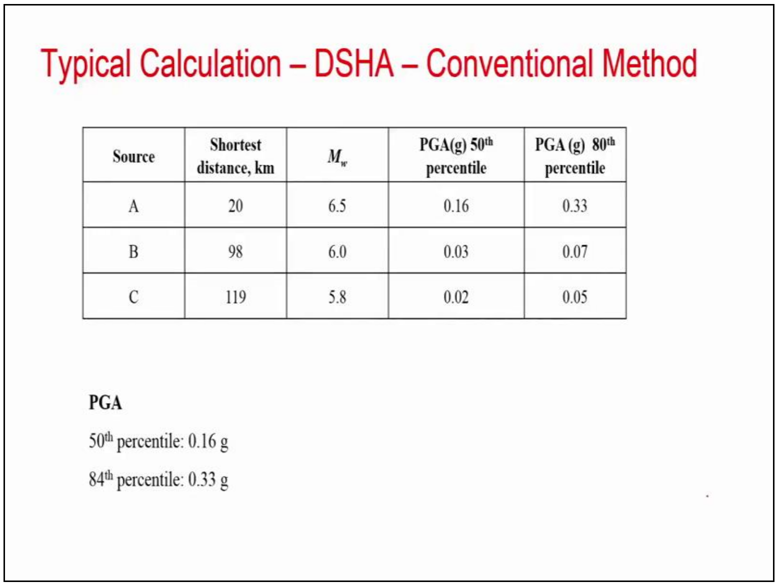

So, let us see how the results are varies. Let us see that seismic source ABC typical DSHA because D and E we ignored become less magnitude. So this is the M max estimated by increment PGA for 50% percentile PGA 80% percentage. So this 80% 50% comes your error term variation ok see median value they give. So, you can vary for the median lowest and highest value you can see the PGA.

From this we can conclude that out of this; whichever causing a maximum one is the controlling earthquake and controlling source you can see this one. So basically the A is considered as vulnerable source and the critical magnitude. Ok. This is from the DSHA approach.

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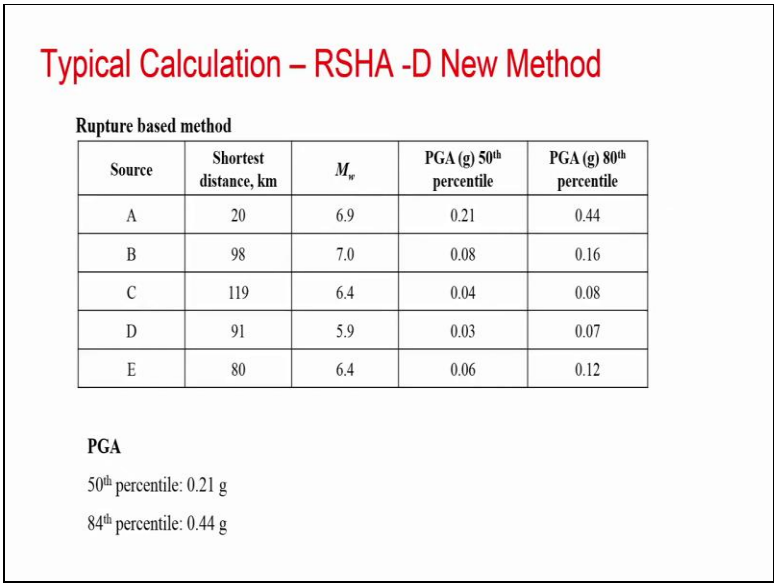
Typical Calculation – RSHA -D New Method

Rupture based method

Source	Shortest distance, km	M_w	PGA (g) 50th percentile	PGA (g) 80th percentile
A	20	6.9	0.21	0.44
B	98	7.0	0.08	0.16
C	119	6.4	0.04	0.08
D	91	5.9	0.03	0.07
E	80	6.4	0.06	0.12

PGA

50th percentile: 0.21 g

84th percentile: 0.44 g

But as I said that it does not account here probable feature locations since your data period is very less. If you go back to the map, if you look at a time period see I want to do hazard analysis on 2020. So I consider the data in the last 50 years, but I have the written period of 100 years earthquake 100 years return period of my design earthquake or the average earthquake in the region. So, in that case the possibility of occurring this earthquake in the next 50 years is very less correct because this occurred on 2010, 1998 which is less than 50 years of the period.

But I have 100 years; return period ok that means if it is occured close 200 years. I may give more weightage otherwise I no need to consider this as a big important for the future earthquake. So that kind of concept has been incorporated in the Rapture based seismic hazard analysis. So how it is incorporated as we have seen that.

So here you see I do not give the weightage to the any of the source. I will estimate M max based on the RLD approach and estimate PGA and estimate like this. So you can see a highest value which is basically the; this one but this is a DSHA procedure where the probable location ok is not so much weighed. So if I want to weigh them so much, so if I take your de-aggregation factor. Ok, so Nm0 ok. So where the alpha and beta if I take from the number of earthquake then this was ok the A and B will give that less weightage and the other source will get a more weightage that reflect in the ruptured based seismic hazard analysis in the probabilistic approach.

Ok. So that is the difference between RSHA. So, here you can see that even though the same source is considered but the PGA values are completely different. Because this PGA value indicates the rupture potential in the region which is not accounted in the conventional way and the GMPs are selected systematically which also changes a value because I selected known experience in the conventional DSHA.

But in the rupture based one I selected based on the regional data so the values are completely different. Even though source may be same but the controlling magnitude and controlling PJ values were completely different. So that is how the rupture based method will be more unique and more representative for any region. Recently this we applied for the; our KRS Dam ok so where this procedure is has been demonstrated. This publication may you find the engineering geology from my website.

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Comparison of SHA & RSHA

Sl No	Parameter in Seismic Hazard Analysis (SHA)	Convectional SHA	Ruptured Based SHA
1	Seismic Study Area	No specific recommendation. Generally taken quote some previous work	Based on furthest intensity (IV- V)/ PGA >0.01 g reported from past maximum earthquake
2	Weightage of past earthquake in future predication	More	Less or Nil
3	Maximum Magnitude	Any suitable way	Regional Rupture character by Anbazhagan et al (2015)
4	Consideration of minor earthquake & associated source	Less or Nil Magnitude ≤ 4/3.5 locations are ignored	Accounted as probable future rupture location and gives more weightage
5	Weights and Ranks of model	Mostly assumed	Estimated based on data support Index of regional data
6	Flexibility in calculating worst scenario hazard values	Maximum by some means	Increasing subsurface rupture length with factor and there by M_{max}

Engineering Seismology

Ok. So let us see what is the summary between these two approach? The seismic study area conventional approach does not talk about anything on seismic study. You can select whatever radius you want some people use 100 kilometre for the DSHA. Some people use 300 some people use 400 there is no specific. But in the rupture based analysis, we say that you select your seismic study area considering the intensity value of the past earthquake radius of 4 to 5.01 and above which is interesting to the structures.

Ok second the weightage to the past and the future prediction actually conventional approach they give more weightage to the already earthquake occurred location. But in the rupture analysis, it gives very less weightage because it consider also potential possible rupture location maximum magnitude any suitable way which is listed 7, rupture analysis highlight that you should estimate M max only by the Anbazhagan etal using the regional rapture character, which is developed by us.

Considering the minor earthquake associated sources generally conventional approach, they ignore the minor earthquake because they always take a magnitude 4 or 3.5 and above per hazard analysis because of that the minor earthquakes occurrence locations are ignored. But in the ruptured based analysis we give more weightage because we assume that it is probable rupture location and give more weightage.

So weightage weight and rank of GMPs, so mostly conventional approach they do not follow any ranking system. And they assumed based on their knowledge that take GMPs and give equal weightage or some weightage which they believe right, who? The person who incorporate hazard analysis or do a hazard analysis are decided a hazard analysis but here we estimate systematically rank them and use that rank and weight for giving the GMP ranking that is why this value will be different.

Flexibility in calculating worst scenario, so here the maximum you can estimate there is no flexibility but here you can vary the RLD percentage, by the way you can define what is the factor you can adapt? Ok because RLD is the mathematical number. You can adopt one means there is no increase ok 1.2 means slightly increased 1.5 means more increased 2 means very high increased.

So that kind of flexibility is there to handle their future fixing up worst, medium, low level requirement of the structure. So, that is one of the highlight in one of the ruptured based analysis. So this comparison of seismic hazard analysis conventional and rupture based analysis for DSHA will give you that insight how the hazard analysis has been done. Ok. So with this we close the entire syllabus of the class.

So you can see that we started talking about the different hazard ok then we talk about the seismic hazard ok how it is very important how many people die? We have seen a different seismic hazard how to protect ok how to minimize that is basically try to understand hazard. Try to estimate a reliable way and educate your people. Then we also seen how the earthquakes are measured and Engineering seismology knowledge begin in the different path.

And different equipment available for earthquake measurement and earthquake quantified quantification, magnitude, intensity on different scale available and different earthquake record and how to convert that and how to arrive a ground motion parameter, time domain parameters, ok frequency-domain parameters we have seen. Seismic station we have seen, seismic instrument to measure earthquake we have seen ok.

So then with that also we have tried to understand a simple model, point source model, (())(40:09). Simulation of ground motion what are the models are available, predictive equation what is the equation. So, with that we also understand how the regionally seismotectonic parameter varies, seismic study area varies. How to estimate these parameters map them and try to finally arrived hazard values for any structural requirements.

So with that we basically covered entire syllabus of the course. I hope you learn something from this course, Ok so I am very happy that you learnt something which is useful for your career or your enhancement of the knowledge to prevent at least few death or one death due to the earthquake are escape from the earthquake. So if you need any further details and you would want to use our service or research you please approach me ok my website IISC like Anbhazhagan IISC if you type in the Google you can find my website also phone number which may be available I think from NPTEL website site.

So I thank you very much for watching this entire 30 plus lectures and taking this course. I hope you got some knowledge about this. If you need more clarification, maybe because of the this video interaction, I could not able to interact with you and not very sure you who are all going to take but anyway, so you can give your suggestion and feedback even if you want to extend this course next level. I was talking about that amplification estimation liquefaction estimation.

Ok if you want to extend this to that level site characterization like microorganism procedure you please comment so that I can see best I can offer this course in the future. So if you any suggestion to improve this course also welcome so that I can incorporate my regular teaching in the M. Tech and PHD level. So I tried to tell you what I learnt what I am doing. Ok, so that may be here and there are some pitfalls will be there which maybe you can bring to the notice. I tried to correct it.

Your feedbacks and commands may be helpful for NPTEL as well as to improve the course in overall in the future. Thank you very much for taking this course. I wish you all the best. I also wish you all the best for final exam. I hope all of you can clear easily this course and get good grade. Already my question papers are set and supplied to the NPTEL office. Thank you very much. Thank you one and all.