Introduction to Engineering Seismology

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Module No # 03
Lecture No # 11

Earthquake Recording Instrumentations; Concept of Seismograph & Build your own seismograph

So vanakkam so we will continue today lectures on engineering seismology. So last class we discussed about the wave character and application of the wave character on the different part. So we have seen that if you know the wave character very well. So you can able to know what type of wave you receive and you are in the P wave shadow zone or S wave shadow zone so you or your seismic station.

And when this wave are coming which type of wave you can expect with reference to the origin of the wave to your building that we are understand. And also we have seen that there is a deep geophysical investigation has been carried out. People try to map the stiffness and the density variation using this wave understanding ok. So that is a so today class so as we since we discuss about the wave today class we are going to see how this waves can be recorded ok.

So, that what equipment is used how this equipment was development. So the earthquake recording instrument the concept of seismogram and build your own seismogram is going to cover in the today class.

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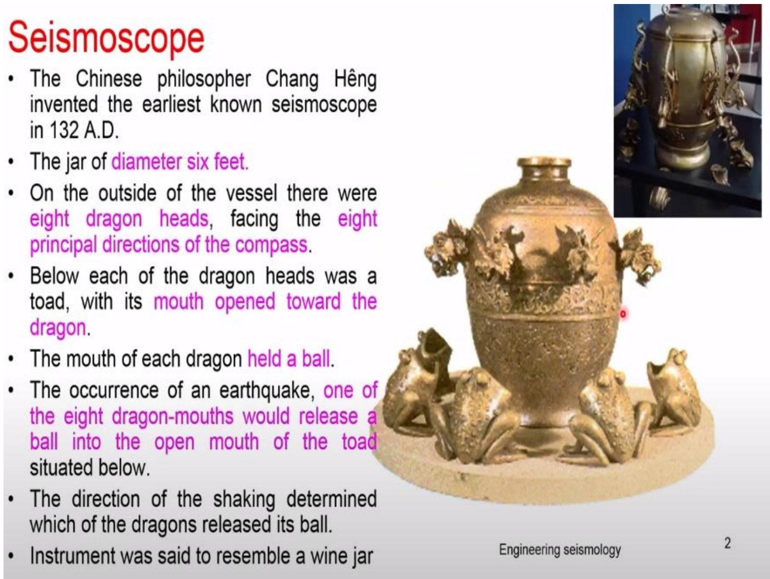

So the instrument which records the seismic signal ok is called as a seismoscope or seismometer which we have seen already. So this earthquake recording is not the new things ok. So this is exist since ancient time ok. So particularly it was exist since Asia in 1932 AD dated 1932 AD the seismoscope has been found. So if you remember when we talk about the earthquake I have also shown the earthquake god one we have shown Booma Devi and another one I have shown one Chinese symbol basically ok.

So next to the Chinese symbol there was person who is holding a small kind of jar and standing that is a Chang Heng. So basically the seismic Chinese scope ok seismoscope has been invented by the Chang Heng in 132 AD ok. That is the time where the seismic instrument has been exists. So how this instrument was this was like a very big jar ok which has about 6 feet diameter ok. You can see 6 feet diameter jar which has basically 8 dragons you can see the 8 dragons around this.

So you can see the dragon this is 2 dragon 2 dragons this 8 dragons oriented on the 8 directions of the earth. As you know that we know the 3 major 4 directions north, south okay so east, west. So if you again you link the north-east, south-east and so south-west and north-west you will get another 4 directions. So these 8 directions there is a dragon. So this is a dragon you can see very closely this dragon is holding something.

So what it is holding basically it is holding a ball. You can see this is ball ok. So then there is a toad ok down below the 8 dragons. There was a 8 toads, this toad was opening a mouth. So the dragon mouth there is a ball and then toad was empty mouth it is opening. So whenever there is earthquake occurring ok then the dragon will drop a ball the toad will catch the ball ok. So this is what happened. So this seismoscope has been used to identify a earthquake like this.

So particularly this is very interesting that direction of earthquake is very well know ok. So that is what this seismoscope provided.

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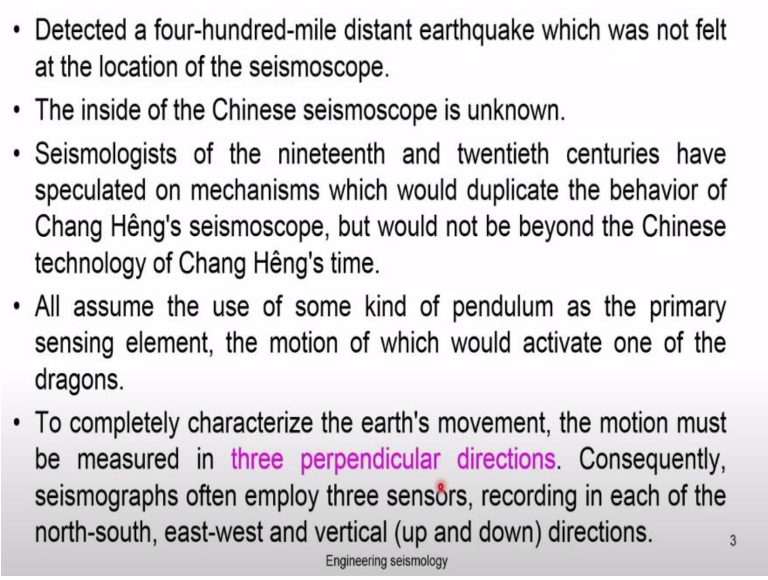

So how far you can record basically it can detect 400 mile distant earthquake which was not felt at local by the seismic people. So it can detect any earthquake occurring from 0 to 400 miles that is closed to 600 kilometer that was the highest very sensitive equipment one can see in 132 AD ok. So that means 400 miles beyond the something happen the instrument capable of recording or notifying that earthquake by dropping a ball ok.

So the inside seismoscope Chinese seismoscope is not well understood up to last year ok. There are many people tried which is not possible to understand. But last year there was article published video and the article published after 5 years study of Chinese seismoscope how it is working? Ok. So but when I started this course actually this not well understood so that the same thing I also continued.

But now it is very clear written how the Chinese seismoscope is working. So if you want you can go through that. But when the seismologist wants to develop a seismometer in nineteenth century and twentieth century those times the Chinese scope is not well understood. They do not know how it works, but it is able to detect a earthquake direction. So I may be suspicious that this people predominantly they might have used this Chinese scope.

Basically to know the direction of the earthquake particularly in Japan kind of country where the earthquake occurring in the sea causes a Tsunami where the people are suffered more. So if you know the earthquake on the Tsunami sea side the people try may be escaped because as you know the Tsunami waves reaches very long time. So I may be suspicious that this people predominantly they might have used this Chinese scope.

It take a long time to reach a shore. So if you know 600 means like 600 meters the Tsunami wave so earthquakes are happened people had enough time like 1 hour half an hour time depends upon the original location. Then they might have moved to escape or reduce the death that is the reason they might have tried to know the earthquake direction rather a amplitude. There that time the people may be living on the nature build house ok or the house which is build using the nature material which does not undergo a failure ok does not undergo a much failure.

Even it fails you will not hurt ok that kind of structure they might have been used. So that is why they are very keen on identifying the location and direction of the earthquake. The Chinese scope was doing that very well. But seismologist want to develop English people want to know that how this Chinese scope are working. So that they can also develop a similar kind of equipment to record a earthquake which is happening so since historic times.

So all assume that there is use of some kind of pendulum as a primary sensing element, the motion of which would active one of the dragon ball this is the assumption because they could not able to cut and see the seismoscope. Even today the Chinese seismoscope is exists in China. So what all I was telling the last year there was a discussion and scientific article people who are interested to know that can go and study how this was build.

They basically given a cross section, dimension everything. So to complete a characterize a earth movement the motion must be measured in 3 perpendicular directions. So consequently the seismogram, often employ 3 sensor recording each north-south and east-west and vertical direction and that is how you should do.

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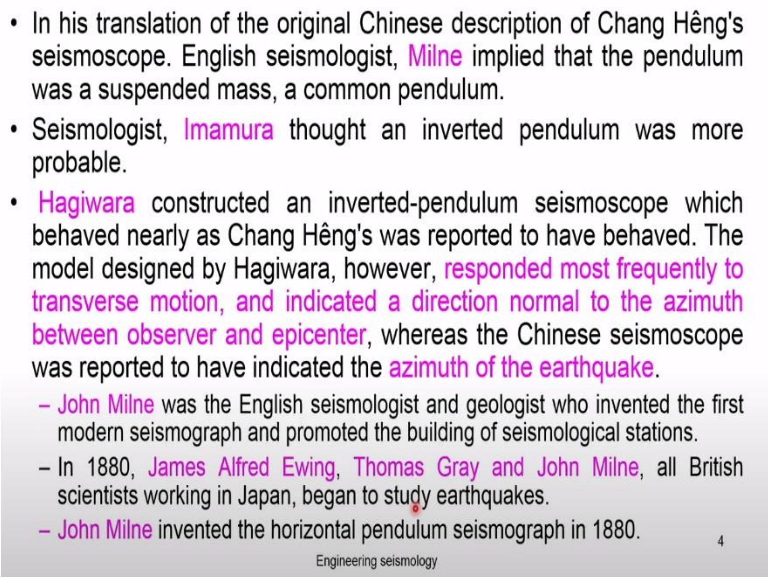

So basically the Chinese seismoscope is a translation is original Chinese description so Chang Heng seismoscope. English seismologist Milne implied that the pendulum was a suspended mass is a common, pendulum which will help to get activate a bar. So later the seismologist Imamura though an inverted pendulum was more probable way to activate a ball in the dragon mouth ok. The Hagiwara constructed a inverted pendulum seismoscope which behaved nearly as a Chang Heng was reported to have behaved.

The model designated by the Hagiwara however responded most frequently to transfer motion indicated a direction normal to the azimuth between the observer and the epicenter. So the Hagiwara basically tried to understand this seismoscope during the nineteen twentieth century but tried to stimulate but he success some extend to activate a ball but unfortunately the ball was dropping perpendicular direction of the wave. That means it is not dropping at earthquake direction.

So they could not able to completely explain the concept behind the Chinese seismoscope ok. So later John Milne was a English seismologist and geologist who invented the first modern seismogram and promoted building seismological station throughout the world so that people can measure and understand earth interior and understand the earthquake and try to minimize damage due to the earthquake ok.

So in 1880 the James Alfred Ewing and Thomas Gray and John Milne the all British scientist working in Japan began to study earthquake. And John Milne was invented 1880 as the first seismogram in the world. So now you can see that any earthquake which is recorded before 1880 you may not have the earthquake recording at all. So this 1880 is how much it is just about 120 years back that is all nothing more 120 years back. So there is no instrument that so how it works basically seismoscope. So it is works with the pendulum ok.

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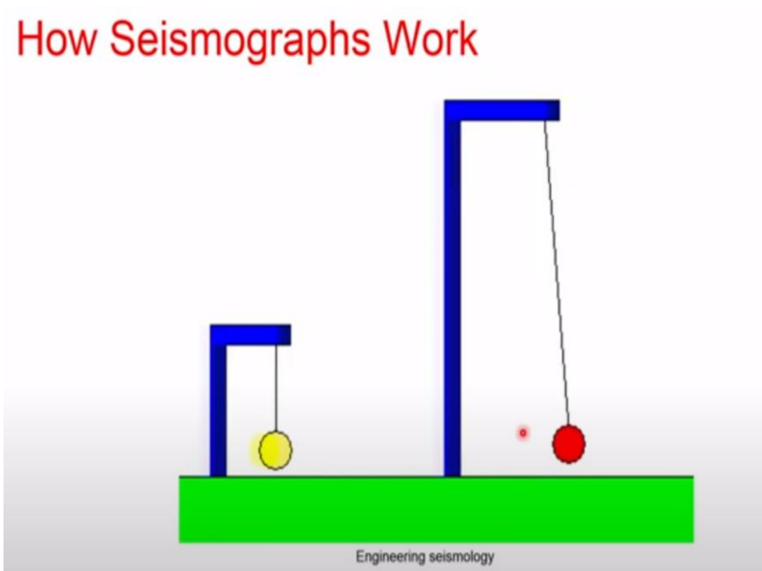

So there is a pendulum so it will act as basically stationary when earth is not moving. So when the earth is it is own speed moves it is stationary. When there is a vibration, takes place ok it responds to the vibration and try to give that graph. So the pendulum height and then mass in the pendulum place a important role to level up vibration can be recorded ok. So this is how the seismogram works ok. So this is how the people started developing a seismogram at initially.

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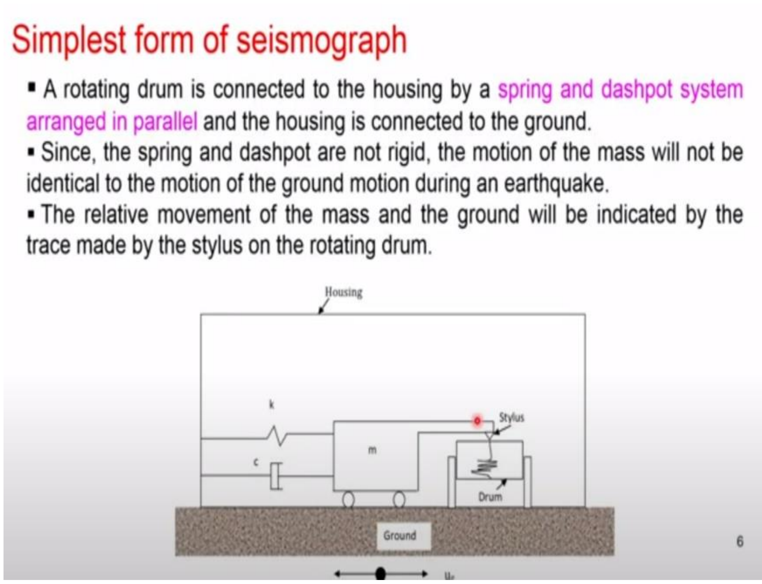

So the simplest form basically a rotating drum connected with the housing of spring and dashpot system. So basically this is the spring and dashpot system so arranged parallel housing connected to the ground. So this is actually mass which balancing so when the earth is normal so this basically this mass and spring and dashpot will be in balance position it does not move at all. So this is the drum where the moment is monitored. So it will be like a straight line.

So when there is a movement in the earth basically it creates a relative moment that moment is marked like this. You can see it is marked like this ok. So it is marked like this where you can get record of the earth quake.

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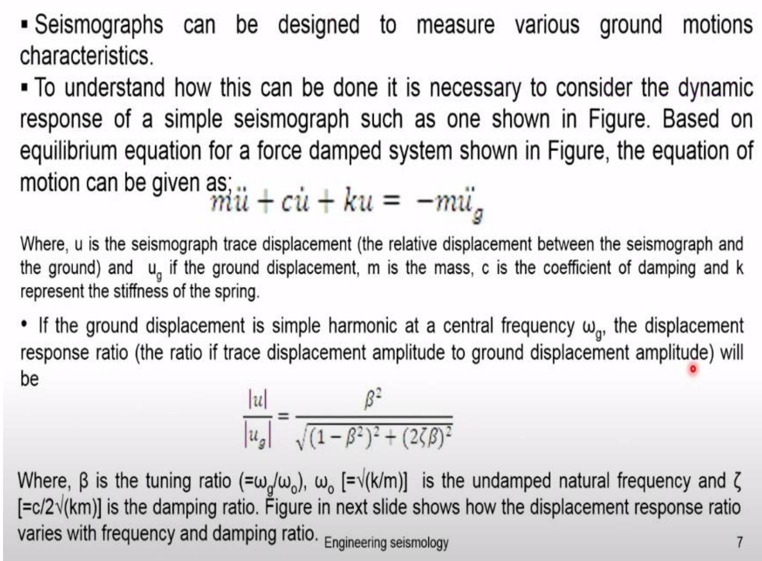

So this can be explained further the seismogram can be designed to measure various ground motion characteristics. To understand how this can be done it is necessary to consider a dynamic response of the simple seismogram ok. So such as one shown in figure previously based on the equilibrium equation for a force damped so and so system ok. The equation of the motion can be given like this.

Here the u is the seismogram trace displacement and the relative displacement the seismogram and the ground and the ug is the ground displacement, m is the mass, c is the coefficient of damping system and k is represent as. So the ground displacement is simple harmonic central frequency wg the displacement response ratio that is the ratio of the trace displacement amplitude to ground displacement amplitude will be this. So this decides what type of amplitude you can measure? What kind of signal you can measure?

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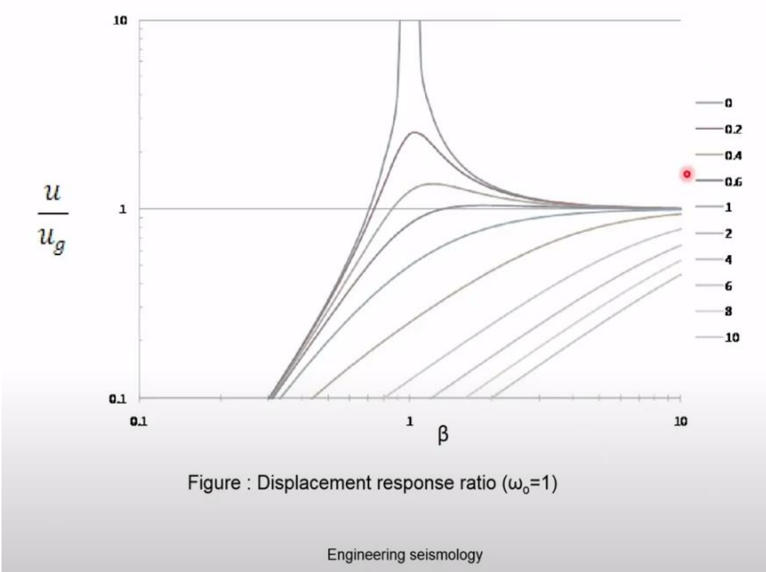

So by varying this how the displacement response you can expect. So this give you the idea that how you can build your seismic instrument you want to record a big earthquake if you want to record a small earthquake. So which will be discussing; in the coming classes in what type of equipment it will work. So this is how it works basically these are all the engineering subject mathematics.

But this level you should know that how it works that is more than enough ok. You no need to worry too much about all those derivations (()) (13:07) equation. Some of you may be as I said that you may not studied engineering mathematics which will comes on only on engineering degree not on the other degree so that is fine.

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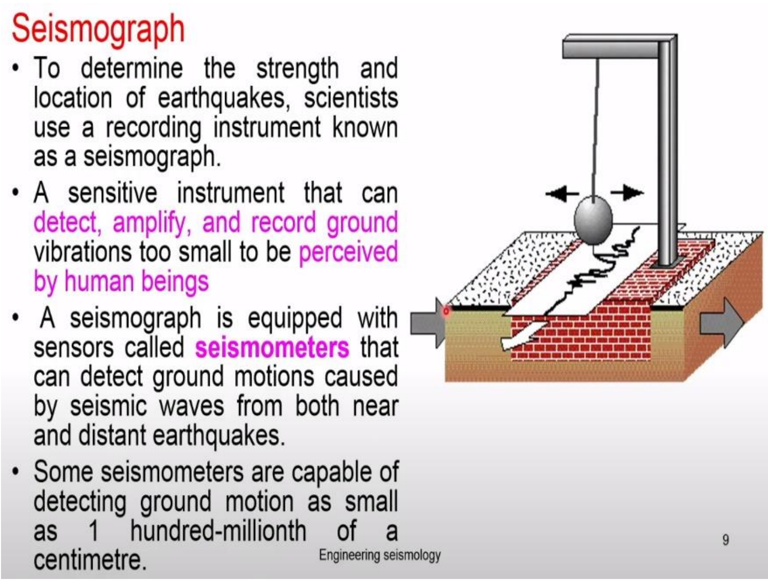

So the seismogram so as we explained that so the mash dashpot or if you have even a simple pendulum so ok with this one where you can mark a pen. So there is a drum which rotates to determine the location and strength like the amplitude of the earthquake which will help you. You can see here this is the normal condition. So when the earthquake vibrates it starts moving. So it depends upon the vibration nature this will move very large and very less and then it will again come after the migration comes it comes to the rest.

The sensitive instrument which can detect amplifier record vibration so, generally whatever instrument records they put some amplifier so that even a small motion can be also seen properly. Seismogram equipped with the sensor called seismometer that can detect a ground motion caused by the seismic waves from both near and district earthquake. Some of the seismic meters are capable of detecting ground motion as small as 100 millionth of the centimeter ok. So which is close to the nanometer micrometers kind of scale you can record ok.

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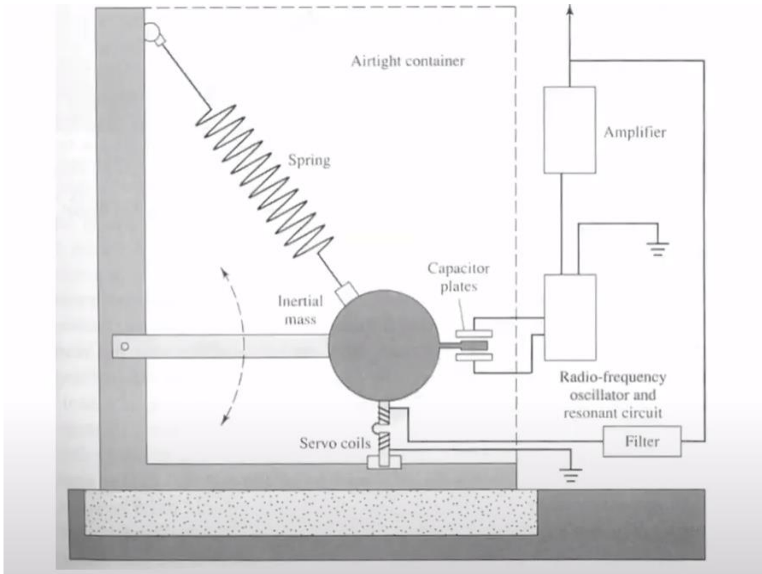

So this is the concept which again explains a modern seismic thing in the electronic system. So where there is a coil which creates basically the gap between that so this is the pendulum which is old or mass it is old by the spring ok. So when there is a vibration this mass will vibrate there is a coil flex between this signal voltage differences will be created. That voltage difference will be amplified then recorded as a volt versus time ok. That is how the modern seismometer works. So this mass and this will be deciding what level of accuracy you should have.

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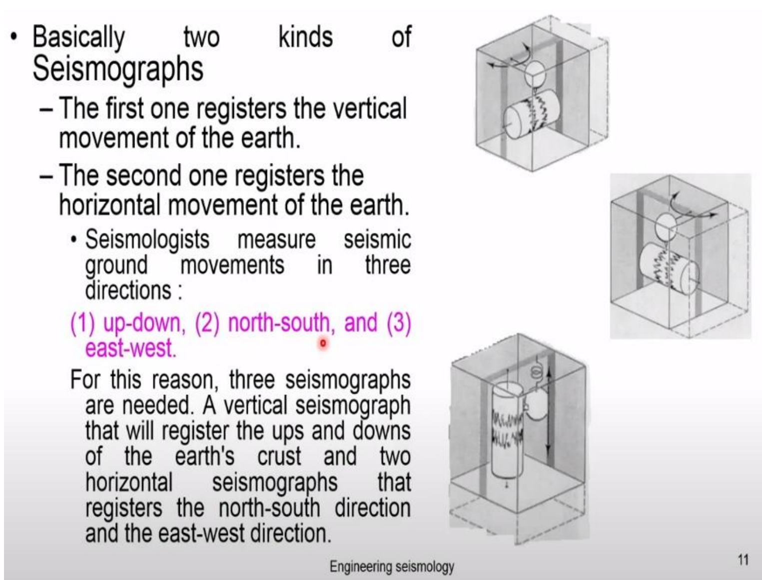

So basically, as we have seen that so the earthquake, need to be recorded on 3 directions there should be a 3 kind of voltage difference with respect to the mass arrangement in the equipment ok. So you can get the 3 components of the recording and which will help you to get a waves.

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So we can see how this waves are get recorded through this video you can see very carefully this video where it gives a how this waves are gets recorded on 3 components. Earthquakes produce different types of seismic waves that can be identified on seismograms. But did you know that each seismograph station produces 3 different seismograms for each earthquake. Why is that? Does is it one tell you how big the earthquake was?

Earths movement is in 3 dimensional and 1 component only reflects on direction of movement. If a station had only one component you would only know about movement 1 direction. Different instruments on the seismograph measure 3 types of motion up, down or vertical motion, north-south motion and east-west motion. Let us take a close up exaggerated look at how a house would be affected by each direction of motion.

When the house is shaken in the east-west direction this shows up on the lower component nothing is recorded on the north-south or vertical components. When the house shifts north-south this shows up on the second line. When the house is shaken in an up, down or vertical motion, only the top seismograms records the motion. During an actual earthquake the house can move in all directions. Why is that? Earthquake produces different types of waves like body waves and surface waves.

And these waves travel out from an earthquake in all directions, Body waves like P and S waves travel a curving path through the earth. As a result they arrive at seismic stations from below. P waves are compressive waves they cause temporary microscopic deformation of the earth in the direction the wave is traveling. Thus energy is primarily recorded on the vertical component of seismogram with less energy recorded horizontally.

S waves move more slowly and more destructive since they advance with a shearing or back and forth motion because S waves arrive later than P wave they are usually seen on a seismogram as a second pulse. S waves cause deformation perpendicular to the direction of wave travel which is primarily horizontal or back and forth motion with less energy recorded on the vertical or up and down component. The slower surface waves such as love and Rayleigh waves move in a more complex undulating pattern and thus show up on all 3 components.

In conclusion, it is the combination of signals that gives seismologist information about the magnitude, distance, and type of earthquake that occurred.

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So we could understand that so the earth produces a different direction of the wave so to easily classify and characterize at least you should be studying the 3 direct components of the waves. So which is like vertical 2 horizontal component as you have seen that the P waves are basically a compressive and primary wave where you can see the dominant vertical component. But when you see the S wave direction this may not be recorded.

So any seismometer so in the initial development they used single sensor seismometer but, later they understand that the single seismometer does not help you need a 3 component seismometer. So that is why we need to have this one.

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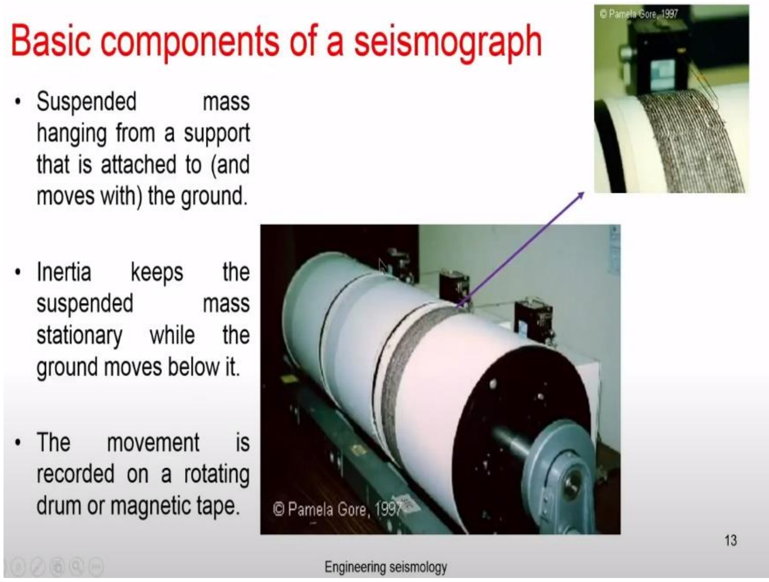

So that means any seismometer should have the some basic component to record a earthquake. So, one is that a suspended mass hanging from a support attached in the ground so such that where it can able to detect a vibration occurs on this 3 direction. So the inertia keeps them suspended mass stationary while the ground moves below it. The movement is recorded as a rotating drum so there is a drum which needs to be attached to the mass and the suspended unit. Wherever the movement occurs it will automatically record.

So those days olden days as you have seeing nowadays all of them are digital and mobile phone. So on those days actually there is no electronic system was there. So the people used to record this in the drum which piled by the magnetic tape or paper smoked paper where they use to record. So to record wave so this is the basically a typical record if you watch some of the scientific English movies basically when the earthquakes they show this kind of figure even today. But now all of them are digitalize we can also discuss about that in our class.

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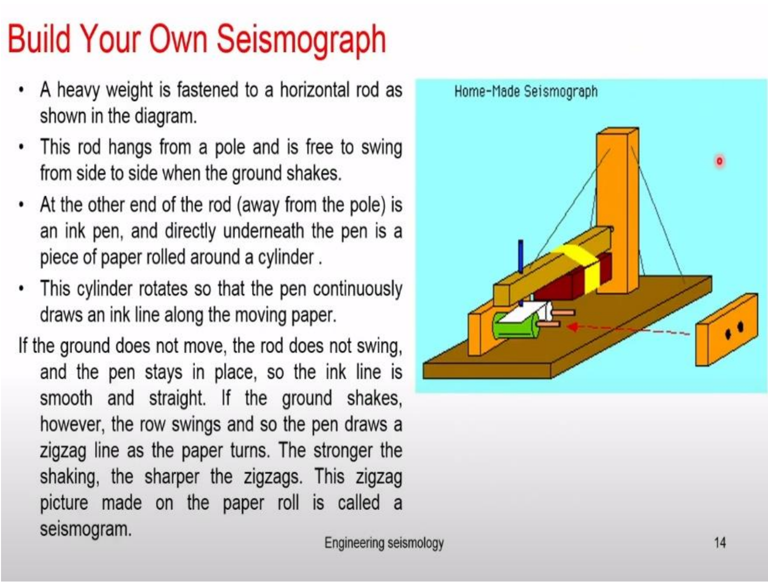

So basically this, reassemble this one so this should have the mass ok which balance inertial forces and the drum to record that vibration. So if you make that simple component of that you can build your own seismometer. So basically you can have your vertical wooden heavy weight like that there is a horizontal frame which can connect with the hinge here basically. Then you can have the mass which where it can be stationary when there is no shaking is occur.

And then you can this can move when shaking that then you can have a small portion with 2 drum with paper. So then if you shake this ok by hit this this will create a vibration. So this is how you can build your own simplest seismic instrument ok. So this even you can see homemade seismogram making in the Youtube. So there are lot of explanation scientist, have given you can also if you are interested to continue your carrier in this direction you can see.

For your information India we do not have indigenously developed seismometer which is capable of measuring the earthquake. Right now all the seismometer, are India has been imported ok. So when imported and use actually we will have lot of issues with the maintaining that and then when whenever there is repair all those things.

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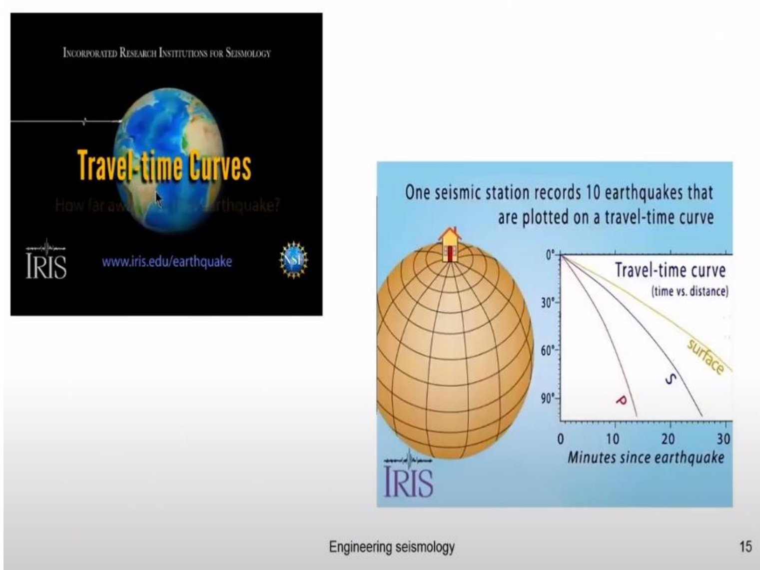

With these seismic signal basically so will help to basically to get your waves arrival time.

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So we will see the video one by one basically so after building the seismoscope basically you need to record a wave you will see typically how these waves are recorded

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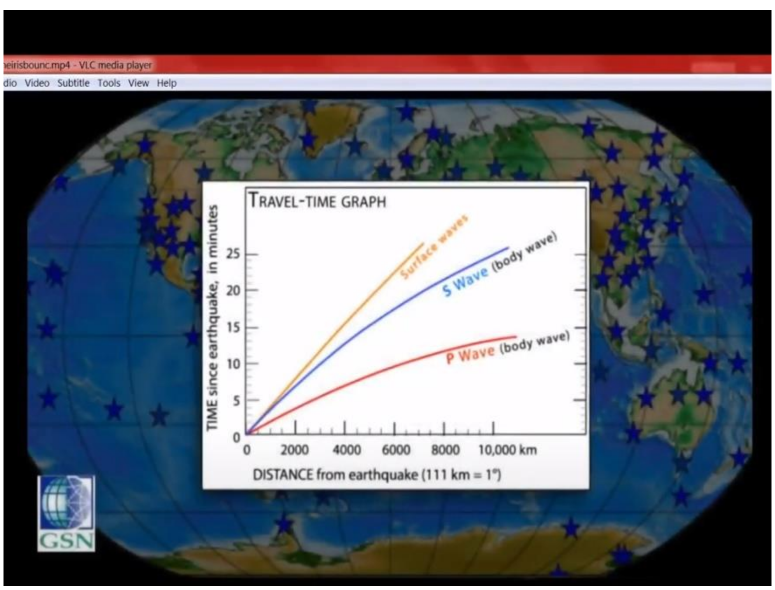

So here you can see how the earthquake arrives and how the travel time has been created by the different seismometer in the world. So you can see like the distance from the earthquake and what type of wave you will get and the time shift which is happening.

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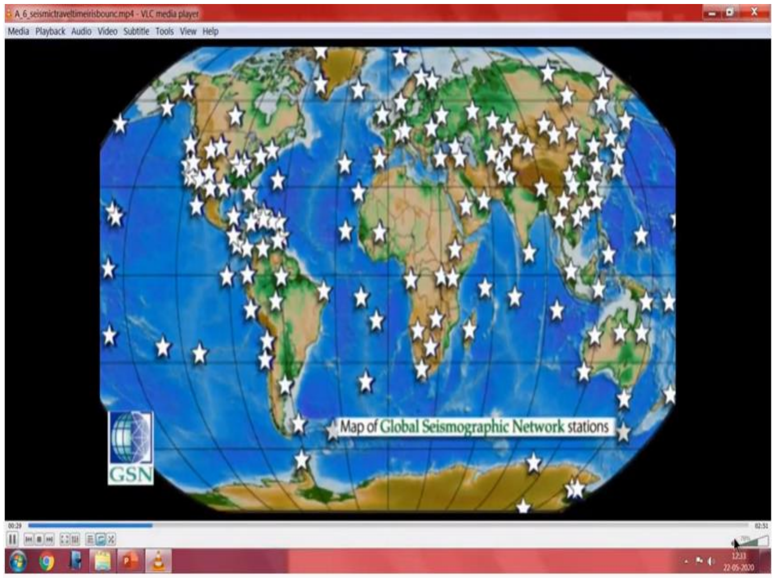

So this will help you basically to figure it out where the earthquake is origin ok so which waves you are recorded ok. So that is what you will get from here.

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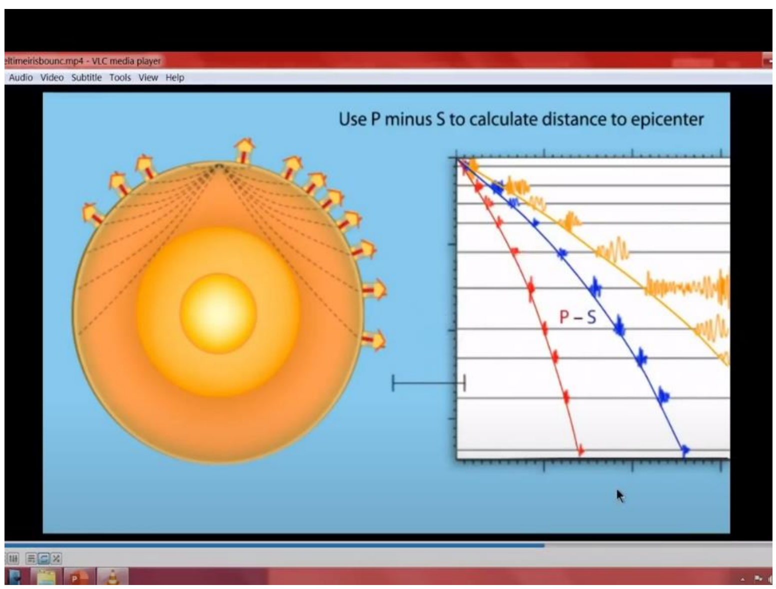

So here you can see basically the earth is given the distance and time in minute. So there are different places like 0, 10 degrees so now the earthquake generated you can see the understanding of the S and P waves where it recorded. You can see that point 1 so the P wave arrived, S wave arrived. You can also see the how the buildings are vibrating for that particular wave. Even you can see the S wave travels P wave travels ok.

So the P wave basically slowly traveling the S wave so you can see that when you have the systematic placement of the seismic instrument you can basically capture that velocity pattern very well. You can see here that is what it help having the many seismometer installed you can see here ok. So similarly the surface wave so you can also see here when the waves are propagating you can also notice a S wave and P wave shadows zone.

If you can very clearly understood so you can also seen the S and P wave shadow zone in this. So this is how you can get velocity at that particular location. You can see here the average velocity of the region which is called as a P and S wave region.

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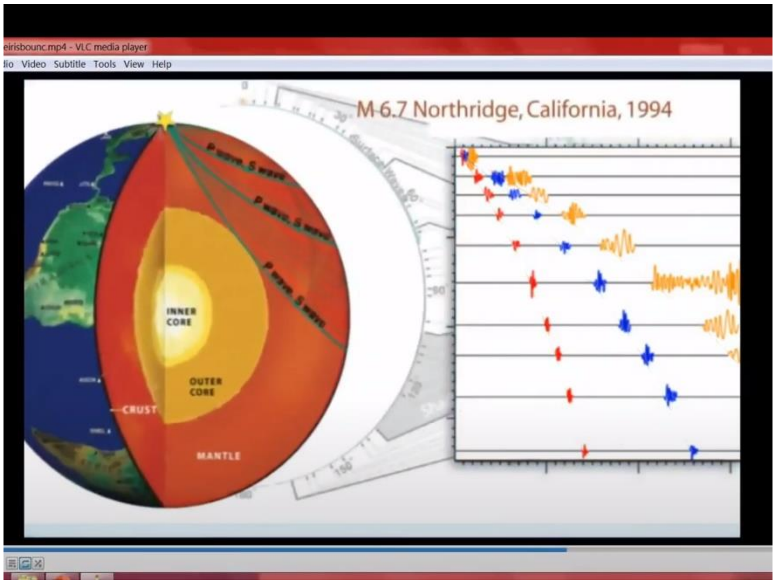

So you can also see this video yourself with audio where you can very clearly understand so these things are useful to get a earthquake ok, so recordings as well as interpreting the earthquake data ok. So as we discussed that amplitude and the wave speed changes with the medium. So having the same equipment throughout the region may not able to detect all, the earthquake. So in that case basically the earthquake which type of wave you want to detect and what type of instrument you need you can get a overall idea.

So this is basically the frequency of the wave different waves which is generally dealt in the universe and the type of source which create. For example earth tide, earth tide means the earth rotation creates a vibration that basically in the range of.

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Seismic sensor-seismometers

Typical frequencies generated by different seismic sources

Frequency in Hz	Types of Source
0.00001-0.0001	Earth tides
0.0001-0.001	Earth free oscillations, earthquakes
0.001-0.01	Surface waves, earthquakes
0.01-0.1	Surface waves, P and S waves, earthquakes with M > 6
0.1-10	P and S waves, earthquakes with M> 2
10-1000	P and S waves, earthquakes, M< 2

Engineering seismology

So this is the frequency range where you can see this one ok this is the earth tide. So then the earth free oscillating earthquake so you can see this one and the surface wave earthquake if you want to see that that means if you want the instrument on this frequency range you can only record a surface basically earthquake. The surface wave, the P wave earthquake magnitude above 6 you can expect this.

So the P and S wave earthquake with magnitude above 2 you can expect here. The P and S wave earthquake magnitude less than 2 you can expect here. So if you want to measure all of them your instrument should be on the combination of frequencies ok that is, was what it has to do. So your selection of the particular frequency instruments, are important to record the size of the earthquake and the type of the wave.

The size of the wave and type of wave so based on this only you can get a data ok. So we will discuss about the more about the seismometer and how it works and then the remaining things in the next lecture also. So with this we will close this lecture thank you.