Introduction to Engineering Seismology

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Lecture – 57
Seismic Hazard Analysis – Introduction

So vanakkam. So we will continue our lecture on Engineering Seismology. So we have come almost very close to the end of the course. So we have been discussing last close to like 28 to 29 hours of lectures about the different aspect of engineering seismology. We tried to understand the earthquake hazard caused by the earthquake, okay. So different hazard and how people have died, okay.

So among the different hazard so which hazard causes more damages like ground shaking hazard we have seen. Then we also try to see how people try to understand the earthquake, okay. So initially in olden days how the people try to understand the earthquake we have seen. So followed by, we also try to understand how the earthquake scientifically defined, okay. So, that we have seen.

So after scientifically earthquake defined, we also try to see how the earthquake physics, how the earthquakes are occurring, okay. What is the plate tectonics that we try to understand? So then the plate tectonics, how the waves are generated, okay how the different types of waves are defined wave character, okay. The range of velocity and different type of wave with respect to their particle moment.

Then how the waves are measured seismic instrumentation, different type of seismic instrumentation, older seismic instrumentation, okay. Which instrumentation you should use? What are the number of stations are record, global network, national; regional network and then the array kind of network that we have discussed. So then followed by how the recorded data can be used to estimate a; the earthquake size, okay the qualitative manner intensity, okay.

So, different intensity scale and then road damage intensity scale which is specifically for the roads, okay. Then followed by we also discussed the magnitude, okay registered magnitude which are developed in 1935. So then followed by the surface-wave magnitude, body wave magnitude, local magnitudes of coda wave and then the duration magnitude. We also discuss the universally well accepted known magnitude as a seismic moment magnitude, so, where the rest of the magnitude saturate, this magnitude does not saturate. So this we have seen.

Further we also seen how the recorded earthquake data acceleration time history, acceleration velocity time history can be interpreted to get a useful parameters for the engineering application. So we are doing the; seen the time domain parameters frequency domain parameters, okay. Then we have also seen the duration this one. And then the models earthquake prediction models to assemble this intensity are the PGA or PGV the frequency or duration as the function of the M and R how it is developed, okay all those since we have seen.

So we also seen that how the; we are getting the; basically the different parameters from the earthquake data like simple source model, okay. How you can relate a simple properties of the medium? How the waves are propagating? How you can estimate the amplitude of the wave by relating the energy? So that also we have seen. And we also seen what are the simulation models are available, which is considered the regional tectonic parameters, okay like the SMSIM FINSIM, EXSIM models.

So where you can synthetically simulate acceleration time history of the data, okay. So we also discussed about the response spectrum and design spectrum. So acceleration time histories, okay. So then further we gone to the discussion about the different geology and seismology, okay and then seismotectonics and past earthquake in India. So all those discussion we made, so we also reviewed.

So today onwards, we are going to discuss how to estimate a ground shaking hazard, okay. So we also talk about the seismic zonation map, microzonation. What is meant by microzonation case study of microzonation. The objective of the microzonation. Microzonation as a different steps, in that I discussed that the estimation of ground motion parameters.

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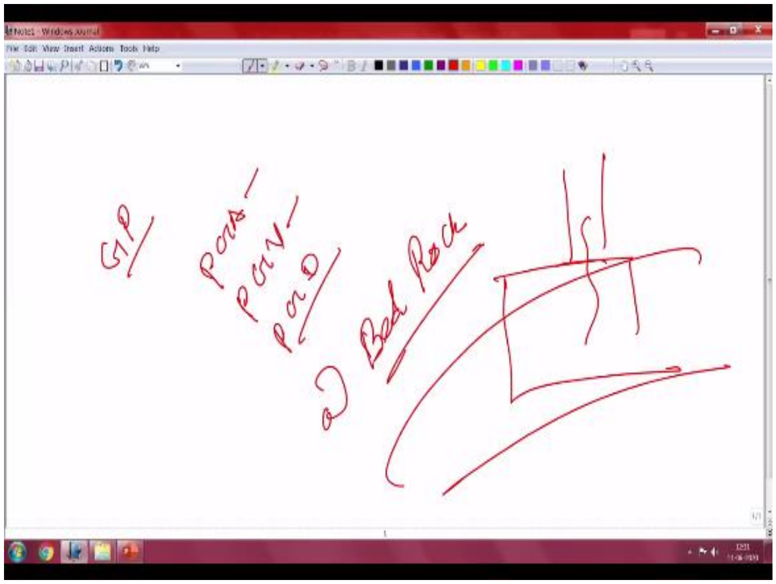

So the estimation of the ground motion parameters, okay. So in the form of PGA, okay, PGV or PGD displacement, velocity and the acceleration. So this is the; at bedrock level,. So, how? That is a first and foremost step in the microzonation. As I told you that in this class, we will be only discussing the hazard analysis at bedrock level, okay. So, the next microzonation steps whatever involved maybe we can discuss that is only applicable to the people who have the geotechnical knowledge, okay because; or civil engineering background.

Otherwise when I talk about the soil properties and then the; how the soil properties are affecting the wave and then how the waves are getting transferred? All those information need to have what is mean by soil? What different types of soils are there? How the soil will behave, okay when you want to know about the liquefaction, landslide. So because of that aspect we are cutting our course only up to the bedrock hazard analysis which is the first and the foremost step of any zonation map preparation, okay.

So that for that we are going to discuss hazard analysis from this class onwards. So this may take a couple of hours. But this is a very important aspect of the; your basic zonation requirement. And not only about the zonation requirement, you first place your structures any structures nuclear power plant or building above the bedrock directly, okay with the crust rock or bad rock, then whatever we do analysis that is sufficient. Only if we place your structure on soil, then whatever analysis we do need to be further modified considering the soil in the region, okay.

But otherwise bedrock placing of structures this information are sufficient particularly any structures on southern part or peninsular part mostly with the big structures or important structures are kept on the rock for example, dams, most of the dams are kept on hard rock, most of the high storey buildings are kept on the hard rock, okay except few coastal cities. So those kinds of places value what we do? What we discuss here will be sufficient for the design.

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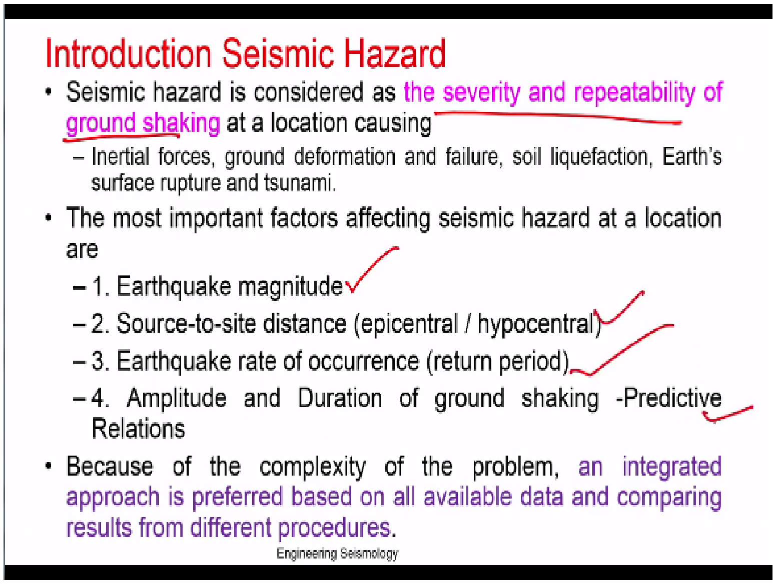

So the hazard analysis basically give the information or try to help to predict a reliable way of seismic hazard parameters. Particularly here, we talk about the parameters. So, the severity and the repeatability of the ground shaking at any location, okay. So how severe like what is the amplitude it varies? How frequently it repeat? These two aspects are basically estimated or so the forecasted in the hazard analysis. Why these are very important?

The inertial force the ground deformation and failure, soil liquefaction, earth surface rupture, tsunami; all those things are function of the severity and the repeatability of the ground shaking. So that is why you need to estimate that as a first and foremost part of that any zoning work or any engineering requirement. The most important factor which affecting the seismic hazard basically; the earthquake magnitude, source-to-site distance and then that is like epicentral/hypocentral and the earthquake rate of recurrence and amplitude and duration of the shaking.

So, there are the amplitude, okay in the form of intensity, in the form of PGA PGV all those predictive relations, okay. So, how these values are changes as the function M and R, so that we are basically looking at. Because of the complexity problem, so there is always need for integrated approach, okay to take care of this kind of analysis and produce here most reliable result, okay. That is what we should look further in this.

So each and every aspect of this component we are going to discuss in detail in our coming classes. And finally, how this can combinedly and integrated to arrive a best reliable hazard values at any site, okay. That is what we are going to do.

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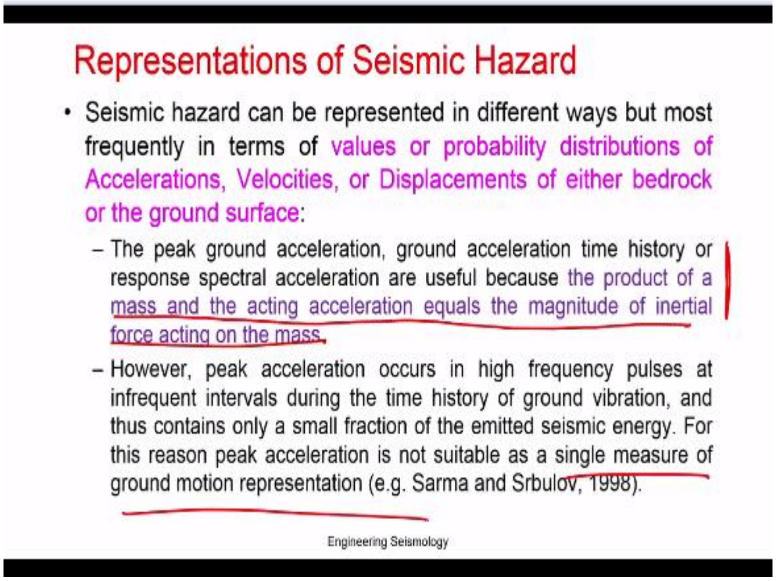

So the hazard analysis represent okay, the result, what is the result it can produce? So it should give a most frequently in terms of values or probability of distribution of the acceleration, velocity and displacement either bedrock or ground surface, okay. So in the form up intensity, acceleration, displacement or velocity or duration so these are all the some of the common way the hazard analysis should produce a result, okay depends upon the application.

So the peak ground acceleration, ground acceleration time history, the response spectral acceleration useful because the product of mass and the acting acceleration equals the magnitude of inertial force of the mass. So that is why the peak ground acceleration, ground acceleration or the acceleration time history, those are all the very important for engineering application.

So, however peak acceleration occurs at high frequency pulses. So, intermediate intervals during the time history ground vibration contain only a small fraction of the emitted seismic energy. For the reason peak acceleration is not suitable for the single measures of the ground motion parameters.

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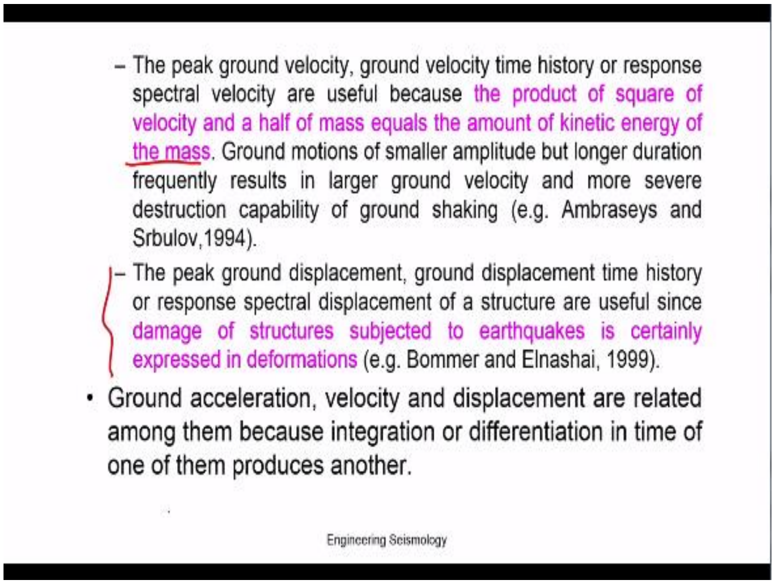

So we should go further beyond peak acceleration that is why we will consider a duration and the other say peak ground velocity, peak ground velocity times history response spectrum velocity. So this product a square and half mass equals to the amount of kinetic energy and the mass. So okay so, particularly the structures sensitive to the intermediate period, these values are record. So the ground motions of smaller amplitude, but longer duration frequently result in the larger ground velocity more severe destruction capability of the ground shaking.

So the peak ground displacement and ground displacement time history and response control displacement of structure are useful. Damage structures subjected to earthquakes certainly essential of the deformation. So the deformation based data is also useful in the structures, which is sensitive to the displacement region. So, the ground acceleration, velocity and displacement are related to the along with; because the integration and differentiation of the each one can be obtained.

Any one of them if you predict or estimate or measure you can get the other one by integration or differentiation, which we have discussed in the prediction of the; I mean the; the interpretation of the seismic record, okay.

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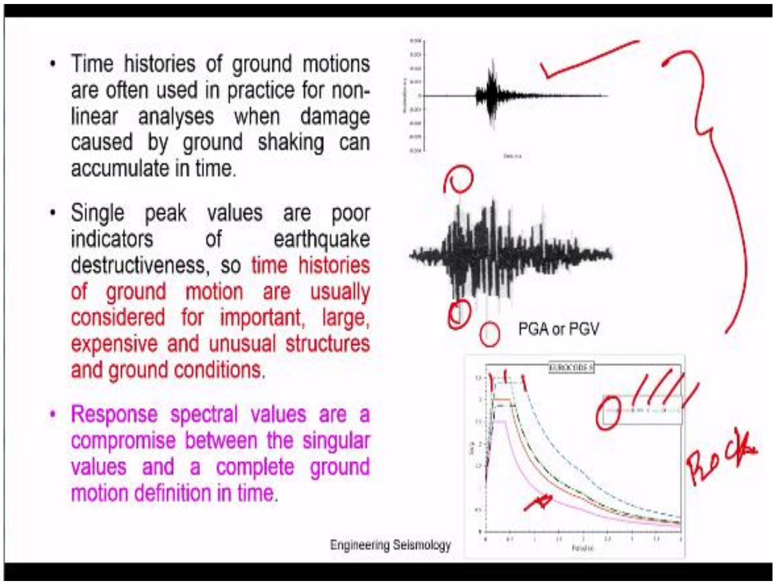

So basically we have seen the time; the acceleration time history look like, okay. So then if we want to arrive from that time domain parameters like PGV, PGV so this is how you can pick up you can see like this whichever values we need. So from this you can do the frequency domain analysis like convert the acceleration time history as a response spectrum. That response spectrum categorized based on the different condition. So, what we are going to discuss basically the site A condition, okay so this one. So, where these represent a rock, okay.

So the other places soil, okay as a variation as I told you that Indian code given a similar shape, okay for the up to velocity region. But the rest of the model code this is actually Eurocode 8 which has been updated recently to those 14 and 18 where they can give the spectrum for different site class you can see. So depends on that here the peak value, cut of period and then the bands are keep changing.

So these are all the information one has to produce a part of your hazard analysis and further steps, okay. So; but hazard analysis; what we are going to discuss only concentrating on the bedrock but not beyond that. So this may be if the time permits, so we can discuss in the other another NPTEL course if you like, if you give the feedback about the class, okay.

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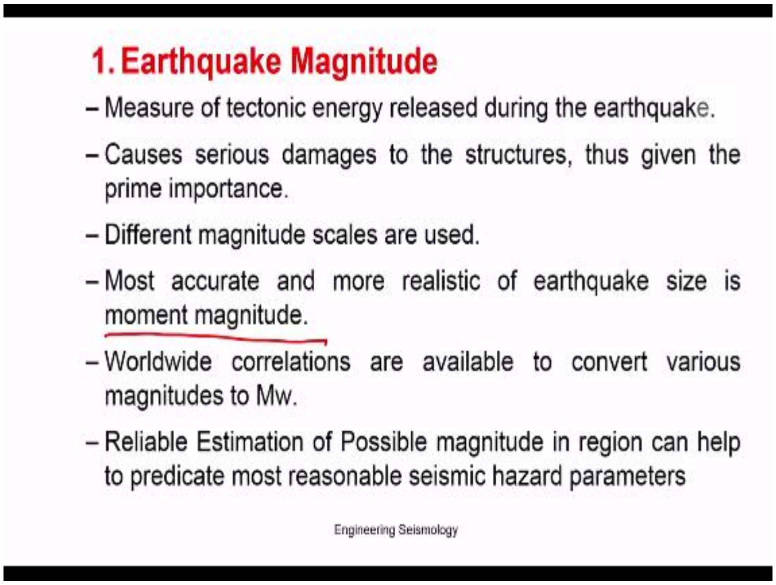

So when we talk about the parameters, we told that the first and foremost parameter which controls any earthquake is the magnitude. So the magnitude is the function of how much energy released at source, okay. The measure of tectonic energy released during the earthquake is represented by the magnitude particularly the most reliable magnitude is the seismic moment magnitude, which implies how much rupture taken place.

The causes serious damage to the structure that give the prime importance. So different magnitude scales are used, okay. So as we have seen that when the initially there was using the intensity followed by the register or local magnitude scale. Then there are a regional scale they use a duration magnitude coda of a magnitude. Then followed by the body wave magnitude, surface magnitude, okay which are the two of them are teleseismic magnitude.

Then the moment magnitude; where it occurs the seismic moment occurring in the source. So most accurate more realistic earthquakes size is actually the moment magnitude as on now, okay. The worldwide there are several correlations are available to convert one magnitude to another magnitude. Since when you are considering your analysis, your magnitude what you going to take should have the similar magnitude type. You cannot take some value such a Ml like local magnitude, some values as Mw like moment magnitude, you should be same or way of handling the magnitude.

The process at which you convert from all the magnitude type to single magnitude is called as a homogeneous, okay. Earthquake catalog homogeneous and converting that. Worldwide there are several relations are available for that. The reliable estimation of possible magnitude in the region is another important parameter. One is that you study a data and get a magnitude occurred in the region.

That is a one step. Second, what is the forecast for the future earthquake like estimation of maximum possible earthquake in the region, okay. So that also very important. That contributes your hazard values, okay. If you estimate Mx wrongly your hazard value what you are estimating also will have that error. So, that is the importance of the magnitude one has to understand.

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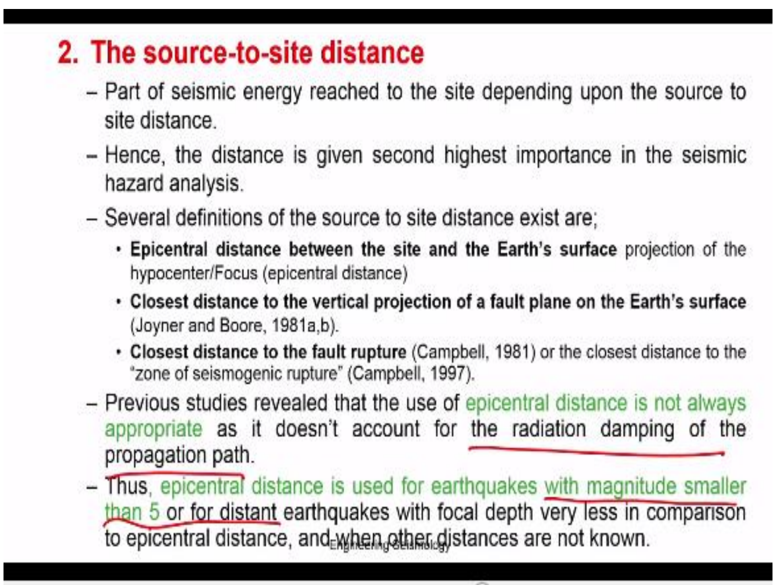

So once you establish a magnitude, the next is where this magnitude going to occur? As we have seen that anyplace the amplitude and duration is the function of where it originated? How long it travels, okay. So those two parameters are the important. So in that case so, this earthquake where it origin like source-to-site distance, where the site you are expecting and where it originate? The part of seismic energy reaches to the site depending upon the source-to-site distance hence the distance given second highest important in the seismic hazard analysis.

Several definitions of the source-to-site distances followed. The epicentral distance between the site and the earthquake surface projection, so, okay. So like hypocenter or Focus we have seen when you project a hypocenter or Focus to the surface and measure distance from that to the site to the epicentral distance. Closest distance to the vertical projection of a fault plane to the earth surface is called as a Joyner Boore distance.

So this distance was defined by the Joyner Boore and he used most of his studies Joyner and Boore studies. So since some of the equations are; predictive equations are function of this, so, this distance also in the consideration in some of the cases. Then the closest distance to the fault rupture and the closest distance to the zone of seismic rupture. So these are the some of the distance they use like hypocentral distance closest to the hypocenter distances focus point to the site.

So the closest to fault rupture is the rupture end to the site. So these are; the previous studies when we are discussing about the simple source model, okay. The plane source point source model, we have seen that the hypocenter distance are the more reliable distance where you can use in any kind of analysis. So that means the use of epicentral distance not always appropriate as it does not account the radiation of the damping and the propagation path, okay.

So, we should always use hypocentral distance. The epicentral distance can be used if the earthquakes are smaller in size particularly magnitude 5 that is what we have seen in the; when we talk about the simple plane source model. So we have discussed this point, okay. So, R when there is not known, okay proper other distance are not known you can take this as a reference. For example, some of the old earthquake only people reported about the felt intensity, so we do not know what is the depth of earthquake and all this thing. So those kind of cases you can use this as a reference distance.

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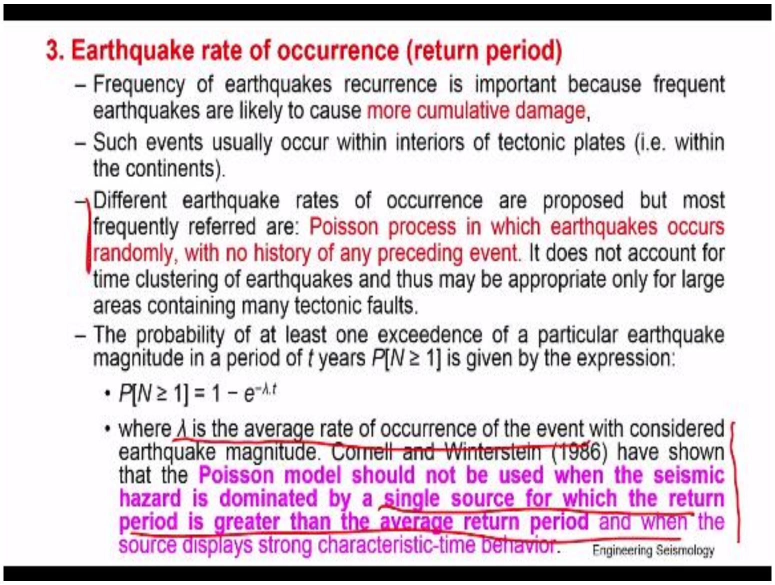

So, the another one is the, the earthquake rate of recurrence, okay. That is called as a return period, okay. So the frequency of earthquake recurrence is most because frequent earthquake are likely to cause more cumulative damage. So the earthquake which is occurring moderate magnitude frequently will cause more damage than the one big earthquake in the region. So the frequency how frequently the earthquake can occur in the regions also.

The third important parameters such event are usually occur within the interior of the tectonic plate. So where this kind of frequent earthquakes are causing large damages. Different earthquake rates recurrence are proposed, but most frequently referred model our used models are the Poisson process, okay. The Poisson process in which the earthquake occurs randomly and no history of any preceding event.

So that was a Poisson model which is taken into assumption. So it does not occur account for the time clustering of the earthquake and thus may be appropriate only for the large areas containing many tectonic fault. It does not bother about the previous earthquake occurred in that region. So the probability of the least one exceedence of a particular earthquake magnitude in the period of t, okay the N greater than 1, so given by the expression, so, the probability of least 1 recurrence 1 minus e the power of lambda and t where lambda is average rate of recurrence.

So this recurrence rate we should estimate, okay with the considering the earthquake magnitude. So the t is a period what you consider? So the Cornell, okay so highlighted that and shown that the Poisson model should not be used when the seismic hazard is dominated by a single source for which the return period is greater than the average return period of the N there is data in the region. So this particular concept is important when you try to merge a different seismic zones and the different seismic sources.

For example, somebody want to do the hazard analysis at Sikkim? So Sikkim you can see that the western part, okay there is a western transformed boundary action and subduction earthquakes, okay. Then intraplate earthquakes are occurring and then if you come to the north and eastern part where there is a active Himalayan region. So when you consider this kind of composite geological formation where the Poisson distribution model does not work well. That is what the assumption was given.

Many people they basically do considering that. So what you should do basically, you try to separate them divide them appropriately and use separate the recurrence model on each one, okay. When you do that then this error can be minimized, okay. So that was a message you should take from the earthquake rate of recurrence on return period.

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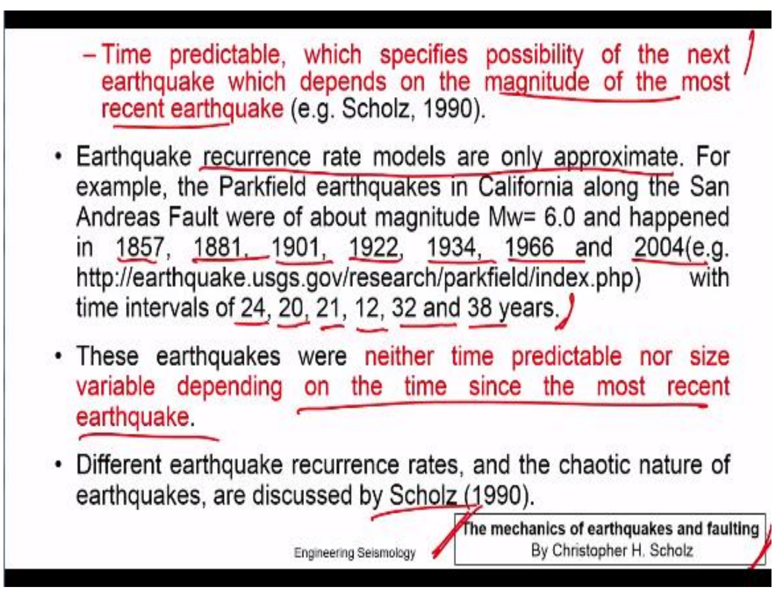

So but this return period, okay the time predictable which specify possibility of the next earthquake it depends upon the magnitude of the most recent earthquake and the scientist shown okay are observed. The earthquake recurrence model is only approximate. Does not mean that it will predict a more reliable return of earthquake. For example, the Parkfield earthquake in California along San Andreas Fault were about magnitude of 6, okay happened in 1857, 1881, 1901 and 1922, 1934, 1966 and 2004.

You can see that the return period 20, 24, 20, 21, 12 and 32 and 30. None of them follow any recurrence model, okay. It is only a approximation, okay to account that you should remember. So these earthquakes are neither time predictable nor size variable depending upon the time since the most recent earthquakes are occurred, okay. That you should always remember. But if you try to relatively use the regional data, at least you are close to the expected values. And you can decide what is the risk you want to take, okay.

The 2% probability you want to take, 10% probability you want to take, 50% probability you want to take. That depends upon that your safe of the structures will increase, okay. So, different earthquake recurrence rates and the chaotic nature of the earthquakes are discussed in this book. So, this book if you want to study about the recurrence model and research you can refer this book, okay which is one of the classical book where you can get all this information.

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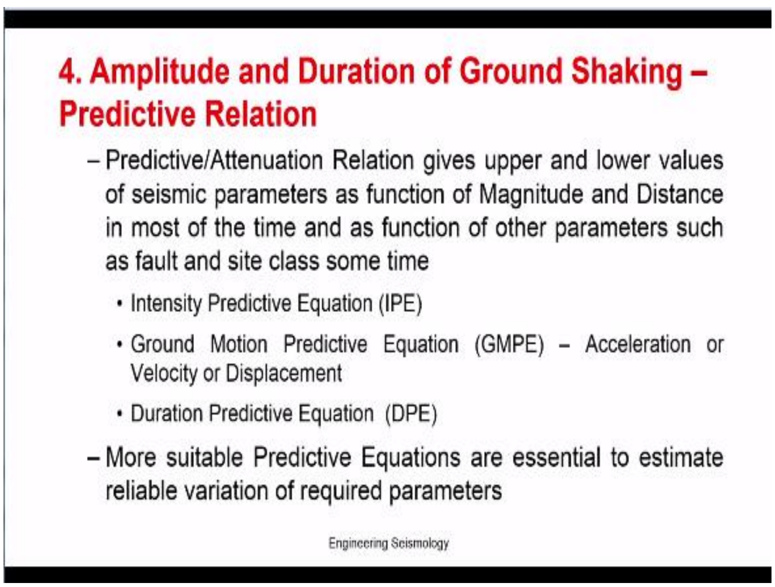

The next is the predictive equation. So the predictive equation what type of hazard you want to estimate. So that depends upon the; what you are looking for? For example, I am looking for the investment of the infrastructure at a particular region. So Bangalore I want to invest on some of the real estate buildings, okay. So then I should know that what is the intensity this region experience if I want to predict the intensity so that I can know that this intensity scale is expected damage in this region is possible.

Accordingly, I can decide that how much investment I can do like seismic vulnerability and building damage related prediction. So, that cases you need the intensity predictive model. You need a hazard analysis to predict the intensity, okay. So that is the kind of study you will be looking at that. So, that kind of relation what relation and what purpose will be decided on fourth part of the hazard analysis before starting a complete hazard analysis, okay.

So, up to three steps are same only the selection of the equations changes in this one, okay. Second, I want to predict a PGA RPGV. So relatively acceleration based in the ground motion prediction equation, velocity based the ground motion prediction equation or displacement based ground motion prediction equation I need to consider. So, that kind of predictive equations so we should look at, that is called as a ground motion prediction equation.

So, the intensity based one is the intensity prediction equation IPE and GMP for acceleration or velocity. And the duration prediction equation, so the duration prediction equation where you can predict a duration, how many times the similar cycle will repeat? How much energy it dissipate? So those details can be used to that. So one has to get most representative predictive equation in the region, okay.

So as we have discussed a Douglas predictive equation summary, we have seen that in the world for more than like 600 700 GMPs are developed so far, okay and each one has it own merit and demerit. When you want to do hazard analysis some particular location, you should consider what for you are doing, okay and what; in the predictive equation you should use, okay how far the predictive equations are suitable.

So all those consideration one has to give when you are talking about the implementing the predictive equation. So now we have seen that the first part of hazard analysis is basically what parameter you are looking for, okay. So the basically you will be look for the severity and a frequency of particular parameters or particular values in the region is you are estimating. So the estimating of severity and repeatability of seismic, okay so, parameters is called as hazard analysis.

That hazard analysis is controlled by the four major factor magnitude, distance and the recurrence model and they predictive equations, okay these four factors. We have seen that the magnitude, so, you will have different magnitude you have to convert and estimate maximum possible magnitude. Distance hypocentral distance, epicentral distance, Joyner Boore distance, most reliable distance is the hypocentral distance most reliable magnitudes is the seismic moment magnitude, okay.

So, then you recurrence model, we have seen that among the various models the Poisson model represents a well the earthquake the phenomena, so, people use Poisson model. We also seen that the Poisson model even though we use which cannot be used by the composite assemblage of the seismicity. So, composite means basically if you have the two different set of seismic settings in the region you cannot use together same recurrence model.

You should derive the different recurrence model for the different seismotectonic activities or the behavior of the source in the region, okay. That is a one other thing. We also seen that this recurrence models are approximate is never (()) (26:36) really match with actually what happens, okay. It is very difficult to predict the behavior of the nature particularly seismic activity and crystal deformations under very difficult to predict very accurately, so that you should keep it in mind whenever you do.

So, these parameters appropriately used and estimated through a predictive equation. So the predictive equations also like three major predictive equations will help you to get these parameters. There are several type of predictive equations are there, but these three are most useful for the hazard analysis at the bedrock level. As well as the intensity actually represents a surface level of the damage.

Other two can be bedrock and surface depends upon the input what you have or GMPs what do we have? So next class, we are going to start about the how a basic hazard analysis steps one-by-one we can go. That is what we are going to discuss. So with this, we will close today class. So thank you very much for watching this video. So I will meet you in the next class with the starting of hazard analysis first step of seismotectonic map preparation. Thank you very much.