Introduction to Engineering Seismology
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Lecture No -35
Recapitulation - 7

Vanakkam, so we have been recapping all our engineering seismology lectures so as I told you that so all this knowledge what we have studied we are going to use and apply to get a reliable estimation of the earthquake hazard, which is the prime importance for the safe design as well as disaster planning and management system. So in that aspect so the understanding of all the different aspects we are being summarizing by recapping of these classes actually.

So last class we have look at the earthquake measurement and then the quantification, sizing and all those things. So the today class we are going to talk about basically the interpretation of the earthquake record which comes from the seismometer or accelerogram record so the wave form data what we comes. So one of the major issue we discussed.

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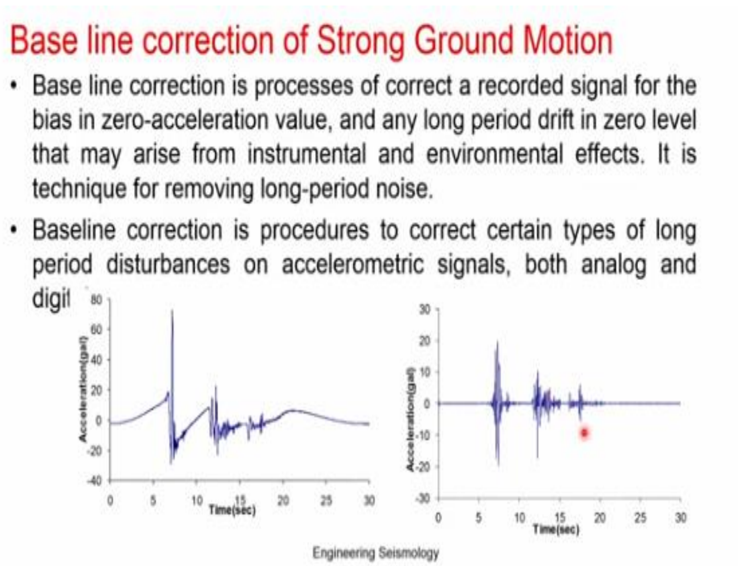

In the earthquake data interpretation that so most of the earthquake data what you are seeing, so what you are recording in the instrument so may not start with the zero due to the some physical problem in the station some kind of noise or bias kind of thing so you basically end up in the recording the data's like this. So this is the typical record I found myself in the one of the strong motion acceleration data.

So this data first before using and interpretation this data first has to be corrected, that correction is called as a base line correction. So the baseline correction is the process to remove the drift so in the 0 level in station so most of the acceleration and the velocity value should start with 0 end with 0 that is the right record. In case if it does not have you have the drift in the record so you should apply a base line correction and try to remove that.

There are different type of baseline correction we have been discussed so one of the simplest way is basically, so take a average value and try to deduct and make it a 0, so or you can use a more complex based analysis also to get it, so finally this baseline corrected data looks like here this is the corrected data you can see how this corrected data so that wave sounds are very beautiful so that you can identify what type of wave and what is and all. Once you corrected the data;

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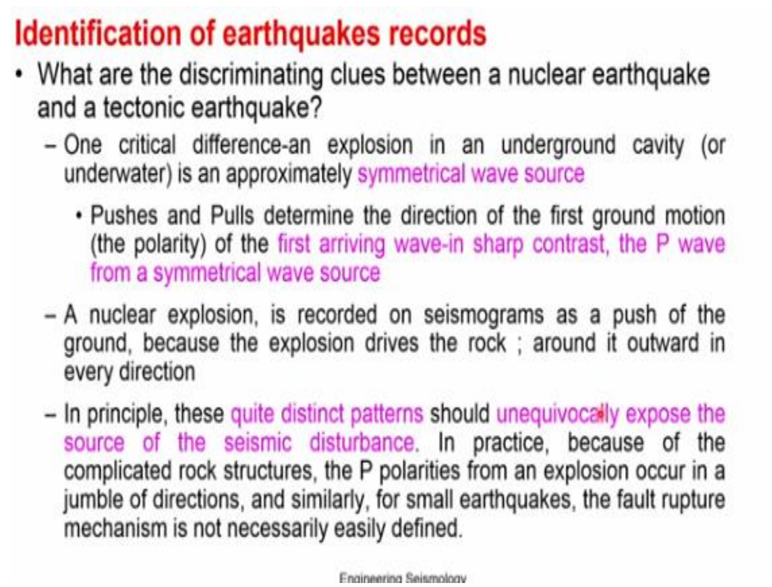

Next you have to confirm that whatever record vibration recorded by the seismometer or a accelerometer is a earthquake or a some other vibration which is caused during the type of the earthquake data we have seen that the earthquake data based on the source it can be classified as a five category, we have seen that the tectonic force is the responsible for the remaining. So responsible for the earthquake to create and that kind of vibration only we are interested.

So remaining are the collapsible earthquake, man-made earthquake, impact earthquake, earthquake created by some vibrations artificial. All those things we are not interested. Basically we have to remove those kind of data. So for that reason the wave form what you recorded itself as used as a parameters. So one is that so the explosion generally done in a shallow depth. So that depth of the earthquake will help you to identify it is earthquake or the explosion.

Second the wave type push and pull are basically originate from the source, the pushes generally happens when the blasting in the same rock so that means all the record what you get from the non-earthquake or explosion kind of things will have the push as a first arrival source and the waves also will be symmetrical since it travels under the rupture happens propagation happens on the smaller area, the waves are symmetrical.

So this kind of like a unique unity or equal way kind of things are unique in the explosion but in the earthquake it will be irregular because of the source propagation happens at longer distance and source rupture happens, which is controlled by the rock property and overburden thickness and pressure at the particular location. So that is why you need to identify that these are all the some of the;

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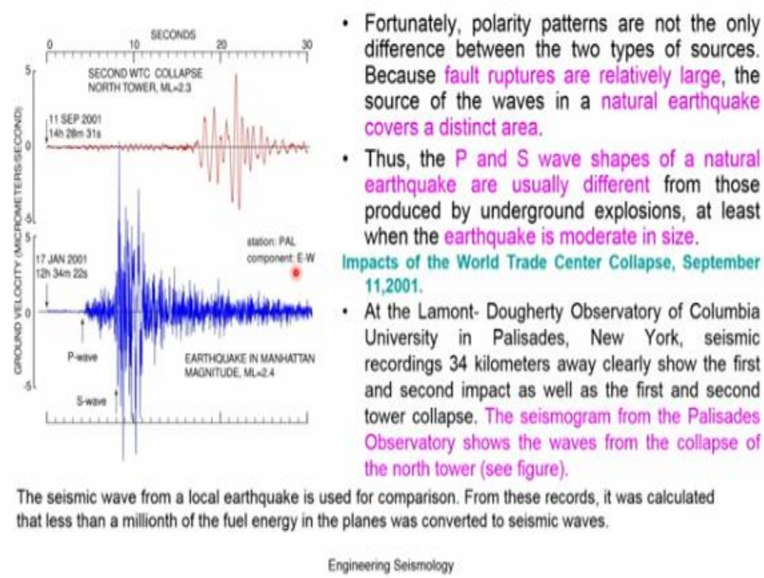

Simple way you can identify we also discussed about the how the real earthquake under the impact due to the explosion. So with reference to the twin tower blast record in the USA. So, this is a typical earthquake waveform record. So this you can see the 2.4 magnitude at a earthquake Manhattan. So the same place there is a the twin tower nearby it has been same station the impact of the twin tower due to that blasting time has been recorded.

You can see the waveform symmetries can you see the waveforms here. The amplitude of the wave the particular the symmetry of the waves, you are almost in the equal and both side here is not like that. So these are all the way you can interpret here it is a earthquake record or non earthquake record. So there are some datas which is impossible to define it is earthquake or non-earthquake record.

Those are all called as a mysterious event. There are many such events are reported but generally this happens when you have very one equipment will locate that earthquake which may be happened very far from the seismometer. So all those things create a confusion that it is some kind of earthquake or it is a natural some kind of phenomena like a lightning or the impact or the terrorist attack kind of thing.

So, I may be also told you the example that in Bangalore, there was a vibration and sound felt by the seven several people and then finally they confirmed with seismology observatories and also from other people. It is due to the fighter jet flight movement from swooning to other sonic waveform range because of that there is a big boom sound and followed by the vibrations also at a few locations.

So these are all the way the one can get the its recorded data is the earthquake. So apart from that in modern days;

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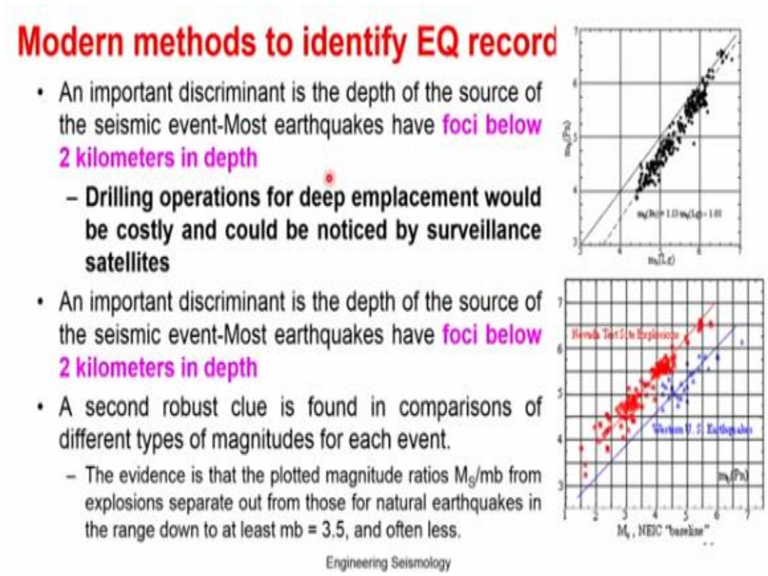

So as you know that you can get a Ms and mb and a magnitude from the recorded data which has anyway saturation capacity but the smaller magnitude Ms and mb is a more reliable. Those plotting up this actual earthquake and then the experimental or explosion data you find a distinct pattern in the region, so this distinct fashion will help you to say that this is the earthquake data what you recorded is from the real earthquake or from the blasting then focal depth which we have already discussed.

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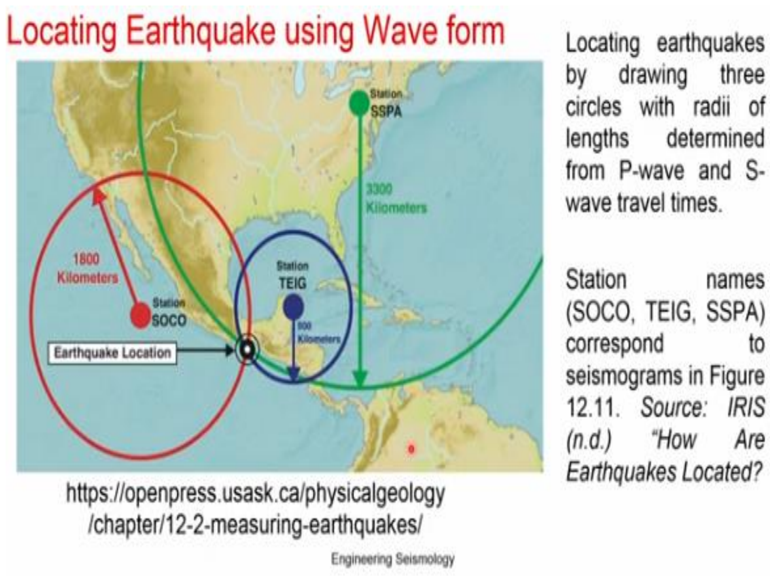

So this data recorded at several stations once you identify this is the earthquake and then you can estimate a arrival of P wave and S wave which we have seen so then using the P wave and S wave arrival then taking a average velocity of the particular regions you can estimate what is the distance origin point to your station from the your data, the way form data. So then you draw a circle of that distance radius finally all the circle where it meets that point is called as a epicentre location when you has a three station.

When you coupled with the four and five station you can also get a depth perception that is a depth of earthquake so you can basically get a epicentral distance location of the locating the earthquake and then the hypocentral location, all these things are possible using the waveform data you get.

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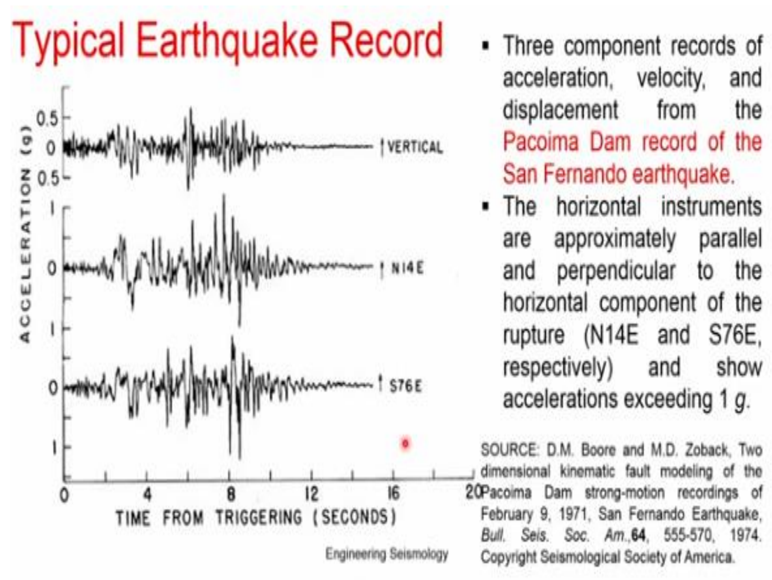

So this waveform data basically looks like this here, this is a highest g recorded typical earthquake where you can see how the wave amplitudes are changes and with respect to them. So this data when interpreting that this data will tell you the size of the earthquake that is what we have seen amplitude.

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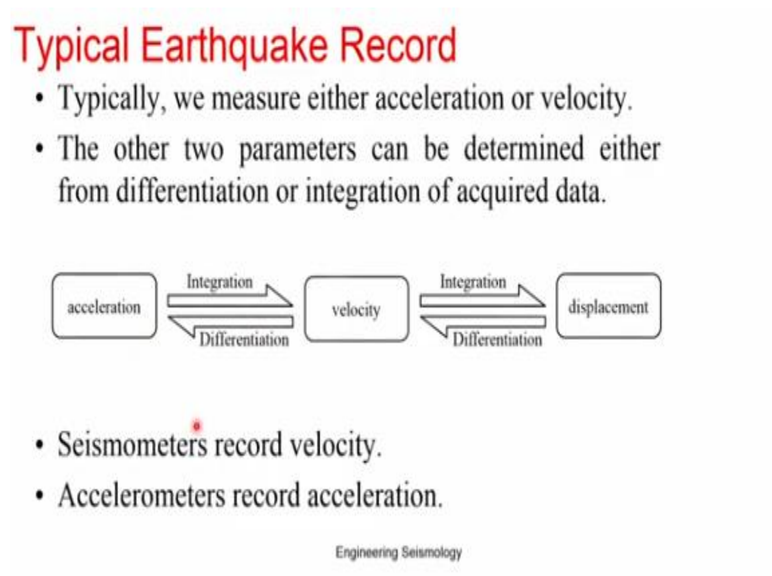

So the earthquake data in each station you will be recording as a velocity or acceleration so you can convert from one unit to other unit by taking a integration and differentiation so this is the typical example. So from acceleration to velocity if you want integrate, velocity to displacement again integrate. So displacement to velocity differentiate velocity acceleration differentiate this one so this gives you that.

So all the any station which will have the 1 type of recording may be acceleration or velocity and it can be recording the 1 component or 3 component depends upon the instrument type so from that each data each component of the data can be converted into three form.

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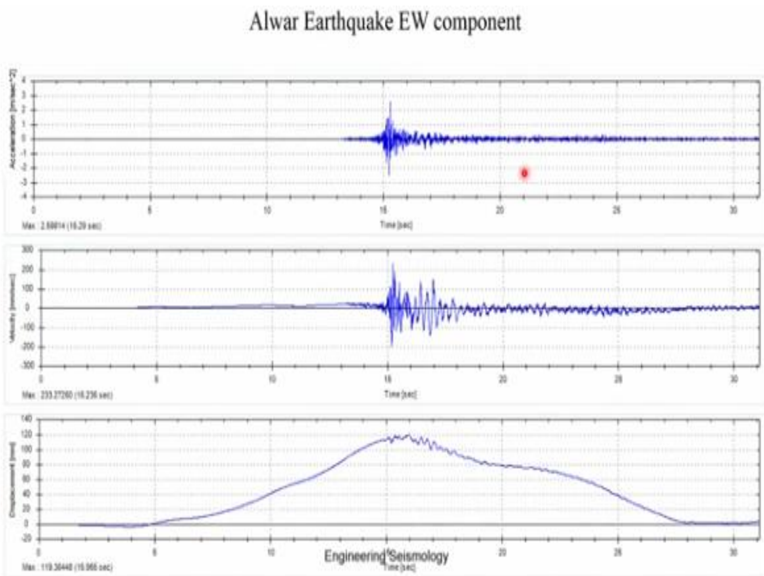

So like velocity time history, acceleration time history and displacement time history. So this is the typical east west component of the Alwar earthquake which is reported you can see how the data's are changes, so one of them might be recorded remaining are basically obtained by integration or differentiation.

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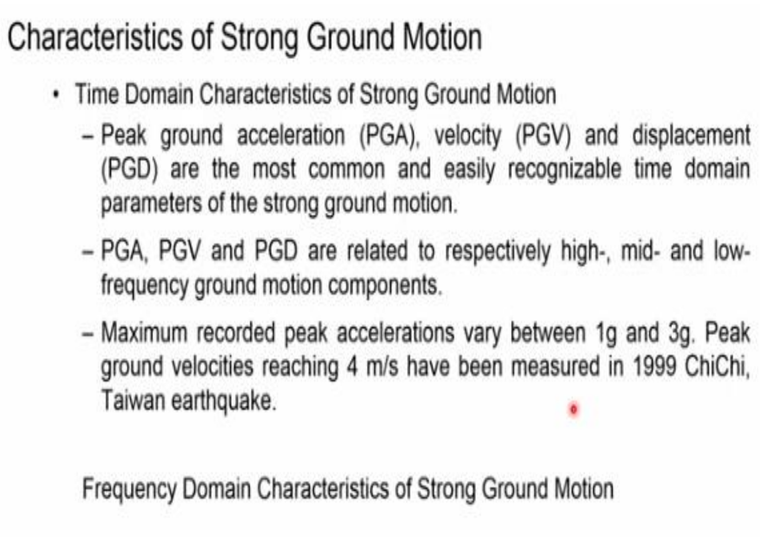

So from this once you are done that this is then you can estimate a time domain parameters of peak ground acceleration, peak ground velocity and the peak ground displacement. So this is the just a single peak value in this plot. So single peak value which may be the positive or negative but the absolute value only will be reporting. So, why do you need to measure three component of the data?

So as you know that the waveform is controlled by the each frequency content of the waveform. So the acceleration is controlled by the high frequency wave. Velocities are controlled by the intermediate frequency, displacement controlled by the low frequency. So if you have the structure, which is has some natural frequency, then the ground motion of we should see that this frequency does not match with the ground motion frequencies.

So that is the reason this peak values are estimated which represent here different segment of the frequency so or controlled frequency kind of;

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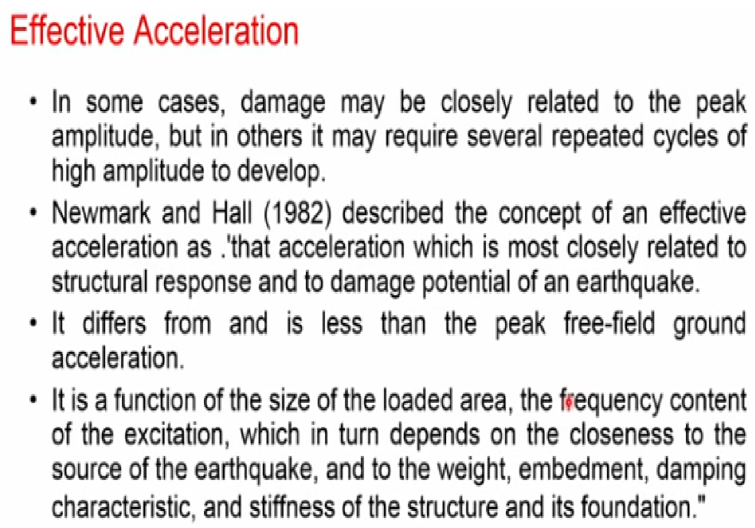

Apart from that we also studied about the effective acceleration. In some cases the damage may be closely related to the peak amplitude, but in other it may be required several repeated cycle. So the repetition of the amplitude rather than taking a single value, so the repetition the amplitude taken into consideration, they come up with the idea of defining the effective acceleration.

So this is the acceleration where the most closely related to the structural response to the structural potential of the earthquake. It differs from it less than the peak free field the ground acceleration. If the function of the size loaded area and a frequency content of the excitation which is turned depends upon the closeness of the source of the earthquake and weight, embedment, damping characteristics, stiffness of the structure and its foundation.

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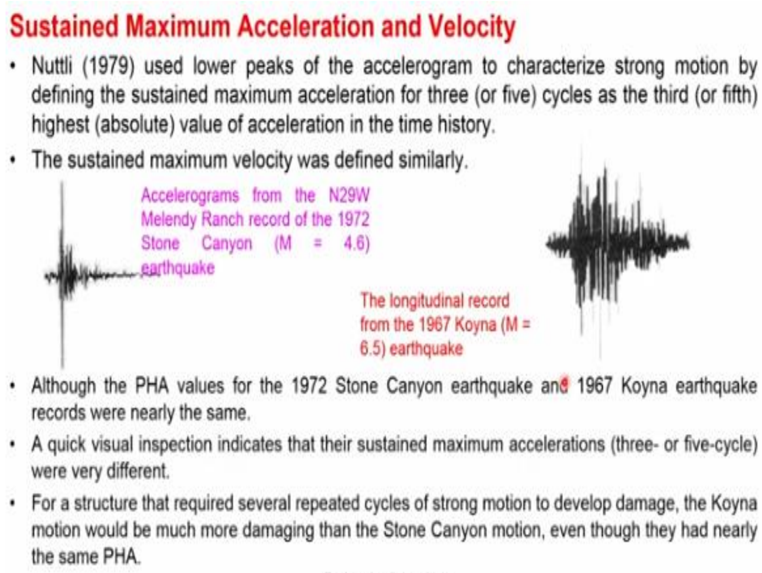

So the another one is a sustainable acceleration like a particular number of cycle, how particular values are repeating. So we have seen that a lower amplitude repeating several times will cause a more damage than the very large amplitude repeating once. So that is actually has to be accounted that is why the time domain parameters of sustained effective design acceleration.

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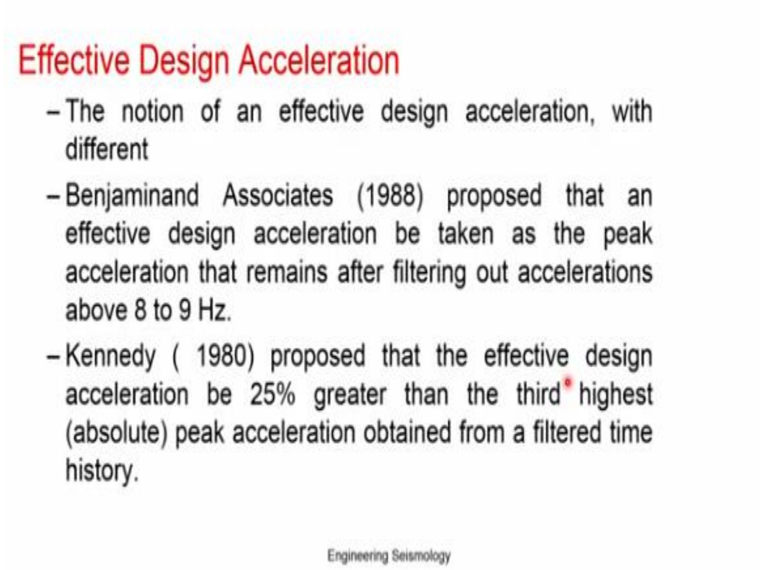

This is also again the design acceleration. So arrived for a to processing a data filtering out your data for a particular frequency. So Kennedy proposed the effective design acceleration should be 25% greater than the third largest absolute peak acceleration obtained from the filtered time history. So these are all the data we get directly from the plot of the earthquake.

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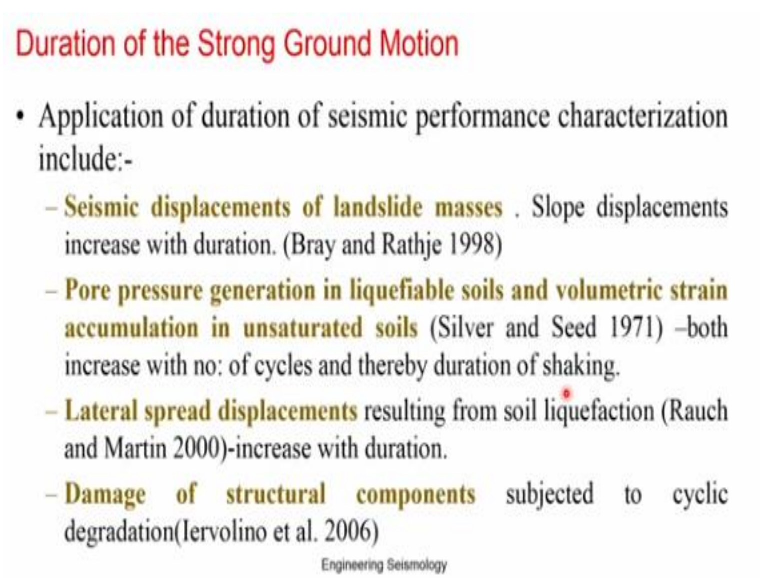

The other data is like since the amplitude does not represent properly the entire time history of the data, people come up with the concept of estimating the duration. So why because that is damage of the building depends upon the how many times the same cycle repeats and then the landslide and then the liquefaction pore pressure generation due to liquefaction, lateral spreading, damage structural component, all those is affect actually affected by the number of times the particular amplitude repeats.

So that in order to define that a people come up with the idea called a duration estimation or duration.

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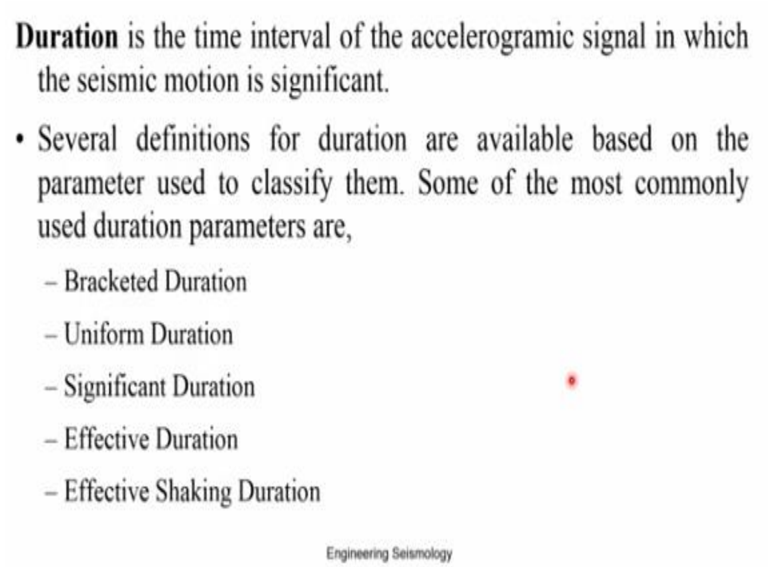

So there are four variety of duration bracketed duration, uniform duration, significant duration, effective duration, effective shake duration. So depends upon the way in which you handle your data this duration type changes for example, bracketed duration.

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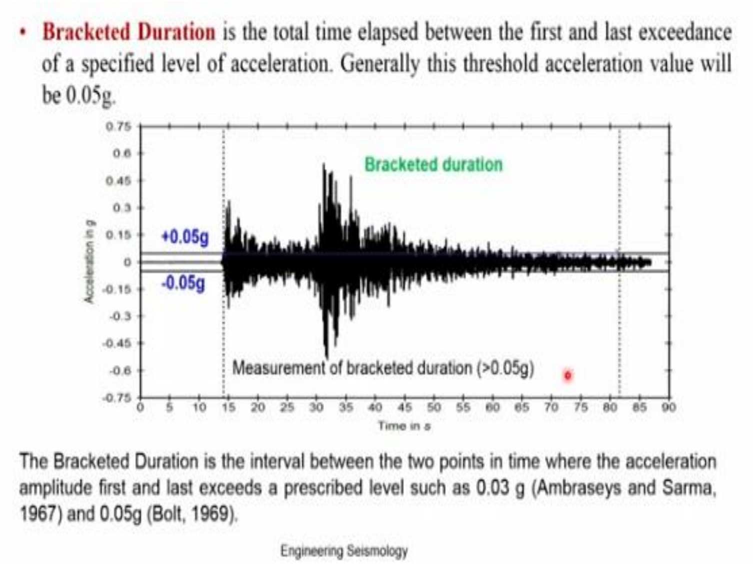

Say some threshold acceleration values are given in the threshold value starting and end point is called as a bracketed duration. So initially, they have used 0.05 later, they shifted to 0.03g to define a bracketed duration. So this is the typical way of bracketed duration.

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- **Arias Intensity** is defined as the time-integral of the square of the ground acceleration and is given by

$$AI = \frac{\pi}{2g}\int_0^{Td}(a(t))^2 dt \ (m/s)$$

where, a(t) = acceleration in m/s^2, t= time in *s*, g is the acceleration due to gravity and Td is the duration of signal above threshold.

➢ Theoretically the integral should be infinite.

Husid Plot is the time history of the normalized Arias Intensity i.e. Arias Intensity expressed as percentage of Total Arias Intensity represented as the normalised variable h(t)

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So then the acceleration time history further converted as a acceleration square to and then defined to Arias intensity, you can see the Arias intensity here. So where you can time integral square ground motion is given here. So this Arias intensity plot of Arias intensity in the percentage with respect to time is called Husid plot.

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- **Significant duration(D_a)-** Based on the accumulation of energy in the accelerogram represented by the integral of the square of ground acceleration, velocity or displacement.
- It is the interval over which some proportion of the total integral is accumulated.
- The most commonly used are the interval between 5-95% ($D_{a5-95\%}$) and 5-75% ($D_{a5-75\%}$) of the Arias intensity.

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So the Husid plot will be used to get you know that how much energy so released in a time then they come up with the concept of significant duration. So where the 5 to 95% of the releasing time is taken into account or 5 to 75% of the Arias intensity. So this significant duration is also very important.

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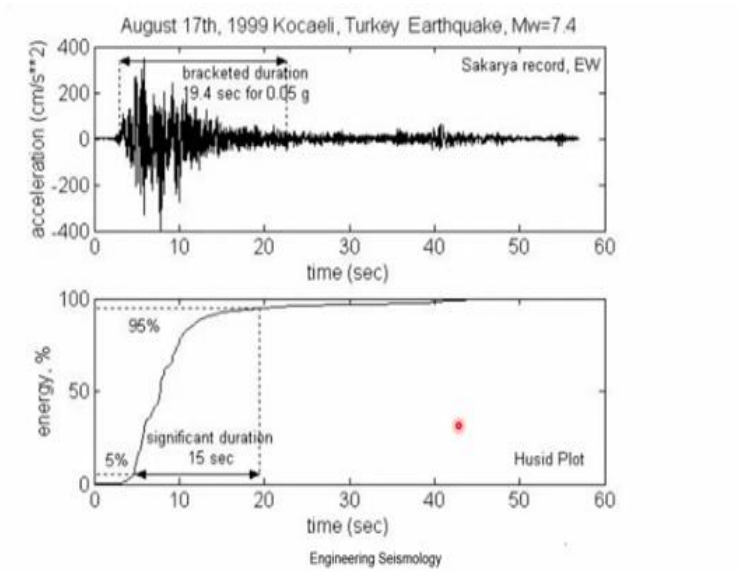

So you can see that for a same data the significant and bracketed duration may not be the equal, there will be always difference.

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Effective shaking duration (ESD) - The time interval between the first and last amplitudes by considering values ≥0.01 g were noted.

Then, the accumulated energy of the three components produced the Effective shaking duration (ESD) for the time window, which has 5–95% of the total energy within the amplitude threshold.

- This definition considered the major energy part and the part with amplitudes > 0.01g.

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So then the effective duration, the time interval between the first and last peak considering the value up 0.01g effective shaking. So this was the new duration definition by looking at effective significant and shaking point of view and these definitions are given.

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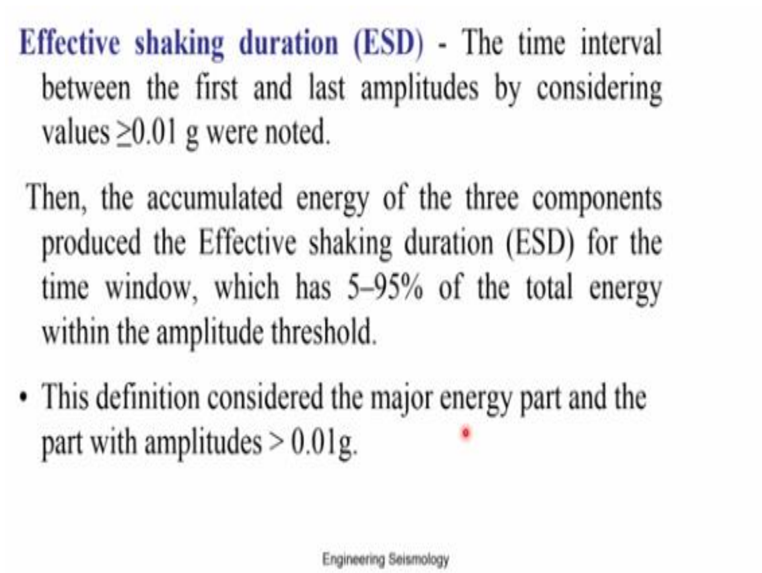

You can see the effective duration definitions are given 5 to 95% above 0.01g so clubbing together, you can get a effective duration.

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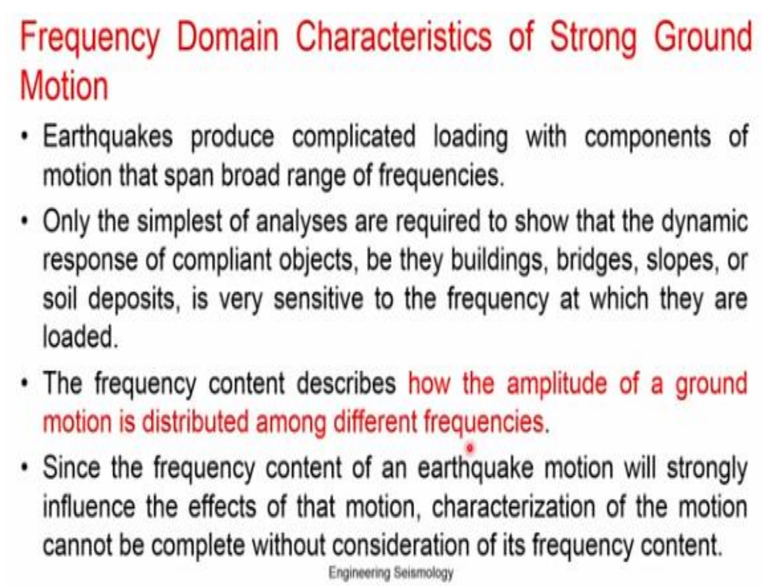

So the frequency domain characteristics of the strong motion the earthquake produces complicated loading system. So with the component of taking the in the infer the data only by looking at a 1 peak value or the how many times the peak 1 particular value repeated like duration and then the amplitude based interpretation may not be sufficiently to reflect how the different frequency the amplitude changes.

So in order to find out that the frequency domain characteristics the processing has done. So here basically the complicated loading system so how the frequency spectrum reflect a amplitude and different frequency, the frequency content describe how the magnet amplitude of the ground motion is distributed among different frequency level.

So that means whatever data you are getting from the seismic record after you doing baseline correction filtering and everything you need to convert data into the Fourier transformation. Fast Fourier transformation or point Fourier transformation that transformed data can be give you the frequency domain characteristics or spectrum that is what we are going to discuss now.

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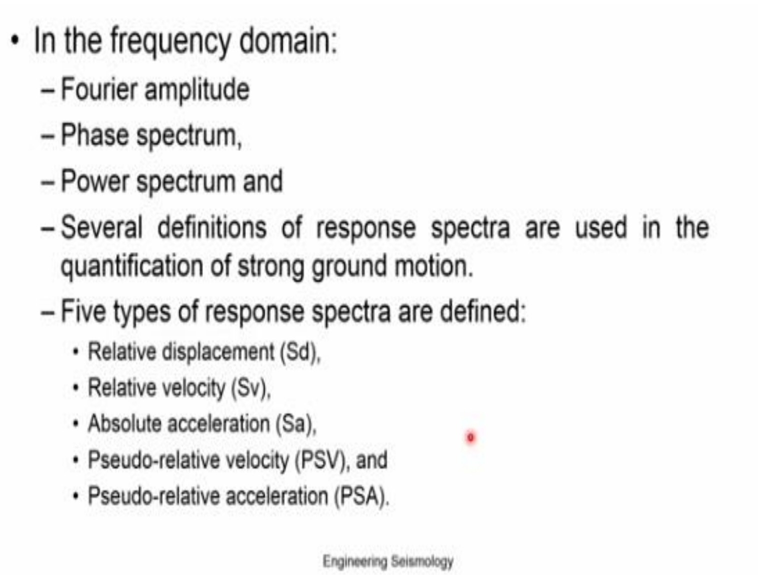

So you can see a difference frequency domain parameter Fourier amplitude, Fourier spectrum and then Power spectrum several definitions of the response spectrum are used to quantify the strong motion record. 5 types of response spectrums are used relative displacement, relative velocity, absolute acceleration, Pseudo-relative velocity and the pseudo-relative acceleration and velocity.

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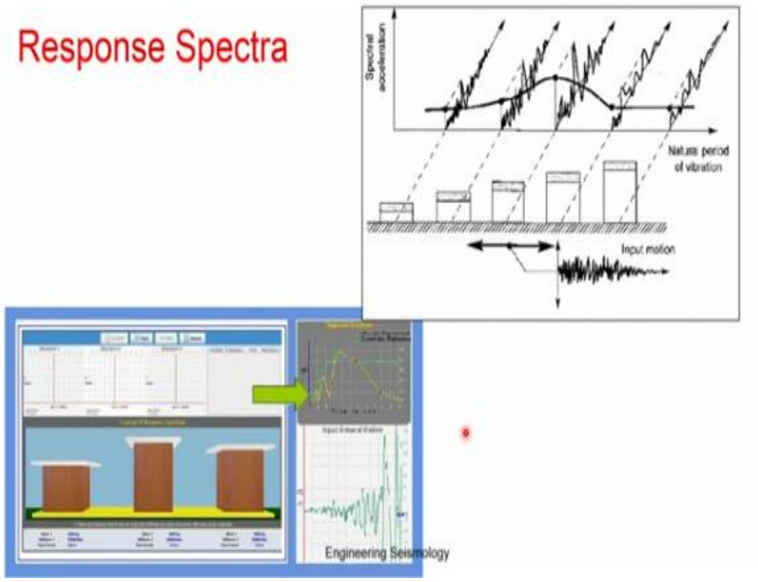

So this Fourier amplitude and spectrum will help to define basically your response spectrum, this is like response of the single degree freedom structures for a given period for the given earthquake. You can change your period again, you can keep the same single degree, you can get a response, that response together you generate that is called as a response spectra.

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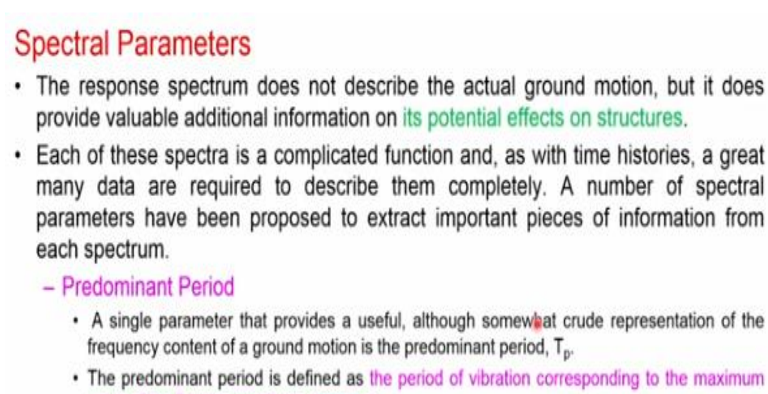

So this response spectrum the frequency Fourier transformation of the data can be also used to estimate a predominant period, fundamental period of the system. So where you will be taking the H baby ratio from the data and try to get here this fundamental frequency.

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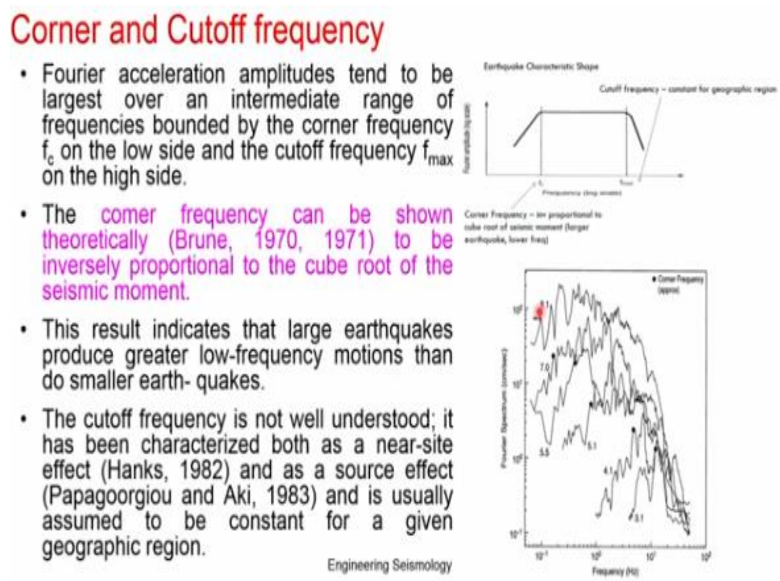

So that while designing you will not change the this one. Then another frequency domain parameters what we have seen was actually the corner and the cutoff frequency. So that is really related with the seismic moment of the a particular earthquake. But a large extent it is useful to interpret a source parameter and path parameter required for modeling the earthquake, the frequency.

So it has a corner frequency cutoff frequency. So where you can see this is the corner frequency, this is the cutoff frequency.

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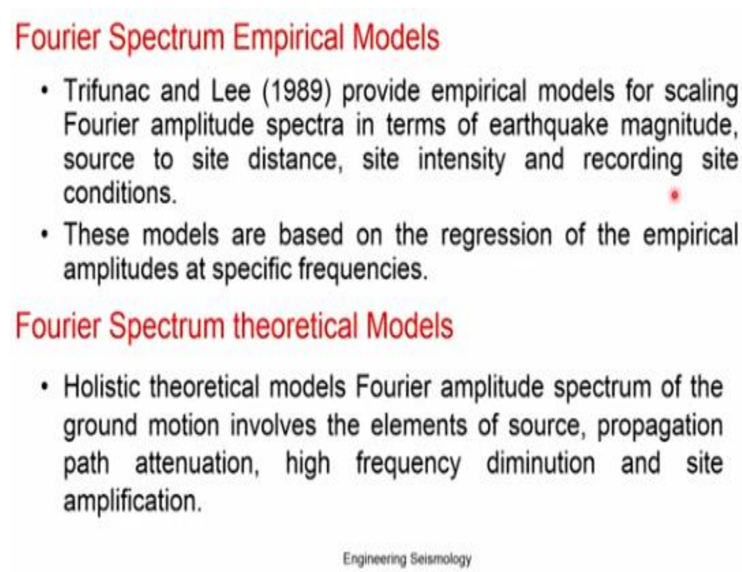

So the Fourier spectrum can be obtained by empirical model and theoretical based approach. So this theoretical approach basically.

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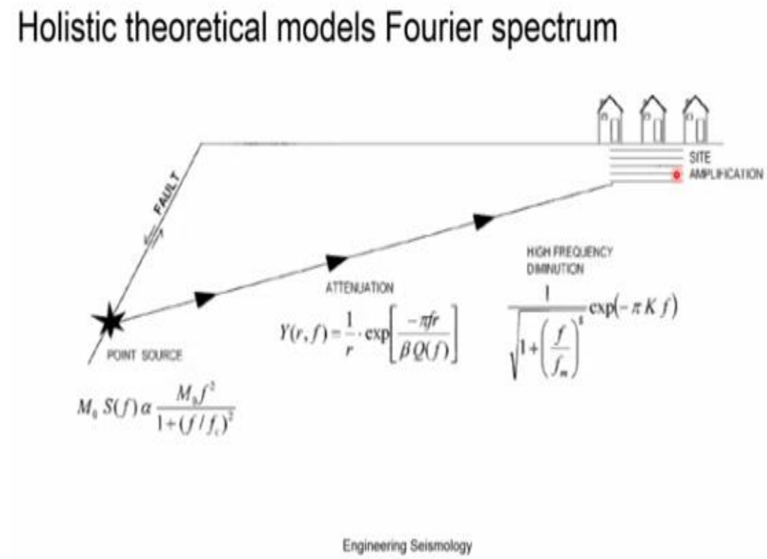

Gives a source for the attenuation and high frequency domination factor then it recorded at site. So these are and so this mathematics if you get all this mathematics and know how to estimate this parameters you can do basically very good research on engineering seismology, particularly India this kind of model and arriving a practice are not very addressed, very well addressed.

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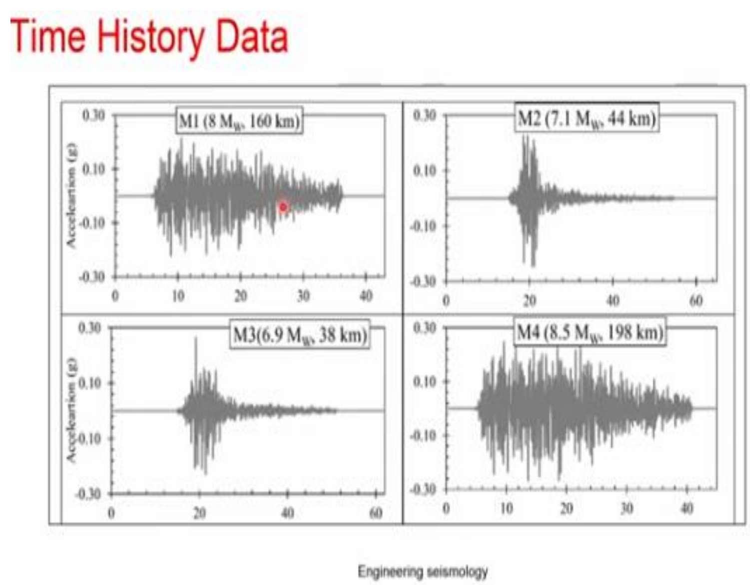

So this is a typical time history data of different magnitude with different distance, which will give you the glimpse of idea, you can get a peak amplitude from the this one and as well as the you can get the duration.

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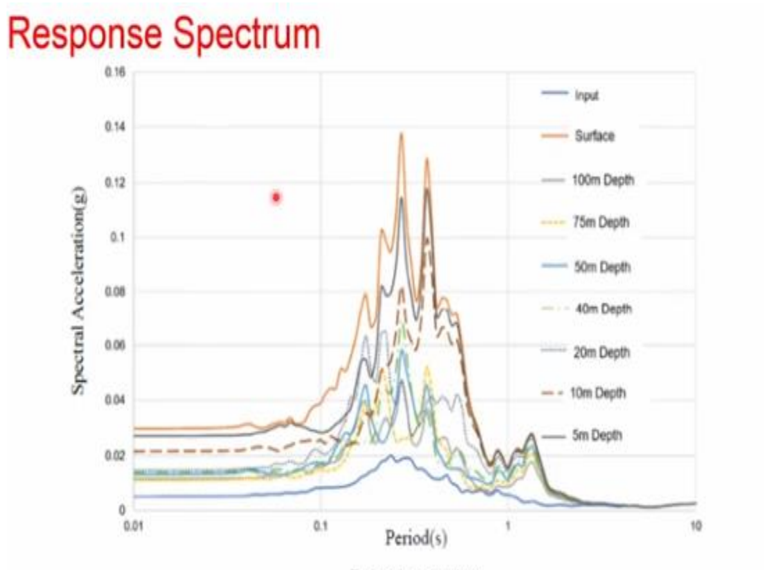

So then we also discussed that this data further used to get a response spectrum this response spectrum also varies with the depth that means the response spectrum at surface at 5 meter, at 10 meter and 20 meter may not be the same. So by the time you finish your course, this course the you can see one of our paper where we estimated a depth-based amplification in the Indo-Gangetic basin using 275 location measures the area velocity and also some micro atomic studies. So that is what you can get a response spectrum. So once you get a response spectrum.

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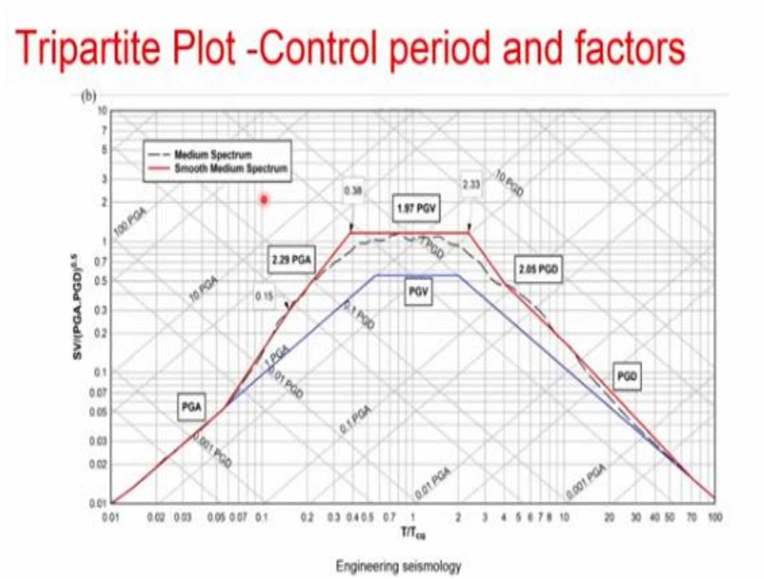

The next part is taking that response spectrum to the design level, so that is done by the Tripartite plot we have discussed what is mean by Tripartite plot. So what is the amplification factor? What is the cutoff period? How it is estimated? And what really mean a Tripartite plot? It shows basically the variation of the your amplitude and the also the duration taking into account. So this Tripartite plot is more advanced level.

So as per India concern this kind of development of spectrum itself, very limited. So this is about the interpretation of the seismic record. So this interpretation will help you basically to get more reliable parameters to design as well as to simulation purpose, that is what we have been discussed this parameters. So the more details of each and every aspect has been discussed in the respective class.

Here I am giving the overall view of the what we have discussed in the particular class. So with this we close this lecture. Thank you very much for watching. We will see the next class again. Thank you.