Introduction to Engineering Seismology
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Lecture No-31
Recapitulation - 3

So vanakkam, we will continue our lecture on engineering seismology, so we are recapping basically what we have taught in the so far in the several classes, so that the people who even see this videos for the next couple of hours can be able to understand the whole subject. So only here I am highlighting only the very important part, so if you have to go to the detail you can go to the each lecture.

So, here in the half an hour we try to cover three, four lectures together and give the highlight of the what we are discussed so far and how it is important for the your next classes that is what we are doing. So last class we discussed about the earthquake mechanism, plate tectonic and then the earthquake also occurring, continental drift theory all those things. So, today class, so when they started understood that the earthquakes are happening due to the so the plate tectonic kind of things.

Then people try to so understand the earthquake source, and then classify the earthquake depends upon the where it occurs and classify the earthquake where it occurs the source mechanism, or the fault kind of things. So, as I told you that the earthquakes releases breaks and releases energy, so generally they breaks are frequently happening where there is a weak zone that weak zone is called as a fracture, fracture or crack.

So in the geological form the as I said that the each plate is a rock, so there is a fracture in the rock, cracks in the rock that particular place is called as a fault or it is a fracture.

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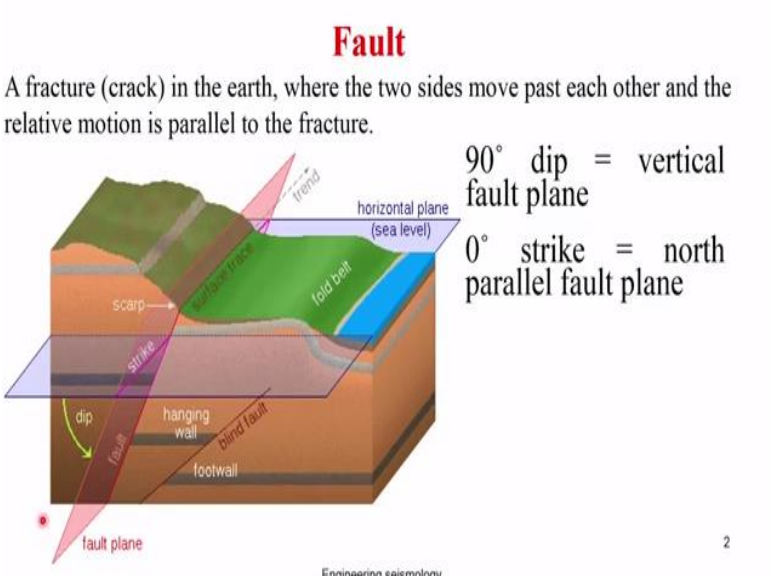

You can see the fracture or crack, where two sides move past each other and relative movement of the parallel to the fracture so this is how you can visualize the source. So basically the fracture is the joints or the weak zone you can see here this is the fracture, so this is the fault so sometime this fault come up to the surface and causes a surface evidence, so that is what you have seen in the San Francisco there is a two fault visible there is a crack physical cracks are visible.

Sometime this may not be appearing in the surface due to the formation of the soil and weathering and sometime it may not even reach those kind of fault was called as a the blind fault, so the fault consists of the both side I said the weak zone it has a two side, so one side is called as a hanging wall, the other side called as a foot wall, so that means the fracture zone two side you will have one side will be the hanging wall another side is the one.

So the plane the line fault line is called as a fault plane, so the fault plane makes angle with the horizontal plane is called as a dip you can see, so this is the dip if there is a fault is vertical perfectly vertical you should have 90 degree dip, the fault plane makes angle with the north direction is called as a strike. So this is the strike, so the fault plane makes angle with the north direction is called as a strike the fault is oriented towards north direction, you will have the 0 degree strike.

So that is what written here, so these are all the way you can define your fault dimensions, so we have been discussing the dip and then the strike. So, when we are simulation of earthquake, we told we might have told I told so you need a dip angle, strike angle for give us a input so that dip and strikes are defined in the very long back on the class called seismic sources.

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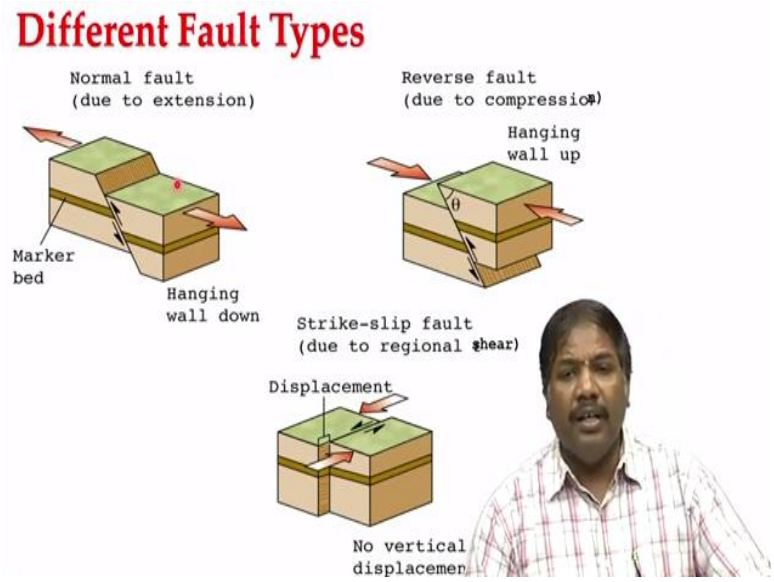

So, depends upon the how the hanging wall and foot wall moves each other what kind of force involved the fault can be categorized a different types, this is called as a type of fault. So this can be broadly into 3 groups and then you can make it to 3 into 3, 9 category how the broadly 3 group. So, let see how we are making one is the normal fault, so normal fault means basically the hanging wall moves down, you can see here.

The hanging wall moves down the force involved is actually tensile force so this kind of fault is called as a normal fault, so now you can see that the divergent boundary belongs to the normal fault. The second is reverse fault, so where the hanging wall moves up the compressive force is involved so this is the convergent kind of fault plane convergent boundaries are comes under the reverse another one is a strike slip fault.

So, where the fault moves each other does not cause any vertical displacement, so these two are causing a vertical displacement so this is only causes a shear so this is a strike slip fault which is occurring in the predominantly on the transformed boundary. So, now you can see that there is a

downward movement and then there is also a shear movement then this became a normal strike slip fault.

Here, the upward moment and as well as the shear this is a reverse strike slip fault, so like this, you will have the combination if it has a rotation not only movement it moves vertically horizontally and causes a unequal rotation because it is a earth phenomena you cannot define very perfectly like this should happen like this, like this, like this, not the earth it can happen it is own way in the nature.

So, that is why sometimes you have vertical displacement, horizontal displacement and also rotation the thrust fault. So that kind of fault is called as a normal strike slip thrust fault, so reverse strike slip thrust fault. So reverse thrust fault or normal thrust fault or strike slip thrust fault, so something like that which involves your displacement rotation, horizontal and vertical displacement.

So this is how the 3 major category of the fault can be defined and 3 into 3, 9 category you can produce out of this depends upon the location this can expected to occur at a particular place. So, this is about the different type of fault.

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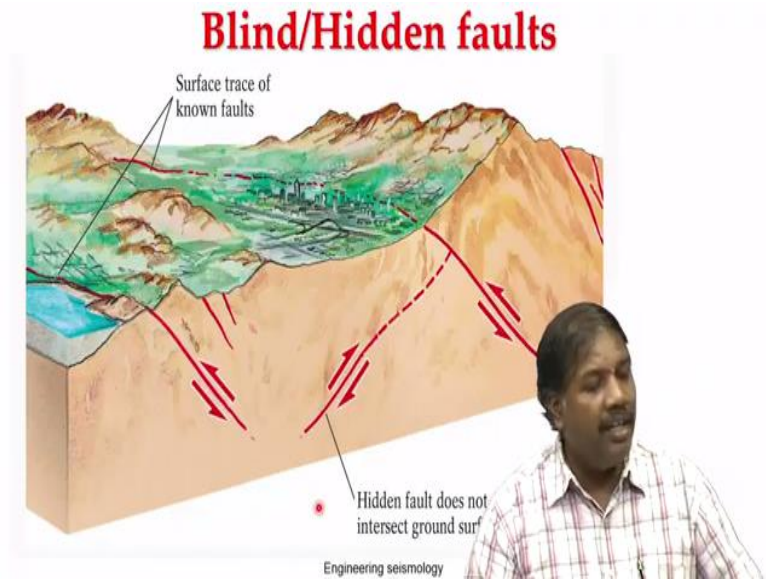

So, we also discussed about the blind fault, the blind fault means the fault it never approaches to the ground, but still it causes the earthquake it has a fault plane and it is also contribute to the seismic activity. For example, this is the earthquake you can see the fault plane. So even it ruptures it goes because there is another fault. So this rupture will hit and stop here only it does not proceed further or does not go to the ground.

So this kind of fault is called as a hidden fault or a blind fault. So these things are only comes to notice soon after the big earthquake in that area after recording the data one can find out what kind of source mechanism, what depth, what dimension fracture then they can map this kind of fault. So, now you may be understand that why I do recapping. So if you see that many things what we studied the later stage of the class, these are all the class we discussed to previously but after understanding the simulation and then the earthquake measurement all those things.

Now, we visualize this definitions and discussion of these things very well. So that is what I am doing the recapping actually because it is the knowledge of the subject. So you will understand more and more if you read and then repeat the same thing again. So that is why the blind fault and that can be understand if you have the earthquake record.

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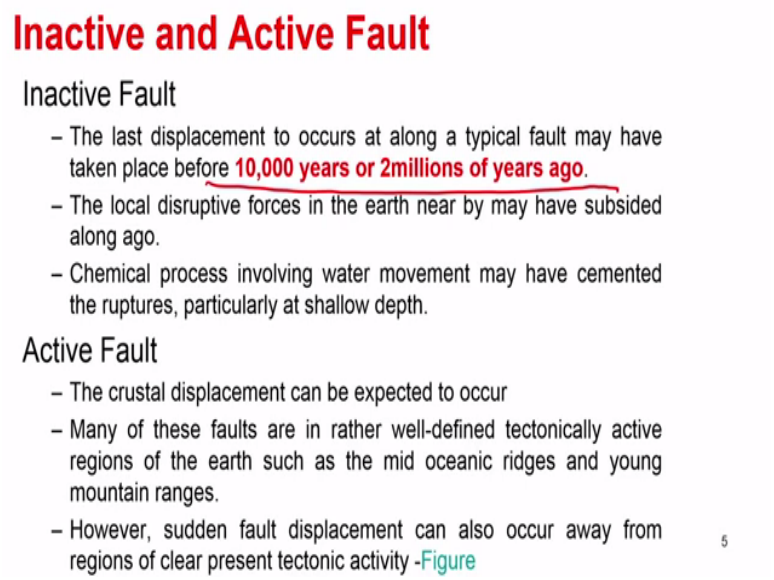

So the fault can be categorized, so whatever we discussed earlier hidden fault, blind fault, surface fault kind of things which is based on the orientation and location. Another is the active and the

inactive fault, this is the two major category, which is very responsible are very important, so for the hazard analysis and prediction of the earthquake hazard, future earthquake hazard. So if you have to predict future earthquake hazard at a particular location, you should need to know what are the faults are active, what are the false are inactive.

Why? Because as I told that the fault is a fracture and weak zone this fracture weak zone might have been caused by the several million years, as we have seen that this fractures are keep changing it position location everything with respect to the geological age. So the activity is a very important to assess further future hazard at particular location. So the inactive fault the geologists or seismologist given some kind of guideline to define inactive fault.

So the last displacement to occur at along a typical fault may have taken place before 10,000 years or before 2 million years. So those kind of location or fault can be defined as an inactive fault. So this, what you can do you can take a samples from the particular place carbon dated different material available in the carbon date all the material in the particular weak zone shows that it is very old that means there is no activity has been happened in the recent.

So those kind of plane or fault, you can define as a inactive fault, you can ignore those things for the seismic hazard analysis, and the next is the local disruptive forces on the earth near may have subsided long ago. So, there is no movement, there is no movement of the plate in that area. There is no land mass movement. So, how do you know the plate moment? I hope I have told you this.

So there is a global positioning system very high precise global positioning system which has been anchored in the crystal rock. Crystal rock means the crust projected to the ground that ground they anchor it. So this all the places and all the continent it is available. So in particularly, if you look at India where the crust rock formation you can find Bangalore the crust rock you can see is a Lalbagh.

So whenever you go to next time, Lalbagh you can see the Lalbagh rock know that rock is actually the crust rock. So that moment of that rock actually implies that plate movement below

the several kilometre because that rocks comes and projected in that plane not only there within IISc also we have the crust rock, if you had a chance to go to IISc. So there is a main guest house after the main guest house there is a swimming pool in between there is the outcrop that outcrop basically is a crust.

So the crust formation come to the surface due to the weathering it becoming a hard granitic rock that kind of rock people will identify and position a high precision global positioning system. Then if you monitor that system with reference to some point then you can know that it is moving or not. If there is no such kind of movement is taking place in that plate that is called as a basically subside long ago, there is no moment that is basically inactive plate or inactive fault or inactive source those kind of weak zones are the inactive source.

And apart from that you can also taking water the chemical process involving water moment may have cemented rupture, particularly shallow. So, sometime what happened, due to this weathering and all even there is a fracture. So this slow down are subside the moment of the fault will the water act with the materials in the rock or soil it make become a chemically composite due to the weathering process.

And this chemical may be filled there this kind of weak zones and which become a solidified that kind of things also is a evidence for the inactiveness in the particular area. So, this is how you can take inactive fault. So then how do you define active fault? So active fault, you can define the crust displacement can expected to occur. So the crusted displacement means there is a moment in the GPS high precision GPS position showing that the crust is moving.

So that kind of place you can take it as a active fault. Second many of these faults are rather well defined tectonically active regions of the earth as a mid oceanic ridges and young mountain ridge. So you can see that we are telling that the Himalaya is growing every year so many centimeters, 2 centimeter, 4 centimeter whatever the number. So which indicates that how it grows there is a moment occurring in the plates that indicates that this regions are active under the source in that region like fault in the regions are active fault.

Similarly the oceanic ridge where the volcanoes are occurring which indicates that there is a movements are occurring on the plate. So otherwise the sudden fault displacement can also occur away from the region clearly present a tectonic activity. So even if you place a seismic instrument for a some period of time, there is a minor earthquakes occurring in those regions will indicate that there is a seismic activity or you can take a carbon dating of the material.

And also define period or moment occurs in that region using the carbon dating that kind of things also will be useful.

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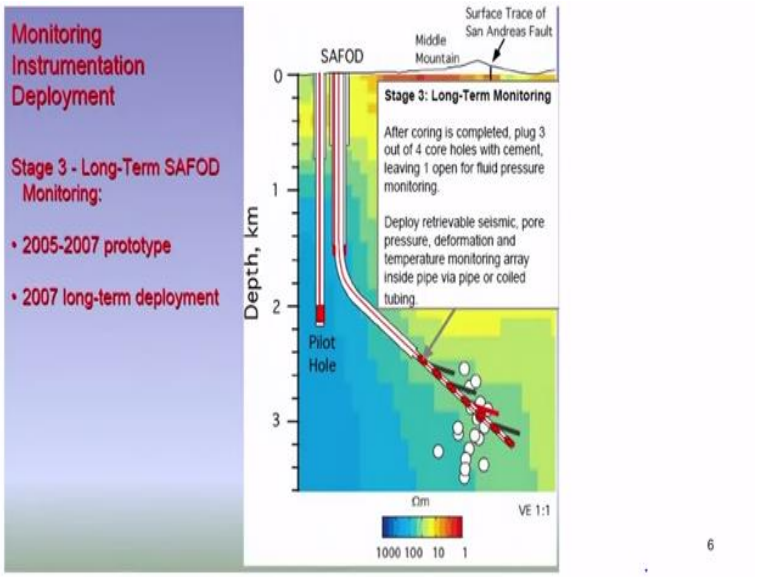

So people try to understand each activity and fault movement by doing a very detailed studies those kind of studies has called as a monitoring instrumentation deployment of the seismic source. So, this is actually a San Francisco where San Andrews fall. So people drilled bore well up to 2-3 kilometer and instrumented that and tried to monitor how the stresses in the sensors are recorded how the displacements are recording.

So that you can able to predict the earthquake accurately, so this kind of research I mean, but this needs lot of enormous funding, I do not know the country like us we are afford to do this kind of drilling and all but still this kind of project also take kind of India recently Koyna they try to understand the seismic source by drilling a bore well and say putting the sensor collecting the core is in the Koyna earthquake region.

So this is the similar kind of study or they are also done in the San Francisco the source like that drilling and then occurring as of the different earthquake and then the sensors are monitoring and then try to see that how accurately we can forecast a earthquake based on this data, but as on now it is not very success even though they spend several crores of rupees like 500 crore, 1000 crore, or 5000 crores I do not know exactly what amount they have spent.

But, those amount after pumping so much amount also there is nothing like they could be able to say that because we measured this many data the earthquake going to come this time nothing like that, there is no scientific development happen on earthquake prediction. So only they have studied what happens? This is a typical study. So where you can see the drill hole and then fixed lot of sensor and try to monitor the stress strain induced in this region due to and earthquakes and a recordings all those things are taking into places.

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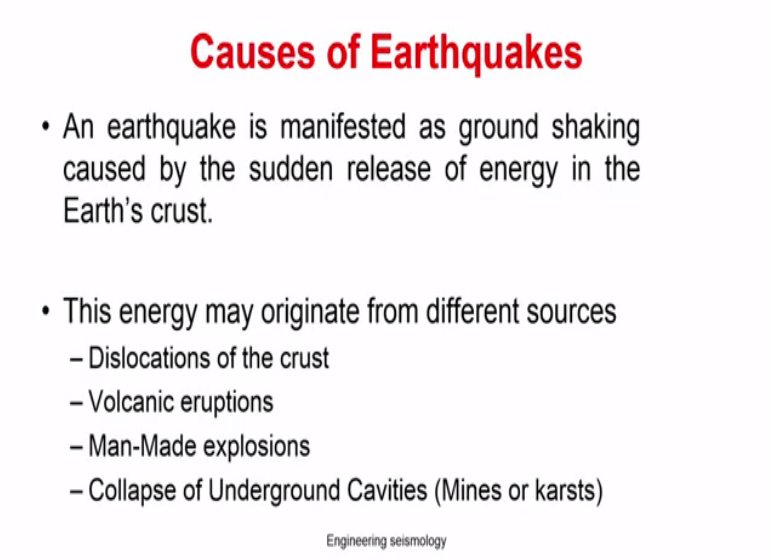

So this is what about the seismic source and the classification and activity, like inactive and activity, so the other one is so as we even though call it as an earthquake, earthquake, earthquake. So as you are seeing that the earthquake occurring at different places will have different form of seismic wave and different strength of energy release, different way of the wave propagation is happening.

So the understanding of earthquake the vibration, so is a very important. So generally, the earthquake is called as a vibration created in the Earth. So depends upon the vibration the source the earthquake can be defined as a different type depends upon where it occurs it can be defined in different, depends upon the depth it occurs it can be classified. So the types of earthquake causes of earthquake, so you can see.

So the energy may be originated to cause a vibration from different sources. So based on the source we can say that the dislocation of the crust which is a tectonic, volcanic eruption due to the volcanic activity, man-made explosions. So where you can do some bombing and blasting and then collapse of underground cavity mines and karsts, so these are all the way the energy originates from the different part of the earth.

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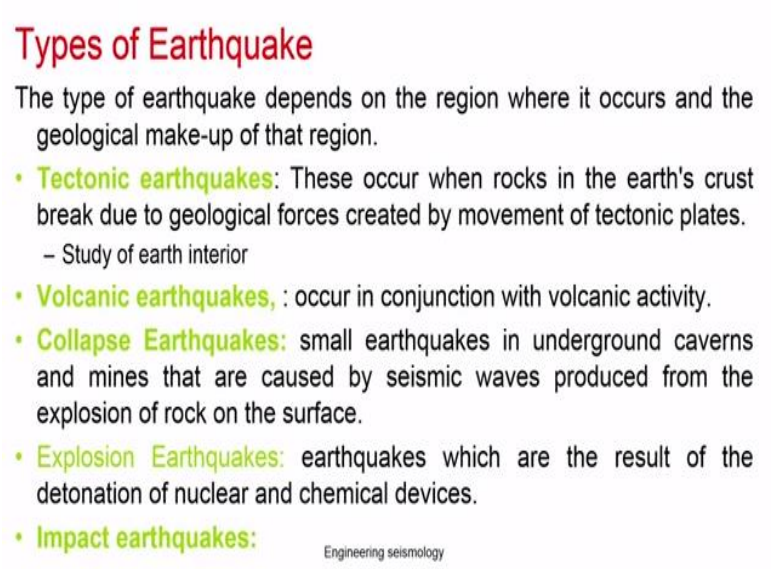

The source of energy will give you the type of earthquake. So the tectonic earthquake basically these all are the earthquake which occurs due to the earth crust breakup, movement of the earth crust and break up and geological forces created by the movement and tectonic these are called as a tectonic earthquake. More than 90%, 95% of the vibration happening in the earth is due to the tectonic activity.

So the volcanic occurs conjunction with the volcanic activity at a particular place. So this vibrations also recorded this is a volcanic earthquake, collapsible earthquake occurs due to the

explosion of mines and then caverns where this mines and caverns, so try to equalize the force. So, these cause some kind of vibration that is a collapse earthquake this collapse earthquake is generally expected above the mining area.

For example, people who aware South India, there is a KGF, so after a movie of KGF many people may be knowing what is the KGF? So the KGF is actually Kolar Gold Field. So in that region what they found your gold metal in the earth. So then they did a mining to extract a gold. So, when they did mining basically they cut gold and the non gold material together and bring it to the surface and then they do some kind of chemical processing try to separate a gold.

So gold has been taken the mining dump has been dumped in the near to the gold mine area. So since they removed some material from the earth there is a big vacuum are a cavity created due to this mining activity, this is actually closed mines. So there are two type of mine they do one is the open mine, one is a closed mine. Open mine means they excavate from the surface continuously up to the level they have to excavate.

So those who seen the coal? So Neyveli power plant, so Neyveli power plant and other some of the coal mines are the open mine. People starting excavation from the surface and they remove the material unwanted material dump it on one place and then the wherever they found useful material like a iron ore, coal ore, so iron ore is another open mine you can see in the Bellary region. So then that material they will extract those kind of mines are called as a open mine.

So open mine generally destroy the forest and also change the landscape and it also causes a landslide and other things and all. So in some way extend it may also cause a tectonic imbalance in the region if the open minds are done for the very deep level of overburden has been removed. So, for example, if they remove 500 meter overburden soil at particular place your nearby there is a again against of 500 meter that there is a imbalance between the overburden which causes a tectonical imbalance.

So those are another one type of mine the other one is a closed mine, closed mine means they make a hole then they send a man and the tunneling like a rat was they make a tunnel in the

tunnel they go and excavate wherever they find here useful material. That kind of mining is a closed mine the KGF mine is a closed mine where they have the tunnel entry point the tunnel goes and goes to the several place.

So those people who have seen the, what is the movie called actually this is a very classical movie many of the kids will like. So where they say that if you can go inside earth and there is a one more world below the earth's surface. I am not getting that this one a movie exactly. So where they show that mines, closed mines how it is having a big space below the ground. So ground it may looks plane, you may not see anything.

But once you enter through the mine tunnel, you can see a big area, where people will be working or it will be empty and connected by a track, so kind of things. So the interior of the earth that movie I think interior of the earth. So that movie you can see that they saw a the closed mine inside how it is on the, so this KGF is actually closed mine where there is a big cavity below the ground, but ground people are still living by construction of the house and building a plot lot of things but there is a big cavity.

So we because of the removal of the material the imbalance forces causes that causes earthquake that is called as a collapsible earthquake. So which is happens due to the small earthquakes in the underground cavern, caverns and mines that caused by a seismic wave produced explosion of the rocks on the surface and other activities kind of thing. So these collapsible earthquakes are very famous in KGF people who are living in the KGF area, so you can ask them.

So they feel this kind of vibration very frequently it will not cause any damage to house but still the house will vibrate vessels will fall people will feel that vibration. So another one is the explosion earthquake explosion is the man made earthquake kind of things like people will do terrorist activity or do explosion for the mining or some kind of these kind of the earthquakes are called as a explosion earthquake.

Another is the impact Earthquake impact earthquake is basically this is a some kind of driving something like people who are studied civil engineering there is they know that there is a pile

driving cast in situ pile. So driving the way, they impact that pile in the ground by hammering that create is a impact vibration that kind of earthquakes called as a impact earthquake but you can know that all these four type of earthquakes only 5% in the world only tectonic earthquakes are the 95% of the world.

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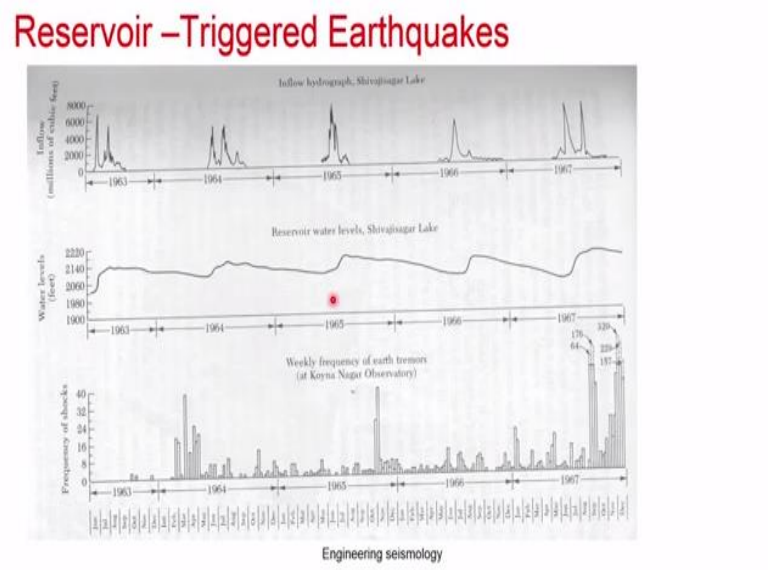

So apart from this there is also a reservoir triggered earthquake, so this happens in the reservoir area where due to the construction of the dam huge amount of the water has been stored at a particular place which causes again the imbalance force at below that location. If there is a chance there is a weak zone fracture fault is exist in those area because of filling up the reservoir and emptying of the reservoir, you will create a imbalance force that causes your seismic activity in that region that is called as a reservoir triggered earthquake.

So the Koyna actually where there is a weak zone the dam has been constructed close to that whenever they fill a dam there is a earthquakes or reporting this is actually the number of earthquake and then due to the filling level of the reservoir, you can see the graph which is very clearly explains the filling they consequently causes a number of seismic events you can see. So there was a one bigger event.

So which is sometimes happens with the large imbalance of the force which is rigor reservoir triggered that is called as a Koyna earthquake many people die due to that earthquake, in

southern India, after that only this reservoir triggered earthquake concept has been developed people try to understand before building the dam or existing dam how the reservoir triggering is happening at particular location has the dam is safe for it is own earthquake are people around is safe or not, they try to understand so these are reservoir.

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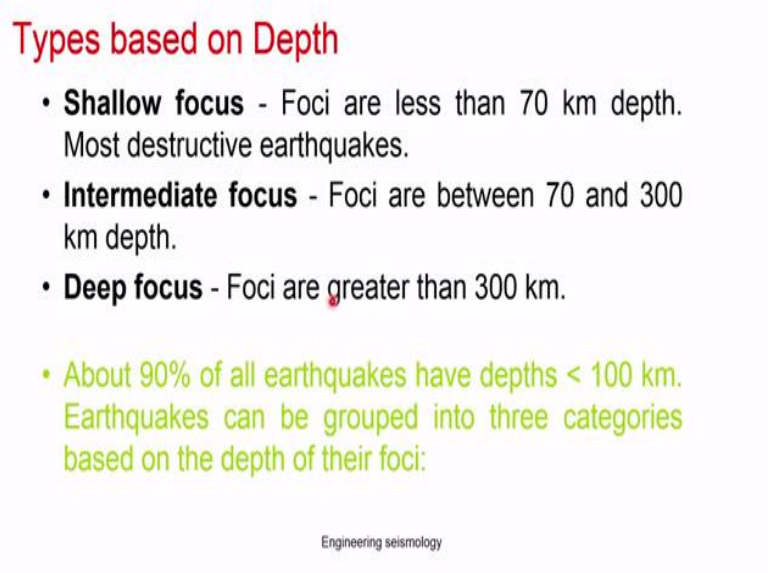

Then the type of earthquake based on the depth, so the depends upon the depth where it occurs it can be divided as a three category shallow focus, intermediate focus and deep focus. Shallow is earthquake occurring less than 70 kilometers deep is the earthquake occurring more than 300 kilometer. So in between 70 to 300 is intermediate focus the about 90% of the earthquake in the world as actually occurring less than 100 kilometer.

So the shallow focus energy will reach very surface very fast and compared to deep focus earthquake.

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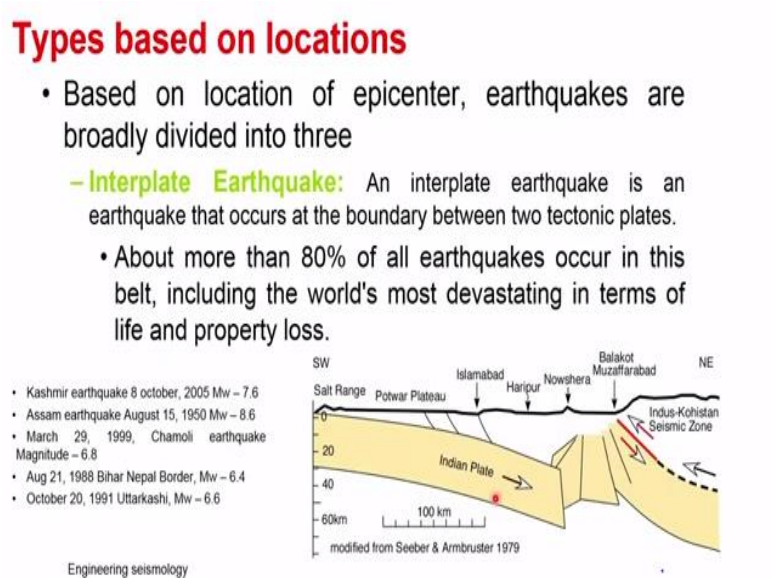

So the another earthquake is depends upon the where the earthquakes occurring so interplate, intraplate, mid plate. So, what is the interplate and intraplate? If you take a the Indian plate you hitting with the Euro-Asian plate, so there is a joints in between this plate boundary. So wherever the earthquake is occurring in between joint of the plate that is called as a interplate earthquake. The interplate earthquake basically due to the plate joints so the moment and then subduction whatever is taking place divergent, whatever taking place that is a responsible for the interplate.

So there are some earthquakes which you can quote for the interplate earthquake, Kashmir earthquake and Assam earthquake, Somali earthquake, Bihar-Nepal earthquake, Uttara Kashi earthquake example for the this kind of interplate earthquake.

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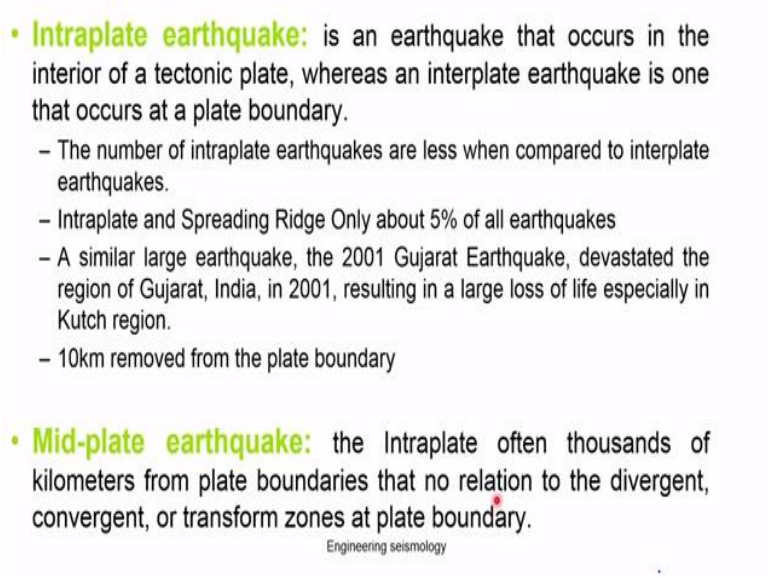

So the earthquakes occurring, so interior of the tectonic plate, away from the interplate region that kind of earthquakes are called as a intraplate earthquake this generally occurs in the away from the plate boundary. So this earthquakes also very violent and vibrant but the magnitude of interplate will be you can expect up to starting from 9.7, 10, 8, those kind of higher magnitude the intraplate earthquakes are moderate in size.

A mega earthquake up to 7, 8 the highest magnitude of reported close to 7.5 or 6 something like that. So up to 8 magnitude you can expect but this also causes a huge amount of the damage. So many intraplate earthquake can be coated for India because the recent about 40, 50 decades we are 4, 5 decades not 45, 40, 50 years or 4, 5 decade. So we actually had several intreplate earthquakes like the Bhuj earthquake, so then the Jabalpur earthquake, Kilari earthquake, Koyna earthquake these are all happened in the intraplate region of the Indian plate.

So these earthquake actually allotted the international community that even intraplate can release a earthquake and kill several people. So then the mid-plate is the earthquake which occurring middle of the plate which is like 1000 kilometer away from the plate boundaries. So, they intraplate earthquake is actually after few kilometer away from the plate boundary, this is 1000 kilometer away from this is called as a mid plate earthquakes.

So we have to depend upon where the earthquakes occurring you can see that the change in the size, change in the wave propagation, change in the energy content. So, after 10 kilometer of the plate boundary, whatever earthquakes are occurring is called a intraplate earthquake. So after 1000 kilometer of the plate boundary, whatever earthquake is called as a mid plate earthquake. So within 10 kilometer, whatever earthquakes are occurring in the plate boundaries is called as a interplate earthquake. So this is what you can see the classification of the earthquake.

So this will help you basically to identify what type of region you live what type of earthquake you can expect in that region like tectonic earthquake, shallow focus earthquake, interplate or intraplate earthquake. As you are seeing that the wave propagation of this earthquakes are completely different. So understanding of this will help you to predict hazard due to this kind of earthquakes.

So with this we finish a recap class 3 where we discussed a fault type, source type and the earthquake type and try to understand classify the earthquake depends upon the depth and location and then the size kind of things. So that is why we are done. So, thank you very much for watching this video. So we will meet you in the next class. Thank you.