Introduction to Engineering Seismologyles
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Lecture-63
SHA - Selection of GMPE

So, Vanakam; we will continue our lecture and Engineering Seismology. So we have been discussing about the hazard analysis. Last class we have seen the How the predictive equations; how the predictive equations are developed in India for how many number equations are there particularly Himalayan region, North East region as well as intraplate region where the major 3 category of the region you can follow. We have also seen intensity predictive equation and duration predictive equation.

So, the duration or intensity predictive equations are very infant stage in the India. There is not much equations are available basically, but people also not use those things in the any model understanding or hazard estimation. Generally people use their estimation of PGA which is very important for the structural requirements for the design of structures and Infrastructures. The PGA is actually very important that is why they used.

But we have seen that there is a multiple number of GMPEs are available. You are seen around 12 for the Northeast region and then around 15-20 for the Himalayan region and 7 and then 3 group for the Peninsular India.

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So if you look at the overall world how the equations can just watch this video, very closely. This is taken from the Douglas website. The reference are given above you can also go through that website and take that. You can see the period the number of equation is developed you can see the graph down. You can see that graph down. How the number of equation keep increasing. You can see that in India up to 1990 there is no ground motion prediction equation.

Ok so 90 we have crossed ok so 92, 93, 94 so there is no GMPEs. So as I shown you that the first GMPEs was developed during 1996. Ok so that we can see the first dot which comes on the

North Himalaya part then followed by the many equation, which is we also developed. So this is there the overall distribution of GMPEs is in the entire globe. So we basically may be around 2-3 decade later on developing the GMPEs and see we do not have the proper ground motion prediction equation, but that was changed after 2000 that was comes 2010 you can say.

There are many equations are come up with the region many of them are having the good predictive capacity also. When you have this kind of larger number of equation how to select a particular equation for a particular region you cannot use and100 equation there should be some kind of systematic way to identify the best equation. As I told you that depends upon the people who estimates the hazard many time they go by the their own knowledge, but which should not be adopted.

For example somebody knows my work they only use my equation as a equation to estimate hazard which is not correct. Ok if they have to systematically review what are the GMPEs are available throughout the world and similar siesmotectonics and try to estimate them why you need to do that after you like if you come to the end of the you are a graph you are seen that close to 400 plus GMPEs are developed in the world or different part of the world.

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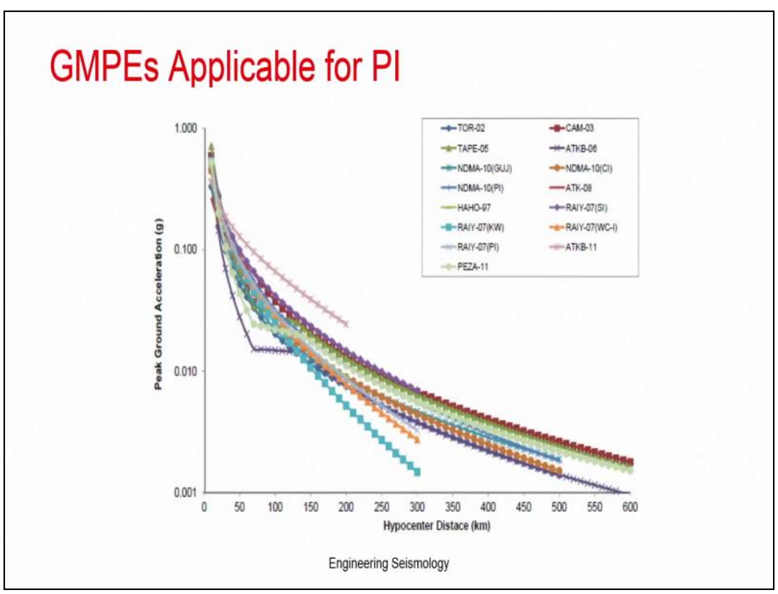

For those situation for example if we take a Peninsular India which is like a stable continent so all the applicable equation, this is the all the applicable equation we can see how this equation goes we see the variation. OK so for a given distance and in the given magnitude you can basically see how the PGA varies see the; is almost very large variation. Ok. So this kind of variations can occur ok when you consider all the equation and which one is correct also if you put you a bias.

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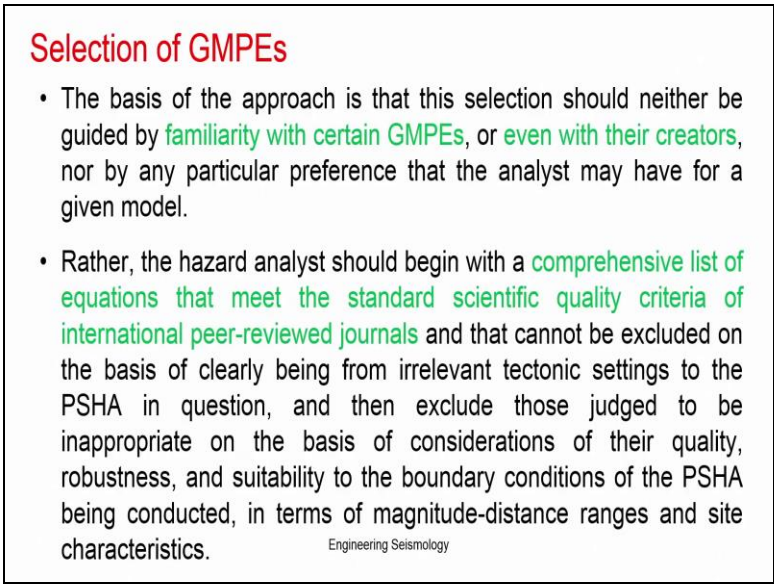

So, in order to overcome that actually scientist given a systematic procedure how to select your GMPEs, so there are two way of procedure they have give one is that procedure based on the qualitative. Qualitative means based on the some setup steps are conditions without any mathematical background. Ok, so that kinds of steps are basically used to correct. What they said actually this equation, whatever they published you should have been published in the peer reviewed journal. That means it should be reviewed by the expert working on that area.

So now you again that review also is question who reviews? Ok is not that all the time people will give the unbiased review comments and many times some people will give like it depends upon the person who write a paper. Person who reviews your paper depends upon the journal type. The review keep changing so that kind of; that is why this is qualitative selection, but they say that peer reviewed journals will be more applicable equations you can list.

And then I can also see the tectonic environment for example stable continent. I should look only for the earthquake data from the stable continent people who used and developed GMPEs. I should not look for the active region GMPEs for stable continents. Inappropriate tectonic environment should be avoided model not published in the Thompsons Reuters and good journals should not be considered. The data set used to derive model is not presented accessible format. If somebody not giving the data set and is then you should not consider that equation was so good because the reliability of the equations are depends upon the data what they have used.

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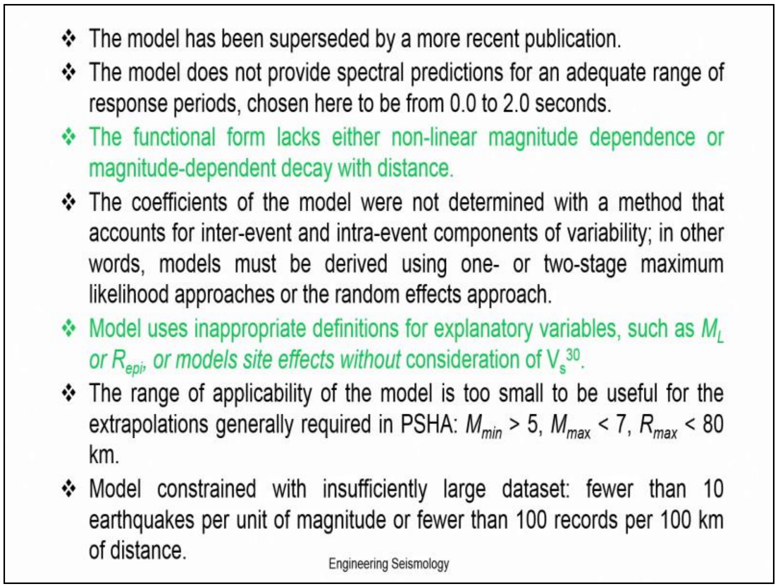

Ok, so that kind of equation that you should see and model has been like same author published three equation like in 91, 2001 and 2010 and 2014 then you should use the most recent one as believed that they have been updated with the different data set and then that a second like you should have that the period of the equation at least 2022 which is interested for the structural requirements that also should be the condition.

Functional form lack of either nonlinear magnitude depends on the functional form what they use ok for the developing GMPEs also need to be accounted. Ok because sometime irrelevant function or nonlinear function if they used in GMPE it will lead to a error. And then what type of distance they have used hypocentral distance, AP Central distance and shortest distance. Ok the magnitude what magnitude they use.

So, these are all the some of the qualitative conditions where one can consider Shortlist equations are available.

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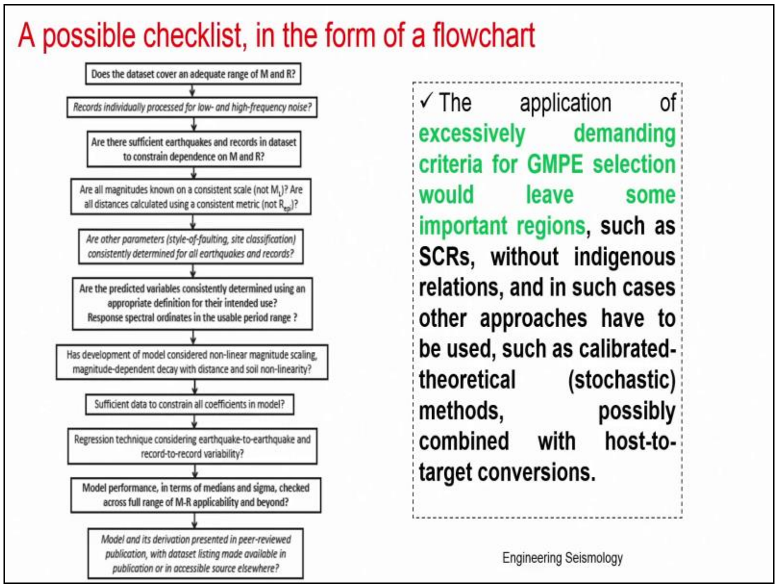

But this is a criteria given by them. But this is all qualitative again there is as I said that there may be always bias. Ok, but this kind of things.

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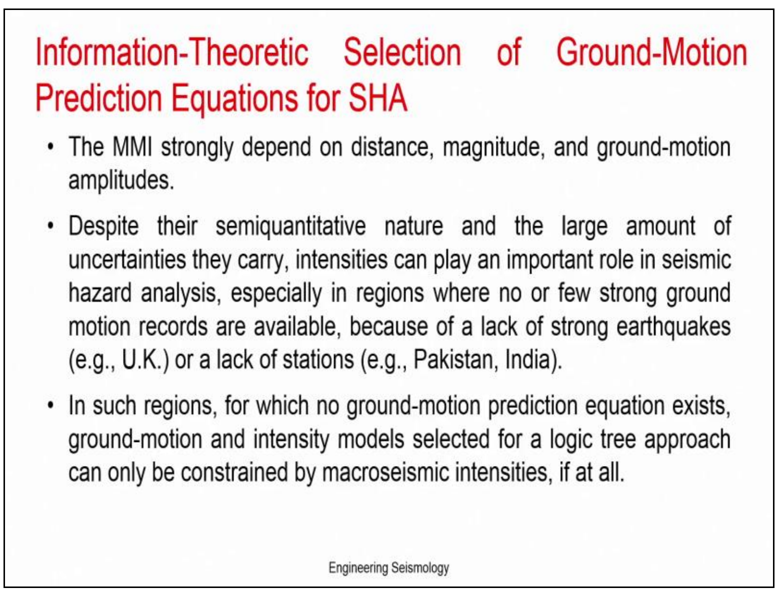

So, in order to overcome this ok basically the systematic procedure has been derived by the scientist. Ok using the information theoretical approach where you can select a ground motion based on the some recorded data in your region or there is a data which is actually intensity data available for the region. This is basically helps even the equation developed for the rest of the world can be adaptable for your region as long as the equation predicts well with the your own regional data.

Ok. So basically this was intended but there are many countries they do not have their own GMPEs. So, even that India before 1996 we do not have any GMPEs, Pakistan so there is no GMPEs before several years so something like that. So in order to overcome that ok the new procedure has been suggested.

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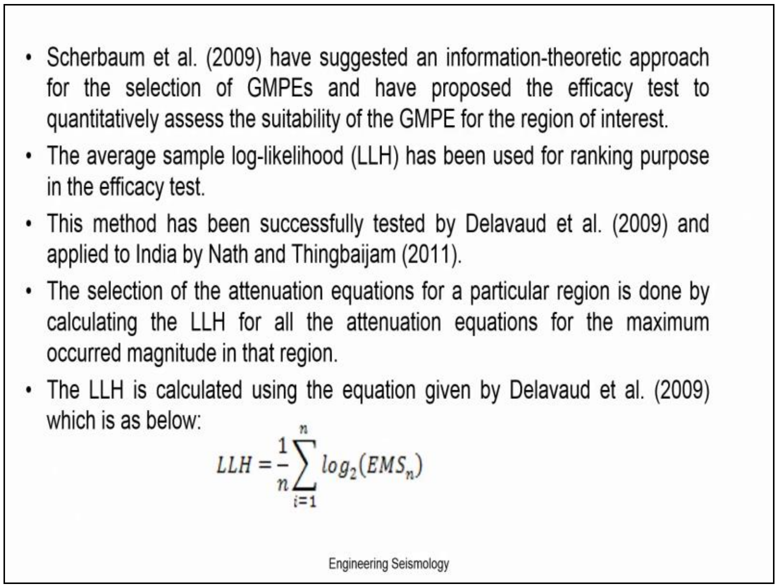

Which; is called as actually the theoretical approaches or efficacy test using the log likelihood estimation. Scherbaum et al 2009 suggested a information theoretical approach for the selection of GMPE have proposed efficacy test ok so quantitatively to access suitability the GMPE of the region. So we are going to discuss in detail this with the typical calculation so that when you doing any hazard analysis, you do not bias used by your knowledge. You only go by the; what is theoretically should be done are what is correctly should be done that part we are going to discuss here.

So basically, you first identified the list of applicable GMPEs in your region you prepare a complete list. Ok once you are done that then you can go by this theoretical approach. Ok. So you prepare a list and collect a available recorded ground motion data or the isoseismal map anything is fine. If you have the isoseismal map you need to have the conversion from intensity to PGA. If you have directly recorded PGA it is well and good.

Ok, if this is the first; once you have collected that then you estimate the log likelihood values of each equation and compare that value how with the recorded value for the set of recorded value and try to arrive a LLH based on the number of model and then the error associated. The EMS is given for the intensity based calculation by the Delavaud. So, you can use PGA.

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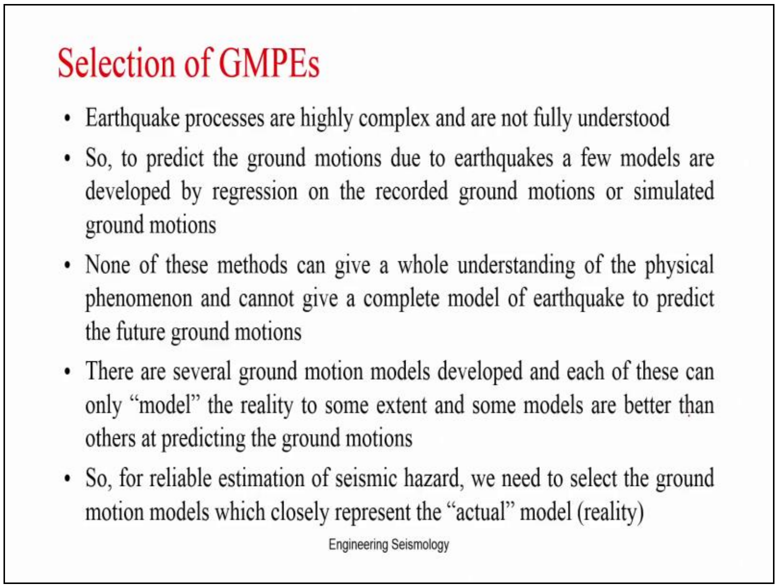

So, this works basically to select more suitable equation ok particularly because this seismotectonics more complex and not fully understand. So its selection of equation without any proper procedure leads to a lot of error. So that is why this kind of actual; so basically the reliable estimate of seismic does not need to select a more appropriate equation, which is close to the actual future earthquake or representative of the actual hazard in the region.

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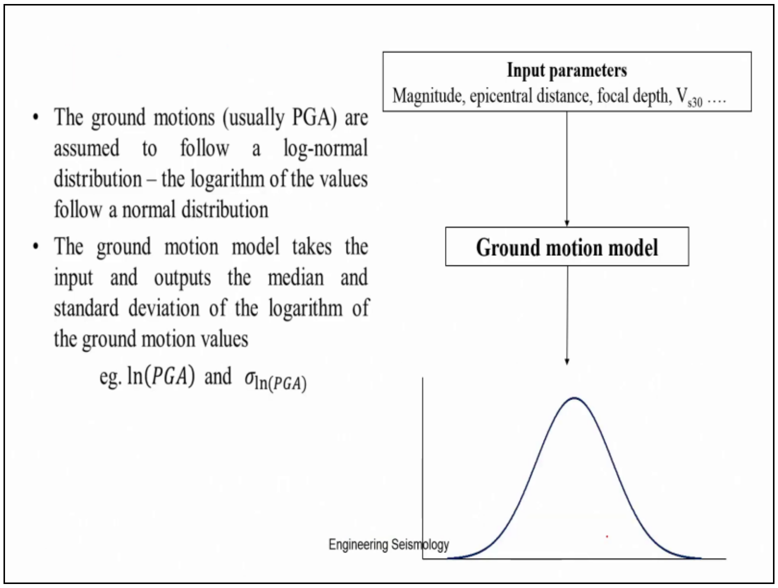

So that region for example, you take so from the GMPE you get a ground motion model that model basically is the function of magnitude epicentral, focal depth VS30 something like that. So this basically you have the actual model for the one region which you do not know ok you are saying that you do not know that what is actual model suitable for the region? But you have the model so, which is basically similar functions of parameters, but it is more or less may be applicable may not be applicable.

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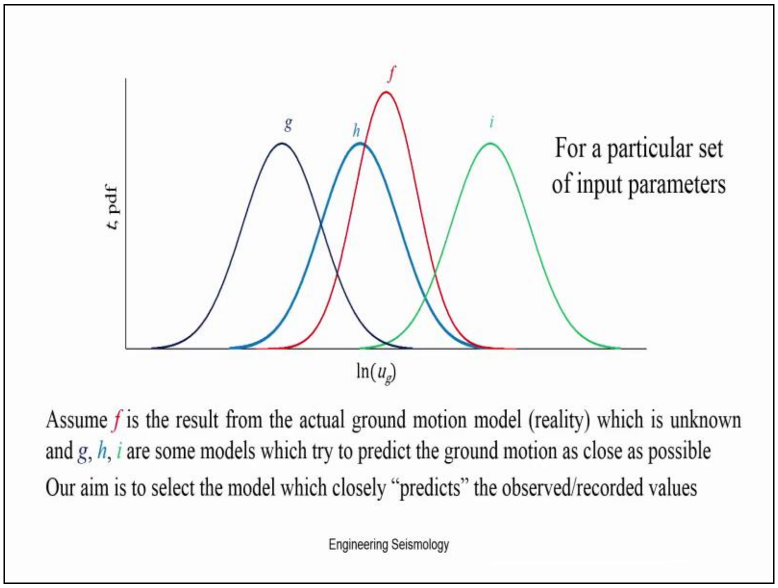

So those models ok for example this is your actual model. This is the different model applicable for your region. As I said that you select all the applicable model which is g, h, i these are all the applicable model. This is the actual model what you are going to do. So, how this selected model close to the actual model that model can be taken as a best model for the region. So that to do that you have to do the efficacy test.

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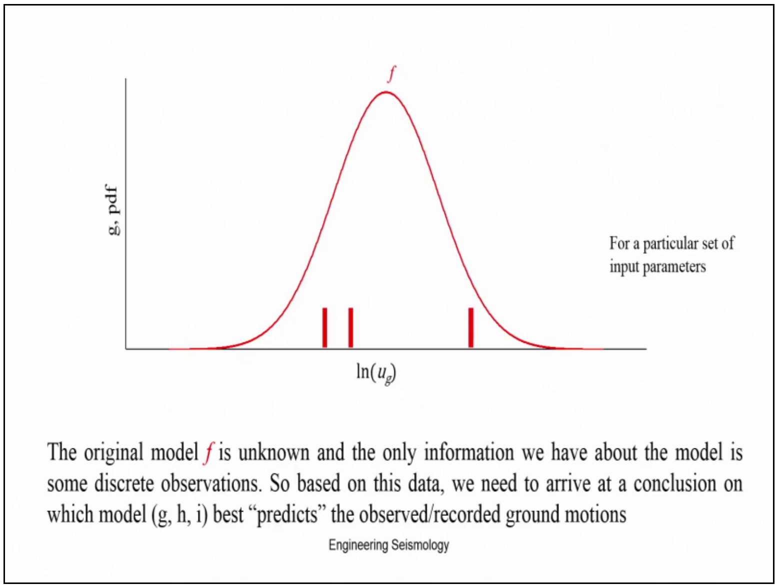

So how the efficacy test is done basically the original model f is unknown, and the only information we have is that about your model is some discrete observation. So, that means we have some data here and there based on this model. So based on this data, we need to arrive at the conclusion like which model like g, h, i like we discussed in the previous chapter best predict a observed recorded data in this unknown model of region.

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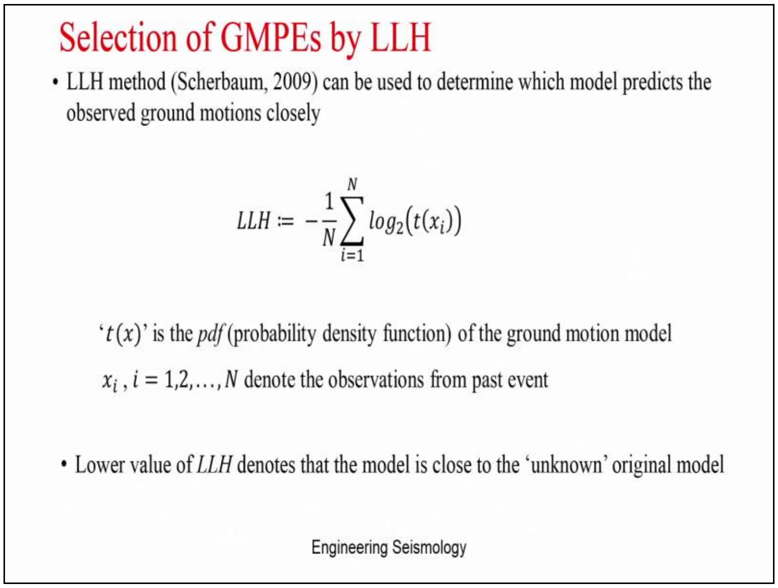

So, what we will do basically the LLH approach suggested by the Scherbaum says that the t x is the PDF probability density function of the ground motion model x i is 1 to n denote observation of the past earthquake data, if you take this ok model from the observed data and compare and take the LLH value ok then you will get your best unknown; the model which is close to the unknown model of the region.

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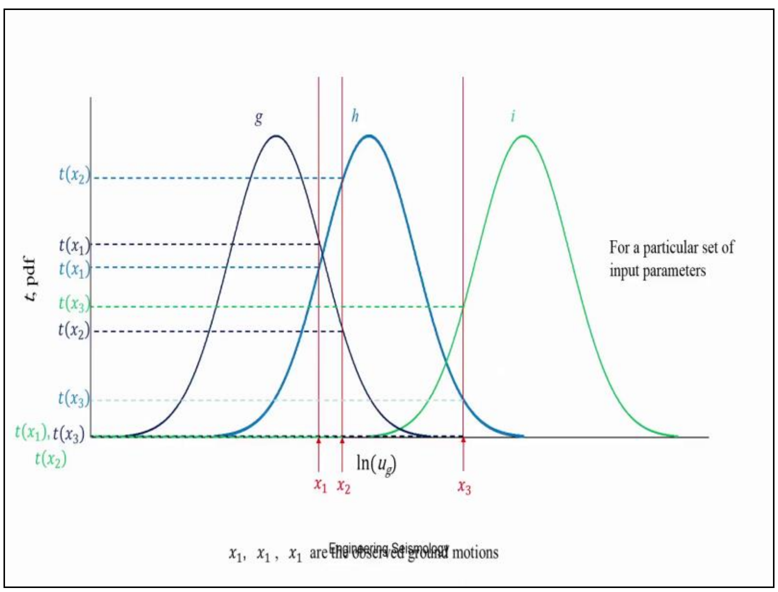

So, for example you estimate a each discrete point. So what is the; from the each model like g, ok what is the g? So, g what are the model you got from the g and h what is the value and t what is the value t x ok, so i, so t x we estimate for i model, g model and h model then respective to x 1 to n you take that.

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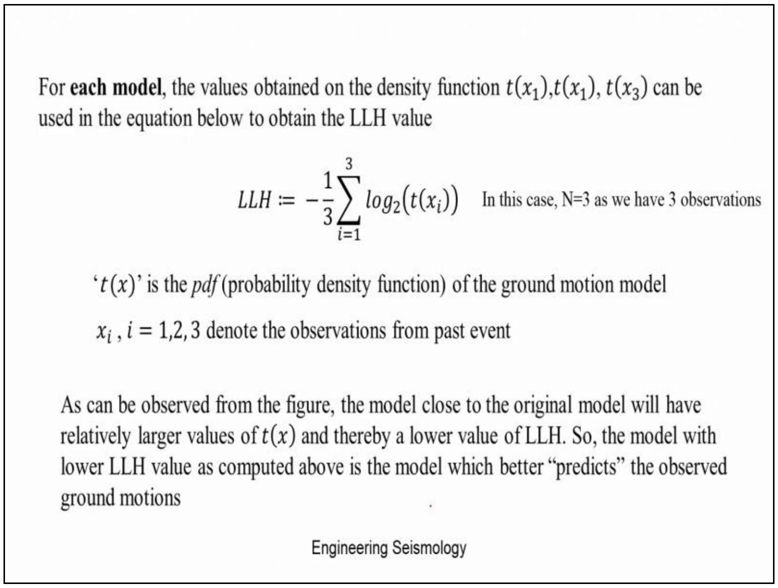

Then from there you go to estimate your observed value and try to compare both. So whichever is giving a lowest LLH value that LLH value is actually considered as a more; that model considered as more suitable models. So for example 3 equation used so 3 you should consider this is from the model are the known recorded data.

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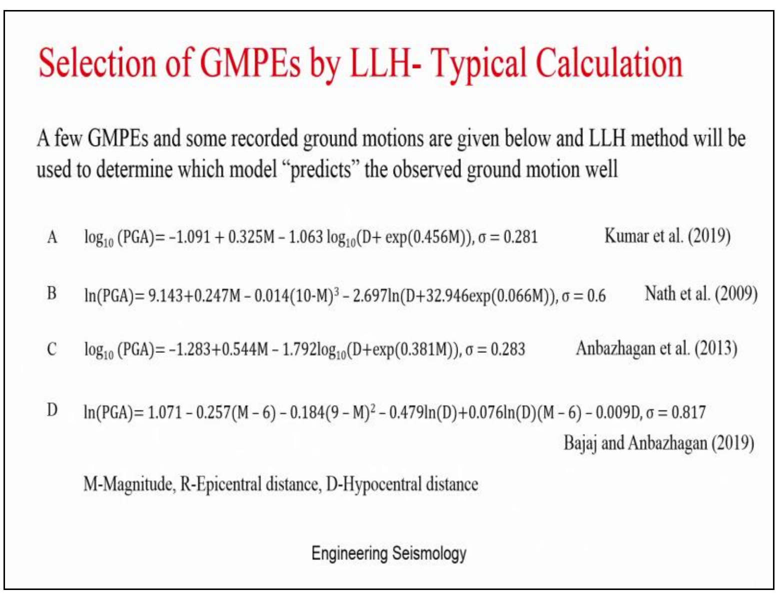

So, I will give you the typical example how it works. Let us take this 4 ground motion model which is applicable for the northern India. So, like one A, B, C, D this is the functional form. Ok in this model. Ok. I have the observed data for the region so much.

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Selection of GMPEs by LLH- Typical Calculation

These are the recorded ground motions of an earthquake

Magnitude, M_w 5.7, Focal depth 10 km

Observation	Epicentral distance, km	PGA (g)
x_1	39	0.367
x_2	59	0.129
x_3	66	0.248
x_4	81	0.140
x_5	84	0.179
x_6	96	0.112
x_7	99	0.069

These are the observed ground motions (PGA) that will be used to select the models

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So I have 7 observed data and 4 ground motion model so how I will select using this. So what I will do basically.

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Selection of GMPEs by LLH- Typical Calculation

$$t(y) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2\right)$$

Calculations – For GMPE-A

Obs.	Epicentral distance, km	x, ln(Obs. PGA)	μ, ln (PGA) From GMPE	$t(x)$	$log_2(t(x))$
x_1	39	-1.004	-2.487	0.044	-4.492
x_2	59	-2.047	-2.806	0.310	-1.690
x_3	66	-1.393	-2.906	0.040	-4.640
x_4	81	-1.968	-3.089	0.137	-2.864
x_5	84	-1.718	-3.117	0.060	-4.068
x_6	96	-2.185	-3.244	0.161	-2.631
x_7	99	-2.669	-3.270	0.401	-1.319
				Sum($t(x)$)	**-21.703**

$$\text{LLH} = -\frac{1}{7}(-21.703) = \mathbf{3.100}$$

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So, I estimate LNF observed data, this is a LNF from the observed data we are converting. Since I know what is the distance and magnitude of the observed value I can use the same thing of the seven model ok 4 model to estimate a PGA and convert that PGA to the again as a LNF PGA ok similar to x I also convert to u ok, then I will take x and u and tried to estimate t x using this relation. So then I take a log n so this equation comes and then submit and take this value is my LLH value.

Ok. So this calculations you can do it in the even in a simple Excel so in case if you are not getting you can talk to our TA they will try to explain. Ok. So this actually coding in the Excel you can do ok calculator may be slightly difficult because we need to code this LN and then exponential all those things. And also the equation GMPE equations are slightly bigger in size. Ok so you can see that the GMPA this is my LLH value.

Similarly GMPE b this is observed estimated from the GMPB and converted then t x and l x and then LLH.

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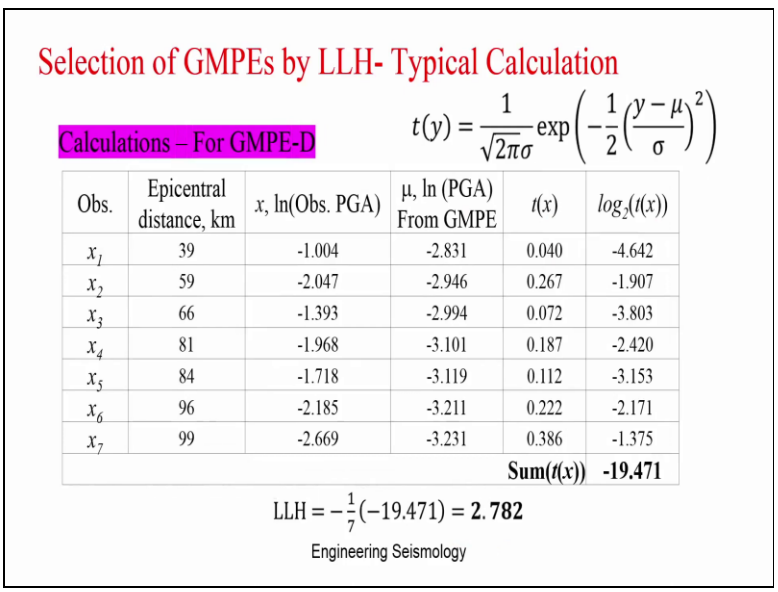

Selection of GMPEs by LLH- Typical Calculation

Calculations – For GMPE-D

$$t(y) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left(-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2\right)$$

Obs.	Epicentral distance, km	*x*, ln(Obs. PGA)	μ, ln (PGA) From GMPE	*t*(*x*)	$log_2(t(x))$
x_1	39	-1.004	-2.831	0.040	-4.642
x_2	59	-2.047	-2.946	0.267	-1.907
x_3	66	-1.393	-2.994	0.072	-3.803
x_4	81	-1.968	-3.101	0.187	-2.420
x_5	84	-1.718	-3.119	0.112	-3.153
x_6	96	-2.185	-3.211	0.222	-2.171
x_7	99	-2.669	-3.231	0.386	-1.375
				Sum(*t*(*x*))	**-19.471**

$$\text{LLH} = -\frac{1}{7}(-19.471) = \mathbf{2.782}$$

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So, similarly for the GMPE C and GMPE D as I said that 4 GMPE we have estimated like this and I tried to compare ok this LLH value and take this LLH values support your data how it can be ranked.

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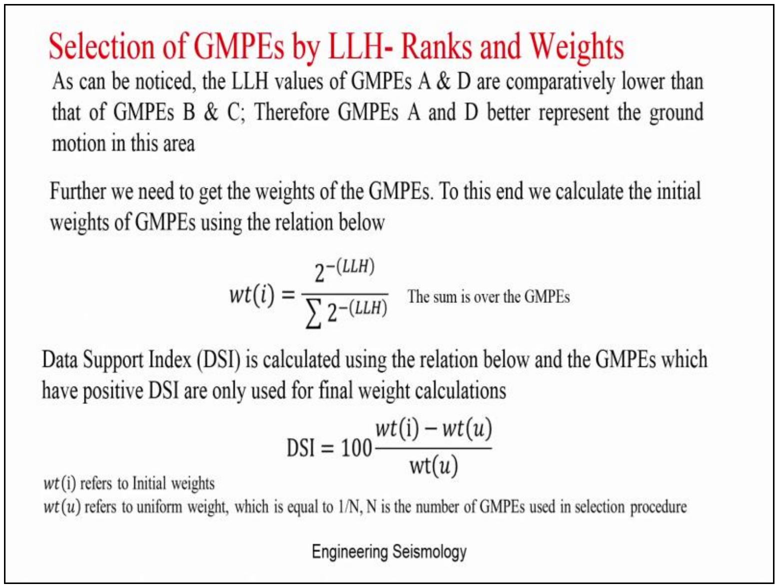

So far that we will use again the Scherbaum based procedure the weight of particular so the model based on the data is actually 2 power of LLH minus summation of the LLH the data support index is actually the 100 weight i weight u and weight. So this DSI and weight will give you the ranking order of the equation.

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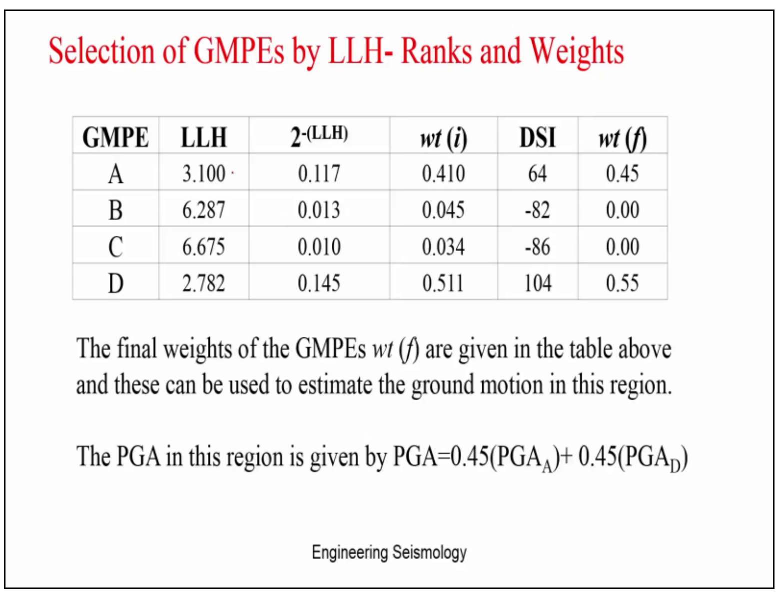

This also it can do it in the Excel so you can see that the 4 model their respective LLH value, as I told you that the lowest LLH value will be the best equation. So among the 4 equation the equation D and A can be the best equation. Let us see how the weights are coming take 2 - LLH and weight and you can see the weight. So, we can see that our support index when you come to the data support index you should have that more data support positive side not on negative side.

So in that case ok, you are basically losing the; your negative part you should remove. So, you can see that this and these are good. In this also again the estimated weights are this one. So this is a ranked 1 this is a ranked 2 so these two equations can be used as a most reliable equation for this particular case for the hazard analysis. This is how you can estimate your PGA.

Since you have the two equations, the equation will give the weightage so much so then you will get here your basically this should be 5 5 this should 0.55 this value actually. So this will be the; this value ok so this value so you can get your PGA value. This PGA value will be more representative. As we have used the regional recorded data of the earthquake to select a different GMPE model ok which may applicable which may not applicable ok so which is developed for this region or any region does not matter.

But we should do after short listing qualitatively you can quantitatively find out what is applicability. So the LLH many times will lead to that it will give you the ranking but it will not tell you how is data support index so that we should also do you a weight and data support index calculation that will give you clearly the ranking and weight of the particular GMPEs.

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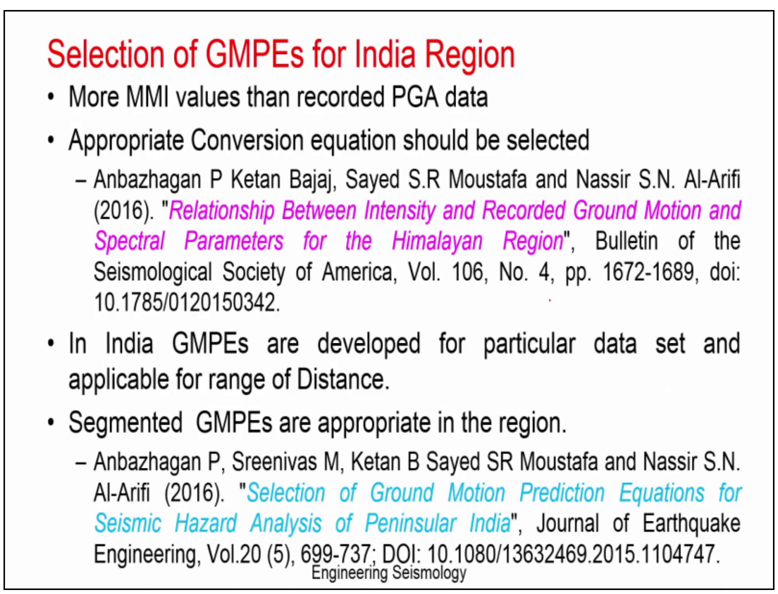

So this study is actually the Scherbaum actually supported for the taken ok for the 0 to 300 kilometre once. So, we find that since our many of the GMPEs are having different distance band some of them less than 100 some of them 100 to 250 something like that and also the taking enter 300 region as a similar kind of wave propagation may not be appropriate. So I come up with the concept of like taking the segmented based ranking of GMPEs.

Ok By we want to say that you can segment the GMPEs 0 to 100, 100 to 200, 200 to 300, 300 to 500, something like that depends upon the available data then you can do that ranking. So we also give any relation between the intensity and PGA conversion particularly Himalayan region where there is no many recorded PGA but you when using the limited available data, you are given their conversion equation that are useful to convert intensity to PGA and do this kind of analysis.

So we have specifically published paper on this GMPEs selection as well as the conversion of GMPEs to intensity you can refer to those papers which also used.

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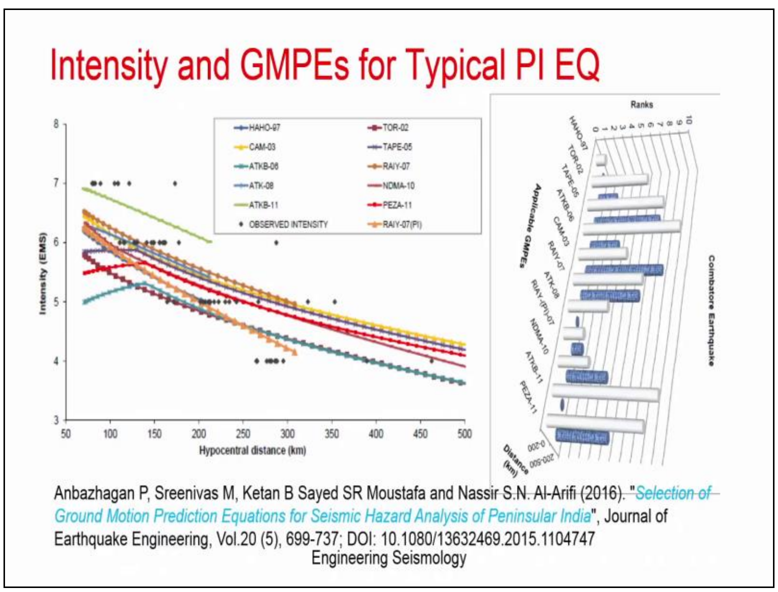

For example typically for the Peninsular India so we take an observed intensity we have done a distance segmented based GMPEs selection. You can see that 0 to , 200 to 500. You can see some of the this one having the ranking; so the one ok the best ok so here are the ranking of 7. 7 is good one. So here 9 so but other distance is coming less you can see ok. So that also for the equation which is not performing 0 to 200 well, but for farming 200 to 500 well, ok. So that kind of discrepancies can be avoided when you do the distance based GMPEs selection or distance segmented GMPEs selection that procedures described.

As I told you that I not only just read and adapt whatever I read we try to do research on that ok this some of our research findings which will be useful to improve our seismic hazard estimation practice in the country. Ok. So this is the way you can select your GMPEs of the different regions. So now you know, what is the GMPE and how the GMPE can be used to estimate the different GMPE can be used to estimate hazard value.

And then how do you select a best GMPE using the log likelihood method. As I told you that this calculations in case if you are not getting yourself, you can talk to the TA as well as me where there will be typical Excel be shared to show how this has been done or will be explained to you. So basically this is like we are discussing in the PPT sometime it may not be make you to work out because it is a video class.

The regular class I will tell you to ok you work out here and see the values and check but it is not possible here. So, anyway that you can clarify with the TA interaction and interaction with me when there is an opportunity.

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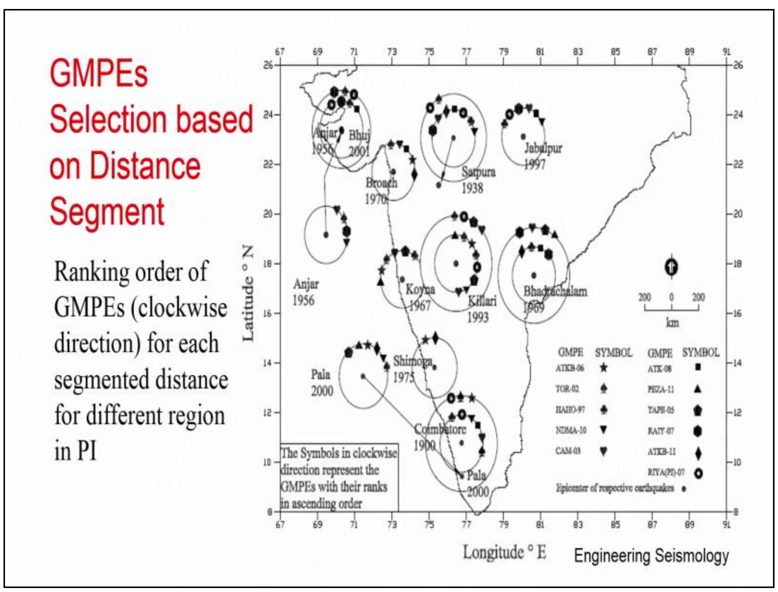

So with this we can see that as I told you that this is a different South India earthquake which is a damaging earthquake. You can see that some of the earthquake will ranked. Ok some of the GMPEs will be ranked for specific earthquake in the first and second is not ranked in the other earthquake or ranked later, for example this particular symbol you can take. So, this is a belong to which earthquake? So, this is a belong to basically the Raghunath and Iyangar.

You can see that ok so from the distance of 200 and above this is placed one. So this gives basically the ranking order GMPEs clockwise direction from each segment distance for the different region. So for the same equation Jabalpur earthquake is comes in the order of 3 ok. So in the Satpura again first, so in the Coimbatore earthquake it is not even coming. Palour it is again first. Ok Shimoga not even placing, Koyna it is in the fifth position.

So we can see that where it rank. Here the 7 Ok, so here are not even surfacing here it surfacing so like that it depends upon the your regional parameters. Ok geology ok, even the GMPE even though developed for the whole Peninsular India we were seen that sometime it is not ranked, sometime it is coming to the best, sometime it is not coming to the best. That kind of analysis will help you basically selection of GMPE analysis will help you to avoid ambiguity of this kind of position in GMPEs.

You select your cases when you was doing the hazard analysis adopting the procedure what we have been discussed. So, this procedure basically part of our rupture based analysis generally because your DSHA PSHA does not talk about anything on selection of GMPEs at all. It gives you can select GMPE that is all. He is silent about what model should check which one is best which one is not best. So in order to overcome that only the rupture based analysis has been framed in that we talk about the selection as one of the criteria.

OK where are you rank them weigh them and identify the best GMPEs for the hazard analysis. So this is that typically GMPE selection done for the complete Peninsular India.

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GMPEs Selection based on Distance Segment

TABLE 5 Typical calculation of Log-likelihood [LLH], LLH based weights [W] and Data support index [DSI]for Coimbatore earthquake using all GMPEs for different distance segments

	0–200 km				200–500 km				Nath and Thingbaijam [2011]* [0–300 km]	
GMPEs	LLH	DSI	W	Rank	LLH	DSI	W	Rank	LLH	Rank
HAHO-97	1.619	53.5363	0.195	1	NA				2.7369	4
TOR-02	2.193	3.4246	0.131	6	1.882	91.7751	0.319	2	2.5859	2
TAPE-05	2.608	−22.6978	NC	NR	4.912	−76.5214	NC	NR	2.8335	7
ATKB-06	3.488	−57.7043	NC	NR	2.154	59.0428	0.265	3	2.3939	1
CAM-03	1.985	19.6301	0.152	5	5.023	−78.2451	NC	NR	2.7810	6
RAIY-07	2.245	−0.0983	NC	NR	4.069	−57.9722	NC	NR	NC	
ATK-08	1.893	27.3306	0.161	4	NA				2.6911	3
RAIY-[PI]-07	1.621	53.5043	0.195	2	1.504	148.8741	0.415	1	2.7526	5
NDMA-10	1.872	29.1081	0.164	3	3.563	−40.1503	NC	NR	NC	
ATKB-11	3.925	−68.8224	NC	NR	NA				NC	
PEZA-11	2.907	−37.2112	NC	NR	3.731	−46.8031	NC	NR	NC	

Note: 1) NA: - Not Applicable and 2) NC: - Not considered and * Previous study in the region.

Anbazhagan P, Sreenivas M, Ketan B Sayed SR Moustafa and Nassir S.N. Al-Arifi (2016). "*Selection of Ground Motion Prediction Equations for Seismic Hazard Analysis of Peninsular India*", Journal of Earthquake Engineering, Vol.20 (5), 699-737; DOI: 10.1080/13632469.2015.1104747

Engineering Seismology

You can see the distance segment what we are given and their ranks and this one this is the typical study by the Nath and Thingbaijam where they used rank, for example the HAHO Peninsular India so we have told that it is ranked 1 for 0 to 1 and then 200 to 500 it is not applicable but they are given weightage of 4. So, similarly the GMPE developed for the Atkinson and Bore 2006 we found that which is not valid for 0 to 200 but it is valid for 200 to 500 when they use 0 to 300 they taken that as basically the number one rank.

So, this kind of ambiguities can be minimised because as we know that the geology place role in the Crystal Rock ok Crystal rock deformation, which is reflected in the geology. So the selection of the GMPEs base and the segmented distance will be more appropriate than the selecting for the entire distance that was highlighted in this paper. So wher you can go through that we are given a typical GMPEs list and selection procedure and how it is applicable and all.

So, this is also quite old because now we are 2020 so these are 2016. Ok. So you we should see that these are basically updated every five years once. So, will be soon updating this after we developed a new equation and all which can be overlooked are we can be again consider for the hazard analysis. With this we will close this class. So we talk about the ground motion prediction equation and how to select a representative ground motion prediction equation for hazard analysis considering the regional data ok that we discussed.

The next class we are going to talk about the seismic hazard analysis of the different method how to do a typical case study with example, so that will be our last class of these course. As I told you that since it is not a I mean sitting class ok. So some of the calculation what I am describing or explaining maybe you may not able to catch up does not matter. It will be given as a assignment for you. So you can also work out and clarify that you are getting the results or not.

If you are not getting the results we can interact with the TA as well as me. So thank you very much for watching this video we will meet you on the next class that will be the last class of our course seismic hazard analysis and typical calculation ok thank you very much.