Introduction to Engineering Seismology

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Lecture No -22
Duration parameters; Duration Prediction Equations

So Vanakkam, so we will continue our lecture. So we have been discussing about the estimation of the time domain parameters, particularly the duration which is a responsible for damage of the structures. So we have seen that higher amplitude lesser duration may not cause a damage but lesser amplitude longer duration may cause a damage. So the understanding durations are very important then scientists start working at finding out the duration.

So the duration is basically the time interval of the accelerometric signal in which the, Seismic motion is significant. So that is what is a duration?

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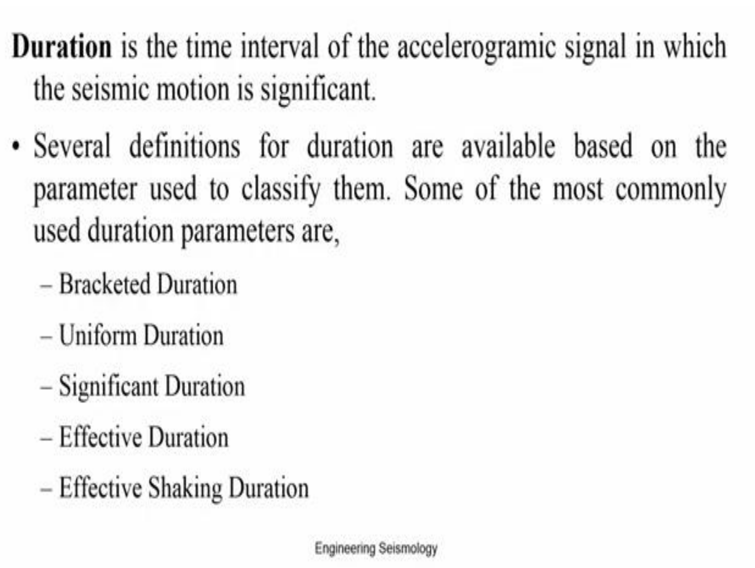

Several definitions of the durations are available based on the parameter used to classify them. Most frequently used to durations are we are going to discuss in our class. So that is like bracketed duration, uniform duration, significant duration, the effective duration and effective shaking duration. So these are all the durations which is most widely used for in the engineering practice.

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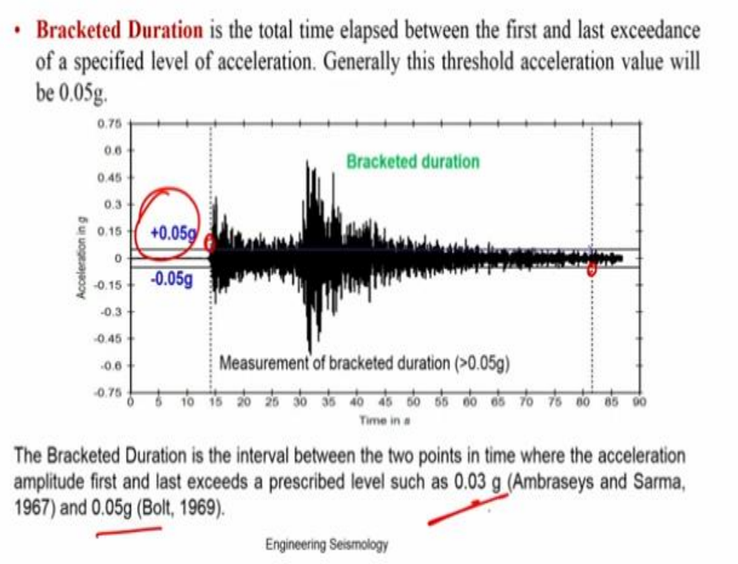

So what is mean by the bracketed duration? So, bracketed duration is actually the time total time elapsed between the first and last exceedance of the specific level of acceleration. In generally the threshold acceleration value is taken into 0.05. So if you plot your acceleration versus time history of the particular ground motion, even though you record some time velocity and you converted to the acceleration by differentiation, then that acceleration time is to you have to identify what is the first, 0.05g which may be the positive or negative.

So you can draw a line which is like 0.05, a -0.05 like this. Then you can see which is the first signal, which is crossing; so that point you can consider as your starting point of the bracketed duration. Then you can see where it ends basically it ends at this place. So this will be considered as a end point of the bracketed duration. So the bracketed, is basically this minus this. So that is called as a bracketed duration. So this 0.5 is consider as a bracketed duration quantity.

The bracket duration interval between the two points in the time where the acceleration amplitude first and last exceedance prescribed level of point this one but this was later has been; Bolt it was suggested by this in 1969 later the Ambraseys and Sarma said that, so instead of point 0.5. one should go for the 0.03. So that means the same bracketed duration you can define for the 0.05 as well as 0.03. So depends on that you are duration changes, this is called as a bracketed duration.

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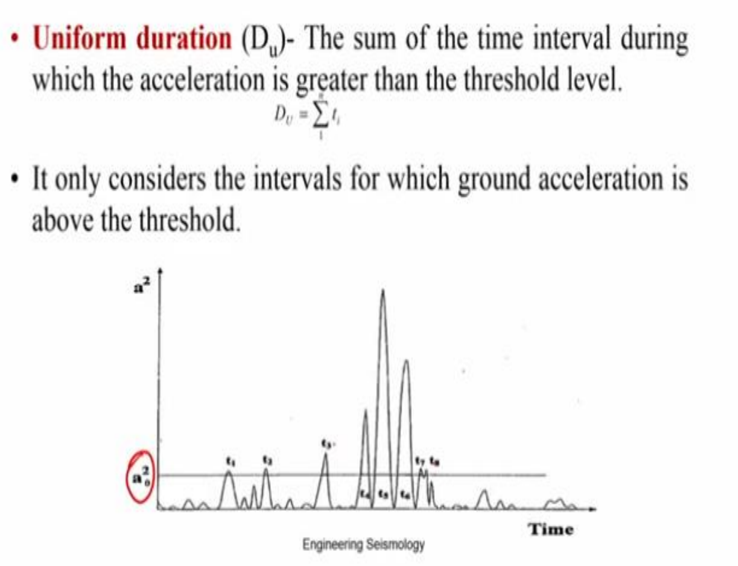

So the next one is a uniform duration the sum of the time interval during which the acceleration greater than the threshold level is called as a uniform duration, so that threshold value is left to the user you can define whatever threshold value basically you plot acceleration versus time history the absolute values only consider the interval for which the ground acceleration above the threshold value, for example you define this as a threshold value.

Then the time t1, t2, t3, t4, t5 wherever it exceeds. So that summation of this is actually the uniform duration of the ground motion. So this you can see the summation of the time interval exceeding the threshold value definition, so this threshold value you can define as per your choice.

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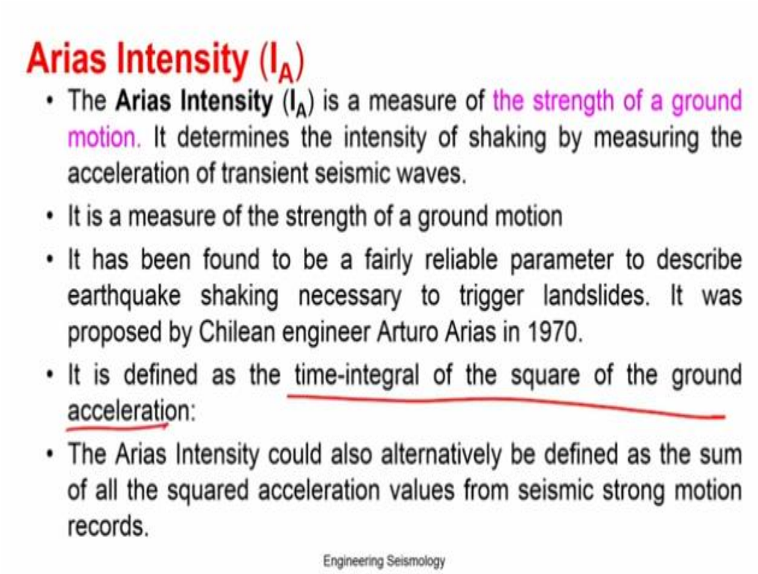

So before going to other duration we will try to understand the Arias intensity, so the arias intensity IA is the measure of the strength of the ground motion it determines the intensity of shaking by measure the acceleration and the transient seismic waves. So Arias intensity, even though the intensity term comes but it was in invented by the scientist Arias, which is not similar to your modified Mercalli intensity or any other intensity which is not similar to other intensity scale which you are used.

This is the intensity which basically shows the strength of the ground motion and determine from the recorded acceleration data are recorded earthquake data, so it is a measure of the strength of ground motion if the larger the Arias intensity stronger is a earthquake, it has been found that fairly reliable parameter to describe earthquake shaking necessary to trigger landslide into a proposed by the, The Chilean engineer Arturo Arias in 1970.

It is defined the time-integral of the square of the ground acceleration is called as a Arias intensity. Arias intensity could be alternatively defined as the sum of the all the squared acceleration values from the seismic strong motion record.

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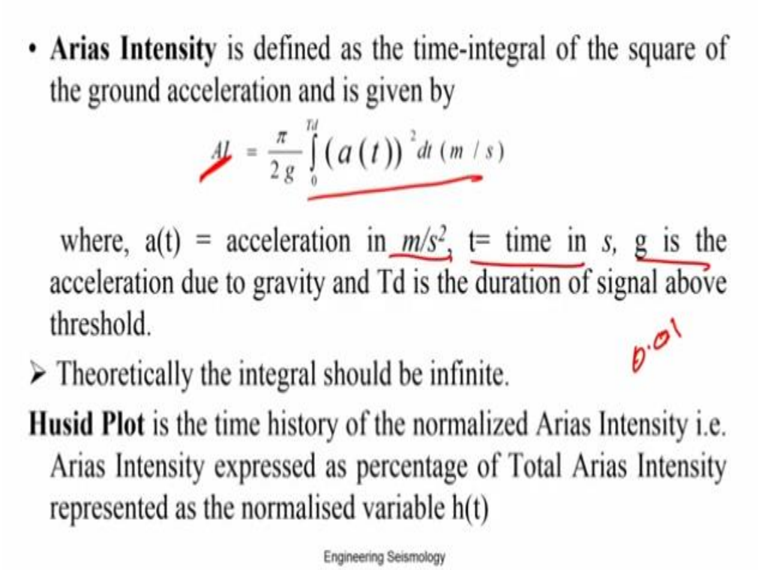

So you can see that the Arias intensity equal to basically the time integral of the time integral of the square of the ground acceleration given by this one so this is the various. Density the square integral 0 to Td, a t is acceleration in metre per second square t in time in second g is the acceleration due to the gravity. Td is the duration of the signal the above the threshold value.

So you can define here threshold value for example generally for the structure requirement, they take 0.01 as a threshold value g, so theoretically the integral should be infinite. So the Husid plot the time history of the normalized intensity the Arias intensity. Arias intensity expressed as percentage of the total Arias intensity and as represent as a normalized variable is called as a Husid plot.

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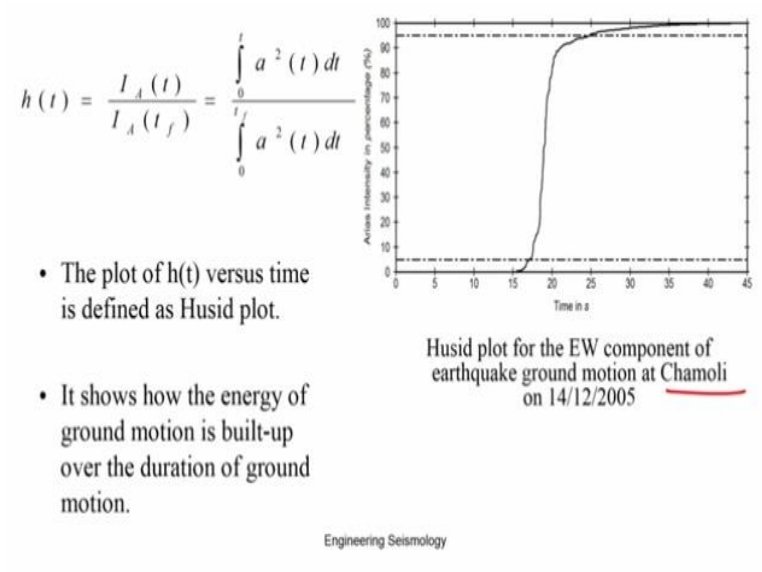

So Husid plot is basically, you estimate Arias intensity you normalize with the maximum value. You define with the maximum value, then you get another plot that plant is called as Husid plot This is the typical Husid plot of the Chamoli earthquake where you can see where it starts and ends you have the different percentage. So this data is being further used for estimating the, duration.

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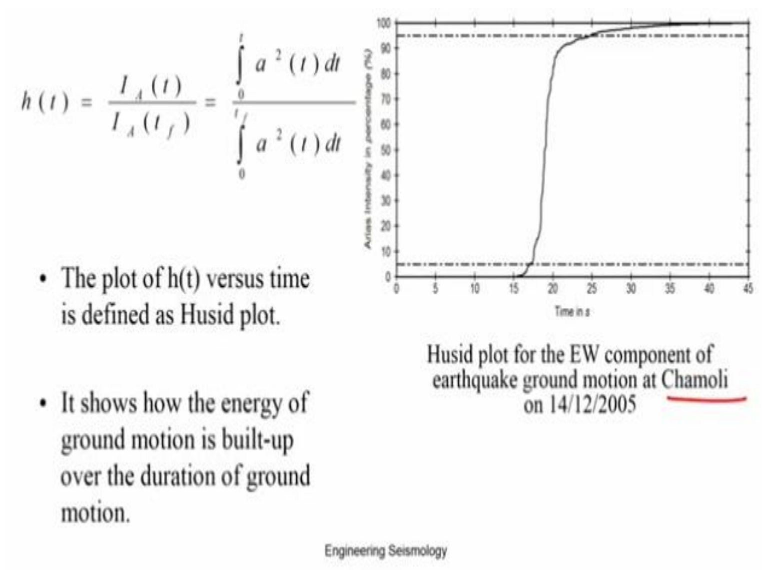

That duration is basically called as a significant duration. So the significant duration is based on the accumulation of the energy in the acceleration represented by the integral of the square ground acceleration velocity at displacement in the Husid plot. So it is the interval over which some portion of the total integral is accumulator. For example, the most commonly used interval is 5 to 95% or 5 to 75% of the Arias intensity we should plot.

So if we take the Husid plot you can see so here, you know, what is the 5%, 20%, 10% like this you draw a horizontal line on 5%, horizontal line on the 95% then you can define here significant duration part that particular period. So a significant duration Da for 5 to 95% is that value. Similarly if you want to define a, so 5 is 75% then you can draw a line. So this duration is called as a significant duration 5 to 75% Arias intensity Husid plot.

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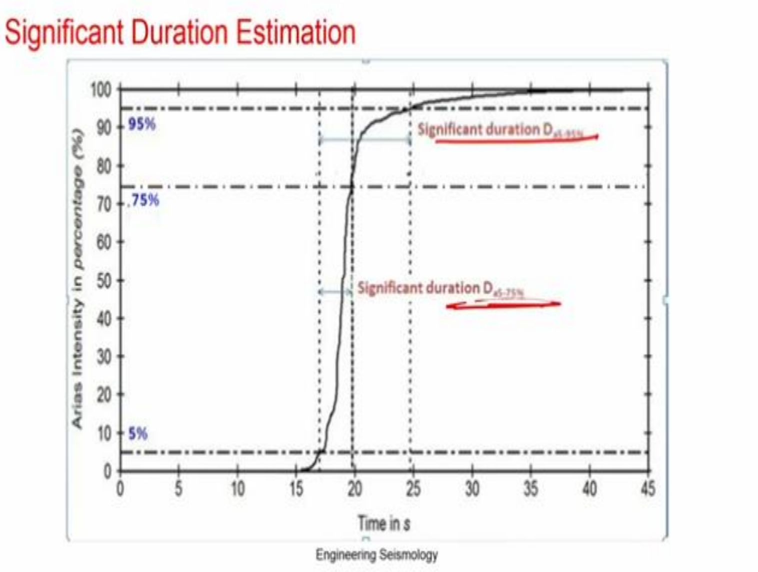

So, this is, so the significant duration basically you can see the typical significant duration of the your typical earthquake. So this one basically gives 5 to 75%, this one will give us a 5 to 95%. So where the 95% of the structure energy starting here, it is the energy where 95% reached 5% starting in 95% reach then reaching to 100% rather structure will collapse. So this period is considered as a significant duration of the earthquake.

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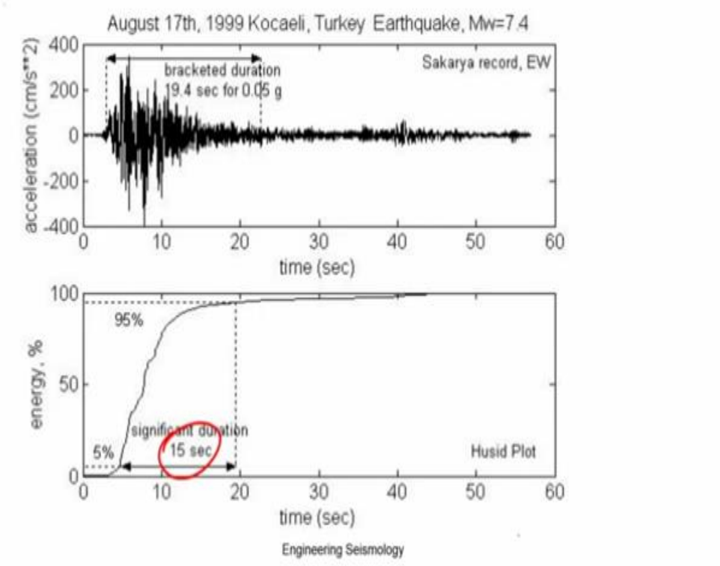

So, this is the typical earthquake where you can see how the bracketed duration and significant duration is. So here you can see that the bracketed duration is 19 for 4 seconds. The same earthquake the significant duration is 15 seconds. So here you are observing directly the your peak ground acceleration and then taking 0.05g. So here the 5 to 95% energy from the Husid plot, which is obtained from the integral of the acceleration square. That is the difference between these two.

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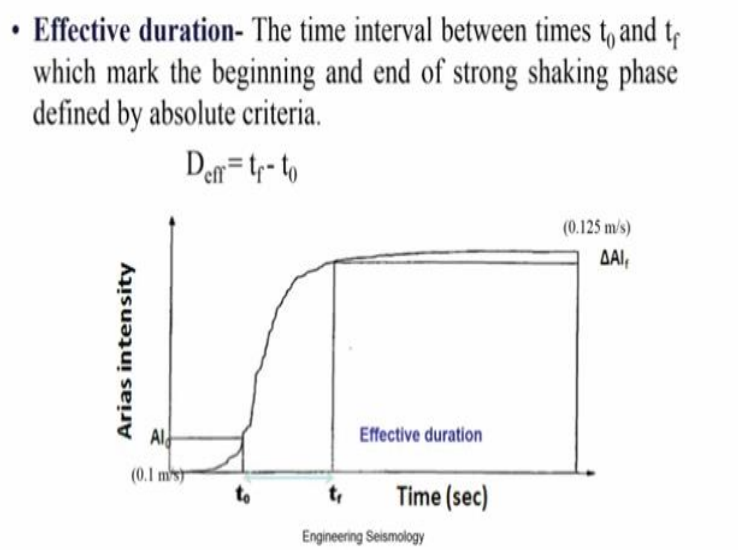

So the next acceleration is called as a effective acceleration. So the effective duration is actually is the function of the time interval between the t0 and tf which mark beginning and the end of the strong shaking phase defined by the absolute criteria. So you define your absolute criteria in the form of Arias intensity then, so the time between the t0 and then the tf, period is called as a effective duration.

So generally, it is absolute intensity is basically they take respective to the 0.1 meter per second. So then this is the value where 0.125 meter per second. So you can see this period is a effective duration.

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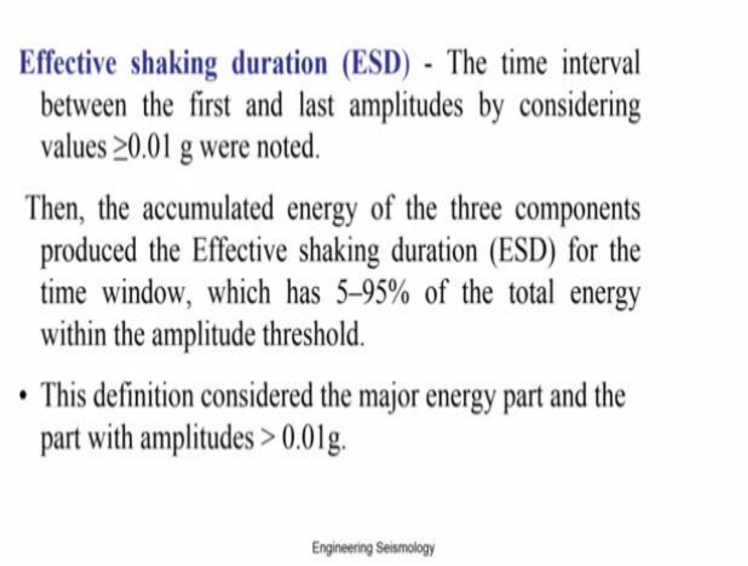

So the effective shaking duration the effective shaking duration is the time interval between the first and last amplitude by considering the value of 0.01 g, then the accumulated energy of the 3 component proceed the effective shaking duration ESD for time window, which is less than which has five to 95% of the total energy within amplitude of threshold this definition considers the major energy part of amplitude 0.01g.

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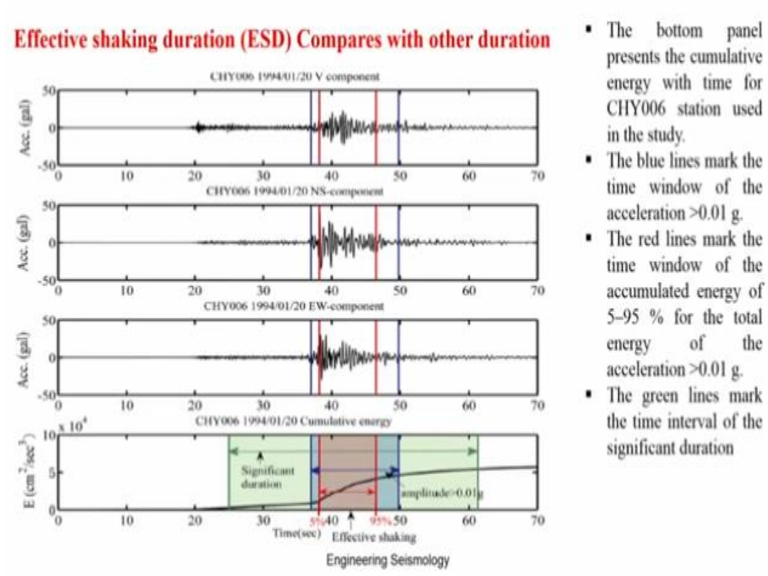

So this effective shaking duration has been recently defined based on the Japan earthquake data. So where they try to see that this significant effective duration giving a different value and again you are getting another values called as effective duration. So in order to attain a uniform level, they introduce the effective shaking duration, which it takes Husid plot into consideration and also acceleration into consideration and the gives the new definition.

So, this is actually the bottom panel. The presence the cumulative energy which the time a particular ground motion used in the study you can see here the significant duration is from starting to year to year and then the effective shaking occurs generally from year to year, where you can see the threshold value of acceleration is exceeding. So the blue line marks the time window of the acceleration, which is 0.01g and above.

So the red line marks the time window of the accumulated energy for the 9 to 95%. So, it can be seen that the significant duration is less than the most the acceleration which causes a damage. So then the come up with the definition of this effective shaking duration, which is more than the significant duration. So more than you were 9 to 95% Husid plot duration, but it is less than the significant duration.

So this damage is caused more on this portion, so this effective shaking duration of this is need to be considered in the design. That is what the new definition it is given to for this duration estimation.

So this duration, so there are we have discussed about the 5 type of duration. So this duration basically important to describe how much time it takes the structure to fail in one angle. Second how much energy the signal carries. Third, how the seismic wave generated to source reaching to your site? So these are all the information included in the duration estimation. So this duration estimation basically can be fine found as your total duration.

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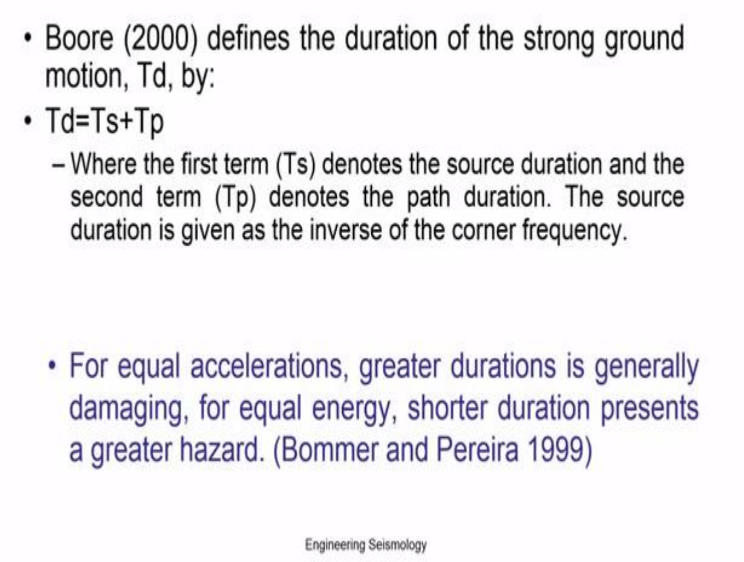

So the total duration is basically Ts + Tp the Ts is basically denoted as the source duration. The second term Tp denotes a path duration, the source duration is given as a inverse of the corner frequency the equal acceleration greater durations are generally damaging. So the equal energy shorter duration present a greater hazard. So these total durations are generally used for the simulation purpose of the ground motion.

So if you want to simulate synthetically the earthquake signal, which is generally you record for the earthquake which does not have the recorded data. So that time you need to know what is the total duration, source duration, part duration. There are studies people carry out on how the source duration, path duration varies at a one place apart from the duration what we discussed in the so far.

So, this duration basically gives idea about how much the energy carried by the earthquake waves, how it basically dissipated how strong it is in the structural system. So, that the longer duration earthquake basically causes here more damage than the shorter duration earthquake with the same amplitude. So this work durations are there, so this durations also as we discussed in the intensity.

So these durations also need to be estimated and this duration there are equations for duration prediction model.

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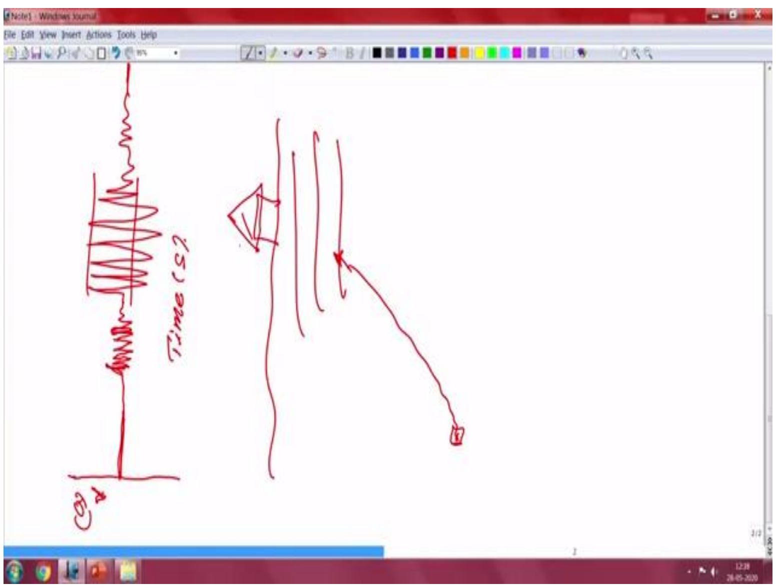

So as you know that this duration is controlled by the a particular location area. So, for example in, this is the ground. So earthquake occurs somewhere. So the waves are reaching like this reaching like this. Then you have the several layers. So it reached this place, so when it reached this place basically it goes to the station where it recorded. So where it recorded it goes actually.

So when it recorded goes like this. So I can make this as a horizontal part, so that it is easy for to understand.

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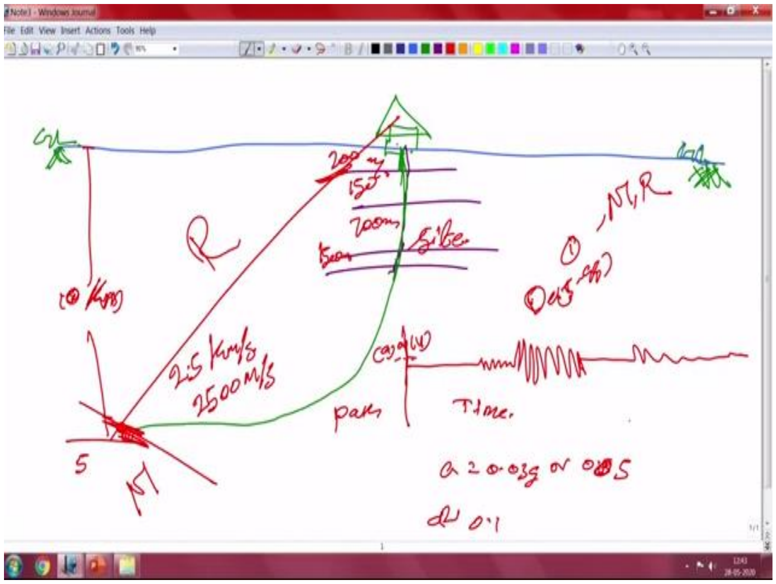

So, this is the ground, so this is the rupture. So this is a rupture point? So then the waves are generated which weaves are travel like this, then you will have the different material, then this waves are basically undergo this way here, so you will have the basically station here which record here earthquakes. So this is basically below the ground level. So this basically ground level.

Ground level this reaches, so this is basically a source, this is the path, this is the site. So this wave starts from here and goes here and so this data only you are seeing as like this. Like this you are seeing, this will be the acceleration are velocity and this will be the time. So we have noticed that the durations are defined is the function of your acceleration values or is the square of acceleration means you can take 0.3 g or 0.05 g where it crosses.

Or you can take Husid plot where you will integrate here acceleration square and it gives here 5% to 95% energy or else sometime that uniform also but where 0.9 g are 0.01 g data into account. You can see that this waves when starting from this place travels like this and reaches so this is generally roughly about ten kilometer from the site, depth ten kilometer. so this station depends upon the station.

So this will be like a traveling on the material where you have the rock which has here 2000 meter per second velocity under this will be the rock which a 1000 meter per second, velocity

700 meter per second velocity, this will be 150, 200 meter per second you can see the this is actually a 2.5. So kilometer per second correct same thing, so here it will be 200, so 2500 you can see that about 10 times.

So more than 10 times is a lower than this because of this the wave which what you can see here are completely different from here, so if we have the facility if you have the seismic record at a bedrock a different level you can understand how this wave duration and the amplitude influence by the local geology, so generally the durations, so we will change because of the several layering system.

The source duration and the path duration will change due to the side condition. So that duration factors are very important which is very specific to particular location so as you have seen that each earthquake you can estimate what is the significant duration per year 5 to 95%. I am giving the example and one value for given M and R, Here M, is earthquake, R is basically your distance.

So like this you can accumulate several data,, then you can also as I told you that intensity predictive equation similar to that one can also generate a duration predictive equation that means you can have the equations with which can be used to find out here duration of the earthquake.

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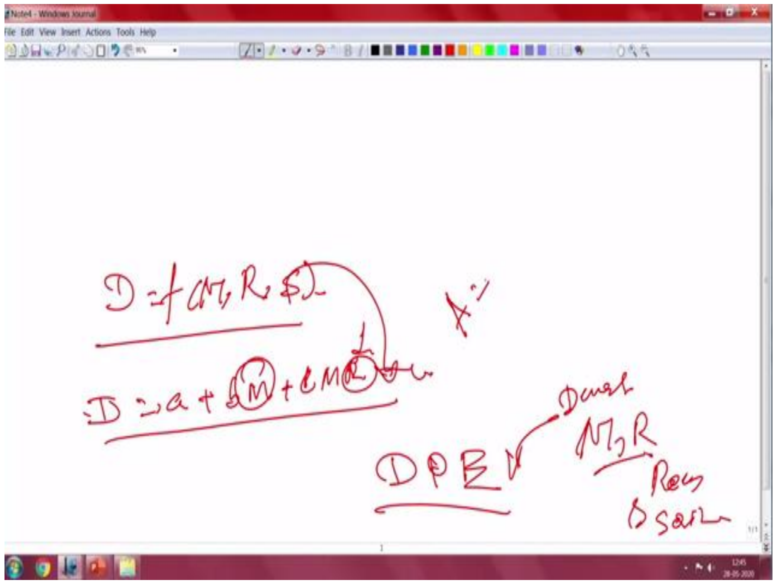

So is the duration of the like, for example D is a function of your M, R and site. So if you have the large number of data, so this will be like a empirical formula which we have seen is the like a + b m + c m R, power d something like that, you can get a multi regression analysis where the magnitude of earthquake, core of the earthquake site can be taken into factor that kind of equations are will be useful to identify what is the duration you can expected in the region.

Because if you have 1 record you will get to only the 1 duration estimator so if you have the large number of record in the region, you can know that how much this durations are where is, what is the standard deviation this kind of functional data are functional form, which is called as a duration predictive equation will be used to estimate what is the duration you can expect further given magnitude and distance at a particular location for the rock side as well as the soil side.

So these are all the very important parameter to design it is not only you get a the ground motion parameters, which is like acceleration that is also there is a equation to predict a peak ground acceleration, so then similarly there is a equation to predict here peak ground duration, peak duration or receive significant duration function form the significant effective or uniform whatever they might be described.

So these kind of development happened in the last 15 to 20 years so where people start that it is not the only the matter up amplitude it is also duration of the earthquake has to be considered particularly when you want to asses a landslide liquefaction and the even a damage potential. So as on India there is not much steady has been done on duration predictive equation, so we have started some work where we have done collected a several data.

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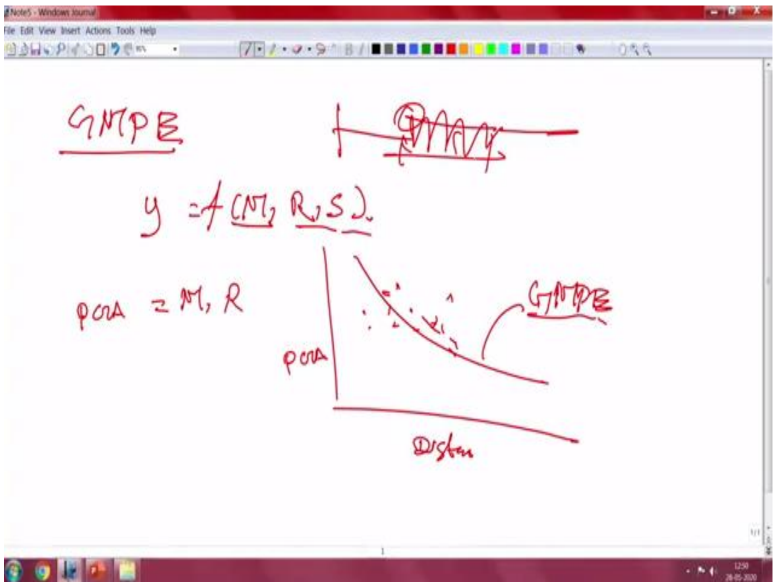

And try to estimate a duration of the different earthquake and try to develop a duration predictive equation, so we have success. So far duration predictive equation for peninsular India because we collected data from the many stable continent region and then try to estimate a say effective duration and significant duration and try to arrive here duration prediction model for the intraplate region, which considers the North East America and then the Australia and some earthquake in the southern India.

So using that we have done that is the first and unique work on duration prediction equation for intraplate region, which is published in the journal of seismology. So as I said that I also do research on this areas, whatever I teach. If you want to refer the paper you can refer. So similarly for the similar kind of equation needed for the Himalayan region. Right now we have done the analysis by we yet to publish.

So we also found that in the same earthquake wherever you have the longer duration, you have the higher intensity of damage. That is what we study; if the durations are more the energy accumulated or energy transferred to the structure is very stronger. That will result here more damage than the regular normal or short duration earthquake. So this duration has to be estimated by considering the data recorded in the region.

Then you can use that many duration record to fit a develop a duration prediction model. So this will discuss further in when we are talking about the prediction models in engineering seismology in later scale. So right now, there is no such kind of duration model developed based on the Himalayan region data as some on now. But there are models which, predict as the function of your peak ground velocity are peak horizontal acceleration.

There are many couple of models are there which is available for southern India as well as the North Indian region where you have the ground motion GMPE which is called as a ground motion predictive equation. So this GMPE basically y, so you can term y then which will be the function of again, your M,R and site S. So M is the magnitude R is a, So as you said that we get here PGA from particular earthquake record.

So that is actually known for the given M and R. So similarly you get a several PGA then you plot the data versus like, PGA versus your distance for the given magnitude then you can do a multiple regression analysis is the function of M and R and the site condition that equation is called as a GMPE or ground motion predictive equation. So from the parameters what we have seen that, you can estimate a, the time domain parameters as a peak values peak velocity peak acceleration peak displacement.

And then duration values, which is the function of basically your how many cycles repeat in the record and as well as the your strength of your energy of earthquake. So that you can, so using this two you can get a predictive models. So this predictive models basically help you to arrive your future what is the expected value for the unknown magnitude and distance. So that is what it can do.

So right now we are interpreted a data direct record of the earthquake we are not done any processing or any conversion of the data simply we are taken acceleration time is t record. Then we interpreted the peak value and how many times it repeats. So that details we have used to interpret the time domain parameters. So the next parameter is basically the frequency domain parameters.

So the frequency domain parameters means whatever time history data we obtained in the seismometer or accelerometer that should be converted into the another form, It will be transformed to the frequency parameters that parameters where I am that you will estimate your some parameters. Those parameters is called as a frequency domain parameters. So these frequency domain parameters are important because the source and the path, these are all the function of the frequency of the wave which we have seen.

We have seen that the low frequency intermediate frequency, high frequency component of the wave, which component which station will record. So these are all related to the seismic moment at sources. So that understanding of the frequency domain parameters will help basically to get your model, ground motion simulation model or synthetic ground motions. Simulation of the ground motions of a particular location is possible using this kind of data.

So which will be we are going to discuss in the next class of the frequency domain parameters. So with this we will close today class. Thank you very much. So, we will see you in the next class.