Introduction to Engineering Seismology
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Lecture No -21
Time Domain Parameters (contd.,)

So Vanakkam we will continue our lecture on the engineering Seismology. So last class we discussed about the seismic record. So how the three-component record is been converted into velocity and displacement and then from displacement to velocity, velocity to acceleration by integration and differentiation method. So we also seen that this converted data can be directly used for basically to get a your;

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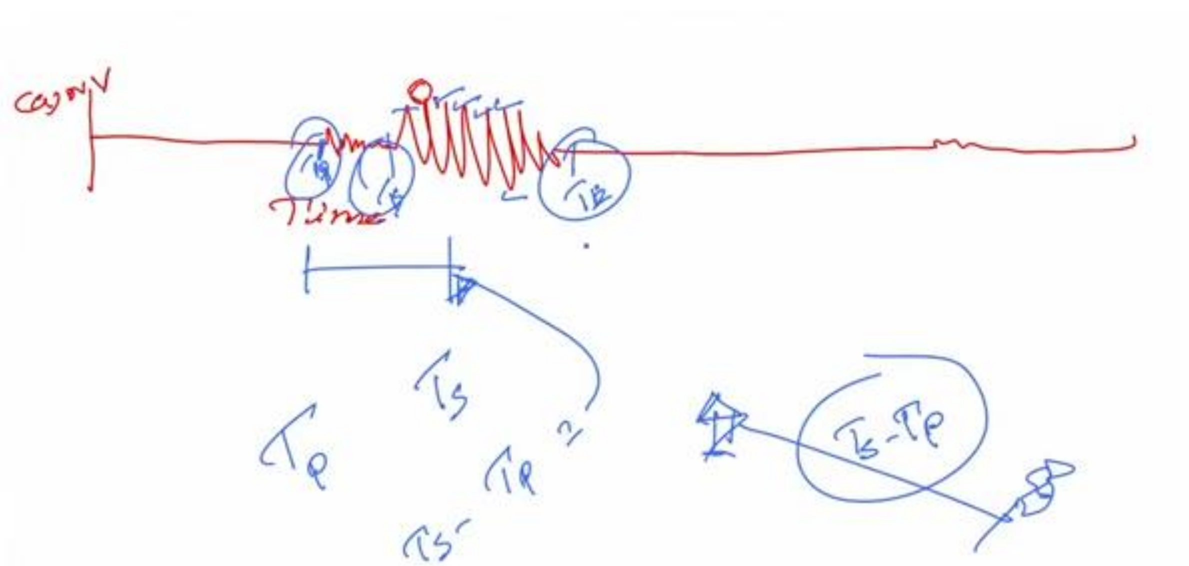

So to get your peak ground acceleration or peak horizontal acceleration and the peak velocity, peak displacement. So we are also seen that these values are basically sensitive to the high frequency the acceleration intermediate frequency is the velocity and displace. Here a typical record basically, so this is the typical record. So this will be the acceleration or velocity is the component.

So you can see generally the peak occurs on the S wave portion. So this what will be peak. So generally the this portion of the data will be looked at by the engineers very well and they will use this for the design as we have seen that during the wave propagation theory that so the S wave basically is a wave where the particles are vibrating perpendicular to the wave direction.

So because of that it creates a large amount of the inertial force and instability in the structure, which you need to be considered for the design. So by looking at this while taking this value is one of the way you can interpret in the time domain, which is a peak values what you are getting. So the other way, so where you can get also the interpretation of the record from the time domain parameters.

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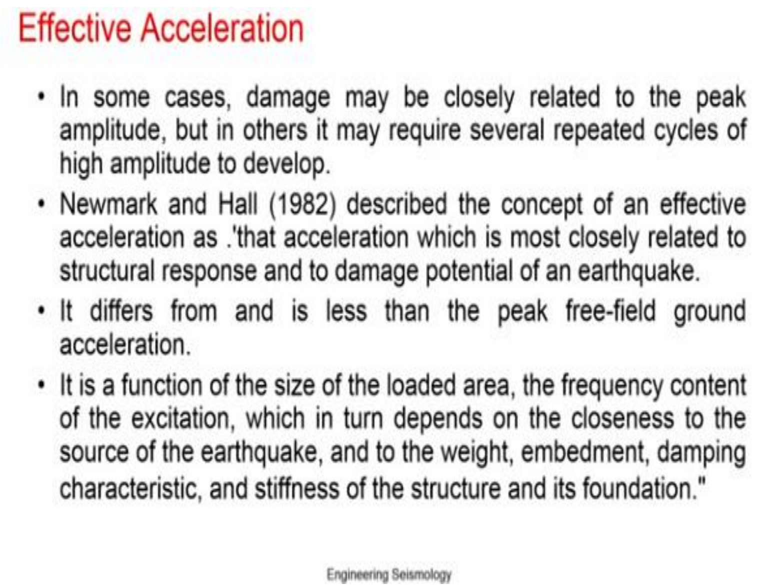

We are going to see. So what is those things basically we are going to see that as the effective acceleration. So in some cases the damage may be closely related to the peak amplitude, but others it may be required here several repeated cycles of the high amplitude to develop. So what it means basically, we actually have the record of this is the peak, which is the highest among all but you can also see very closely in this record even though this peak is slightly higher than that.

There are other component of the so the wave form where this one. So basically, so this 1, this 1, this 1, this 1, this 1, this 1, this 1 which is slightly less than the peak but it occurs several time. So not that all the time the earthquake what you are looking at, the peak value will only will cause. So sometime in the record, you will have them a peak will be slightly larger than the other amplitude of the record.

In those cases the several repeated amplitude may cause here damage of the structure. So, that they come up with the idea of defining the effective acceleration. So where the several cycles of the high amplitude will cause a damage. So the Newmark and Hall in 1982 described the concept of effective acceleration at that acceleration, which is most closely related to the structural response to damage potential of an earthquake.

It differs from and it less than the peak free field ground acceleration or peak horizontal acceleration. It is a function of size of the loaded area, the frequency content of the excitation which in turn depends upon the closeness to that source of the earthquake and to the weight and the embedment and damping characteristic and stiffness of the structure and its foundation. So this is basically a composite mix of the structural parameter and acceleration.

So we have many repeated cycle of acceleration can cause here damage. So the effective acceleration is such kind of many repeated acceleration has been defined as a effective acceleration. So another one is actually the sustained maximum acceleration and velocity. So the Nuttli 1979 used the lower peak acceleration to characterize the strong motion by defining the sustained maximum acceleration for a three or five cycles of the record.

A fifth highest absolute value acceleration of the so why he has come up actually if you watch very closely this.

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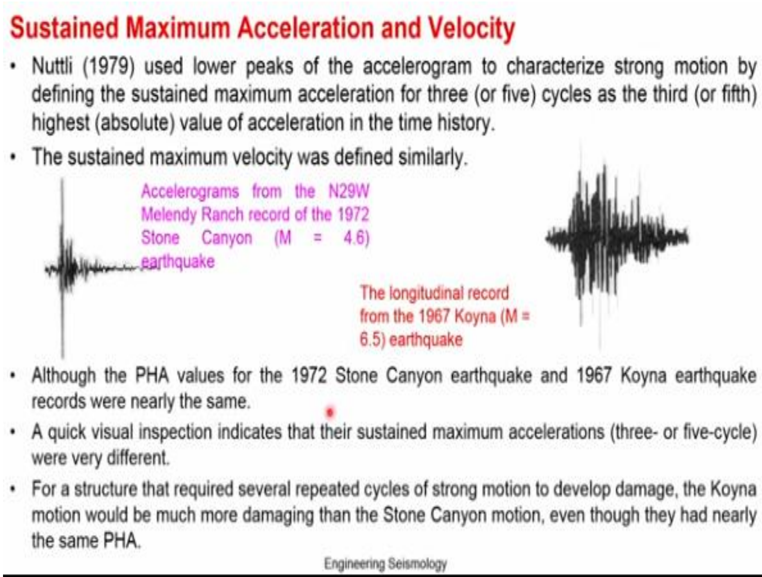

Both the record shown in the figure you can see here this was actually the acceleration from the N29W Melendy Ranch record of the 1972 Stone Canyon earthquake magnitude of 4.2, you can see that here 1 amplitude which is completely twice, thrice the other amplitude in the record. So the similar a longitudinal record from the Koyna earthquake where M is 6.5, you can see that the most of the amplitude are almost like you can see equal.

So this kind of scenario comes the damage caused by this earthquake is actually lower than the, this earthquake. So even though the amplitude wise this may be lower. So even though the magnitude is high this amplitude may be high the magnitude is less but the damage of this will be more. So when you talk about only the peak acceleration it looks like that this is bigger earthquake, it is not so, only the number of repetition also important.

So in order to account this kind of variation in the record so the defined called sustained maximum velocity was defined which is similar to the sustained maximum acceleration. So which is basically for 3 or 5 cycles of the third or fifth highest value of the acceleration time history. Third or fifth highest cycle so that maximum is defined as a sustained maximum acceleration or sustained maximum velocity.

Similarly by the velocity flat, you can take that. So, although PSHA values for the 1972 Stone Canyon earthquake and 1962 Koyna earthquake records are nearly the same the quick visual inspection indicate that their sustained maximum acceleration. 3 or 5 cycle were very different for these 2 that is what you can see, so you will have this one very size sustained acceleration this will have the very low sustained acceleration.

For the structure required is several repeated cycle of strong motion to be develop a damage the Koyna earthquake would much more damaging than the Stone Canyon motion even though they had nearly same PSHA. So this was the message we get. So when you have the sustained acceleration more you will get a expected have the higher damage level than the PHA if the same earthquake.

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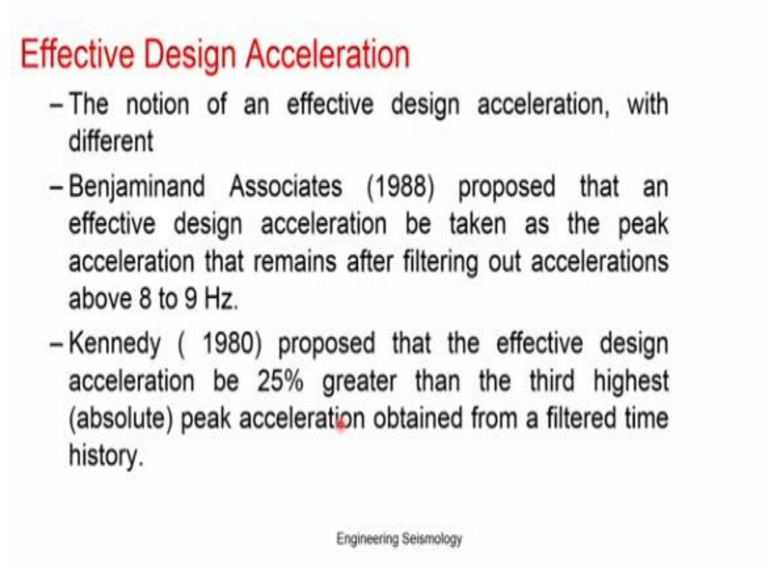

So the another one is basically a design effective design acceleration. The notation of the effective design acceleration with the different, so the Benjaminand Associates 1988 proposed that effective design acceleration to be taken a peak acceleration that remains after filtering out above 8 to 9 Hz. So you can take a data and filter it through this range of frequency then you can take that acceleration as a effective.

The Kennedy 1980 proposed that effective design acceleration to be 25% greater than the third highest absolute peak acceleration obtained from the filtered time history. So this will be like is our sustained time history and above 25% can be taken as a effective design acceleration. So basically so we have seen that the acceleration time history which you get can be used to get a time domain parameters, this time domain parameters can be so picking up directly from the acceleration times history of the plot.

We can see that if you have the three form of the flat like acceleration, velocity, displacement you can get peak horizontal acceleration, peak vertical acceleration, peak horizontal velocity, peak horizontal displacement. These parameters you can pick up. Apart from that you can also get here the effective design acceleration, sustained acceleration, so those are all the parameters which you can obtain from the direct record and the effective acceleration.

So there are three additional parameters which you can get from the direct time history recorded data. So this is why this is called as a time domain parameters for this you no need to do any processing only you need to convert if you have the velocity you can convert that as a displacement and acceleration, you have the acceleration you can convert that as a velocity and displacement. Then after converting you can look at which is the value is the peak which is the 5 cycle 3 cycle values.

Which is repeated a several times so those are all the observation will help you to identify the effective acceleration, effective design acceleration and sustained acceleration and the peak horizontal, peak vertical and peak displacement. Those are all the parameter you can obtain from this kind of observations. So this is the time domain parameters when you look at the graph. So you can also closely observe that there is a time which involves where this is actually a T1 or TP this will be the starting point of the S, so this will be the TS.

Then this acceleration values whatever you see it repeats for that only it end with the some TE or something like that, you can take it ends. So this time also can be directly observed. So this time you can say that if the gap between the 2 time as a duration, you can also get a duration parameters as a time domain parameters from the your recorded data. So basically, you can get TP which you can obtain from this point is the TP.

So the another one is a TS. So the difference between the TS and TP will give you the basically this will, this to this will give you this distance, this indicates that how you are seismic recording station is away from the earthquake. This will be equal to TS-TP this which you convert in the degree to the your; distance, this is the indicator. It says here this one. So each station you can take this distance. So if you take a several station data, you can get a multiple informations on this, for example.

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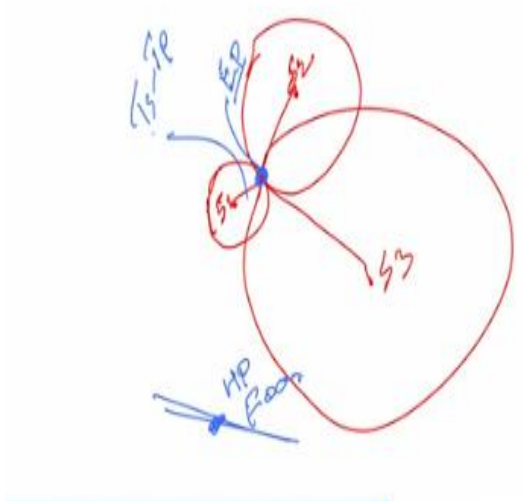

So if you have the data from one station, so they will get this is basically your station location, so then you will get a another station record. So, this is the station location. So you also get a another station record, so where this is the station location. So this is a S1, S2 and S3. So, you know how to find out this, this is what your TP and TS distance. So you will get a this is basically is the function of TS-TP, S wave P wave different.

Similarly for this, this record, so by doing this you can basically pinpoint your epicenter. This is your epicenter. So if you have the one more station, you can also get a depth that will give you the below somewhere it is. So, that will give you the your hypocenter or focus. So this is how the T time recorded on the data can be used to extract this kind of information. So as we have seen that the time arrival can be picked up from the record.

So apart from that we can also get the other time for the different wave that is called as a duration parameters the time domain parameters which shows a duration of the earthquake. So which will be discussing now.

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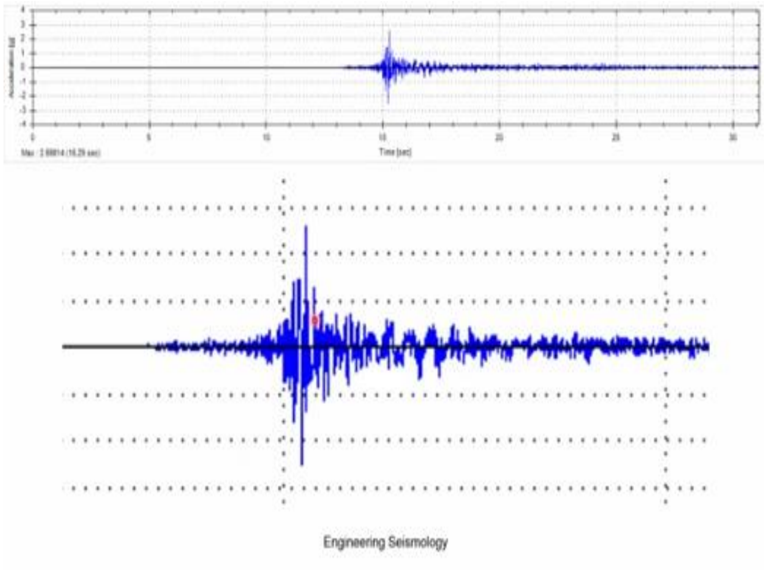

So the duration is another time domain parameter, you can get. So this is the typical record. So where you can see basically this record was actually you have seen in the last class where there is this portion I have zoomed here. From here, you can arrive TP arrival time and the S wave arrival where the S wave is starting that point. So these two will give you to identify the distance between the epicenter to the station.

Many combination of that distance can be used to location of the epicenter point and hypocenter point it can be used. So minimum you need a 3 station to identify precisely the earthquake. So epicenter, 4 station to identify the depth hypocenter and the epicenter location. So this data, will indicate this many cycles are repeating how long this cycles are going beyond some prescribed value is actually discussed in the duration.

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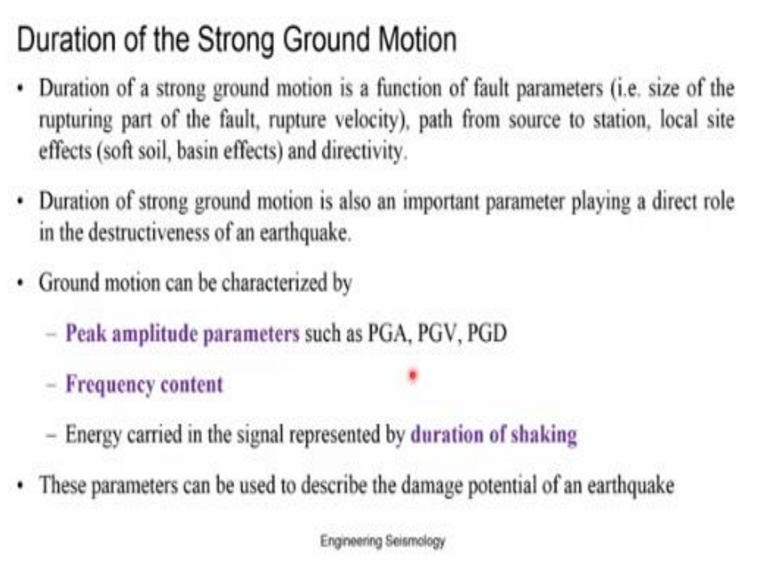

Because as we have seen in the sustained acceleration the damage in not only the amplitude it is also how many times it repeats. So that means how many times it repeats can be reflected in the form of period or duration. So duration of the ground motion is function of fault parameters that is a size of rupturing part of the fault, rupture velocity, path of the source and local site. The duration of the strong motion also important parameter playing direct role in the destructiveness of the earthquake.

So if you have the very high PSHA but peak horizontal acceleration, but you have the less duration then it may not cause the damage but you have the low peak horizontal acceleration, but the long duration it will be cause the this one that is like hitting a one person with one punch strongly and hitting several times a medium punch or slow punch will result a different kind of effect so that is the same thing applicable here.

So the ground motion can be characterized peak amplitude parameters such as we have seen earlier, then the other one is basically the energy carried by the signal represented by the duration of the shaking that duration parameter we are going to see now.

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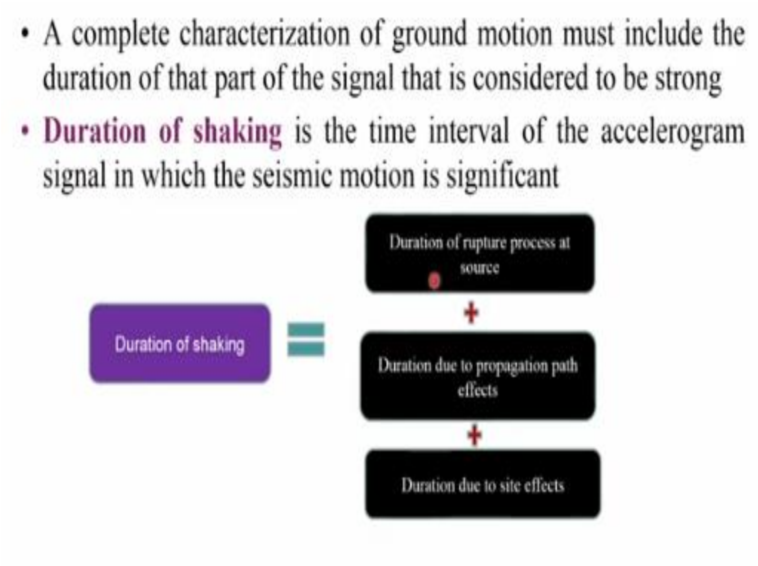

So a complete characterization of the ground motion must include duration of the part of the signal that considered to be strong. Duration of the shaking is a time interval of the acceleration signal which is seismic motion in significant. So the duration of the any particular earthquake is basically duration of the rupture process at source, duration due to the propagation of the effect, duration due to the site. So all these things only reflected in your acceleration time history.

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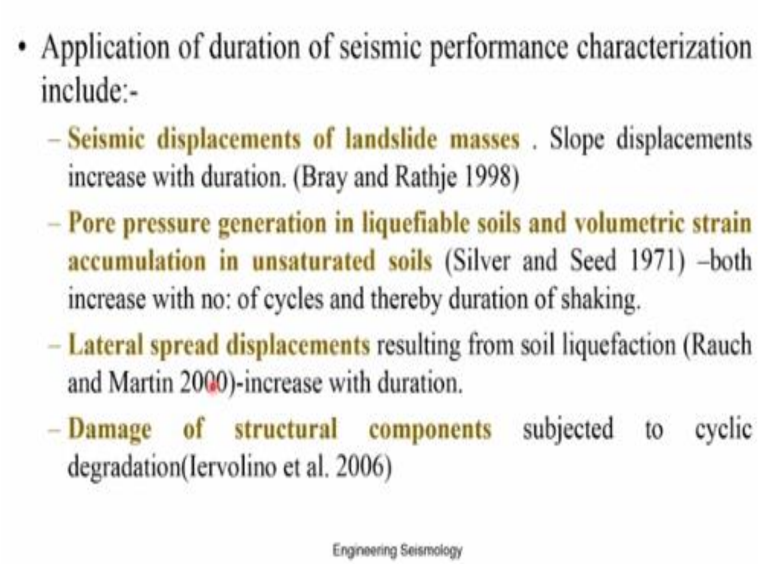

So the application of the duration seismic performance characterization includes seismic displacement of the landslide mass, the slope displacement increases with the duration. So it has been observed that the longer duration earthquake can cause a more landslide than the shorter duration earthquake. The pore pressure generation for liquefaction and the volumetric strain accumulation in unsaturated soil the both increase with the number of cycle and thereby duration of the shaking.

So generally the liquefaction hazard where the pore pressure has to generate the number of cycle helps to achieve the pore pressure very fast and very high level. So those kind of places the duration of the shakings are very important. So laterally spread displacement resulting from the soil liquefaction that is damaged due to the lateral spread are moving of some object from its original position to other position the number of cycle repeating is very important.

Damage of the structural components subjected to cyclic degradation also is controlled by this duration. So there are many places where the first earthquake will leave only the cracks, but the subsequent earthquakes or subsequent vibrations can cause a damage. There are cases which is reported in this kind of aspect.

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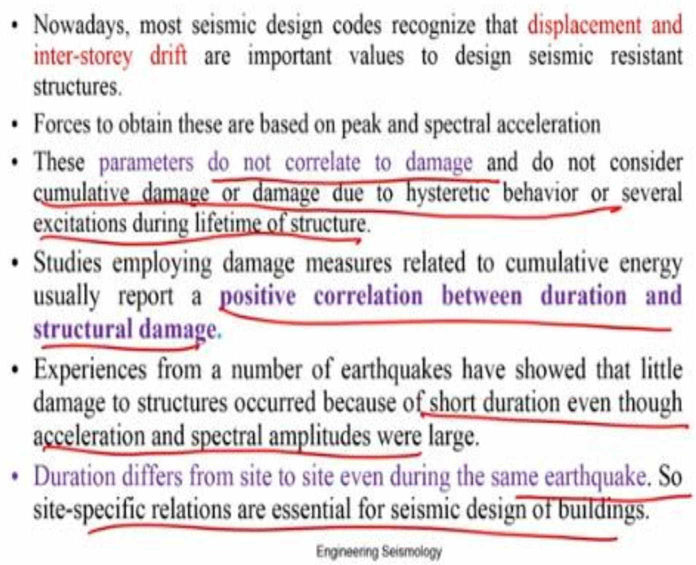

So nowadays the most seismic design code recognize the displacement and inter-storey drift are important value for design seismic resistant structures. The force to obtain these are based on the peak and spectral acceleration. These parameters do not correlate to the damage and not consider cumulative damage or damage due to the hysteretic behavior of the several excitations of the during the life of the structures.

So this consideration has been put effort by the scientist and then they thought that studies employing damage measures related to the cumulative energy usually reported as a positive correlation between the duration and structural damage. So the duration is becoming a part of interpreting the earthquake record. The experience from the number of earthquake have shown that the little damage to the structures occurred because of the short duration the even though the acceleration and spectral amplitudes are very large.

So this was the observation they made. The duration difference from the site to site even during the same earthquake site-specific relations are essential for the seismic design as this duration is controlled by the path source and site. These are all the information are included in the duration of the earthquake.

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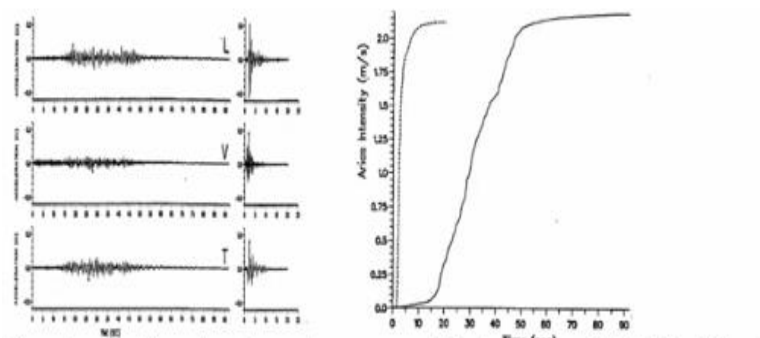

Figure 1a and b: Figure shows two accelerograms recorded in San Salvador with M_s 7.3 in 1982 and the other from a local event M_s 5.4 in 1986 and their respective Husid plots in solid and dashed lines.(Bommer and Pereira 1999)

• Both reach the same level of Arias intensity but over very different periods of time. The 1986 earthquake caused more damage because the same amount of energy was imparted to structures in one-tenth of time, thus imposing far greater demands for dissipation. Engineering Seismology

So this is the typical record you can see that the figure shows two accelerograms recorded in San Salvador with the 7.6 magnitude. So the other local event MS4 1986 and their respective Husid plot and in a solid and dashed line. So you can see that both reaches the same level of Arias intensity while this is actually the Arias intensity we will discuss Arias intensity in the little later and you can see that but over a different period of time. So in 1986 earthquake cost more damage.

So because the same amount of energy was imparted to the structure in a one-tenth of the time thus imposing a greater demand for the dissipation. So like if you have the very broader level of this which basically structure get a enough time to dissipate. Here you do not get enough time. So it basically get a highly damaging very fast. So, this is the information which is help and then interpreted where the durations of the earthquakes are playing significant role in the damage of the structures.

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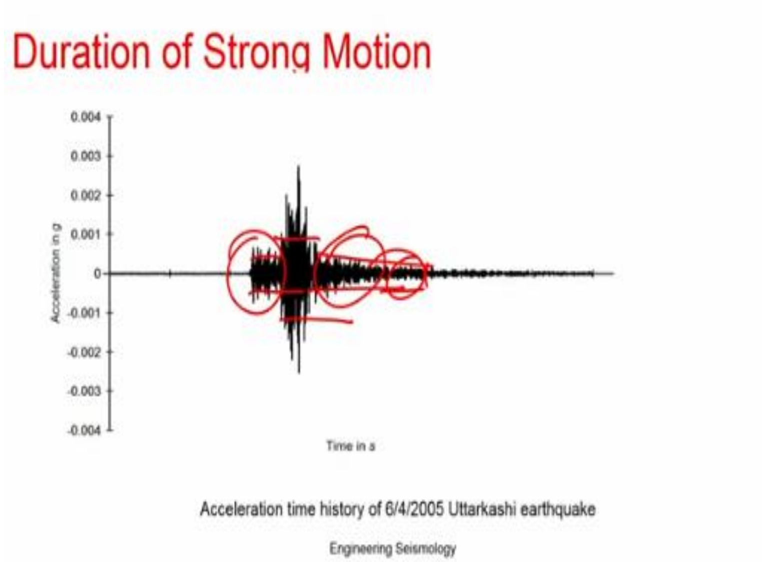

Which basically here implication of the how many cycle it repeats you can see how many cycle it repeats. So this is the duration which you can understand. So, this is the typical Uttarkashi earthquake, you can see that the P wave amplitude similarly repeated for so much then S wave amplitude then again, this one is repeated. So this will kind of a cumulative effect will result in the higher level of damage than a single value peak at short duration. So that is the message which we have to take it from here.

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Duration is the time interval of the accelerogramic signal in which the seismic motion is significant.

- Several definitions for duration are available based on the parameter used to classify them. Some of the most commonly used duration parameters are,
  - Bracketed Duration
  - Uniform Duration
  - Significant Duration
  - Effective Duration
  - Effective Shaking Duration

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So this will help you basically to design properly. So there are different types of duration parameters how this duration parameters can be estimated. So what are the different duration parameters can be discussed in the next class. So thank you very much for watching this video we will see in the next class.