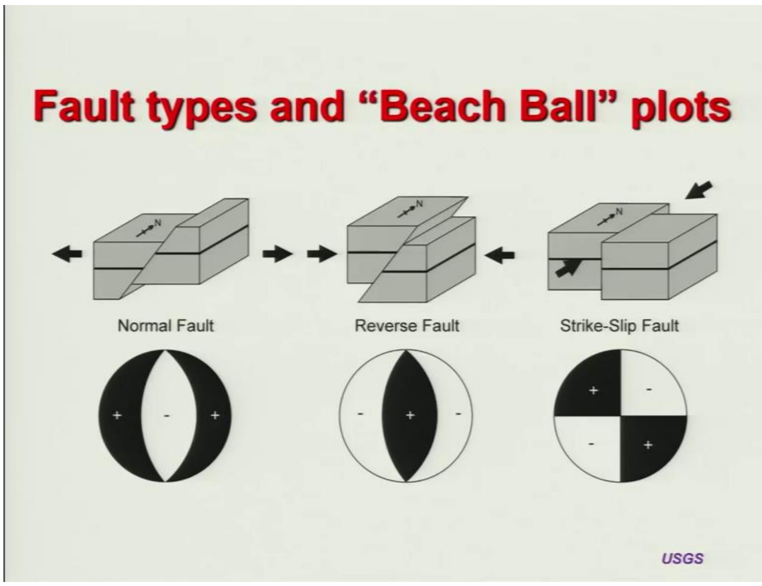
Earthquake Geology: A tool for Seismic Hazard Assessment
Prof. Javed N. Malik
Department of Earth Sciences
Indian Institute of Technology-Kanpur

Lecture # 18
Earthquake Forecasting and Prediction Model (III)

(Refer Slide Time: 00:19)



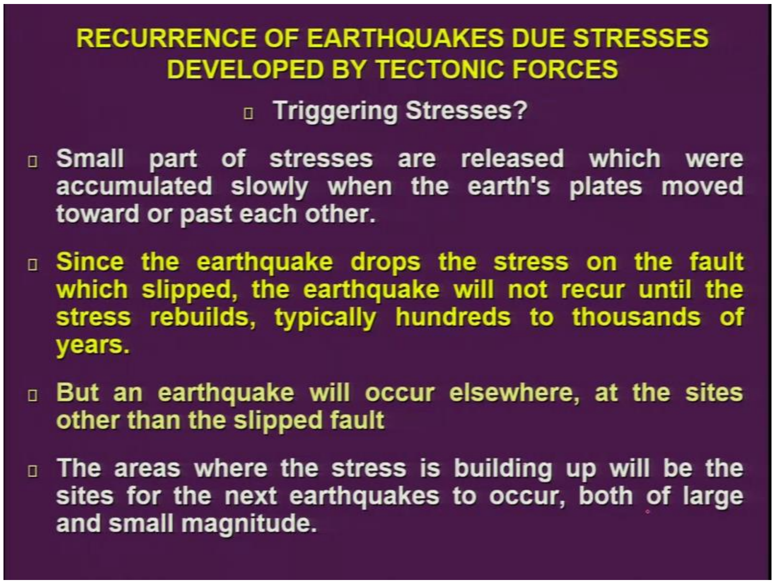
Welcome back. So, in previous lecture mainly I discussed about the how to identify or locate the center of different earthquakes. So, if you are having 3 stations maximum you can identify or locate the epicenter of any particular earthquake. And then we also discussed about that what are the symbols what we are talking about the beach and ball diagrams, which are indicating of different faulting. So, we have normal fault, reverse fault and the strike slip fault.

So, I will not go into the detail of the fault which have been given here, but to just have a brief introduction about this in this case what we see an extension of when the hanging wall on the left hand side moves down long the inclined fault plain. And in case of the reverse fault, the hanging wall moves up in case of along the fault plain inclined fault plain. So, this is a compressional tectonic environment and this is an extension of electronic environment.

And whereas, this one the third one is a strike slip fault, where 1 block moves away from or just past each other with respect to the fault line here. So, in this case, what we see is the right hand side block is moving towards us and the left hand side is moving away from us, but this is we turn as an right side likes that, about the features what we see on the surface. We will talk when we will start talking about the active faults and active faults topography.

And the respective symbols are been given here so, usually in the map after the earthquake, such figures are the symbols will be available, which indicates not what type of earthquake.

(Refer Slide Time: 02:15)



Now, moving further we also had a brief discussion about that the earthquakes distribution of the earthquakes and now coming to the recurrence of earthquake due to stress developed by tectonic forces. Now this before getting into the example of 2001 Bhuj earthquake I will just briefly tell you that why what are the reasons for the triggered earthquakes or more the trigger stresses on different faults because of the because of an earthquake.

So, trigger stresses mainly we say that the small parts of stresses are released which were accumulated slowly when the Earth's plate moved towards or past each other. So, this also indicate that not all the stress or the energy which was when accumulated got released and an single event, but there is some left out stress which is which can trigger the earthquake in near future or you can say that the release of energy at on a particular fault as triggered the earthquake on another one.

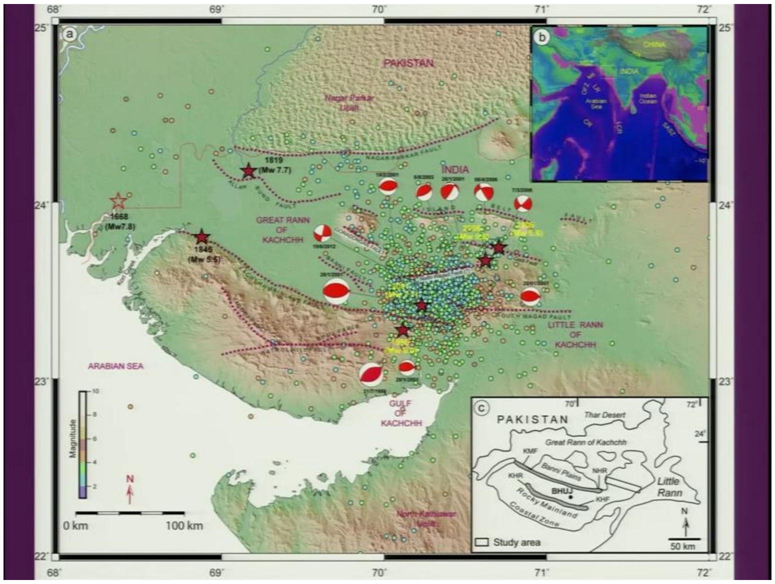
So, usually this has been taken into consideration that if stress is released on a particular fault during a particular earthquake, then then they will be in drop in stress on that particular fault so, that means not the next earthquake on that fault will not reoccur until this stress rebuild and it crosses the threshold limit and typically this the time duration which has been taken to rebuild the stress may vary from 100 to 1000 of years.

So, in case of the areas which are close to the plate boundaries will have lesser interval or that the recurrence interval, whereas, the areas which are sitting away from the plate boundary will have the largest recurrence interval. So, this is usually has been considered that once the earthquake has occurred on a particular fault then they will be in crop in stress pattern, but, and it will remain quiet until the next event because this requires the rebuilding of the stress on that particular fault.

But an earthquake will occur elsewhere at this site other than the slipped fault. So, in this case what we can conclude is not to the earthquake has occurred in particular idea for example, in 1 of the slide, I was talking about that there was 1905 earthquake, then there was 1934 and then we had 1950 it was in case of Himalayas. So, we what we have discussed in during that time was that this portion, which has not triggered any earthquake will form like will indicate a sort of in seismic gap.

But, it is quite possible that we in this earthquake was triggered on 1 of the fault system will exist in the region and then another fault system which is sitting and that particular area can host an earthquake. So, how this; what has been discussed here that the earthquake will reoccur elsewhere and not on the particular fault, but the area maybe the same. So, the area where the stress is building up will be the side for the next earthquakes to occur both as small as well as the large one.

(Refer Slide Time: 06:40)

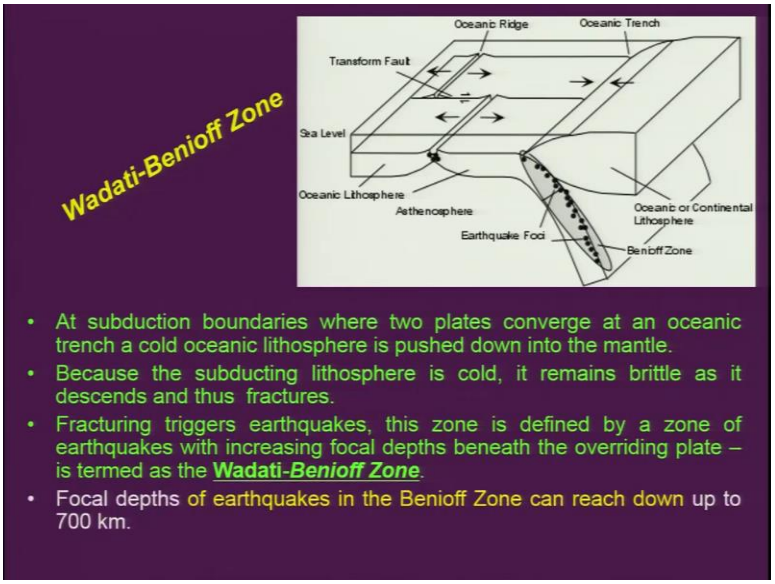


Now, in case of the recent earthquake of 2001 Bhuj earthquake, what we observed was, of course, the concentration of the earthquakes and his aftershocks were confined to this region and that indicate the rupture area but there was sudden increase in the seismicity in this particular region. So, earthquake was triggered here, what we saw that number of earthquakes small magnitude earthquakes, micro earthquakes was triggered and few small magnitude earthquakes which are greater than 5 were triggered.

Further north along could be along with the 2 active faults probably the stress which was released here has triggered the stress which was accumulated in this area and this may host another earthquake a large magnitude earthquake which we will call as an triggered earthquake and similar phenomena was been observed in 2015 earthquake which was along the Himalayan region that was an Gorkha earthquake.

So 2015 was 1 and then immediately after a month, another earthquake was been triggered, which is of which was of similar magnitude. And so, some scientific groups they consider that earthquake as aftershock, but that could be a result of and triggered stress on another fault all on the same fault which was left out that is the stress which was left out might have triggered the another earthquake in that region. So, sometime because of the large earthquake another large earthquake could be triggered in the nearby area.

(Refer Slide Time: 08:47)



So, this part we have already discussed, so, I will just move quickly.

(Refer Slide Time: 08:56)

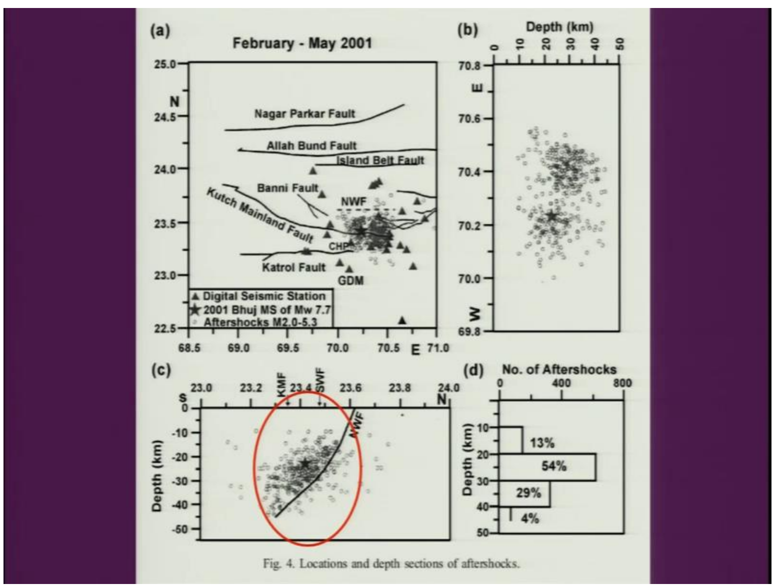
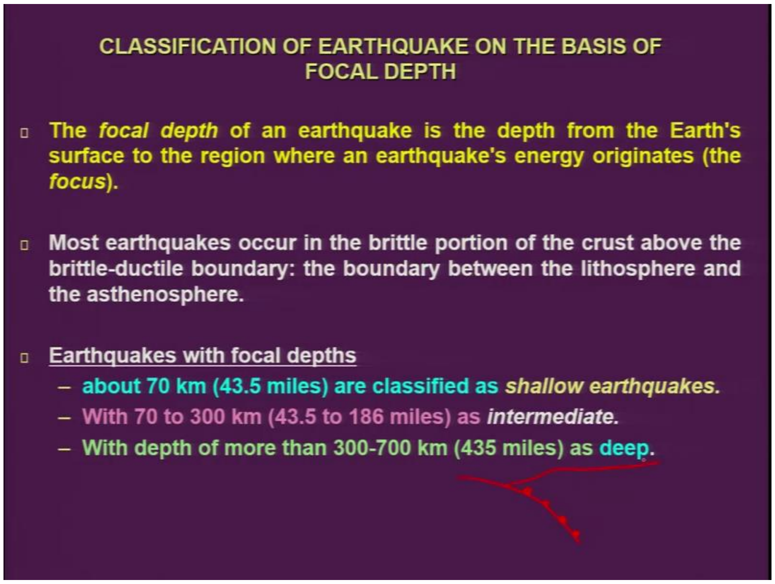


Fig. 4. Locations and depth sections of aftershocks.

So, locating the fault in which direction it is tipping in which hope all the area was ruptured. This has been shown in this diagram this is a plan view, which shows the distribution of the main shock or location of the main shock and distribution of the micro seismicity or the aftershocks. And this has been shown in with respect to again the plan view and the depth which has been plotted. So, this shows that the main shock was triggered at around 25 or 23 to 25 kilometer deep.

And probably was along the north wagged fault, which has dipping due south but in some cases, it has been observed that probably this is not the actual plain because this is an arbitrary line which has been drawn but could be the earthquake was on the Kashmir land fault.

(Refer Slide Time: 10:05)

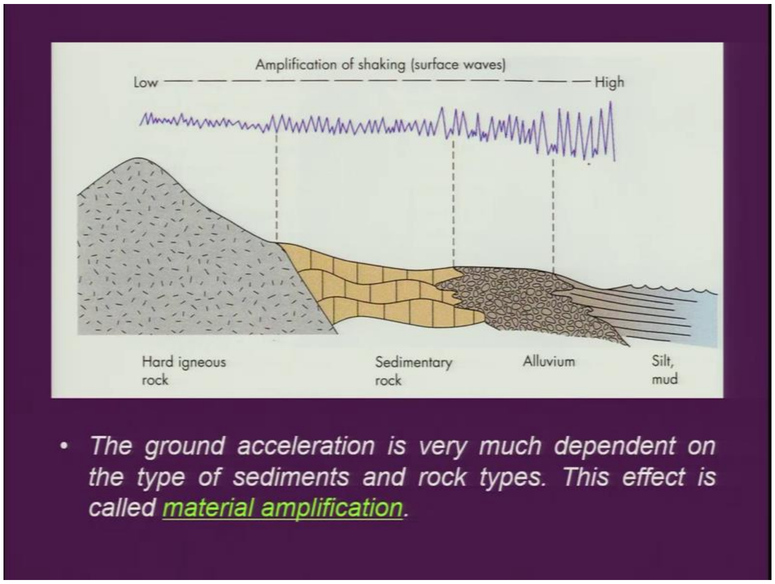


Now, the classification of the earthquakes on the basis of the focal depth this we have been talking about intermediate and shallow and deeper earthquakes we discussed when we were talking about the plate tectonics. So, the focal depth of an earthquake is the depth from the Earth's surface to the region where the earthquakes energy originates. So, this is the point of the focus and exactly on the surface of this point has been termed as epicenter.

So, most of the earthquake occur in the brittle portion of the crust about the brittle-ductile boundary that is the boundary between lithosphere and asthenosphere. So, in terms of the depth if we have to classify the in the broader sense, then up to 70 kilometer depth we classify those earthquakes as shallow earthquakes, with depth ranging from 70 to 300 kilometers an intermediate and deeper earthquakes are having the depth more than 300 to 700 kilometers.

So, this you can refer with the with the figure which was been shown as an in the case of when you show which explains that the whole sub ducting plate will host the earthquakes and depending on depth you can classify those earthquakes either they are deep earthquakes, they are intermediate or shallow earthquakes.

(Refer Slide Time: 11:41)



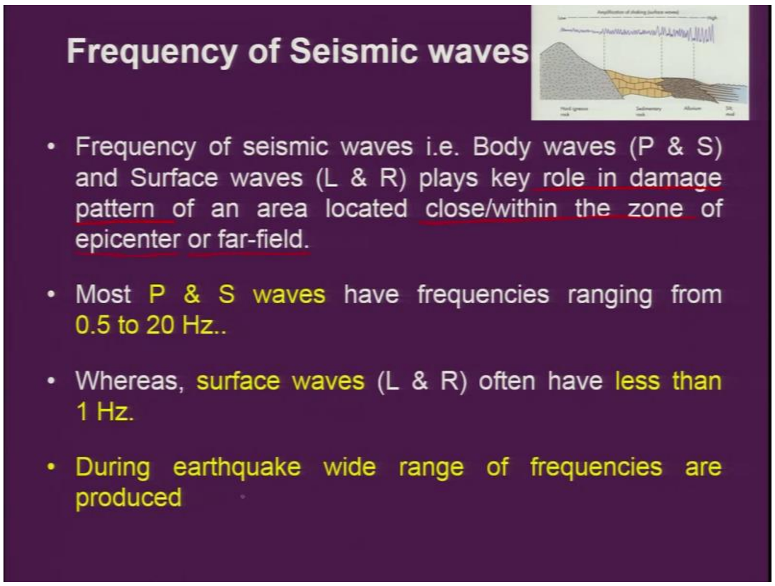
Now, we discussed about the seismic waves, we discussed about the earthquake epicenter was is of course, these are the 2 important parameters and, in 1 lecture we talked about the details of the lithology which plays an important role in terms of seismic shaking. So, after having a brief understanding of the occurrence of the earthquakes and the depth of the earthquakes, then the type of halting the geology also plays an important role in seismic hazard.

So, if you have the different lithology for example, it has been shown here not on the left you have hot rocks, igneous rocks or you take either you can say it is a massive rocks if you are having then we are having sedimentary rocks and then alluvium and then for the final alluvium here, so, the amplification during ground shaking will vary from place to place. So, hard rock will have less amplification and it keeps increasing.

If you move towards the, loose material and in sedimentary rock area, you will have comparatively hybrid amplification, because of ground because of the seismic shaking and here in the case of the alluvium, you will have much larger as compared to the sedimentary rocks and the massive rocks we are having so, the ground acceleration is very much dependent on the type of sediments and rock types.

So, this effect basically is been termed as material amplification. So, along with the understanding that where exactly the sites are located or site of her interest or any urban settlement is located whether it is on sedimentary rock, igneous or metamorphic rock or you are sitting on alluvium depending on that you will have the amplification that during the ground shake.

(Refer Slide Time: 13:51)

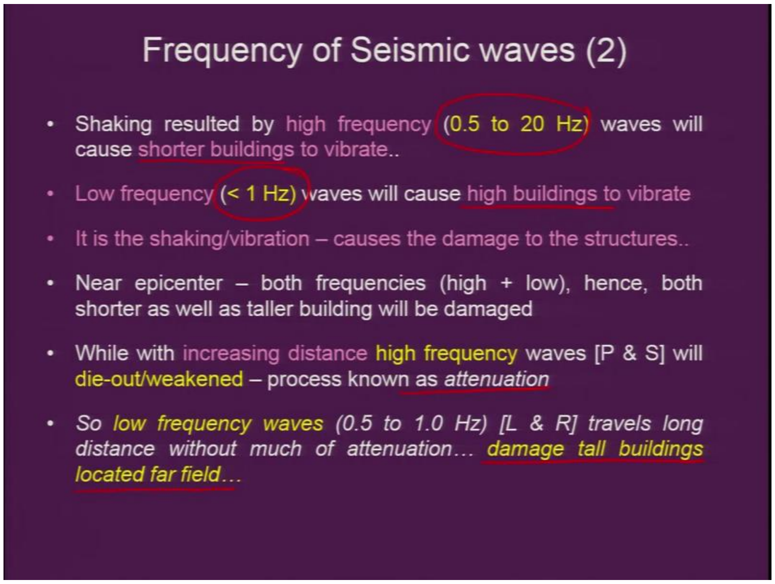


Now, getting into the further detail of the seismic wave and its relation with the amplification the frequency of seismic waves when they say the earthquake is triggered a variety of different frequency of seismic waves are generated. So, the frequency of seismic wave that is body wave and you are having the surface waves plays a key role in damage pattern. So, this is this part is the most important one and this will again depend on the geology of the material that is the geology of the area, what type of material we have at a particular side.

So, again along with that, is 1 the part of the geology, but along with that we have at how for the site is located from the epicenter, whether it is close or within the zone or it is sitting far away from the epicenter zone. So, most P and S wave that is your body waves have frequencies ranging from 0.5 to 20 hertz and whereas, the surface wave we have the frequency less than 1 hertz. So, we have the frequencies which are ranging from 0.5 to 20 hertz we will be able to experience during in any particular earthquakes.

And during any earthquake both body waves and P surface waves will be generated. So, during earthquake wide range of frequencies of seismic waves are produced.

(Refer Slide Time: 15:47)



So, shaking results resulted by high frequency wave which is 0.5 to 20 hertz and that is the that is your body waves and this waves will cause shortened buildings to vibrate. So, if you are having low story buildings, they will vibrate during the body waves which have generated so, and the low frequency waves will actually you are less than 1 hertz. So, in this case what we are having the mainly the, the surface waves will cause high buildings to vibrate.

So, in this case, what we can conclude is both shorter building as well as the taller buildings will vibrate, because both body waves and surface waves will be generated in during a particular earthquake. So, if it is the shaking or vibration usually causes the damage to the structures. Now, near epicenter, both frequencies so, you have the body wave and the surface wave both frequencies high and low will be experienced hence both shorter as well as the taller buildings will be damaged.

So, this is in case of the epicentral region while the increasing distance high frequencies will mostly the P and S waves. So, this will get weakened and this will die out at an increasing distance and this process is turned us attenuation. But the low frequency waves usually, what we have we have like in case of the surface waves that is L and P waves will have tendency to travel long distance without much of the attenuation and this will cause damage to taller buildings which are located far off.

So, what basic thing which we learn the fundamental thing will learn that in case of your epicentral area, you will experience both that is the low frequency waves and high frequency waves as the body wave and surface waves and that will result into the damage of shorter building and taller buildings. So, those will be in those buildings both shorter and taller will be experiencing vibration, whereas, the far distance located areas mostly the low frequency waves will travel without any attenuation and result into the vibration of the taller buildings.

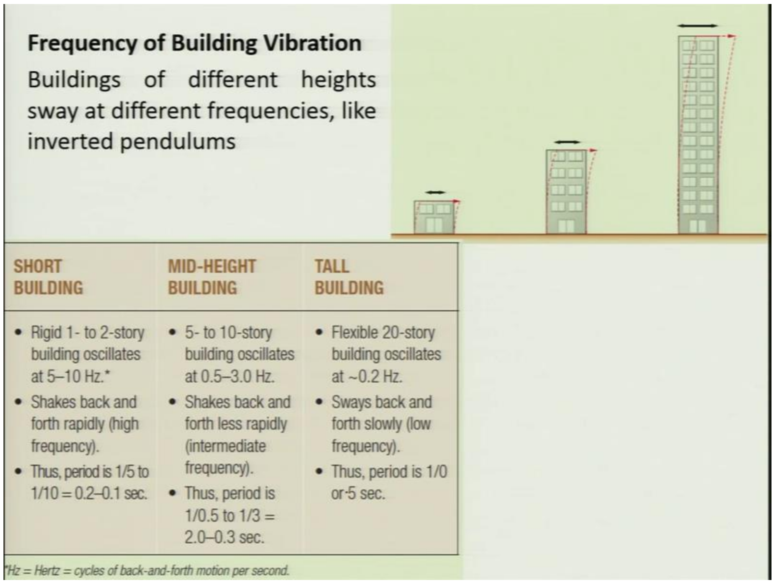
(Refer Slide Time: 18:44)

Table 4-1 Some of the Most Catastrophic Earthquakes in Terms of Casualties*

EARTHQUAKE	DATE	MAGNITUDE (M_S)	CASUALTIES
Haiti, Port-au-Prince	Jan. 12, 2010, 4:53 p.m.	7.0	>222,000—poor building quality.
China, Wenchuan	May 12, 2008, 2:28 p.m.	7.9	87,587—collapse of recent, poorly built schools and apts.
Kashmir	Oct. 8, 2005, 8:50 a.m.	7.6	80,361—mostly in collapse of schools and apartment buildings
Sumatra	Dec. 26, 2004, 7:59 a.m.	9.15	230,000—including from the tsunami caused by the quake
Iran, Bam	Dec. 26, 2003, 5:26 a.m.	6.7	~26,000—mostly in buildings of mud and brick
India, Bhuj	Jan. 26, 2001	7.7	~30,000—mostly in buildings of mud and brick
Iran	June 20, 1990	7.7	~50,000—landslides and adobe and unreinforced masonry
Armenia	Dec. 7, 1988	7.0	25,000—mostly in precast, poorly constructed concrete bldgs.
China, Tangshan	July 27, 1976	7.6	250,000—mostly in collapsed adobe houses
Peru	May 31, 1970	7.8	66,000—in rock slide that destroyed Yungay
India, Quetta	May 31, 1935	7.5	60,000
Japan, Kwanto	Sept. 1, 1923	8.2	143,000—incl. deaths in great Tokyo fire started by the quake
China, Kansu	Dec. 16, 1920	8.5	180,000
Italy, Sicily, Messina	Dec. 28, 1908	7.5	120,000
Ecuador and Colombia	Aug. 16, 1868	?	70,000 total: 40,000 in Ecuador, 30,000 in Colombia
Ecuador, Quito	Feb. 4, 1797		40,000
Italy, Calabria	Feb. 4, 1783		50,000
Portugal, Lisbon	Nov. 1, 1755		70,000—including deaths in tsunami caused by the quake
India, Calcutta	Oct. 11, 1737		300,000
Italy, Catania	Jan. 11, 1693		60,000
Caucasia, Shemakha	Nov. 1667		80,000
China, Shaanxi, Shensi	Jan. 23, 1556		830,000—mostly in collapse of homes dug into silt
Portugal, Lisbon	Jan. 26, 1531		30,000

So, these are some catastrophic events which are been listed here, right up to 2010. But we also had the recent earthquake as I was talking about 2015 in Himalayas.

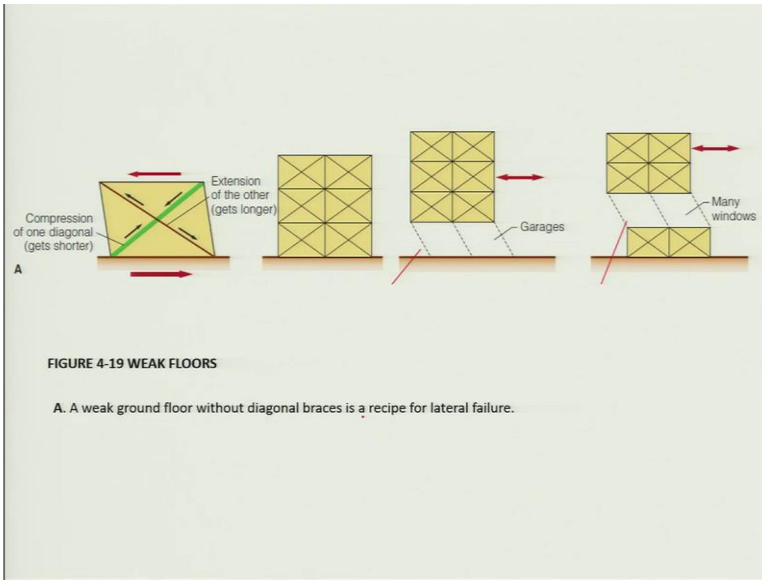
(Refer Slide Time: 19:00)



Now frequency and building vibration if we consider this 2 buildings of different height sway at different frequency like inverted pendulums. So, if you are having the shorter buildings, they will sway less whereas, if you are having the taller buildings they will sway or swing we can say and the larger area has been covered. So, this is the comparison which has been given for the shorter building mid height buildings and taller buildings.

So, buildings with 1 or 2 story building oscillates at 5 to 10 hertz shakes back and forth rapidly within high frequency does the period of this is basically what we are talking about the this way period which is around 0.2 seconds to 1 second and whereas in the case of this 1 this will be higher and in case of this 1 that is here, taller buildings it will be comparatively higher.

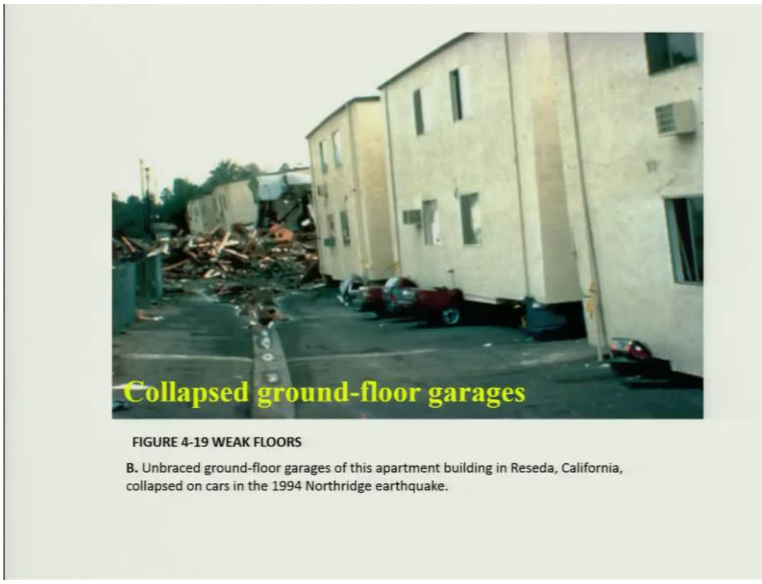
(Refer Slide Time: 20:11)



So, mostly if you are having the buildings which are having the open story and the ground story is an open story or we can see on just on the columns and they will have chances of getting damaged very soon, because the moment will result into the sway of the building. So, if they are been tied up by this members, then the diagonal members and they will may stay or withstand the earthquake around shaking but if you are having this type of buildings, and most of the cities we see that the ground floor has been used for garages.

And that will result into the collapse of this portion. Similarly, if you are having the 2 rigid portions of the building and in between you are having many windows and those regions will also add weak zone and will result into the damage. So, a weak zone a weak ground floor without diagonal presses will result into failure.

(Refer Slide Time: 21:26)

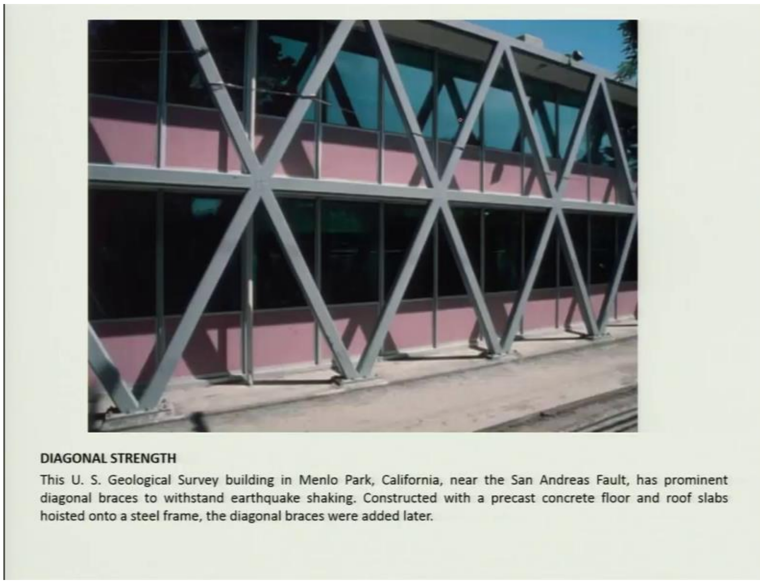


And this is the example of that the collapse of the ground floor which are unplaced ground floor carriages which similar to what has been shown here.

(Refer Slide Time: 21:39)

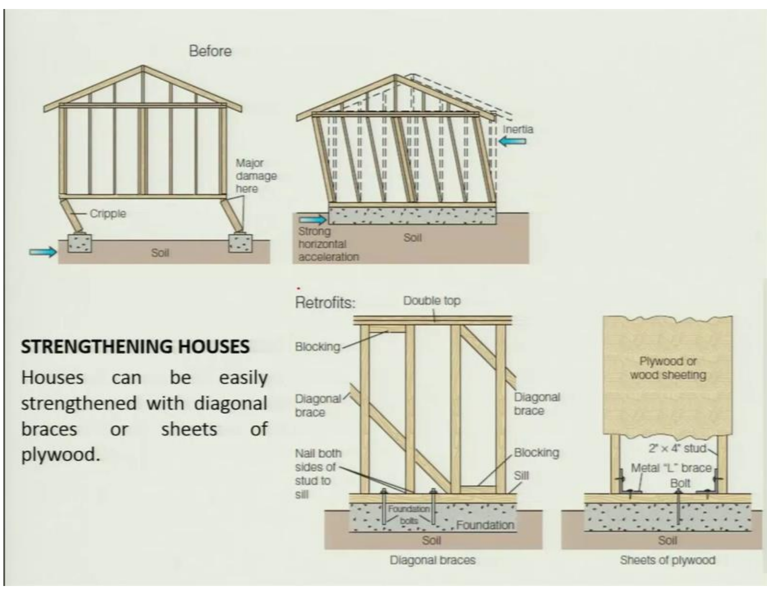
So, this is another case of the many windows which has been located here in between the 2 massive portion of the building and whereas this did not suffer anything because this was all having the walls here. Not the just the columns. So the weaker floor was this which collapsed.

(Refer Slide Time: 22:04)



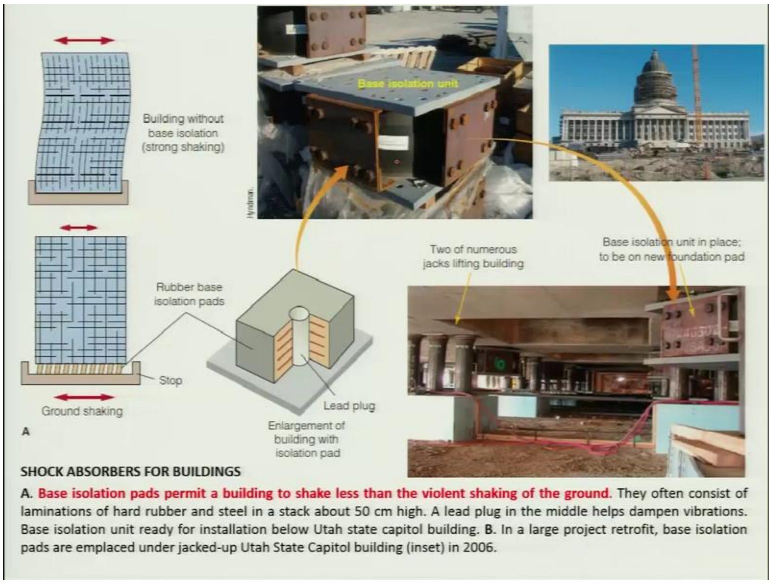
Seen most of the areas there is a retrofit has been done and putting the diagonal braces to withstand the earthquake shaking and this fashion. So, of course, this is not very aesthetic in the sense of the beauty of the building. But the more and most important is to save this building from an earthquake because again, this whole area is with windows. So this diagonal braces will act as protected during the ground shaking.

(Refer Slide Time: 22:42)



Some few more examples of it shows the strengthening of houses which can be done easily with diagonal braces and sheets having wooden houses then you can have use the diagonal braces which can support this whole wall as well as you can use the plywood or the wooden sheets to protect all this otherwise if you have just clamped, then there are chances of crumbling of this 2 columns here and this 2 members will be will be damaged and the same is in case of this 1. But if you have applied the diagonal braces or then apply a safeguard or the structure.

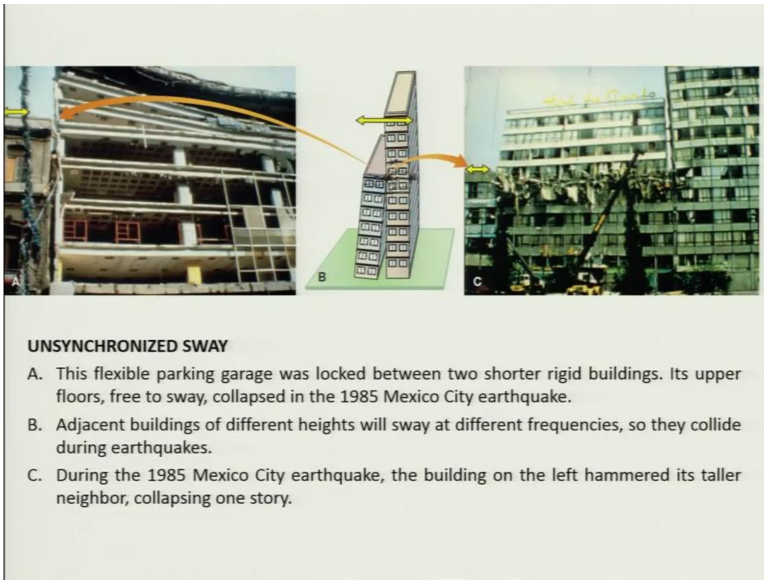
(Refer Slide Time: 23:31)



Now, with the mode development in terms of the seismic safety many countries including India and some places have started using the shock absorbers for the building and this is what we called the base isolation pads with permits a building to shake less than the violent shaking of the ground. So, usually this is comprised of lead and this portion is of rubber base, which have been put at the base of the building.

So, building is going to be resting on this and whenever there is a big event, this component or this portion of the member will absorb the ground shaking. So, this is 1 case which has been shown for the area of this very important building in San Francisco.

(Refer Slide Time: 24:39)



Now, another issue usually has been faced that as we discussed that different buildings will have will sway a different frequency. So the shorter building will have different sway at the larger one will have difference because it will sway large and much more area will be covered here so, if you are having this 2 buildings sitting close to one another, then you will have an effect what is we call the bonding effect and that will also result into the damage.

So, similar to this was from the from 1985 Mexican city earthquake where the 2 building with the different that is shorter was the rigid and then the taller one was more flexible, they collapsed and the they have because this we are different frequency and they collide during an earthquake. So, this was an example from 1985 Mexican city.

(Refer Slide Time: 25:38)

And similar example, but fortunately, it did not damage but what we see here this is a shorter building this taller one, and they have almost collided along this point here and this was from 2015 Gorkha earthquake at Nepal. So, my end here this lecture will continue in the next one.