Hello everybody. Welcome back. Yesterday we discussed about different type of seismic waves. (Refer Slide Time: 0:23)

And mainly the body wave and the surface wave. And we also discussed about their motion and they typical characteristics likewise the P waves can pass through, they are the compression waves, they can pass through all medium. Whereas the S wave, they have the capability of shearing. So they are the transverse waves. They can only passed through solid.

Where is the love wave again, they are the surface wave and rayleigh wave is also surface wave having the motion that is related to love wave. We are having it moves land side-by-side whereas the rayleigh wave as having elliptical. So in short we experience all type of motion at the time of an earthquake.
So we started talking about the earthquake. We will move faster to that. And the this part we already discussed yesterday.

So and we in short we talked about little bit about the earthquake also. So earthquake is a process where or it is a phenomenon where sudden energy which has been stored within the crust is been released along weak zones.
And the surface manifestation of such displacement or dislocation is very well seen in form of the active faults. We will talk later about this, what are the different type of active faults and all that, how we can identify those and why it is so important for the society. Because this helps in reducing the seismic hazard in any seismically active region.

So identification of fault lines and knowing that where earthquake will occur and when it will occur, it is extremely important in developing countries. And in particularly in India we have so many seismic sources available. Like in Andaman , we have in Himalayas and in Kutch region. So we need to have this detail with us.
So yesterday we were talking about this that if you push your two palms against each other and try to slip so there will be some sort of a pressure which will be developed on your palms and then when you slip this, you will find some jerks which are coming on your hands. So that jerk is your vibration which is very typical to the when the energy is sudden energy stored is released.

So energy is getting stored here and then when there is a slip, you will find that the some vibrations are been passed on your hand side. So that is one way you can understand that how earthquake occurs. So for example, 2 plates or the blocks along a weak zone here are colliding with each other or they are there is an energy which is getting stored here because you are applying force from either side and then sudden release of that due to the slippage along this plane, you will find that there is an vibrations which are been triggered. So that process is an earthquake.
And now as I told that there is a, it is extremely important to identify the fault lines, this is an map of from US. Very famous fault system has been shown here. This is what we call as the San Andreas fault system. So we have multiple fault lines on the surface which have been identified by US geological survey and other research groups in US.

Now what the numbers if you look at here, what it says is very, these are the numbers which says about the talk about the slip per year along this particular fault segment. So you have different slip like 3 to 4 mm and 17 mm, 9 mm, 6 mm, 24 mm. Now we need to have for India we are trying to come up with such maps in Himalaya as well as in Kutch region and try to know the slip rates.

That is what we call the slip rate along the particular fault. So higher the slip rate, the chances of having earthquake, more earthquake, more frequent earthquake increases here. So the interval between the two earthquakes will be shorter here whereas the interval between the 2 earthquakes in this region where the slip rate is low will be less okay. So the interval will be sorry larger here. And here you will have the interval will be much shorter.

So we need to have such information to reduce the seismic hazard in the region like Himalayas and all and in Kutch.
Now this is another example which has been given that how these different fault lines slips and why you are having like different slip along the different fault lines. So for example, this has been given in like what they did is that if you can take the plane card set and then and try to put the pressure on either side, so what happens that the plane cards, each plane card you consider that they are the contact is say fault line.

So they will slip at different rate. They will not slip at the same rate. So that is what is happening in nature also. So you are having, the example is from here where the Pacific plate sliding or subducting below the North American plate and then slip along the different fault lines is different, it is not the same. So that is best explained if you can do this experiment on your own and try to understand that how the each card or the contact between the each card slips.

That is your fault line. Here the movement is right lateral where the right side is coming towards us and the left is moving away from us. So this has been explaining how these slips. So it will not slip everyday but it will accommodate the strain along those weak zones.

So strain is getting accommodated or accumulated along these weak zones and the time will come, after it crosses the threshold limit, it will break or it will slip. And that will result into the earthquake.
So now deformation of rock under tectonic stresses. So this an simple stressed-strain diagram which explains that if you keep on increasing the stress, eventually at one point of time, it will break. So initially the material, all material within the earth is an elastic has an elastic property.

And then initially they deformed up to an elastic limit and then there will be a ductile deformation which will go on and finally it will break or the fracture. Now this fracturing or the point where it breaks is your earthquake. Now this is an very well understood.

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So you keep on increasing the stress. A rock deforms elastically. Then plastically before ultimate failing or breaking in an earthquake. So this point or the breaking is your earthquake. So a
complete brittle rock fails as at its elastic limit. So each material has an different elastic limit. But what in short we want to understand here is that all material will eventually break at one point of time.

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So for example, if you take a rock block then you are applying pressure here. So it will initially it will deform. And then, some very blurred lines are coming up, these are the weak zones actually. So this is what happens within the earth also, earth’s crust. So these are the weak zones which are coming up and finally if you keep on applying whatever, it will break. So there is a displacement, if you can see here, this is displaced.

So this is seen on the surface or it is preserved on the surface whenever there is an displacement which occurs along the and this what we call either the fracture or we can say as an conjugate joins. And in a broader sense, we can also talk and say that this is a kind of a fault which has occurred.
So earthquake forecasting and prediction particularly. The forecasting identifies both earthquake prone areas and man-made structures that are especially vulnerable to the damage from shaking because what happens at the time of earthquake is as we have discussed about that mostly you will observe different type of waves which are generated and those waves will result into strong seismic shaking.

And we need to understand that what will be the magnitude of an earthquake, how far it will be triggered, that is the source, how far is the source? Where we are living? So the man-made structures which are vulnerable to such shakings. So whether the earthquake shaking will be strong in our area or not, that we have to understand.

Then earthquake prediction refers to attempt to estimate precisely when the next earthquake on a particular fault, so these are the weak zones which we are calling faults, is likely to occur. Now I have a question here because I keep, this is not we cannot do very precise prediction of an earthquake. It is difficult.

But we can have a range where we can say that fine the earthquake may occur within 25 years or 50 years or 100 years. But it is difficult to say the precisely. But of course we can predict that when the next large earthquake is expected on a particular fault. So that at least we can talk about.
So this is an attempt we can do and there is a field or the branch of Earth sciences which deals with such type of studies are termed as it is known as paleoseismology. So if time permits, I will talk I will give one lecture on paleoseismology and the type of work we are doing in Himalaya and how we have identified the signatures of the old earthquakes or the ancient earthquakes which are preserved on the surface in Himalayan region and in Kutch region.

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So further, the earthquake forecasting is based largely on elastic rebound theory and plate tectonics. So the elastic rebound theory here suggest that if the fault surface do not slip easily passed one another, energy will be stored in elastically deformed rock, just as in a steel spring that is compressed.

But it if it is not it does not slip okay, the energy will be stored in an elastically deformed rocks. Just as in a steel spring, so you try to compress and then finally when it is been released, it will result into the vibrations. So currently, seismologists use plate tectonics motions. So as I was talking in the initial that we have now the GPS, global positioning systems, where we can measure the movement of the plates at a millimetre accuracy.

So this also again we are doing in India. With the help of Ministry of Earth science, we are putting lot many GPS stations in Himalaya to know and to measure the crustal deformation
which is going on in that area. So the measurements to monitor the accumulation of strain in rocks near the active faults.

So we identify for example on surface the fault lines and then we try to put the GPS station on either side of this and try to understand that what is the deformation which is going on between these 2 points. So that what we are doing in Himalaya and this is the…

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So anyway like this is one very important part. Now if you look at the elastic rebound theory what we see here. So we see that the 1st figure which shows the original that we are having the fencing and then we are having a fault line over here which crosses this one, so because of the ongoing tectonic movement, the deformation starts of course it is elastically deformed here. It is not displaced but it is elastically deformed here.

So if you are having GPS stations on the either side, one can easily make out that how much displacement has occurred here. So initial points we are having here and then we are having here but you will see that there are some displacements. So GPS will keep on taking 24 x 7 the coordinates of that particular point. And finally the land ruptures and releases the energy.

So this is the rupture process and the release of energy is your earthquake here. So when the rock rebounds to the original and deformed shape. So this was an elastically deformed here along with the displacement but then finally it goes back. So this portion is finally going back to its original.
And again the process is repeated. Again along this fault line or the week zone the strain will start developing.

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So the same for example the San Andreas Fault system is again shown here. So initially it deforms elastically and then finally it is released here.

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So this again a very famous photograph of the displacement of the fence where the fence got offseted along the fault lines. So this is the fault line over here and this happened in during an earthquake of 1906 San Francisco where the displacement was measured around 2.6 m.
Again this is an example of San Andreas Fault system where what they did was across the fault line here, they put several GPS stations. So you can see these GPS stations here and then so what they wanted to measure is that they wanted to see how this displacement is we can measure and how much will be the displacement close to the fault and how much will be the displacement away from the fault.

So they have measured this and this photograph is the showing the alignment of a rare looking north-west number of so this basically it shows the locations of the GPS and you can understand the scale based on the scale that what is the distance here. So what they did? This is the fault and then we have the different points here. And then maximum offset which they found was around 900 mm where the end point offset they found was around 885 mm.

The best fit line suggests that the average displacement was around 782 mm. So this, one can measure if you are having a very precise location of the fault and then you put more GPS stations. So you can have the close array of GPS station which can measure the amount of displacement or total amount of movement which is taking place and the amount of strain which is developed or stored along this fault plane and you can have the prediction that when will be the next earthquake here.
Now this is a very important part which talks about the stress building rocks and released periodically. Now this is a very simple and very straightforward diagram which talks about the stress here on the y-axis and the time on the x-axis. And it says that over the time that is first if you take the earthquakes are the result of stress that build up over the time. And this stress gradually builds as tectonic forces.

So this is the period or the time where the stress is building up. And the time will come, it will break. So this sudden braking or release of the energy is your earthquakes. So this is the threshold limit of this region which will after which they will be in sudden slip of the rock blocks. Now the point is that, the question remains whether this is so periodic as we have we are looking here that all the earthquakes are systematic earthquakes or there are some changes because this most of the time what now we have found is that this is not very systematic.

Otherwise you can easily predict the earthquake when will be the next one in terms of the time you have. So this is the time of quiescence where no activity will be seen along this one and the strain will keep on developing and finally it will drop out. That is the event.

So these are the events which we see are the earthquakes here. But now most of the places what we have found is that this is not exactly the same but it will sudden some places it will release, the earthquakes are been, smaller magnitude earthquakes have been seen which have been triggered between the two major one. So this is one example which has been given. Now if
suppose there is an the slip which is or the which is continuously seen what we call creeping, then you will not have the major earthquake along that fault.

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So one of the example of the creep which has been observed along the Hayward fault which is an part of the San Andreas fault system, what you see here is they again people live on fault and they have houses on fault.

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So this is a fault line which crosses from here. So people are staying on fault and they are having houses on fault but they understand and they know that this fault is creeping and they also know
that when is the expected next earthquake in this region. But now after the precise mapping of
the Hayward fault, no other construction is allowed on this fault line.

But people understand because their utilities like pipeline, water pipeline or drainage pipeline or
gas pipeline, they are getting the deformed if they are crossing this fault line and periodically
they will have to get it repaired and they keep on monitoring that whenever it is ruptured. So
they need to fix up those things because their pipelines or their houses are sitting right on the
fault.

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So this creeps. Now you can see here, the fault passes through this part over here and you can see
the offset of the pedestrian boundary here. So this is an offset here, the fault passes. So the
movement is somewhat like this.
In another one. Let me remove this one. So here, the fault is running across this part here. It goes along this one over here. And these are all the cracks which are very much common which are formed when there is a right lateral movement. So movement is like this and if you see the close up of this one, you will realise that how that it creeps every time.

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So this is an again a creep which is very well observed. So every time what they do is this is over several years this slip has occurred. So you can see the offset here. So this is here. So this is the amount offset we are having. So this is the result of a creep. So every time they will like repair this because they know that this cannot be stopped.

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So this is an example of creep again on the railway track. So this is an example you can see on the railway track. And this offset is over here. So if you take this, it comes here and then it goes like this. Now this, they have abandoned this railway tracks. The fault runs from here. So they have abandoned and these are the 2 new railway tracks which were been constructed.

So over the time, they keep on replacing this because to avoid the accidents in the area. So they keep on since they are having the understanding of this, so it is they try to minimise the risk in this area. So that is what I was talking. It is extremely important to know where the fault passes through and what is the type of motion or the pattern of deformation along that particular fault.

Either it is laterally deforming or it is moving up and down. So you need to know that part. And how frequently it moves, that is also important. So this is an best example of the creeping which is taking place along the San Andreas fault system. That is one of the fault of San Andreas Fault system known as Hayward fault.
This is another close up of this. You can easily look at the offset here there is an deformation which is going on again here. So they keep on replacing these and these are the new ones.

So this is an offset which was been measured in 2004 here and this is an offset in 2006, Hayward fault.
Again as I told that the utilities are getting deformed. So this is an example of the water duct which is displaced along the Hayward fault okay because of the creeping.

So they know that a giant crack in the earth which passes through the city. So this is an example of Seattle where they understand that there is an the fault which passes through their city. So this is very important that we need to know that from where which place the fault passes.
Now coming to the Indian subcontinent part, we have some information which is available which talks about the deformation and the motion of the Indian plate which goes on. So maybe I can now we can continue this in the next lecture. I will stop here. Thank you very much.