Introduction to Engineering Seismology
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Lecture - 43
Seismic Microzonation of Various Indian Cities

Vanakkam. So we will start our lecture on Engineering Seismology. So last class, we have been discussing about the zonation, seismic zonation. So what is meant by seismic zonation and how the proper zonation can be done by concept of seismic micro zonation. So I have discussed the procedure, which I have developed part of my PhD and explained that how it is very important to account all the seismic hazards in the zonation mapping.

So as you see that the objective of the zonation is basically to give you the data for engineering design, such as the acceleration time is T and then the response spectrum and then the design spectrum. So that is the one main objective. The secondary objective is basically to know that a seismic status of the place, so that the new structure can be designed according to the input developed by that and the existing structures can be retrofitted.

So this is the main objective and also for the government agencies to know that what are the places are seismically more risk and less risk to take a decision, making to establish important facilities or to make some temporary arrangements or program or meeting something like that; all those things are this microzonation part as well as the zonation map is very useful. That is what we discussed in the last class.

So you may be seeing that in the last 2-3 days couple of news regarding the tremors, the minor earthquakes, reported in the NCR in Delhi region. So many people comment about that there are chances of big earthquake in Himalayan region that may also affect Delhi and then there are these earthquakes may be the foreshock for the earthquakes, which are expected main event. So there was a debate, some people say that big earthquake is a due, then how big is the question.

So Himalayan region one can say that a big earthquake means about 7.5, 7 and above magnitude can be expected. So it is obvious that it is a plate boundary, where a bigger earthquake is

possible. So as per Delhi region is concerned, whether these events are a foreshock or not. So that is a big question, but it is very difficult to justify that there may be a big earthquake or may not be a big earthquake.

As you know that, none of the place in the world is free from earthquake. That we have discussed in our previous lectures, during discussion about the elastic rebound theory. So according to elastic rebound theory, so all the places, there may be a possibility of breakage of the rock due to the storing of energy, which is created by the plate tectonic movement and rotation of the earth. So that means, none of the places are free from earthquake.

Only thing, the frequency of the earthquake, at some place it may be very frequent, which similarly occurs in the plate boundaries. So some place, it may be a moderate frequent, where there may be a fracture happening due to bending of plates and moving of plates. Some place, it may have the very large gap. So in that scenario, instead of worrying about that the earthquake is going to happen or not, if it happens, what will happen, all those things, keeping aside of that, as we know that it is not possible to predict the earthquake accurately.

So we have seen when the prediction, 9 methods; we have seen that there are some good precautions, but we have to have the 2-3 composite way of understanding the method. Then, you can able to at least get relatively prediction, but we have seen that the wrong prediction what is the socioeconomic problem, which impact. That kind of scenario is there. So it is always not to worry about the prediction of the earthquake or future earthquake will happen or not.

One of the best way to save from earthquake is basically, we should see that all our structures are designed for the earthquake at least as per IS code. The IS code is right or wrong or the values are represented; that is a different issue, at least if we design as per the current IS code, IS 1893, 2016 version, you can at least save from the collapse of building. So collapse may not happen. So that is very sure.

So people who have designed their buildings, NCR or Delhi region, they no need to worry about that the earthquakes are going to come or not. Even if comes, nothing will happen to you. You

are very sure. So those who are watching this video, I want to give this message since you are studying in Engineering Seismology, it is better yourself also to understand what we are talking and how it is relevant for the practical.

So those have designed their buildings, apartments or houses, or whatever building against the seismic recommendation by the Indian seismic code, so you no need to worry about that the earthquake comes. If there is even a moderate earthquake is possible in the Delhi region, if it comes, you will not get worried about that. You will have worst case, some cracks here and there, but in case your house is not earthquake resistant designed, your house has not taken care of the amplification, your house design not taken care of the liquefaction in the site, then you have to be really concerned.

Because as we said that the earthquake may come anytime, anywhere, since we do not know what was the first history of the particular fault and particular location, it is very difficult to say that when it is going to come. So it is better, you should be prepared. So that is one of the aspect where your seismic microzonation concept has been introduced in India. When you look at the history of the Indian code, which we will be discussing in the little later stage.

So we do not have very robust advanced seismic zonation map of the country, which I will explain you later stage, why I am talking like that. So on considering that, after 2001 earthquake, Bhuj, the government realized that there many people died in the Bhuj, which was predominantly by the amplification and liquefaction and many school have died. That made the government to concern about that.

Then people highlighted that the current zonation practice in the country is not perfect. It is on macroscale. So we have discussed what is the macroscale. It is basically based on the geology and seismicity; it is not based on the local soil condition and site effect on liquefaction. So then, the government felt that there is a need for doing the microzonation of at least urban settlement where people are accumulated more.

Particularly, Ahmadabad many people died, which is more than 250 km from epicenter of the Bhuj earthquake. Then, it was realized that then government initiated the microzonation or zoning study of the country. They started funding the research initiative. So that research initiative only yielded seismic microzonation of Bangalore, which was part of my PhD. I have done extensive study where we have developed a streamlined methodology for seismic microzonation.

So today, we are going to talk about as on now, what seismic microzonation is understood by the people and what they have carried out, what they delivered in India. Even though I have developed seismic microzonation in 2007, there was some work, which was done before 2007, some work after 2007. So there were lot of research and development, because there are many, even people started doing microzonation study at UG level.

People who study B. Tech in Civil Engineering, B. Tech in Earthquake Engineering or anywhere related to civil and earthquake geology, they started doing the microzonation at UG level. I do not know really like four months what kind of work you can do. So even a course which is a part of that entire process is itself offered a semester. I am not sure of UG projects are, but people start doing that.

So we will be highlighting some of the project, which is carried out as seismic microzonation in India. We also highlighted some of the classical work, which is carried out for the particular urban centers on seismic hazard analysis, all those things in today class and continue for the few of our extra classes in these aspects. As we told that the zonation is basically division of area, which has a similar earthquake effect, which considers all the aspects, which can happen due to the earthquake. That is what we told.

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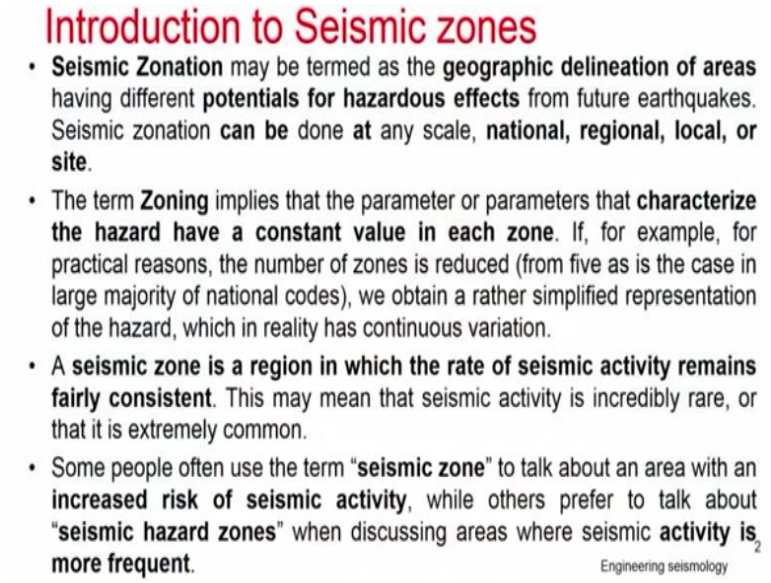

It is basically delineating the area, geographical delineation of the area, where there are all the earthquake effects are similar at that particular location. So this can be done at a different level. We have seen like macro level, micro level and nano level. So depending upon the input what you give, what is the scale you consider, this study, there was an ISMG guideline to define a different level of seismic microzonation studies, which we have discussed in the last class. You can refer your old notes.

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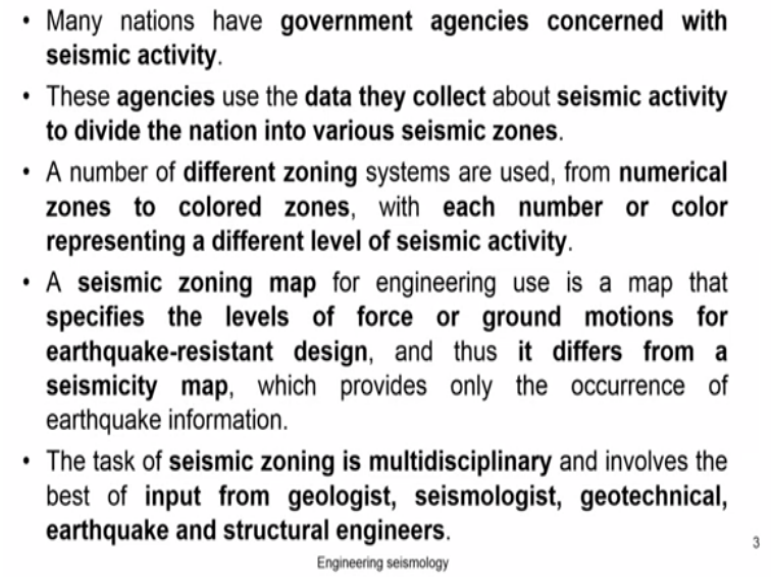

So we have seen that these microzonations are really concerned for the government, because there many people will die. There are huge loss of economical loss, which creates a lot of trouble in industry as well as lot of money has been wasted for the unpreparedness of this kind of thing.

So that is why they thought that preparation of zonation map at microscale on each cities are important, which will help for the new design at a particular place and as well as retrofit the older buildings.

As you have seen the smart cities, there are about 90 smart cities marked by the government, where the small, small places or cities, small towns are getting converted into the urban level. So that people can stay there and instead of accumulating in the bigger urban, which is already exploded beyond its limit. So this will help. In this also, the zoning of that particular city, smart city will help to identify where you can locate different facilities.

We have seen that the location of the important (()) (11:04) facilities should be away from the highest risk area. So we should see that on the hospitals and all those things. So in that aspect, the seismic zonation is a multidisciplinary, which should involve a geologist, seismologist, geotechnical earthquake and structural engineer or the person exposed to all these aspects can be taking up this kind of studies.

So generally, if the civil engineers involved, who has exposed all these aspects and study all these aspects after master level, you can get relatively suitably representative zonation map, as long as he is experienced and gone through all the literature about the microzonation.

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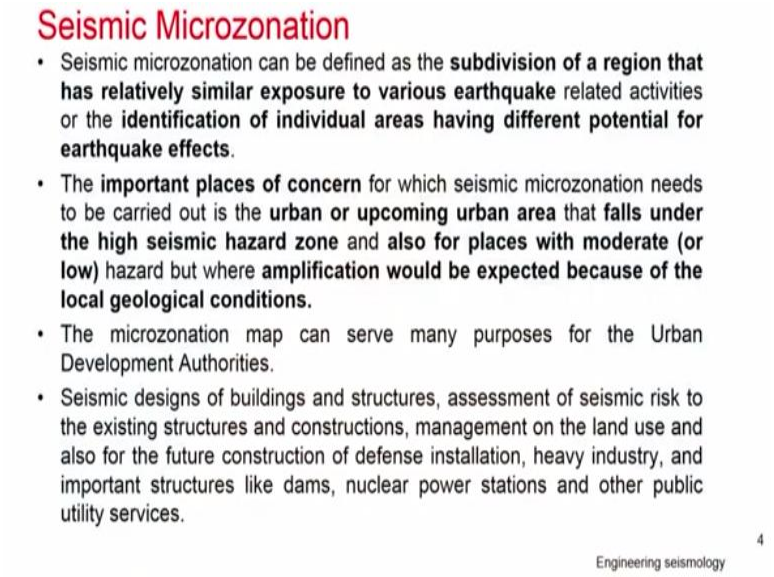

So the microzonation is subdivision of the region considering the various exposure of the earthquake effect. That is what we have seen.

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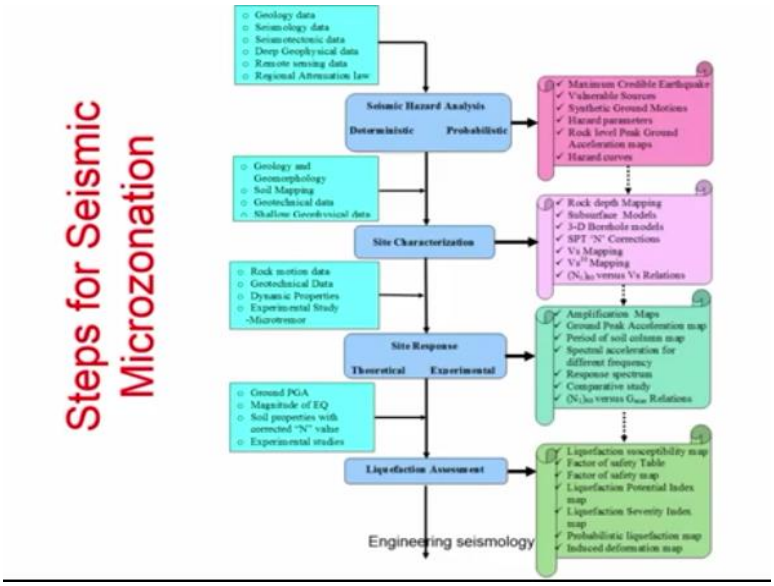

So we have seen that this consists of about 7 classical steps, starting from estimating the bedrock level hazard, then characterizing the soil, then estimating how the waves are getting modified in the site response studies using theoretical and experimental approach, then assess the liquefaction. So all these one output will be the input for the next step.

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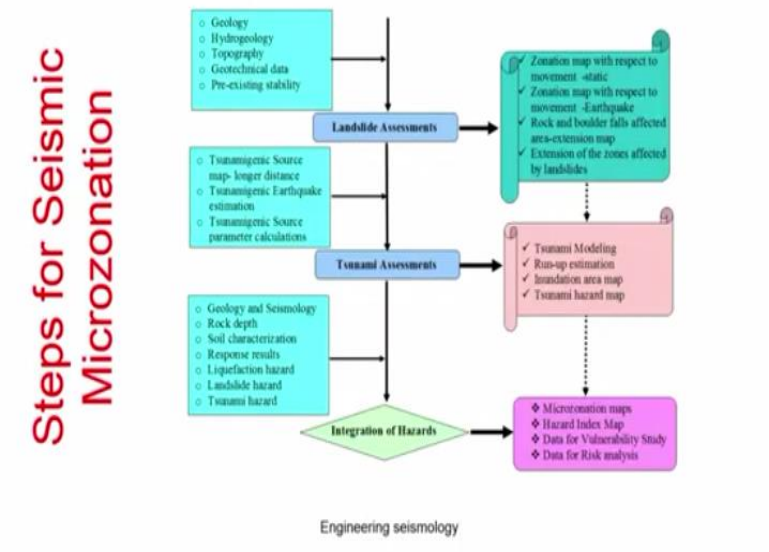

And then estimate a landslide possibilities, which is highly possible only on the hilly region, and then estimate the tsunami hazard, which is only possible on the coastal region. After estimating

all these hazards independently and take out the hazard and assign a proper weights and ranks and then finally prepare a zonation map, which shows a hazard index and then the design spectrum, acceleration time history, so that people who are willing to design the structure in this region, they will take this input.

So recently there was a discussion in one of the NDMA meeting like National Disaster Management Authority meeting. This microzonation, what was the output, how it is useful for the civil engineer. So why this discussion was taken place, when I discuss the different microzonation studies in India carried out, then you will understand. Why this discussion? We are also going to see the ongoing microzonation effort by the Indian government particularly under the umbrella of Ministry of Earth Sciences and National Center for Seismology. That is also we are going to discuss today.

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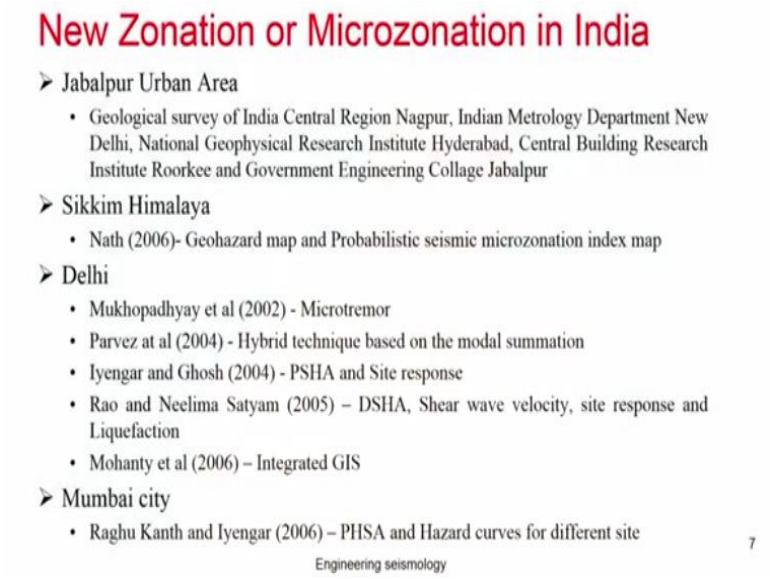

So if you see that, the seismic microzonation, there are some part, which is completed and published as a report to the public or published by the NDMA, where a public can access this report. So there are some things, which are done partially, but NDMA is not officially issued those as a microzonation map of that particular city. The city, which has completed the microzonation basically Jabalpur, Sikkim, and Delhi and then Bangalore.

These are all the places, then Guwahati. These are all the places the work was completely completed. The cities, which is done by others, but not released as an official record by the NDMA, but state government done, are Mumbai city. So here also given the brief about the people who are involved on those kind of studies in this slide actually.

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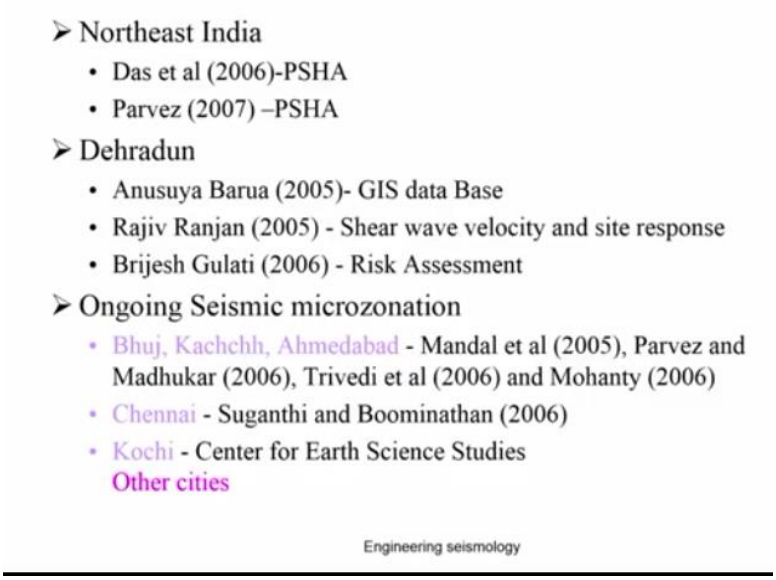

So then, there are people who have done for specific area from the international funding or their own arrangements in the state level or something like that, the Northeast India, Dehradun. So there are some cities where the microzonations, people are doing. These are all some of the cities like Bhuj, Kutch, Ahmadabad, Chennai, Kochi, Mangalore, Coimbatore, then Bhubaneswar, so now even recently 8 more cities are awarded by the contract ISR Gandhi Nagar for the microzonation. So I will give you the glimpse of the some of the major work, which is completed part of this microzonation studies.

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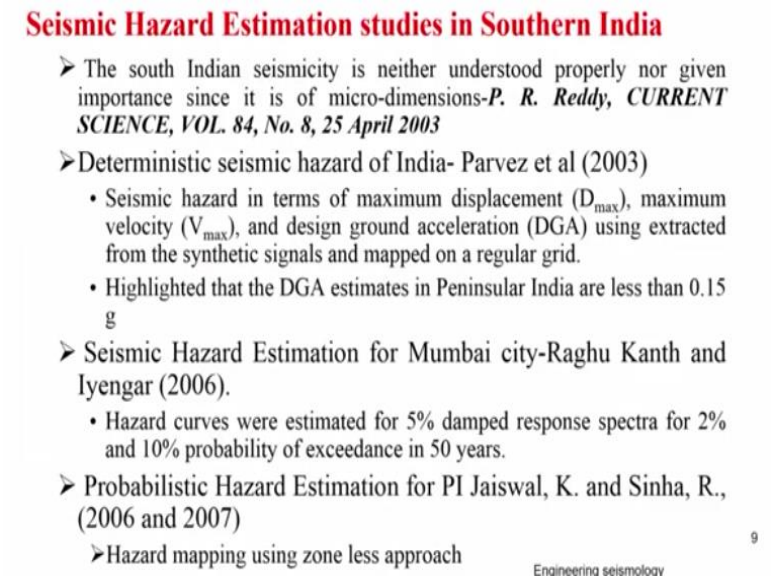

So let us see the seismic hazard estimation studies in the South India. So this South Indian Seismic hazard estimation actually carried by many people, but it is not basically a complete microzonation study, but as we have seen that the estimation of the hazard also a part of your microzonation step. That is maybe the first step to estimate rock level PGA level. So there are few places where it has been estimated.

So South India, it was done was done by Parvez et al, where he estimated the maximum displacement, the design ground acceleration, then there was another article where they tried to estimate Mumbai city using the hazard curve determinacy probabilistic approaches and then whole Southern India by the probabilistic estimation by the Jaiswal and Sinha. So these are the people, some of them they estimated the hazard values, not any other things.

So this is a part of my zonation, but it is not complete microzonation or zonation map further useful for this one. So as such, there is no any classical work, which can quote as a South Indian seismic microzonation work, other than Bangalore, work which is published and officially released as a book from the NDMA. Those who are willing to see that book, you can go through. That is almost my PhD thesis.

Maybe my name may be acknowledged or may not be acknowledged, does not matter, but if you see my PhD thesis and that book, it is almost similar, because I have done that work part of my PhD on the seismic microzonation. I am not going to discuss Bangalore work in detail.

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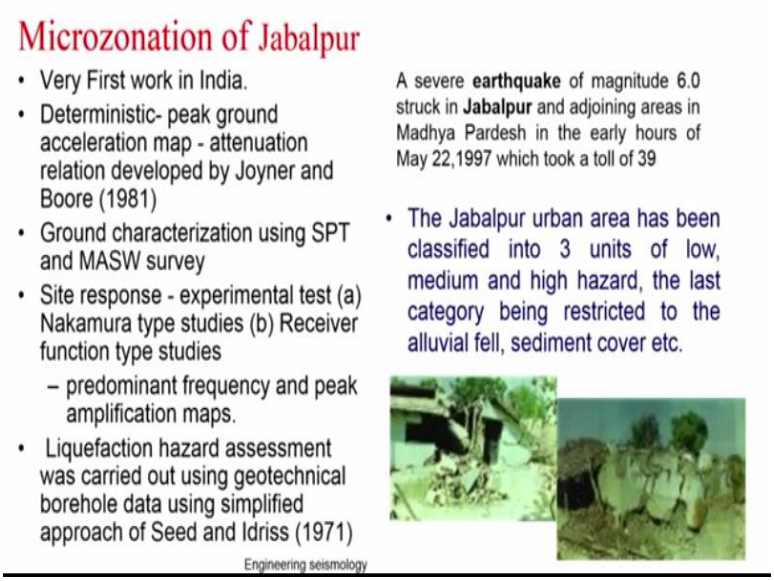

Because there are a lot publications are available, so I only discuss the others work, what they have done, so that we can compare a methodology developed for the microzonation or what is meant by microzonation and what is the work carried out by others, so that you can one to one relate and see what are the improvement needed or how sufficient that work is to represent a zonation map of a particular place.

So in order to make an understanding of that, now I am going to explain. So the first microzonation work in this one was actually Jabalpur microzonation. So this was done basically. There was a severe earthquake of 6 magnitude stuck Jabalpur and adjoining area of Madhya Pradesh in early hours of May 22 ,1997, which took around 39 people have died. So after this Jabalpur and Bhuj earthquake, the seismologist or geologist believed that there should be a microzonation of the particular area.

So then they thought instead of taking Bhuj itself, because that time only the earthquake happened and this study also initiated little longer, I mean before the Bhuj earthquake. So they have taken Jabalpur as a city for seismic microzonation work. So what they have done? I give

you the glimpse of the work, what they have done. Basically, they carried out seismic hazard analysis by the deterministic approach.

Here, you should note because when we are talking about the hazard analysis after completing of this microzonation and Indian seismicity classes in the future, you should know what is the deterministic and probabilistic approach, why it is important. I will be discussing, but right now I am just giving what they have done. So they carried out hazard analysis by deterministic approach. They used a ground motion prediction equation, which is also called as attenuation equation developed by Joyner and Boore in 1981.

So this work was basically published, I think, around 2004 or 2005, but they used the GMPS, which was developed by Joyner and Boore in 1981. When we are talking about the predictive equation, we told that any predictive equation should be subsequently represent a region and has been developed as much as the new. So these people have also done complete ground characterization, which is the second step.

They used SPT data and MASW survey and they also carried out site response studies by the Nakamura type studies receiver function, where they tried to estimate a predominant frequency, which we have discussed what is the predominant and then peak amplification map. Further, they also assessed liquefaction; assessment was carried out using the geotechnical borehole using simplified approach suggested by the Seed and Idriss.

So even though we are not discussing the liquefaction, site response, site characterization in detail, but you should know that these are all the work, which is involved in the particular map. They published a first level seismic microzonation map.

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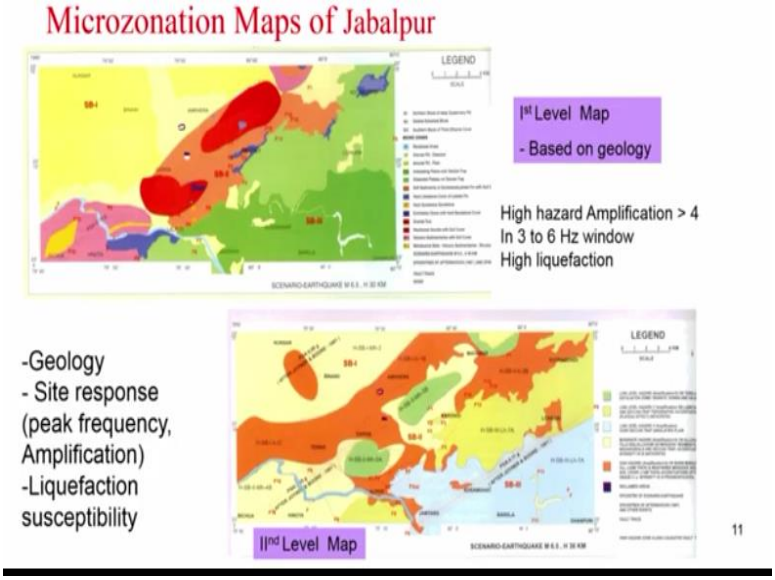

So you can see they are given like different coding and colour, where the hazard levels are included. So they found that the hazard amplifications are as high as more than 4, in the 3-6 Hz window and then it also mapped a high liquefaction area. So this is generally done based on the geology. This map was done based on the geology. So then, they updated this map where the geology and also improved by taking into the soil data where the site response really carried out, amplification estimated, liquefaction estimated.

So all these factor they put together and revised the map. This map they call it as a second level microzonation map. You can see now the red pattern and then the colour change. So you can see how this one changed the zonation pattern. This shows that where we include amplification liquefaction basically your zonation gets altered. So the geology based zonation may not be so appropriate. So that is the message you can take by comparing these 2.

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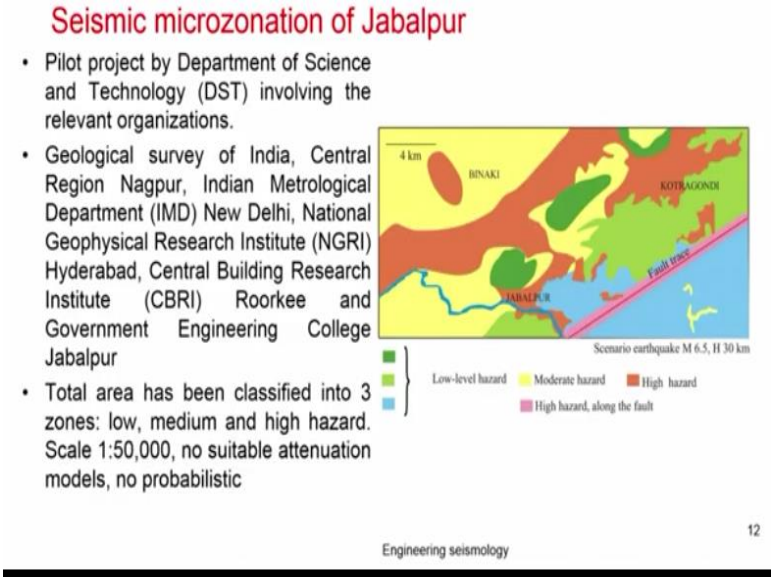

Further, they also tried to estimate a risk by considering some scenario, where the pilot project by Department of Science and the geology of survey in this work actually who are all involved actually, the Geological Survey of India, Central Region Nagpur, and Indian Meteorological Department, IMD, NGRI, Central Building Research Institute; they almost spent close to about 4-5 crore rupees to take up this work.

Total area has been classified into 3 zones, low, medium, high with the scale of 1:50,000. Here the overall basic command was that, even though this was the first work in India, but it is not a first work that can be quoted as an example for microzonation. I had a chance to go through the complete microzonation report during PhD, where it has come for review to the IASC, where I have been pinpointed all the necessary improvement needed in the report.

Then only the first map what you have seen based on the geology has been improved by including the amplification liquefaction, finally arrived. This is the final map, which is officially released by the government. Those who are interested, you can basically browse and get the details about the Jabalpur microzonation. This has given a starting point, kick start in India where the next work has been improved considerably by systematically analyzing the procedure and other things.

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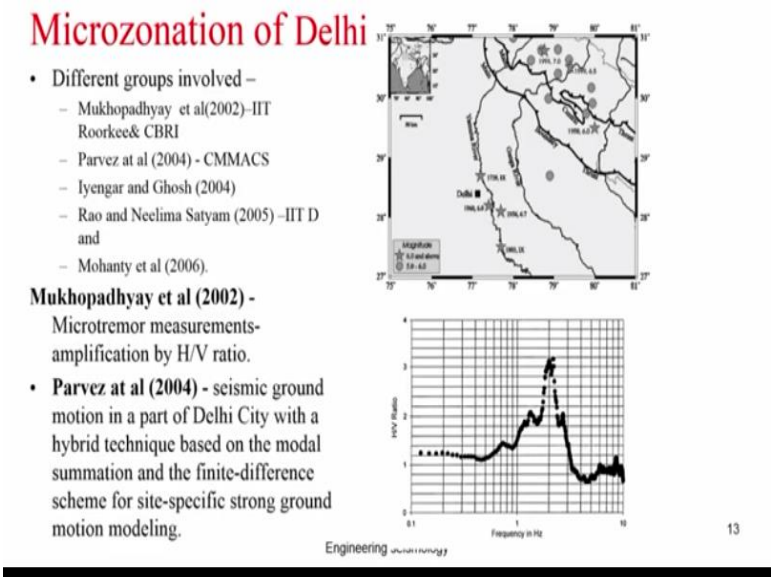

So the next work what carried out for the seismic microzonation of Delhi. Delhi was actually carried out by the different people. They are basically carried out by a group of scientist working on different place according to their availability and the interest they carried out. So this was like the Mukhopadhayay IIT Roorkee, CBRI, then Parvez et al CMMACS, Iyengar and Gosh, IIC, Rao and Neelima IIT Delhi, Mohanty.

These are all the people basically they carried out microzonation. Then later, even IMD MOES taken up all these input and then further improved and then they finally released a complete microzonation map of Delhi. So here Mohanty carried out microtremor study H by V ratio. Parvez carried out hazard analysis and tried to get a spectrum, which based on the past earthquake data.

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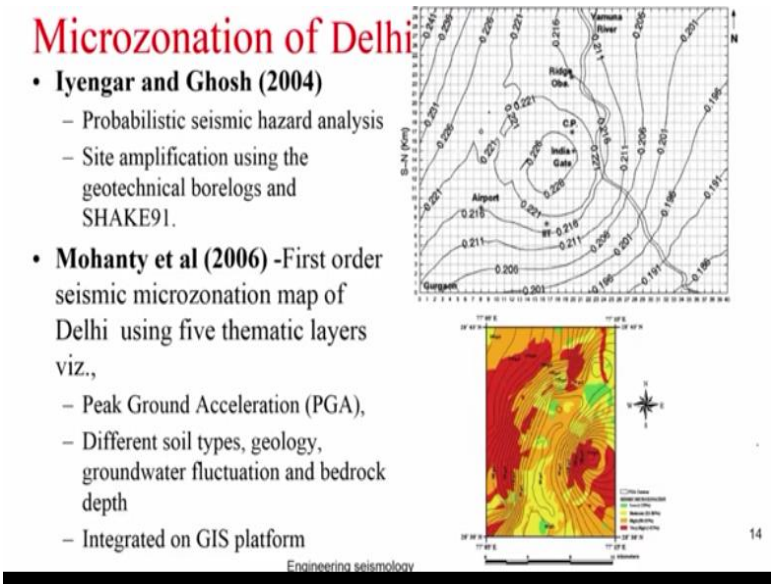

And then Iyengar and Gosh did a PSHA analysis and tried to give a PGA distribution at bedrock. So when you are talking about this one, you can see basically they also consider soil amplification during the shake. You can see the value of G value around NCR. So if somebody considers their house design around this, basically your house may not get collapsed. So this was predicted for around 2004, which was roughly about 15-16 years back.

Then Mohanty carried out complete microzonation study and tried to estimate the H by V ratio. When the H by V ratio basically, there are some geologist and seismologist believe that doing a microtremor study and mapping a predominant frequency is called as a microzonation. The microtremor study and predominant frequency, but as I told you that the predominant frequency will help you only to give the fundamental frequency of your soil colour.

So this is basically related to the thickness of the soil column. So that thickness again depends upon the regional correlation established between the H by V ratio and predominant frequency. So as such, the predominant frequency estimated may indicate as we have seen that the geology and isoseismal maps are very well matching, similarly the thickness of the failure pattern, isoseismal maps are very well matching in the past earthquake.

So the knowing of thickness will help you to know that where the more severe earthquake hazard can be expected for the same earthquake. That is all; it does not really give you the

microzonation map, which is required by integrating the 6 parameters. It does not give that kind of map only by using a microtremor studies, because we have been using microtremor study for different cities and we found that, these microtremor studies are function of your predominant frequency and established relation between the soil thickness and predominant frequency.

If there is a change in this, this estimation can be completely wrong. So one has to remember that, but the people who carried out these kind of studies and claimed that that is a microzonation of this one.

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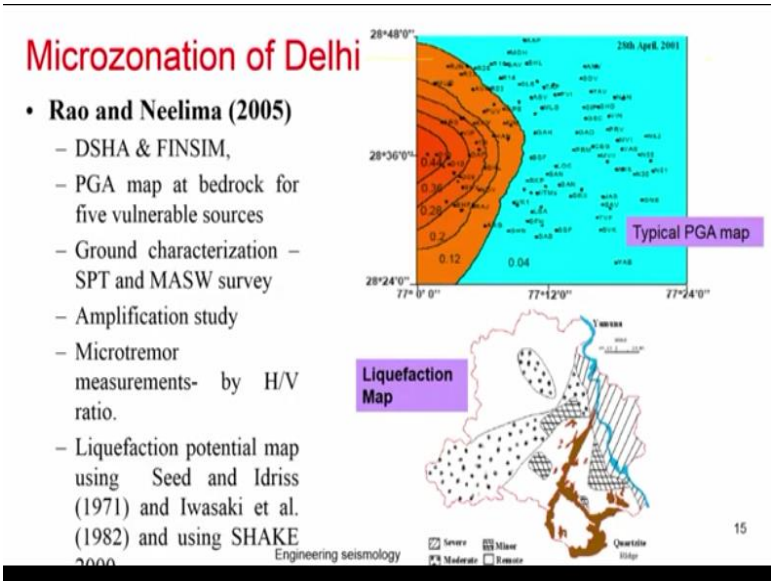

Then, the IIT Delhi, professor Neelima Sathyam carried out a part of her PhD, where she did a complete hazard analysis, liquefaction analysis, site response and characterization using the MASW finally, they produced map, which shows a different hazard level. They even used a simulated synthetic ground motion, which is useful or required for the site response study. So they developed a PGA bedrock map and said that there are 5 zones, that can be arrived from this one.

Then, they measured the soil properties using the SPT and MASW and amplification studies from using these data and this input; they carried out site response analysis and (()) (27:42). Then, they also did microtremor to compare the results obtained from the borehole and MASW are synchronizing. Finally, carried out liquefaction potential map using the Seed and Idriss,

Iwasaki and SHAKE kind of thing finally produced liquefaction potential map or liquefaction severity map.

So this is the map. You can see that this is actually the Yamuna river, so the region which is close to Yamuna river as a severe liquefaction possibility you can see here. So the people in this region really should concern that their buildings, even though the building as I said that the building designed for the earthquake resistant structures, but they did not take care of the liquefaction possibilities in the structure and the structure may sink inside the soil or it will collapse or tilt.

That is these are severe, then the moderate region, these 2 are the moderate region, so the white one has a remote, the another area has a minor. So this is where you can see, wherever the river deposits are there. So this is the place the liquefaction possibilities are there.

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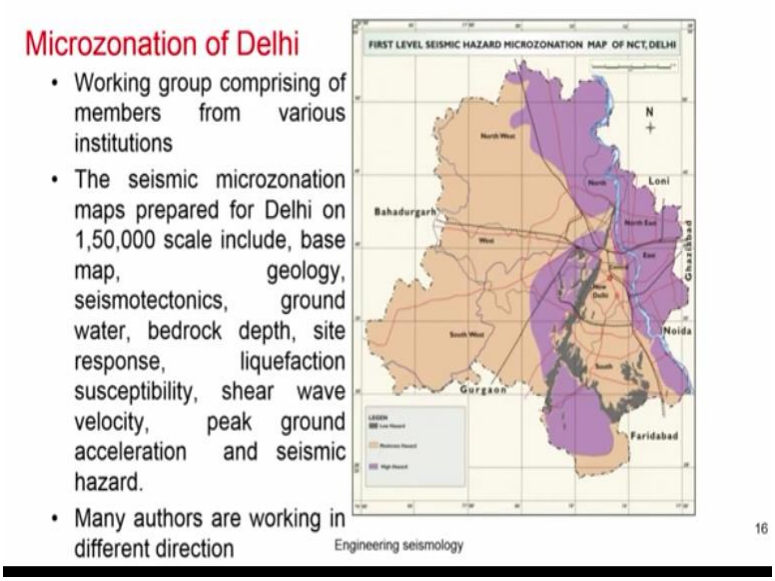

So all these combinely produced, so then finally as I told you that there is an IMD and other institutes also work. So finally, they created a liquefaction microzonation map of Delhi, which includes all the hazard analysis, site characterization, soil data, site response and liquefaction as a landslide, tsunami is not possible in Delhi. So removing that, they carried out a detailed mapping and prepared a seismic microzonation map with 1:50,000 scale.

You can browse this report where they accounted all the possible hazard, where the bedrock depth, liquefaction, shear wave velocity, amplification. Finally, they produce a map which shows low hazard, then a moderate hazard and then high hazard. You can see that wherever there was a liquefaction possibility we told, those are all the places considered to be high hazard region. So in this also, wherever the rock outcrop is there, basically this is the shallow bedrock sites.

So where they consider that as a basically low hazard, as the amplification liquefaction may not happen. So when we discussed about the different types of hazard, we have seen that the amplification, ground shaking hazard is basically causing more than 70% of the deadly earthquake in the world. That is what we have seen. So knowing that this hazard, it is very important for any microzonation study, the map, which represents considering this will be the more reliable one microzonation study.

As on now, Delhi is one of the classical work, which accounts all of them with appropriate ground motion prediction equation as well as the regional they can talk on. So this was done by, the recently updated map was released by the Ministry of Earth Sciences where the previous work by Rao and Neelima, Mohanty, and Iyengar and Gosh, all those works are basically integrated. Finally, the microzonation work of Delhi is available.

Those who are living in Delhi, if you want to know that what was the given design force at that particular location, you can basically Google it and find out microzonation report or you can obtain a copy from the Ministry of Earth Sciences, because it is a publicly funded project. So you can know your region falls on which category, what is the force that is expected in that region. Your building is designed or not, if you know that it is designed, then you no need to worry.

If not designed, you should really concern and try to improve the building area or if you are constructing new one, you can adopt to this procedure for construction of the new one. Right now, we have discussed about the microzonation importance and also the 2 typical case studies, one is the Jabalpur, another one is the basically Delhi region. Those who are in Delhi now you can understand that how severe earthquake in your region.

You no need to worry as long as your buildings are designed for the earthquake. If not, you should at least concern and be alert, so that something happens, you will escape. With that, we basically close today's lecture. Thank you very much for watching this lecture. We will meet you in the next class. Thank you very much.