Earthquake Geology: A tool for Seismic Hazard Assessment
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Lecture - 21
Earthquake Magnitude and Intensity Scales (Part II)

Welcome back. So in previous lecture we discussed mostly about the different type of magnitudes and at the end we discussed about the importance of the moment magnitude and how the moment magnitude is being calculated using seismic moment.

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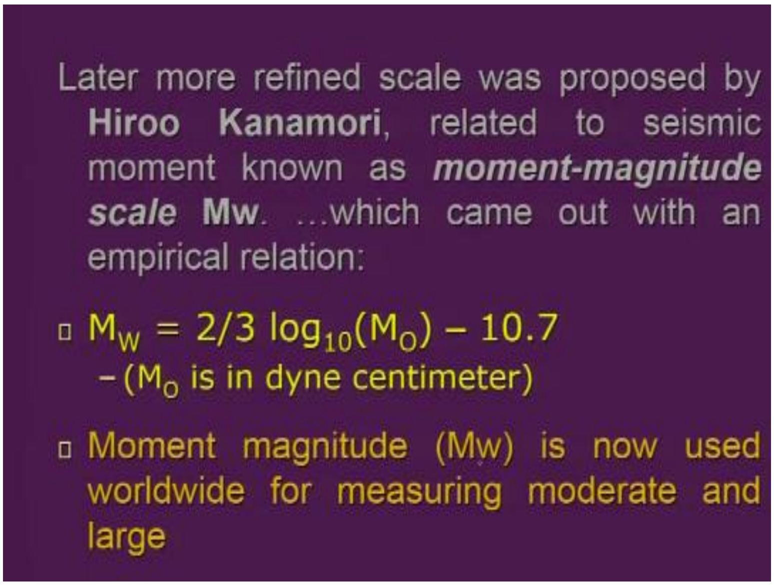

And this is one of the most accepted magnitudes scale that is your moment magnitude.

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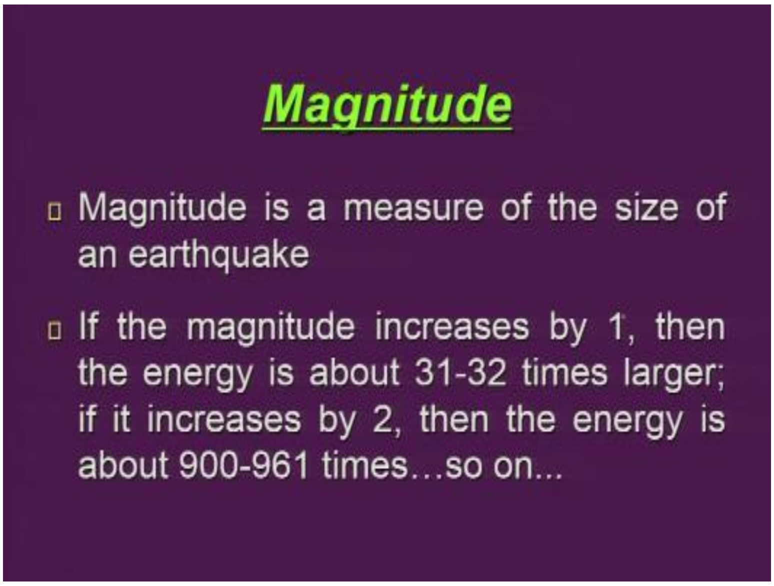

And further if you look at the magnitude in terms of the energy. So usually we take the magnitude is a measure of the size of an earthquake and if you increases the magnitude by 1 then the energy is about 31 to 32 times larger. So if it increases by 2 then the energy is about 900 to 961 times and so on. So you can make out with this that how much amount of energy will be required if you if are required to suffice 1 magnitude earthquake or maybe you can say 2 magnitude earthquake and similarly with the one magnitude.

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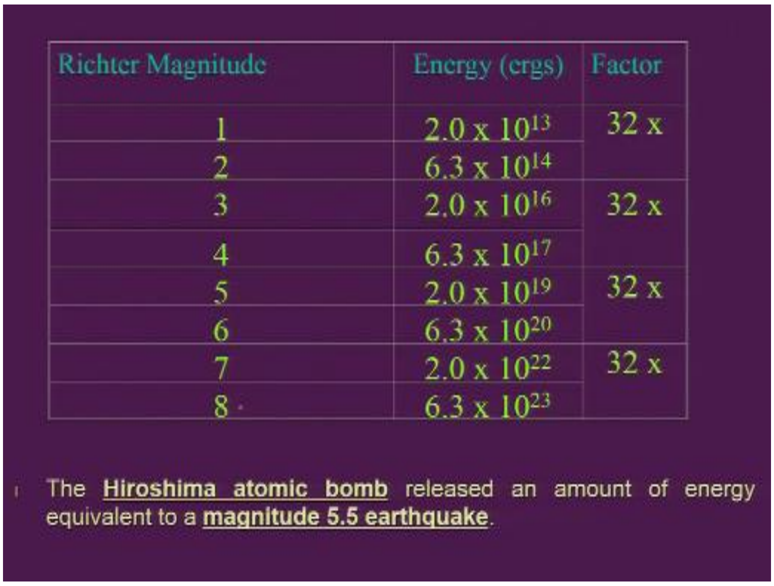

Richter Magnitude	Energy (ergs)	Factor
1	2.0×10^{13}	32 x
2	6.3×10^{14}	
3	2.0×10^{16}	32 x
4	6.3×10^{17}	
5	2.0×10^{19}	32 x
6	6.3×10^{20}	
7	2.0×10^{22}	32 x
8	6.3×10^{23}	

The Hiroshima atomic bomb released an amount of energy equivalent to a magnitude 5.5 earthquake.

So this is just to make you understand the table, but you have the multiplication factor you have of 30 to 31 or 32 and in case of the Hiroshima atomic bomb which was been released the amount of energy which was been released was equivalent to 5.5 magnitude. So this was almost a very small magnitude earthquake. So you can understand that how much amount of energy will get released when you are having the earthquake of 8 magnitude.

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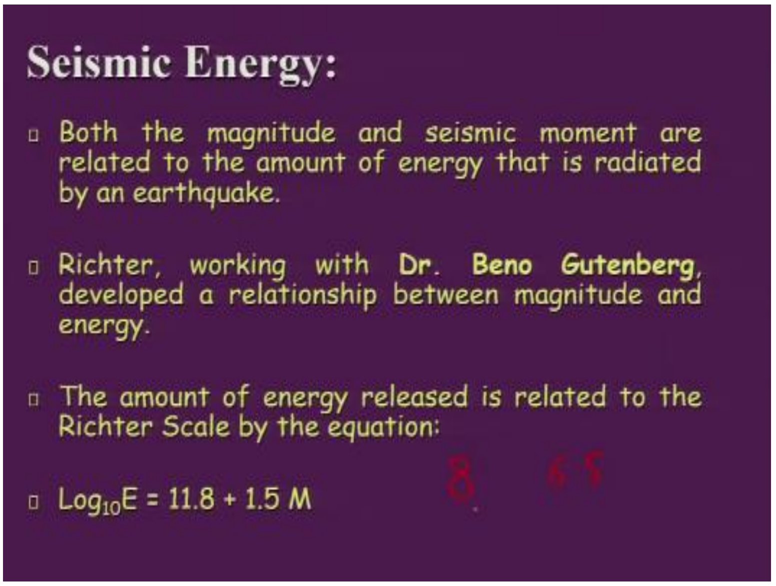

So seismic energy both the magnitude and the seismic moment are related to the amount of energy that is radiated from an earthquake. So Richter working with Gutenberg developed a relationship between the magnitude and the energy. So this is helpful when you want to understand that how much amount of energy is really required to suffice and for example if you are having.

So this is the equation which has been given Log E = 11.8 + 1.5 this is in magnitude M. So if suppose you are having the earthquake of 8 magnitude expected in the region and you are having several numbers of 6.5 magnitude earthquake which are recurring then you can based on this you can calculate that how many earthquakes you will require to suffice the energy of earthquake with magnitude 8.

And how many earthquake in sense for 8 how many earthquakes of 6.5 will be required. So even 6.5 earthquake is considered to be damaging earthquake in some of the regions where we are having poor construction and all that, but the ongoing deformation is capable of causing an earthquake of magnitude 8 then several numbers of 6.5 magnitude earthquake occurring in that region will also not be able to suffice the amount of energy which is required to trigger an earthquake magnitude of with 8.

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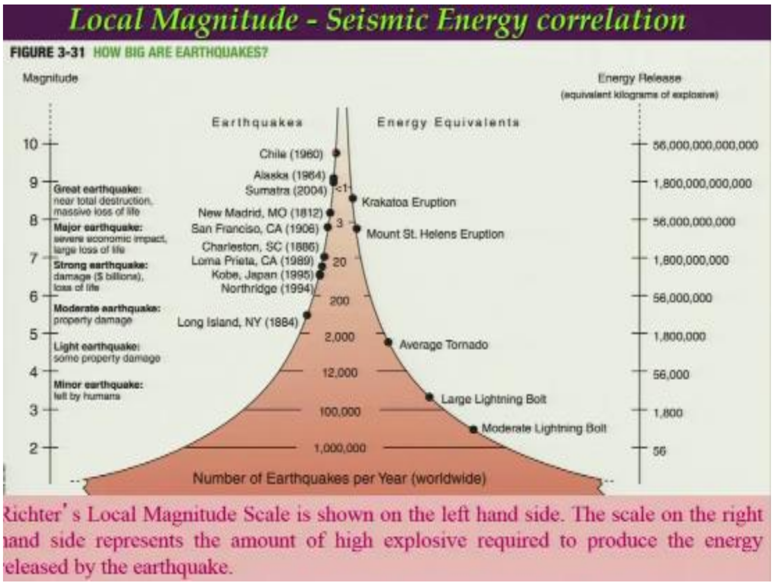

So this is the scale and the relationship which has been given here so this side it shows the amount of energy equivalent to in kilograms of an explosive and this is the scale which has been given here the magnitude scale and we are having the earthquakes which are between 8 and 9 or greater than 8 are considered to be great earthquake and then above 7 up to 8 has been considered as an major earthquake, strong earthquake, moderate light and minor one.

And in top here so if you look in some of the literature mostly we will find that the Sumatra Andaman earthquake of 2004 was 9.3 and very close to the so far considered as a second largest earthquake that is in 1964 Alaska earthquake and the largest one so far recorded 9.5 is the Chilian earthquake.

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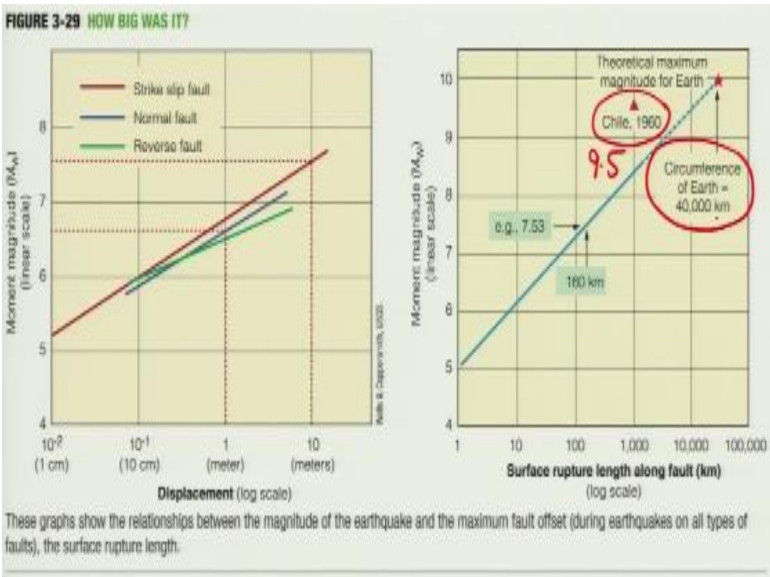

Now further what we have seen in the previous slide that we talked about the energy released during one magnitude earthquake and the next higher one. These 2 graphs shows that what is the relation between the magnitude and the displacement on the fault. And the magnitude and the surface rupture length along the fault. So this is on the fault and along the fault on this strike.

So if I have to put the sketch here then we are talking that this is the fault trace on the surface and the amount of displacement which will be seen on fault is your rupture length. So I am just putting in block diagram here so this is the amount of slip you are going to expect during in particular earthquake and then rupture on the surface. So this is what has been (()) (06:12) in kilometers.

So in both the cases what we see is that if you are having the larger magnitude earthquake then larger will be the slip on different types of faults which you can make out based on the curves which are been given here. So, in case of the reverse fault; in compressional tectonic environment and extensional tectonic environment along on the normal fault and along the strike slip fault when you are having the share or any 2 plates which are passing or the block of the rocks passing with respect to one another so along the horizontal plain.

So you are having different curves which have been given here for red. So you are having like if you expect an earthquake of 7.5 then the displacement which is expected on the fault will be around 10 meter and then similarly with 6.9 or so then you are having the different on the strike slip fault you will have less than 1 meter on the normal fault you will have almost 1 meter and in case of the reverse fault that is also almost like 1 meter on fault.

So and further on the other graph if you see there is this comparison given between the magnitude and the surface rupture length. So in case of your Chilian earthquake of 1960 the magnitude was 9.5 and the rupture which was experienced was around for almost length was 1,000 kilometers. Now if you extrapolate this line and say that okay you will have a magnitude of 10 which is till date not recorded at all.

But if this occurs 10 magnitude then the whole circumference of the earth will be covered. So the rupture length will be of almost like 40,000 kilometers.

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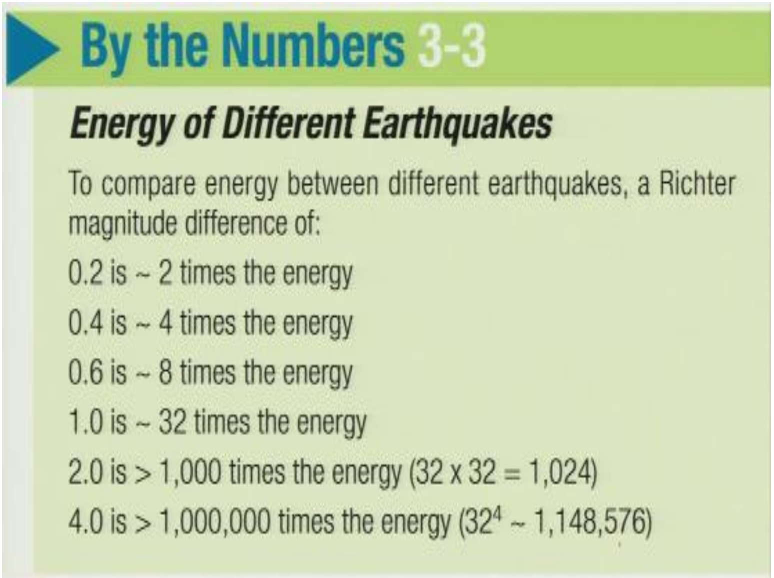

So by the number the energy of different earthquakes to compare energy between different earthquakes or Richter magnitude difference of 2, 4, 6, 1 and then so on if you go then you will be able to understand that how much energy it will be required if you are having like for example if you have 2 magnitude earthquake then the energy is around 1,000 times the energy of this one and then you are having 4 magnitude then it increases by this amount.

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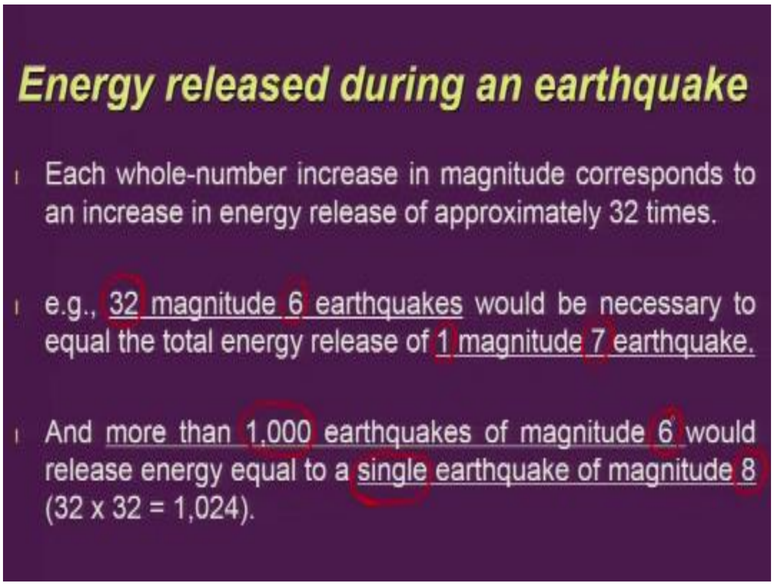

So energy released during an earthquake each whole number increases in magnitude corresponds to an increase in energy released by approximately 32 times. So, example 32 magnitude 6 earthquakes, so, 32 number of magnitude 6 earthquakes would be necessary to equal the total energy release for 1 magnitude 7 that is one number of magnitude 7 earthquake.

So you can imagine it is just that you are increasing the magnitude by 1 okay you are having 6 and you are having 7. So if you are having 1, 7 magnitude earthquakes you require 32 number of 6 magnitude earthquakes which is again moderate magnitude and this is large magnitude here. Similarly, more than 1,000 earthquakes of magnitude 6 so you will require 1,000 number of magnitudes earthquakes of magnitude 6 would release energy equal to a single earthquake of magnitude 8.

So you can imagine that the Himalayan region is capable of triggering the energy which is available based on the deformation pattern the Himalayan region can trigger earthquake of magnitude 8 and if you are having continuously about 1,000 earthquakes that will be able to suffice the energy of only single 8 magnitude earthquake. So this is the difference between the magnitude and the amount of energy.

So sometime we feel that we had enough number of 6 magnitude earthquake. So energy is completely released in that region and you cannot expect having 1,000 earthquakes in that particular region. So the energy will always remain available or the strain accumulated will always remain available even though we are having large modern magnitude earthquakes and large number of modern magnitude earthquakes which are occurring in that particular area.

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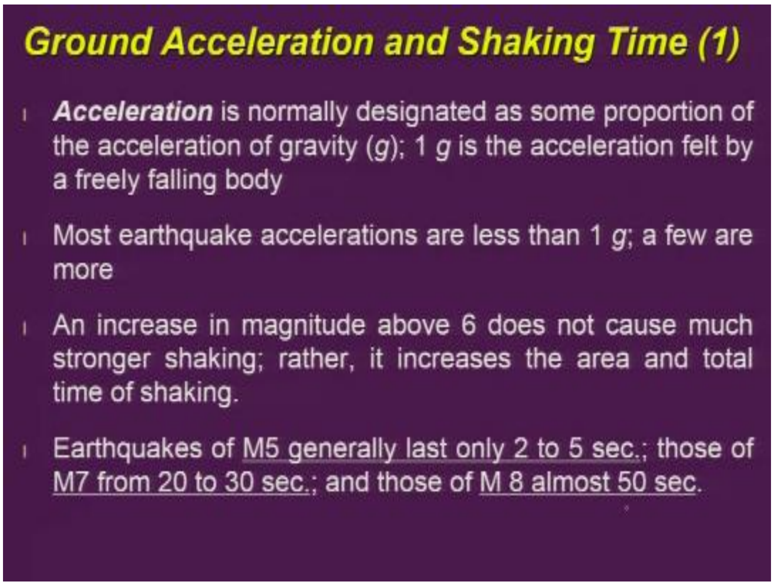

Now grounds acceleration and shaking time the acceleration is normally designated as some proportion of the acceleration of gravity g. So 1 g is the acceleration felt by a freely falling body. Now this is important because when we are talking about the ground shaking and ground shaking or seismic shaking will result into the moment of the earth surface and that will result into your total damage or partial damage.

So most earthquake acceleration are less than 1 g a few are more and increase in magnitude above 6 does not cause much stronger shaking rather than it increases the area and total time of shaking like for example earthquakes of magnitude 5 generally last for only 2 to 5 seconds those of magnitude 7 from 20 to 30 seconds and those of magnitude 8 almost like 50 seconds.

So if you are having like the weaker structure of this time duration of ground shaking during 5 magnitude earthquakes will not result into the damage, but if you are having even 7 magnitude earthquakes then the time duration for the shaking is around almost more than around 10 times more. So you are having 20 to 30 seconds and in case of the 8 you are having much more up to 50 seconds.

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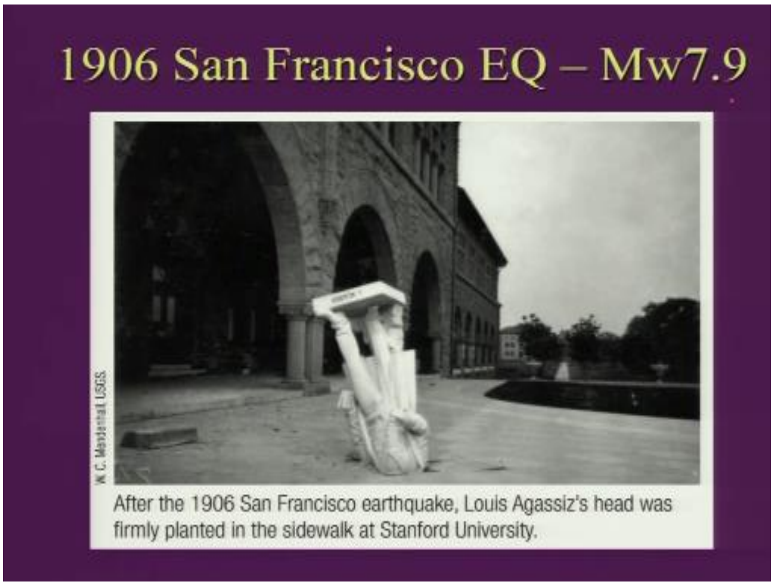

So, mostly the ground acceleration will result into toppling of the structures or damaging the structure in total. So this is an example of 1906 San Francisco earthquake magnitude was 7.8.

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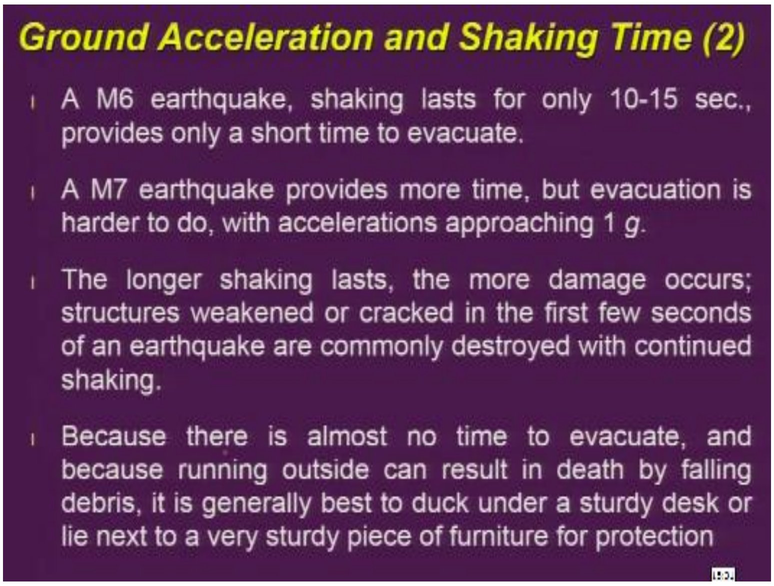

So a magnitude 6 earthquake shaking usually last for only 10 to 12, 15 seconds that provides only a short time to evacuate because you need to plan for the mass evacuation. So this will provide in very short period okay whereas the magnitude 7 earthquake provides more time, but evacuation is harder because the ground shaking will be much higher and acceleration will be approaching about 1g.

So the longer shaking lasts, the more damage occurs structures weakened or cracked in the first few seconds of the earthquake are commonly destroyed with continued shaking. So this is what I was trying to explain in case of magnitude 5 that the time is less so the weaker structure will withstand, but if you are having the longer shaking during large magnitude earthquakes so no damages usually occurs because the initial stage.

The structures will be weak and are cracked and if it last for longer period then they will be destroyed commonly such buildings will be destroyed because there is almost no time to evacuate and because running outside can result in death by falling debris it is generally best to duck under the sturdy desk or lie next. So this portion comes under the safety measures so you can put yourself under the desk or any hard or steady objects which can make you which will allow you to be on the safer side from the falling objects due to ground shaking.

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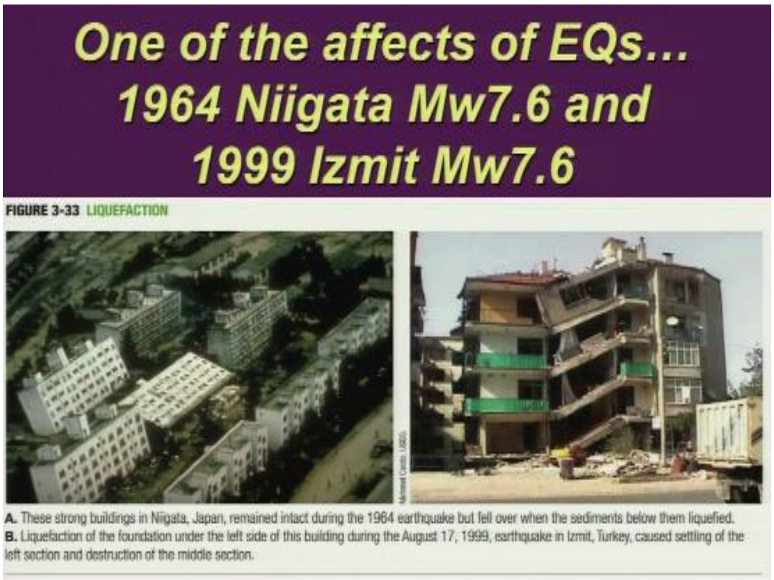

So one of the affects of earthquake that is 1964 Niigata earthquake of magnitude 7.6 and 1999 is Izmit earthquake this was from Turkey. So secondary phenomena which has been seen here is the liquefaction and another one is the damage pattern. This is mainly because when both the damages were related to the secondary effect and that is the liquefaction phenomena. 1964 Niigata earthquake and 1999 this is from Turkey and these images from Japan.

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Modified Mercalli Scale

Intensity Value and Description	Average Peak Acceleration (g is Gravity = 9.80 m/sec^2
I. Not felt except by a very few under especially favourable circumstances. **II**. Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing. **III**. Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated.	
IV. During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like heavy truck striking building. Standing automobiles rocked noticeably.	0.015g-0.02g
V. Felt by nearly everyone, many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.	0.03g-0.04g
VI. Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.	0.06g-0.07g
VII. Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.	0.10g-0.15g

So if you look at the comparison between the Modified Mercalli Scale the intensity has been given here and the details which we have already discussed for different intensity and the expected ground acceleration which has been listed here. So this like for example you are having 7 intensity of 7 the damage are negligible and the ground acceleration will be ranging between 0.1 to 0. 15g.

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VIII. Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stack, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (~M 6)	0.25g-0.30g
IX. Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (~M 7 to 7.5)	0.50g-0.55g
X. Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks.	More than 0.60g
XI. Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly. **XII**. Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into the air.	More than 1g

Whereas in case of (()) (17:00) and similarly this will keep increasing and when you are having the intensity of 10 or 12 then the ground acceleration will be more than 1 g and this is extremely dangerous. So I will end here with this topic and will continue with the new topic on active faults and topo active fault topography in the next lecture. Thank you so much.