**Introduction to Engineering Seismology**
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**Lecture - 44**
**Seismic Microzonation of Various Indian Cities (Continued)**

Vanakkam. So we will continue our lecture on Engineering Seismology. So we have been discussing about the seismic microzonation studies done in India. So we have discussed about the Jabalpur work, which was the first and foremost work, where kick started microzonation in India, then followed by we have seen the Delhi microzonation, which was funded by several agencies.

Finally, as on today, the updated classical report on seismic microzonation on Delhi is available. I also said that the seismic microzonation of Bangalore has been completed as an example study, even though the Bangalore is in Southern part of India and placed on seismic zone 2 as per Indian zonation map, but still we have done that systematically to demonstrate how microzonation study has to be done. As I said that the Jabalpur was started before the Bangalore.

So only they could do some patchwork and finally publish a microzonation work, but the Delhi work was done after the Bangalore, where they have done systematic studies and improved, the final map has been prepared. So there are some other works, which is parallelly done along with Bangalore or before, those work we are going to discuss. So today's class will be continuation of yesterday class. So another work microzonation map published is the microzonation of Sikkim. So Sikkim, a state as you know that it is a state.

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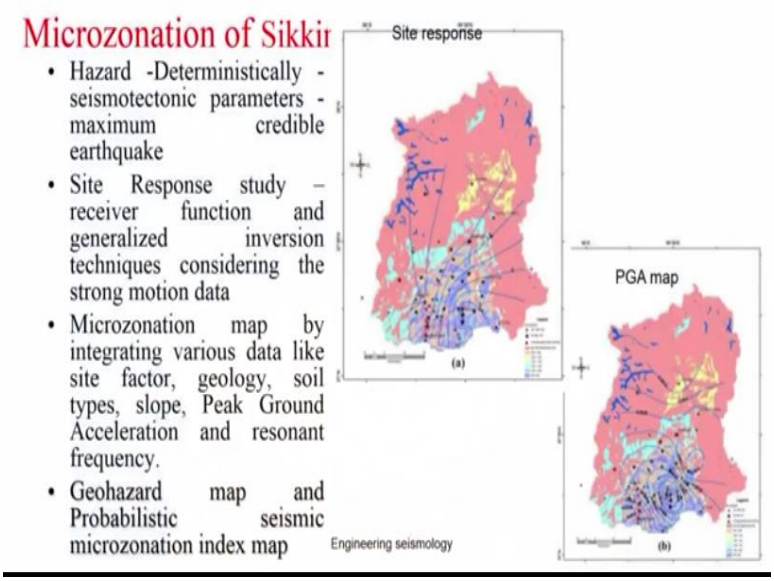


So Delhi and Jabalpur basically is a city. So in between the micro and macrozonation, because the study area is very large. So what they have done here basically; they carried out a seismic hazard analysis by deterministic approach, by considering the seismotectonic parameters in the region and maximum credible earthquake. Then, the site response study was carried using the receiver function and generalized inversion technique considering the strong motion data.

So these people basically, this was done by the IIT Kharagpur. They setup a permanent seismic station at different parts of Sikkim. They collected data. They tried to use the data as part of the study. So that was one good way of accounting some earthquake, which is happening during the period, I think. So the microzonation map was prepared by integrating the site factors, which was obtained from the microtremor studies or something like that and the geology and soil type, which was again obtained from the geology survey of India map.

And then, peak ground acceleration and resonant frequency, so the peak ground acceleration has been estimated by considering the detailed seismic hazard analysis, which we will be discussing in the future classes. So finally, they prepared a geohazard map, probabilistic seismic microzonation in that map, where you can see that given a PGA distribution, which is useful for the design of building and also they have given basically the amplification map and hazard index map, the high, low, medium. Intermediate kind of classification also there, tried to establish in

this work. This work was actually started before Bangalore, but completed during my microzonation study.

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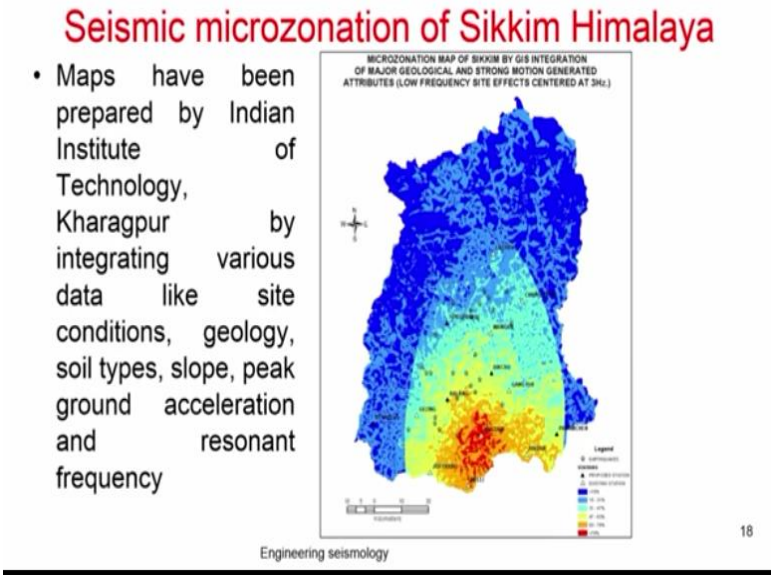


Where we have been also involved in the suggesting and improvement of those work. Based on that actually, the microzonation map, final map has been prepared by taking into all the consideration, which is discussed in the steps given by this. So only thing, this map since it is done for a state level, the accurate information gone with the microlevel may not be so appreciable as expected in the microzonation details, where you can see the station and then the hazard level.

So the proposed, existing station and then the hazard level, where there are some seismic stations are set up and monitored by the IIT Kharagpur on this state, basically for the improvement and establishment of the better earthquake zoning of the state, which was also under a process. So this was a map. This report also basically released by the Ministry of Earth Sciences. We can browse it like a seismic microzonation of Sikkim, Himalaya; you can also browse that.

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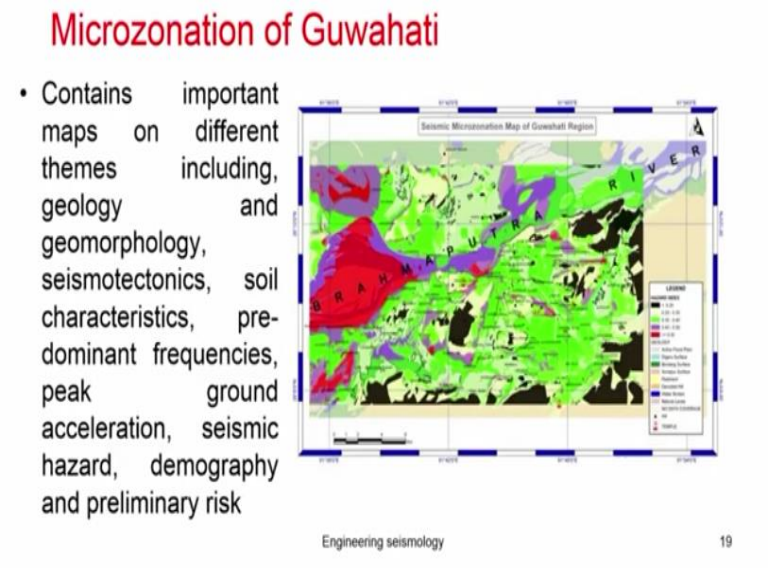


So another study, which was again carried out for the microzonation of Guwahati. This consists of Guwahati, Northeast part again, where they consider all the aspects, which we have discussed with the seismic microzonation of Delhi, where geology, geomorphology, soil characteristics, site response, amplification and liquefaction and then finally integrated the hazard map. So you can see the hazard index values given here.

So the very dark colour is having the lower hazard index. The red colour is having the higher hazard index. So these hazard index depends upon what is the weightage you assign for each microzonation parameters, such as bedrock hazard value, the geology, the geotechnical data, and amplification, liquefaction, landslide and tsunami. So based on the density of the data and velocity what you obtain, you get these hazard values are similar.

So you can also see that the interpretation of this microzonation hazard value may not be same. For example, in Sikkim, it is written hazard value of 0.5 and Guwahati it is written 0.5 and Delhi it is written 0.5. These 0.5 at different regions are mean different level of exposure. The 0.5 with respect to what is the lowest level, not 0.5 means, it is so much hazardous, such things are there. As the integrations are done specific to the parameters responsible in the region.

So this work also has been revised several times and then done and then the seismic microzonation of Guwahati map is also released by the Ministry of Earth Sciences. You can find

that maps and related plots, where you can get a book volume of report, which is useful for the design as well as the retrofitting the existing structures.

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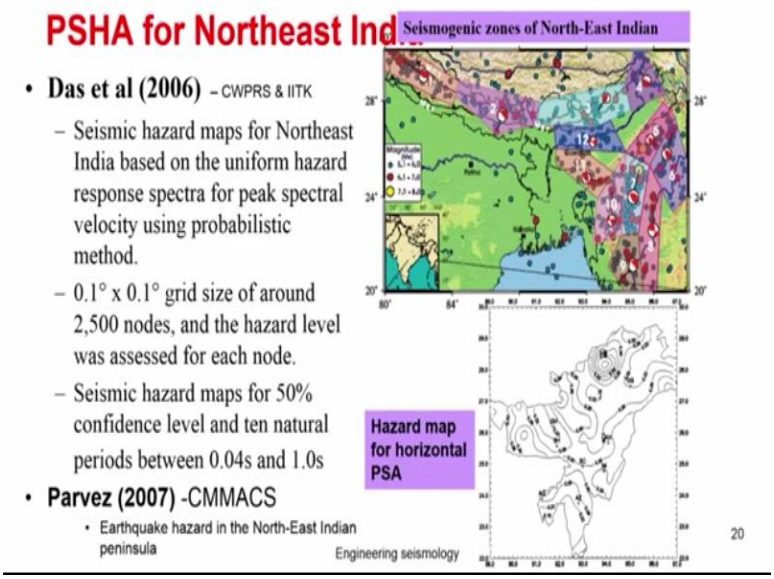


Similar kind of microzonation kind of work, many people as I told you that started working on microzonation. So this is some of the work in the Northeast, Das et al Central Water Power Research Institute CWORI and IIT Kanpur. So they carried out a detailed study and then they prepared a map of 0.5-0.5 tilt size and then something was there and then they prepared a seismic hazard analysis map 50% confidence interval and given PGA distribution map by considering all the seismic activity.

You can see the different seismic zone and then included and then given a PGA distribution map for the entire Northeast region. So even Parvez et al also did some studies and then he also produced a map, which was also integrated, but here you can see that entire northeast region has been clubbed as one entity; they tried to do. Here they stopped basically seismic hazard analysis, which is a part of zonation, but not a complete microzonation. So that one has to remember when you refer this kind of publication.

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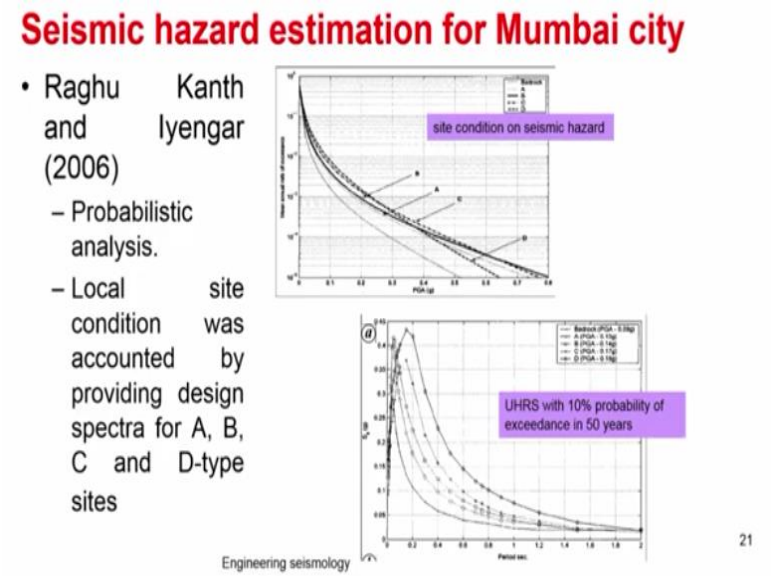


So the another work as I told you that Mumbai people have done hazard analysis. So basically the probabilistic and deterministic hazard analysis has been carried out, tried people to get a hazard curve, which includes basically a bedrock seismic hazard value and consider the soil thickness in the region as a site class. That is some kind of concept, where comes on the site characterization and then estimate a surface hazard, so where the waves are considering the soil in the region.

So that they produce different hazard curves, we will discuss about the hazard curve and then the uniform hazard spectrum during the probabilistic seismic hazard analysis. So they estimated that and given for different sites of Mumbai. So this is basically maybe up to the step 3, bedrock level assessment, soil data, here actually people have collected a soil data or assumed a classification as it may present at some of the location. Then they estimate an amplification using an empirical method. So then they produced this kind of map which claimed as a seismic hazard analysis of the Mumbai city.

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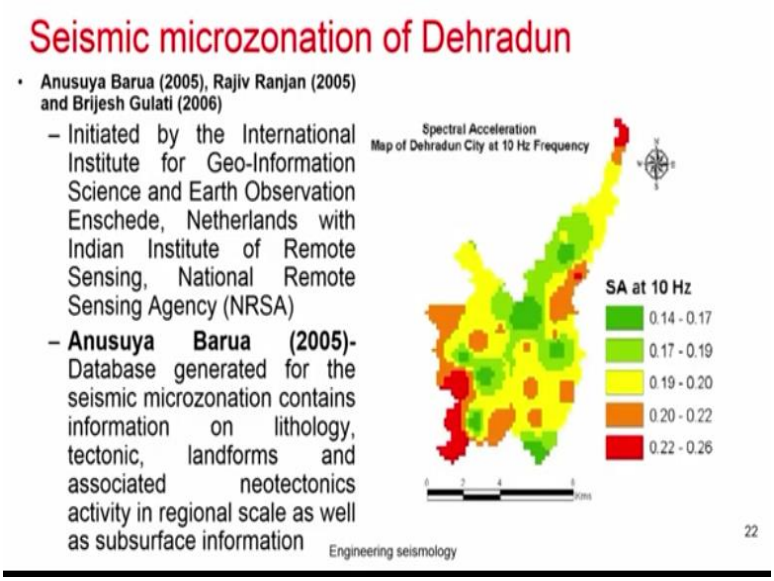


So another work, which is done by Dehradun, Wadia Institute of Technology, where a number of students, the PhD students worked on different topics, then finally all these values are clubbed together and produced as a microzonation work. So Dehradun, the Wadia Institute of Technology, Dr. Mahajan, right now he is working on the other institute. So he was one of the pioneer person in MSW survey in India.

He is the first one to carry out seismic surface wave testing in India and published paper based on that, which was one of the classical works we can quote here, where some of the students are extensively involved on different aspects of the microzonation. Finally, they produce a microzonation map. So Anusuya Barua 2005, Rajiv Ranjan and Brijesh Gulati, those are all the people who worked with Mahajan, when he was in Wadia Institute of Technology.

This microzonaiton work was basically initiated by the International Institute for the Geoinformation Science and Earth Observation, Netherland, the Indian Institute of Remote Sensing and National Remote Sensing Agency NRSA, then Anusuya carried out database for the contact lithology, tectonic, landforms, and neotectonics, regional scale and subsurface information and then they tried to produce spectral acceleration map of Dehradun at 10 Haz frequency. So you can see the spectral acceleration values corresponding to 10 Hz, 0.01 second basically. You can see how much the SA; spectral acceleration value they have mapped.

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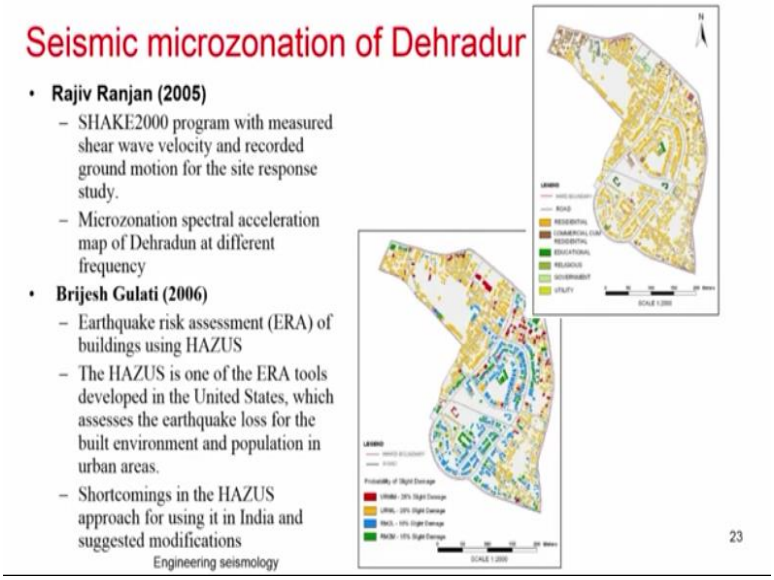


So then Rajiv Ranjan did the extensive MSW study and used site response package called SHAKE. The SHAKE is a commercial program available to estimate amplification. So then he tried to get amplification at different levels of the Dehradun city, where he tried to map the variation of the shear wave velocity, variation of the spectral acceleration for Dehradun. Further, Brijesh Gulati, where he had taken the earthquake risk assessment of Dehradun using the HAZUS program.

HAZUS is basically a program which is developed by the FEMA, USA. This program basically if we give the building stack and then rock level PGA and all, where you can try to get the vulnerability index of the building. So this depends upon the building. You can see the different building types, then different utility of the buildings, residential, commercial, education, religious, government all those things and then how much the damage you can expect.

This is the study characteristics of the Brijesh 2006, where the vulnerability assessment study has been done. So this patch of the work different, differently done, but at the end compiling all of them and releasing a zonation map and risk map, I think is not done as per my knowledge, maybe we have to check. But this was done part of that institute collaborated with other institute and it is not initiation by the MOES.

But as I told you that this is a classical work done by the first time, particularly the mapping a shear wave velocity, measurement of shear wave velocity and then running the site response analysis using the shake. So that was a classical Rajiv Ranjan work, which was graded by professor Mahajan from Wadia Institute of Technology, presently I think he is affiliated to other institute. So this is about the microzonation initiation by the Dehrahun.

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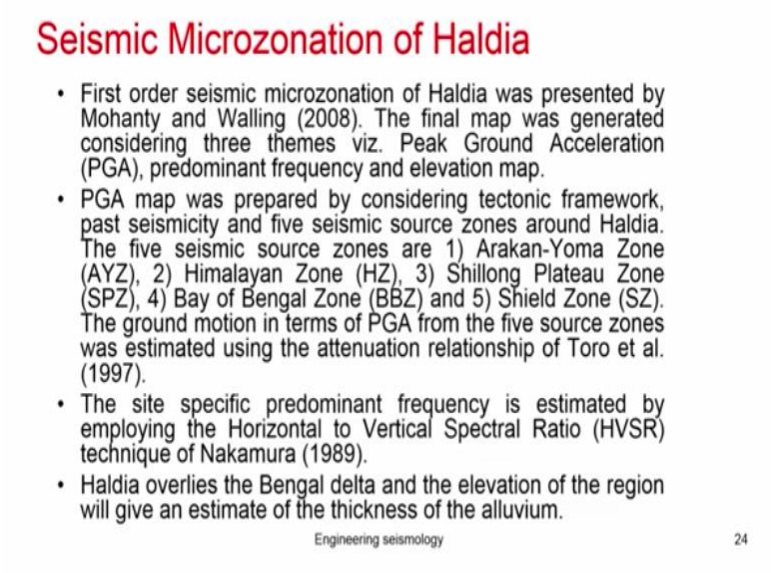


So the similar kind of studies, people have, as I told that with funding or without funding, there are a lot of works parallelly carried out by different people to try to say that whatever work they have done, they call it as a microzonation, irrespective of the number of component involved. Even, I told that people do the microtremor study and call it as microzonation, do hazard analysis call it as microzonation, do VS measurement and map a VS map measurement call it as microzonation, do liquefaction mapping and call it as microzonation.

Even though I said that the integrating of all of them at proper weights and ranks depends upon the region and producing a final map in terms of hazard index value, that is the final microzonation map. The first order microzonation map of Haldia was presented by the Mohanty and Walling in 2008. The final map was generated considering 3 things, like peak ground acceleration, predominant frequency and elevation map.

You can see that the considered PGA, which will take care of the seismic hazard analysis and then predominant frequency, some extent take care of the soil and elevation map; this is also again a soil, which is indirectly amplification. So the PGA map has been prepared by considering the tectonic frame work, past seismicity, and 5 seismic source zones around Haldia. So they delineated different 5 zones, which they are expecting.

So site specific predominant frequency is estimated by employing the national, horizontal to vertical ratio of the technique given by this one, like microtremor studies. Haldia overlies the Bengal delta and elevation of the region given estimate of thickness of the alluvium in that region.

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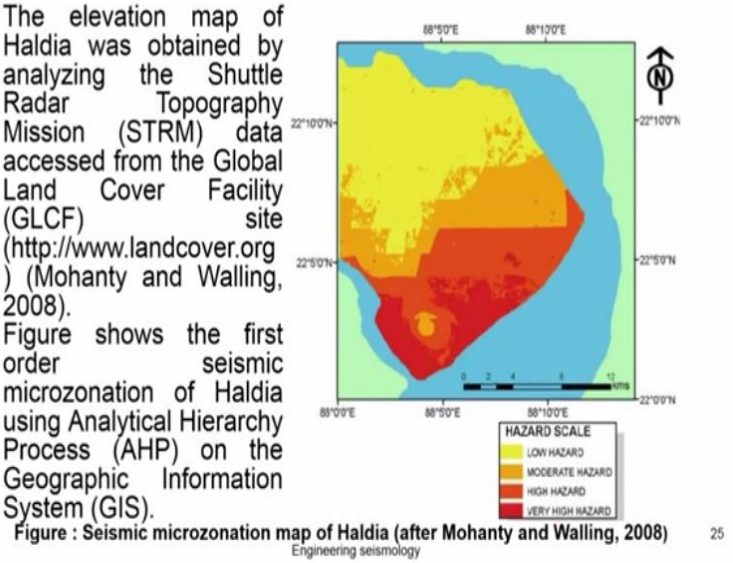


So this is the hazard value prepared by Mohanty by considering whatever 3 parameters we discussed earlier. The elevation map of Haldia was obtained by analyzing the shuttle radar topography mission, the data assessed from the global land cover facility, then the figure shows the first order seismic microzonation map of Haldia. As we have seen that the macro level map, which is like level 1, level 2, level 3 as per international recommendation, considering the geology and seismicity can be considered as a level 1 this one.

That is why they call it as a microzonation level work. So they have given like low, moderate, high and very high. We can see the colour pattern; the darker colour basically is the high hazard

regions. Even though they claim that it is a river deposit, but there is no liquefaction analysis has gone into the hazard mapping of this one. I am not very sure. I expect that this region may also get liquefaction possibilities, but it was not published as liquefaction included map for this particular region.

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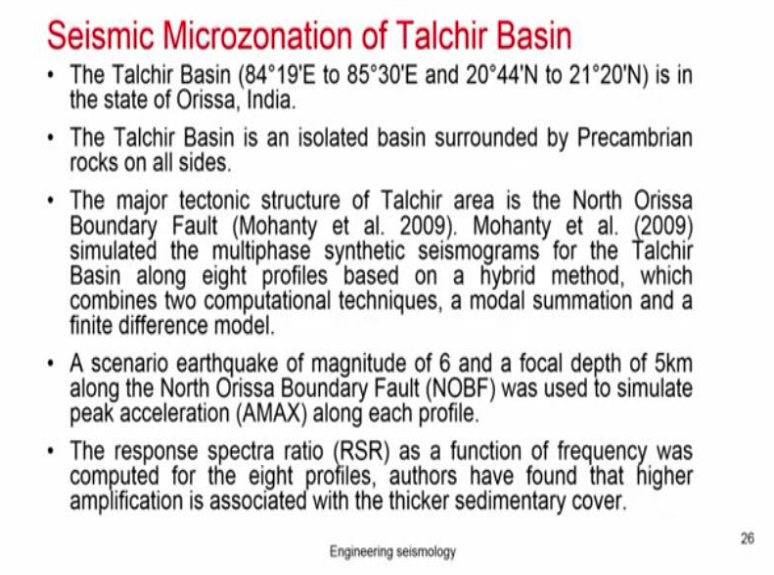


Similarly, the seismic microzonation of Talchir basin was done. So Talchir basin, the dimension is given. It is in Orissa, where the isolated basin around this one. The major tectonic structure Talchir basin has been reviewed. So Mohanty et al gave the multiple information, particularly generated a synthetic ground motion of the Talchir basin and they used like finite element simulation and scenario earthquake magnitude of 6 and focal depth of 5 km along the North Orissa boundary fault.

This was used to simulate peak acceleration AMAX along each profile. The response spectrum ratio, RSR as a function of frequency was computed for 8 profile. The authors have found that higher amplification associated with the thicker sedimentary cover. So with that, they published this one.

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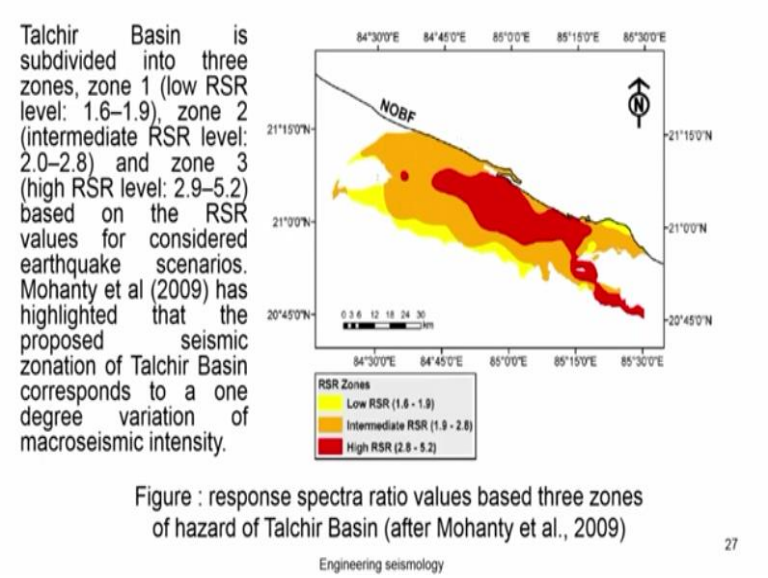


This, you can see the fault and associated this one, you can see. So the Talchir basin is subdivided into 3 zones, one is like RSR is so much, zone 2 RSR is so much. So the value based scenario at the Mohanty has highlighted that proposed seismic zonation of Talchir basin corresponds to the 1 degree variation of the macro intensity scan. So this is actually macro level and they only consider again 3 parameters. Then, they will talk about the liquefaction and other things of the basin generally, which is associated with that. They are given like low, intermediate, and high.

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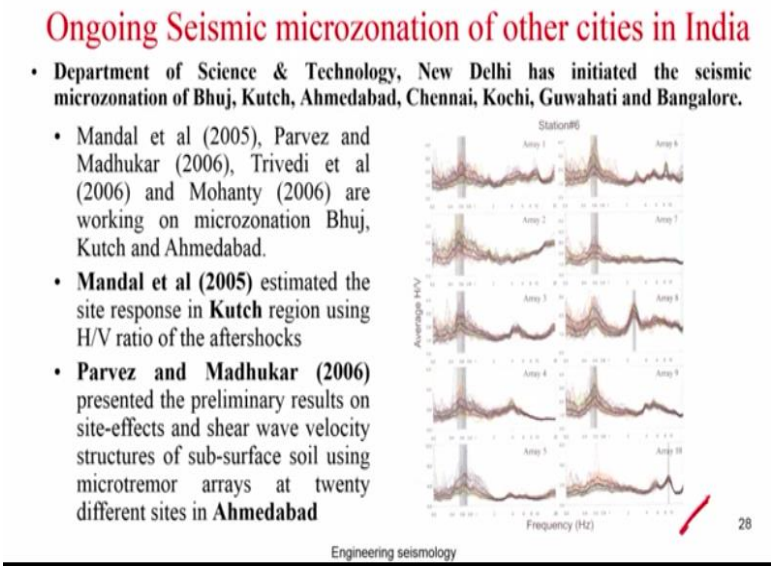


So there are, as I told you, that there are many other people who carried out a microzonation component study and claimed as a microzonation of that particular place or a city, so one of them

like Mandal, Parvez, Madhukar, Trivedi, Mohanty are working on Bhuj, Kutch and Ahmadabad and people try to estimate a H by V ratio and then mapping at that predominant frequency, they also call it as a microzonation. So the Mandal estimated the Kutch region using H by V ratio.

Parvez and Madhukar presented a preliminary result of the site effect shear wave velocities of surface soil using the microtremor array at 20 different sites of Ahmadabad and this kind of result they produce and map the predominant frequencies. This is actually the predominant frequency at different location, then they map. So mapping of this will help you to understand how the geological formation, thickness of the soil varies at particular study region, wherever you study.

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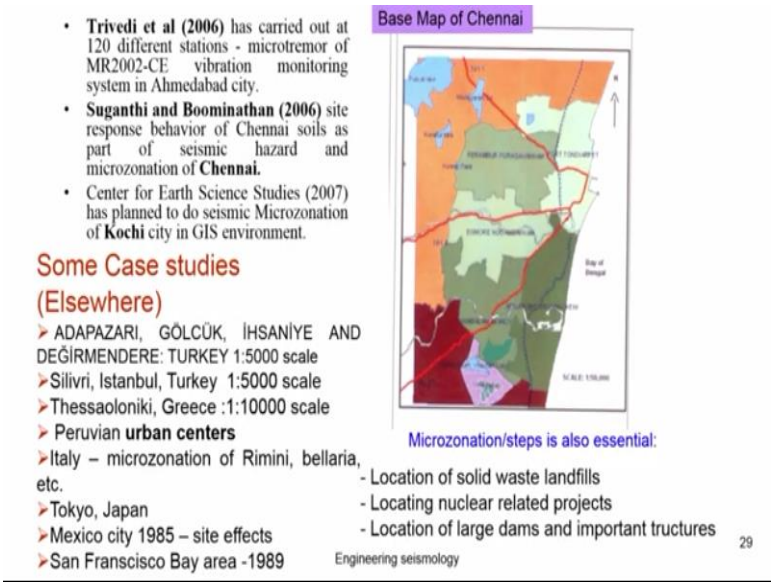


So similarly the microzonation work also carried out by the Chennai city, which was carried out basically the IIT Madras professor Boominathan and his group. Then, even some other people also carried out microzonation of Kochi, where the CESS and then Trivedi carried out microtremor studies. Then, finally these are all the people. They produced independently the report as well as the publications.

So the systematic integration of the hazard, which is published only for the few cities in India right now. You can say like the Guwahati, Delhi, so then Bangalore, as a city. As a state, you can say that Sikkim. So there may be large number of publications, that might have come from each

microzonation component of the work microzonation work, but the systematic hazard index value, which considers all the parameters or all the earthquake hazards effect in the particular locations are very important.

In this time, I need to also highlight that there are several microzonation studies in the world. They are like this Turkey, Istanbul, Thessaoloniki and then Italy, then Japan, Mexico, San Franscisco, so these are all some of the classical work, where the piece and bit up work has been done at different places and published as a microzonation work. So I think the Thessaoloniki work is one of the composite work, where they integrated all the possible different hazard parameters into that.

The second is Istanbul. So that is also one of the classical work, where they tried to basically delineate the area, which are higher and lower seismic hazard index or seismic risk where you can facilitate or you can locate solid waste landfill, nuclear power plant and large dams in the low seismic region. That was one of the major objective of doing this seismic microzonation. So if you have done a seismic microzonation, you can delineate an area and then you can try to avoid high risk area to place any of the important facilities.

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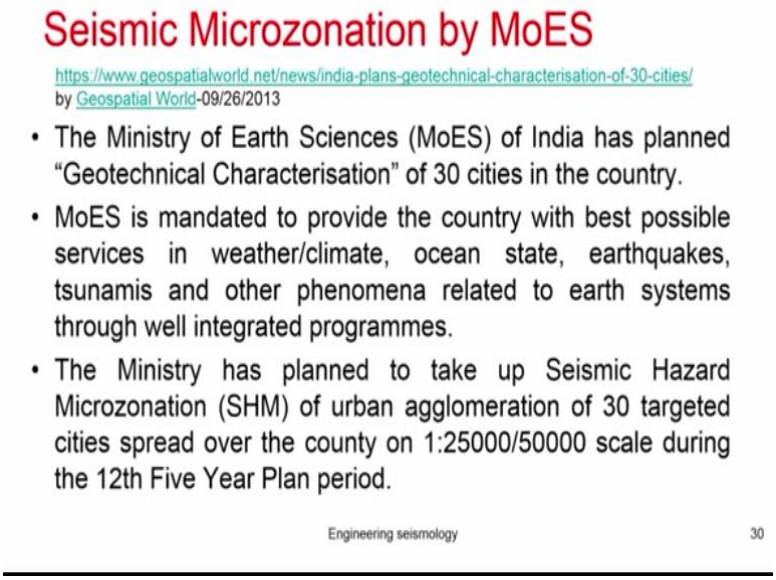


So as I said that the people here and there collected grant from different ministries and then the state level or central level and then they tried to generate a hazard values and then microzonation

map as they think. So generally the seismologist, the geologist, they concentrated more on the H by V ratio. The geotechnical engineers more concentrated on the amplification ratio, the structural engineer more concentrated on the PGA response spectrum kind of things.

But we have seen that the microzonation is basically synchronizing all the possible hazards. Again, I will recap the different hazards, what we consider. So all the possible hazard means first the direct ground shaking hazard, which comes from the hazard analysis at bedrock level, then characterizes the soil and then understand how the soil thickness varies at a particular city and then how it is amplified or modifies the seismic wave, how it is potential to fail due to the liquefaction.

That is the second part. Third estimate the amplification by integrating the hazard bedrock values and the soil data collected at step 2 and then produce the amplification map or amplified ground motion data at surface. Once you have done that, then you check that how the soils will undergo failure due to liquefaction as you know the soil data collected earlier. So then, if you know the liquefaction possibility, that is fine.

If the area is under a hilly terrain or hilly region, you should also need to consider the landslide possibilities, which is one of the major component in the hilly region. Then if the areas or cities are located close to the coast, you should consider also the tsunami possibilities and tsunami hazard map. Then, you can integrate all these hazard appropriately with assigning the weights and ranks and guess their hazard map.

As on we have seen that, even though there are many microzonation, if you Google it seismic microzonation in India, you can find plenty of papers, which is systematically listed by the Google, but the systematic microzonation map published is only applicable for the few cities, like Delhi, Guwahati, Sikkim, and Bangalore. So Bangalore work, I did not discuss. So then the ministry felt that when there is change in the investigator and institute and then depends upon their knowledge, the microzonation has been claimed at a different level, not at uniform level.

So then the ministry of earth science taken an initiative basically to characterize the 30 important cities in the country and carry out a microzonation study. So this was actually what they have done actually. So the MOES mandated to provide country with best possible service of weather and climate, ocean state, earthquakes and tsunamis, and other phenomena related to earth system.

Hence, they felt that publishing up the seismic hazard feature or hazard index or hazard zonation map also part of the MOES system as it is under the IMD, where there are a lot of stations have been maintained for recording the seismic data, which we have seen. So the ministry planned to take up seismic microzonation of urban agglomeration, particularly 30 cities spread over the country with the scale of 1:25,000 or 1:50,000 during a 12-year plan. So this was initiated in 2013, as a part of 12-year plan.

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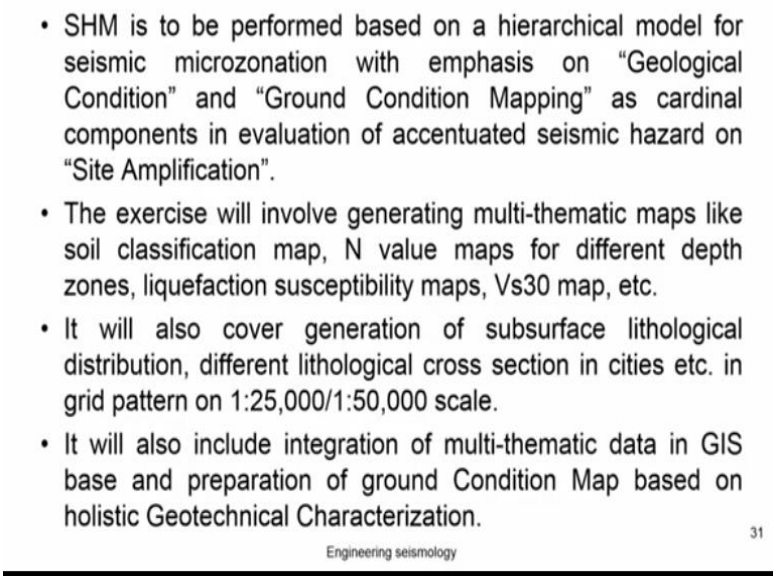


So now basically, they have given some of the cities, they already started, which is undergoing. So the seismic hazard microzonation is to be performed based on the hierarchical model of seismic microzonation with emphasis on geological condition, ground condition mapping and the amplification and liquefaction. So this exercise involves generating multi-thematic map in the particular area and try to understand the soil and soil properties and integrate with the seismic and geological data and try to get a liquefaction amplification of the particular location.

And finally produce hazard index map. That hazard index map should be good. As I told you that, in order to do the uniform microzonation, the MOES, NCR National Seismological Center.

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So what they did basically? They have taken several cities, then they are basically doing the microtremor measurement by measuring the predominant frequency. Then they are drilling a borehole and getting SPTN, then VS measurement by the MSW and downhole survey. Finally, all these data they systematically integrate with the bedrock level hazard estimation and give a microzonation map. So the zone 1, zone 3, zone 2, zone 4, like this on each city.

So presently the ongoing microzonation work is under process for Mangalore, Coimbatore, and Bhubaneswar, where I am also academically involved to microzonation of these cities. Apart from that, they also recently awarded 8 important cities in UP. Those cities also, where they adapt a similar kind of procedure, where now there is a guideline for how to do the microzonation, what are the parameter you should receive and what are (()) (28:51).

So this was basically based on my PhD work as I said that, microzonation of Bangalore city, where we consider all the possible hazard and finally integrated all of them and produce a hazard index map of Bangalore, which has been done as to show the case study for the country. So based on that only the MOES basically taken up this kind of microzonation studies. So this is about the glimpse of microzonation studies done in India.

So by looking at all these things, you can see that very systematic microzonation study area limited in the country or available for the very few number of cities, when compared to agglomeration in the entire India. So we have cities with several crores of population, but our microzonation studies are not available for all those cities. Anyway, the MOES now under the preparation of these kind of maps, hopefully in the future we will end up in the good zonation map of each city.

So what is the good zonation map? If somebody adapts a systematic procedures and discusses the in the microzonation map and give a robust microzonation map at particular location that will be the more reliable microzonation map. With this, we will close this class. Apart from these kind of microzonation regional level, in the world level also people do a macrozonation.

So the world community is interested on macrozonation and they produce lot of macrozonation maps frequently to the entire world and from data from each individual countries, small, small, and big, big countries and that global seismic hazard assessment or global seismic hazard model, global earth model hazard model, something like that they call. We will discuss about that, what was the status for India, which work has been referred there and what was the mapping they produce.

So that you will differentiate what is the Indian microzonation studies and what are the studies carried out by other people in this angle. That we will be discussing in the next class. With this, we will close today's lecture. We will move on to the next lecture in the next class. Thank you very much for watching this video. I look forward meeting you in the next class.