Introduction to Engineering Seismologyles
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Lecture-62
SHA - Prediction Equation for India

So Vanakam so will continue our lecture on engineering seismology. So, I do not know many of you are aware that there was a earthquake in between the Bhuj and then the Pakistan ok then Gujarat ok the Bhuj region of the magnitude 5 plus with focal depth of 10 kilometre. So this earthquake was reported in the USGS website. It has been given a yellow warning not a green. Ok, so, as I told you that if the magnitude of 5 occurs in USA or any developed countries like in Japan and other place.

Ok so that is actually nowhere related, but the same magnitude of 5 is occurred in India which is equal to the effect in the 6 magnitude in Japan and USA kind of thing. So this was the one of the news generally before we are ending our courses of this magnitude happen. I do not know many of you felt are reported on this date where the; yesterday this basically ok 14 June 2020. So, there was 5 plus magnitude of exact magnitude that early 5.1 or 5.4. Of course I am not very sure I did not see that Indian Meteorological data, but USGS it was announced that actually.

So we have been discussing about the prediction of the seismic hazard values ok estimation of the seismic hazard value. So you have seen that the estimation of seismic hazard values one has to know what is the maximum expected magnitude. What is the minimum ok distance it can occur and then what is the recurrence relation based on the past seismicity data? So these things we have discussed. So, these parameters going to the; your hazard estimation and basically the hazard estimation is done using the predictive models or predictive equation.

So, today class we are going to discuss about what are the different predictive equations are available particularly in Indian scenario as and now I tried to make the effort basically do going through different research paper and try to summaries those equations part of my course ok, but this equation as on today. And also you need to verify the original papers ok you should not take it from the course directly. We should verify original paper if you want to use that equation and estimate hazard values only I am giving you that summary.

So it is not a main reference, so you should check original paper. Some of the equation given developed by my own team also, but still you should go to the respective paper rather than looking at our PPT. Our PPT will give you the information about the; what are the different equation we are having ok as on today? Ok, so this may be keep updated frequently depends upon the period ok and the data as well.

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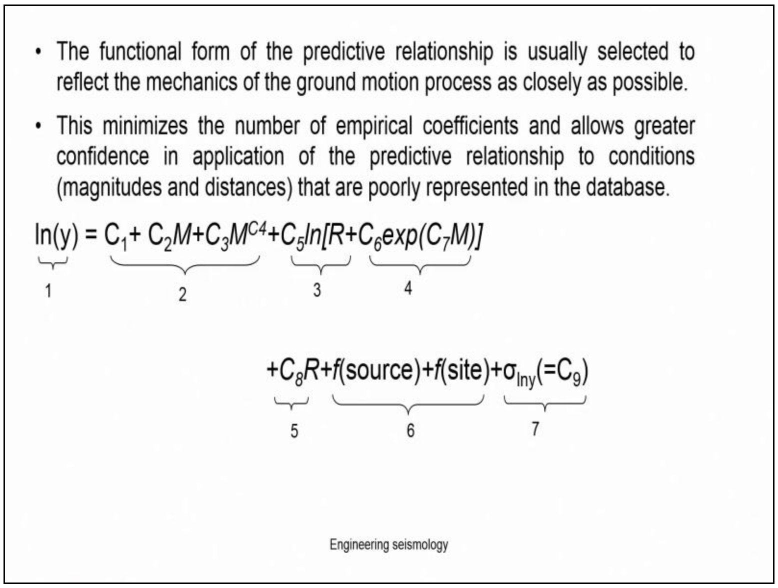

As we have seen that the predictive equation is the function of M which we have seen that the maximum magnitude M and then R, so R is your hypocentral distance. So remaining are the source parameters, site parameters and error term. So, this are the major component so generally the M and R is a major contribution factor. So, the source and site is if you know that well defined source type like that normal fault, rivers fault, trust fault, transfer fault. Site means soil site, rock site. Ok subsoil medium soil, hard soil all those information will be incorporated in the GMPEs. Ok. So that is called as a ground motion prediction equation for the estimation of acceleration.

Ok or velocity if the intensity that is intensity predictive equation, if it is the duration. Is the duration predictive equation so for the ground motion prediction equation generally gives for the SA at 0 or PGA to the SA at a different period depends upon the equation when they develop?

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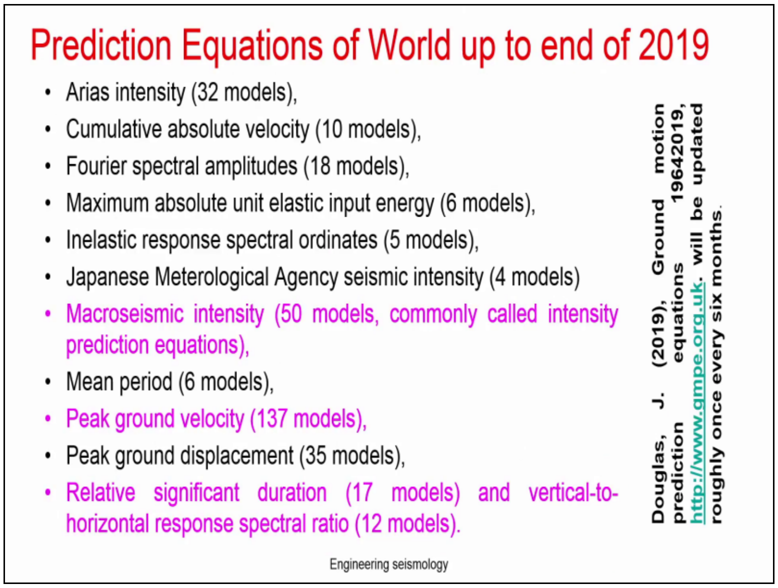

So, these are all the parameters are useful for your prediction of the future hazard values. We have seen that the ground motion prediction equation or predictive equation, where is a different parameters starting from various intensity cumulative and all I told you to refer Douglas 2019 report for the Global summary. Ok in that. The major equation will be interested on the intensity predictive equation.

And then peak ground velocity ok and then acceleration you predictive equation and then duration predictive equation these are all the things were routinely used in the seismic hazard analysis.

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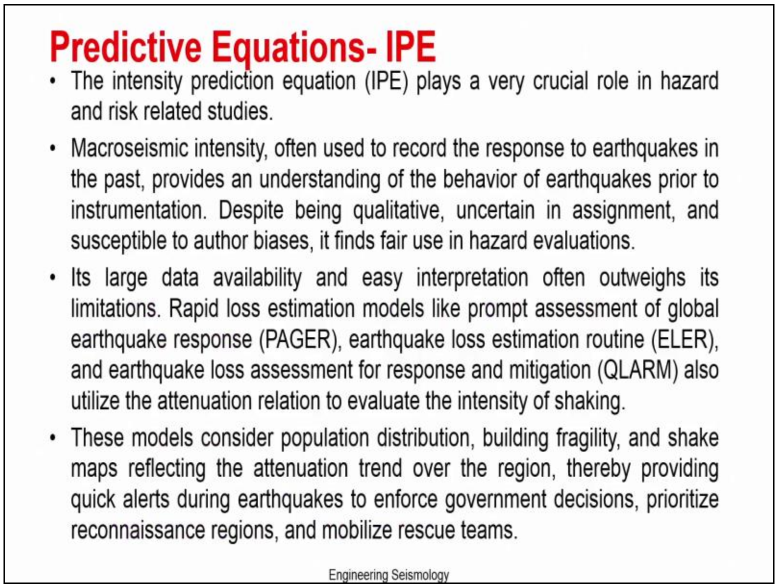

Ok. Let us see. What are the predictive equations we have as I told you that the number of predictive equation developed in India is much, much smaller than the number of earthquake occurred? So even a great earthquake you can say that a number great earthquake, for example, the number of great earthquake we have seen it was close to 11, 12 earthquake which has caused extensive intensity damage olden days before 1950 where there is no earthquake measurements are there.

But if you look at intensity predictive equation in the country right now, we have only one equation valid for the entire country. Ok. So intensity predictive equations are called as a IPE which gives the is the function of M and R you will get a intensity value for any region depends upon the past earthquake where they developed. It plays a very crucial role in hazard and risk estimation. Risk means like how much the damage you can expect.

How much intensities because intensity scale describe a damaged. If you know that damage you can estimate how many fatalities can happen. How much economical loss happen. So the micro intencity often used to record response of the earthquake in the past provide understanding of the behaviour of earthquake prior to the instrumentation. Despite of being a qualitative data uncertain assignment the susceptible unsettled biases find fair use in the hazard valuation since there is a instrumental data is lacks the many of the country one of them even India.

If you have seen that many of the greater earthquake we do not have the record. Ok. We do not have the instrumented record or obviously, we should go for the olden way of quantifying the earthquake intensity and then convert that into the PGA or you can use it as such to predict your what is the loss. So, large data available and easily interpreted of out of own weight. Its limits rapid loss estimation model; like prompt assessment of the Global earthquake response earthquake loss estimation, ok routine ELER and then the earthquake loss assessment and response and medication.

So these are all the sum of the world level programs where they are ask us what is the economical loss. What is the financial loss, how much the people will die? So those kind of models highly depends upon the intensity predictive equation. So, intensity predictive equations are so equally important particularly if you want to assess your risk and loss for any particular region because PGA will give you the only the PGA distribution.

How the failure pattern that can be obtained only from the isoseismal based model. So this model consider population distribution, building fragility, check map reflecting that innovation trend over your region thereby providing a quick alert during the earthquake to enforce government decision. Priorities recognize region and mobilize the rescue team. So, basically it to help on the disaster management planning , the disaster planning and management.

Even when I read the news that we are been talking about the micro tremors in Delhi and other region the NDMA approach Ministry of Earth Science asking them. Can we need to do anything for this? Can we be prepared for the handling any big earthquake in the region, so that is why they approached. Such kind of the preparedness the planning will need to know what is the kind of lass you expect for the projector magnitude. So that reason the intensity equations are very highly useful one.

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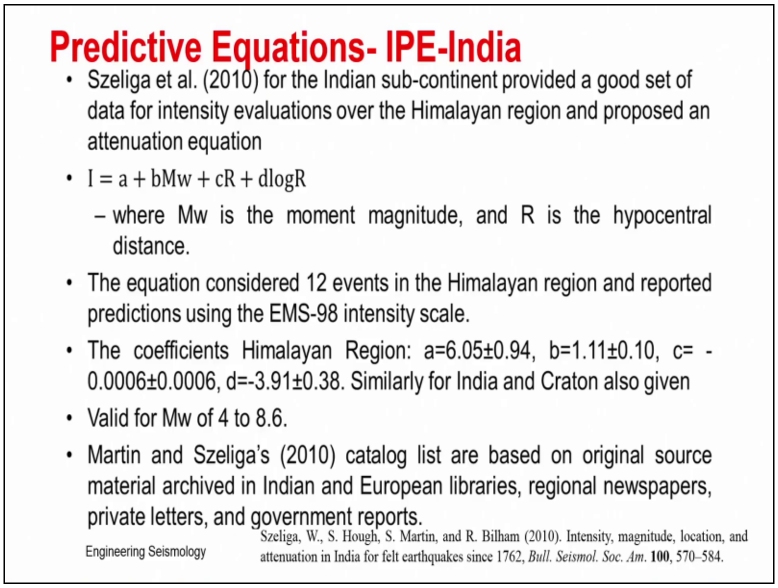

As I told you that in India there was only one equation which is a developed by Szeliga et al. This is the equation where is given so he provided basically the Himalayan region different coefficient, Craton region different coefficient all over India different coefficient. If you want to go know about the more about this Szeliga equation, please go through this, this equation also developed 2010 there was after that considerably there are few earthquake occurred Isosales maps also be available this need to be modified or updated, that is we are actually working on that some of my students.

Hopefully we can also come up with the new intensity equation for southern India and North India soon. The equation basically considered as a 12 events, the Himalayan region and reported predicted using the EMS intensity scale. Ok the coefficient of Himalaya regions are given here Martina and Szeliga catalogue list based on the original source materials archieved in India and European library, see regional newspapers, private letters and government report.

These are all the information they compiled and used to assign intensity at different distances. Magnitude from the past earthquake observation and try to get this recurrence regression equation, which is called as a intensity predictive equation which will be useful to predict intensity for any future earthquake.

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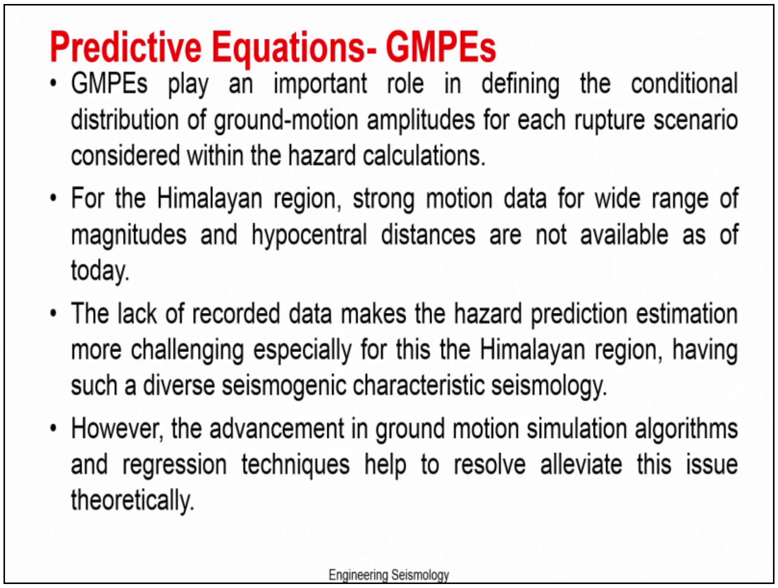

The prediction of equation GMPEs ok is the next one. So the predictive equation ground motion model. So, that this is GMPEs are basically the function of your acceleration or velocity. Acceleration means again the peak ground acceleration or SA. So those kind of equation predictive equation is called as a ground motion prediction equation because you direct know what is the motion amplitude ok that is why ground motion.

This plays a very important role on deciding that your hazard at particular calculation. So the accuracy of this kind of developed equation are very important ok, not only the accuracy. You should also see that what is the data they consider. So for example as we know that the seismotectonic of the region influence the what is the magnitude there occurred? What is the depth it is occurring? How much is the acceleration plot look like? How the duration is?

So if you develop for example the east ok part of India where the geological seismotectonic setting cannot be used in the West part of India even though is reminds same. You have to select this kind of GMPEs depends upon the seismotectonic details of the region when matching the seismotectonic region. For example the Peninsular India ok consider a stable continent region can be matched with the similar stable continent region in the world, for example, East ok Northeastern America is a stable continent region.

Many earthquake of data recorded are the understanding happened in the peninsular India has been used in the Northeastern part of the US to predict hazard and understanding the earthquake effect. Ok. So even the Bhuj earthquake that they were taken a very big lesson from the Bhuj earthquake and tried to they their designed for their buildings on that one, but still our side we forget after Bhuj earthquake most of the things.

So, we have been keep moving same way what we are doing which has to be corrected at least in the future generation.

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GMPEs for Himalayan Region developed in India

1	Singh et al. (1996)	SI_96
2	Iyenger and Gosh (2005)	IYGO_05
3	Nath et al. (2005)	NA_05
4	Sharma and Bungum (2006)	SHBU_06
5	Das et al. (2006)	DA_06
6	Nath et al. (2009)	NA_09
7	Sharma et al. (2009)	SH_09
8	NDMA (2010)	NDMA_10
9	Gupta (2010)	GU_10
10	Anbazhagan et al. (2013)	AN_13
11	Bajaj and Anbazhagan (2019)	BAN_17
12	Kumar et al. (2019)	KUM_19

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So in India as I told you that GMPEs was not well developed very olden time. The first GMPEs was developed in the actually 1996 by the Singh et al then afterwards and again 2005, 2005 and 2006, 2006, 9, 6, 10, 10, 13, 14, 19, 19. You can see that the gap ok, there is a huge gap period between that this is the short form of the equation which I will be referring next time. So the equations are at least started doing but still the number of equation available for the entire India is less than the number of disasters earthquake in the country.

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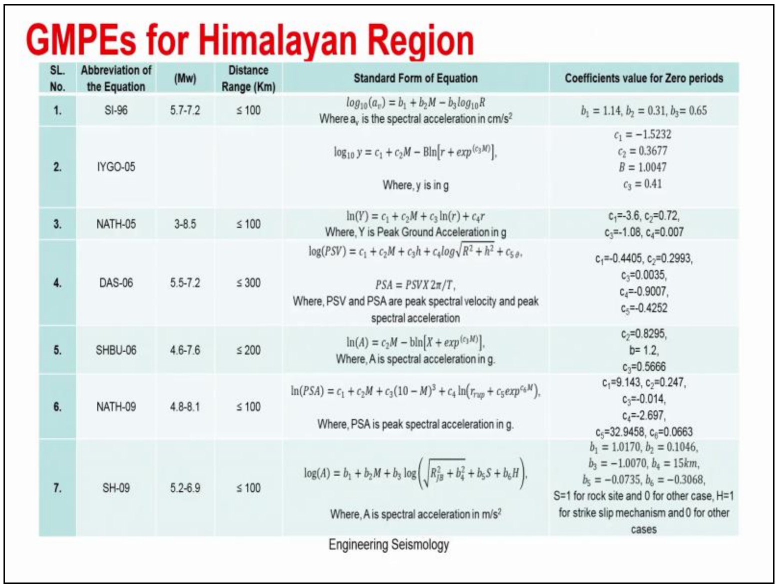

GMPEs for Himalayan Region

SL. No.	Abbreviation of the Equation	(Mw)	Distance Range (Km)	Standard Form of Equation	Coefficients value for Zero periods
1.	SI-96	5.7-7.2	≤ 100	$log_{10}(a_v) = b_1 + b_2M - b_3log_{10}R$ Where a_v is the spectral acceleration in cm/s^2	$b_1 = 1.14$, $b_2 = 0.31$, $b_3 = 0.65$
2.	IYGO-05			$\log_{10} y = c_1 + c_2M - B\ln[r + exp^{(c_3M)}]$, Where, y is in g	$c_1 = -1.5232$ $c_2 = 0.3677$ $B = 1.0047$ $c_3 = 0.41$
3.	NATH-05	3-8.5	≤ 100	$\ln(Y) = c_1 + c_2M + c_3\ln(r) + c_4r$ Where, Y is Peak Ground Acceleration in g	c_1=-3.6, c_2=0.72, c_3=-1.08, c_4=0.007
4.	DAS-06	5.5-7.2	≤ 300	$\log(PSV) = c_1 + c_2M + c_3h + c_4log\sqrt{R^2 + h^2} + c_{5\theta}$, $PSA = PSV X 2\pi/T$, Where, PSV and PSA are peak spectral velocity and peak spectral acceleration	c_1=-0.4405, c_2=0.2993, c_3=0.0035, c_4=-0.9007, c_5=-0.4252
5.	SHBU-06	4.6-7.6	≤ 200	$\ln(A) = c_2M - b\ln[X + exp^{(c_3M)}]$, Where, A is spectral acceleration in g.	c_2=0.8295, b= 1.2, c_3=0.5666
6.	NATH-09	4.8-8.1	≤ 100	$\ln(PSA) = c_1 + c_2M + c_3(10 - M)^3 + c_4\ln(r_{rup} + c_5exp^{c_6M})$, Where, PSA is peak spectral acceleration in g.	c_1=9.143, c_2=0.247, c_3=-0.014, c_4=-2.697, c_5=32.9458, c_6=0.0663
7.	SH-09	5.2-6.9	≤ 100	$\log(A) = b_1 + b_2M + b_3\log\left(\sqrt{R_{JB}^2 + b_4^2} + b_5S + b_6H\right)$, Where, A is spectral acceleration in m/s^2	$b_1 = 1.0170$, $b_2 = 0.1046$, $b_3 = -1.0070$, $b_4 = 15km$, $b_5 = -0.0735$, $b_6 = -0.3068$, S=1 for rock site and 0 for other case, H=1 for strike slip mechanism and 0 for other cases

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Ok that I want to emphasize you can see the short form of the equation we have given. So, you can see the magnitude of range valid and the distance it is valid and this is a general equation they use but you can refer the original paper and the constant respective constant for the details. You can also see that ok so you can see that the magnitude range. So one has to be careful about that particular magnitude which is applicable or not. Ok and then they are also given equation form like site class, rock all those parameter you have to carefully go through and try to understand and know you applicability and then identify that equation suitable to you or not.

So this anyway will be discussing the next class selection of the GMPEs. So, further we will discuss on this.

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GMPEs for Himalayan Region

SL. No.	Abbreviation of the Equation	(Mw)	Distance Range (Km)	Standard Form of Equation	Coefficients value for Zero periods
8.	GU-10	6.3-7.2	150-375	$\ln(Y) = c_1 + c_2M + c_3h + c_4R - g\log(R)$, Where, Y is peak spectral acceleration, g=1.55	c_1=0.4598, c_2=0.6909, c_3=0.01130, c_4=-0.00202
9.	NDMA-10	4-8.5	≤ 500	$\ln(PSA) = c_1 + c_2M + c_3M^2 + c_4R + c_5 ln[R + c_6 exp^{(c_7M)}] + c_8 \ln(R) f_o$ Where, PSA is peak spectral acceleration in g, $f_o = \max(\ln(\frac{R}{100}), 0)$	c_1=-3.7438, c_2=1.0892, c_3=0.0098, c_4=-0.0046, c_5=-1.4817, c_6=0.0124, c_7=0.9950, c_8=0.1249
10.	ANBU-13	5.3-8.7	≤ 300	$\log(y) = c_1 + c_2M - b\log(X + e^{c3M}) + \sigma$ Where y is SA in g, X is the hypocentral distance in km	$c_1 = -1.283$, $c_2 = 0.544$, $c_3 = 0.381$, b =1.792
11.	BAN_19	4-9	10-750	$\ln y = a_1 + a_2(M - 6) + a_3(9 - M)^2 + a_4 \ln(R) + a_m \ln R(M - 6) + a_7R + \sigma$ $a_m = a_5$ *if* $M < 6$ *and* $R < 300$ Else $a_m = a_5$ R is the hypocentral distance	a_1=1.071 a_2=-0.257 a_3=-0.184 a_4=-0.479 a_5=0.078 a_6=0.076 a_7=-0.0085 σ=0.817
12.	KUM_19	5.0-7.0	15≤R≤250	$\log A = C_1 + C_2M - b\log(X + e^{c_3})$ A is in g X is the hypocentral distance	$C_1 = -1.091$ $C_2 = 0.3245$ $C_3 = 0.4561$ $b = 1.0632$ σ=0.281

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Because see the equation I can see that the NDMA may be the most robust one where the gap between the I mean the magnitude ranges very wider, but there are also some issues there because this was completely synthetic data. As I told you that NDMA is completely Synthetic data. So rest of the data is actually considered the recorded but it is only a short distance it valid you see 100, most of them are 100 kilometers except Das et al.

But the Das et al magnitude is this range is very small 5.5 to 7.2. So, similarly so then we actually tried to overcome that so by adopting a more data and consuming more distance. By combining synthetic and ground motion data that again further we modified. This is basically for the Himalayan region so you can see 4 to 9 we developed and it is within 10 to 750 kilometre. So then Kumar he has developed this one with this much distance.

So as on now I mean this is a equation which can be used widely for all the range of distance. Ok. Let us see how this equation surfaces in your LLH approach like selection procedures.

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GMPEs for Peninsular India

S. No.	GMPE	Abbreviation
1	Iyengar and Raghukanth (2004) (Southern India)	IYRA-04-SI
2	Iyengar and Raghukanth (2004) (Koyna)	IYRA-04-K
3	National Disaster Management Authority (2010)	NDMA-10
4	Bhabha Atomic Research Centre (2017) (1)	RDS1-17
5	Bhabha Atomic Research Centre (2017) (2)	RDS2-17
6	Bajaj and Anbazhagan (2019) (Variable Stress)	BAN-19-VS
7	Bajaj and Anbazhagan (2019) (Constant Stress)	BAN-19-CS

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Similarly Peninsular India we have about 7 equations out of 7, 2 was developed by us, 2 was developed by the Bhabha Atomic Research Centre they have their own equation because they are the ones who basically do the detailed seismic hazard analysis for the nuclear power plant particularly the Tarapur, Vizag, Kudankulam and then the Chennai. So, these are all major plans in the South India so that they developed their own equation.

Since I was expert member in those committees this equation is also reviewed by me and assesed by me. Then NDMA they generated for entire India. So, Raghukanth and Iyengar are the very first equation in the Peninsular India where it was developed 2004 ok bye considering the Koyna earthquake and other thing. So, this is the basically if you narrow down the; this one it actually about only 3 equation why because the equation 1, 2, 3 is done by same group of researchers.

This is done by the same group. Ok. This is the 2 this is the one and this is the three only three people worked on this and developed equation which needs to be enhanced because after 1950. We have seen that number of earthquake damage in earthquake in India is close to 5 ok, but still we are the only three GMPEs developed by the three groups with the different this one.

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GMPEs for Peninsular India

Sl. No	Abbreviation of the GMPE	Functional form of the equation	Constants	Validity: Magnitude Range [M_W]	Validity: Distance Range [km]
1	IYRA-04-SI	$\ln(y_{br}) = c_1 + c_2(M-6) + c_3(M-6)^2 - \ln[r] - c_4 r + \ln[\varepsilon_{br}$	c_1 1.7236 c_2 0.9453 c_3 -0.0725 c_4 0.0064	5.0-8.0	30-300
2	IYRA-04-K	$\ln(y_{br}) = c_1 + c_2(M-6) + c_3(M-6)^2 - \ln[r] - c_4 r + \ln[\varepsilon_{br}]$	c_1 1.7615 c_2 0.9325 c_3 -0.0706 c_4 0.0086	5.0-8.0	30-300
3	NDMA-10	$\ln\left(\frac{S_a}{g}\right) = C_1 + C_2 M + C_3 M^2 + C_4 r + C_5 \ln(r + C_6 e^{C_7 M}) +$ $C_8 \log(r) f_0 + \ln[\epsilon]$ $f_0 = max(ln(r/100), 0)$ Sa is the spectral acceleration, M is the moment magnitude, r is the hypocentral distance in kilometers	C_1 -5.2182 C_2 1.6543 C_3 -0.0309 C_4 -0.0029 C_5 -1.4428 C_6 0.0188 C_7 0.9968 C_8 0.1237	4-8.5	1-500
4	RDS1-17	$\log_{10} y_{br} = c_1 + c_2 M + c_3 M^2 + c_4 R + c_5 \log_{10} R + c_6 M \log_{10} R$ Where, y_{br} = Peak ground acceleration M = Moment Magnitude R = closest horizontal distance to the vertical projection of the rupture surface in km	c_1 -2.14643 c_2 1.182929 c_3 -0.10797 c_4 -0.00117 c_5 -2.85761 c_6 0.259535	5.0-6.5	40-300km

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So this is the typical equation where you can see the range of magnitude it is applicable you can see.

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GMPEs for Peninsular India

Sl. No	Abbreviation of the GMPE	Functional form of the equation	Constants	Validity: Magnitude Range [M_W]	Validity: Distance Range [km]
5	RDS2-17	$\ln(y) = C_1 + C_2(M-6) + C_3(M-6)^2 + C_4(\ln R + Max(\ln(^R/_{100}), 0))$ $+ C_5 \mathrm{Max}\left[\ln\left(\frac{R_M}{100}\right), 0\right] - C_6 R$ Where, y = PGA in cm/s^2 R = hypocentral distance in km M = Moment Magnitude	c_1 -1.0087 c_2 0.975 c_3 -0.2559 c_4 -2.1553 c_5 -6.0061 c_6 0.05542 σ 0.5241	5.0-6.5	40-300km
6	BAN-19-VS	$\ln(y) = C_1 + C_2(M-6) + C_3(M-6)^2 + (C_5 + C_6 M)\ln R$ $C_7 R + \varepsilon\sigma$ for M≤6 $\ln(y) = C_1 + C_4(M-6) + (C_5 + C_6 M)\ln R + C_7 R + \varepsilon\sigma$ for M>6 y = PGA in g, ε is the standard normal variable M=Moment Magnitude R = Hypocentral distance	c_1 2.995 c_2 0.589 c_3 -0.216 c_4 0.486 c_5 -1.878 c_6 0.098 c_7 -0.005 σ 0.667	4.0-8.0	10-500km
7	BAN-19-CS	$\ln(y) = C_1 + C_2(M-6) + C_3(M-6)^2 + (C_5 + C_6 M)\ln R + C_7 R + \varepsilon\sigma$ for M≤6 $\ln(y) = C_1 + C_4(M-6) + (C_5 + C_6 M)\ln R + C_7 R + \varepsilon\sigma$ for M>6 y = PGA in g, ε is the standard normal variable M=Moment Magnitude R = Hypocentral distance	c_1 2.642 c_2 0.253 c_3 -0.079 c_4 -0.054 c_5 -2.199 c_6 0.155 c_7 -0.004 σ 0.422	4.0-8.0	10-500km

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So ok then the RDS and here are also now I can say that this is the most the wider range of distribution and magnitude applicable GMPEs ok for the Peninsular India. So, GMPEs for the Northeast India; basically Northeast India; as I told that is a complex so you cannot use a GMPEs North as well as the Southern India they have their own equation. Some of them is applicable in the Northern India also may applicable to the Northeast as they used a composite data but still the applicability has to be validated.

But sill the author claim that it is applicable to both so that is why it has been listed here. You can see the 99 Singh et al, Sharma, Singh et al 2016, Nath 2012, Nath et al 2005, Das et al the range magnitude and distance.

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GMPEs for North East India

SL. No.	Reference	Abbreviation of the Equation	(Mw)	Distance Range (Km)	Standard Form of Equation	Coefficients value for Zero periods
7.	Sharma and Bungum (2006)	SHBU-06	4.6-7.6	≤ 200	$\ln(A) = c_2M - b\ln[X + exp^{(c_3M)}]$, Where, A is spectral acceleration in g.	c_2=0.8295, b= 1.2, c_3=0.5666
8.	Baruah et al. (2009)	BA-09	2.5-5.0	≤ 145	$\log(Z) = aM + blogR + c$, Where Z is spectral acceleration in cm/s^2	a =0.086, b =-0.547, c =0.185
9.	Nath et al. (2009)	NATH-09	4.8-8.1	≤ 100	$\ln(PSA) = c_1 + c_2M + c_3(10 - M)^3 + c_4\ln(r_{rup} + c_5exp^{c_6M})$, Where, PSA is peak spectral acceleration in g.	c_1=9.143, c_2=0.247, c_3=-0.014, c_4=-2.697, c_5=32.9458, c_6=0.0663
10.	Sharma et al. (2009)	SH-09	5.2-6.9	≤ 100	$\log(A) = b_1 + b_2M + b_3\log(\sqrt{R_{JB}^2 + b_4^2} + b_5S + b_6H)$, Where, A is spectral acceleration in m/s^2 S=1 for rock site and 0 for other case, H=1 for strike slip mechanism and 0 for other cases	$b_1 = 1.0170, b_2 = 0.1046$, $b_3 = -1.0070, b_4 = 15km$, $b_5 = -0.0735, b_6 = -0.3068$,

Again Sharma and Baruah et al, Nath, Sharma et al ok so that range can see them and some of them he was given very small magnitude of range I am not very sure what kind of application you can use this GMPEs.

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GMPEs for North East India

SL. No.	Reference	Abbreviation of the Equation	(Mw)	Distance Range (Km)	Standard Form of Equation	Coefficients value for Zero periods
14.	National Disaster Management Authority (2010)	NDMA-10	4-8.5	≤ 500	$\ln(PSA) = c_1 + c_2M + c_3M^2 + c_4R + c_5ln[R + c_6exp^{(c_7M)}] + c_8\ln(R)f_o$, Where, PSA is peak spectral acceleration in g, f_0=max[ln(R/100),0]	c_1=-3.7438, c_2=1.0892, c_3=0.0098, c_4=-0.0046, c_5=-1.4817, c_6=0.0124, c_7=0.9950, c_8=0.1249
15.	Anbazhagan et al. (2013)	ANBU-13	5.3-8.7	≤ 300	$\log(y) = c_1 + c_2M - blog(X + e^{c3M}) + \sigma$ Where y is SA in g, X is the hypocentral distance in km	$c_1 = -1.283$, $c_2 = 0.544$, $c_3 = 0.381$, b =1.792
16.	Bajaj and Anbazhagan (2018)	BAN-18			$\ln Y = a_1 + a_2(M - 6) + a_3(9 - M)^2 + a_4\ln R + a_m\ln R\ (M - 6) + a_7 + \sigma$ $a_m = \begin{cases} a_5 & for\ M < 6\ and\ R < 300km \\ a_6 & Otherwise \end{cases}$ Where, Y is ground motion parameter in g, M is the moment magnitude R is the hypocentral distance in km	$a_1 = 1.071$ $a_2 = -0.257$ $a_3 = -0.184$ $a_4 = -0.479$ $a_5 = 0.078$ $a_6 = 0.076$ $a_7 = -0.0085$ $\sigma = 0.817$

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Similarly this is for the; this one is a Bajaj et al where our equation, which is very recently done constrain to the both north and North Eastern part of data. You can see the respective equation and coefficients. As I told you that all this equation if you want to use you should not take it from this class video, you should take their respective paper and check everything and use it. Ok.

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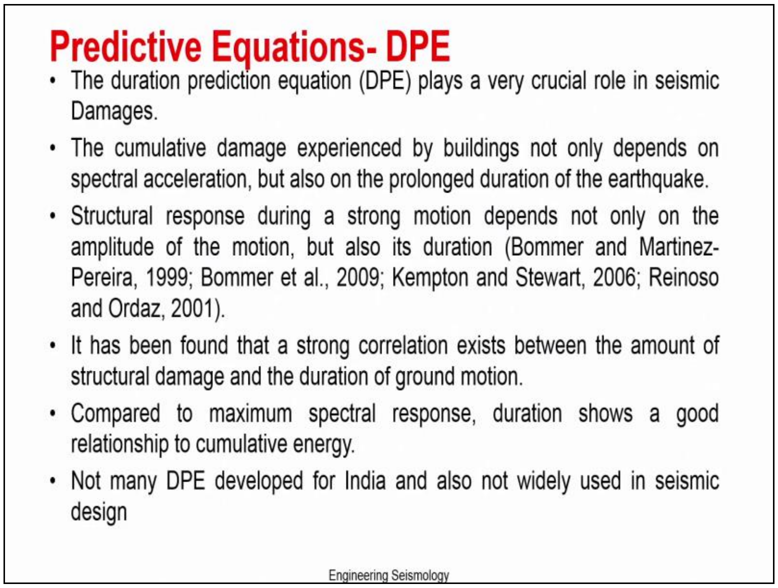

So these productive equations are useful to estimate your peak ground acceleration peak ground velocity and peak ground displacement. And also here acceleration time is really like it you will get here your response spectrum parameter those are all the GMPES are there. Another important parameter ok so apart from the intensity and then for PGAs and PGV there is another parameter like duration. We have seen the durations also plays a very important role in the damage of the success.

The cumulative damage experienced by the building not only depends upon the spectral acceleration or peak ground acceleration. It is also depends upon how the longer duration taking into picture. So that actual response during the strong earthquake depends upon the duration of this one. So the protecting duration also very important there should be need for duration predictive equation for any region. We have seen the Douglas summarized so many predictive equations.

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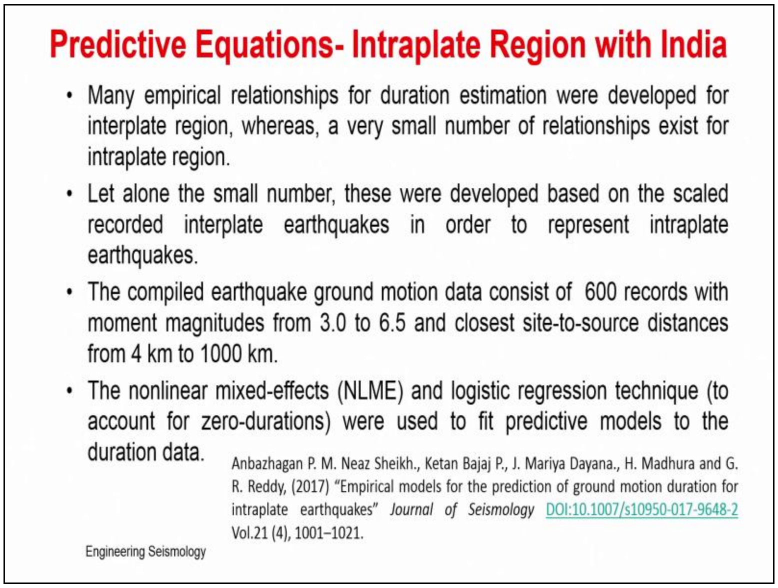

As per India concerned the predictive equations are very, very limited. There is no predictive equation at all. There is only one equation which was developed by my research team, but that is also for the intraplate region not for India. We have used India data. So, basically southern India we collect different data from the intraplate region particularly where the Bhabha Atomic Centre they used some of those intraplate GMPEs those data's that has been shared.

So then we have used that and then we come up with the new equation considering the Australia and then the other intraplate world region data from the BRC and Indian data from ourselves. So this is a paper you can refer for the; this GMPEs and see. This paper gives the ground motion prediction equation for the duration, predictive equation for the duration so this is applicable to this range and distance of this range.

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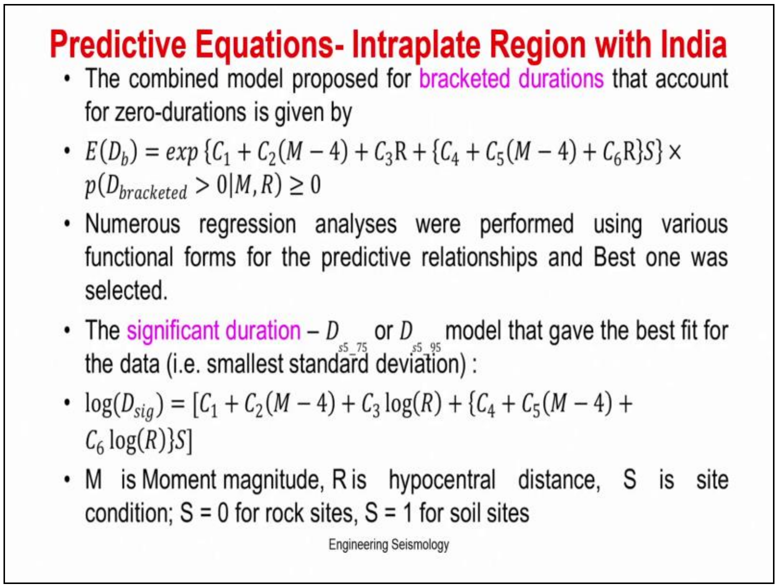

This is our first equation for the prediction duration of the intricate earthquake. So this published in the region. We basically estimated that bracketed duration. This is a function we have used then again, we done for the significant durations 5 to 75, 5 to 85 this the function we used.

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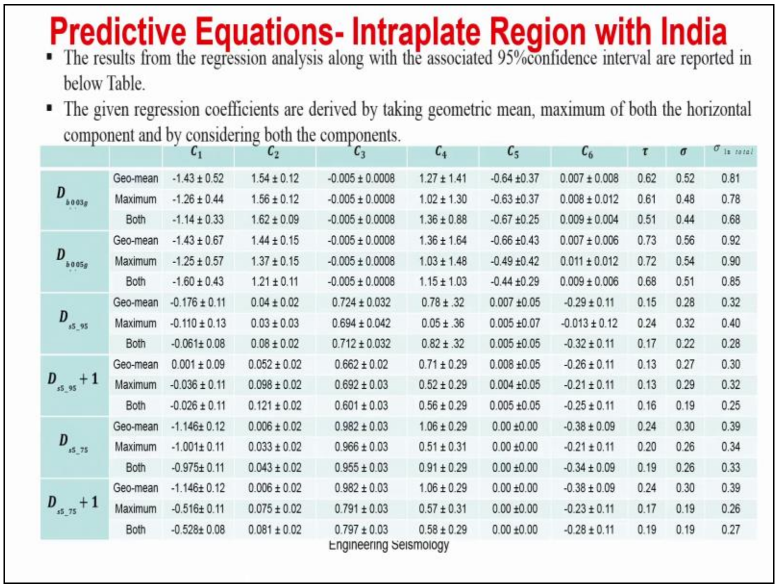

		C_1	C_2	C_3	C_4	C_5	C_6	τ	σ	$\sigma_{\ln\ total}$
D_{b003g}	Geo-mean	-1.43 ± 0.52	1.54 ± 0.12	-0.005 ± 0.0008	1.27 ± 1.41	-0.64 ±0.37	0.007 ± 0.008	0.62	0.52	0.81
	Maximum	-1.26 ± 0.44	1.56 ± 0.12	-0.005 ± 0.0008	1.02 ± 1.30	-0.63 ±0.37	0.008 ± 0.012	0.61	0.48	0.78
	Both	-1.14 ± 0.33	1.62 ± 0.09	-0.005 ± 0.0008	1.36 ± 0.88	-0.67 ±0.25	0.009 ± 0.004	0.51	0.44	0.68
D_{b005g}	Geo-mean	-1.43 ± 0.67	1.44 ± 0.15	-0.005 ± 0.0008	1.36 ± 1.64	-0.66 ±0.43	0.007 ± 0.006	0.73	0.56	0.92
	Maximum	-1.25 ± 0.57	1.37 ± 0.15	-0.005 ± 0.0008	1.03 ± 1.48	-0.49 ±0.42	0.011 ± 0.012	0.72	0.54	0.90
	Both	-1.60 ± 0.43	1.21 ± 0.11	-0.005 ± 0.0008	1.15 ± 1.03	-0.44 ±0.29	0.009 ± 0.006	0.68	0.51	0.85
D_{s5_95}	Geo-mean	-0.176 ± 0.11	0.04 ± 0.02	0.724 ± 0.032	0.78 ± .32	0.007 ±0.05	-0.29 ± 0.11	0.15	0.28	0.32
	Maximum	-0.110 ± 0.13	0.03 ± 0.03	0.694 ± 0.042	0.05 ± .36	0.005 ±0.07	-0.013 ± 0.12	0.24	0.32	0.40
	Both	-0.061± 0.08	0.08 ± 0.02	0.712 ± 0.032	0.82 ± .32	0.005 ±0.05	-0.32 ± 0.11	0.17	0.22	0.28
$D_{s5\_95}+1$	Geo-mean	0.001 ± 0.09	0.052 ± 0.02	0.662 ± 0.02	0.71 ± 0.29	0.008 ±0.05	-0.26 ± 0.11	0.13	0.27	0.30
	Maximum	-0.036 ± 0.11	0.098 ± 0.02	0.692 ± 0.03	0.52 ± 0.29	0.004 ±0.05	-0.21 ± 0.11	0.13	0.29	0.32
	Both	-0.026 ± 0.11	0.121 ± 0.02	0.601 ± 0.03	0.56 ± 0.29	0.005 ±0.05	-0.25 ± 0.11	0.16	0.19	0.25
D_{s5_75}	Geo-mean	-1.146± 0.12	0.006 ± 0.02	0.982 ± 0.03	1.06 ± 0.29	0.00 ±0.00	-0.38 ± 0.09	0.24	0.30	0.39
	Maximum	-1.001± 0.11	0.033 ± 0.02	0.966 ± 0.03	0.51 ± 0.31	0.00 ±0.00	-0.21 ± 0.11	0.20	0.26	0.34
	Both	-0.975± 0.11	0.043 ± 0.02	0.955 ± 0.03	0.91 ± 0.29	0.00 ±0.00	-0.34 ± 0.09	0.19	0.26	0.33
$D_{s5\_75}+1$	Geo-mean	-1.146± 0.12	0.006 ± 0.02	0.982 ± 0.03	1.06 ± 0.29	0.00 ±0.00	-0.38 ± 0.09	0.24	0.30	0.39
	Maximum	-0.516± 0.11	0.075 ± 0.02	0.791 ± 0.03	0.57 ± 0.31	0.00 ±0.00	-0.23 ± 0.11	0.17	0.19	0.26
	Both	-0.528± 0.08	0.081 ± 0.02	0.797 ± 0.03	0.58 ± 0.29	0.00 ±0.00	-0.28 ± 0.11	0.19	0.19	0.27

So, if you want to get the coefficients and other details you can check this table, which is given in the paper. So you can also go through, so this we have defined basically different duration significant and bracketed type of duration and we have given this equation where people can use M and R as a function and to get this one. We also consider rock site and soils site that means rocks site we will have different duration soil site will have the different duration your M and R may be the same ok that message you should I take it from here.

So these equations are useful to predict duration if you are interested for the liquefaction, slope stability and anything structural damage related studies, you need this kind of equations. So, these equations are very important role ok in hazard analysis. Because hazard analysis basically you are estimating how much peak ground acceleration we are going to expect, how much intensity you are going to expect, how much the Spectral acceleration at different period we are going to explore, how much duration we are going to expect.

To estimate that you need this kind of predictive equations with this is also called as a attenuation relation. Ok, the generally ground motion prediction equation something like that. All those things mean a same there is a predictive regressed equations, which is the function of M and R and then the soil type and source model. So generally source soil type they use for large number of data accurately available. Otherwise M and R is generally used. Ok.

So this equation as I told you so many equations in India itself. If you look at a global scale you have much more. So, how this equation should be systematically selected for any particular region so generally for the normal people who do the hazard analysis without knowing the detailed knowledge about understanding seismotectonic and then seismicity in the each region. They selected randomly any equation or they used based on their own knowledge on the GMPEs and then do a hazard analysis that how you will get affected by that how the hazard values will affect that also going to discuss part of our course.

So we we will discuss a selection of GMPEs why it is important in the next class. Thank you very much for watching this video, so I will meet you in the next class. Thank you.