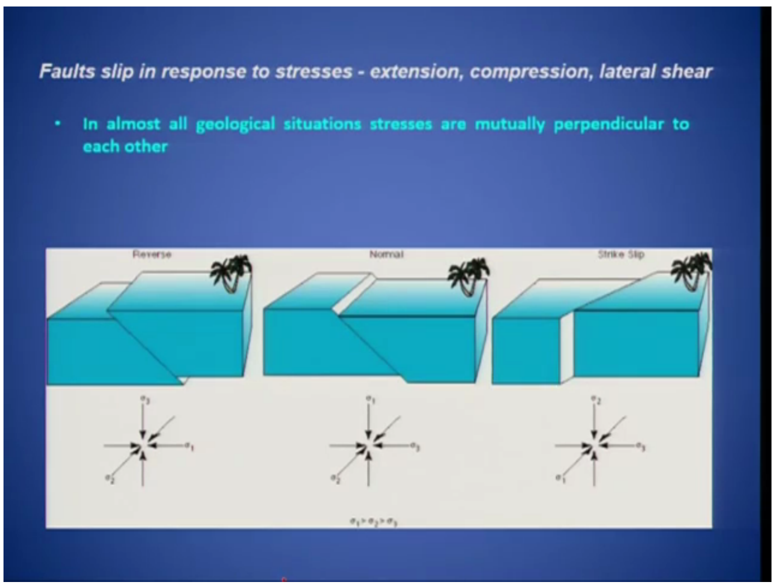
Earth Sciences for Civil Engineering Part-2
Professor Javed N Malik
Department of Earth Sciences, Indian Institute of Technology Kanpur
Active faults and its related hazard in India (Part-2))
Module 1
Lecture No 5

Welcome back so in previous we talked about the active faults, what are different type why in what way we define the active fault.

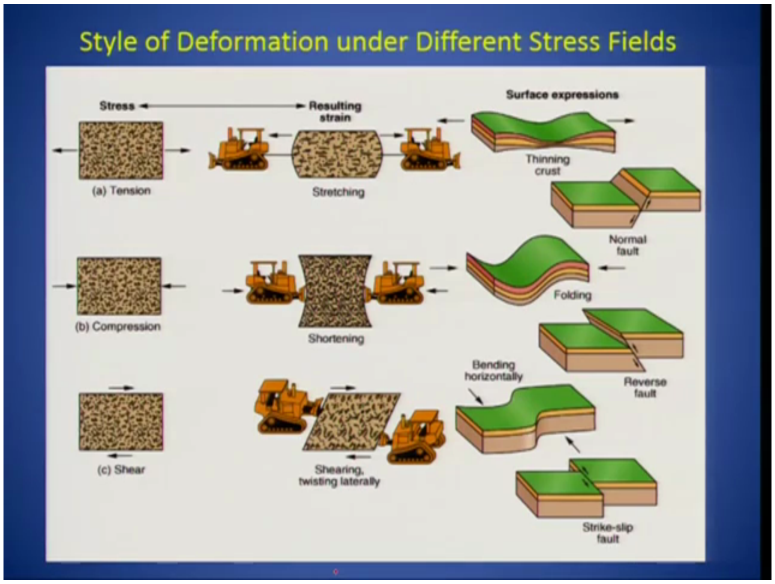
(Refer Slide Time: 0:28)



So let us see couple of examples of that but before going to the particularly the active fault part let us see what we have, how we can classify different faults. Now, fault slip is mostly we have taken in response of the stresses, either they are extensional, compressional or lateral shear okay. In almost all geological situations, stresses are mainly which we take, they are mutually perpendicular to one another.

So if you are having like sigma 1, sigma 2 in this fashion okay then you will have a reverse faulting and this is mostly seen in the areas where we are having compression tectonic environment and if you are having the sigma 1 which is at the top and the least along the fault plain then we will have the normal faulting, this is in the extension tectonic environment and then if you are having an oblique okay then we will have the strike slip faulting environment so mostly this is the we see where, in Himalayas also, we have this type of faulting which has been seen like one of the largest fault system we are having of strike slip motion is Karakoram fault so we based on the the differential stresses, how they are acting upon and mostly based on the sigma 1, we classify a different type of faults, whether it is a reverse fault or a normal fault or a strike slip fault.

(Refer Slide Time: 2:06)



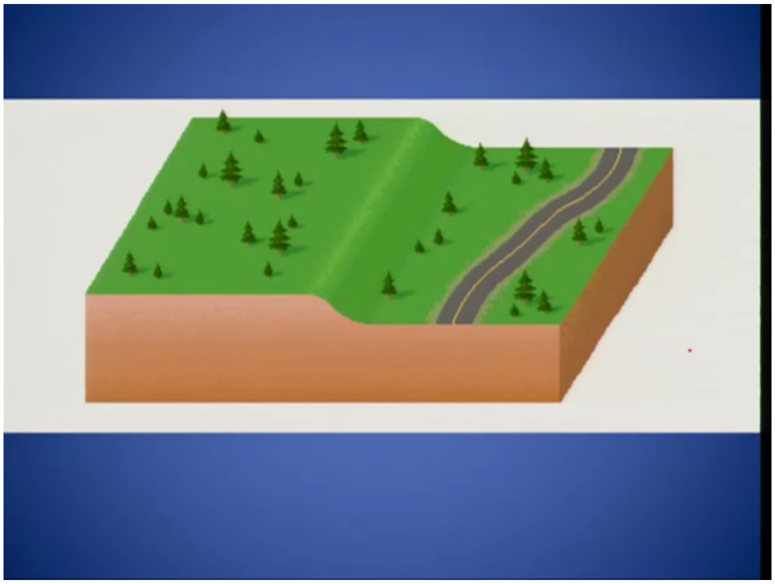
And style of deformation if you take in general okay then what we have is that if we are having the extentional tectonic environment then we will see the normal faulting and mostly what you all will be able to see is the thinning of the crust so we are thinning up the crust over here but if you are having the shortening okay so this was the stretching here but if you are having shortening in the compression tectonic environment here so we will mostly have the folding and we are looking at the the shortening of the areas okay and finally what we see is the displacement in terms of the reverse faults of the thrust faults and if you are having shearing okay so we are twisting the area okay then we will have mostly initially we will (fee) see the bending and then we will have the strike slip motion.

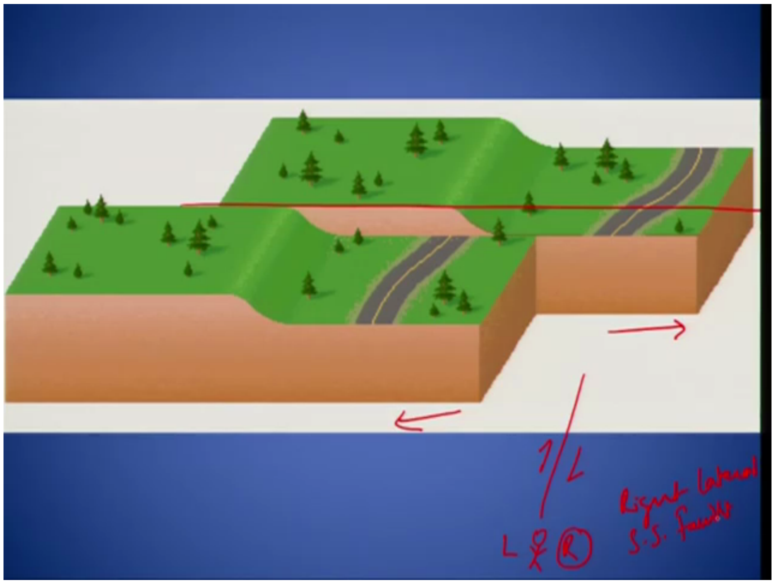
Okay so the motion will be along the strike slip. Now if you are having the combination of both this folding, shearing then we will have dip slip folding so dip slip folding can be either like public slip what we call so we will have reverse component and strike slip component or we will have the normal component and the strike slip component so both we can have in combination which can occur.

(Refer Slide Time: 3:29)

Now this is a one of the very famous example of the fault scarp from California where you can see the fault scarp over here. This is the the surface expression of the the faulting which took place in California and if you know this location like that is what I was talking about an emphasizing most of the time that if you know the location then you will avoid putting your structures on this okay because this will displace and this is what we call the active fault. So this fault or the the the area will be displaced during next earthquake so this is what we call the faults marked on the surface or the manifestation of the crustal deformation on the surface.

(Refer Slide Time: 4:34)

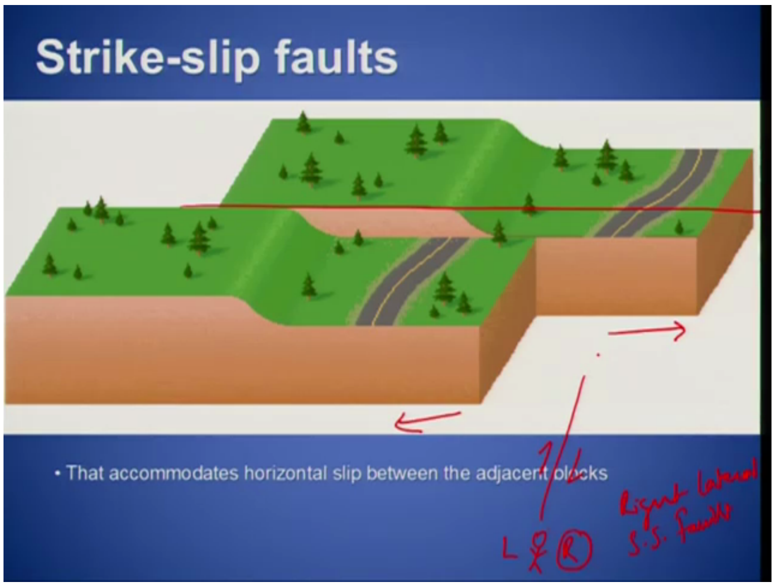


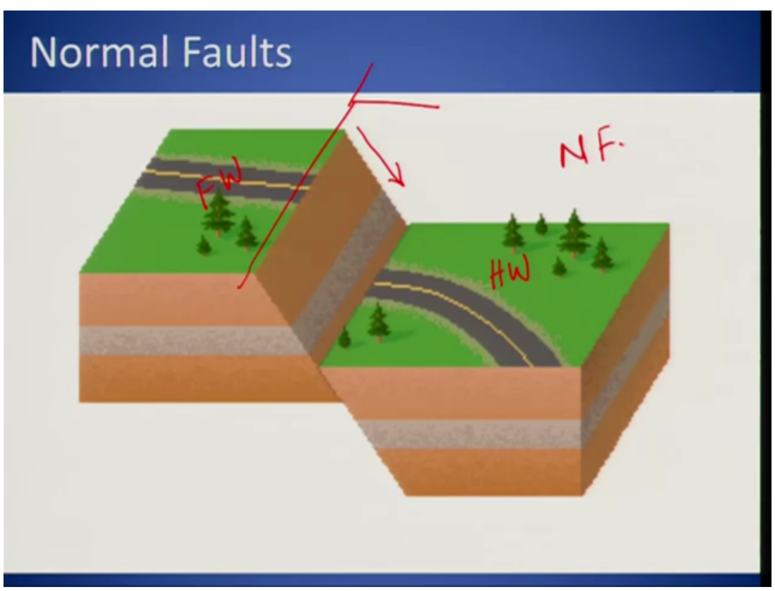


Now in this cartoon which clearly shows that one block has moved past each other in a particular direction okay so I will just put again, if you see this so this block has moved in this direction where as this block is over here okay so this is the strike of the fault so it has moved along the strike of the fault hence it is termed as the strike slip fault.

And if you stay like if you are having a strike here okay and if you are staying and you are viewing the area from this place okay then this is right and this is your left okay so if this block has moved like this and this has gone like that okay so the block moving towards you, based on that, you will term fault as a right lateral strike slip fault so this is what we we can we can classify and if it is opposite then we will as this is irrespective of where you are standing, either you are standing on this side or you are standing on this side, this will be the same so this is an example of the right lateral strike slip fault.

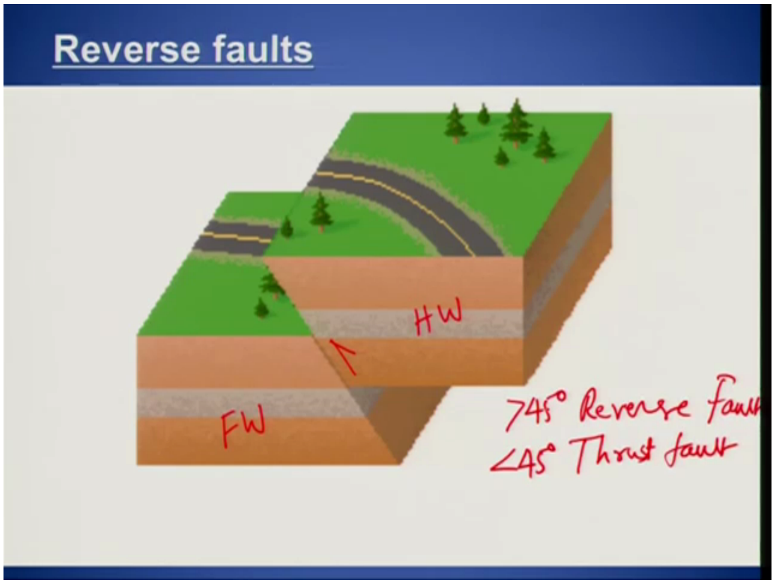
(Refer Slide Time: 5:56)





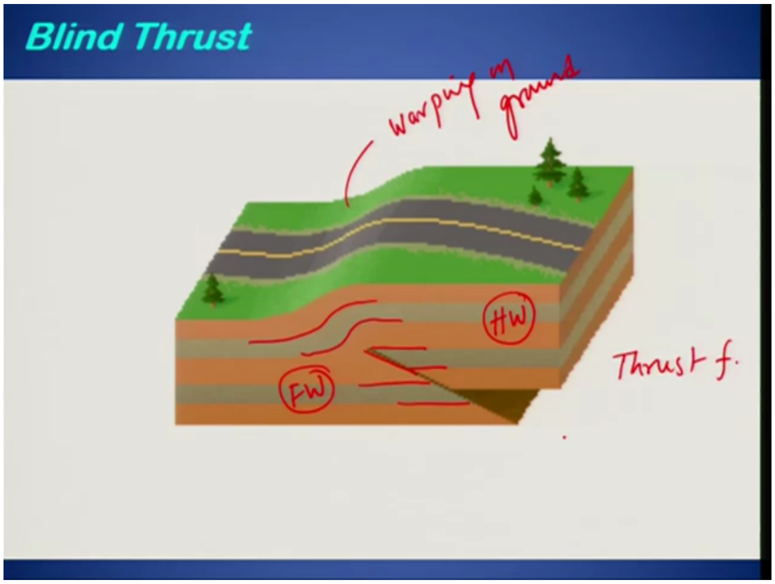
Another one. Now this shows the movement along the dip okay so this is strike, you are having so this is your dip direction so along the dip, the movement occurred so this is our dip slip fault and since the hanging wall, this is hanging wall this is what we call the foot wall, this is this will remain stationary okay so this will be the stationary wall, this will be the wall which will move this is hanging wall okay so hanging wall has moved down okay hence we termed this an normal fault.

(Refer Slide Time: 6:47)



And if the hanging wall has moved up so in this case, this is the foot wall and this is your hanging wall. Hanging wall has moved up. So if the hanging wall is moving up with respect to the foot wall then we term that as an reverse fault and if we consider the angle depending on that you can classify whether it is an reverse fault or reverse fault or we can say it is an thrust fault. So based on this, you can classify whether it is so this if it is less than 45 degrees and this is greater than 45 degrees.

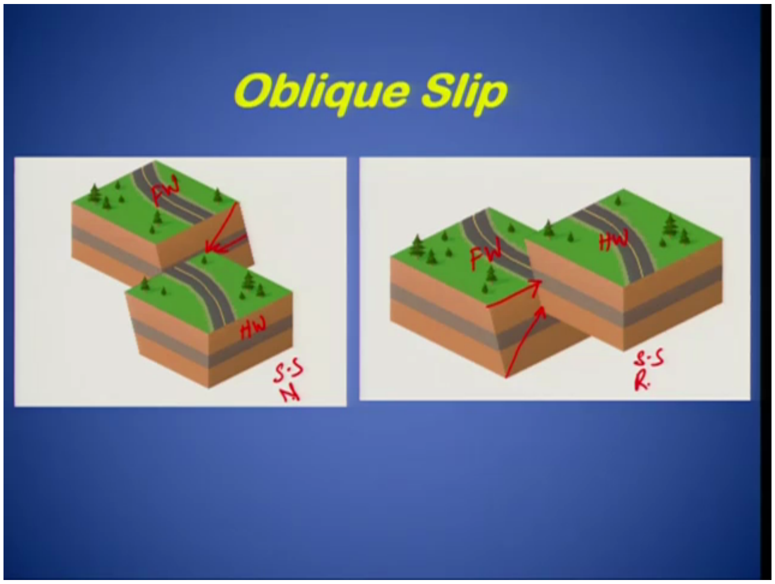
(Refer Slide Time: 7:44)



Now, here there is an interesting thing okay. What you see is that at the lower part, there is a displacement but in the upper part, we have deformation okay. So what we we can say that this is like this is a there is a folding here of this layer, this layer just got folded but this layer got displaced okay so there is a displacement over here but there is just a folding okay and no displacement is been seen on the surface. Just we see what is the what we call the (())(8:21) on ground.

Such type of faults or the displaces are termed as since this again we have to say that see look at this part that this is a hanging wall and this is a foot wall okay so based on this we can say that this is an angle is probably low and so we there is a thrust fault and since there is no displacement on the surface, we termed this as in blind thrust. Okay. In another way, I you should say that the the rupture has not seen the surface okay hence we say this is a blind thrust.

(Refer Slide Time: 9:10)



Another combination which I was talking about so what we have here on your right hand side, we are having a block which has moved in this direction and which has also moved like that okay so we have the 2 components here okay. We have the component along the strike, we have the component along the dip also. So we call this as an dip strike or an dip slip faults but in other terms we call this as an oblique slip fault okay.

Here also we are having the moment which has tuckered is like this and the movement which has occurred is along the strike also so this block has moved down, this is your hanging wall, this is your foot wall, this is your hanging wall, this is your foot wall, so this is having the the strike slip as well as you are having reverse component okay. Here you are having strike slip, you are having normal component so in general we talk this as we call this as an oblique slip faults okay.

(Refer Slide Time: 10:43)

Now coming to the earthquakes, we all understand that the earthquake is a sudden release of the stored energy within the earth crust okay so what we have experienced over the past, now earthquakes mostly will result into strong ground shaking and ground shaking will result into the damage or to the buildings okay so people mostly get affected because of the pattern of construction and all that.

So this is the part of the what the civil engineers should take into consideration by understanding where the earthquake is likely to occur they should know and what will be the magnitude of that, based on that definitely they they will design the structure following the buildings codes and all that. Here are few examples from 1994 this is from Log Angelis earthquake. Damaged pattern, not many houses were been collapsed.

(Refer Slide Time: 11:37)

This is from 1995 Mexico City earthquake. Huge damage.

(Refer Slide Time: 11:43)

This is from 1995 Kobe earthquake okay. Now here one interesting thing what they have done is, they preserved the surface rupture okay and this photograph shows the museum of fault rupture. So they have preserved the fault rupture and they this is the way how they have created the venue to have this public awareness okay so people now like tourists go there and then try to see that what exactly happened and how the earth moved and what are the signatures of such movement over the time so this (mag) again the magnitude was above 7 and this was one of the devastating event in Japan.

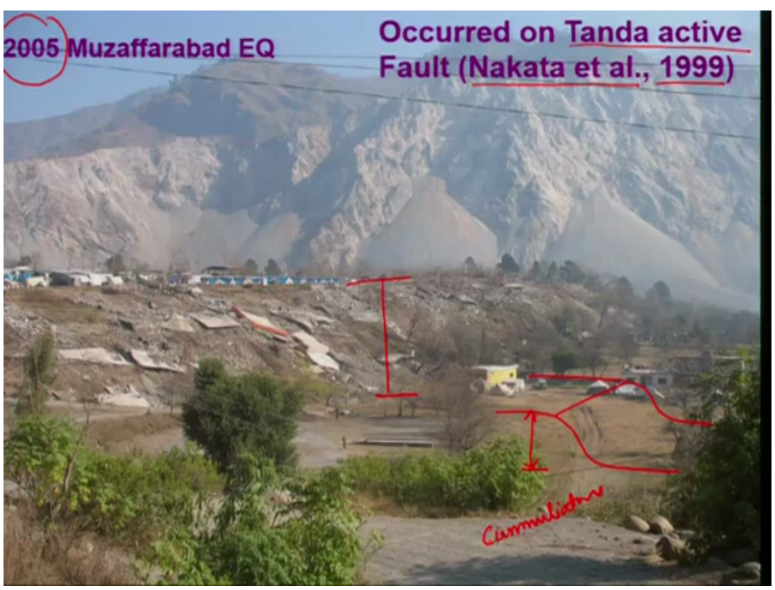
(Refer Slide Time: 12:43)

This is from 2001 Bhuj earthquake, many villagers experienced total damage. When we see total damage, that means all the houses in that region or in that town got damaged or they were raised to the ground okay.

(Refer Slide Time: 13:04)

2005 Kashmir earthquake experienced huge damage not only in the part of the the Pakistan side but in the Kashmir side also.

(Refer Slide Time: 13:17)

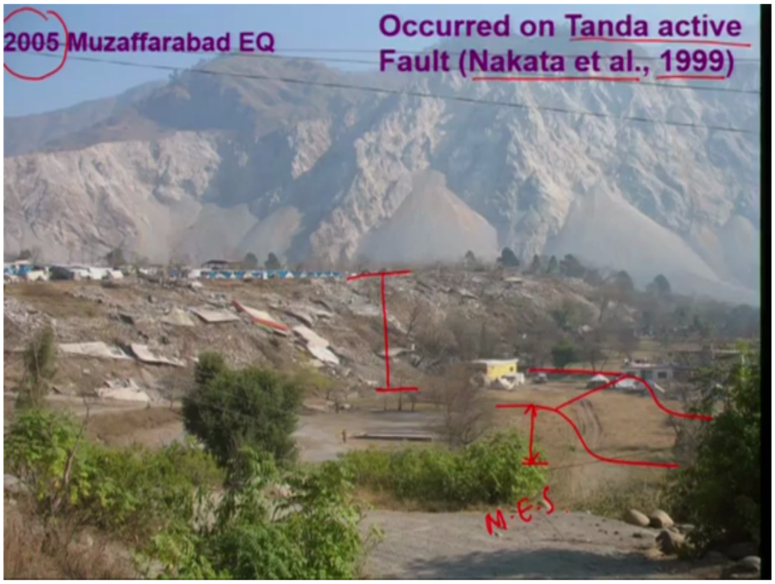


Now this is one interesting part which usually I talk about. Now 2005 Muzzafarabad earthquake occurred along a known fault okay which was known, termed or named as Tanda fault. This was identified long back by a Japanese researcher and he is my teacher also. He identified this fault in

1999. He informed the geological survey of Pakistan that this fault is likely to slip in future and this is one of the active fault in this region okay.

But the geologists did not pay much attention on it and it was been experienced in 2005, so this was on the known fault and what you see in this photograph here okay, you have a scarp here, this is what we call the fault scarp so if I sketch here, it looks like something like this okay so this is a scarp which is quite high okay. That means that this scarp was not developed just because of the recent 2005 event, this shows the cumulative this is what we cumulative scarp so it has the acquired the displacement over the time okay.

(Refer Slide Time: 15:18)

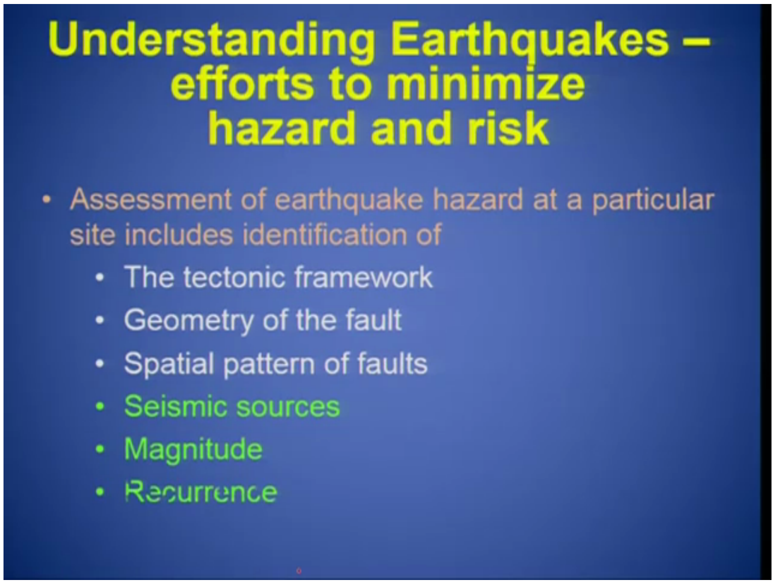


So it is a multiple even scarp okay, a multiple event scarp and if you carefully look at what happened here okay, so fault line, if you have to draw, I will put the fault line over here, okay passes through this area here and this is the type of the reverse fault or the thrust fault okay. So buildings which were been sitting on the scarp were been raised to ground so this all squarish part which you see are the top of the room or the roof of the houses okay, they were raised to ground whereas this survived. Nothing happened to this okay.

(Refer Slide Time: 16:09)

So this is your foot wall and this is your hanging wall. So hanging wall moved so if I put the the fault here then this is something like this okay so this moved okay so this is your hanging wall and this is your foot wall so more ground acceleration will be observed on the hanging wall side as compared to the foot wall side. So this one of the best example which you should learn from, this is a lesson which has been taught to us that we should not ignore any active fault if it has been identified and that what we are doing in India. We are trying to identify these these type of active faults, from which locations it is passing through and what is the history or the background of that active fault in the region okay.

(Refer Slide Time: 17:07)

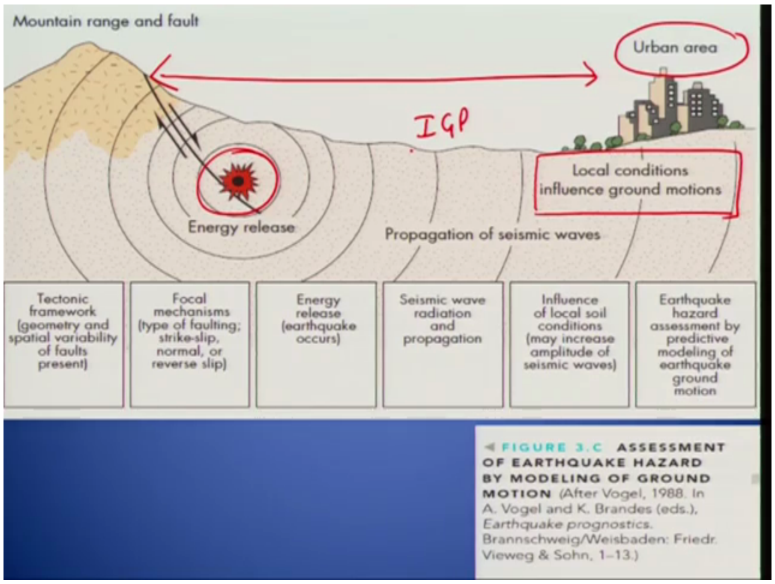


Now understanding earthquake effects to minimize the hazard and risk okay. So what best we can do to minimize the hazard and risk, assessment of earthquake hazard at a particular side includes identification of 1. The tectonic framework so regional tectonic framework has to be identified. What will be the pattern of the regional whether it is any compressional tectonic environment whether it is an extensional or it is having the oblique deformation going on so that we have to take into consideration okay.

So based on for example in Himalayas, we have to look at that what is the pattern of deformation, that is compressional tectonic environment okay that we need to understand then based on that, we can talk about the geometry of all things so we need to know that what is the geometry of all things whether there is a normal fault or there is a reverse fault or thrust fault or strike slip fault.

Then spatial pattern of the fault okay, whether the the pattern of the fault changes along the strike or it remains the same. Then seismic source okay, how deep the earthquake will occur in that region which will be shallow or deep earthquakes. What will be the magnitude of an earthquake? If any earthquake along the particular fault takes place okay and then what is the recurrence interval. So this all information if you have you will be able to reduce or minimize we can say okay the hazard and risk posed by such mega earthquakes or large magnitude earthquakes in seismically active regions.

(Refer Slide Time: 18:50)



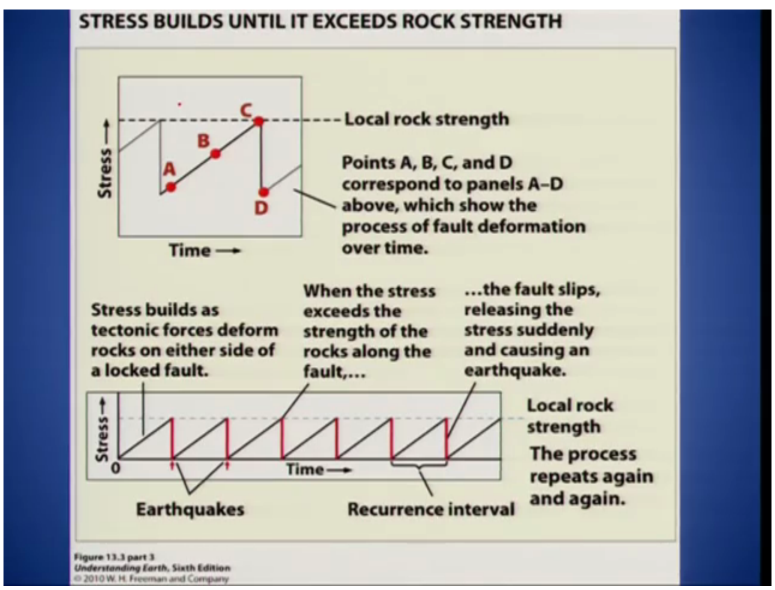
So in short, what ultimately we aim to okay, we are extremely bothered about that what will happen the the urban cities okay but in India we talk about that what will happen to Delhi okay but it is not just Delhi, there are many cities which are sitting close to the foot heel zones of Himalayas which will be affected if we are going to have a large magnitude earthquake in near future so this is extremely important for us to understand now in short, like why what we are interested in, we are we want to know that what what is the local condition of the the specific side or the urban side how far it is sitting from the the fault. If the fault is over here then how far it is sitting okay? What is the distance between this fault and all that?

How deep will be the earthquake? So same, what we (were) talked in the previous one that we know the tectonic framework okay, we need to know the focal mechanism, what type of faulting will take place, we need to know how much energy will be released because this is extremely important to understand and this depends on the magnitude of an earthquake okay and then seismic wave, radiation and propagation so if you have the fault or the source of the earthquake sitting in different area.

Like for example, we are having the settlement here and then earthquake source is here then the waves will propagate in this direction okay. When the earthquake will settlement is this so we need to know that what will be the radiation and the propagation of the seismic waves. Influence of local soil conditions okay. This we talked in the previous course because this will amplify the seismic waves traveling through different type of material okay.

So if you are having softer and sandy material then we will have the more (amplica) amplification in that area. So for example, if we are we say that this is the Indi Gangeitc plain then we should be bothered about it okay so this this part should bother us because this will have more amplification of the seismic waves. Earthquake hazard assessment by predicting models and earthquake ground motion. This is again is related to the seismic wave propagation so we are mostly interested in knowing that what will be the magnitude, how far we are sitting from the the fault, active fault okay.

(Refer Slide Time: 21:47)

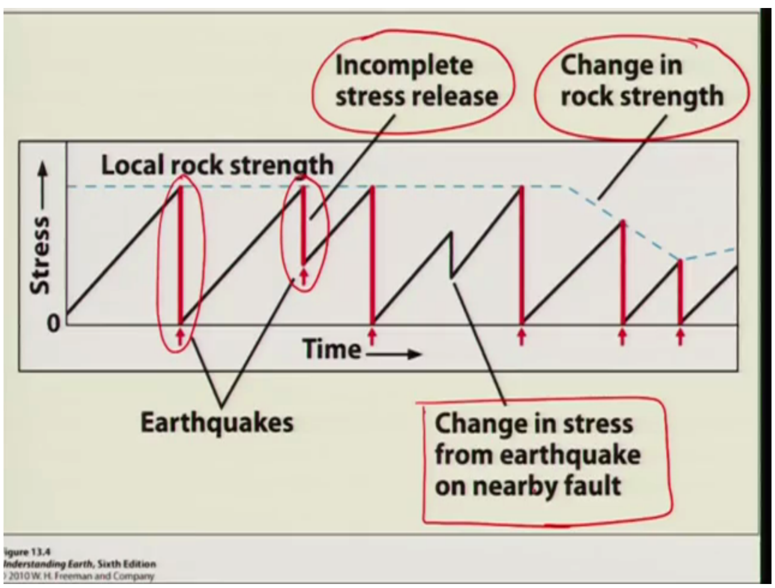


Now about the recurrence interval if we look at okay, about the earthquake recurrence interval, it has been understood that the it depends on the the strength of the rock and all that okay but whether this is correct. If both, we have been talking about that over the strain will develop if we keep on building up the stress okay. Now if we keep on building up the stress at a particular threshold point, the rock will rupture or the crust will rupture.

Again to trigger the similar magnitude earthquake, you will require this much of time okay, so again the strain will build up and then there will another rupture. If this very systematic pattern is been repeated okay then we can easily predict the earthquake okay so for example, we can talk about the recurrence interval okay so if this was the amount of the time which was been taken to acquire the strain to slip here then what will be the next here okay so this time okay, we will have another earthquake.

So this is one point which we can, we keep on talking about that okay. If if we are having very systematic earthquakes, earthquake pattern or the repetition then we will have the the next earthquake which can be predicted but this never happens.

(Refer Slide Time: 23:26)

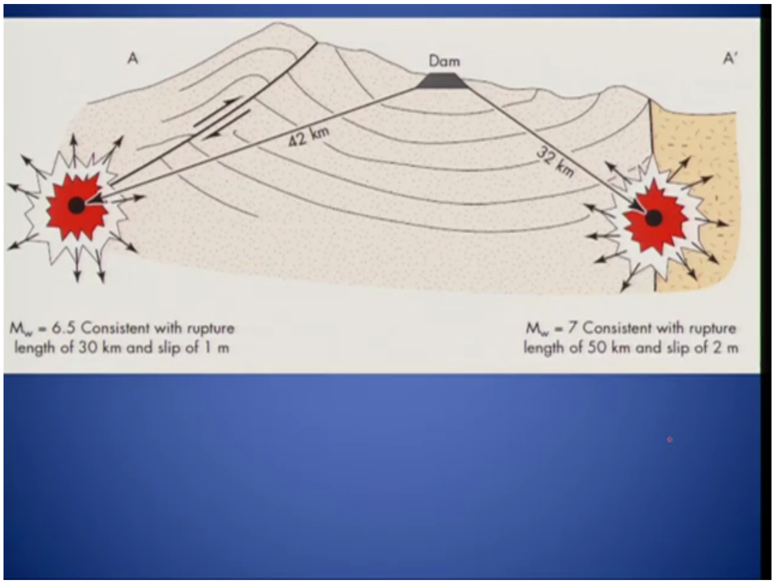


Because some time we have the major earthquakes which have occurred here and in between we may have a moderate magnitude earthquake okay. Now this moderate magnitude earthquake will lead to incomplete release of the strain which can very quickly trigger the other event okay, it could be on large magnitude and this whole thing is dependent on the change in the strength of the rock so if you change because over the time, the strength of the rock change because of that you may not have a very systematic earthquake occurrences okay.

The repetition or the time which is been taken, the recurrence will change okay and that what we have experienced in Himalayas also but then also I would say that if we do the studies in a proper way, we will be able to identify the locations of the active fault and we will be able to at least say that okay this will be the magnitude of an earthquake which is expected on that particular fault.

So this is an advantage of what we are doing identification of active fault in mapping okay so change in the stress from earthquake on the nearby can also trigger the earthquake in that area okay so if you are having an earthquake on the another nearby fault, it can also result a trigger, the earthquake on the fault which was not going to trigger an earthquake very quickly in the recent time okay. This is what we call the triggering earthquake or triggering stress sorry so the stress has been has resulted into the increase in the possibility of occurring an earthquake in the different fault okay. But this is what usually we will we will expect okay. If there is a change in the rock strength and all that.

(Refer Slide Time: 25:43)

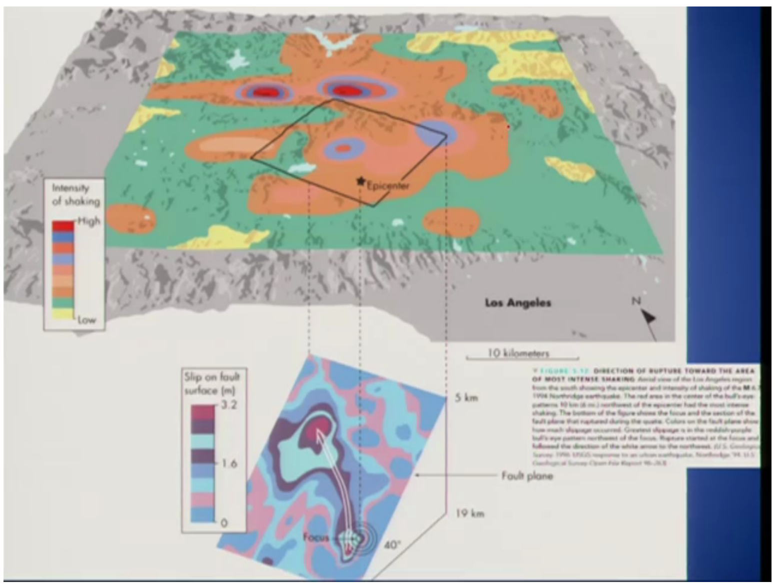


So finally what what is important for us and why we are trying to understand and know the the location of the active faults, as I told that we are interested that how far we are sitting from the the fault okay, how dip it will occur okay. That is one one point and what will be the magnitude of these events okay. So for example here we are giving 2 2 (exmp) un 2 scenarios okay.

One is like 6.5 okay, we are just sitting away then this fall can trigger the magnitude of 6.5 okay whereas this earthquake is away but it will slip okay to the larger amount okay. Now in this slide, there is an that what were been talking about that we are interested in knowing what is the location of the fault okay so here you are there are un 2 faults, this is one and this one is another one okay on the surface and how much far they are located and for example, if you take the epicenter then how far they are located from each other okay.

So one is like MW7 so this fault is capable of triggering consisting with the consisting with the rupture of 50 kilometers and the slip will be 2 meters whereas here, there will be less slip okay which is around 30 kilometers okay.

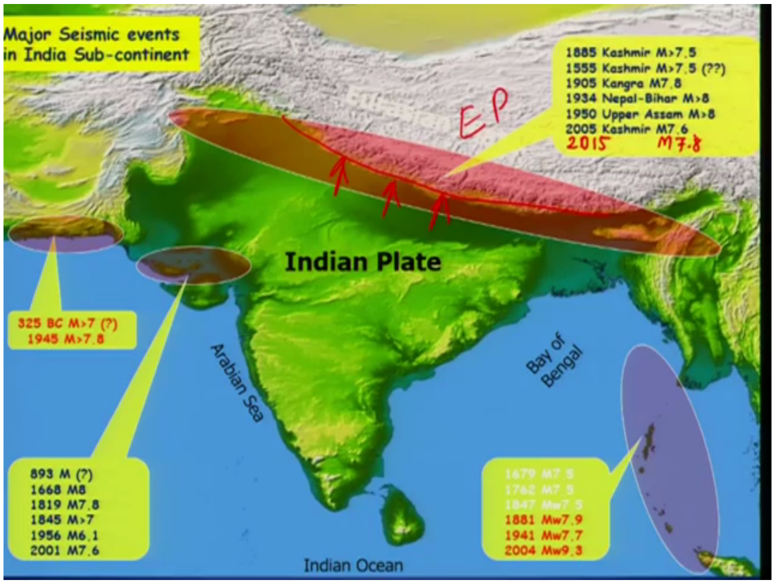
(Refer Slide Time: 27:07)



Now, the most important part which we require from for for the settlements around the area or the side specific studies okay, we require that what will be the intensity of the shaking in that particular region okay. Now if you see this picture here okay, this shows that there are no same colors everywhere but most of the proportion is having this one okay so that that depends on the that these areas will have low intensity if the earthquake is triggered and if you are if you are having the epicenter right sitting over here okay then and then the red areas are will have the the higher intensities.

Now, this depends on the that what is the lithology or the or the geology of this idea so that will vary from place to place and that what we call is extremely important to have is the seismic solution map, micro seismic solution map not on the regional scale but on the on the mirco scales okay of different areas okay so this is this is what ultimately is required so how far is the fault from the city and on what type material the buildings are been standing that is extremely important.

(Refer Slide Time: 28:30) 30:41



Now coming to the Indian part okay, we have like we I would say that we are not left out from any side okay so we have if you start from the South, we have Andaman and Nicobar here which has which experienced several earthquakes of magnitude 7.5 and greater okay in 1679 then 1732, 1849, 1881, 1941 and then we are having finally the mega one was 2004 okay so this is the the area of subduction zone and Sumatra Andaman subduction zone.

Coming to this Assam side, we have the large the the magnitude earthquake was 1950 and then coming to this area, this whole area is extremely active region okay and then on the on the western side we are having the Makhran subduction zone okay, so this whole area of the Indian subcontinent, there is a coast line okay because we have extensive coast line, this coast line is vulnerable to not only the earthquake shaking but also from the Tsunamis which will be triggered from the subduction zones on the on the eastern side and on the subduction zone on the western side whereas this region is extremely prone to the large magnitude earthquake that is the Himalayan zone okay.

So we are having the collision which is going on over along this boundary okay over here, the Indian plate is subducting or colliding with the Eurasian plate and we have couple of earthquakes listed over here okay so we have 1885, 1555, 1905, 1934, 1950, 2005 okay and I have not added here more is the 2015 Kodari earthquake okay so we are having another one in Nepal which was 7.8 or so okay so we have another events from this region also okay.

So this shows that this area is extremely active. Along with that, we have the region of Kutch which is again one of the most active region in this stable continental region because we consider that this part of the India falls under the stable continental region okay so if this is there then then even we are having very large magnitude earthquakes from this area okay. Now question is, whether we should consider this Kuachchh as an stable continental region or we will start discussing this part further in the next lecture. Thank you so much.