Introduction to Engineering Seismology
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Lecture No-25
Seismic Source Parameters

Vanakkam, we will continue our lecture on engineering seismology. So, we have been discussing about the frequency domain parameters, we told that frequency domain parameters are so highly useful for the simulation of ground motions. So particularly to get the source, path and then the site, variation which with the attenuation is a function of frequency these values are changes. So we discussed about the corner and cutoff frequencies.

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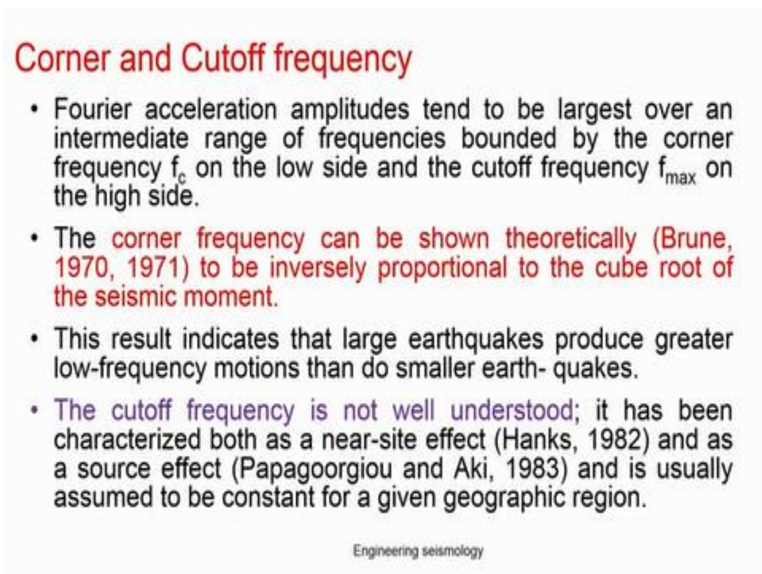

So we have seen in that the corner frequency is basically, inversely proportional to the cube root of the seismic moment. So depends upon the seismic moment means is actually the seismic moment is function of the magnitude. So depends upon the magnitude of earthquake basically the corner frequency keep changing.

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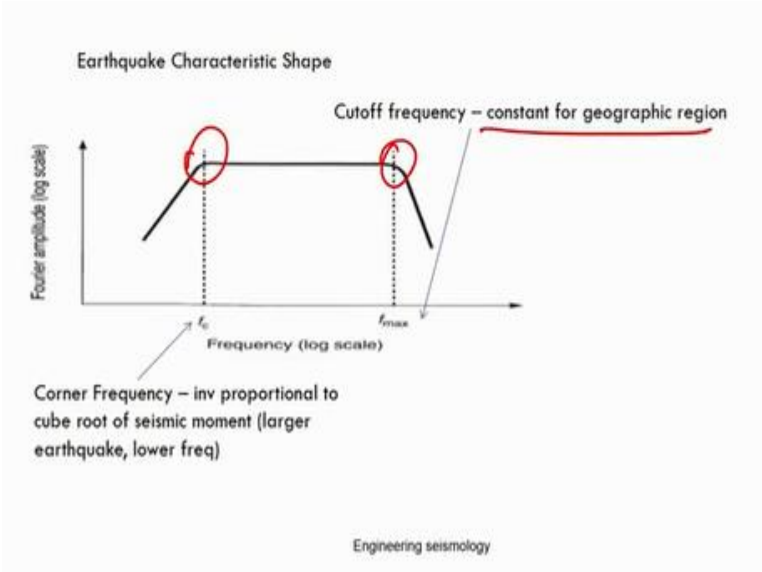

So this is basically a corner frequency, so which is inversely proportional to the cubic root moment of the seismic moment. So, this is the cutoff frequency, so this is basically constant for the geographical region. So, this is f max.

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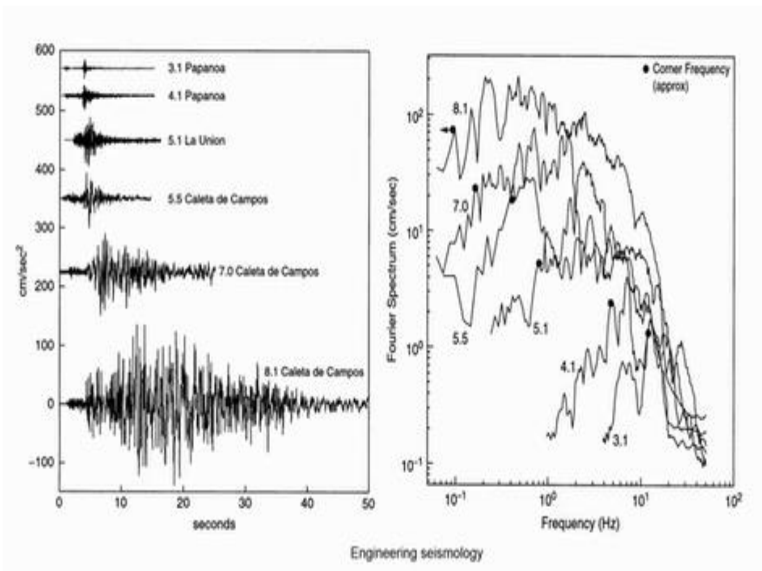

So, this is a basically different earthquake recorded data. So how the; your corner frequency changes you can see the lower magnitude to higher magnitude, how this changes which is basically the function of seismic moment in term the seismic magnitude.

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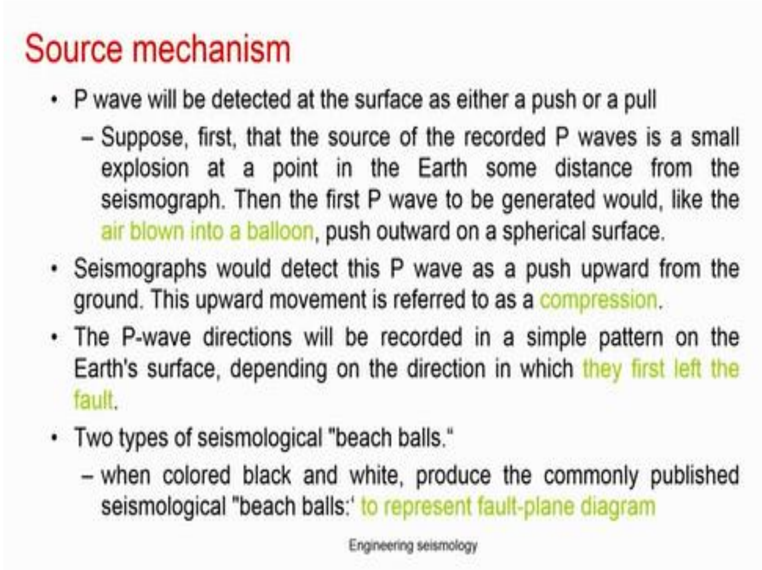

So we also talk about the predominant frequency and all those things. So, today class so we will be seeing a simple simulation of ground motions, theoretical models and the source mechanism. So what is mean by the source mechanism? So the source mechanism is basically described what type of fault it is and what type of the force is actually radiated from the earthquake source or released by the earthquake it is a compression or tension force in predominantly we described.

So if you look at your earthquake data. So which we even we discussed during our fault kind of description also we have seen normal fault, reverse fault, and transfer fault, we have seen that the normal fault generally compression force is generated. So reverse fault generally the tensile forces generated. So the shear force is generated and transfer fault that is what we have seen.

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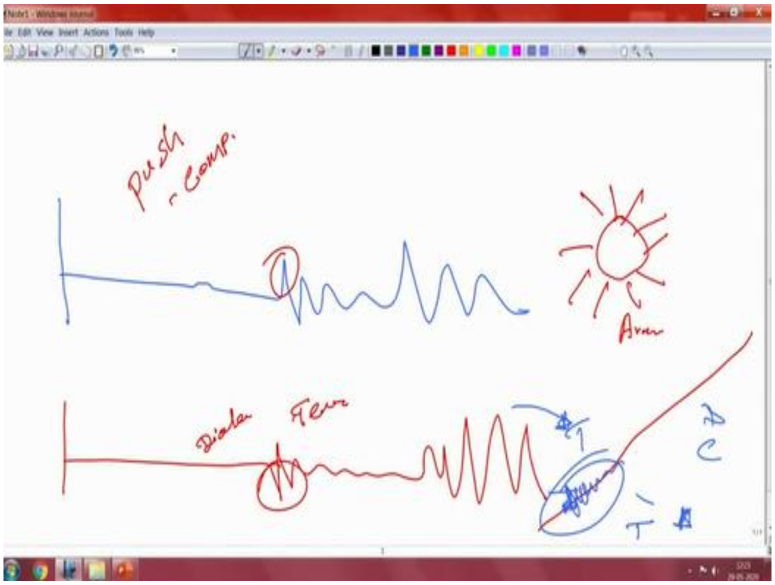

So we also seen that the waves what you are getting basically, okay? So like this, so this waves and then so the same earthquake another place may record like this. So we have seen that the ground push and pull, the push basically is a compression indicative normal fault, so the push. So dilation indicate a so tension force. So generally occurs on reverse fault.

So how it happens? So we also described that in order to identify a particular ground motion is basically a earthquake or blasting in the rock. So we have noticed that so most of the blasting happens in the smaller area, so where you will have the push up all the record. So you will have the push up all the record in all the direction that is what we have seen in the so the artificial blasting or artificial earthquake.

So in the natural earthquake, it may not be like that since it is happening with the, rupturing of like for example, this is the fault. So you will get rupture at a, so one places larger one places are higher. So then like this the so depends upon the where the seismic instrument. So where the seismic instrument located, so you will get tension or compression or tension. So, describing this tension, compression combination what happens at source is called as a source mechanism.

So when I talk about source mechanism, I also need to so explore like most of you might have went to beach, so I do not know many of you beach you play a ball over the beach but the beach whatever ball you are using to play is completely different from the ball which you play in the normal ground or football ground or volleyball ground. So, I do not know many of you notice it that. So why it is so? So the ball which specifically used in the beach is called as a beach ball.

So the source mechanism the combination of tension and the compression forces described as a ball, that ball is basically called as a beach ball or source mechanism diagram. So today we are going to discuss in detail about how to get the source mechanism at a particular place due to particular earthquake. So the P wave will detected surface as a either you push or pull suppose the first of those source of record P wave in the small explosion at a point of earth some distance from the seismogram.

So then the P wave to be generated would be like a air blown into balloon, so push outward a spherical surface that is what we have seen that when is explosion comes you will get a compressional wave. Seismogram would deduct P wave as you push upward at the ground the upward moment you refer as a compression. So the P waves directions will be recorded as a simple pattern of the Earth's surface depending upon the direction of the first left in the source or fault.

Two type of seismological beach balls are used when the colored beach ball and black and white beach ball, so as I told you that the beach ball is different from the your regular football and volleyball. So, your regular football, volleyball may have the unique color, so it is the color will be almost similar with the some kind of design but a beach ball is a ball with described in the color-color pattern.

So, the color-color pattern the ball described moreover the other football and volleyball basically it is it has the outer cover inside there is a air balloon or tube where it is compressed air will be there inside, so even sometime the outer damages you still the ball will useable but in beach ball basically this is a plastic ball colored and different colors, which is a contrast, attractive colors, so the attractive colors means you can easily identify the color that kind of color ball.

Why that kind of color ball, which is made up of like the plastic because a beach generally you have the sand, you see all the rough surface like football or volleyball, so it will stick on the ball you cannot use those balls in the beach as you know, that beach sand is dry as well as wet at the some portion, so you cannot use your regular ball, so that is why this plastic balls it does not stick mud into the ball that is one thing.

Second, as you know that the beach you will always have the good amount of sunlight, so uniform color ball will be difficult to identify the ball is missing, so but if it is a colored pattern it is very easy to identify that is why a beach balls are the unique. So, you can see whenever a next time and you watch any kind of beach play you can see that most of the western country people they use this kind of ball.

So in India I am not very sure people used to play ball in beach and all particularly this colored pattern balls are familiar, but now you can Google it and find out how the beach ball are they. So here a beach ball will be expressed in the two pattern black and white, one shows a compression one shows a tension. So, since it has a pattern of color which is called as a beach ball which is a source mechanism?

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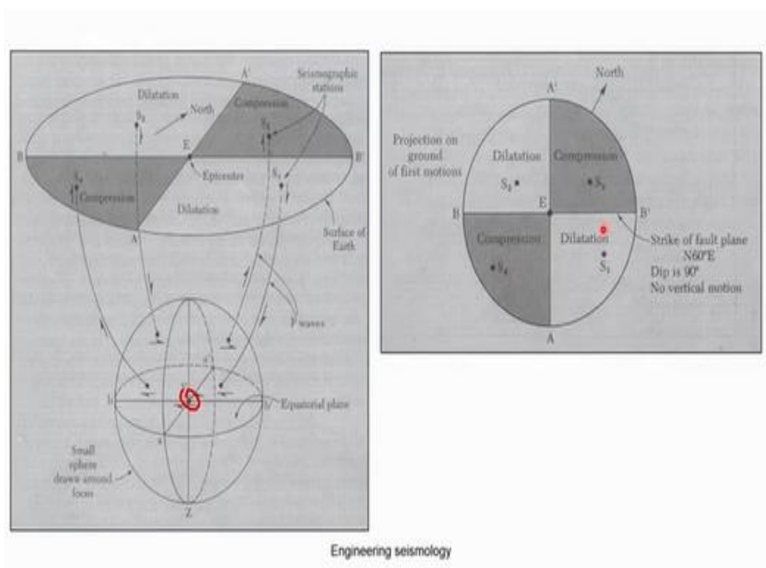

So if you look at this image carefully this is a sphere of the globe, so where earthquakes are occurring so then this earthquake are recorded at a different station as I told you that you need a three minimum station to find out the location of the earthquake. So not only three there will be large number of stations, it will be recorded. So depends upon what the energy released at this point say a station will expect a compression and a tension.

So tension is called as a dilation compression is called as a; so here the compression is represented as a positive tension is recognized as negative, so you can project that and make it as a circle you can see this is a circle. So basically in the circle you can project, so and then plot wherever you have a tension wherever you have the compression. So after plotting that you try to identify that area covered by the tension and this one then it gives you a diagram like this a beach ball in the plane view, so that is called as a source mechanism.

So, this is the typically source mechanism for the so strike fault plane and N north degree east and dip. So this will also give you the dip and strike angles how much the compression, tension forces are released in the particular place. So the P wave arrivals surfaces the Earth have the surface and how it is integrated. So this is how your source mechanism is generated. So now if we recall that we have been discussing when the interpretation of the earthquake magnitude or estimating diagram.

So, I have shown that there was a diagram which is shown similar to this in the color that is called as a source mechanism diagram. So soon after the each earthquake report people also release about what type of fault it is? what type of source mechanism associated with respect to normal means normal fault whatever; how the beach ball reverse fault how the beach ball and then the thrust fault was a beach ball and then combination of this by changing this portion of energy, they also release a;

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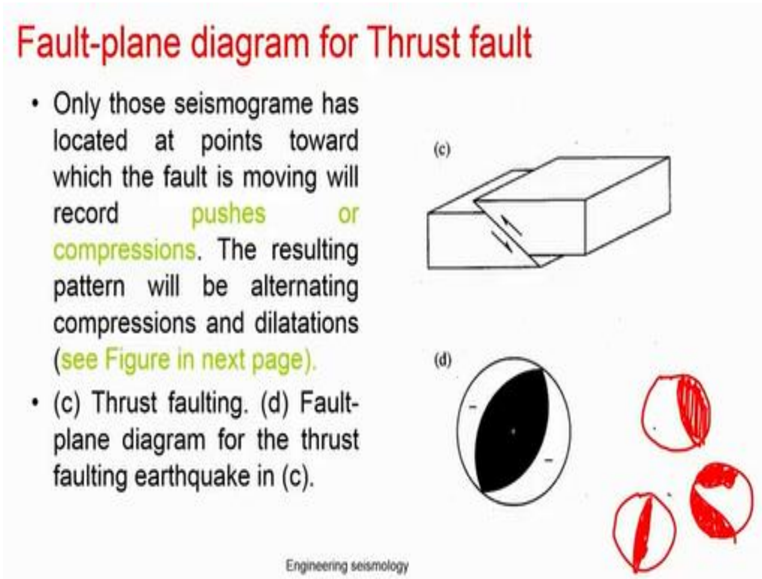

So which will help you to what type of sources is? So, let us see how the fault-plane diagram for the normal fault. So the seismogram located at point which the fault moving away where the pull and dilations are the first P wave motion. So as you have seen that the normal faulting fault-plane diagram of the normal faulting is given in this is the normal fault and this is the fault beam. So white region represents which the first motion of dilation negative and then the black region represents at the compression motion is a positive.

So you can see the compression portion on both side and negative position in the middle. So this kind of fault source mechanism is called as a normal fault beach ball, or source mechanism. So the fault-plane diagram for the thrust fault, so where you have the only the seismogram has located point. So where the moving will record push and compression the faulting pattern will alternatively express as compression dilation.

So the middle portion will have basically your compression portion and the outside you will have the dilation portion. So these kind of fault-plane solutions are given in the C and that respective the fault-plane diagram is beach ball diagram is given in the d. So like this each earthquake they will generate a beach ball diagram and the release that shows here your source mechanism. So you will have here this shape will be keep changing with respect to different Earthquake.

So this one, for example, some people will release a beach ball only by locating a like this. So this means only these much portion you have the positive remaining portion is negative. So some balls will be. So even when the faults are behaving the reverse strike sleep and the kind of things then this will be released like this, so like this also they will release. So you can see a different type of beach ball.

So even you can see sometime like this and then the like this. So it should be sphere. So you can see like this like this. So it depends up on the fault orientation and the size, rupture around how much tension force it released this will be there. So this data's are obtained from the multiple seismometers and try to plot it in the, so the plan of the sphere and then that plan is used to represent like this, this is how they will represent. So these are source mechanism concept which you need to understand. So after understanding the source mechanism concept the next is basically.

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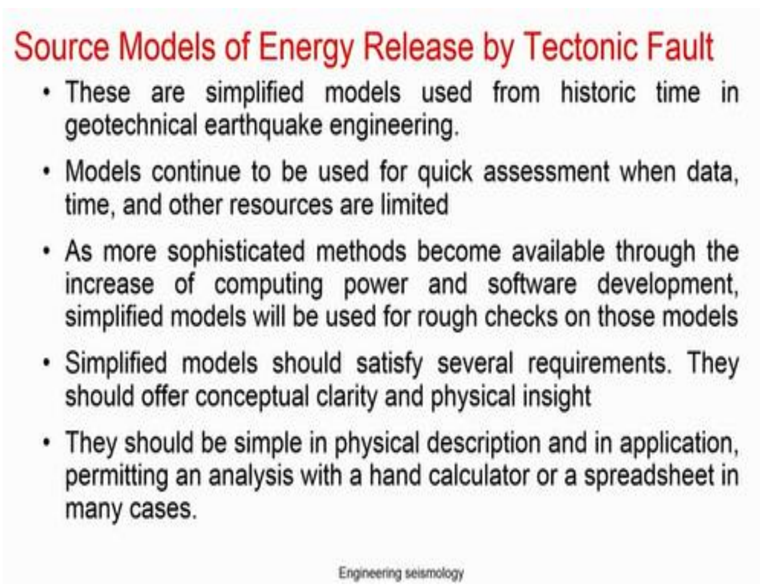

We will get a source model for the energy released by the tectonic fault. So this is basically a simplest model which is used to tell how the seismic energy varies with the distance by is the function of your magnitude and the distance. So these are all the simplified model used historic times in the mostly on earthquake geotechnical engineering. So people who deal with the earthquake and the geotechnical issues, they use this models continue to be used for the quick assessment when the data and time and the other resources are limited.

So now there are very complicated models which you can use high end computing facility to simulate the data, but this is the simplified model one can use even in the Software and normal regular computers also simplified model satisfies several requirement, they should offer conceptual clarity of the physical insight of the earthquake that is why this models are still used in the check and quality of the data what you receive how it matches kind of thing.

They should be simple in physical description in application permitting an analysis with that hand calculator as spreadsheet in many cases.

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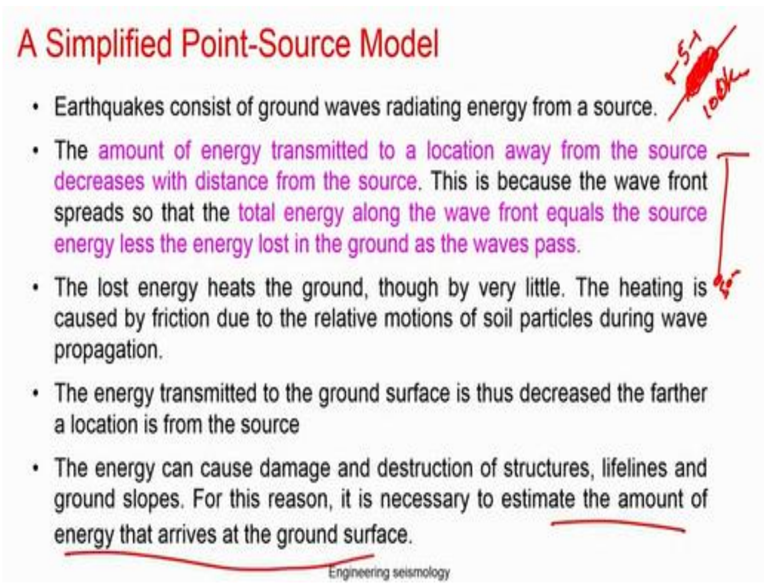

So the simplified faults source model and the point-source model. So there are two types of models are there first we will let discuss about the fault point source model, point-source model means here the source is assumed as a point. So, as we described that so this is the fault, so you may expect here rupture at this place. So, when the fault is like 100 kilometer. So this rupture will take place maybe the 5 kilometer depends upon the earthquake 5 to several kilometers.

So if the smaller earthquake this lower will be the rupture. So in that case, if these earthquakes are occurring at 10 kilometer deep and then so then this dimension, whatever you are talking about here 50 meter or 100 meter distance will be very small. So in that case assuming the rupture as a point source is a logical rather than a areal source it is valid for the only smaller magnitude kind of thing; that means the point source models are suitable for the only simple earthquakes, smaller earthquake.

The amount of energy transmitted to the location away from the source decrease with the distance from the source. So, whatever energy generated at the source as the energy travels on distance, the energy is consumed by the heating up travelling medium part of the energy and part of the energy basically transferred to the waveform that waveform will reflect what is the energy? So as the distance the energy will be reduced as the heating takes a time.

This because the wave front of the spread to the total energy along the wave front equals to the source energy less the energy lost in the ground wave pass. So by knowing this at one particular place, whatever energy you receive is basically the total energy minus energy lost by the travelling the distance. So the last energy heat the ground, though very little. The heating is caused by the friction due to the relative movement of the soil particle during wave propagation.

The energy transmitted to the ground surface is thus decrease further locations from the source. The energy can cause damage and destruction of the structures, lifelines and ground slopes. So, where this region it necessary to estimate amount of energy released arrives at a particular place. So energy is responsible for your basically damage and ground destruction. So you should know what is the energy arrived at.

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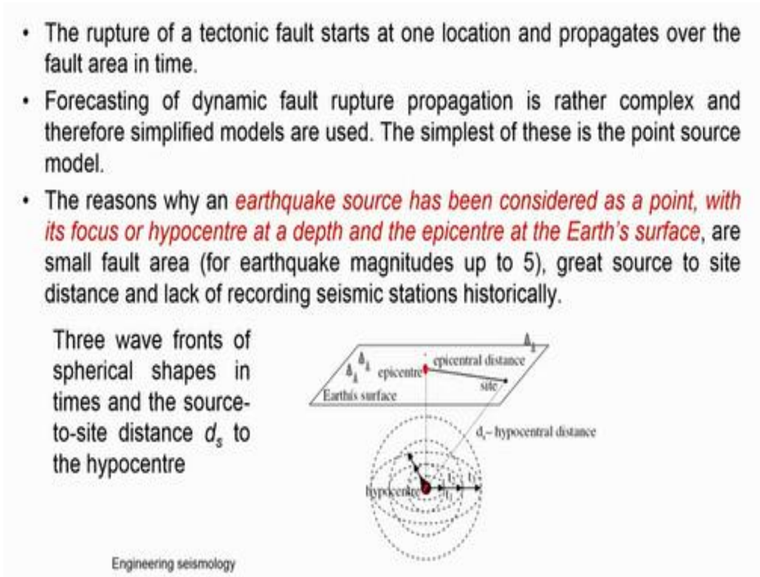

So the rupture of tectonic fault start at one location propagates over here fault entire area in time. So it starts here and then propagates in all the direction, so that is what we describe. So the forecasting dynamic faults rupture propagation. So the forecasting dynamic faults rupture propagation. So rather complex and the therefore simplified models are used to explain this concept, the simplest of this model is a point source model.

The reason why the earthquake source has been considered as a point it is focus or hypocenter at a depth where the epicenter at the earthquake surface or the fault area is small the earthquake magnitude up to 5, the great source to site distance, lack of recording seismic stations horizontally. So historically, so this small distance, the larger distance and smaller rupture length can be called as a point, particularly magnitude up to 5.

So, three wave fronts is spherical wave when the earthquake occurs here. So when the earthquakes occurring here, so basically three wave front starts and travel on different direction. So if we consider the sphere of the earth, so the distance what it travels is basically ds. So, this is the point focus on a surface projection is epicenter which we know and this is the site what you are expecting, the distance between this is ds which is a hypocenter distance.

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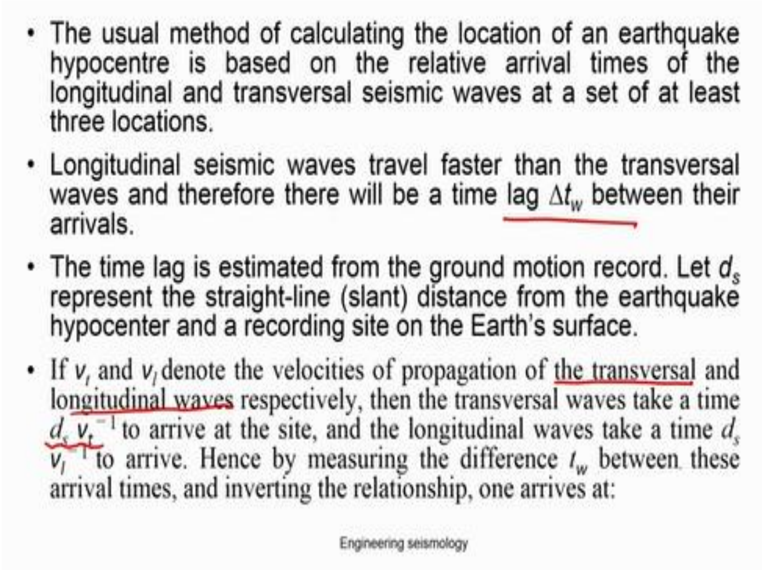

So, usual method calculating the location of the earthquake hypocenter based on the relative arrival time of the longitudinal transverse wave at a set of at least three locations, which we have seen two lectures back. So the longitudinal seismic wave travels faster than the transverse wave therefore, there will be a time lag of delta t, which we have seen P wave and S wave arrive that time gap between these two other very important.

The time lag is estimated from the ground motion record. Let, ds represented the straight line, slant distance from earth hypocenter and recording on the earth surface. So the vt and vl denote velocities of the propagation of the transverse wave which is a S wave and the longitudinal wave which is a P wave the transverse wave like to distance. So the time is equal to velocity into distance, as I told you that you get the velocity of the region is average value and distance, you know.

So you get your time equal to distance into velocity the arrive the site the longitudinal waves take a ds, so the vl to arrive ends the measuring distance will be tw is the time lag between the this arrival time the inverting the relationship one arrives;

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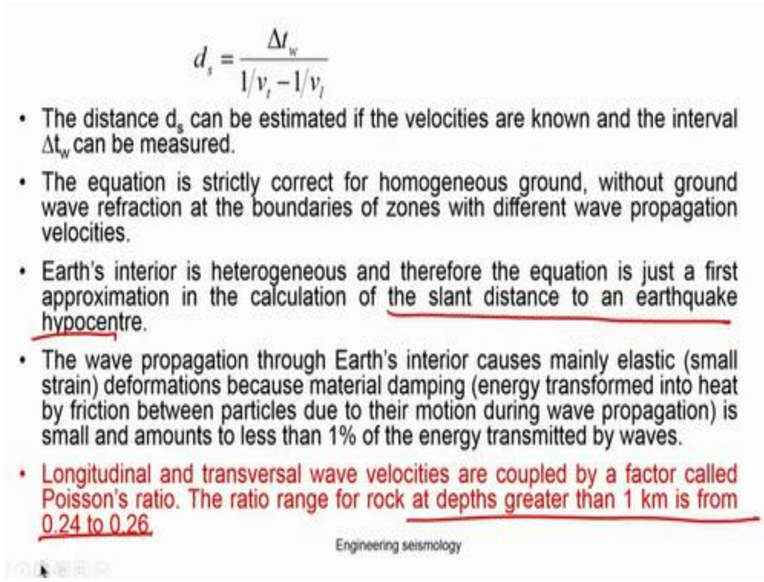

At ds is equal to this time lag and 1 by velocity of the transverse wave - 1 by velocity of the longitudinal wave. So the distance ds can be estimated if the velocities are known on the interval of the length. So the interval you can estimate from the recorded data, velocity from the regional average velocity can be estimated by knowing this you can estimate this ds. So this equation is strictly correct for a homogeneous ground without any ground wave fraction at boundaries of the zone with the different wave propagation velocity.

So here we assumed that the velocities are throughout the region is same, so which is homogeneous. So medium is only possible. So earth interior is practically hetrogeneous therefore the equation just first approximation of the calculation of the slant distance of the earth hypocenters, these assumptions you do not know. The wave propagation through earth interior causes mainly elastic small strain deformation causes material damping.

Energy transverse into the heat by friction between the particle of their motion during the wave propagation the small amount the amount less than 1%. So the longitudinal transverse wave velocities are coupled by factor called Poisson's ratio. So the range for rock at depth greater than the 1 kilometer is basically this is the Poisson ratio for the rock values. So rock your Poisson really values are there.

So the deeper level basically you will have the rock materials only not your soil material. So this is the range. So which is a very narrow range the value variations are negligible.

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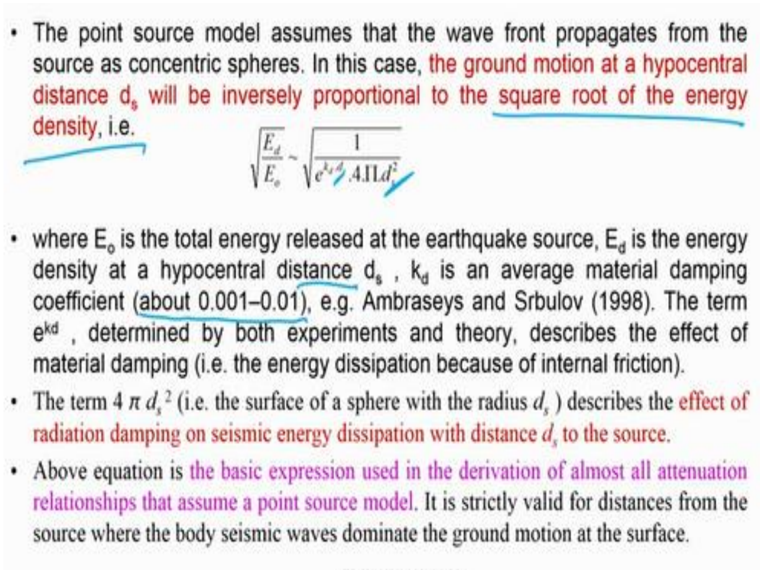

So the point source model assume that the wave front propagates from the source as a concentric sphere at in many cases the ground motion at the hypocentral distance ds will be inversely proportional to the square root of the energy density, the energy square root of a energy density. So that is basically the Ed divided by E naught the root, so approximately equal to 1 by E power kd ds and 4 pi into ds square, so ds we know what it is.

So, now we will see E naught is actually total energy released at the earthquake at source, ed is the energy density at the expected location, Kd is average material damping coefficient which varies basically this is amount. So Ambraseys and Srbulov, the term ekd determine the both experimental and the theoretical describe that the effect of material damping, energy dissipation because of the internal friction.

So the term 4 pi d square the surface sphere of the radius ds basically describe the effect of radiation damping on the seismic energy dissipation with the distance ds to the source. So the above equation basically we are converting to the sphere into 4 pi multiplication the above equation the basic expression used to derive almost attenuation relationship assume that the point source model.

It strictly valid for the distance from the source where the body seismic dominated by the ground motion at a surface, this is the validity of this model described.

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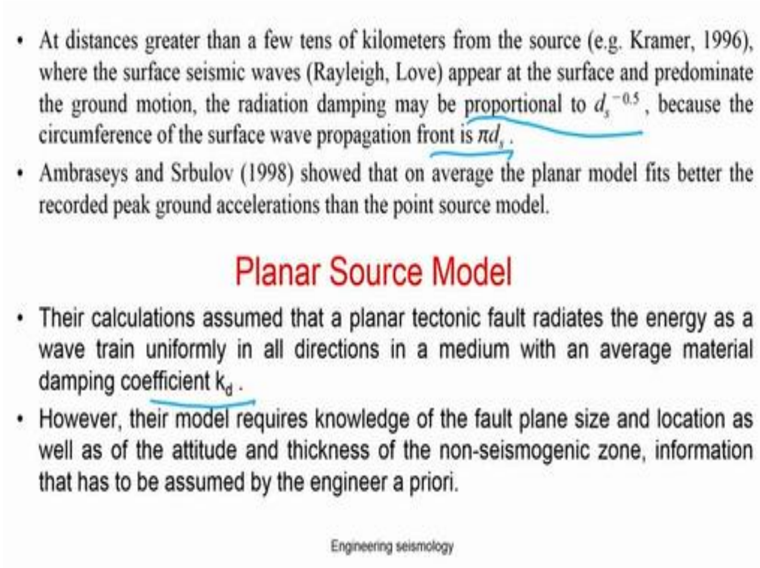

So the distance greater than a few tens of kilometers from the source, where the surface seismic wave, Rayleigh wave appears to be surface and predominate ground motion, the radiation damping may be proportional to ds of 0.5 therefore such circumstance the surface wave propagation in front will be the pi d. So Ambraseys and Srbulov 1998 showed that the average planar model first fits better than the peak acceleration.

So this is about the point source model. So further the people scientists worked for bringing out the planar source model were the source has been considered as a area that is the planar source model. So their calculations assume that the planar tectonic fault radiates the energy as a wave current uniformly in all direction in a medium average material damping the k, kd is a coefficient for the material damping.

However, their model requires knowledge of fault to plane size location of well as well altogether, so the non seismic zone information of that has been assumed by the engineering inferior.

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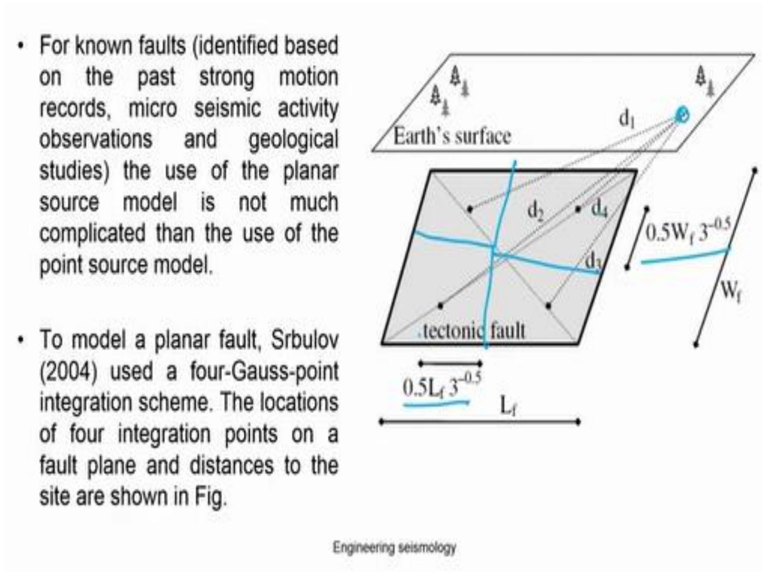

So for example earlier, we have seen that the one location as a point projection epicentral distance, hypocentral distance when the area is this one then the area can be gridded as here different small, small grid and each grid you can get here d. So you can get here d at each d1, d2, d3, d4, then that d is linked here. So they have a total width is double Wf, total length is Lf this is basically the source area and the grid portion is the function of this, that is a good portion.

So the known fault the identified based on the past strong motion record, micro seismic activity observation and geological studies the use of planar source model is not much complicated than the use of point source model. The model planar fault, Srbulov 2004 used four-Gauss-point in integration scheme. The location of four integration point fault plane, distance is actually given in the figure.

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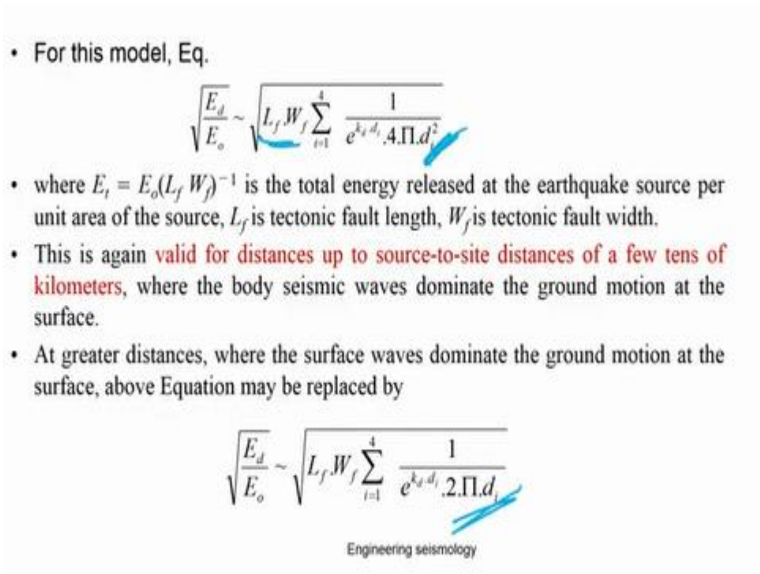

So from this the similar kind of energy loss variation integrative with the variation with the areal dimension of the source where you can see di indicate the distance under this L basically taking care left on Lf and Wf taking care of the size of the planar source. So the Et is equal to E naught into Wf sum up. So by total energy released at this earthquake source the unit area source the Lf is tectonic fault L Wf is the tectonic width of the fault.

So again, the valid distance up to the source to site distance of few tens of kilometer where the body wave seismic wave dominated ground motions are to surface greater distance where the surface of dominated the ground motion distance, then this can be altered by looking at like this. So where you can see the influence of the so the di basically, you can see how this changes, that changes you have to observe when you see a surface wave. So that is what we discussed in this.

So this kind of models we can use simply to show how the energy variation from that E naught is actually energy at source if you know the seismic moment and magnitude then you can get the source and the at point how it varies with the time. So Et you can calculate.

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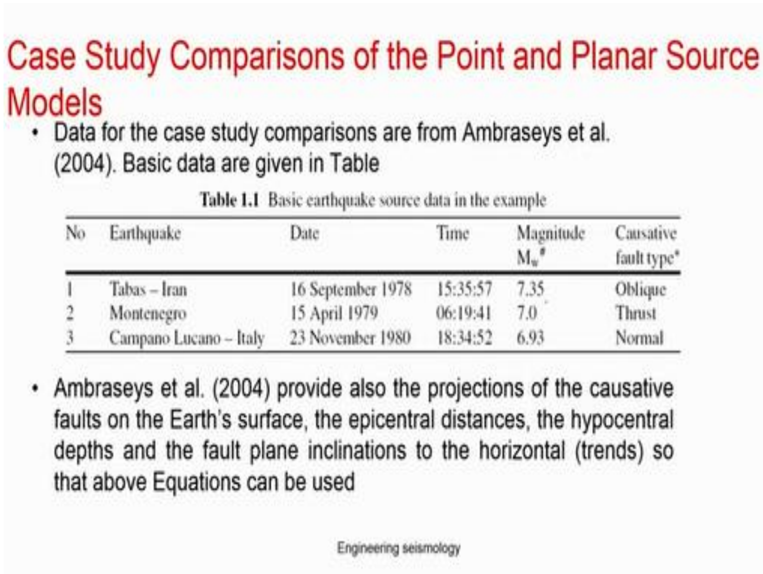

So people have use this model widely to accept how this models are vary with respect to the a particular application? So people have taken a typical record and try to work out model for that earthquake using the point and planar source and compare with the actual record to validate that model. So that of from the case study comparison Ambraseys et al. 2004 basic data given in the table. So you consider basically three earthquake Iran and then Montenegro, Italy.

So, this is the earthquake details, so 78, 79, 80 and this is the magnitude of the earthquake this is the magnitude of the earthquake MW and this is a fault type what they use. So Ambraseys et al. 2004 provide also the projection of the causative fault and earth surface, epicentral distance, hypocentral depth, fault plane inclination of horizontal, so that the above equation can be used effectively.

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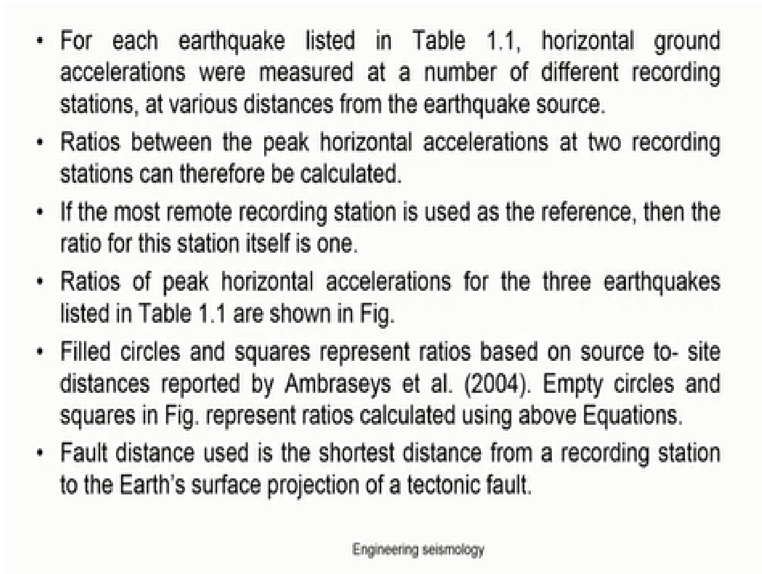

So each earthquake listed table 1.1 horizontal ground acceleration were measured at a number of difference recording stations, at a various distance from that. Ratios between the peak horizontal acceleration at two recording stations can be therefore calculated. If most remote recording stations are used as the reference then the ratio of the station itself is a one. The ratio of peak original acceleration was the three ground motion listed in the table 1.1.

So the ratio of the horizontal given in the figure, so the filled circle of square a represent ratio based on source to site distance reported by Ambraseys empty circles represents the calculated using the equation, the fault distance used to shortest distance among the recording station to the earth's surface projection of fault.

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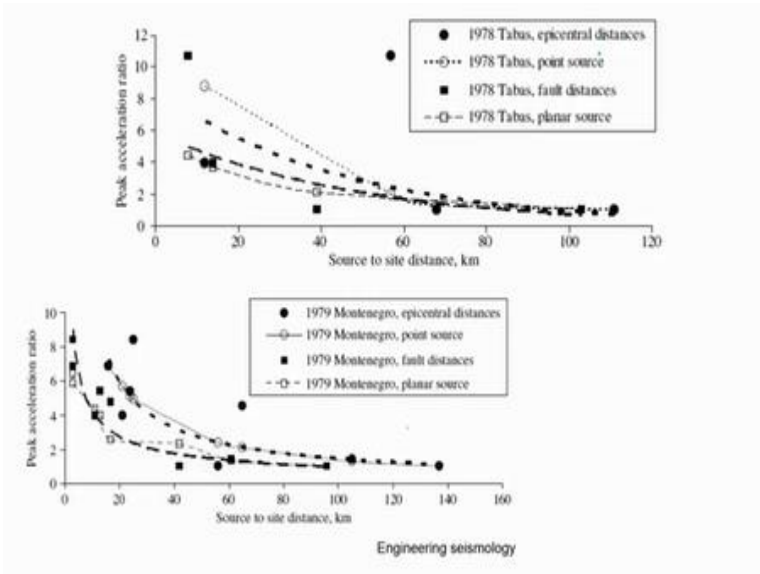

So you can see here the peak acceleration and source to site distance one is from the epicentral distance model and then point source model, fault distance and then fault to pronounce((29:15)) but the same earthquake you can see how this data's are varies. You can also see further another earthquake how this data's are varies, you can see it has a variation with respect to point and planar source model.

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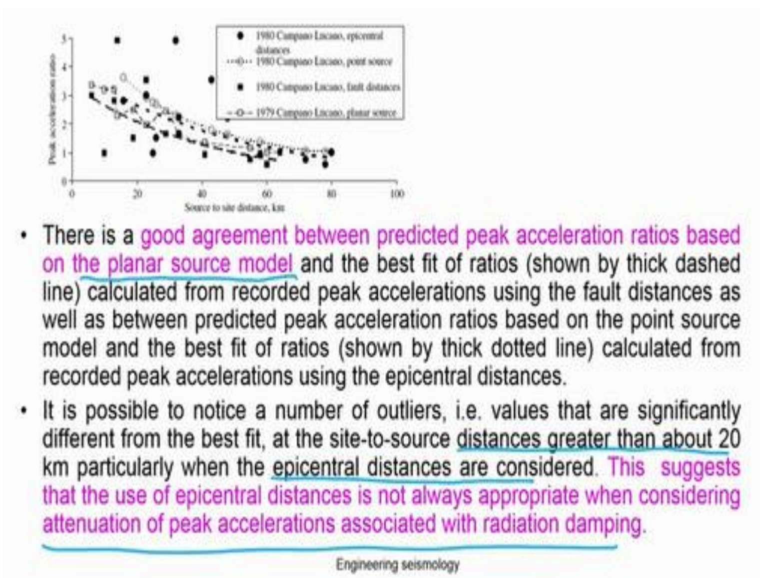

So this is for the; another earthquake, so from analyzing this so we can understand that. So there is a good agreement between the predicted and the peak acceleration ratio based on the planar source model, there is a one thing. So the best fit ratios by thick dashed line calculated from the recorded peak acceleration using the fault distance as well as predicted peak acceleration based on the point source model, the best bit ratio calculated from the recorded peak acceleration using the epicentral distance.

So it is possible to notice that number of outliner the value that are significantly different for the best fit, so at the distance to source distance greater than about 20 kilometer particularly when the epicenter distance or used. You can see that when the distances are away from that the distance the variations are very large. So this suggests that the use of empirical distance not always appropriate when considering the attenuation of peak ground acceleration.

So that means that so you should not use epicentral distance, as a distance to represent your this one. So the hypocentral distance are, more logically good, second the use of basically point source models are not so effective when you are having the bigger magnitude or basically you can see this magnitudes are very large, you cannot use here point source model. So, if you use the planar source model and hypocentral distance that will be more effective to interpret here attenuation at a model you have the peak values or energy loss with the respect to the distance.

Basically, the energy is reflected in here in your strong motion recorded are seismic record in the form of amplitude and duration. So this variations with the distance is actually reflected in the recorded data. So if you want to capture that very accurately, you should use planar source model and hypocentral distance, not epicenter distance. In olden days basically the use of epicenter distance are predominantly practice.

So after this kind of research people believed that so it is proved that so basically use of epicentral distance is not appropriate to show the decay of earthquakes are energy loss are the energy content in the earthquake. So it is necessary to use hypocentral distance, so particularly when the magnitudes are higher in the order. In case the magnitudes are lower like less 5 and less you can go for the point source model.

If the magnitude is higher in size, you should go the aerial source model or planar source model. So which will be discussing in detail again coming in the, what are the different simulation models are available, how this simulation models are used for simulating the synthetic ground motion, which is record for the application. So, why we need a synthetic ground motion? Basically, as I said that the India has seismic instrumentation after 1960 onwards.

So even the 1960, we have noticed that there is not many significant earthquakes are recorded in some region you but still you want to design your structure for a earthquake because we do not know any earthquake going to occur as we do not know what was possibility. So if you want to design in those kind of region, you need to have the region specific simulation of ground motion which considers here the source parameters, okay source seismic movement and the quality factor or the kappa which is specific to region.

So if you have to account all those things so you can need to generate a simulate synthetically the earthquake motions. So that is why the simulation of earthquake motions are very important for in the absence of the recorded data in region. So, this is a well practice particularly country like India, we have lack of lack of proper earthquake recording. So, hence the simulations are play a greater important to get a predictive equation model as well as the time history data.

Which will be useful for analyzing the important structures like dams, in nuclear power plant, tall structures and valuable structures kind of things and also get to a predictive equations on that, so which will be discussing in the next class. So with this we will close today class. So I will thank you for watching this video. So we will see you in the next class.