Earthquake Geotechnical Engineering

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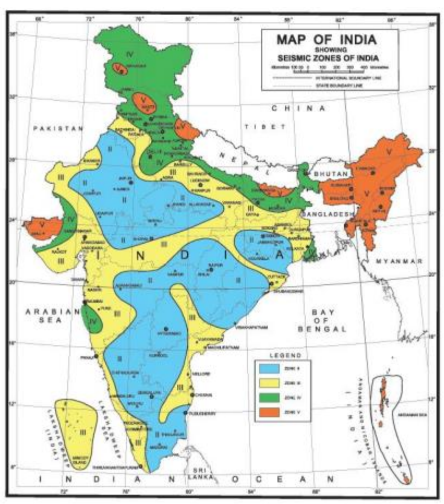
Lecture- 1

Introduction

I welcome you all for this course on earthquake geotechnical engineering. Myself is Professor B.K. Maheshwari. I am working at Department of Earthquake Engineering at IIT Roorkee. Let us talk about the introductory part of this course.

You know that when we talk about this course, it has much importance and the major reason being our country seismically very active and the safety of foundation during earthquake is atmost important. Its course knowledge is required to deal with the behavior of soils during the earthquakes. The proposed syllabus on the subject is very comprehensive and it will systematically empower you to deal with the geotechnical issues during the earthquake for the design of structures and foundations. And I am sure that this course will go long way for all the attendees including students and practicing engineers.

You know that this is the seismic zonation map of our country which is the last updated version IS 1893 part 1 published in 2016.



Much of the area of our country which you could see that in the orange colour, it is seismically very active. It lies in seismic zone 5. So, whole of our northeast region as well as if you see that Andaman and Nicobar Islands they are falling in seismic zone 5. Beside that some parts of Bihar that is Darbhanga, parts of Uttarakhand including Pithoragarh and Chamoli, then parts of Himachal Pradesh including its capital city, Shimla, and Mandi and then you have Srinagar which is capital of J and K and the parts of the region of the western Gujarat that is Kutch and Bhuj region, they fall under seismic zone 5.

Then if you could see that whole of the Himalayan region is either in zone 4 or zone 5. So, the remaining parts of the Himalayan belt is in zone 5. NCR region including capital of our country falls in seismic zone 4 and you have some parts in Gujarat as well as in Maharashtra which lies in seismic zone 4. So, in fact, about 12% of the area of our country falls in seismic zone 5, about 18% in seismic zone 4. So, altogether 30% of the country's area falls in high seismic zone that is zone 4 and 5.

As a result, our country is seismically very active. So, that is the reason that we need to design our structures and when we talk about the structures its foundation is also important. So, the foundation should be also earthquake resistant design. So, that is the basic of this course. When we say that who is target audience for this course, all the students which are pursuing Bachelor of Technology in Civil Engineering or M. Tech or PhD in Geotechnical or Structural Engineering. At Bachelor level, this course could be kind of optional but for Master level particularly those who are dealing with geotechnical or structural engineering, it is kind of a many course curriculum compulsory. Then the target audience also include the faculty members which may be teaching this course to the students and practicing engineers and then practicing engineers which are dealing with geotechnical issues during the earthquakes. So, all are welcome for this course. As for the pre-request is concerned, you may be aware that most of like the colleges have the soil mechanics or geotechnical engineering in their course curriculum of civil engineering and that much knowledge is required.

But still in this course some background of geotechnical engineering will be discussed so that particularly the practices engineers who may have left studies long back may not face any difficulty during this course. Now let us discuss bit about the course contents. The course will cover applications of principles of earthquake engineering to soil mechanics and geotechnical engineering. So, in brief everything is covered in this one sentence. Whatever basic principles of earthquake engineering are there, there will be applied to soil mechanics and geotechnical engineering.

For that first some required basic background which is related to earthquake engineering will be taught in this course. That will start from geotechnical issues during earthquakes and relevant damages during the past earthquakes and these damages are related to naturally for geotechnical issues. Then some background related to engineering seismology will be discussed during this course which will be followed by strong ground motion and wave propagation. So, we will also cover a strong ground motion as well as wave propagation during this course. Two most important topics of geotechnical earthquake engineering, one is called dynamic soil properties, and another is liquefaction of soils that will be covered in much detail.

The course will also cover ground response analysis and local site effects. Further slope stability, landslide and retaining walls will be taught. Finally soil improvement for seismic mitigation will be covered. So, as a result you see that this course will be covered in these six modules. In fact, you may be aware that this is a 12 week course and each week we will have the five hours of contact, that means 5 lectures each week.

So, we have 12 weeks course and contact hours is 30 hours for this. So, what you have here, first one we have divided into six modules. Each module will go for about two weeks approximately. So, altogether you will have 12 weeks. Within one module which will go for two weeks you have contact hours for each week like 2.5 hours.

So, it will be like you have for one module you will require five hours. So, altogether six module will take 30 hours. So, each module will be covered in five contact hours that means 10 lectures. So, M1 will be for 10 lectures, M2 10 lectures like all together we will have 60 lectures and one lecture as you know that it is for 30 minutes and then you have the assignments and all the things which is as per the practice of the NPTEL. As for let us discuss what are the contents of these different modules, what we are going to talk in this course that will give you an overall picture of this course.

First module is on introduction of this course, then second in this module we are going to talk about seismology, then strong ground motion that is SGM. We are also going to discuss seismic seismic hazard analysis of course, not in very much detail because this course is not on hazard analysis only. Then we have wave propagation also where we will talk about 1D, 2D wave propagation and even 3D wave propagation. Then you have second module dynamic swell properties. So, we have in the first module about 10 lectures, in the second module we will have 10 lectures on dynamic swell properties.

In this module we are going to talk about stress conditions using Mohr circle and then stress path which may be perhaps new concept for you. Then we are going to talk about field test which will be covering for low strength as well as high strength. Same is for laboratory test which will be also covered for the low as well as high strength because like the properties of the soils are very much varying with the strain level. So, it is very important that at what level of strain and when we talk about strain here that means shear strain at what level of shear strain we are conducting the test whether it is low strain or high strain and this will be applicable both for field test as well as laboratory test. Once we are done with the test then we are going to talk about stress strain relationship and one of the most important part like you know which is called equivalent linear models for the soil which is quite popular.

Of course, they work in low and medium strain not very high strain, but still because they are simple, they are better than the linear analysis. So, we are going to discuss in detail about equivalent linear model. Then cyclic non-linear models where including hyperbolic models will be discussed and then there will be introduction of advanced constitutive models. So, this second module will be also covered in 10 lectures that means 5 contact hours. Third module, third module consists of two part one is called GRA that is GRA stands for here ground response analysis and the second part is local site effects.

So, when we talk about GRA we are going to talk in detail very much detail about 1D ground response analysis and you will have some numerical also here. Then we are going to talk about two dimensional ground response analysis and of course, little bit on 3D also we will discuss. So, we will discuss ground response analysis in detail and how you can generate the frequency response curve. So, that we will discuss in this. At the end of GRA we will talk a bit about soil structure interaction which is called in short SSI, soil structure interaction.

So, I work lot on SSI, my own PhD was on SSI area related to soil structure interaction. So, I will try to be you know as brief as possible for this because keeping in view that this course is very heavy there are other parts also, but still you will get fairly good knowledge about SSI. Then once we are done then we are going to talk about local site effects. In case of local site effects, the first we are going to talk what is the effect of local site conditions on ground motion, how the ground motion is changed varied due to the local site condition. Next, what is the effect of this local site conditions on design parameters. The design parameters which are used in the design of the structures, foundations and like all of you know other construction activities.

And finally, ground motion time histories. So, that means time histories it will be normally you know the time histories are in the form of acceleration time history. So, that we will discuss what is that. The fourth module of this course which will be on liquefaction of soils. Whenever you talk about geotechnical earthquake engineering or soil dynamics, I think we cannot forget liquefaction.

This is the one of the most important topic in this area. We are going to talk in this topic in two weeks program that is complete five contact hours and it will be like for ten lectures. You have introduction, then what is the related phenomena related to liquefaction we are going to talk. Next will be liquefaction hazard. What are the criteria which make the that soil is susceptible for liquefaction or not? We are going to talk about that.

Factors which may influence liquefaction that will be discussed. How we can decide whether liquefaction will start or not, that will be also covered. Then when we talk about liquefaction, then one term comes liquefaction resistance and this liquefaction resistance will be done in two way. First is the effect of characterization of earthquake loading in terms of liquefaction resistance as well as liquefaction resistance of the soil. So, the loading and as well as the properties of the soil they will be represented in the same number and then they it will be compared that will give you the answer whether liquefaction will occur or not.

What are the current codal provisions according to Bureau of Indian Standards that is IS 1893 that is also going to discuss. Finally, we are going to talk about effects of liquefaction that once liquefaction occurs what will be the expected effects, what are the changes even due to the liquefaction there may be changes in the ground motion also. So, that will be also briefly discussed. Coming to the fifth module which is again for 10 lectures that is on two other topics which is itself both are vast topics but they will be covered in 5-5 lectures each almost. One is stability of slopes, and another is retaining walls.

So, both of the topics you may be aware that they are very important particularly the hilly regions particularly like if you see the Joshimath is a live example that stability of slopes. So, slope stability and that is one of the issue for the landslides. So, what we are going to talk is first earthquake induced landslides. Then static and seismic slope stability analysis. Static slope stability analysis has been bit covered already in your under graduate studies.

We will review it and then talk about seismic slope stability. Once it is done then we will move to the retaining walls. Then static and seismic pressure on retaining walls will be discussed. Dynamic response of retaining walls will be discussed and finally, seismic design considerations will be there. Then the sixth module of the course will talk about soil improvement which is also called popularly ground improvement techniques.

So, this will be also in two parts. One is the traditional methods for ground improvement or soil improvement including densification technique, soil reinforcement, grounting, mixing, drainage. So, the traditional techniques which is used from many years in fact for the you know in this case for particular ground improvement technique people are using even before it come in theory. So, this is something in area where practice was going on from a long time but theory part come later. So, most of the time first it come in theory then it go in practice. But this is one of the issue where already many things are going on including densification, reinforcement, mixing but then now it is documented, it is methods are developed for these techniques.

So, we are going to talk about that. One of the latest issue for the ground improvement many of you may be heard when it comes, it is geosynthetics. So, we are going to talk about that how we can utilise geosynthetics which is the synthetic material as well as natural fibres, how using natural and synthetic fibres, the ground can be improved for earthquake resistant design. So, we are going to talk about that. Next we are going to talk about mitigation of liquefaction using what is we called vertical drains. So, that is also latest technique and one of my PhD students working in this area.

So, we will talk about that perforated vertical drains a little. So, this was all about the six modules of the course. Here you see that references are given that what are we are going to use. The first one is the I think you this is the first book worldwide on solid dynamics. This was written by Professor Samsher Prakash and it was published in 1981.

This was the first book on solid dynamics all over the world. Then Kramer's, S.L. Kramer's book, many of you may be perhaps aware about that which have published in 96. Of course, it is then next version did not come, but this is like we will be kind of a Bible for geotechnical experience at least for time being.

Then we do have some other literatures including handbook on geotechnical earthquake engineering which is by day where lot of you will get examples of earthquake geotechnical damages during the last past earthquakes of course up to 2001. Then the fourth is many of you would have heard that is a basic and applied soil mechanics book by Professor Ranjan and Rao. That will be kind of a reference and I think this is a good book. Many of you would have used this book during undergraduate also. Then there is a book by Professor Swami Saran called soil dynamics and machine foundations.

The latest edition in this book by Professor Tohata on geotechnical earthquake engineering and particularly deals lot of about the liquefactions and practical laboratory aspects of geotechnical earthquake engineering. So, this will be there, but most of our stuff will be from second reference that is from the book by Kramer. Now coming back let us start today with this introduction about this course complete cover what we are going to talk in next 60 lectures. So, the first today we go beyond that. First the module as we said in the module 1 we are going to talk about introduction, seismology, strong ground motion, seismic hazard analysis and wave propagation.

So, today we are going to talk about introduction that is geotechnical issues during earthquakes. The later topic engineering seismology we will talk tomorrow about that. So, let us have first what are the geotechnical issues which is important during the earthquakes. So, I will show you in the second part of the today's lecture damages caused in the during the past earthquakes.

But today let us talk about that introductory part. First what we are going to talk about seismic hazards, what are the seismic hazards and these hazard when we talk about seismic hazard is from geotechnical point of view. Seismic hazard may be from seismology point of view or it could be from a structure point of view. Our focus is mainly on geotechnical part. Then we are going to talk about significant historical earthquakes and major issues during the earthquake and seismic damages.

So, let us talk first seismic hazard. In earthquake when we talk about this slide is little repeating that we already discussed that it is in earthquake geotechnical engineering is nothing but the principle of earthquake engineering which are applied to geotechnical engineering problems that is basically earthquake geotechnical engineering or geotechnical earthquake engineering more or less same thing. It is a branch of soil mechanics which deals with engineering properties and behavior of soils under dynamic stress. So, naturally when we combined in this course we are going to talk for each and every topic related to dynamics simply not with the static point of view. And when we talk about hazard you know there is a difference between hazard and disaster.

So, they are not synonymous words. Hazard is kind of a potential to cause the disaster but it is not itself as a disaster. So, our job as engineers or let us say that scientist is to make that any earthquake hazard or even I say for that reason any other hazard which may be you know landslide or you may have cyclones, floods, droughts, so whatever you name. So, the hazard many of the hazards may be mostly like natural hazards which you cannot avoid then there are man-made hazards. So, for example industrial hazard, fire or so these kind of hazards may be man-made hazards. But as when we talk about seismic hazard or hazard which is due to earthquake it is in natural hazard.

Of course, technically speaking there could be you know that man-made earthquake also which is due to blasting and other things. So, right now we are not talking about man-made it is the natural earthquakes. So, when we talk about a seismic word you know that anything related to earthquake is seismic that means related to earthquake. So, the seismic hazard is a natural hazard which cause tremendous damage around the world each year and hazards associated with the earthquakes are commonly referred to as seismic hazard. Now the issue is here you have seismic hazard as well as other hazards but our job is as a engineers and scientists to stop these hazard to the hazard level rather than they get turned into disaster.

So, seismic hazard is a natural phenomena which we may not prevent or stop but certainly we can prevent the seismic disasters. So, there is a difference between a hazard and disaster and there is a fine line between hazard and disaster. Hazard is natural may be natural and turning this natural hazard it could be the man-made effect that converted into disaster. So, this course is also in the direction that geotechnical seismic hazard should not turn into disaster that is our basic objective during this course. Now what are the common geosacemic hazards? Now geo word has been added that is related to within the seismic related to geotechnical engineering.

The first one is ground shaking. Ground shaking is something between you know that seismologist and geotechnical engineers and it is like you have seismologist may also claim that this is our area and geotechnical engineers. So, this is in between falls in between both seismologists as well as geotechnical engineers. So, when the ground shakes so its effect will come of course on structures too but first will come directly on the foundation because foundation is resting on the soil or on the ground. So, the ground shaking is one of the hazard which is geotechnical hazard, geotechnical seismic hazard.

Then the liquefaction. What is liquefaction? In liquefaction you know that when we talk about soil it is the shear strength of the soil which is the most important property for anything because shear strength of the soil is used for the design of foundations. Shear strength of the soil will be used for let us say will be used for your slope stability analysis, design of retaining walls or many other purpose. So, shear strength is the most important part. Now what happens during the liquefaction? That due to the shaking there is increase in pore water pressure and you know that shear strength of the soil is a function of effective stress. So, when there is increase in pore water pressure effective stress decreases and as a result ultimately the shear strength of the soil decreases.

If the shear strength of the soil becomes negligible that is almost zero, that is the point which we call liquefaction. This is we are going to discuss in very much detail as I mentioned that there will be 10 lectures for this topic so we will talk about it. So, this is one of the geosecimic hazard. Then landslide retaining structure failures that is also geosecimic hazards and we are going to talk again about slope stability and retaining walls so that will be also covered. By the ground shaking hazard will be covered in ground response analysis as well as the in-dynamics soil properties and many other topics.

Then we have here fourth one lifeline hazards where not only one hazard we have you have a number of lifeline hazards are basically those hazards which are generated or created by the lifeline structures or maybe you can say that due to the damage or due to the failure of the lifeline structures. When we talk about lifeline structures you could have hospitals, you may have the bridges, dams, power, communication lines. So, they may not you know directly have impact but their indirect impact is too much on the society as well as on livelihood. So, this is another lifeline hazards and some of the lifeline hazards are directly linked with the geotechnical earthquake engineering particularly for example earthquake earth field dams.

So, you have that directly for geotechnical earthquake. Then one of the like you know this another hazard which is linked with the earthquake and our country faced this about 20 years back in 2004 that is the tsunamis. So, the tsunamis is also a geotechnical earthquake engineering issue because tsunamis will be generated only due to earthquake and for that tsunami to happen an earthquake should originate inside the sea. So, all the earthquake which originate in the sea that will not create the tsunamis. So, that is also we are going to talk about tsunamis in this course bit. Now coming to that let, us have a glance of that what are the different historical earthquakes in the different countries and we are going to talk about only out of the our country only great or major earthquakes.

Great earthquakes are those earthquakes which have magnitude higher than 8 and major earthquake is around more than 7. So, when we talk about United States. So, its western parts including California and western states they are seismically very active. Then eastern side, central United States is relatively seismically not so active however still in central

US also like on and off some earthquake come. For example, 1811 earthquake which is New Madrid earthquake, New Madrid is a place in the central USA where a series of earthquake have come with the magnitude all three more than 7, 7.5, 7.3, 7.8 named as a New Madrid earthquake and this happens almost same time when we do have earthquake in our Kutch region of Gujarat. Then 1906 San Francisco earthquake which magnitude 7.9 which already cross more than a century back. So, that is also known to engineering community.

Then 1940 El Centro earthquake with 7.1 magnitude, 1964 Niigata 7.5 and Alaska 9.2. So, Niigata is a place you may be aware that it is in like Japan. So, this Niigata 1964 listed is here from Japan not from here and Alaska 9.2 is from United States. Both of these earthquake happened within a span of three months one was in June another was in March and they shook at the time to largest economy of the world in 1964 and both are one two common geotechnical phenomena which we are going to discuss later also in detail that is for landslide and liquefaction. Then we do also have in Japan also I think yeah you see the Niigata is come again back so in this slide. So, you have 1923 Kanto, Kanto is a region near Tokyo 7.9 magnitude earthquakes.

So, this was a big great earthquakes in Japan long back 1923. Then 1964 Niigata 7.5 in recent earthquake in 1995 Kobe earthquake 6 magnitude 6.9 and very recently our 10 years 12 years back 2011 Tohoku earthquake is magnitude 9. Now when we talk about our country our country is as I mentioned in the beginning with the seismic jonesian map of the country our country is also seismically very active.

We have witnessed 1819 Kochi earthquake with magnitude 8. This is the 1819 earthquake happens in the same region where recently we have 2001 Bhuja earthquake. Then 1897 Silong earthquake it was magnitude 8.7 in Meghalaya Northeast. 1905 Kangra which is in Himachal with magnitude 8. 1934 Nepal Bihar earthquake with magnitude 8.3 and Nepal Bihar earthquake is famous for liquefaction phenomena. Of course that time liquefaction was not known but later on now we do not suggest that it was the liquefaction phenomena which occurred in Nepal Bihar earthquake. 1950 Assam earthquake with magnitude 8.6 so all these earthquake which is listed from our country on this slide 5 earthquake they all have magnitude 8 or greater than 8.

So that means they are the great earthquakes which happened up to 1950. So in 150 years almost you have 5 earthquakes more than magnitude 8 and out of these 5 you have one is no two is Northeast another is Nepal Bihar border in Himachal and Assam, Himachal and this Kachchh region. So Northeast is that is why it is in Satsang june 5. Now coming to after 1950 we have 1967 Kohina earthquake where Kohina dam was damaged with magnitude 6.6. Then Nepal Bihar earthquake is magnitude 6.6 in 88. We have Uttarakashi earthquake in Uttarakhand with magnitude 6.5 then we have 1993 Latour earthquake 6.4 Jabalpur earthquake with magnitude 6 and Chamoli 6.8 which occurred in 1999. So in this slide you see that most of like earthquakes are either magnitude 6 greater than 6 so less than 7.

So these are the major earthquakes which occurred between 1967 to 1999. So that means after 1950 we do not have any great earthquakes in our country including Northeast so it is a long time. When we talk about recent one in this century it is started from 2001 Bhu's earthquake 7.7 magnitude then Kashmir 7.4 in 2005 Sikkim 6.9 Gorkha that is Nepal earthquake of 15 5.7 that happened in fact it was in Nepal but it also shared with the border with the India. Then we have Manipur earthquake 6.7 in 2006-16 and recently Punjab earthquake with magnitude 5.6. So that means in this century if we do have Bhu's and Kashmir earthquake more than 7 magnitude but so in last 17 years after 2005 India have not witnessed any earthquake more than 6.9.

So that is why many scientists, seismologists are there that gap theory is saying that we may have some earthquake soon. So, this was all about geotech introduction of geotechnical earthquake engineering and we will continue in the next lecture. Thank you very much for your kind attention.