Earthquake Geotechnical Engineering

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Lecture- 2

Introduction (Continued)

I welcome you again for the second lecture on this course, which is in continuation to the first lecture, where we talk about introduction of earthquake geotechnical engineering. And mostly in this lecture, we are going to talk about the damages, particularly geotechnical damages during the past earthquakes. So, let us see that first what are the major issues during earthquakes. Again, when we talk about major issues here, that means related to geotechnical. So, when we talk about geotechnical, the most important is foundations and the surrounding soil which are subjected to time varying dynamic loads.

So, naturally when this soil as well as foundations, they are subjected to dynamic loads, their behaviour is different than what is during the static loads. So, particularly what are the issues which may crop up during dynamic loading? The one is the behaviour of soil is normally non-linear during earthquake excitations. Then your foundations or the soil may be subjected to excessive or large settlement. So, this is also one of the issue which we need to deal during earthquakes.

And particularly if your foundation is on loose saturated cohesionless soil, then there may be a problem of liquefaction. We discussed already what is liquefaction in the first lecture. If you are in the hilly areas, then or in the sloping grounds, then landslide could be one of the issue which need to be dealt and that is also a geoseismic hazard as we discussed in the first lecture. Before we go ahead and then we implement what are the theory we will learn during this geotechnical earthquake engineering course. During past earthquakes, there are number of examples in which foundation damaged, in some cases causing collapse of buildings, bridges, dams and many other structures.

These are discussed in next few slides. So, here we are going to talk about damages in past earthquake and our focus will be on geotechnical damages. First like one of the seismic damage, one of the example we are going to discuss in detail is from 1964 Niigata earthquake which was with a magnitude of 7.5. This earthquake resulted in dramatic damage due to one of the geotechnical phenomena that is liquefaction.

When the earthquake strike, there were approximately 1500 RCC buildings in Niigata city and out of these, normally you know in the Japan though there are apartments which are the low rising buildings made of the woods or like lightweight structures. So, we are not talking about this, rather we are talking about reinforced concrete buildings and out of these about more than 300 buildings damaged during that earthquake. Out of these about 200 settled or tilted, originally without appreciable damage to the superstructure. So, you see this slide. In this slide you can easily see these buildings here. This line, first line is almost they are vertically, it does not appear there is any settlement or tilt in these buildings. But one of the focus building is here, let me put it here with this highlighted, you could see that this part here. In this case, this is typical example of liquefaction induced bearing capacity failure. Here building kind of toppled down, but there is not much damage in the superstructure. So, here what happened, the foundation of the building failed due to the liquefaction induced bearing capacity failure.

So, this was building turned down here. However, there are some other buildings which are still standing like nearby here, but it get tilted. It did not come on the ground, but it is also, so it is issue related to again bearing capacity and settlement of the foundation. So, these are the typical examples of 1964 Niigata earthquake where foundation either failed or damaged due to earthquake. There is a liquefaction induced settlement and tilting of the building and this is an apartment building again during Niigata earthquakes.

So, you could see that how much it settled down. So, it is zoomed one picture. Then we do have some damage of foundation in the bridges also, that is substructures of the bridges. This slide is from again from Niigata earthquakes and here lateral spreading caused bridge pier foundation to move and it get rotated so much that simply supported bridge span fails. So, it is not only the failure of the span, before that it is the failure of the foundation and this foundation failure occurred due to lateral spreading or what we call lateral spreading is one of the phenomena due to this liquefaction induced.

So, this is another example of the failure of a bridge due to lateral spreading of the soil where the abutment buckled, and it is during 1952 Tokachi-Oki earthquake with magnitude 8.1 in Japan. We have seen so far damages during the past earthquakes. This is one of the good example where this water tank which is situated on the piles on pile foundations survived during the earthquakes. So, this is one of the example we suggest a pile foundation in earthquake mitigations of foundations.

So, this is a storage tank which is supported by concrete piles. Soil underneath this tank liquefied during 1995 Kobe earthquake with magnitude 6.9. So, later investigation suggested soil get liquefied and there are some small minor damage in the piles but there was no damage at all in the superstructure.

So, it survived if it would be on shallow foundation and if liquefaction of the soil would have occurred then this tank would have collapsed. So, this is one of the good example suggesting that it helps if you know select the proper foundation then it may help in mitigation. Then another example from Japan Higasi-Nada wire duct collapse due to foundation failure which occurred in 1995 Kobe earthquake. So, what you could see here in this case is a pier, pier get completely damaged, it again is related to the foundation failure. So, the foundation below failed.

So, it pulled down the complete structure due to the foundation failure. Then again the Nissimomina-Kobri approach in 1995 Kobe earthquake which is also from Japan 6.9 magnitude earthquake. This example is from Taiwan which is of 7.6 magnitude Chi Chi earthquake of Taiwan and the bridge name is Wushi bridge its pier get damaged.

The kind of damage you could see in the pier this is basically due to this primary damage which is due to this what we could say that site conditions was not very good, seismically very active site. So, as a peculiar damage which you could see in the piers of this bridge which is tiered apart completely even it has been made earthquake resistant design. So, if we do not select the site properly then this kind of damage can be expected and this we are going to talk about this issue when we talk about local site effects. In the next slide this is from Bhuj earthquake and again damage to pier bridge in 2001 Bhuj earthquake and these kind of damages are not only from due to the structural issues, but there are issues in the pier also. So, they are related to geotechnical issues which we are going to talk in detail in during this course.

Then I show you another good point during the Bhuj earthquake there is a bridge called Rudra Matha bridge which sustained the damages during the Bhuj earthquake of magnitude 7.7 and just after the earthquakes it was inspected and it was found that this bridge is okay. So, it was opened for the traffic. Here one of the issue which I am going to discuss is related to geotechnical earthquake engineering. Here you can see that you have the bridge and then piers are there, but let us talk about foundation in the next slide.

So, one of the foundation below the pier looks like this and this is the pier and you have this bottom of the pier or it could be this pile cap or so what you have here surrounding soil these kind of fissures these kind of cracks in the soil they are clearly indicating that there was lateral spreading in the soil means that the soil conditions due to the liquefaction phenomena it have spread out. However, still this structure or this foundation of this bridge survived and there was not much damage to this rather than only small cracks in the foundation that is why this bridge was functional. So, the liquefaction occurs, but it still survive. So, it may happen sometime if properly designed structures and then they may survive their foundation as well as their superstructure will survive during the earthquakes even the liquefaction occurs then also. Now, this is another example where this got damaged and this bridge on the is on the river Paliyar river in Kerala and this bridge got

damaged due to 2004 Sumatra earthquake tsunamis during Sumatra earthquake with magnitude 9.

The damage to this bridge is due to the tsunami not the direct shaking of the earthquakes. So, what we are discussing here is damage due to tsunami and you could see the first picture and in fact this photograph is taken by us when we went for the tsunami damage survey in southern part of our country in the first week of January 2005 after this 2004 earthquake. So, this is near Kanyakumari in Kerala. So, we went from Kanyakumari to this there between it is between Kanyakumari and Trivandrum River Paliyar. So, this bridge was connecting two villages called Kilnamana Kudi and Milamana Kudi.

So, what happens you could see only this deck is gone completely, span of the bridge washed away due to the tsunami and you could see the substructure part where you could see the piles foundation down and on the top of you have pile cap and then you have this this one is sitting on the top of it. And one of the span like in the second photograph from the top you could see one of the span is here which is gone, then you have another span which is visible which is like you know floated during this. So, later when we investigated that there was an issue there was no clamping between the super structure span as in the substructure like it was bearing failures between this. So, though the substructure was intact and super structure got washed away due to tsunami. So, this is also one of the issue which need to be taken care during the tsunamis which is geotechnical earthquake engineering related to phenomena.

Now, let us talk about Sikkim earthquake of 2011. We also visited the Sikkim and these are the photographs collected by our team. So, there was huge landslide and you know during this landslide before the earthquake as well as after the earthquake there was heavy rain in that area. So, this landslide was not only because of earthquake, but they are coupled with the rain induced as well as earthquake induced landslides. So, this is one of the photograph.

What happened is one of the water stream changed its path and it caused lot of damage at downstream villages and this one of the fellow which is working to somehow divert or protect their villages by diverting but it was a huge. So, this is another photograph from southern Sikkim. You know that there are four district in the Sikkim north-south-east-west. So, this is from southern Sikkim and you could see there are landslides. So, most of the like this earthquake epicenter was in the north Sikkim which covers much part of the state and, but damage was all over almost.

Then these are some photograph from Sikkim earthquake only. There are failures to the retaining walls in the first photograph of course it is not very much clearly visible. But what I could see here there are cracks on the retaining walls and you know the retaining walls are used to support the foundation and typically in the hilly areas when the retaining

wall get damaged then their foundation gets fails. So, anyway we are going to talk about in this course about retaining walls also. So, that is part of this course we will talk in detail.

So, here you could see the failure of the retaining walls. This is from Sikkim earthquake. Then these are the landslide photographs from recent Nepal earthquake of 2015. So, and you already may be aware about that that lot of damage occurs in 2015 Nepal earthquake. Due to earthquake a landslide occurs and it calls damage to buildings, roads, bridges all things.

Coming to back to historical earthquakes in different parts in more detail what we have talked. The names and magnitude we already discussed but now let us talk from geotechnical earthquake point of view. When we talk about Kanto earthquake of 1923 of Japan there was a death of about 1 lakh people. And it was earthquake of 7.9 magnitude but almost great earthquake of Japan.

There was a damage in Tokyo Yokohama area in the capital of the Japan and there was damage due to tsunami in coastal regions also. And that is the like after 1923 the earthquake engineering started taking a major discipline in Japan. then you have 1964 niigata earthquake with magnitude 7.5 and death were reduced to 26 only but it caused widespread liquefaction. So, Niigata 1964 earthquake is also famous for that, after that liquefaction studies started worldwide.

Then you have Kobe earthquake of 1995 with magnitude 6.9. Death was quite heavy keeping in view that Japan is was quite advanced in earthquake engineering particular at that time but still death were more than 5000. And again, in this earthquake widespread liquefaction and landslides were there. Recent one 2011 Tohoku earthquake of Japan with magnitude 9 deaths was about 16000 and there was widespread tsunamis in Fukushima region.

So, why I am talking about all these earthquake in Japan because they have importance from geotechnical earthquake point engineering point of view. In all these four earthquake there are phenomena related to geotechnical earthquake engineering whether it is liquefaction, landslides or tsunamis. Continue with this let us see United States. New Madrid earthquakes which have three continuous earthquake of 7.5, 7.3, 7.8, three large earthquake occurred in two months span they are widely felt and they are famous for ground motion studies point of view that is also geotechnical engineering phenomena. So, for these earthquake ground motion prediction equation GMPs was developed and they are still used. And they are compared as I mentioned before this New Madrid earthquake is pretty much compared with our Kutch region because New Madrid earthquake geology and geotechnical settings are appear to be similar to what we have in the Kutch or Bhuj region of our country. Then San Francisco earthquake of 1906 with magnitude 7.9 and there was death of about 700 people. This earthquake is famous for rupture of San Andres

fault which is about like 430 kilometer rupture was there on the ground because it was primary damage due to when you have the rupture of the site and it produced about 7 meter offsets. Then you have El Centro 1940 earthquake of magnitude 7.1 with deaths about 9 and there was large ground displacement of imperial fault and why this 1940 El Centro earthquake has been much used in research and particularly by engineering community because this was the first earthquake where the acceleration time history was recorded 1940. So, the first engineering Sieismogram was available for this. Then continue with the United States earthquake we have in Alaska in 1964 with magnitude 9.2 and death was about 131 and this earthquake is also called the Good Friday earthquake and it is notorious for liquefaction and landslide lot of liquefaction and landslide occurred. Then San Fernando 1971 with magnitude 6.6 and death was about 65. This earthquake from our point of view is famous because there was a near collapse of lower San Fernando dam which is layer San Fernando dam is an embankment dam earth or rock filled dam. So, that is like you have so there was damage to this dam.

And this whenever the studies comes across about dams then San Fernando dams are remembered for earthquake. Then in 1989 Loma Prieta earthquake of magnitude 7.1 with a death 63 there was ground motion amplification liquefaction. Even ground motion amplification is a geotechnical earthquake phenomena of course liquefaction is also there so we are going to talk about that.

Then recently North East earthquake of 1994 with 6.8 magnitude and death was about 61 there was extensive damage to buildings and lifelines structures. Continue with this let us talk about our country India. As I already mentioned we do have the Kutch earthquake in 1898 and this earthquake was widely felt, you know that it depends on the ground condition. The similar effect was observed during 2001 Bhuj earthquakes. So, whenever an earthquake comes in the Bhuj or Kutch region it is widely felt or like you know this even like across far away as far away to Bihar and UP and then even this Bhuj earthquake of 2001 was like sensed in Bangladesh also.

Then you have Assam with 8.7, Kangra 1905, 8 magnitude, Nepal Bihar, Assam 1950 with magnitude 8.6. So here this Nepal Bihar earthquake though occurred in 1934 when this earthquake occurred people do not know what is liquefaction. So this phenomena but later investigation liquefaction term is started after 1950s or so. Later investigation suggested that what happened in 1934 was a liquefaction which was a geotechnical earthquake phenomena and these earthquakes of Assam, Kangra, then Kutch these Assam and Kangra Northeast so they are famous for landslides because like landslide occurred during these earthquakes.

Koyana earthquake of 1967, 6.5 there was a damage to dam but that dam was concrete dam so it got damaged during this Koyana earthquake. We do have Bihar 1988 earthquake with 6.6 magnitude and death was more than 1000. Uttarakashi which is in Uttarakhand

1991 and there was death was more than 700 with 6.1 magnitude. Then you do have others like Killari which is in Latour in Maharashtra with 6.1 magnitude and death was more than 10,000 and the reason being that it hit an area which was not at all prepared for the earthquake. This was like most of the buildings was not engineered so that was the reason that lot of death and damage occurred even with 6.1 magnitude earthquake. Then Jabalpur earthquake 1997 though magnitude 6 it was not very high but because this epicenter was close to a big city so there was a death about 38 in the Jabalpur earthquake.

Then you have 1999 Chamoli earthquake with magnitude 6.3 where death was about 100 this is known for landslides because in Chamoli earthquake there was landslide particularly in Gopeshwar. Then Bhuj earthquake of 2001 with magnitude 7.7 and death was about 20,000 in this earthquake and though magnitude was 7.7 but damage and death was like a great earthquake and it was watershed to cause awareness. Then we do have Sumatra earthquake where tsunami was generated 2004.

Kashmir earthquake of 2005, 7.6 magnitude it is known for landslides and death was about 50,000. Then we do have Sikkim earthquake as we discussed some of the photographs there was landslides magnitude was 6.9 and death was more than 100. Then we do have Manipur 2016 which was also known for landslides 6.7. So this was all about our country but as I mentioned there are earthquake in other parts of the world also. Let us have a quickly glance on that. We do have in Italy 1908 with 7.5 and death was about 83,000 so that was quite like a casualty was very high.

Chile earthquake of 1960 with magnitude 9.5 is known to be the highest magnitude earthquake recorded so far where death was about more than 2000 and this many of the death occurred due to tsunami the largest earthquake record so far and there was widespread tsunami. In fact this tsunami you know they started from Chile and these tsunami waves hit the Japan after 22 hours. So they traveled through like know that half of the globe during this and caused a lot of damage and casualty. Then Chinese earthquake of 1976 with magnitude 7.8 is considered to be the highest casualty earthquake where the casualties here picked about 7 lakhs but it is somewhere between 5 lakhs to 10 lakhs and you know that the figures do not come from the China and so death was very heavy it is in about in around million so this is the highest casualty earthquake so far.

Then you have Mexico 1985 earthquake again 8.1 earthquake of Mexico death was about 10,000 but what we are going to discuss about Mexico earthquake is ground motion local site effect it is known for local site effect and which we are going to discuss when we talk about local site effect. Kocaeli earthquake of 1999 7.6 with that is about 17,000 again known for landslides. Chi chi Taiwan earthquake with 7.6 magnitude and death was about 2400. So this Turkey and Taiwan both earthquake was very close they occurred in 1999 and magnitude was also more or less 7.6. Then you have Java Indonesia 2006 earthquake with magnitude 6.2 and death was more than 3000. So, this was in 2008 wenchuan

earthquake in China where death was more than 70,000 and 2008 was the year when there was Olympic Games in China Beijing, there was World Conference on earthquake in Beijing and this World Conference on earthquake engineering in Beijing was just after this earthquake which occurred.

So, thank you very much for your kind attention and this get over with the introductory part of this course with what we have discussed was the many damages during the past earthquakes. So now we will continue with the first module in the next lecture. Thank you very much.