Introduction to Engineering Seismology

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Module No # 04
Lecture No # 20
Interpretation of Earthquake records (contd); Time Parameters

Vanakkam, so we will continue our engineering seismology course lecture so last class we have discussed about the enterprise of the seismic record. So the seismic record what we record in the seismogram are seismoscope okay. So basically it gives the waveform recording okay this waveform record depends upon the energy released in the source and then how long it travels and what location it records.

Basically source, path and size so the combination of the effect is reflected in the waveform data. So this waveform data only used to assess the energy released by the earthquake and size of the earthquake and many more things which is useful for the engineering application okay. So last class we discussed about the first part of the interpretational seismic record. So first of all how you can make a record perfect by applying a base line correction if there is any drift in the earthquake recordings.

The followed by we have seen that after applying that baseline correction so this record can be further identified that it is a recorded seismic events or it is a artificially generated some kind of vibration by machine or blasting kind of things. So we have discussed about the several wave we can identify the natural earthquake or artificially created blast vibration kind of things. So with that we finish today we are going to talk about the next level of the interpretation particularly we are going to talk about the part of time domain parameters interpretation of the seismic record.

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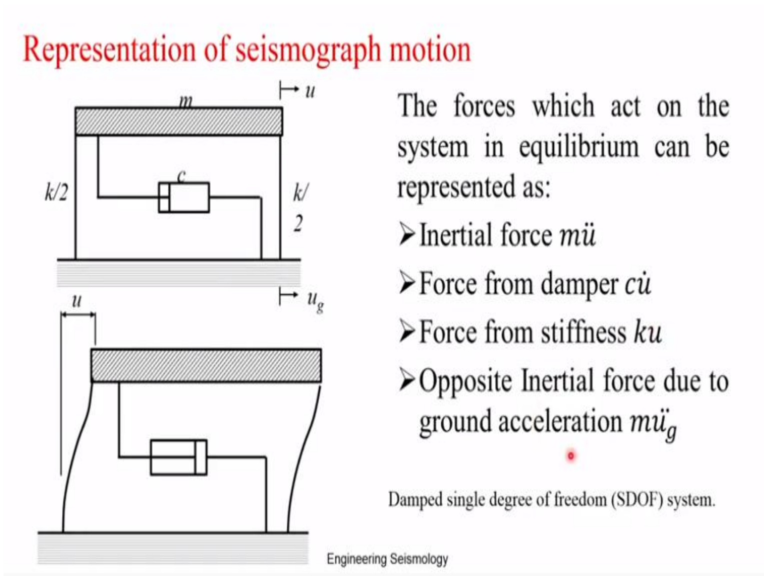

So as we have seen that during the seismic instrumentation part the seismogram works basically a damped single degree freedom system component. So where there is a mass and then there is a damping and the spring constant. So when the stationary so this part basically moves as a so there is no movement here okay. So when there is a displacement basically okay so then there is a relative movement of the ground okay.

So that basically takes care the your recording waveform details okay so this involved like the inertial force m into u and the force of the damper. So which is like cu and force stiffness ku the opposite internal force due to the earthquake acceleration is mg.

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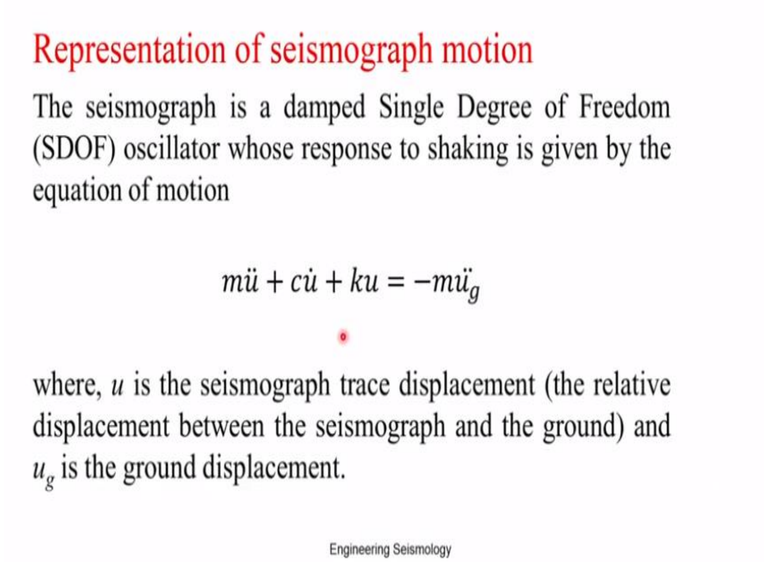

So which; can be easily basically understood by the single degree freedom wave equation so this is the form of equation which is solved to get a seismogram waveform recordings basically okay. So this equation basically implies that seismogram, trace how much the acceleration or velocity or displacement is happening due to the particular vibration. So that is what this earthquake record represents.

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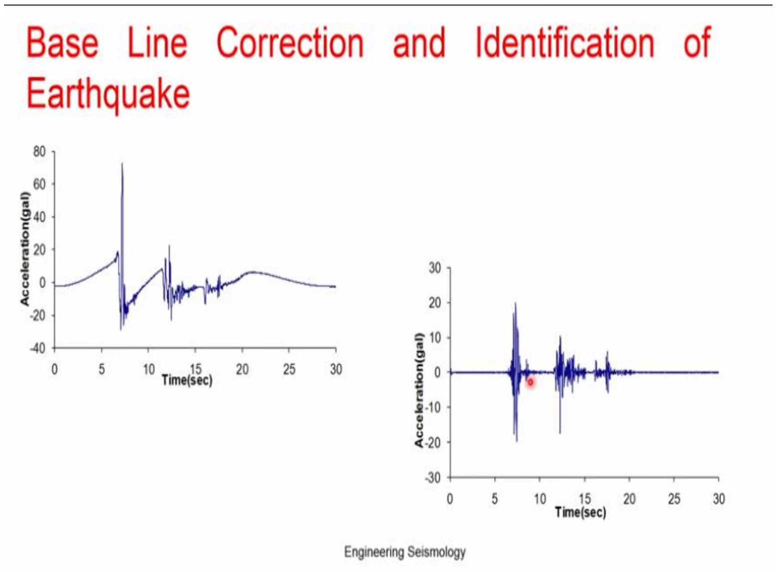

So we have seen that when the earthquake record represents maybe like this so which is at does not have any baseline correction. So once you apply a baseline correction you can see the record like this which is a perfect seismic record okay. So up to that we learnt in the last class how to identify the perfect seismic record. So as we have know that this perfect seismic record may consist of the different composition of the waves such as a body wave, P wave and S wave.

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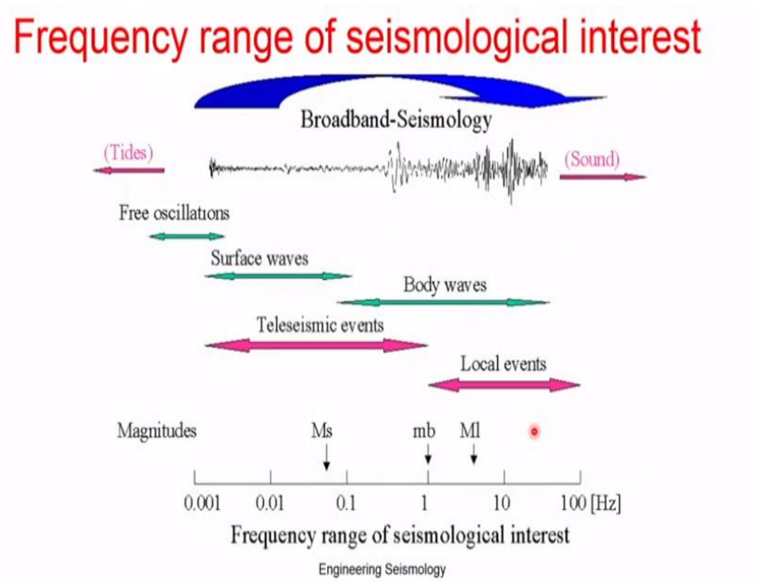

And also which the surface wave, rally wave and love wave depends upon the where the seismometer is located and where the earthquakes is occurred. So in general the range of frequency a seismological interest what we look for that. So any vibration which will be looking at like this a vibrating signal so basically the earth okay the tide okay there is a earth tide means basically the vibrations caused due to the location of the earth okay.

That kind of waves; are called as a earth tide which is generally having the frequency range of 0.001 hertz and below okay. So which is called as a free oscillations so then the waves the surface wave is the next frequency range which comes from generally 0.001 to 0.1 hertz. So then the body wave again from 0.01 to about more than 10 close to 100 hertz. So the range which covered by the free oscillation frequency to the body wave frequency middle of that range basically can be covered with the teleseismic events which can be generally recorded by the broadband seismogram okay.

So this is the event you can record so this means if you have instrument like this okay teleseismic event or broadband seismometer or very band broadband seismometer who could able to record very long distance earthquake in your site. So the, another one we have seen that a local event which is basically recorded so by the regional seismic network which have discussed what is mean by regional network.

Regional network is basically instrument which operated to measure earthquake happening within the region okay. So within these are all the body wave predominantly can find in the regional network and surface wave and body wave composite predominantly find in the teleseismic or very broadband record okay. So by looking at this type of wave one can estimate a different magnitude which we have studied.

So like Ms where, you can use a surface wave mb you can use a body wave Ml you can use a highest component of these 3 of them. Generally the S wave will be the highest component of the so the ml basically the S wave based magnitude S wave which is like a local magnitude. So we also studied about the magnitude saturation and then the moment magnitude which is the function of the fault rupture slip and stiffness of the fault okay. These are all the parameter which controls.

So these parameters will be reflected in the seismic record of the particular location or particular earthquake.

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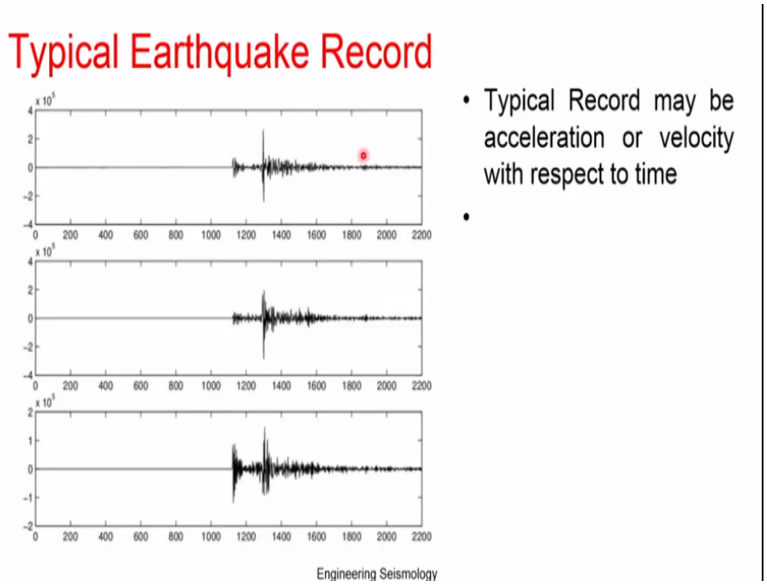

So the seismic record as we have discussed that there will be a typical okay so single component record or multiple component record okay multiple means like 3 components generally they use. So the 3 component record basically implies that the one component they orient horizontal component 2 was a north direction. So that means the north south is the one of the component the, another one is perpendicular that east west another direction.

The third one will be the vertical component so this is the basically a typical earthquake we can see the north south portion of the earthquake where you can see there is a one type of wave arrival. So possible this will be a P wave then, followed by there is a S wave arrival then followed by there is a small portion where you can see the surface wave okay. So this is another again there is east west component you can see basically the similar type it is recorded.

But if you see the amplitude of the record basically it has a different so amplitude it is not equal to this one okay. Then you can see the vertical component vertical you can see that the P waves are very predominantly reflected that is what we are seen when we have this animation recording the seismic station typical record. We have seen that vertical waves are reflected okay so the P waves are well reflected in the vertical component of the record so that is what you can see.

Then followed by your S wave then again there is a small surface component wave component are there. So this record may be obtained was recorded station which is maybe the close to the epicenter location maybe within a 100 or 200 kilometer the close means it is a regional scale 50 meter, 50 kilometer, 200 kilometer, 100 kilometer these are the regional scale record you can see.

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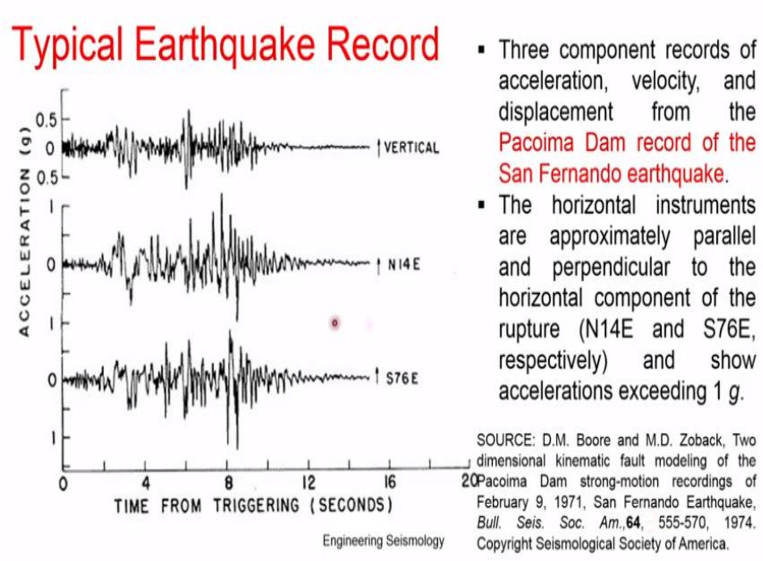

So if you look at the some of the large earthquake okay so where you can see that there is a distinguished difference between the velocity based records and acceleration based on. So the previous one basically the velocity based record this is actually the velocity sensor where the 3 component velocity has been recorded. So this is basically from the seismograph okay so the next one accelerograph this is actually a 3 component record of the Pacoima Dam. So recorded at, San Francisco earthquake so we have discussed about the San Francisco earthquake.

So which is largest earthquake in the; San Francisco due to the transform boundary at San Diego place okay San Andreson Fall. So which was caused a very big damages fire hazard which I discussed you know. So that earthquake actually it as a considerable amount of acceleration has been created against the gravity. So this is the typical component of that you can see here basically the acceleration actually goes to 0.1, 0.5 to 0.5g, 1g even some of the place we can see that it exceeding the 0.1g okay.

So the horizontal instruments are approximately parallel to the perpendicular to the horizon component of the lecture. So where it shows the acceleration are so here they observed that the horizontal component of the instrument was actually so perpendicular okay so the approximately parallel and perpendicular to the component of the rupture direction. So because of that only you get a very high g value recorded in this component particularly the north okay.

So north 14 component you can see which is exceeding the g so the similarly for the south continent so it was like there is a factor which controls although the rupture direction rupture directivity. So in case your seismic instrument oriented towards your north direction and fault also rupture on the any north or east west direction. So then you will have the record of high level of acceleration or velocity at particular place.

So these are all the information one can so have in the mind when they are processing and try to understand the so earthquake. The same earthquake which is recorded in the same distance and elsewhere it may not be oriented towards the fault directivity but you will have the less acceleration or velocity value okay. So this kind of directivity also influences the seismic record so this is the typical seismic record of the earthquake okay.

So you can see this earthquake actually the y axis basically acceleration or velocity so the x axis will be the time where that particular wave is arrived how it is arrived? So this data was taken from the old publication so where that Boore and Zoback. So Boore is one of the well-known world level seismologist so who is working on USGS now he retired. I do have some kind of interaction with him and he used to refer some of my work for his research related activity so he is a well-known seismologist basically. So from his initial stage publication in 1971 so those days publication this data was taken.

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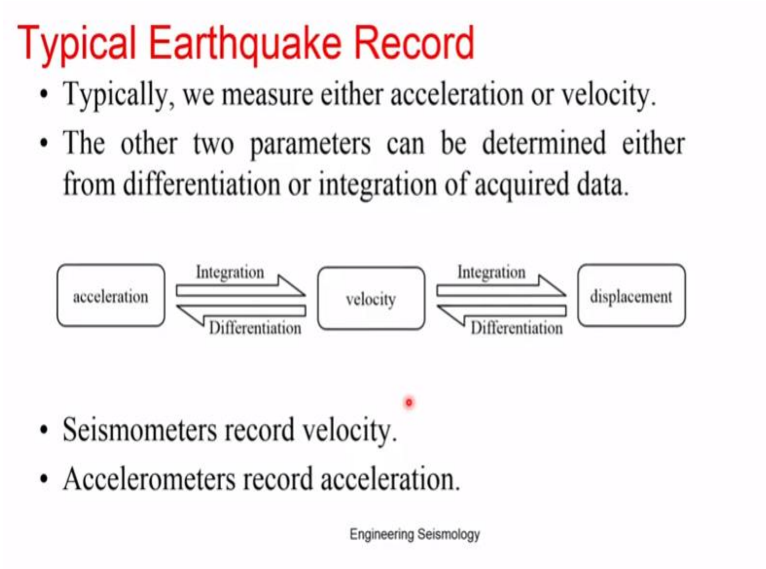

So as I said that the seismometer record velocity so the accelerometer record acceleration but in general so for the particular structural application. So we may need acceleration or velocity at displacement depends upon the, what type of structure it is what natural frequency of the structure. Okay so that is the taken in to account so from 1 parameter if recorded you can estimate all other parameters.

As you know that okay so the acceleration can be integrated you can get velocity. Velocity can be integrated you can get a displacement. So if you want to displacement to the velocity you can differentiate, you can differentiate the velocity you will get a acceleration. So this is how any 1 parameter recorder will be converted into other parameters which is required for the, your engineering application.

So this particular step is very important because you know what record it is from there you can convert to the record which you need for the engineering application. So generally seismometer or seismoscope records a velocity and accelerometer or accelogram will record a acceleration versus time.

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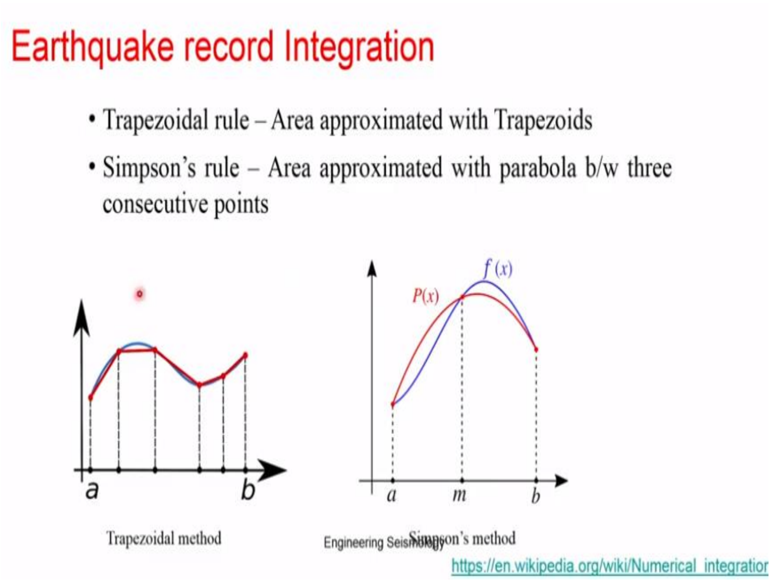

So how do you get you converted basically the earthquake record integration generally so if you have the earthquake record okay so as we have said that the acceleration you can integrate and get the velocity so record know. So like that one of the record okay you should take and you might have studied in the engineering this one that. So there is a integration and differentiation methods okay, so generally up to like B.Tech level or up to UG level we study this integration differentiation basics, and all but we may not even really understand where these are really applicable.

So those kind of mathematical rules okay mathematical integration differentiation are used okay so in the different engineering application. One of the engineering applications in the engineering seismologist actually the integration is used to convert data from 1 like from acceleration to velocity, velocity to displacement. So there are 2 types of integration tool they use one is the trapezoidal rule and the one Simpson's rule.

So these are all the well-known integration methods generally we solve part of our course program. Those who are not studied engineering mathematics maybe you will have some difficulty in what is this Trapezoidal rule and Simpson's rule. You can refer the website here Wikipedia information so you no need to worry about that how to solve this as long as you are not going to process data yourself.

But only you should know which data should be integrated which data should be differentiated and what method we should use. So the integration generally the Trapezoidal rule and Simpson's rule are used so this is how the Trapezoidal rule is taken and this is how the Simpson rule they apply.

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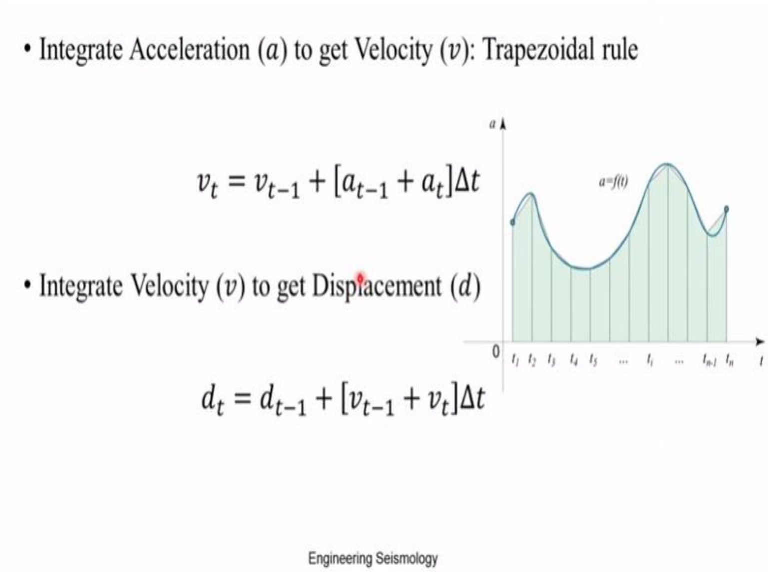

And with use in that you can convert the data from one form to another form per user integration of acceleration to get a velocity so this is the integration typical formula. Similarly the velocity to displacement this is the typical formula where you will get your 1 acceleration to velocity, velocity to displacement. So knowing this method like you should use integration and what type of integration and that is sufficient okay.

So nowadays there are software which is coded this okay so readily available to get your integration differentiation done. Only you should know how this works that is enough because our objective is not to teach you the processing of earthquake record I will teach a mathematic behind the processing of earthquake record. Because of that we are not going to in detail only you should know what you should know what you should do how you should do that is sufficient for the knowledge of this particular part.

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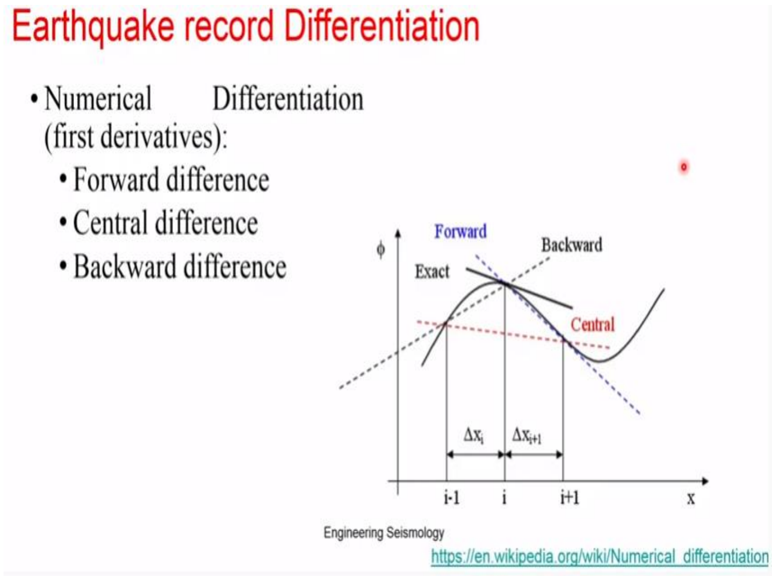

So similarly so the differentiation you can do the numerical differentiation like first derivative. So the forward difference and the central difference and backward difference so any of the 3 method can be used any of the one method can be used to get from displacement to velocity, velocity to acceleration. So the more information about this methods can be obtained from this book or any standard.

So differentiation integration mathematics books which is taught in the first year of the engineering courses or even sometime +2 level also people study this kind of formulas okay integration differentiation kind of things which will be sufficient. Once you integrate and differentiate a particular type of wave form okay, will be transformed to the other form of wave form.

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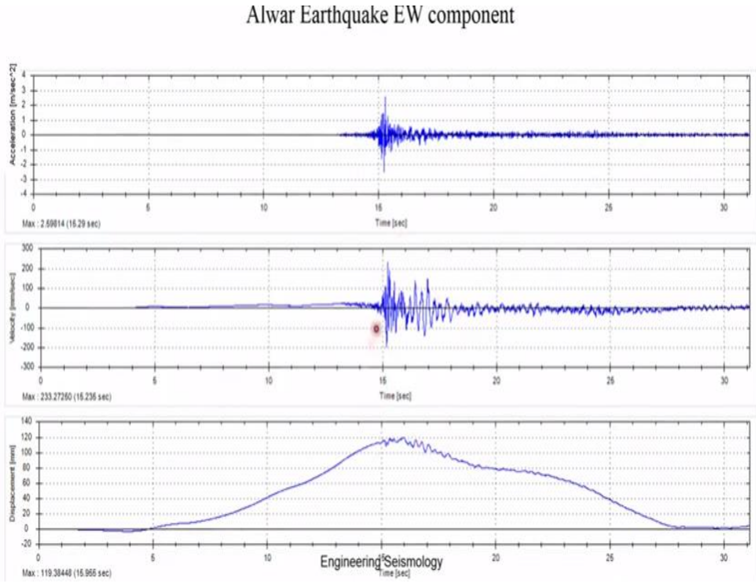

So this is the typical earthquake so where the all were earthquake east west component. So each record okay the each component of the record can have 3 type of plot one is the acceleration time is to plot, the velocity time is to plot and displacement time is to plot. So this is basically the east west component you can see the acceleration plot where you can see the acceleration start with 0 and almost end with 0.

Similarly the velocity component you can see how it goes and end with so displacement component you can see where it goes under. So wherever the peak is there you can get a higher displacement in this region.

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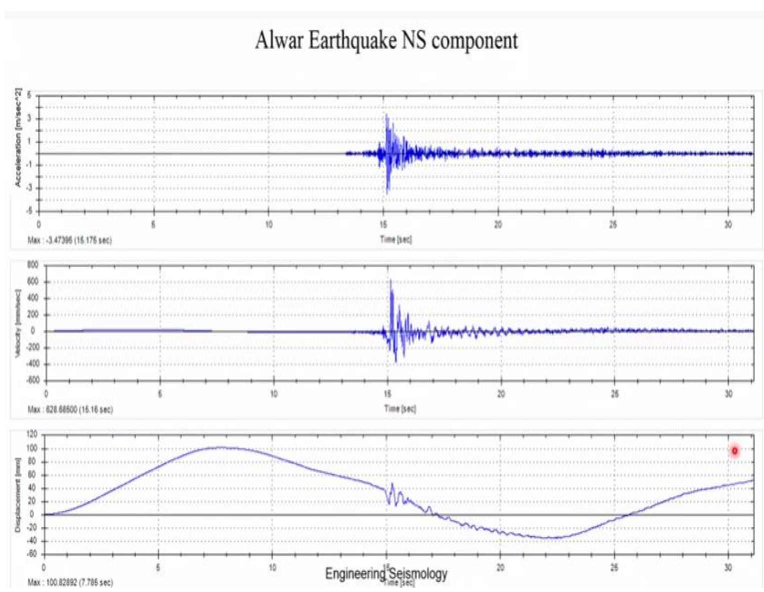

(refer time: 17:21)So similarly this is the same earthquake north south component you can see here so where the acceleration velocity and displacement okay. So you can see even the displacement not attaining the 0 at the end of the record okay.

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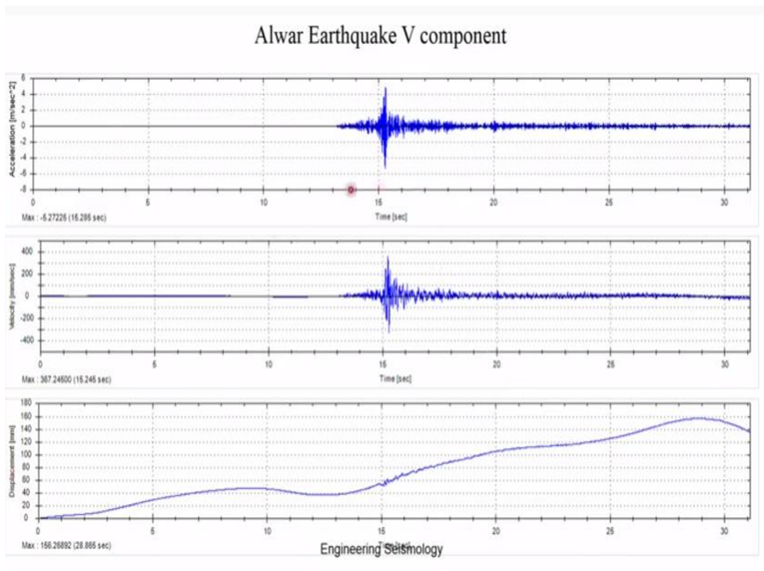

So similarly this is the vertical component where you can again get this one you can even see the permanent sometime information in the vertical direction. So this particular earthquake you can see the permanent deformation in the vertical component. So the each component of the data okay can be converted into other form like acceleration form velocity form and displacement form. So that is what we seen here okay.

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Characteristics of Strong Ground Motion

- Time Domain Characteristics of Strong Ground Motion
  - Peak ground acceleration (PGA), velocity (PGV) and displacement (PGD) are the most common and easily recognizable time domain parameters of the strong ground motion.
  - PGA, PGV and PGD are related to respectively high-, mid- and low-frequency ground motion components.
  - Maximum recorded peak accelerations vary between 1g and 3g. Peak ground velocities reaching 4 m/s have been measured in 1999 ChiChi, Taiwan earthquake.

Frequency Domain Characteristics of Strong Ground Motion

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So now so you have the recorded earthquake data which consist of the 3 component okay so 2 horizontal 1 vertical that 3 component again you can convert into the 3 form of data. Like acceleration time is T velocity time is T and displacement time is T okay. So this is the first preliminary process we have to. Once you convert all this data's okay then you can get what data you need for the engineering application.

As I told you that so when you interpreting the data there are 2 types of interpretation or 2 data observation made to attain a data. So 1 observation is basically you look at a data okay and note down the values that is like a time a domain formation of the data. A time domain means like acceleration versus time velocity versus time displacement versus that is the time domain. So by looking at those data you get directly some parameters those parameters, is called as a time domain parameters okay.

So the another one is you use this data and transform to other stage okay so that stage are basically is a frequency domain parameters that your time is to transform to the fast Fourier transformation then you will get a the Fourier spectrum okay. So Fourier power spectrum, Fourier response spectrum like that several form of spectrum you will get that from that spectrum you derive some parameter that is called as the frequency domain parameters.

So generally the time domain parameters the first value they take from many record is actually the peak value of particular plot like peak ground acceleration, peak ground velocity, peak ground displacement. So this PGA, PGV and PGD is the short form which related to respectively high and mid and low frequency of the ground motion component. So that means if you are getting the acceleration value peak so that will be responsible for the high frequency component of the ground motion.

We were getting the velocity the mid frequency of the component and if you are getting the displacement at the low frequency component. So that means it depends upon your natural frequency of the structure one can decide which parameter you should use or consider for estimating the seismic force. So if the structure that is again the function of your structure height and structure mass.

So far the maximum recorded peak acceleration there is from 1g to 3g which we have seen in that the peak ground velocity reached so far reaching was 4 meter per second in the 1999 ChiChi earthquake Taiwan. So this is the highest level of PGA and PGV has been reported in the literature.

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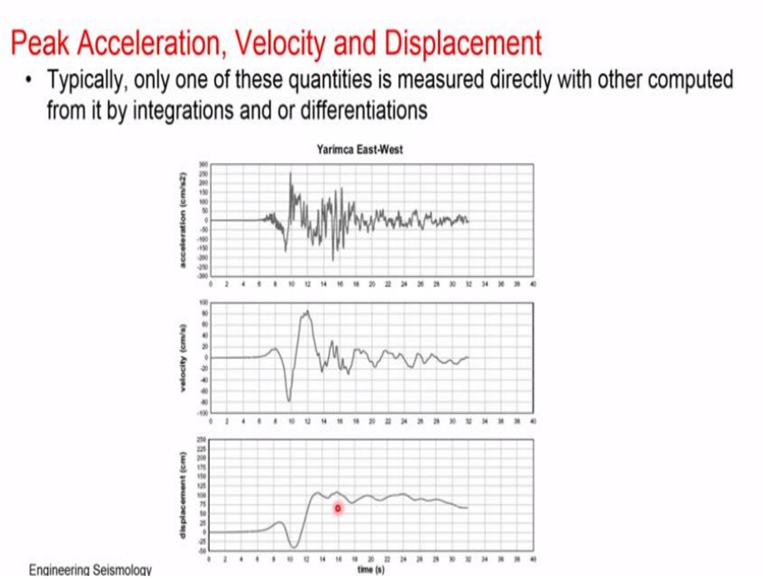

So the peak ground acceleration basically as we seen that the each component of the data can be converted into 3 form. So this is the (()) (21:01) so from here we will observe a peak, peak means absolute value not without sign. Among with this, whichever is maximum okay that is actually the peak acceleration. Similarly whichever is maximum; is the peak velocity is really similarly whichever is maximum is the peak displacement okay. So that you can directly see the waveform data and get the data that data is useful for the several engineering applications.

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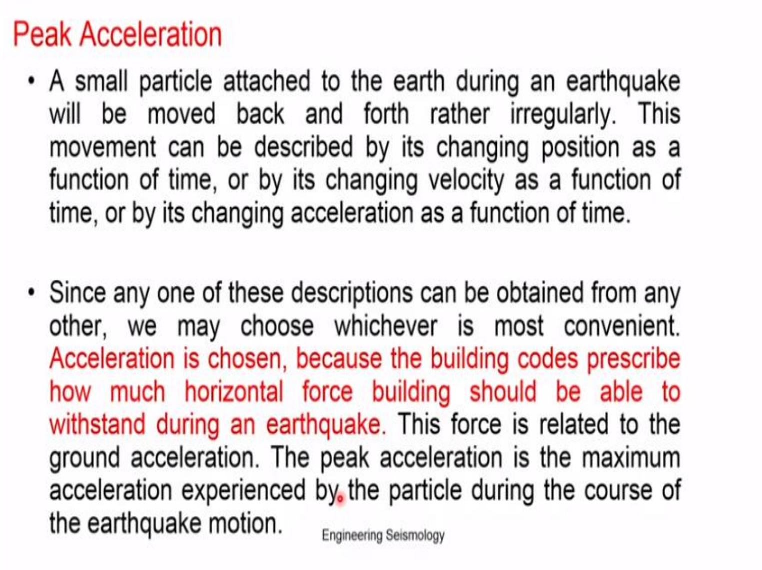

Okay if you look at the peak acceleration a small particle attached to the earth during a earthquake will be moved back and forth rather irregularly okay. So this movement can described by the changing of position of the function of time by change in velocity as or is the change in the acceleration is the form. So in this movement the peak value basically is called as a peak acceleration.

Since any one of this describe can be obtained from the any other so by like integration differentiation. So we may choose whichever is most convenient is acceleration is chosen because the building code prescribe how much horizontal force building should be able to withstand during a earthquake. So this force is related to the ground acceleration the peak acceleration is the maximum acceleration experienced by a vertical during a course of earthquake acceleration okay.

Or the maximum waveform recorded in the seismogram okay seismogram whatever it is records so the wave form whatever you are getting is the seismogram record is your peak acceleration.

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- The most commonly used measure of the amplitude of a particular ground motion is the peak horizontal acceleration (PHA).
- The PHA for a given component of motion is simply the largest (absolute) value of horizontal acceleration obtained from the accelerogram of that component.
- By taking the vector sum of two orthogonal components, the maximum resultant PHA (the direction of which will usually not coincide with either of the measured components) can be obtained.
- Horizontal accelerations have commonly been used to describe ground motions because of their natural relationship to inertial forces; indeed, the largest dynamic forces induced in certain types of structures (i.e., very stiff structures) are closely related to the PHA.
- Vertical accelerations have received less attention in earthquake engineering than horizontal accelerations, primarily because the margins of safety against gravity-induced static vertical forces in constructed works usually provide adequate resistance to dynamic forces induced by vertical accelerations during earthquakes.
- The peak vertical acceleration (PVA) is often assumed to be two-thirds of the PHA (Newmark and Hall, 1982)
- The ratio of PVA to PHA, however, has more recently been observed to be quite variable but generally to be greater than two-thirds near the source of moderate to large earthquakes and less than two-thirds at large distances (Campbell, 1985; Abrahamson and litehiser, 1989).

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So this peace acceleration also can called as a peak horizontal acceleration because as we have seen that each earthquake will have the 3 component 2 horizontal 1 vertical. So the peak ground means it is mean a maximum of that so then when the knowledge was developed there was a record from their rock and as well as record from the ground surface. So then how do you differentiate that is why they are called it as a so the peak horizontal acceleration.

So it may be recorded at rock maybe recorded at ground does not matter so you can also call it as a peak ground motion or you can also call it as a peak horizontal motion or a peak horizontal under acceleration the PHA okay. Generally the PHA which means a recorded at bedrock level okay; or station. So PHA given component motion is simply the largest absolute value of the horizontal acceleration obtained from the accelerogram in the component.

By taking a vector some of the 2 orthogonal component a maximum resultant PSHA okay so the direction may not be usually not tensile with the either measured a component can be obtained. So this PSHA can be also obtained as the orthogonal component of the 2 horizontal component that is way you can also. So horizontal acceleration have commonly been used to describe the ground motion because they are natural relationship in the inertial force indeed that largest dynamic force induced certain type of structure like various structures are closely related to PHA.

So the scientist researcher found that so the damage is the function of the peak acceleration created and this acceleration are basically related with the inertial force of the structure that is why they use. So the vertical acceleration have received less attention in the earthquake engineering than horizontal acceleration and primarily because the margin safety erase gravity induced by the static vertical force constructed a work usually provide adequate assistance to the dynamic force induced by a vertical acceleration during earthquake.

So the peak vertical acceleration is often assemble to be a two third of the peak horizontal acceleration which was suggested by the Newmark all in 1982. But now there was observation and findings that this peak vertical acceleration changes to region to region it never be, a two third. The ratio of PVA and PHA however as more recently being observed be quiet with variable but generally greater than two third near to the source to moderate to large earthquake and less than two third long distance that was the some of the observation has been made.

So India actually nobody was studied this kind of observations so one has to estimate how much we have the two third or this one. So when you look at this one I need to also give you the idea about what we are talking basically.

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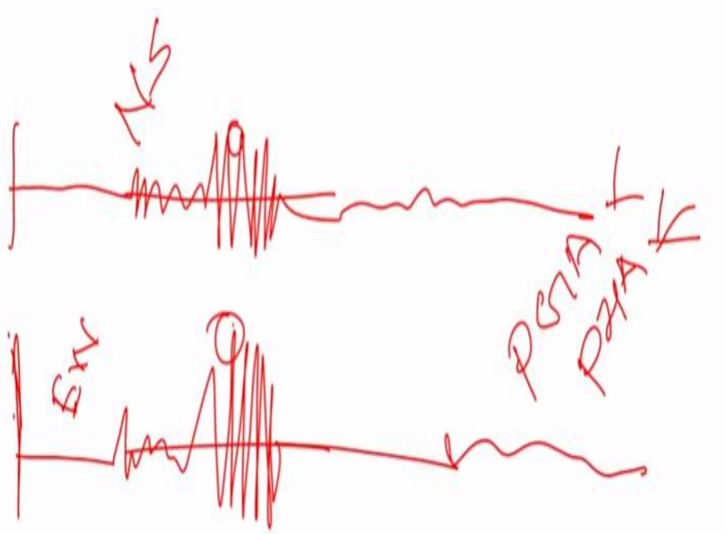

So this is the typical earthquake okay so this maybe the north south okay so this will be the so the so east west component then this one. So here this is the east west so the peak value will be absolute peak value will be identified. For example you have this one so here if you go this the highest will be the may be this one. So this value whichever among this value whichever this maximum can be called as a PGA or PHA okay 1 value or you can also take both of them find out a orthogonal value that can be also called a this one.

So they will specify which is the; single of 2 component peak or orthogonal of 2 component so the orthogonal value generally less than the highest one and maybe more than this one. So with this will be described for this one in the particular record. So the vertical component so generally is whatever recorded data so then that peak you can take sometime in the absence of the recorded data they use to two third of the value.

In olden days but now the two third value is not universal so it basically various with the place to place okay so that is what we found in the many of the research. So this peak acceleration values are very sensitive to the high frequency of the data. So if you are constructing the high frequency structures then you should consider peak ground acceleration or peak horizontal acceleration for the design parameters.

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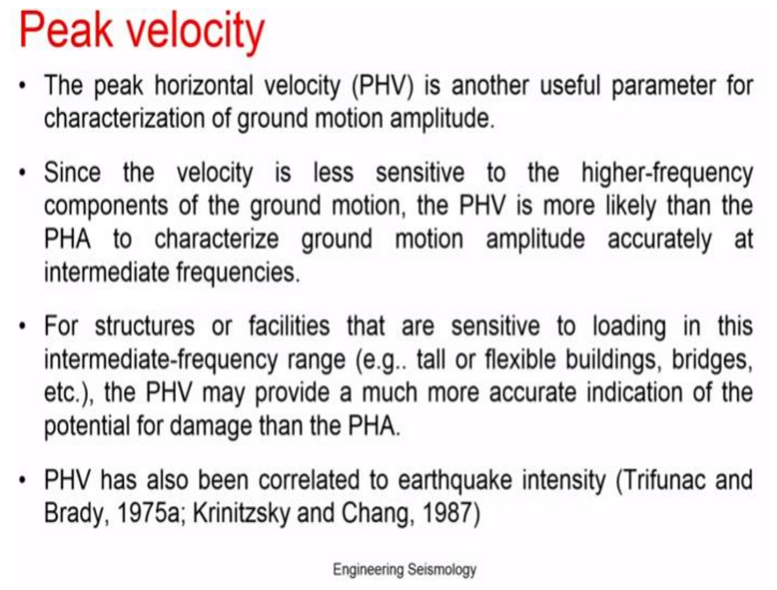

So the next one is basically a peak velocity the horizontal velocity or peak ground velocity is another useful parameter per characterization of the ground motion amplitude. Since the velocity is less sensitive to the high frequency component the ground motion the PHV is more likely to PHA to characterize the motion amplitude to accurately per intermediate frequencies.

So generally when the intermediate frequency range okay will show you the high peak velocity or peak horizontal. So the structure or facility that is sensitive to the loading in the intermediate frequency range such as a tall structure flexible building bridges the PHV or velocity based design as to be done. The velocity parameter should be taken as a input for designing this kind of structures.

So the PHV has also been correlated to the earthquake intensity by the several researches where you can see the how the particular structures are got damage how much percentage got damage with respect to PHV angle. So whenever you have this kind of tall structure flexible building bridges and all your acceleration is basically meaningless you have to consider a velocity data and peak horizontal velocity for the design.

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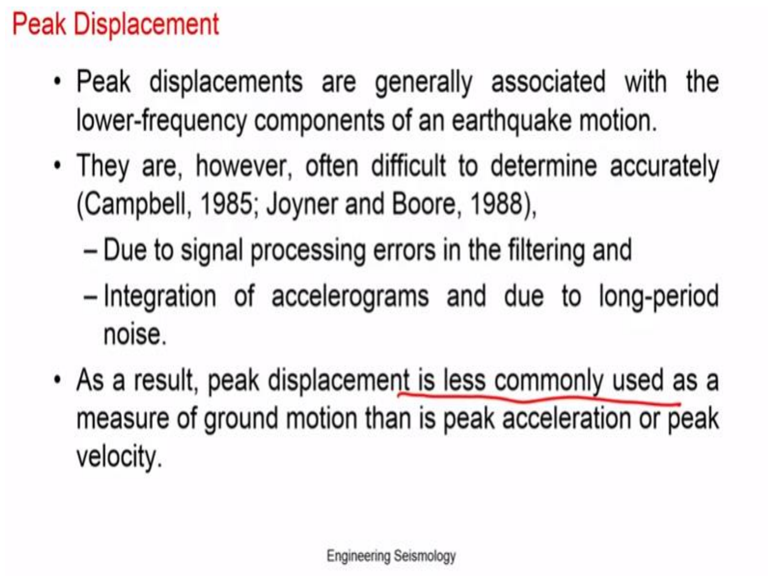

So the another one is the peak displacement so the peak displacements are usually associated with the lower frequency component of the earthquake so they are however often difficult to determine accurately due to the signal processing error in the filtering and integration of acceleration and due to the long period noise okay. As a result peak displacement less commonly used okay peak displacement less commonly used to measure a ground motion than a peak acceleration or peak velocity okay.

So this is very less used in the engineering but nowadays there is a displacement based approach okay so where they design where they consider the displacement parameters for the design of those kind of structures. Particularly the low frequency structures where the peak displacement is used as a parameter to design. So we have seen so far so we have taken a typical acceleration time history of the data or typical record okay 3 component records.

So it has a 2 horizontal component okay so south west direction east west direction 1 vertical component and each component you can convert from 1 form of data to other form of data. For example the seismometer record as a velocity you can convert the velocity to the displacement by integration and you can convert velocity to acceleration by differentiation okay. So you convert that data will be useful for engineering application once you converted this kind of 3 forms of data with single component.

So then you can consider the 3 after converting the 3 form of the 3 component data that we have the 9 component okay 9 data you will have for a single earthquake at single station. So then you among this 2 horizontal component okay so you will have 2 horizontal components so this 2 are horizontal component has basically 3 forms. So you can consider acceleration where is the peak velocity where is the peak then you can report what is the peak horizontal acceleration peak ground acceleration.

Similarly peak horizontal velocity or peak ground velocity we have seen that in order or differentiate easily the bedrock and surface. So if it resonate a horizontal it is a preferably source it as a bedrock record if it is written as a peak ground it may be recorded at soil, site and the ground okay. That is the way you differentiate so this data so we have seen that the accelerations are sensitive to the high frequency range.

So that the high frequency structure high frequency which has the structure which has a natural frequency higher okay that as to be designed by considering the acceleration. The structure which has a medium frequency okay that as to be designed by considering the velocity peak velocity or velocity component of the data and the structure which is sensitive to the low frequency range need to be designed by the displacement.

So we also seen that the velocity is basically two third of the acceleration in general but however the recently this is not a uniform value it various region to region which has to be found out and used in the practical design application rather than assuming the two third okay. So displacement generally not so used for the design as it is getting accurate displacement or peak displacement is a may not be possible due to signal processing error and filtering.

And then there is a long term noise also will affect the quality of the data so with this we will close this class. So next class we will see what, are the other parameters time domain parameter we can interpret from the earthquake record. So thank you very much for watching this video so we look forward in the next class.