Introduction to Engineering Seismology
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Lecture No-29
Recapitulation - 1

Vanakkam, so we will start today our lecture continue from the yesterday class. So, so far what we try to do is actually we try to understand how the earthquakes are occurring. So how the olden days the earthquake was understood by the people and then what are the hazard earthquake can cause? So what are the different types of natural hazards? So followed by how this natural hazard causes the disaster?

So then among the earthquake what are the different type of possible hazards are there? So then followed by how to measure the earthquake? How to classify the earthquake, so then the earthquake mechanism, how the earthquakes are occurring? So where it is occurring? so all those things we try to understand.

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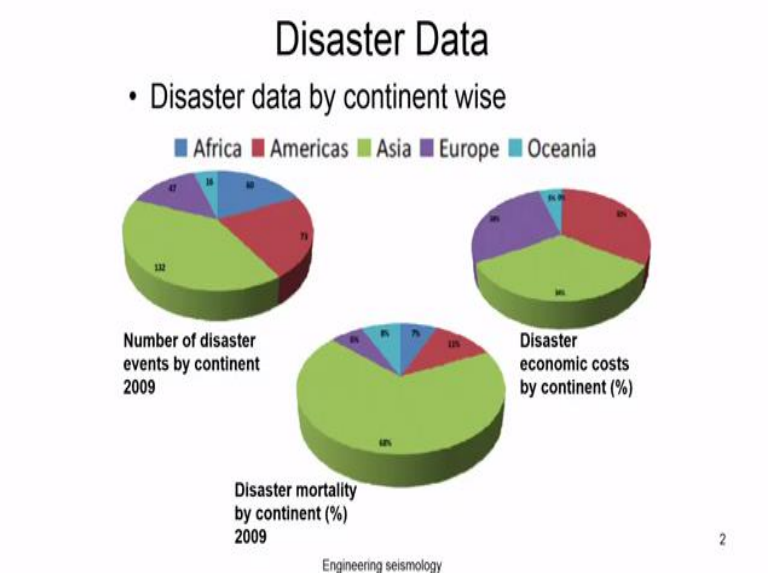

So fault mechanism and so many things. So followed by we also seen that is how to record the earthquake and instrumentation and how to quantify the earthquake basically? How to quantify the earthquake, that also we were actually started understanding that. So then how to interpret a

recorded so data using the wave propagation theory. So how to interpret the record, we in the prospective of the seismology as well as in this prospective of the engineering.

So we have seen time domain parameter frequency domain parameters. So how to interpret all those things we have seen and we also seen that this interpreted data further used to derive a predictive models in the earthquake as I told you that this predictive models are very important to estimate your earthquake hazard or predict earthquake hazard. So whatever knowledge we gained so far basically the understanding of the earthquake.

So which is a seismology part more or less is predominately what we covered was actually seismology part. So this understanding of the earthquake only will give you the proper way forward for predicting the earthquake hazard. So the next part is basically the application using the knowledge what you are gained, in the engineering prospective. So, before going to the application as we have covered different variety of subjects starting from the natural hazard to the earthquake parameter prediction and the then predictive equations kind of things.

So it may be necessary we should recap what happened in the so many classes with highlights on the different part. So that it will be clear even if you are not something is clear on the earlier. So now this recapping, so the revision of this part is will be useful because next hour we are going to talk about the application how this knowledge what you gained will be used for the application.

So that is what we are going to talk about. So before going to application part, so, we have to understand and recap the; what we have done. So the next couple of hours I will be talking about the highlight of the each and every content what we discuss in the class. So that even the previous version video, you are not able to watch or you did not time to skip or something was happened.

This recap will help you to gather the very important aspect of the seismology part of this one, so the application before that. So we started basically try to understand the continent wise so how

the people are basically; also experienced a disaster and different continents so that is what we started the initially. So we started discussing about the number of events that continent wise.

So there are about 5 major continent we can group them like Africa, America, Asia, Europe and Oceania. So among that we have seen that the Asia is experiencing the very large amount of the disastrous event. So this disastrous event includes all the hazard; so, including earthquake hazard. So it includes all the hazard including earthquake hazard. So we also seen that for this percentage of share. So how many people will die how the economical losses?

So if you look at very carefully, so in Asia we found that around 68 percentage of the people die due to the this kind of natural disaster. So natural hazard when compared to any other continent. So we also highlighted that say even though it is 70% of the people will die the economical loss with respect to different continents. Ours was almost equal to the, so the European and the America continent because of the cost of living difference.

So these are all the way we try to understand how the disaster creates impact like how many people will die? What is the economical loss we face during the earthquake? So our economical loss is not so much but the human casualties are more in Asia which may be because we have been highly densely populated. So that means many people live in the small area. So that is maybe the one of the reasons.

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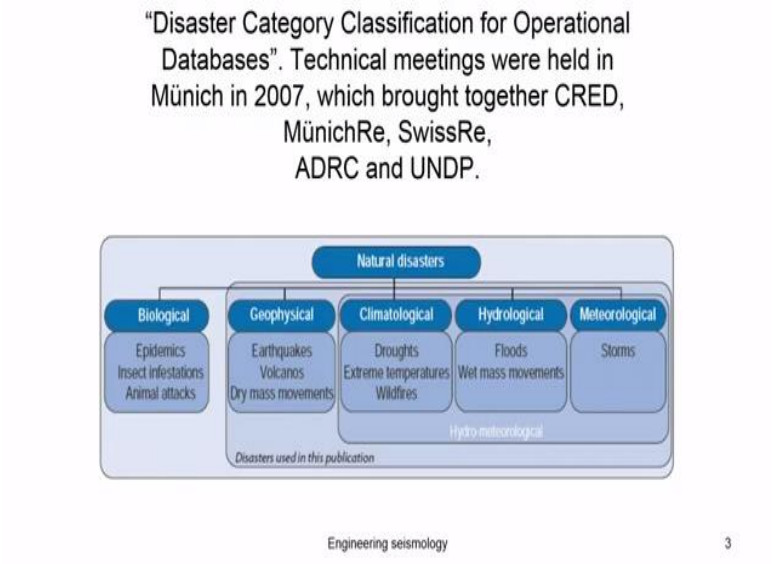

So this disaster includes about a 5 major category disaster, which is like a Biological, Geophysical, Climatological, Hydrological and meteorological. So right now the hydrological and then the meteorological events are able to predict the considerably, so the disaster or the mortality; so the number of people die due to these hazards are reduced considerably nowadays.

So the biological things are still challenging as you might have seen that so we have been facing this Covid 19, so now which is one of the biological related hazard. So which is causes many people to die and lot of lockdown and the economical issues all those things basically biological hazard. So which is somehow can be controlled or minimized, some way of practice or doing some kind of traditional medicine or something like that.

So the another hazard, so the climatology, which is a drought and extreme temperature and wild fire. So this also we do not have much control but generally these are all the problem in most of the case in forest regions, very hot regions kind of things. So the another hazard, which is predominantly causing the lot of death and the economical loss due to the infrastructural development problems.

So those are all the geophysical hazard basically they are earthquake, volcanoes and dry mass movement. So where your construction quality or construction practice or the construction design is not capable of handling these kind of natural events, which will cause a death and as

well as this one. So that is what we try to understand. So the geophysical hazard consists of three parts so among that the earthquake is actually the more pronounced one among the all these 3.

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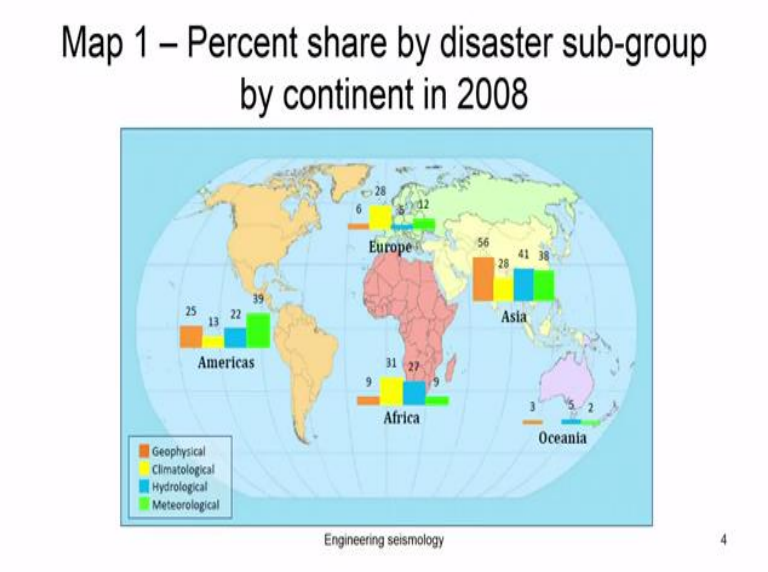

So we have be seen that other percentage of the share disaster with respect to each subgroup and continent wise again. So these maps clearly source the 5 major continents and also the each subgroup you can see that the Asia the number of event share on geophysical is are very high when compared to any other continent. So, the other hazard basically the metrological and then so are very high in American continent.

So but it is slightly less in our place but the mostly these are all the hazard where you can predict, these are all the events where you could be able to predict using the state of part knowledge nowadays available. So these events the failure or disaster are the whatever happens due to this kind of events other than geophysical are able to control with the human knowledge and then the traditional practice.

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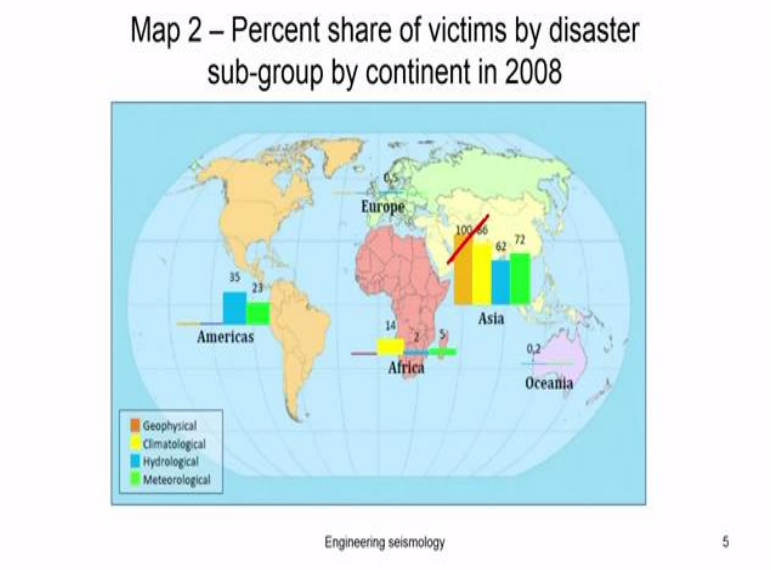

So this is actually the number of people die with respect to the each hazard type. You can see that even though 56% of the geophysical hazard is expected all over continent, in the Asia is 56% when compared to all over other continents. So but the number of people die due to this geophysical hazard actually 100 when you compare to any other continent. So that means if the 100 people die due to the geophysical hazard that 100 happens in only in Asia.

So, but if other hazard you can see that our percentage is actually not very low but relatively smaller like when compared to geophysical hazard like 72, 62, so 86.

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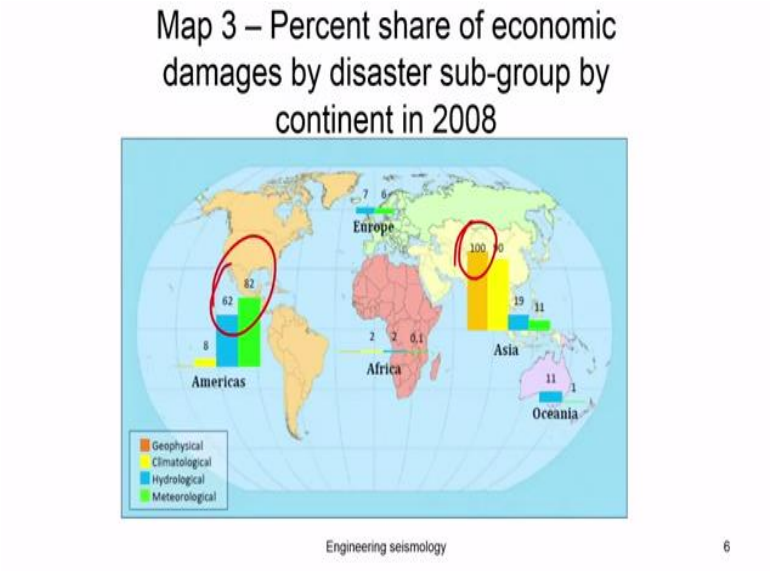

So the understanding of geophysical hazard a basically help to reduce the economic as well as the basically the, so mortality rate or death rate in the, Asian countries even the economic loss what we face also very high particularly on geophysical hazard. But other hazard where the economical loss is very low you can see that the basically the hydrology and metrological hazards are very high in the economical loss created by these hazard is very high in the America when compared to other continents. So that is a things we can get.

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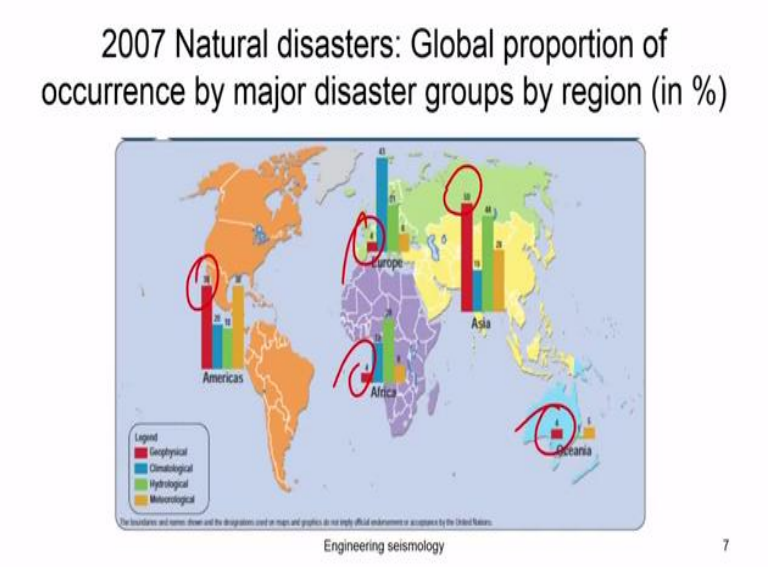

So the overall, the global wise, so the occurrence these hazard natural hazard portions, so which we have seen that the Asia is always around 50, 60% of the occurrence we can expect so the other continent also you can see the occurrence for example here you can see around, so 34 so the 50 and I am only talking about the geophysical hazard you can see here, so this is the percentage difference.

So basically this two the global portion occurrence of this but because of occurrence of this how the risk we are? So how our future or our number of death and economical loss for this kind of hazard so for the predicted.

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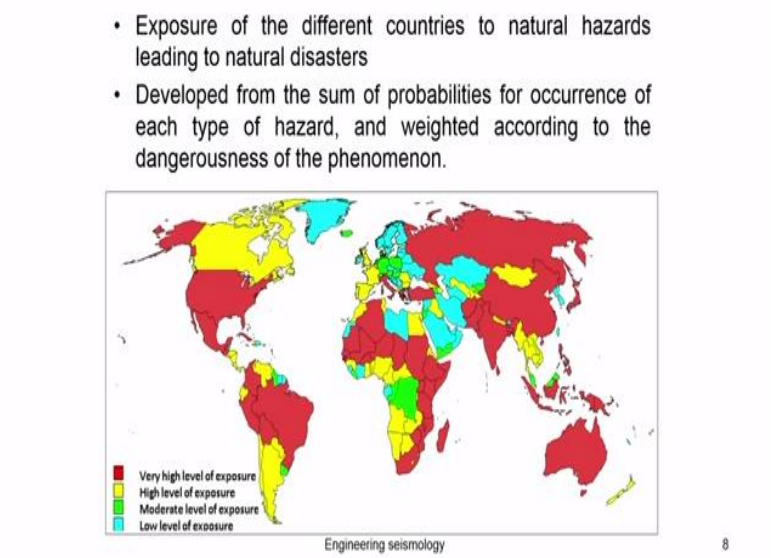

For the future you can see here, so the level of exposure, so that means level of exposure means so how many events how much you will expose so the red part goes a very high level of exposure, so the Asia, US and then the many part of the world is that as then the yellow portion. So remaining the green and blue so but because of this exposure, how we going to affect or risking our self on, so these things is the question. And that the prediction model done by the scientists.

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Show that so even though the risk is very high at a several developed countries, but the, number of event expected on those countries are very high but the risk due to that event is actually

moderate to low. So that is what you can see US, the previous slide it was completely red. Very high level of exposure for the any kind of disaster but it is a moderate to low level of risk.

So exposure is very high but the risk is moderate and low, but if you look at same with respect to Asia, you can see that the, exposure also very high and then the, risk also very high. So this as a several reason for that so one of them is improper knowledge, improper preparedness, so improper construction practice, so improper code of practice, so high density population, so these are all the some of the issues which makes even a high level of exposure, high level risk where the western countries or developed countries.

So high level of exposure but the moderate and low level of risk. You can see here so the low and moderate level of risk. So which clearly indicate that the disaster towards particularly the disaster towards earthquake or any natural disaster, so we need to upgrade ourselves to handle this properly.

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So the, handle this properly we need to upgrade, so the one of the way to mitigate and the earthquake risk and preparedness to solution for all this things, so mitigate and reduce the risk is basically you have to go for the earthquake preparedness guideline are required. So what we should do to do those kind of things, so we have discussed that we have to try to understand the perception of the origin of the earthquake and the propagation of the seismic wave.

So that is what, so first we have to understand earthquake, if the earthquake comes our seismic waves travels. So these two are the very major component the first and the priority component of the reducing and the minimizing the risk. So that is what we try to understand in our course as on now. So then once you are done that, so once you are able to predict, so the time domain parameter of frequency or predictive equation whatever.

So then you could be able to have the your the expected seismic hazard at the particular location, so then you have to understand the structural pattern what we built to house? What we construct? How this kind of structure behave for a this predictor hazard? So the understanding of the behavior of all kind of structure under the seismic action which you understand here. So first step one whatever in it, so then once you know, that this structures are sustained these structures are not sustained, then you go further rehabilitation and retrofitting of the existing structures.

So that is a very important steps to minimize because as I told you that the earthquake never kill people only the structures which is build by the engineers or insufficient knowledge people will collapse with the causes lot of so mortality as well as the risk. So the development of appropriate code of practice and giving the design values and the guideline to construct the building, so will help to reduce this kind of hazard.

So the development of quality control to ensure to a correct application all legislation are the another important step to implement all those. So if you follow this steps systematically so you can mitigate and minimize the risk due to the earthquake or the death due to the earthquake or economic loss due to the earthquake.

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So that is why the understanding of earthquake is very important. So that is what we discussed in the first, like a couple of hours, so I have given you overall global picture what we have discussed why it is important so even this information will be useful to handle your class. So within the earthquake, so once you identify earthquake as a metal, so then we have to understand perception of the earthquake. So the earthquake events occurs so earthquake is part of geophysical hazard.

So which is a component of 5 major hazard in the world, so in the earthquake the earthquake can cause a different type of hazard. So what are those hazards, so that also we discuss the earthquake can cause here direct ground shaking, so the ground displacement and the flooding and landslide and liquefaction and fire and the Tsunami, so these are all the different type of hazard, one can expect from the earthquake depends upon the site condition under the infrastructure facilities and different things.

So all of them may not be possible at one place so, but most of them possible at few places. So something like that, we have to, these will be these hazards will be very specific. So we try to understand when this hazards are happen what really happens in the from the past earthquake? So we have been talking that the ground shaking hazard.

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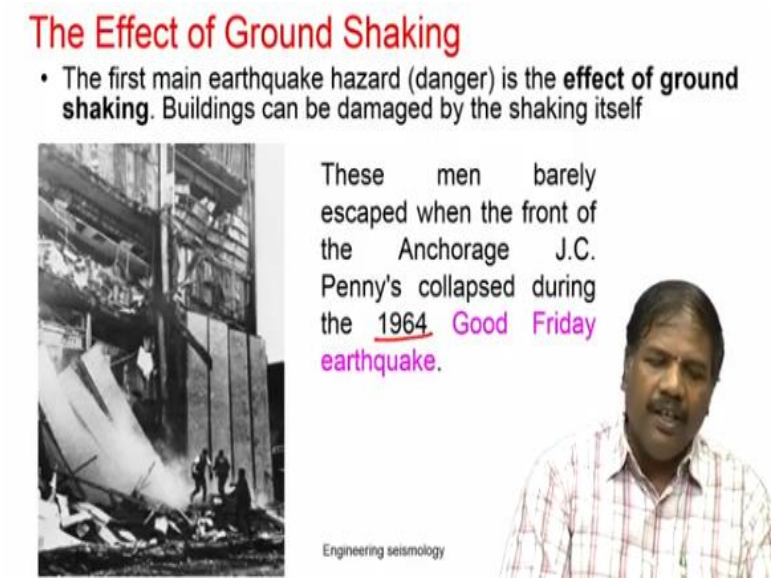

So the ground shaking hazard basically, it is a direct shaking of earthquake like vibration created by the earthquake, if the structure not able to handle that vibration then it will collapse. So those kind of failures are called as a ground shaking hazard. So generally the structure which is not designed for a vibration, only static they consider they did not consider the dynamic even they consider dynamic but they consider a lower level.

So those kind of structures are may expect to fail this kind of ground shaking hazard. So, this is the typical example where you can see that a big disaster happened. So during the Good Friday earthquake in 1964. So this is the one of the classical example where the earthquake shaking cause that means the structure was stable usable during the normal condition. When earthquake comes this structures are failed basically a structural components are failed.

So this kind of failure basically happens due to the failure of the structural component, which is not capable of handling the load. Those kind of shaking effect is called as a direct ground shaking effect.

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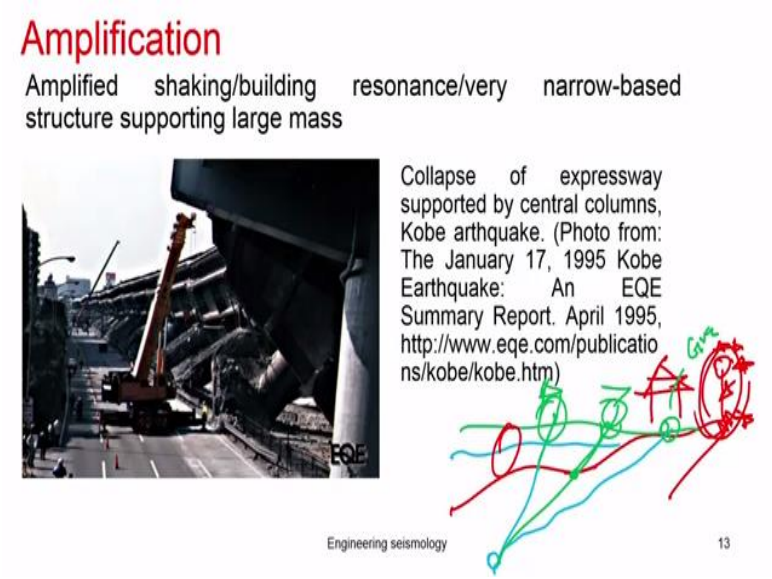

So, this is the one of them the second one is actually. So as I told you that, when the seismic waves propagates waves from medium to medium; so from the seismic bedrock to engineering bedrock to the surface. So because of the change in the medium material stiffness and thickness. So this undergoes here wave propagation, wave modification. So that causes a wave changes that we discussed as a amplification.

That amplification produces a additional force to the structure that causes a collapse. So here the structure may be considered but because of the your, amplification effect. So the, what force you are consider is insufficient. So that causes here has amplification based hazard. So basically, so this is the place where you can see that house you are constructed. So this is actually the region, so where this is actually the bedrock.

So Just I will give you the brief overview of the what is the amplification? Why it occurs. So this region basically filled with the soil. So you have the soil here. So when the earthquakes starts from here, so its radiates on different direction. So basically if you have the house here and then house here. So depends upon the wave at this place and this place. So basically, you will get a different dynamic force or vibration level which you are, that is what we have seen in the wave propagation theory.

So a particularly some of the structures which comes fails, this will be the direct ground shaking hazard. So this is due to the amplification of the waves due to this portion this power. This is basically amplification due to the soil medium. Sometimes the structural configuration itself not sufficiently designed to take a vibration so that causes a failure, so that kind of failure will call it as a basically amplification failure.

So that happens for example this is a typical bridge side. So where the mass of the bridge generally the bridge you have the pier then there is a foundation hidden below the ground and the top of the bridge you will have the roadway which is generally the wider in length. So these dynamic force what it comes basically. So as we all seen that when the medium is like that, so this dynamic force get vibration this is keep shaking.

So this shaking is not accounted the natural period of this system and then this stiffness and height is not modeled the properly are not understood how it behaved during the this earthquake waves. This causes here imbalance between the head and the foot, so that create a collapse. That kind of collapse also we can say it as a due to the amplification waves due to the structural system.

So one is the amplification due to the soil system, which is called as a soil amplification. So another is due to the structural system; the stiffness difference, mass difference in the structure will create a imbalance between the base and top. So, those who are I mean sitting in the seismically active area or people who are experienced earthquake, so if you are living in the apartments, which is relatively tall enough, so people living in the basement are the ground floor will experience less vibration than your people living in the ten storey are 12 storey.

Because of this mass imbalance and the shaking level created by the vibration or the amplification effect of the waves due to the structural system. That kind of things also call it as amplification, this is the typical study which is caused due to such kind of amplification the bridge got collapse, so this is the typical study.

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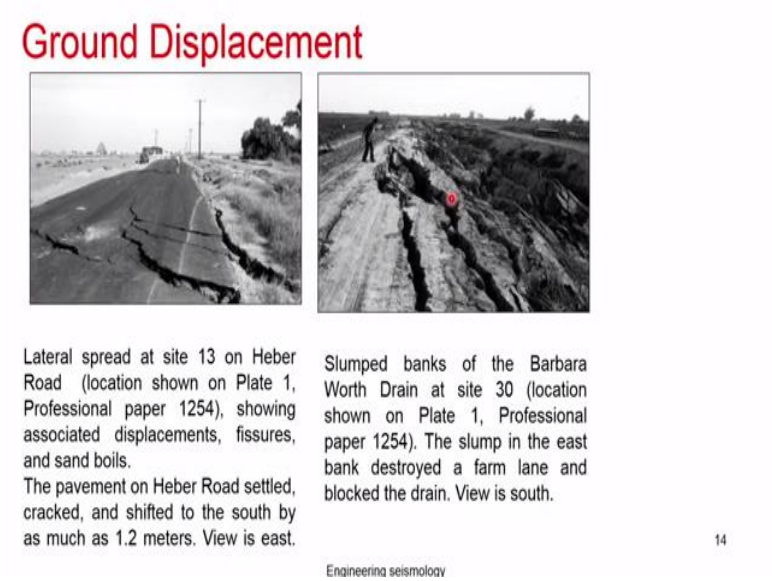

So then next is the ground displacement, so the ground displacement there is a permanent displacement, caused in the ground due to the earthquake, which happens the generally because as we know that the soil is actually assemblies of the particles. So this particle size varies from micron, so two micron, three microns lowest size to the 50 mm, 100 mm, 200 mm to the largest size, it depends upon the geological formation and which area it is; all those things.

So when the particles the individual particles coefficient less soil where the particles you can see by the plane I, so that particle is we call it as a coefficient less soil this soil does not have much attraction between the particle. So those kind of places when the vibration comes this vibration basically try to move the particle. The moving of particle basically result in the moving of the ground layers.

You can see this is actually the ground layers moment. So which causes basically the permanent ground displacement is the typical maybe the road where the moment is caused a crack and as well as the moment. Similarly this is another embankment where you can see there is a huge amount of the failure due to the displacement of the soil. This kind of displacements called as a ground displacement.

This happens generally there is a soil which has a less attractive forces of the particle which basically moves during the wave propagation during the vibration created by the earthquake. So that kind of hazard also is one of the major concern in the earthquake engineering.

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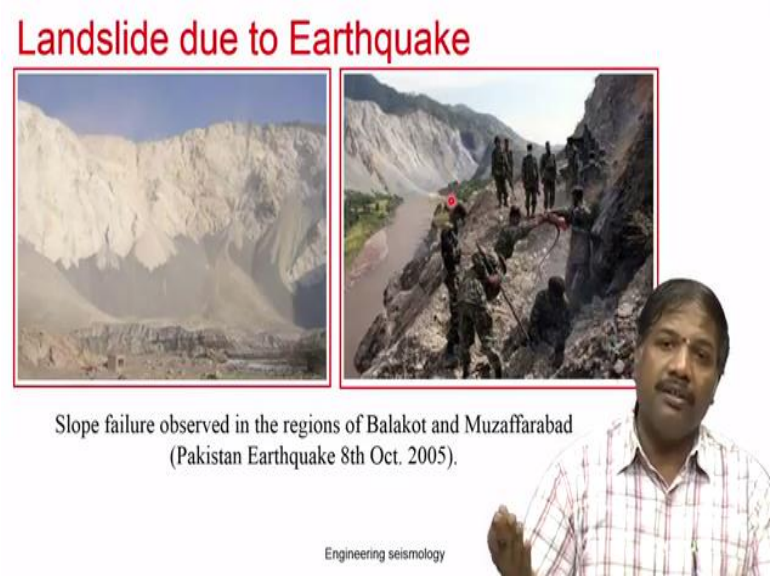

So the another one is a landslide, so this hazard generally occurs in the hilly region, so where basically the landslide is expected due to the loose deposit of the hill formation, so due to the shaking with the basically brings down the whats all loose deposit in the upper, this bringing out the soil basically blocks the road and then the several death and lot of consequences in the hilly region particularly the region like this Kashmir.

So the Sikkim, Tripura all the hilly terrain wherever the hills are there, so this is a one of the concerns. So the earthquake create additional force in the slopes which is become in stable and collapses and causing lot of disturbance and that disturbance basically landslide. So even a small magnitude, 5.5 or 6 moderate magnitude can cause 1500, 2500 landslides, so this was a some of the history where we can take it from the past earthquake. So this will be the another major hazard due to the earthquake.

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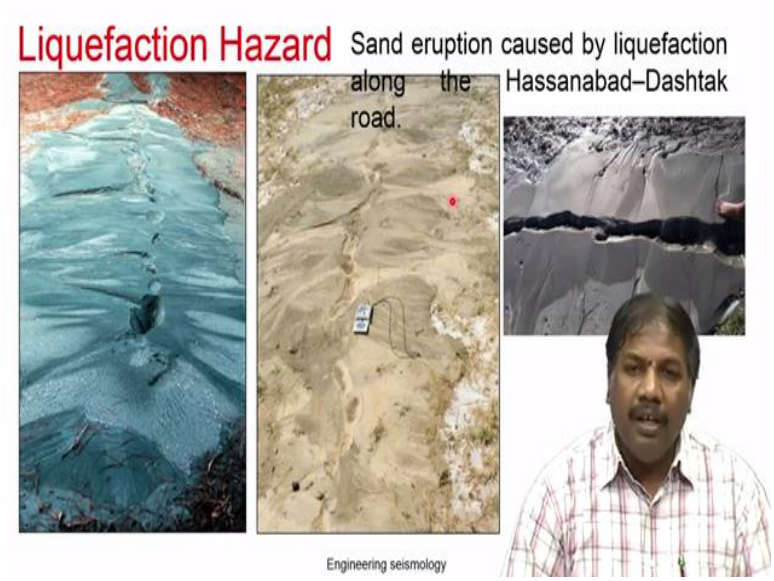

So we also try to understand liquefaction, so generally the liquefaction basically occurs in the coefficient less soil as I told you that when the earthquake comes the coefficient less soils are having the free tendency to move. When it saturated in the, this one the effective structure reduces to 0 during vibration time that instability and causes a ejection of that material out so this is actually surface features of the liquefaction.

So the understanding of liquefaction hazards are very important and this hazard also causes lot of damages so this has been noticed in the;

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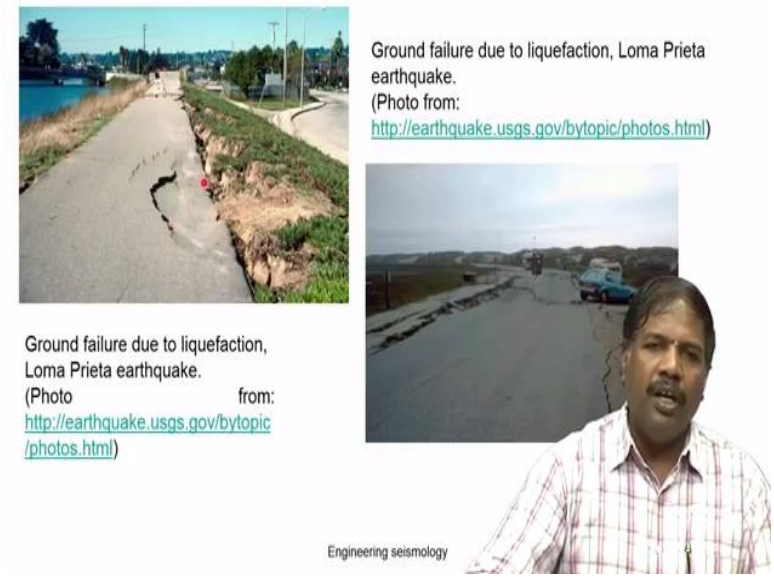

About several older earthquakes where it caused a lot of failure in the dams, houses and others this is the typical cases where the liquefaction caused the dam embankment failed, earthen embankment to fail this particles see here. So the liquefaction occurred below not that always liquefaction expected to occur on the surface of earth, it also can expected to earth, the below the earth surface and all those things.

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So apart from these things, the so these are all basically the earthquake on the soil related thing there are some hazard which is also related with the earthquake, so one of them is a fire hazard. So the fire hazard basically what happened, so as in the urbanized way people try to give the gas connection through your pipeline, to the all the houses this gas connection what it makes basically so this gas connection this pipes are not designed for the vibration to not able to handle the vibration during the earthquake, it breaks that leakage of gases causes a fire.

Or leakage of electricity, short circuiting will cause a fire, so this was the many earthquakes the fire was reported. This is one of the classical example of the Loma Prieta earthquake. San Francisco earthquake there are huge number of people died due to this fire not because of the earthquake that means the houses are intact people are not died but the fire created due to the leakage of the gas as well as the electrical short circuiting spread all over the city and many people died. So the fire also one of the major hazard among the different hazard in the earthquake.

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So then on after the fire so the another one is a Tsunami, so Tsunami things are expected to occur only on the places where the city located to the coast, so sea so the earthquake occurs below the sea or big water body the fault is located. This fault causes a vertical displacement, that displacement basically lead to the enormous release of the energy to the water.

That energy carried by the water when it reaches to the shore because of the less side, so in order to compensate a energy the waves are Increases its height wave amplitude are wave height that wave hit people who are near to the sea shore or other big water bodies that causes a lot of damage and people. This is the typical tsunami, so 2004 tsunami, so where people are running to escape from the tsunami, you can see how the wave height when compared to the normal sea level.

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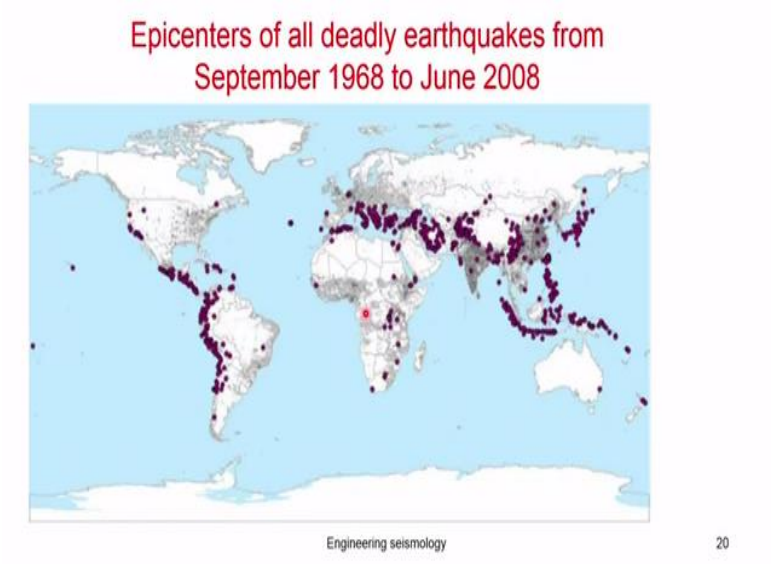

So this is the classical example, so all this hazard if you look at all these hazard how it is occurred in the last 50 years, so scientists are done wonderful job by collecting all this earthquake and a number of people died and then try to compile and understand that so this is basically the disaster or deadly earthquake among the world from 1668 to 2008, which is roughly about a 40 years of period.

You can see that these are all the earthquake which is disaster means basically deadly earthquakes, means more than 10 people died due to this. Then they try to understand among the different earthquake hazard which hazard causes a more damage, more death.

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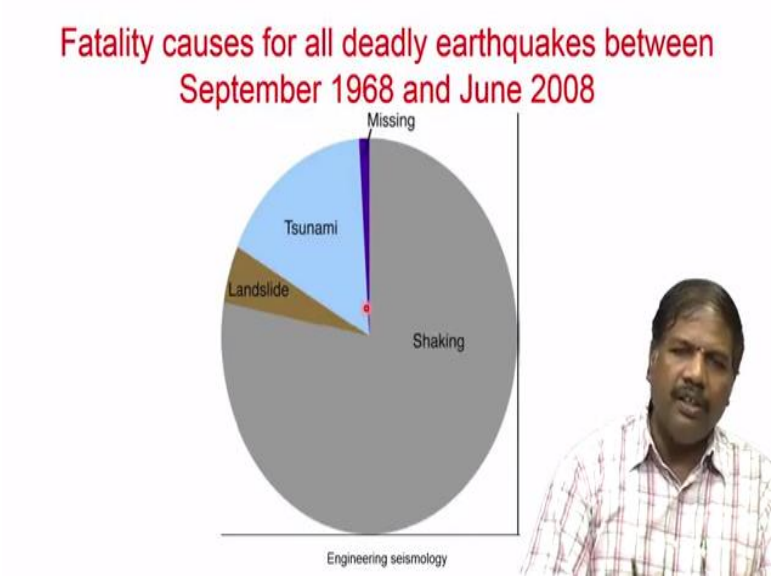

So this is basically the share of each hazard whatever we talk about the ground shaking, landslides, Tsunami, so the ground shaking includes amplification, ground motion, liquefaction all of them club together in the ground shaking as all of them related to the ground soil. So the landslide related to the hill, tsunami related to the sea. So that is why these are clubbed. You can see that more than 75% of the hazard has been caused due to the, this ground shaking kind of which may be direct wave or modified wave or wave causes liquefaction.

Or this kind of things are can be clubbed in that you can see a 70% of the shaking basically so it is done on that.

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So this is basically including the 2004 tsunami event, so if you, remove the 2004 tsunami event which has a large number, so you can see that close to 80%, of the hazard caused by the shaking, so the remaining major portion is a landslide remaining Tsunami and missing so the including 2004 excluding the 2004, so the ground shaking is the one of the major hazard which has to be considered in the design of building and then the settlement places where it has to be modeled properly.

So this is the non-shaking like if you remove the ground shaking hazard and then whatever hazard is there if you clubbed you can see that landslide, Tsunami and is a very major component

particularly landslides are the very huge it is close to the 70% when compare to any other all. So here the 2004 tsunamis basically removed.

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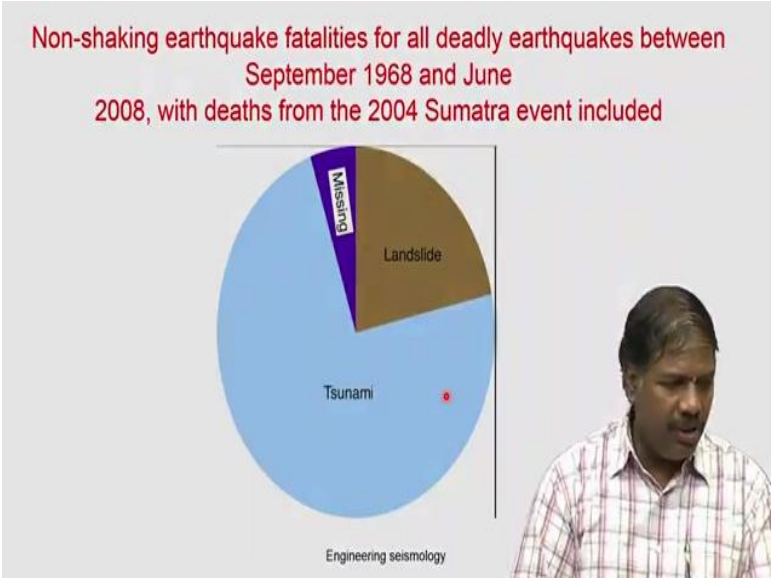

So the including 2004 if you see that the tsunami plays here major role that is a number of people died due to the non-shaking hazard including Sumatra earthquake actually Tsunami is a major component. Next is a landslide so these are all gives idea, how the natural hazard, the earthquake hazard and how it is important? How to mitigate? So all those things we have discussed in the about more than maybe two three classes in the last time.

But I just summarized all of them here to give the glimpse and idea of the recapping the what we have done so far. So with this we close this video, so we will recap the next lectures in the coming classes, thank you very much.