Introduction to Engineering Seismology
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Lecture - 03
Different Earthquake Hazards

Vanakkam. So we will continue the last class so lectures actually. So last class we discussed about so what is meant by hazard. How the hazard become a disaster, okay. So then what are the different type of natural hazard. So we also look at like that how the world over different continent experiencing the number of natural hazard and then the loss due to the natural hazard so with respect to human as well as economic.

So we understand from that so basically even though the Asia the number of earthquake or the any natural hazard okay, so considerably high, but the economic loss is actually 50% of the developed countries. So similarly, when you look at a human loss okay, so the Asia experiencing the more number of fatality when compared to the rich or developed countries, okay.

So if you want to reduce this kind of hazard okay we have to be prepared ourself. So we have seen a five step of preparation, so starting from perception and understanding of the wave propagation and designing the structures and retrofitting that and things like that. And then we also seen that this has to be carried out institutional way and then individual way.

So I told you all of you to go through what to do when earthquakes are comes. What are the things you should follow as a individual and also what you should do to prevent this kind of human losses within your family. So I hope all of you are gone through that and may be things like that maybe in the my TS will have some kind of assignment related to that.

So with the continuation that we have seen that so the institutional way of dealing this hazardous is a prime importance to reduce the human as well as the economical. So one of the institutional way is basically educate the people, okay. So educate the

people and preparing a drill if the earthquake comes what to do, okay. So that is a major things.

So in the part of education system, so basically, so the NPTEL taken initiative to create a online web courses as well as the video courses kind of things. So this subject also part of that, where the engineering seismology to be taught to the anybody who is having the slightly better understanding of the education and read and write capacity.

So this engineering seismology course as I told you that it is been framed such that people with plus two qualification also can take this courses, okay. So with the continuation that so today we are going to talk about the more of earthquake and try to understand how the earthquake create a different type of hazard. So we have seen that the earthquake as a part of natural hazard okay. There are about four major category we divided.

So earthquake comes under a geophysical hazard where the volcano and dry land mass movement is there. So followed by so we have seen that among this three earthquake as major this one. So today we are going to see that within the earthquake okay within the geophysical then earthquake, within that earthquake what are the different hazard parameters or hazard created by the earthquake, okay, which is called as a earthquake hazard.

That is hazard caused by the earthquake we call it as a earthquake hazards.

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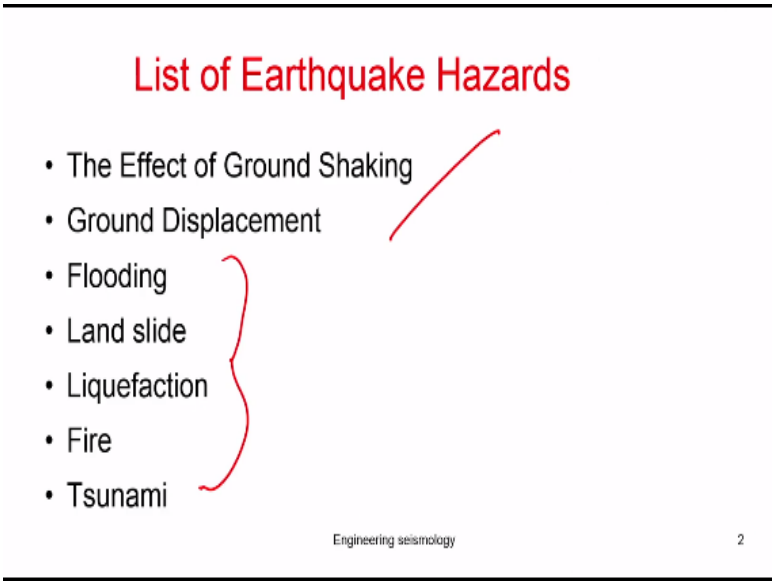

So this earthquake hazard actually we can categorize as a two major group. So one is that basically the direct effect of the earthquake. So which is the seismic waves, so comes from the directly can basically cause damage or human losses, okay. So that kind of hazard is called as a direct hazard.

So the another one is basically induced hazard. So the induced remains the earthquake cause some kind of disturbance in the soil or structure. So that can cause a hazard, okay. That kind of hazard is called as a induced hazard. Actually the direct hazards are the effect of ground shaking and ground displacement or the direct hazard. The flooding, landslide, liquefaction, fire and tsunami are the induced hazard.

So we are going to discuss how this. So why do we need to understand this because if you want to design or if you want to prepare yourself to minimize human loss and economical loss due to earthquake, which we have studied in the last class how much damage we are experiencing, how much how many people who are dying, what is the percentage of the share all those things.

So if you want to minimize that first you have to understand when earthquake happens, what are the different hazards are happening? So we have seen that the effect of the ground shaking, ground displacement, flooding, landslide, liquefaction, fire and tsunami. So these are all the list of hazards caused by the earthquake or the earthquake hazards, okay.

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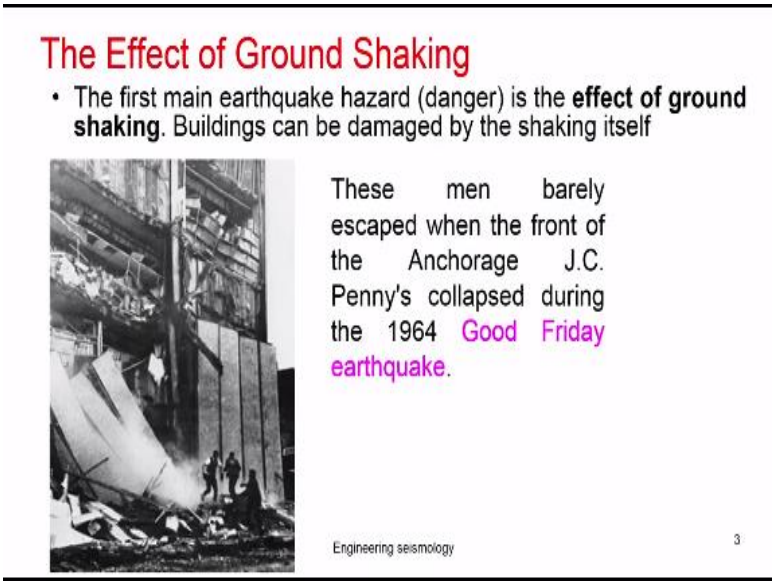

So let us see how this hazards. So if we look at this picture, okay. So this is actually the effect of ground shaking. So when the earthquake comes actually okay so whatever the vibration created by the earthquake, which directly comes to the structure and affect a structure. So that kind of hazard is called as a the effect of ground shaking. So this is the main earthquake hazard.

So irrespective of the region this direct shaking you can experience when the earthquakes are there. If the magnitude is small you will experience a less shaking. If the magnitudes are larger, you will experience a more shaking. So that is the general trend. So this is basically so when the earthquake are resulting lot of damages people try to understand how this damages and all.

So this is basically a Good Friday earthquake occurred on 1964 so where you can see that the earthquake caused severe damage to the building. So people are trying to escape due to this. So it is basically directly.

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One side of this Anchorage street dropped drastically during the 1964 Good Friday earthquake.

Loma Prieta earthquake damage in San Francisco. The soft first story is due to construction of garages in the first story and resultant reduction in shear strength. (http://earthquake.usgs.gov/bytopic/photos.html)

Soft first story/inadequate shear strength

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So this is another one where the you can see that a part of okay so one side of this Anchorage street, okay basically failed and it caused lot of damages, okay. So then the down picture you can see that this caused by the Loma Prieta earthquake damage in San Francisco. So where the soft story, soft story means story which is generally constructed without any wall, okay.

Only with the columns, okay. So those are all the practice generally people use for the parking slot and all. So the direct shaking sometime because of the stiffness difference between the top and bottom will cause a huge damage at this kind of. See this is the typical damage where you can see that it was actually in the San Francisco earthquake damage.

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Kobe earthquake damage. Failure of the first story caused partial collapse of upper stories. (http://www.eqe.com/publications/kobe/kobe.htm)

Northridge earthquake soft first story (parking level) damage. (Photo from: Brown, R.D., Jr., Lessons reaffirmed, extended, or revealed, *Earthquakes and Volcanoes*, Vol. 25, No. 2, 103-106, 1994)

Heavily damaged apartment building, Reseda. The building has collapsed onto its structurally weak first story, partially crushing several parked cars. This type of damage was common in the epicentral region; partially open first-story levels have poor resistance to strong, horizontal ground motion. The piles of debris and the destruction on the left are the results of a fire that broke out after an aftershock. Photograph by J. W. Dewey.

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So then you can here see the another typical example where the Kobe earthquake damage. So the failure of the first story caused a partial collapse of the upper stories okay. So similarly the Northridge soft story parking like this one. So you can see that so where the earthquake caused.

You can see that the structure is basically intact here, but because there is a stiffness between the top and bottom difference, so which caused basically the imbalance first and then caused the damage, okay. The only soft stories are collapsed and the remaining house is intact. So even if you design, sometime a earthquake, these kind of things are not taken care the building may experience a failure, so which has to be accounted, okay.

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So this is the again a typical failure due to the Northridge earthquake soft first story parking level damage. And then similarly, this is a particular unique case where you can see that the bottom and top are intact but the middle actually you are experiencing a experienced a failure. So why this was happened?

Maybe this particular place may be used as a office or something like that, where the stiffness between the top and then bottom may be different. So that the stiffness difference is not able to tolerate the vibration first created by the earthquake, okay. So these kind of things you can expect.

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Mid-story collapse, Kobe earthquake. (Photo from: The January 17, 1995 Kobe Earthquake: An EQE Summary Report. April 1995, http://www.eqe.com/publications/kobe/kobe.htm)

House shifted off its foundation, Northridge earthquake. (Photo from: Dewey, J.W., Intensities and isoseismals, *Earthquakes and Volcanoes*, Vol. 25, No. 2, 85-93, 1994)

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So the another one again you can see that whatever the similar discussion we made. So the mid-story failure where you can see basically this level. See the top and bottom are intact. So this is actually the another a small single story building. There is a school of thought that it is only a multistory will damage, single story does not. Nothing like that okay. So it is if the structure is not withstandable for the particular vibration it will damage.

So here you can see that this house shifted its foundation and then base because of the moving so like this, okay. So this movement basically caused a shifting of foundation and the floor of the this particular buildings due to the Northridge earthquake occurred, okay.

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Column failure, Loma Prieta earthquake. (Photo from: http://earthquake.usgs.gov/bytopic/photos.html)

House shifted off its foundation, Loma Prieta earthquake. Photo from: http://earthquake.usgs.gov/bytopic/photos.html)

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So similarly this is another building where you can see that house shifted its foundation Loma Prieta earthquake. And then there is another building where the column failure due to the Loma Prieta earthquake you can see that how the column reinforcement all those things, it is almost like buckled and collapse drastically, okay.

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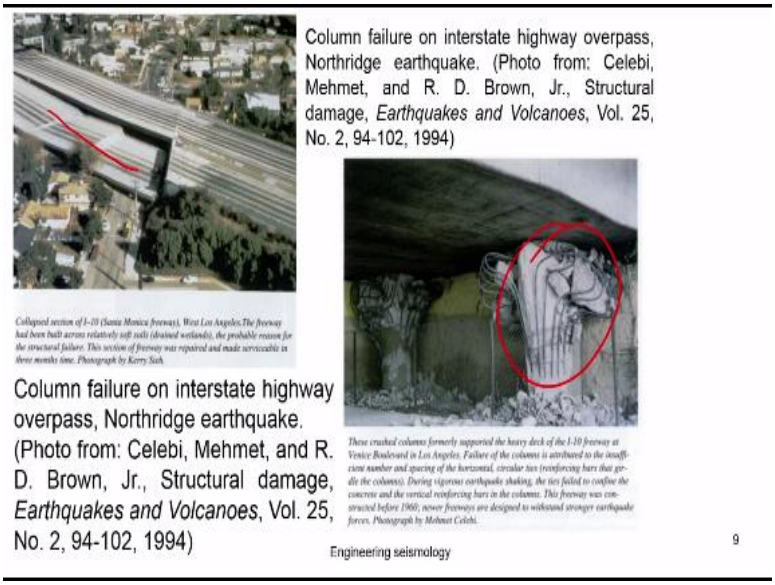

So this is another failure where a column failure interstate highway overpass Northridge earthquake. So where you can see that part of the bridge is actually a completely collapse, you can see here, okay. So similar the column failure, okay. So interstate highway express where you can see the how the reinforcements are buckled okay and then caused a failure.

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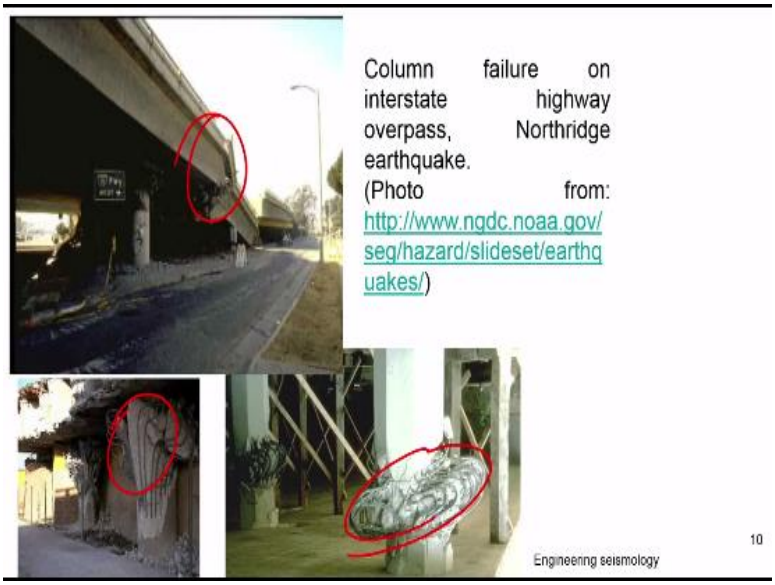

So the column failure again on the another earthquake where you can see there is damage here. So you can see the damage okay. So these are all the damage. These are all the routine common damage to the structural component when the direct shakings are coming to the building, okay.

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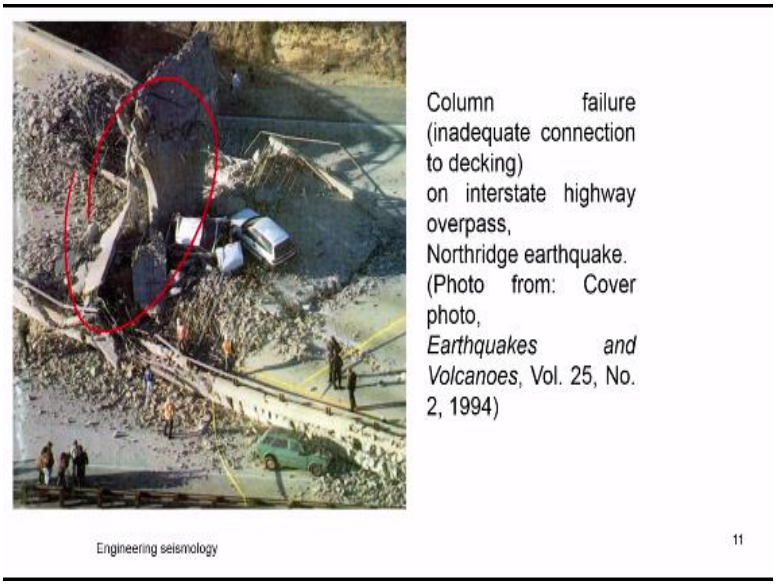

So this is another bridge, okay so where the inadequate connection between to the decking and bridge in the interstate highway due to the Northridge earthquake you can see here. So here you can very clearly understand that the direct shaking, so direct shaking means even if you are constructed your building on the very rigid foundation okay or a rock okay the force comes from the earthquake basically causes to the additional dynamic force to the structure.

If that structure is not designed for that dynamic force, which will undergo a failure. If it is designed at least it will may take that load and sustain. So this kind of direct shaking whatever caused by the earthquake will resulting a damage are the huge. So this direct shaking is possible irrespective of the location. So if earthquake comes any place direct ground motion hazard or ground motion shaking is the prime. The next one is actually the shaking due to the amplification.

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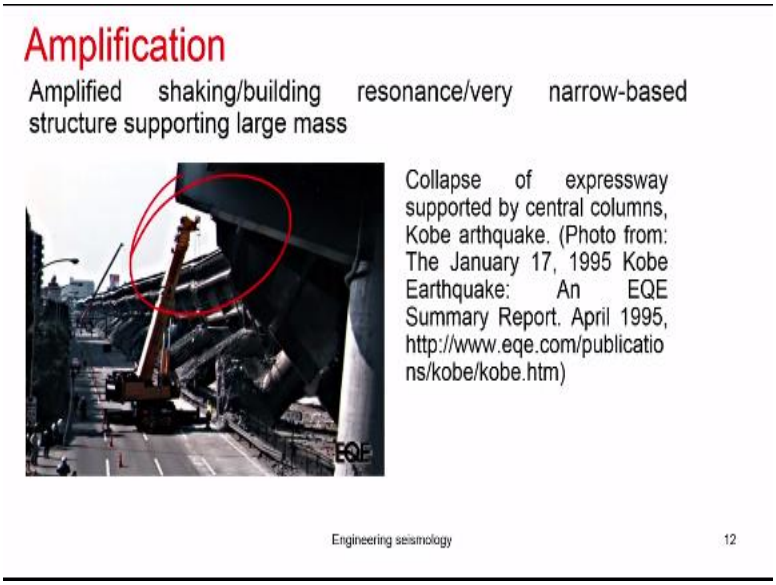

So amplification means the seismic waves whatever comes okay we will be studying this in detail later classes. So right now the amplification means the seismic waves whatever generated okay by the earthquake at the source when it travels a path when it travels from the very deep location to the surface, as you know that the ground actually the top surface we have the soil followed by the dense soil then followed by the rock.

These are general geology most of the region. So when you have the this kind of difference stiffness material the wave propagates on all this layer basically undergo a modification. So that modification basically result in amplification and attenuation. The amplification means that basically the wave amplitude frequency duration content increasing, amplify okay that is amplification.

So attenuation means these three component reduces okay, so these are all things. So because of this amplification so even though the earthquake when it has only rock okay your earthquake magnitude is for example, 0.25g. But when you have the composite layer, rock, weathered rock and then the soft soil, dense soil different layers, these waves are get modified.

So basically it amplified. That amplified wave become a 0.25 become a 0.35, 0.45, 0.65, depends upon the thickness and stiffness of the layer. So that kind of amplification will cause basically a additional force than the regular direct ground

shaking. So the failure caused by this also huge in nature. So there are some cases this basically the amplification, shaking related is a failure.

So this is the amplified shaking building resonance are very narrow based structure supporting a large mass. So this also happens sometime if you have the structures which has like a thin slender column and then you have the very large top okay like a pendulum, inverse pendulum kind of things. Because of that mass imbalance, you will get this kind of resonance as well as the amplification of the seismic waves.

That means, there is a seismic waves bottom it is different top is different apart from the soil. So this collapse due to these kind of failures are called as a amplification shaking failure. The collapse of expressway supported by the central column of Kobe earthquake actually one of the classical example of this kind of failures actually.

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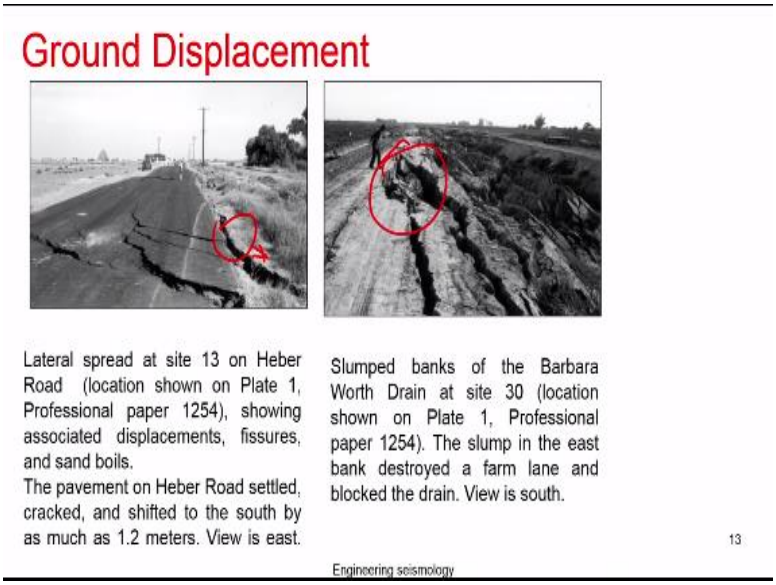

So these are all the direct shaking. So the another one is actually so the another direct earthquake failure is actually say the ground displacement. So in the previous cases, the ground does not undergo any displacement or your structure kept on the rock, okay that kind of condition. Only the waves are modified and waves are causing a additional force to the structure.

So that kind of things are the direct shaking failure or the ground motion failure. So the next is the ground itself undergo a deformation. So as you know that so the most of the places we see a soil. The soil is actually composite of the several individual

particles. So due to dynamic load okay this particles try to move okay this try to move from its position, original position to the changed position because of the this waves.

So that kind of things will create a ground displacement or a additional movement of the soil layers in the location. That kind of failures are called as a ground displacement failure. So you can see that this particular road okay where you can see that the grounds are basically the original level was maybe the before failure it may be together. So this location.

After failure is basically moved this direction, you can see here, this kind of. So similarly, this is the another one is the bank of some of the drain or the small canal kind of things. So where the earthquake cause the additional force. So from its original position, the masses are moved after earthquake okay. So these are the very common ground displacement.

This also happens to the direct waves coming from the earthquake, okay. So it is not induced any additional this one.

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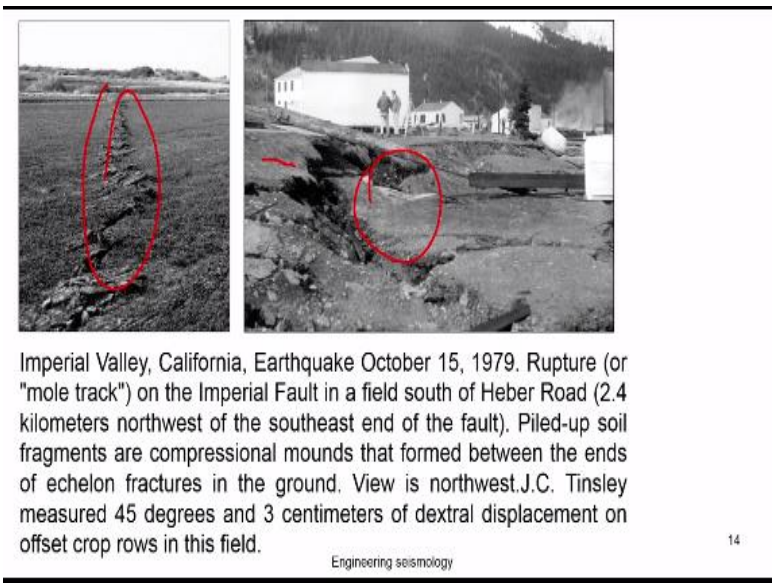

So these two hazards are called this one. So apart from that if there is places where you are living top of the fault or this one we will discuss that in the later stage. So you can see like this a ground displacement you can see here. And then here you can also see that the original level was like this. So after the earthquake this was actually moved to this, okay.

There is a huge, this is actually Imperial Valley, California earthquake October 15 1979 okay. So where the fault location, you can see the fault surface rupture okay which caused a displacement and also the movement of the land, okay.

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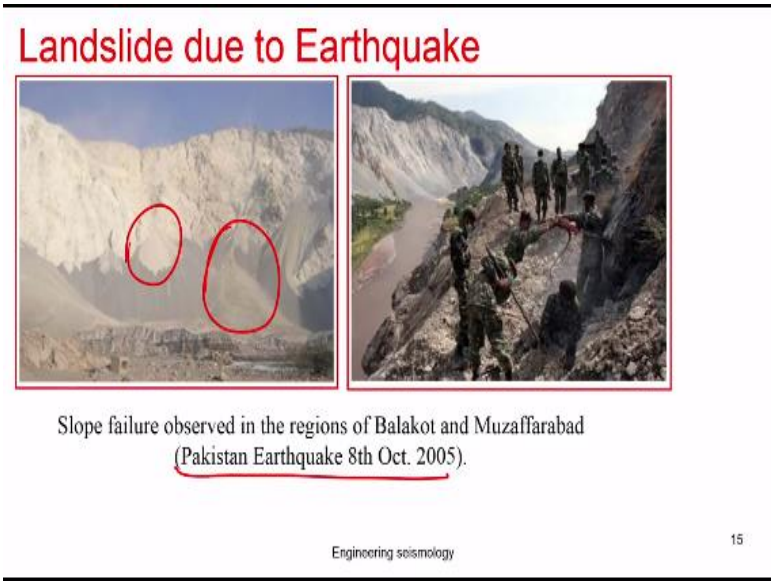

So this is actually the other failures. So far we have seen a direct failure. So now we are going to see about the indirect failures okay or induced failure. So the induced failures means the seismic waves or seismic force causes okay some kind of disturbance in the that material that result in other consequences okay. It induced some kind of. So for example as you know that so the hills okay so you have the hill.

We have the lot of trees followed by the thin layer of soil then followed by the rock. This is the most of the cases in the hill. So when the static condition so this will be stable because you may not see any landslide or anything but when the earthquake comes okay the thin layer sitting on the surface will undergo a this vibrational forces which will move from its original position.

So that means the movement of the soil induced by the earthquake that movement causes a landslide or it will create a big landmass movement, okay. Those kind of failures are called as a landslide failures. So this landslide failures most of the time, it is occurred in the hilly regions, okay. So wherever hill and slopes are there you can expect a landslide. So it is not only the land it also occurs in the sea.

Sometime there is a if you have the huge valleys and ridges in the sea floor, so due to earthquake you can see floors are get moving together. There was a recent studies that reported that there was a similar kind of sea landslide occurring inside of the sea, which causes a additional disturbance in the sea, okay. So this is the typical landslide caused by the Pakistan earthquake occurred on 2004.

So this earthquake actually occurred when I was doing my PhD. So you can see actually there are lot of roads in our Indian border region has been completely destroyed. So there are many places where you can see the amount of the material and this one you can see here, so how much. So there are places where this kind of landslide even caused several villages to be buried completely okay.

So there was a some you as you know that below the hill there will be a soil deposit, people will be settling okay. So in that region a small village or 10 family, 100 people are settling. But this kind of landslide actually bury them all together as there are many villages are disappeared because of this kind of landslide hazard. So it is very dangerous.

So people who are living in that region should be know that even if the earthquake comes we will not get a any landslide there in the settlement area. Then they can be escaped.

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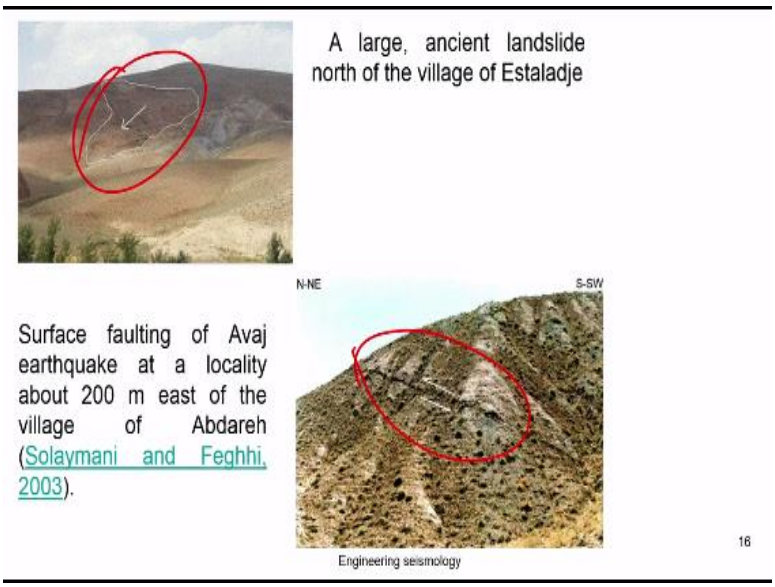

So this is another place where you can see the large ancient landslide north valley of the Estaladje. So you can see basically the movement of the land this one. And also this is actually the surface faulting on the hill. You can see basically how the land moved okay, due to the this earthquake things.

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Saeed Abad rock block slide which occurred near the village of Saeed Abad. Prominent scarp on the behind of ridge crest (cannot be seen in the figure) showed as much as 10 cm downslope displacement. The pile of boulders downslope from the outlined area is due to a rock slide and several rock falls, which originated during the earthquake from the same slope and the right slopes.

Rotational movement in the banks of Kharrud river resulting from lateral spreading.
The white arrow shows the rotation of the earth block.

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So this is another one. So where you can see there is a huge slippage of the overburden above the rock, so due to the earthquake. And this is the another one where you can see there is a damage this place you can see, okay. It is basically a rotational movement. It depends upon the earthquake direction and location depth you can experience a different type of process.

So this particular place there is a rotational movement which caused a spreading of the lateral spreading and landslide kind of things, okay.

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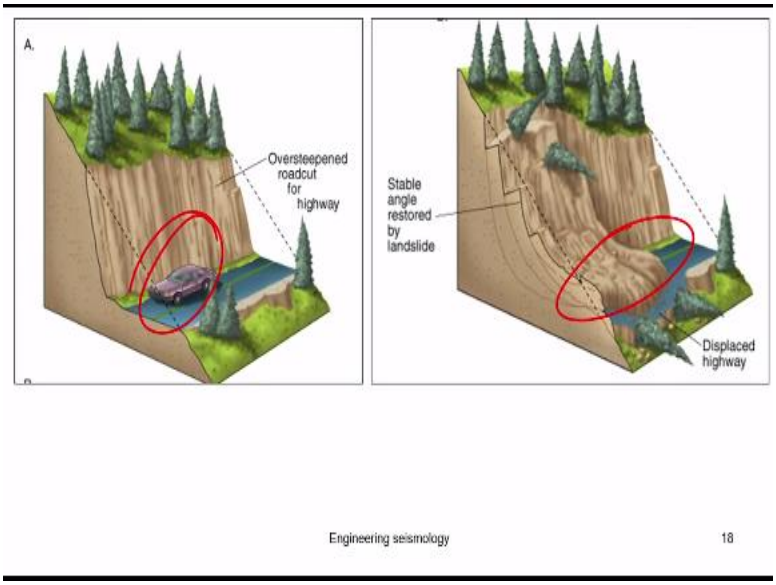

So this is the, so this is the typically basically per the human development the people cut a hill or the ground and then they make a road. So if they do not consider the dynamic force, due to the earthquake in that region, which result in the damage like that. You can see here these are so much deep. So in the static condition it may be stable.

So when you go when you go for the dynamic extra vibration comes basically it may not be stable, so which causes this kind of accident. So this is very common in most of the north hilly region and Northeast region of the India. So recently I had opportunity to visit after Sikkim earthquake okay to the some of the area. So during a earthquake actually, so there are several landslides are occurred.

It was even a small, moderate magnitude, it is not a very big magnitude. It was around 5.7 or something like that. 2500 landslides are occurred. There are many roads are disconnected because of the failure of the bridge and slope failure and landslide failure okay. So like that it is a very common in these regions whenever there is earthquake are occurring. So one has to consider this hazard as a part of the earthquake this one.

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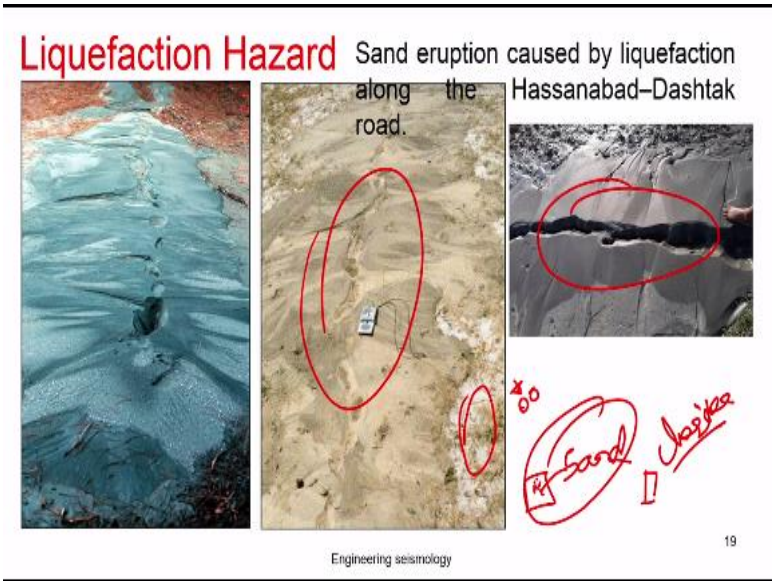

So the another one is basically a liquefaction hazard. So the liquefaction hazard basically so when the ground is saturated okay then the soil in the ground is actually a cohesion less material. Cohesion less material means material which is easily separatable okay. So it is assemblage of the different particle size, but it does not have any the particle attraction forte like cohesiveness okay.

Generally civil engineering student will be knowing what is the cohesion less and cohesive soil. So people who are not a civil engineer so I can explain simply what is meant by cohesive and cohesive soil. So basically the particles you could able to see okay so by the eye okay a small particle assemblage of the small particle make a soil. So for example, sand, sand is a typical example.

So this is actually cohesion less soil because these particles are not attracted by the particle contact forces. But if you have the materials like clay okay so which is very sticky, these particles are very thin. The particles are attracted by the its own attractive forces. So those kind of soils are called as a cohesive soil okay, cohesive soil. So this soil basically is having the more attraction and more bonded.

But this soil is having the less attractive and less bonded. So this kind of soil okay the cohesion less soil which saturated in the earthquake sorry saturated in the water, when earthquake comes okay so this saturated water create a additional force to the water. So the per pressure get built up. So this contact between these particles basically lost due to the that vibrative force and the additional force created by the vibration.

Then this soil particles start flowing okay. So the flowing like the solid became a liquid. So that stage called as a liquefaction. So this is the typical places where you can see this is actually a original ground. You can see that without liquefaction. So after liquefaction this entire ground become like this, you can see. So the mud will be ejected and the all the water will be coming.

So which is like the dissipation of the pore pressure occurs. So this is the typical soil where this thing. So this kind of liquefaction generally occurs on the cohesion less soil. For example silt, sand, gravel okay. So this kind of combination of this kind of particles will cause a liquefaction. So this liquefaction occurs on the a plain land so nothing to go to happen. But it occurs below the building okay. So then you will have the damages.

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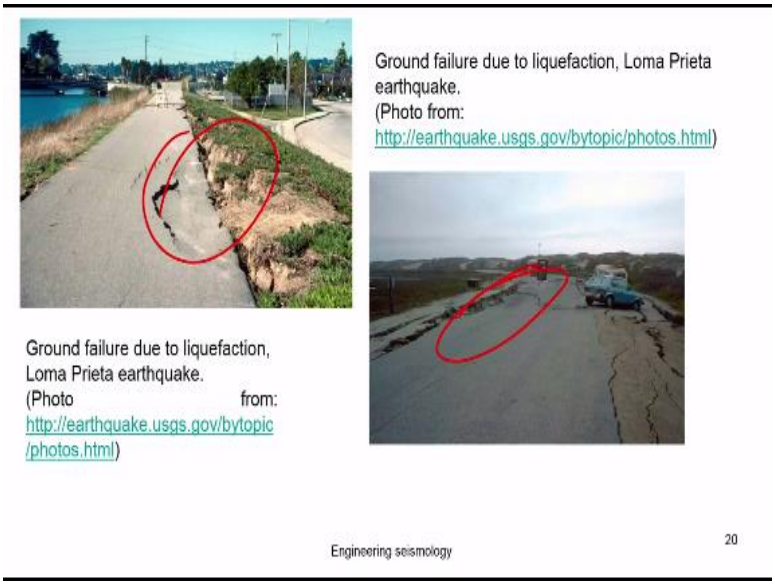

So this is the typical liquefaction occurred okay so below the embankments or a dam structure. You can see that the failure of this kind of things happens below the layer where the particles are get separated and the shear strength become a zero. So you can see that there is a top layer get subsidence.

So similarly, this is the another road, where you can see basically the failure due to the top layer which is happened liquefaction due to the bottom layers in the place. So these are all the things are very dangerous, because you do not know which what layer

is going to liquefy. So that liquefaction in the particular layer will cause a one is that if it is in the surface you will get a things like this similar to that.

If it is in the below some layer you will that failure will cause a surface like this.

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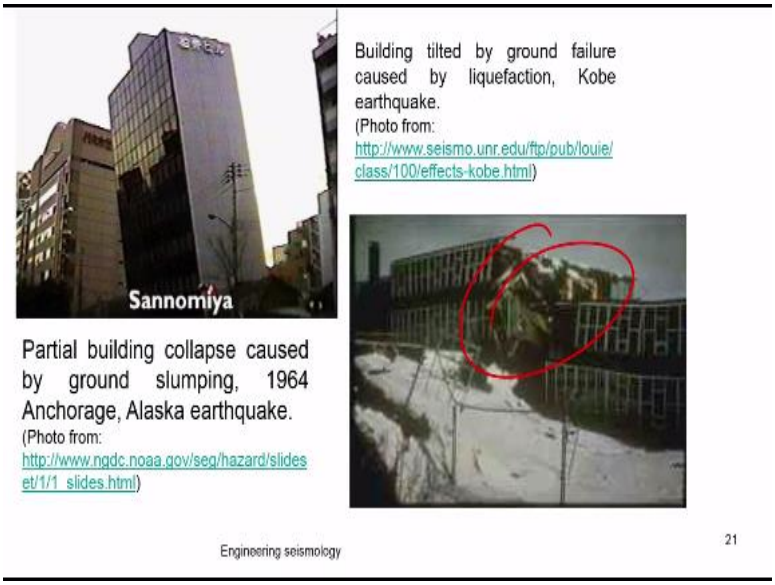

Even if sometimes if it is below the water body or below the this one where you are keeping your foundation. This foundation become a instable and it will rotate and tilt and failure. So this is the some of the building where the foundation okay where you keep a foundation below that layer is got liquefied. Because of that so there is a loss of bearing capacity and there is a huge settlements which try to tilt a structure.

You can see that the original structure basically tilted because the soil below the foundation is liquefied okay. So similarly, there is a partial collapse because the part of the soil basically liquefied in the entire building area, where you can see that there is a partial collapse due to the this kind of liquefaction at foundation level. So you may not see the liquefaction at surface but the liquefaction happened at below some depth okay.

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So these are need to be considered while you designing the new building or you are retrofitting the new building for the earthquake. So the another hazard is actually so as we said that so the earthquake can cause a different way. So when you have the nowadays in India, you might have seen that the GAIL actually putting lot of gas pipelines on the different cities and as well as villages and different places.

So this pipeline okay as you know that it is a pipe which is connected with a joints and then whenever there is a change in the direction they will put a bend and then different connectivity and valve and all those things. When earthquake are occurring okay so this joints and pipe should capable of taking that vibration. So in case if it is not able to take that vibration, the pipe breaks or cracks, okay.

The gas kept in the pipe will be released. That gas will cause us a fire. So that kind of fire will destroy you and your city. So this kind of fire hazard is the another induced earthquake because the earthquake does not cause a fire, but the human development such as a gas line or such electrical line cutting or short circuiting will cause a fire.

So this was a big major issue in the Loma Prieta earthquake and San Francisco earthquake where this gas line okay so and then the electricity caused short circuiting that created a fire. That fire is not controllable in the throughout a city. That entire city got fired and it got huge amount of the damage. Even though the buildings are intact, but because of the fire, it got a problem.

So those who are visited the San Francisco basically if you go San Francisco you can see that in San Francisco State, every street corner and with different spacing interval you can see the fire hydrant pipes, okay the firefighting pipes. Why? Because during the San Francisco earthquake 1906 this earthquake caused huge amount of the fire where they could not be able to survive.

Many people are died, lot of economic losses. So when you have the time you can also visit a museum, how before fire and after fire, what are the steps they have taken it is explained. So from that time onwards people are very cautious that when earthquakes are come, you should also see that there is a possibility of fire occurring due to the earthquake.

Which happens basically non stable pipeline or electrical connections or such short-circuiting of this electrical connection due to the vibration forces okay. So which is the huge in nature. Sometime the building may be designed and the building may stand if the fire happens, still you will have the huge amount of the loss.

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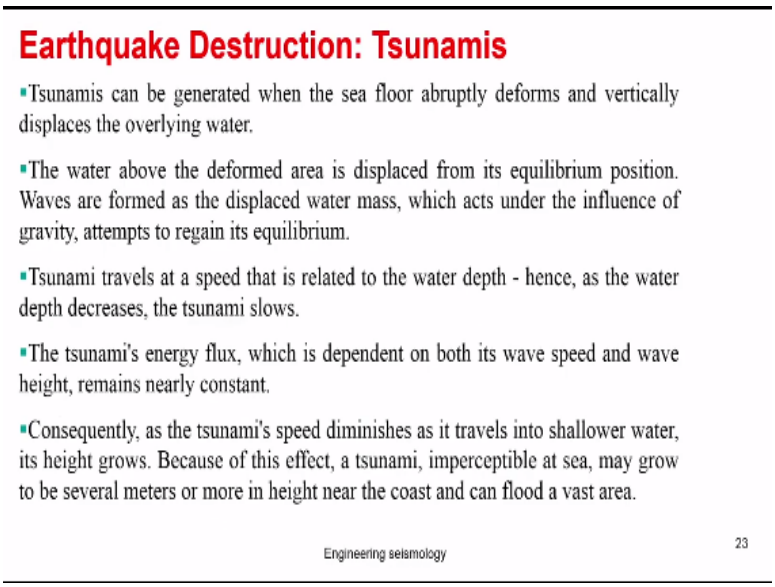

So the another one so apart from fire there is a flood. So flood generally happens when there is a dam or water body storage, okay. So even though I did not put explicitly slide here, but it is so whenever you have the dam or water body storage, okay, so when the earthquake comes, if the vibrations are not tolerable by this damn structures, that fails. So the failure of that not only result the collapse of the structure, the huge amount of the water stored in the dam will be released.

So that will cause basically downstream side flooding and which will cause a human loss as well as a economical loss as you know that the dams are basically temple of the country, where most of the people get a agriculture from the damn water as well as a drinking purpose. So this kind of buildings are very huge. So 2001 during the Bhuj earthquake actually there are several dams are failed.

So fortunately that time all the dams were empty. We did not experiencing the flooding. But there are many cases this dam failed due to earthquake that caused huge amount of the flooding in the downstream side many people died and buried alive and the lot of consequences actually.

So now our country actually after 2001 earthquake after understanding the lot of failures, okay, so now the dam agency like Central Water Commission, CWC. So looking at all the old dams, how these dams can experience what are the seismic forces, these dams are safe, we need to retrofit, if it breaks how many people will be affected, how much area will be inundated.

So what is the thing. So that is called as a DRIP project, which is called a Dam Rehabilitation and Improvement Program by the Central Water Commission. So where they got huge amount of the funding from the World Bank, they try to improve all the banks which is called dams, which is called as a DRIP dams, okay. So this kind of initiative is going on.

So maybe some of you who are taking this course also may be working on that. So you have to know that dam is basically what kind of seismic force is expected. The dam is stable, it may be the earthen dam or masonry dam or a concrete dam, does not matter. This dam is how much seismic force is going to express experience okay. So it is stable for that or not we should know okay.

So this is the flooding induced by the earthquake. So the next another well-known and major hazard of earthquake is actually tsunami. So the tsunami word itself very new to us. So last class when we are discussing about the perception and the knowledge of the old earthquake, I mentioned about the 2004 tsunami earthquake.

So many of us our generation we well aware about tsunami because of the 2004 earthquake, which caused many people die and then it has come in the news and most of us aware. So when earthquakes are occurring below the sea or below the water body, okay? So if the fault created by the fault rupture and it creates a vertical the displacement. So that vibration whatever caused by the earthquake will be carried by the water, okay.

So that vibration causes the increasing in the wave okay. So height, so that height will result in the flooding up on the seashore or the water body shore and which also results a additional water flows to the structure around that and the people will become a stable and they may be dragged by the this force and they will die. So you may be knowing that about a more than three lakh people died due to this 2004 tsunami.

These tsunamis are very common in Japan and other places, but India it is very rare okay. So but during in the last 50 years, we experienced only the 2004 tsunami. There was a tsunami which was experienced very long back, but those things only we could able to see by the paleoseismology study. So knowing of this tsunami can occur or tsunami can be induced by the earthquake or not is also important.

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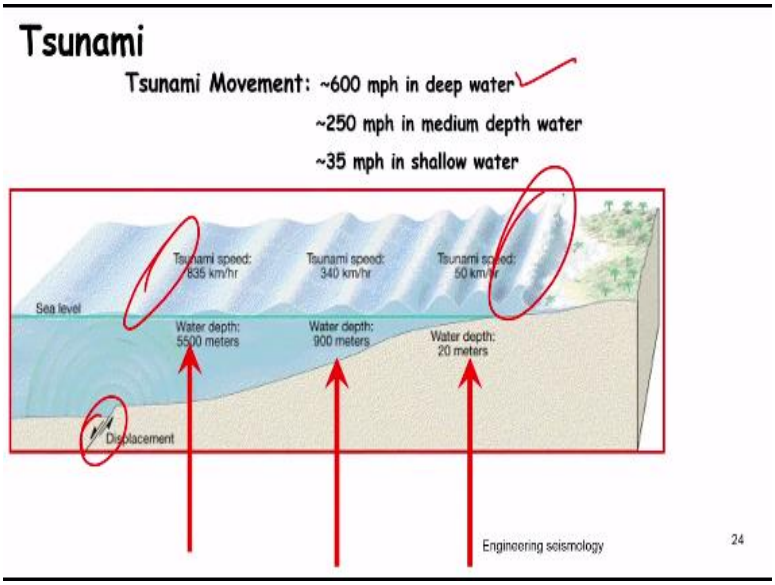

Why because this tsunami will cause a huge amount of the force and many people and die and lot of economical loss. So how this tsunami occurs. If you look at the this is a

fault or seismic source. So it ruptures and breaks and releases a vibration which causes a the vibration forces to the water. So this vibration force is carried by the entire water column depth okay.

So when it happens when the middle of the sea or far away from the shore, where the water thicknesses are very large. So because of large the wave heights are very small. The way heights are small. But when this wave this energy get transformed to the entire water body, so this keep moving. So when it comes to the close to the shore as you know that the thickness of the water reduces.

So in order to compensate a energy basically the water wave height will increase. You can see that the waves are height keep increasing when compared to here and here. So okay. So then when come to the shore it will have the very big wave. So this is the speed at which it travels basically. You can see that in the deep water it is this one. In the medium depth water this so much. The 35 kilometer per hour and this one.

So the beauty of this is actually even a very long distance earthquake like 2000 km, 3000 km earthquake okay away from you also can cause a damage to you. That is the tsunami wave causes. As you know that 2004 earthquake the Sumatra okay, it was roughly 1500 kilometer away from the our place okay. That caused there and it took about a two hour to reach a that seismic waves carried by the water body.

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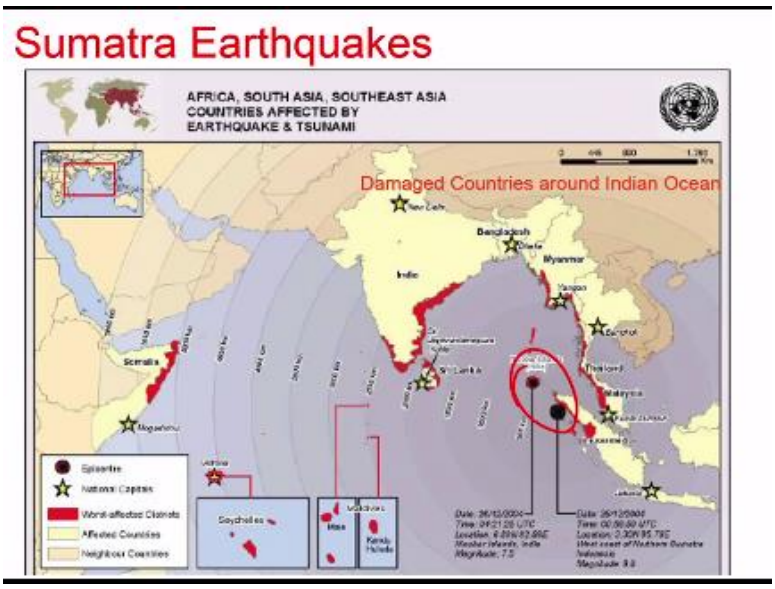

And it comes to the shore, which created a huge amount of the loss. So you can see basically, this is your seismic source where the earthquake are occurred. Then this waves are traveled at different speed. You can see the speed is written here actually. So when these waves are approaching the shore, okay the height of the waves become a enormous, which is not sustainable by the human being and some of the buildings which caused huge amount of the human life loss as well as the economic loss.

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So this is the typical Marina Beach photo during the 2004 earthquake. You can see basically this is the original sea. So you can see how much the water was inundated. So this is basically road which you go by vehicle and get down to see the beach know. So this is basically a road. This is the up to this and then flooded further.

So that day people who are in the beach and people who are gone to walking and seeing many people died, okay. And here one interesting things to know that so generally when tsunami occurs, people has to move away from the coast. Since our people does not have knowledge about the tsunami, many people went to see how tsunami is coming. Because when there was a before tsunami comes actually the water will recede back okay.

It will go inside and then come back. So while going inside actually if you know that it is big waves going to come you can run away and escape. But people thought that it is something a peculiar phenomena, they went and see how far it went inside. Then

when the big wave comes, they are all stuck and died. So because this is actually lack of knowledge okay.

So any water body which is behaving unusual okay than the usual you should immediately run away. Otherwise you will end up in the problem, okay. So that is the common lesson we should know. So many people, even highly educated degree holders and people who are went to walk, they are all went and see how the tsunami waves are, why the sea went inside without knowing the tsunami going to occur.

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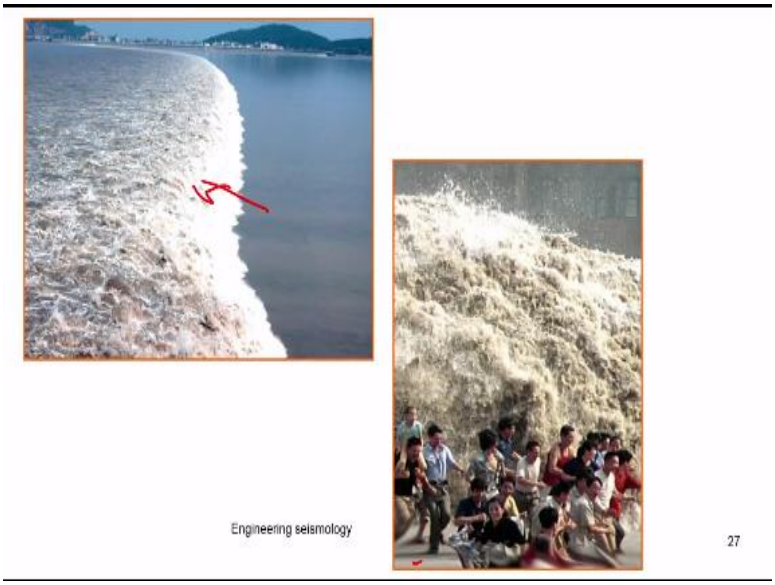

You can see the height of the wave which caused by the tsunami. You can see basically it is close to the shore, you see how much it is. So when it comes to the shore the land you can see how much we say it is a normal human being you can see that four times five times the waves are get high. So whatever you run basically you will be dragged.

If you are lucky enough, you are holding something at least you can escape slightly from this kind of hazard. So it necessary for the places where the coastal regions these hazards are very high okay. So the coastal region we should know if there is a possibility of tsunami, if there is a possibility, how to minimize that, how to reduce that or how our structure can be constructed against a tsunami okay. So this is the major hazard which caused there.

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So this is a typical photo. You can see basically the water was inundated to the very high level where you can see the car and other thing. So this is after tsunami where the all the non-stable or the permanent fixed objects okay. So the object which is not permanently fixed with the ground is moved considerably from the place and this is the typical photo of the after tsunami, how the vehicle, car and all those things are happened.

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So this is basically a satellite photo of the waves. So where you can see that the normal wave and tsunami waves where you can easily see the big rays of the waves okay. So that is in the satellite. So these kind of hazards are very dangerous, okay. So with this actually so we have discussed today, like what are the different type of

earthquake hazard we can expect. So we have seen that there are two type of earthquake hazard.

So one is that the direct okay shaking which is like the ground shaking hazard or the ground displacement which happens due to the direct vibration. The another one is the induced hazard. So the induced hazard is basically when earthquakes are occurring the vibration caused by the earthquake will induce this kind of hazard. So we studied seen how the this induced hazard of landslide can cause.

What are the consequences that we have seen. And then we have seen the flooding, and fire and liquefaction and tsunami. These are all the induced hazard. So even though these hazards are happening at different places due to different earthquake, at one particular location these hazards may not be the, all of them may not occur, okay.

So for example, you are living in the hilly region where you have mostly found a loose material which is cohesive in nature, you may not experience a liquefaction. You may not get a tsunami also, okay. So if you are living in the close to the sea you may not expect a landslide. Most of the sea terrains are the flat in nature. So it is specific to location.

So based on the particular location these hazards need to be estimated and you should consider that force in your design of building our infrastructure so that you can reduce a damage due to this hazards. So for example, I can give you a typical list of hazard you can expect in the place like Delhi. For example, if you want to see what are the hazard possible due to the earthquake in Delhi.

So you can expect a ground, direct ground shaking. The ground shaking direct ground shaking is basically common for irrespective of the location. So that you can expect. So Delhi basically there is no hill, there is no landslide can occur. And more or less there is no big dam, upstream of the Delhi so you do not expect a flooding also. So no landslide, no flooding and no tsunami also can come because it is not in the close to the sea.

So remaining hazard like the liquefaction may be possible, amplification may be possible, ground displacement may be possible and direct ground shaking is possible. So you should consider all these forces to be estimated and your structure should be designed for that okay. That is a classical example. Similarly, if you want to do it same thing for the Mangalore okay, so what are the possible hazard.

So you will need to add a basically a Mangalore basically close to the sea. So you can expect basically a tsunami hazard okay. That is also one of the major component. So since it is also sea with sand you can also expect a liquefaction and direct ground shaking and amplification. If some part of the Mangalore even you have the hills.

So okay where the Mangalore airport basically on the hill, you can also expect some landslide there. So it should be assessed depends upon the geographical location and different possible hazard. So first thing is any place you should first identify what are the possible earthquake hazard at particular location. Once you know that then you can work towards try to estimate that precisely and try to design for that.

So that is the reason before starting our the entire course content, this chapter discusses the different earthquake hazard occurred in the past earthquake okay with example with the Indian typical cases. So with this we will close this lecture. So since last three classes we have discussed the different content. So what are the typical questions okay you can expect on this basically.

So you need to know individually like particular cities told you, you should be able to know what are the list of earthquake hazard you can expect. And then depends upon the different continent level which one is major. Like economic loss is major or human loss is major you should be able to tell. And then how you can prepare yourself institutional way as well as the individual way to minimize the human and economic losses due to this earthquakes.

So that also can be understood. So all those things understanding and reading on this direction will help you to tackle some of the questions. So thank you. We will see in the next lecture.