Introduction to Engineering Seismology
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Module No # 03
Lecture No # 12
Seismic Sensors

So vanakkam, so we will continue our lecture on engineering seismology so last class we discussed about the seismogram. Basically we talk about the oldest seismogram Chinese scope how people try to understand that. So finally they figure it out that some kind of the pendulum okay the mass with suspended so inertial provision we could able to pressure a vibration so that is why we have understand.

From there people have seen that there is a need for recording a 3 component of the vibration as the wave will respond for a particular vibration. For example the P wave will be more dominantly reflected in the so the vertical component. So the other component like the S wave and the surface wave will be reflected in the horizontal component. So the measuring of 3 components are very important we also end up in saying that a different type of waves created by the earth quake and its natural frequency or frequency band or range.

So which will help you if you want to measure the earthquake above 6 you should have the instrument which as that particular frequency.

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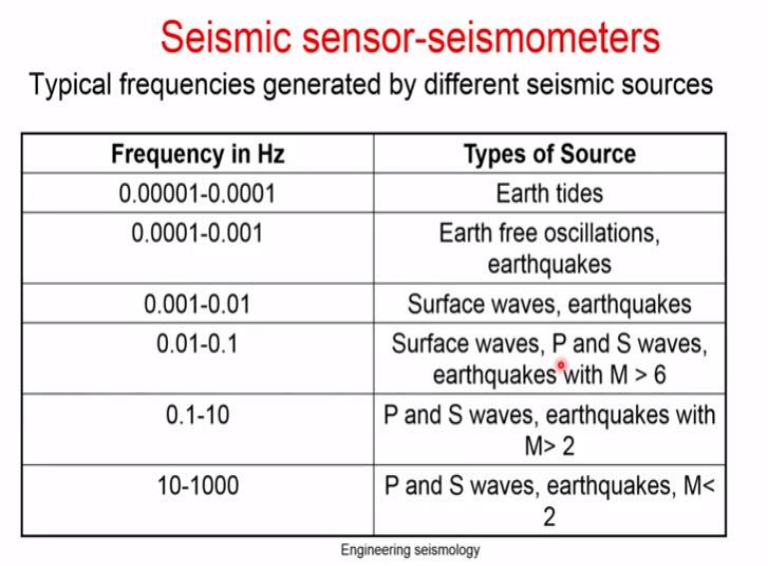

And if you want to measure earthquake above 2 and then what should be there and above less than 2 what should be there. So then if we want to measure a earth tide what should be there this is what is. So the type of equipment from the minimum requirement for equipment. So all those things are very important to record a particular earthquake okay so you can have the equipment such that you can record earthquake at anywhere in world or, it can have the equipment such that you can record earthquake at a near to our home or in your country or in your continent.

So depends upon the sensitivity and the application one as to choose a particular type of wave so frequency, range of the equipment.

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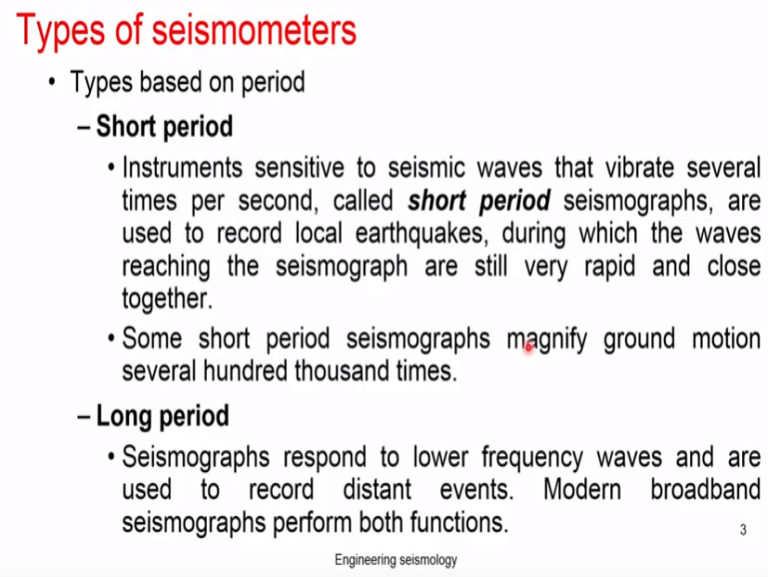

So where you can record a particular wave so seismometer can be broadly classified based on its requirement and application. So based on the period of record okay you can classified as a short period and long period. So the short period mean the instrument sensitive to seismic wave that vibrates several times per second are called as a short period seismogram are used for record local earthquake during which the waves reaching the seismogram or still very rapid and close together.

Some short period seismographs are, magnify the ground motion several 100 times for the display and noting down the amplitude and all. So the basically this short period sensors are useful to record local earthquake. That means if have the short period seismic equipment installed at IISC I could able to only record earthquake which is happening in and around IISC or in and around Bangalore I cannot record earthquake happened in the Delhi using the short period sensor installed at IISC okay.

The similar way the long period sensor the long period seismogram respond to the lower frequencies waves that are used to record the distant events modern broadband seismogram perform both short period and long period function. So for example I want to record earthquake occurring at Delhi my equipment should have the long period capacity okay it should be low frequency should work that is why long period you will get.

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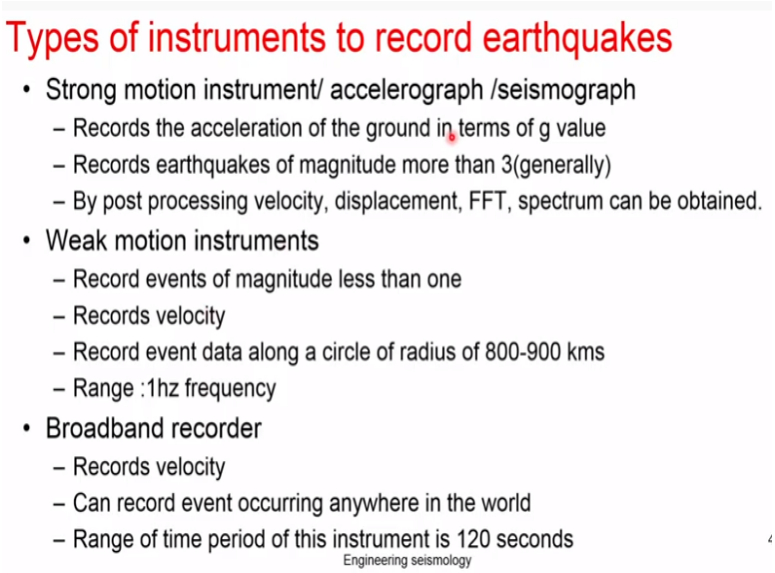

So that is how in a so based on the type of record okay the type of data what we record in the instrument again instrument can be classified as the 3 major category. One is that strong motion instrument or accelerograph instrument or seismogram. So, record acceleration of the ground in terms of g value that means it will record very high vibrations and record earthquake magnitude more than 3 and above. By post processing velocity and displacement Fast Fourier spectrum can be obtained.

So if you want to record a high level earthquake vibration close to the source you should have the strong motion record. Particularly earthquake 3 and above that means if we have the strong motion instrument at particular place okay if we are getting a local earthquake smaller in magnitude you cannot record that in their particular instrument. Second the weak motion instrument record events some magnitude less than 1 and record velocity in the function of velocity records.

Earlier one is the function of acceleration so it record even that along a circle radius of 800 to 900 kilometer this we should remember the weak motion could able to record a 800 to 900 kilometer and works in the range of 1 hertz frequency. The broadband seismometer record velocity can record event occurring anywhere in the world range time period of the instrument is 120 second. For your information we have the seismometer at IISC which is imported one to record 120 meter second capacity and also weak motion and also strong motions.

So we have a 3 category of seismic instrument with us which we will use it for the recording the some kind of signals.

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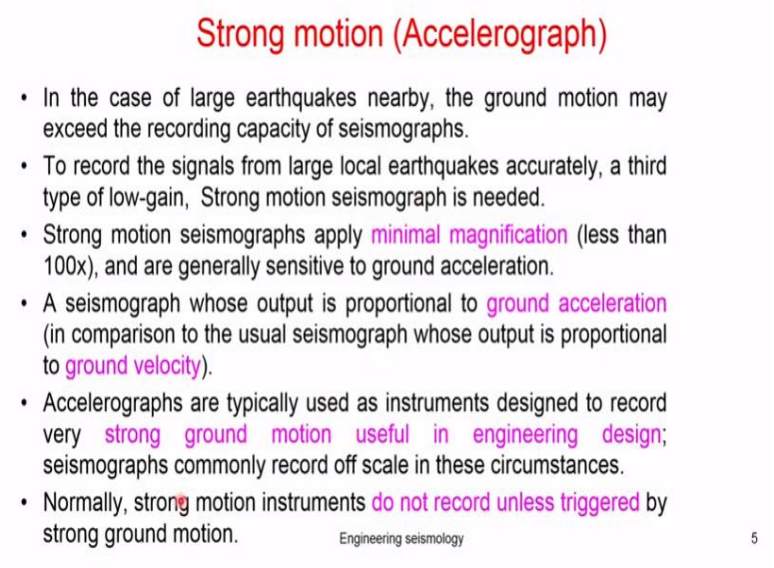

So, to do more know about the strong motion accelerogram in the case of large earthquake nearby the ground motion maybe exceeding a recording capacity of seismogram. Basically velocity capacity of the seismogram to record signals from large local earthquake accordingly the third type low gain and strong motions seismogram is needed. So the strong motions seismogram, apply a minimum magnification less than 100x and are generally sensitive to the ground acceleration.

A seismograph whose output is proportional to the ground acceleration is comparison to the usually seismogram those output is proportional to the ground velocity. So generally seismogram will record a ground velocity accelerogram will record a acceleration. So the accelerogram are typically used instrument design to record very strong ground motion useful for engineering design. Seismogram commonly used to off scale this circumstance.

Normally strong motions instrument do not record unless triggered by the strong motion signal okay this as a option were you can define a cut off level and it can be triggered. So, that we will see what is the trigger mode and continuous mode record in the coming this one.

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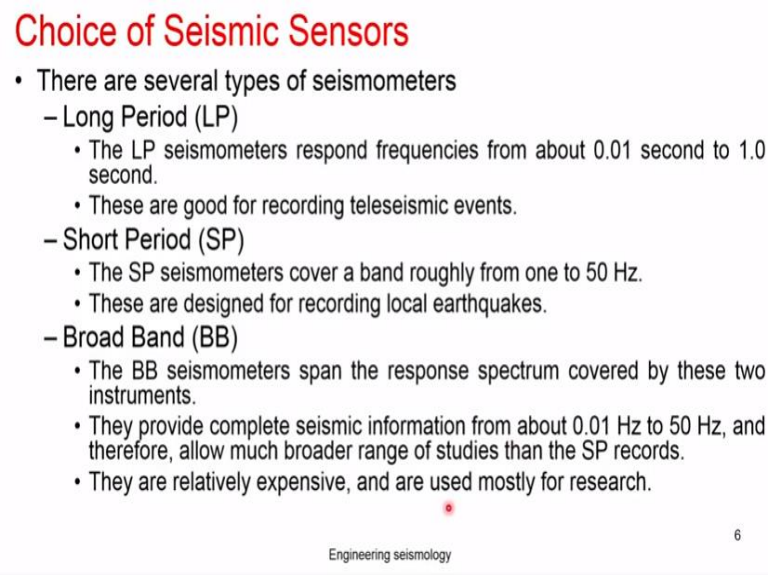

The choice as depends upon this character of the seismometer so one can go for the choice of seismometer depends upon the application. As I told that long period seismometer are if you want to use this will be useful for in the range of frequency you should be 0.01 to 1 second or good recording for the distance earthquake. Short period will be cover in the range of 1 to 50 hertz these are all design to record local earthquake.

Broadband seismometers span the response spectrum covered by these 2 instruments. They provide complete seismic information from 0.1 hertz to 50 hertz and therefore allow much broader range of studies, are SP record. They are relatively expensive are used most for the research application.

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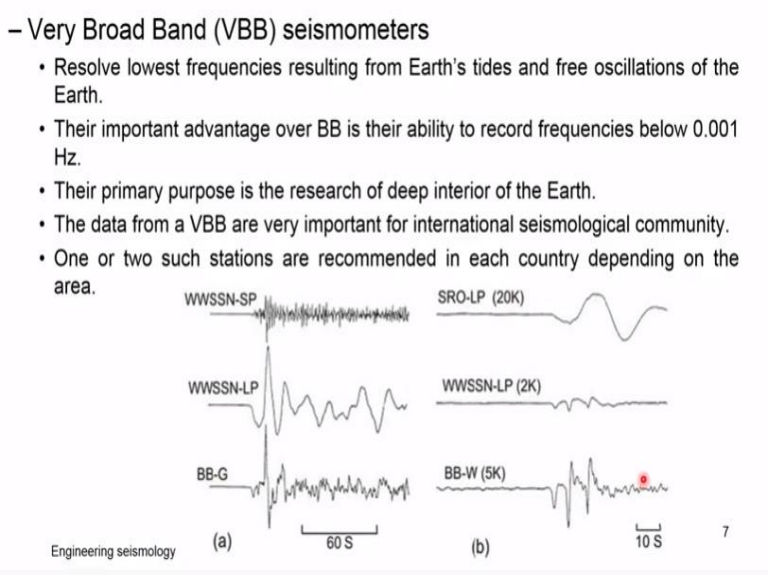

So now a day's apart from these 3 there is 1 more called very broad band seismometer so it resolve lowest frequency resulting from the earth tide and free oscillating of the earth. Their important advantage the BB is their ability to record frequencies below 001. Their primary purpose to research and deep interior of the earth data from VBB are very important and international seismology community. 1 or 2 such stations are recommended for each country depending on the area where it located.

You can see the similar earth quake recorded by the different seismometer you can see the long period short period and then the BBG equipment. Similarly the signal for the different signal you can see the amplitude and the recording time which makes a different. So you have to choose a proper instrument depends upon the your particular application.

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Okay so in the olden days basically this was recorded all the earthquake was recorded in the analog. So they have the mass and the inertial force balance system such that it can record vibration accordingly. So the analog seismometer still working in some of the places but not all the places so I am fortunate enough when I was doing my UG and like B.Tech or BE and ME degree. So since I have interest on earthquake I went to the metallurgical observatory in Chennai where I could able to see a analog record earthquake recorder installed in the place where it was drawing a continuous line like this.

So it basically what I have seen just give the presentation so basically there was a drum it was like this a earth tide okay. So you say that there is no vibration it is placed at Nungambakkam in Chennai I am not very sure where it is placed nearby it goes like that there is a earthquake then it will record like this okay. It depends upon the wave it will record and then it will come to the original position.

So this is how the wave getting recorded where there is a ink pen or there is a pencil which is connected the photographic paper this are recorded. So once you recorded this in the analog system you will take this paper and try to place it on the graphic sheet and try to identify how much the amplitude? What is the starting time? What is the end time? And from that you can estimate where is the earthquake origin that is what we discussed in the last class.

You could able to get if you know the average velocity of the region you could able to get the origin point and at the earthquake using this time difference okay that is what it is possible in.

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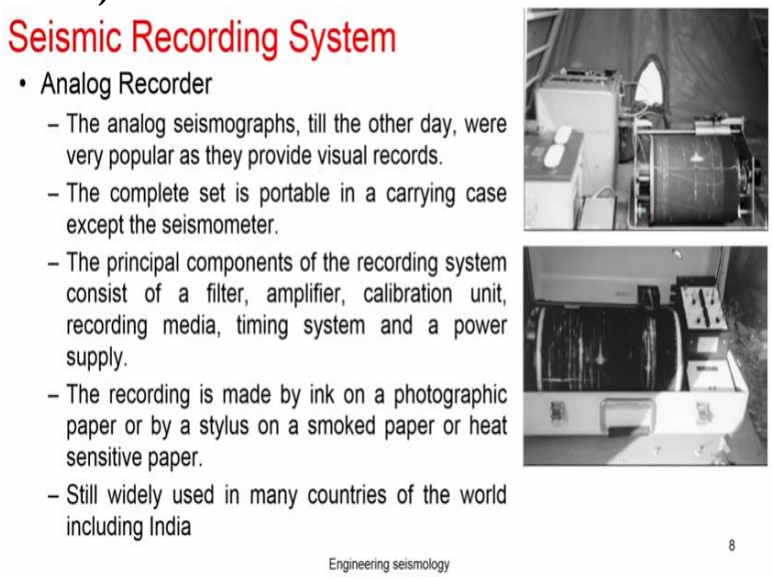

So this has been widely installed most of the countries okay so just erase this part. So you can see here so this is the typical analog recorder portable in nature where people take this and see you can see this is basically how this record. Okay this is a record which you have to see here so most of the English movie when you see this you might have seen this kind of old movies where you can see record. So similar kind of this is the portable one with there are permanent stations also in turn what I have seen in the Nungambakkam is basically the permanent station.

So India as per my knowledge I am not very sure any how many analog system presently working. But most of them are the converted digital but if you want to specially see the analog system which is used olden days you can visit IIT Roorkee earthquake engineering department, where they have the show case of this instrument in that location when you had chance to visit there you can see this analog instrument how this one.

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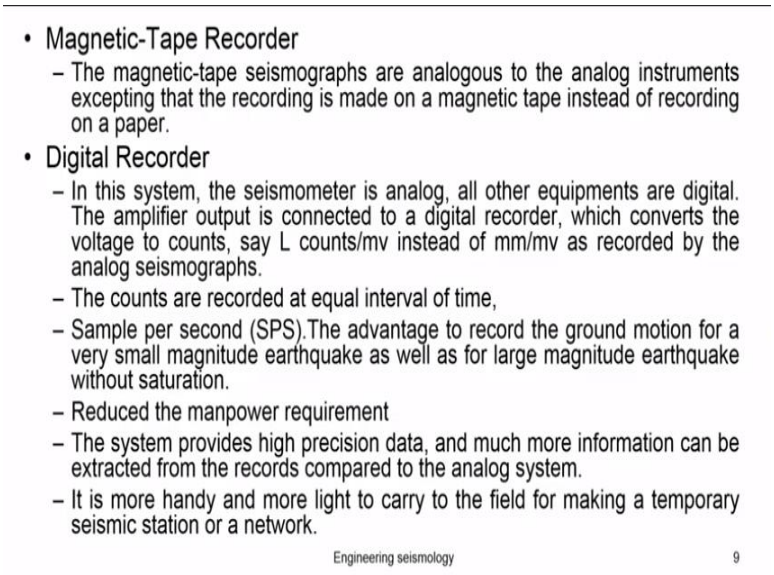

So this was the Millen version of the record so where they start using the paper and magnetic tape and then followed by the smoked paper all things ideas come, as we have seen that the music initially we used to see the disk based recording followed by the cassette with tape then we come up with the CD. So now we are recording in the pen drive okay so I am the generation I have seen all of them so those who are in my age and older than my age they might also, seen all of them.

Maybe the new generation who was studying +2 or degree they may not be seen the disk and tape recorder but still it is available in the; if you want you can go on and see the many places. So in case if you had chance to visit IISC particularly, when the open days going in the march time you can see a different recording system use in the computer like this magnetic digital and punch card and lot of things in the SCRC when the open day comes.

So the later after electronic development, as happen the digital recorder system come into picture so in the digital recorder system made many thing easy for the seismologist. As I told you that the hard copy of the recording you have to take it and then cut the paper and take it and put on the graph sheet and try to see how the amplitude time various. But here such issues are not there this so you can get everything directly in the digital in terms of the count okay it is the volt count per time okay how much volt it is count.

So basically you can also control this reading for the how many samples you can record for a time that is sample per second you can record 100 or 200 or 50 or 10 depends upon the storage available in the instrument and the data requirement. So this is a basically reduces the man power required for the analysis and the interpretation of the data which is highly useful for the modern seismometer now a days.

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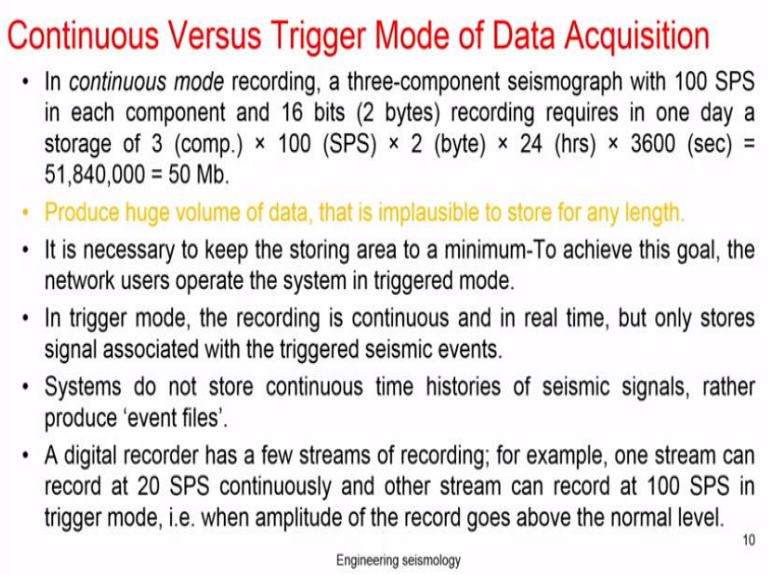

So in the digital thing comes so the people as to undergo a some understanding about the seismic data okay. So what is that one is that same per second so how many samples you can handle per second that is 1 capacity event. Second depends on the that we will continuous recording triggered mode recording you should understand continuous recording means the seismic instrument can continuously record a data okay.

So and store it and that is a continuous recording triggered mode means so since if you want to avoid unnecessary signal which is a earth vibration or vehicle vibration recorded. You want to only focus on the earthquake you can tell the seismometer or command seismometer using the digital computer program. Okay saying that I want to only record above this value of the count okay 0.001g or 0.001 meter per second something like that you can specify so that you can record only the interesting earthquake record needed for the analysis remaining we can discard.

So this; kind of trigger mode of operation or trigger mode of data acquisition are predominantly used in the seismometers to avoid unnecessary delay. For example the seismic station kept at

very remote place okay where there is not possible to go and access that frequently. So you can command that only record this earthquake so that the storage will be maintained. But now because this was the case when the storage was big problem because, when I do that under graduate degree the floppy usually used as the storage.

So it as only the 15mb or something like that so but now we use a small pen drive which as capacity of TB's okay. So, terabyte data which could able to handle so like that now the seismic, storing system electronic storing system capacity increased considerably. So now a days it is triggered continuous mode is not too much save the storage space but one can you should know that seismometer continuously monitoring only the recording decides a trigger mode it is not half okay the equipment is continuously working.

Triggered mode means only it record the position of the data which is exceeding the level will be stored as a file remaining will not be stored. The continuous mode everything will be stored that is the difference between this one.

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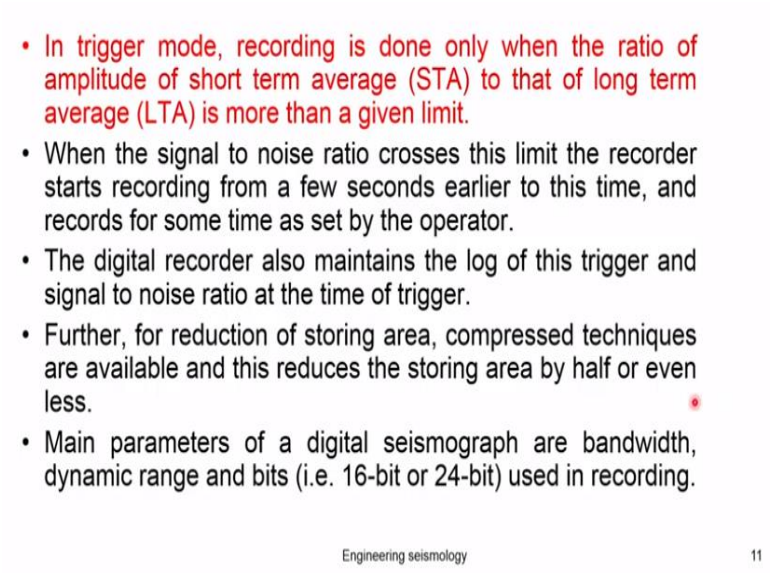

So the continuous trigger mode also taken into account of the so the ratio of the amplitude short average and long period average. So this is giving you the STA and LTA so this gives the idea like what type of signal we want to record okay you can specify this signal and you specify the level of these values based on that you can get a record. So whenever you have chance to visit

IISC or you can mail me if you want to see this seismometer personally and know all, those component how it works and all.

So you can explore or you had chance to see some other place also we can arrange so otherwise we will also see if there is a possibility that I can record a complete video of this and try to upload. So before ending up the course I am not sure but let us see how it goes and all. So this is how the seismometer continuous and triggered mode operations are happening.

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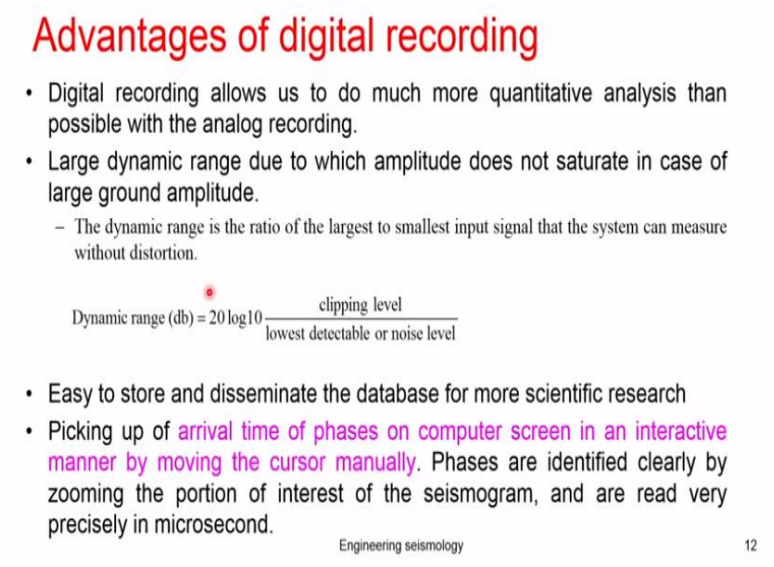

So this helps basically the digital recording allows to do much more quantitative analysis then the possible than the analog recording. The large dynamic range due to which the amplitude does not saturate; in the case of large ground amplitude. So, dynamic range is ratio of the largest smallest inputs signal that system can measure without distortion. You can see there the dynamic range and low clipping level and lowest deductible noise level.

So we using this you can get a; your dynamic range adjusted accordingly you can record a store. So easy to store a data and disseminate and analysis the data okay so you can also pick a arrival point okay so very accurately using the curser as you know that computer you can enhance and zoom and then play with the data in the digital platform.

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- Filtering of the trace can be done with the digital seismograms. It is a straight forward matter to convert the time domain into frequency domain, and see how the earthquake motion is distributed by frequency.
- The filtering is applied to a broadband seismogram. One can emphasize surface waves by lowpass filtering, and body waves by high-pass filtering.
- Frequency domain analysis or spectrum analysis by Fourier Transform can be done, and many source parameters can be obtained. The reason for performing this kind of analysis is for modelling earthquake source, site response studies etc.
- Ground motion along any direction can be obtained using the three component digital data. In many studies it is necessary to obtain radial and transverse component by vectorial rotation of the two horizontal components. Further, S-wave is very clear in transverse component. In addition, P-wave group is absent in this component and this can be used to find the direction of the epicentre from the observatory

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So that advantage and also you can apply necessary filter very accurately to remove some of the noise which you find which is not a earthquake. For example, when earthquakes are occurring there was a continuous noise in the region there due to the some operations of motor or something else then you can avoid those kind of noise by applying a proper filter which is possible in the digital and may not be possible in the analog that easily.

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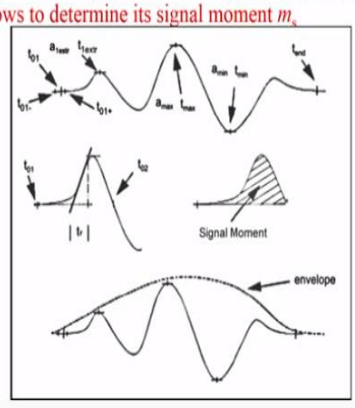
- Further, digital records allow to estimate ***wavelet* parameters**. Such parameters provide much deeper insight into the seismic source processes and seismic moment release. The duration of a true ground displacement pulse t_w and the rise time T_r to its maximum amplitude contain information about size of the source, stress drop and attenuation of the pulse while propagating through the Earth. Integrating over the area underneath a displacement pulse allows to determine its signal moment m_o



A schematic diagram showing time (t) and amplitude (a) function, signal moment and wavelet envelope (IASPEI, 2002).

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So those are all the provision you get apart from that as we told that the wave okay the wave pattern, wave arrival okay wave shape decides which how many layers the waves are passed. How the source is how the path is okay where the origin point those are called as a wave let

properties. So the digital record, allow, estimate wavelet parameters such parameter provides much deeper inside into the seismic source process, seismic moment release.

The duration of the true ground displacement tw and rise time Tr to its maximize amplitude containing information about size of the source stressed up which we have discussed last time what is the stressed up. Attenuation of the pulse propagating through earth integrating over a area underneath displacement allows to determine a signal moment ms. So all those things are possible in the digital record which is not possible in the analog record.

This is a typical digital record where you can pick each and, every point useful information which will help to estimate the different wavelet parameters okay.

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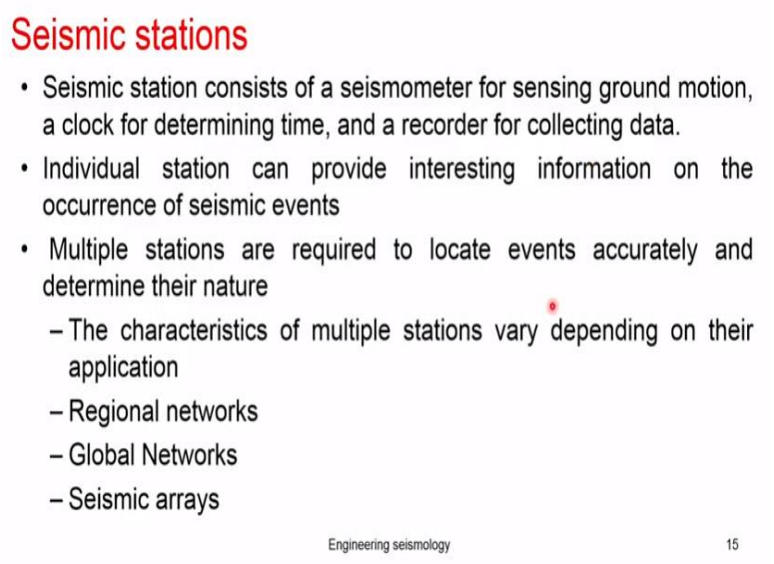

So this about the equipment and digital record analog record we have seen so the next we are going to see a seismic station. So seismic station is the place where the seismometer housed or kept is called as a seismic station. So generally the seismic station should consist of the clock okay which is synchronized with the real time monitoring in the globe. Like for example now the days all the seismic station synchronized with the satellite so that the time keep on updating universally and there is a recorder and sensor to detect a vibration happening.

That collection of that and then storing the data so these are all, the minimum component any seismic station should have. So the clock and co-ordinates with like GPS coordinates with

communicating with the satellite and then the recording system and storage device. So the individual station can provide interesting in information about the occurrence of the earthquake. If you have the one station you get the signal waves recorder.

So it depend upon the expertize what you learned so far you can say that there was a earthquake occurred at this place this type of wave I recorder then further if you look at the very closely the type of wave and arrival time by chance if you have the P and S wave then you can see that this is the radius I got a earthquake okay. This my earthquake recorded at this radius from the station that information can be obtained from the single station.

But maintaining single station will not help to find out very accurately location of the station so that is why the maintaining the seismic station the multiple numbers, are mandatory. There are 4 way the seismic stations are maintained one is the regional network, global network and seismic array. So we are going to discuss all of them now so the regional network typically consist of tens to the occasionally 100 of seismic station spaced at the interval of 10 sub kilometers.

So this generally recorded kept in the regional level for example Bangalore region there may be seismic station kept in and around Bangalore that is called as a regional network. Monitoring the seismic activity within and surrounding the network or used to characterize a particular region.

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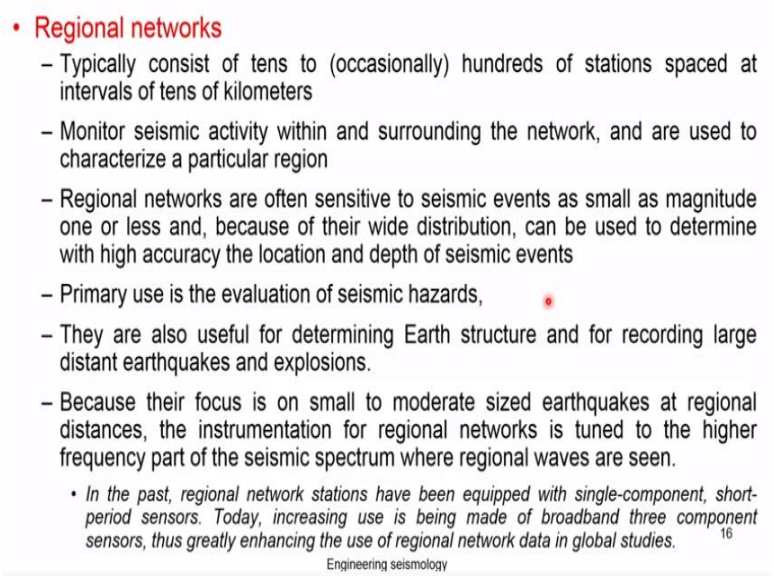

Regional network are often sensitive to the seismic event as small as magnitude one and less and because their wide distribution can be used to determine very accuracy of the location depth of the seismic event. Primarily uses the evaluation of the seismic hazard they are useful for determining the earth structure for recording the large distance earthquake and explosion.

Because their focus on small moderate earthquake, at to regional distance instrument of regional network is tuned to higher frequency part of seismic spectrum where the regional waves are same. In the past regional network were run by the equipped with the single vertical component later the single component equipment are destroyed. So they are changed to the 3 sensor component and many regional networks are in the 3 component.

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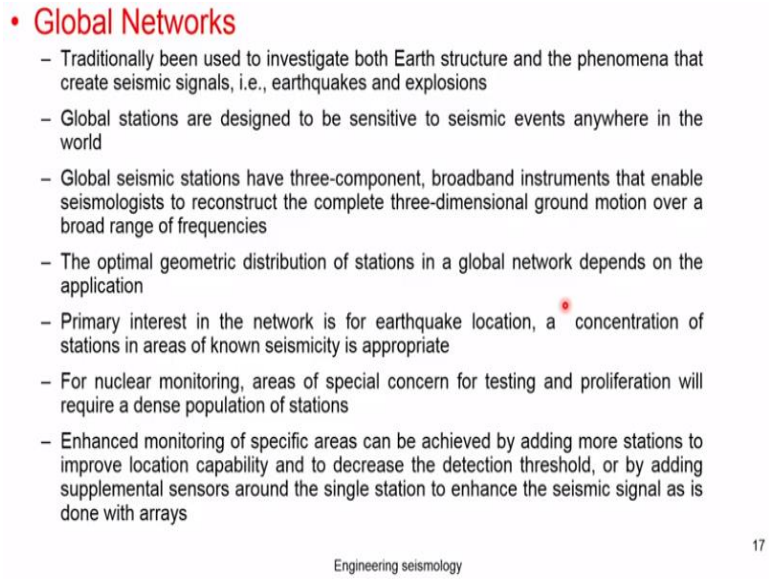

The, another one is the global network traditionally been used to investigate the both interior of the earthquake phenomena that create a seismic signal such as earthquake and explosion. The global stations are designed to sensitive to the seismic event anywhere in the world that means the global network could capable of very broadband system record earthquake anywhere in the world.

Global seismic stations have 3 components so the one vertical to horizontal so optical geometry distribution station globally so that even the earthquakes are occurring at the different place where stations and shadow and some other stations in the region can pick up. So that such that

global networks are this one. So this is especially used by the some of the countries for the nuclear monitoring phenomena and also some blasting and other activities and all.

So here I could share interesting news so you might have seen that whenever there is a some kind of nuclear testing happened in the North Korea immediately the US come to know and then they say that you have tested Nuclear this one. You know how? The global network so basically the in the name of global network a particular country or a group of scientist they give a free installation of seismic meter to different countries.

People thinking that we get money we have to install this seismometer it is not for the your benefit basically in the name of recording earthquake they also monitoring what is happening in your region okay. So even people try to make that not to happen by intelligence way so one of the interesting story I can share here that you know when Abdul Kalam was the scientist at ISRO we tested a first nuclear explosion in the Rajasthan.

So what they know how they planned their activity as you know that US basically NASA monitoring the entire globe using the remote sensing the process of satellite scanning okay. So where they scans satellite and in the so basically testing up nuclear things you have to move your large military force because to you have drill deeper level like 1 kilometer, 2 kilometer and then also you evacuate a people in the region and that entire region should come to the control of army okay then only you can decide what can be done in the particular location.

So the moving up this kind of large army force under will be scanned in the satellite scanning what is happening throughout the world. So what Abdul Kalam did actually they have a sand storm in the Rajasthan where the air mixed with the sand dust you cannot see what is happening in the ground. So during that period that 15 days they moved everything and settled and drilled and then they did the nuclear explosion and test then because this global network this explosion has been captured in the seismometer.

Immediately US come to know that okay there was a explosion it is happened in this place then they find out based on the signal how much explosion have been explored based on that only they come to know that there was a nuclear testing happened in India. They asked India and put

some ban finally our country also agreed that yes we have done that is we have done for our safety purpose okay.

So this are the global network basically used for that kind of prime importance not only understanding the earthquake all the country this kind of global network are known to government unknown to government has been installed okay that is the global network.

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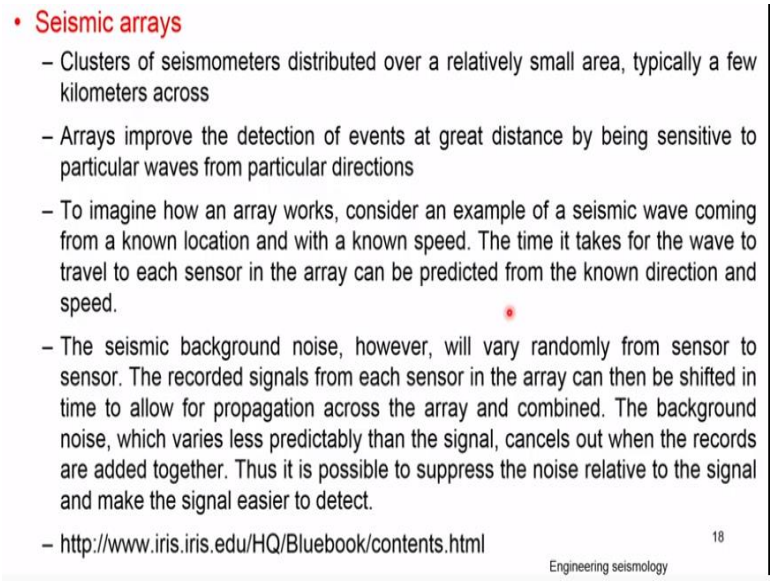

So the another one is the seismic array so the seismic array basically try to understand how this waves are changes with respect to the soil deposit in the smaller region. The clusters of seismometer distributed over a relatively small area typically few kilometer across. Arrays improves deduction of event at the greater distance by being sensitive to the particular wave of a particular direction.

So these are all used to understand how the wave amplifies attenuates and how the liquefaction occurs at particular region which are the wave get reflect and amplified those kind of studies can be done in the this array kind of station.

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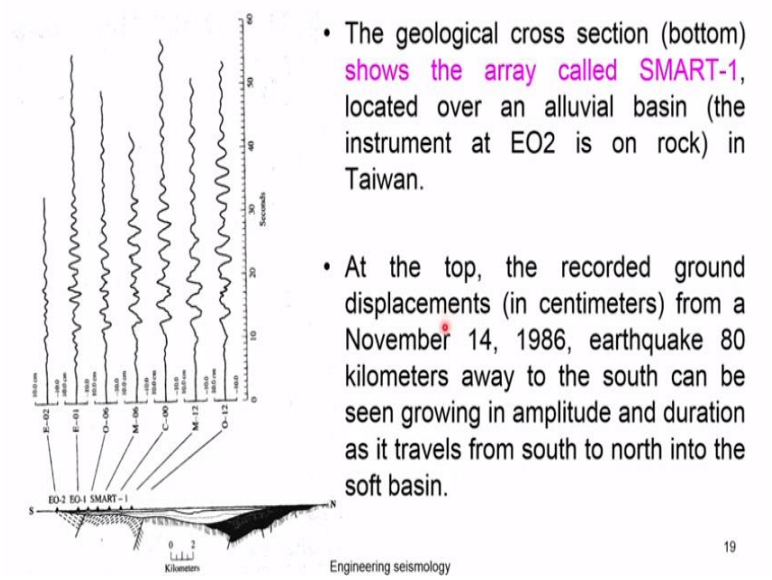

So this is the typical array which is maintained by the smart one in Taiwan where you can see that this is actually the dimension. So these are 2 kilometers means so this is throughout within like 10, 20 kilometer. There is a station which is installed on the rock then again there is a deposit like our Indo-Gangetic basin where they installed several see the same earthquake signal how it various it a distance.

And you can also relate with the inside soil how it various so this kind of understanding up amplification and soil wave character changing nature of the place you can do this which will help to design a building at this kind of region okay so that is what which will be seismic array does.

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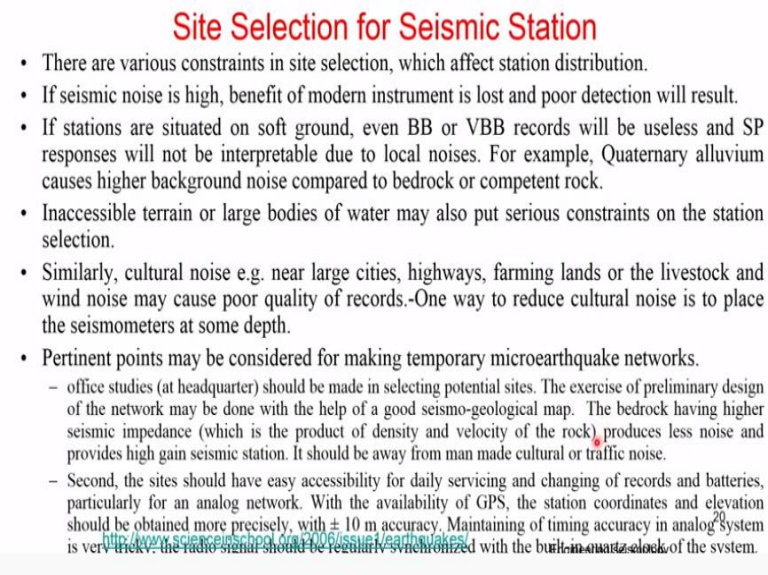

So basically this seismic station combination of different seismic station we can call it as a array and then the regional network and global network. But this seismic station before installing the seismic station you should have some minimum requirement to fulfill that particular site is good for seismic hosting a seismic station. What are their those requirement there are various constraint in the site selection, which affect a station distribution the seismic noise is high benefit of modern instrumentation lost because of the very sensitive the noise will be always recorded and disturb data processing.

And poor deduction will results some time and at the stations are situated on the soft ground even BB or broadband station or very broadband record there will be useless. The SP response will be not be (()) (28:16) that may not be we should not choose your station at soft ground. So inaccessible terrain and long bodies of water maybe put series constraint to reach station for maintenance and getting the data.

So that should be avoided similar cultural noise near large cities, highway and any industries all those places try to avoid because that will create a vibration noises to the seismic radar will be removed. So dynamic point is actually is may consider making the temporary micro (()) (28:47). So, office studies headquarters should be made selecting potential sites so that the safety of the equipment and then processing and all those things will be easy.

So size should be easy to accessible under should be exposed to the properly to the sun and satellite signals. So that the GPS coordinate and time updates are keep happening. These are all the criteria one can consider while selecting the seismic station.

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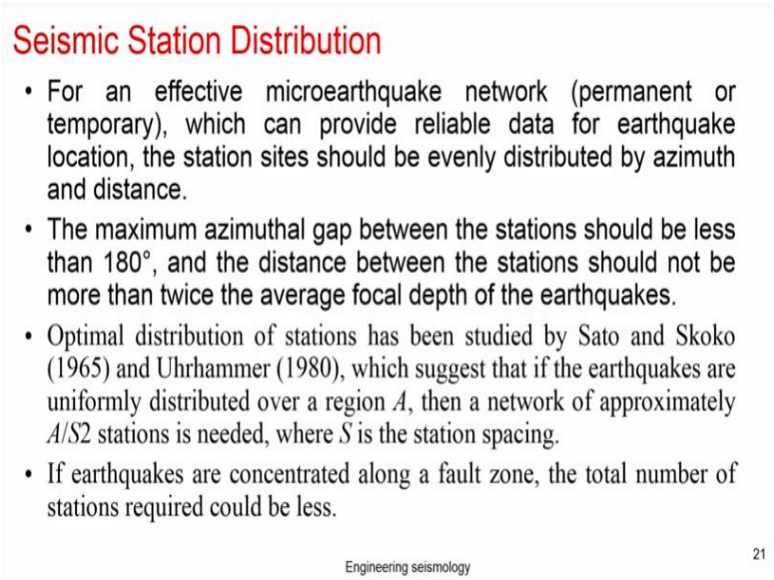

So in a given region how many stations we should have so there was a some international discussion on that. So and a effective micro earthquake network like permanent temporary which can be provide reliable data for the seismic earthquake location stations site should be eventually distributed by azimuth. So the maximum azimuth gap between the stations should be less than 180 degree. That means if you keep 1 station so if you keep 1 station here the another station should be within the 180 degree means you should be somewhere here or here like this within the 180 degree at the azimuth within the stations.

So the optimal distance between the 2 station basically the optimal distance between the 2 station is basically decided based on the area of this one. So for example if you take the area is A the network approximately A / S2 the S2 is the station needed where S is the station placing. The earthquakes are concentrated along the fault total number of stations required could be less. So generally the station the distance between the station S should be decided twice average focal depth of the earthquake.

That means if you have the earthquake focal depth is 10 kilometer so you should roughly have 20 kilometer as a distance not very large distance it will create a error in identifying the depth

and position of the earthquake like a epicenter location and the distance it will causes a error if we have the less number of station okay. So with this we close this lecture so basically we understand how the seismometer as a useful to record the different signal what is the minimum requirement what are the different seismic network has been operated what is the consequence of that.

And then followed by we also understand what is the minimum station and requirement for placing the equipment and hence setting of number of instrument how it is done. So the regional network and then the; global network and array kind of things. So as per India concern we maintain regional network at only at Delhi I think. So we were the many stations are there close to Delhi so then other places we have some station but which is not fulfilling the requirement of this.

So we will discuss the seismic instrumentation of India in the next class so that when you collect any data from the IMD or seismic recording agencies. We should know what is that limitation we should know the accurate it will for that it will help you. So with that we close this lecture thank you so we will meet in the next class.