Introduction to Engineering Seismology
Prof. P. Anbazhagan
Department of Civil Engineering
Indian Institute of Science - Bangalore

Lecture - 46
Global Earthquake Risk Map

Vanakkam. So, we have been discussing about the microzonation work, part of our engineering seismology course lecturing. We have talked about the global seismic hazard mapping done in 1992 by Bhatia et al and then how it was done and all. So then followed by, we also talking about the global earthquake model, GEM where they prepare a global scale seismic hazard map for different countries, like 30 countries.

Basically they carried out this work individually and tried to collaborate and mix and then make it as a common platform, where the procedures and then the mapping tool and then the mapping level remains same and then it has an option also whenever there is a change in the model and data, it can automatically update. So that was one of the beauty of this model. So this we discussed that they developed in the OpenQuake program. We have seen that as India, they have given iterative map where we can see the PGA distribution.

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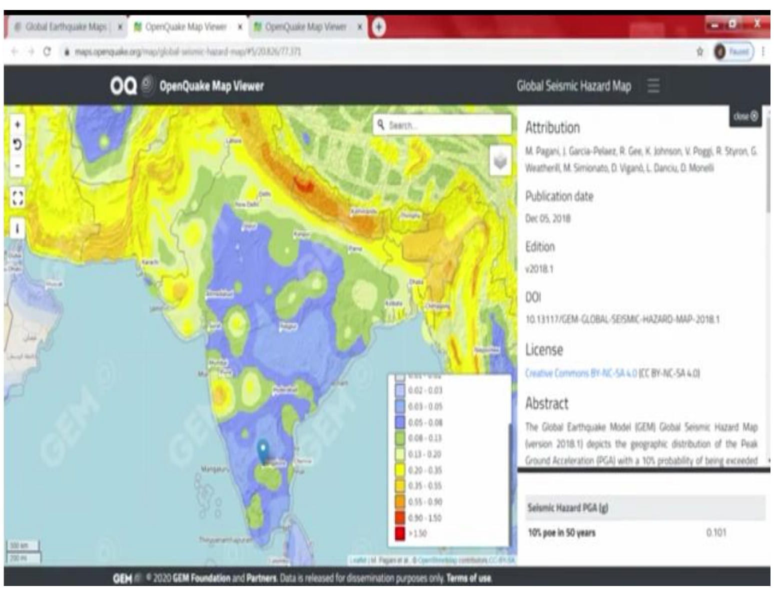

So even if you pick up a particular point, for example I want to know what is the hazard at Salem? You can see the hazard at Salem. This is the value. You can see it. This is the hazard at

Salem, but if I go to Bangalore, even though it is marked all of them in green with the range of 0.08 to 0.13, but you can see the variation. So such kind of iterative map or interactive map will be useful for the regional level planning and city level planning.

So that is what we have to target part of any microzonation mapping system. So hopefully, our future NDMA map, which they are planning to produce; will be having such kind of map, city level, where you can see the variation with respect to different parts of the city. For example, if you are in Chennai city, you can see what is the hazard value of the central railway station and what is the hazard value of Tambaram, what is the hazard value of Meenambakkam airport.

And what is the hazard value at Koyambed, what is the hazard value at Anna Nagar, and what is the hazard value at Madhavaram. So like that, different places how the hazard value changes, so that should be clearly extractable and viewable and that type of mapping system should be adopted. So as I told you that this is the macro scale map, which says the hazard range, hazard value, but which does not consider a regional variation.

Then, why these maps are very important? Why they do? Basically, these maps are estimated to know the exposure and risk of the particular country. So when you are talking about the hazard analysis, basically when we are talking about the hazard analysis, different hazard, not hazard analysis. When we are talking about the different hazard, we also talk about the risk and exposure. In the first class, we have told that which of the countries are highly exposed to a seismic risk. So how they say? They say based on this kind of global scale studies.

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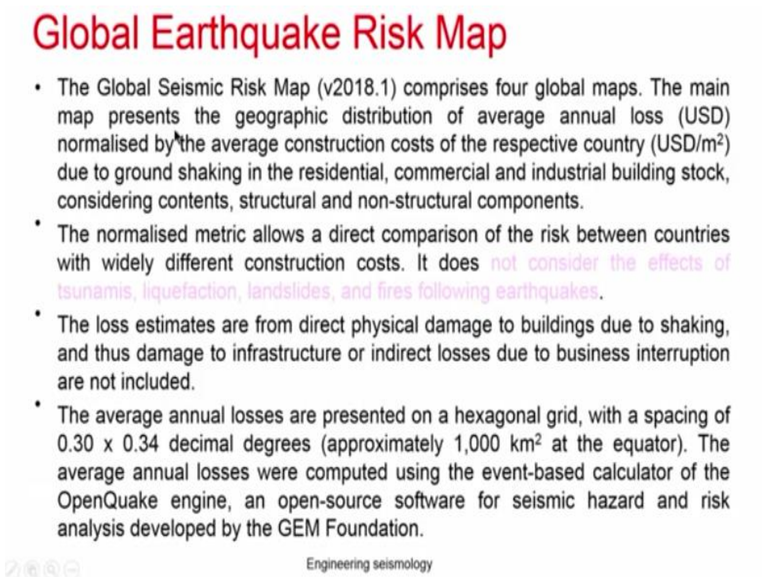

So the idea of this map is basically to generate a risk and exposure map using this, not for building design, basically the global level, we know that which are the countries are highly risk seismically, which are the countries are flood risk, which are the countries are drought risk, like that. Why this information are needed? People who want to invest, as you know that now the global, now the international business or each country can buy from other countries.

They can invest and produce something. People who want to invest their money to make something on country level; they want to know that what is the status of this one. For example, somebody wants to start a factory in India to produce something. So then they look at this seismic hazard map; then they look at what is the risk associated in that. So they try to invest where is the low risk region, so that even something happens, their factories are safe with respect to earthquake, not economically.

Similarly, they look at several risk factors for the investment, wherever the low risk is there, they go for that. So such way like preparing that kind of larger scale and continent to continent, how this region is basically involved and these kind of studies are done. There are agencies or companies, they do this kind of systematic analysis and produce a local scale map. There is RMS, risk model solution, there is one company, who produces and gives input to the insurance company.

Who do the housing insurance, they decide that this area I want to take housing insurance, how much is my premium. For that, these kind of data are all useful. So the global seismic risk map is comprises four global maps. The main map presented the geographical distribution of average annual loss, normalized by the average construction cost of the respective country due to the ground shaking residential, commercial, and industrial building considering contents and structural and non-structural component.

So they prepare basically the risk, how much financial loss. For example, if I start a factory here, if the earthquake comes, how much the financial loss I incur in one year, 5 years, 10 years, such kind of understanding will be done using this kind of global level data. Then, the normalized matrix allows direct comparison of the risk between the countries with widely different construction cost. It does not consider the effects of tsunami, liquefaction, landslide, fire and earthquake.

You can see that this cost, what the risk right now they have given in the global earthquake model, only considers the direct ground shaking hazard, not the tsunami, liquefaction, landslide, and fire, because these minor level information incorporating in the global level will be very complicated, but at least it will give you where it stands with respect to the direct ground shaking hazard in the bedrock level condition.

The last estimations are from the direct physical damage to the building due to shaking, those infrastructure indirect losses due to the business interruption are not included. It is only because that building damages, the earthquake happens, what is the earthquake effect? So this they studied from the previous earthquake and used to model these kind of damages. So the average annual loss are presented on a hexagonal grid with a spacing of 0.3 by 0.34 decimal degree, approximately 1000 square kilometer at equator.

The average annual losses were computed using the event-based calculator of the OpenQuake engine and open-source software seismic hazard and risk analysis developed by the GEM model. So how this map was developed, they were given actually. This was map produced from the hazard and risk analysis developed by the GEM foundation, which comprised the data from different region.

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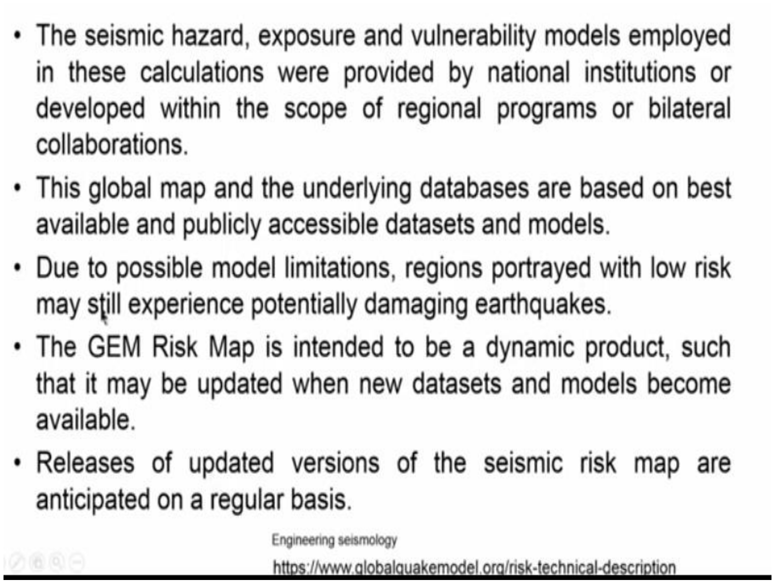

So the seismic hazard exposure vulnerability models are employed in these calculations, were provided by the institutes or developed within the scope of regional programs by bilateral collaboration between the teams. These global map underlying database are based on the best available and publically accessible dataset or model. So that means the dataset, as I am talking about the availability of seismic data, how important, which produces a more reliable zonation map and risk map.

That is how they say. So due to possible model limitation, regions portrayed with low risk may still experience potentially damaging earthquakes. This is what we have discussed. So there is a chance that even though it is marked as a low risk, there may be high hazard due to the damage in earthquake, because of the lack of model and data at a particular place. So the GEM risk map is intended to be dynamic product such that it may be updated when new dataset and model become available. Releases of updated versions of the seismic risk map are anticipated on regular basis, where they will be listed.

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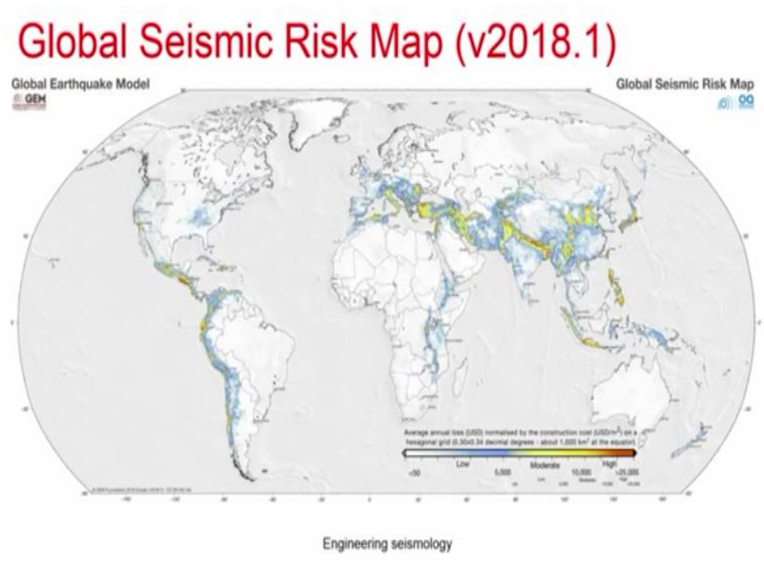

This is the global risk map. So this risk map will give an average annual loss due the earthquake in USD, normalized by the construction cost of the USD per meter square on the hexagonal grid of this much size about 100 km region. So you can see it varies from less than 50 dollar to about 25,000 dollar at a particular place. So now we can go to the iterative map in the screen. As I told you that.

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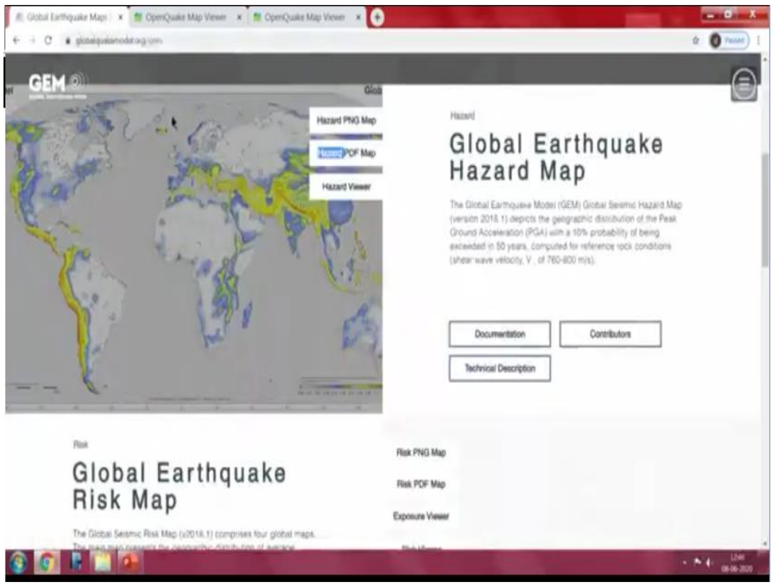

This is the earthquake hazard map. So let us see the risk map. So the risk map, you can see this is the risk map. You can go very minute level.

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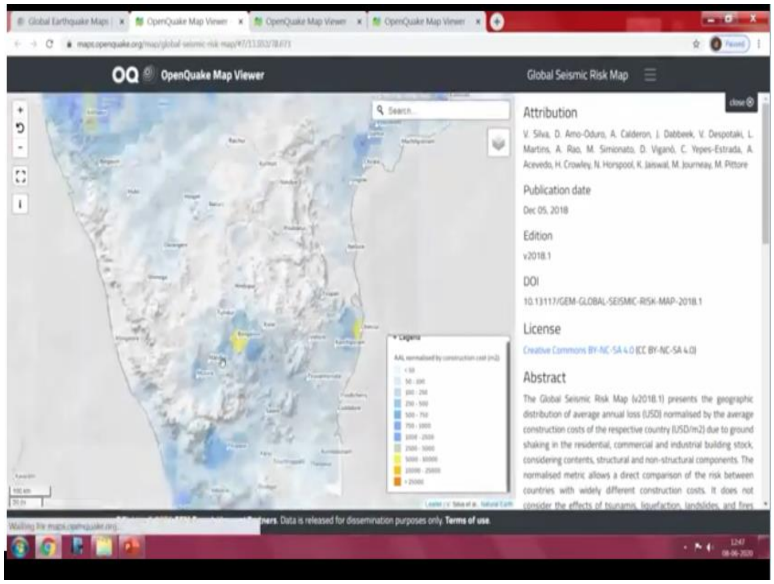

So here you can see that in our hazard map, this entire area basically marked as same hazard value, but when you go to the risk, you can see that Bangalore has a higher USD loss when compared to nearby area. You can see here. See, the region, country, how much the loss, everything you can get as iterative information, see. This is also average annual loss. So such kinds of maps are produced. People want to invest.

For example, they look at Southern India as the option, within Southern India, they look for Bangalore, Mysore, Chennai, and Hyderabad like that they look at. Apart from looking at the potential other factors, they also consider this as the factor.

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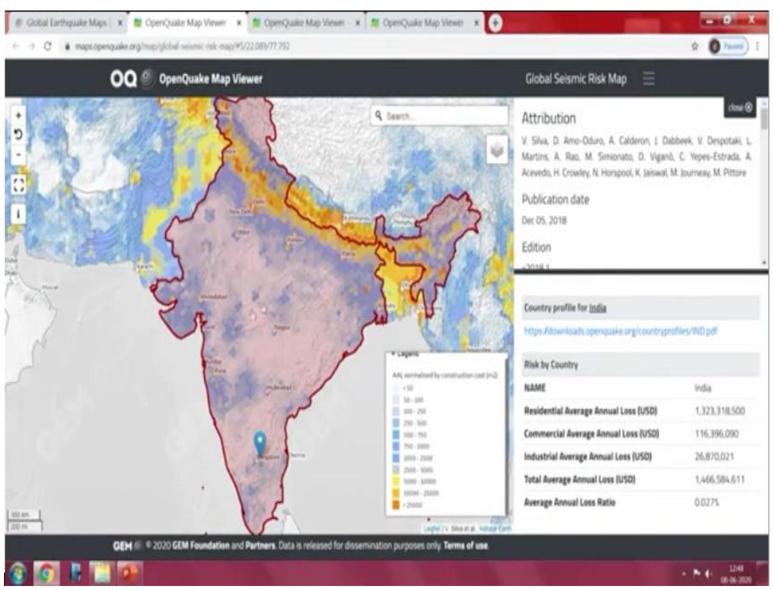

If they look for India, again they look for the North India, South India, how is Delhi, how is the UP, how is Bangalore, how is Hyderabad, how is Telangana, something like that, they look and take a decision for the proper investment. This risk map will help on all those kind of decisions. So this is the overall image file, you can get the interactive map from this website. As I told you that, the entire class of the last and this class, what we are talking about the GEM from this website. So I should thankfully acknowledge them for providing this information. This is useful to know how the zonation maps are important for different aspects. So this is the risk map.

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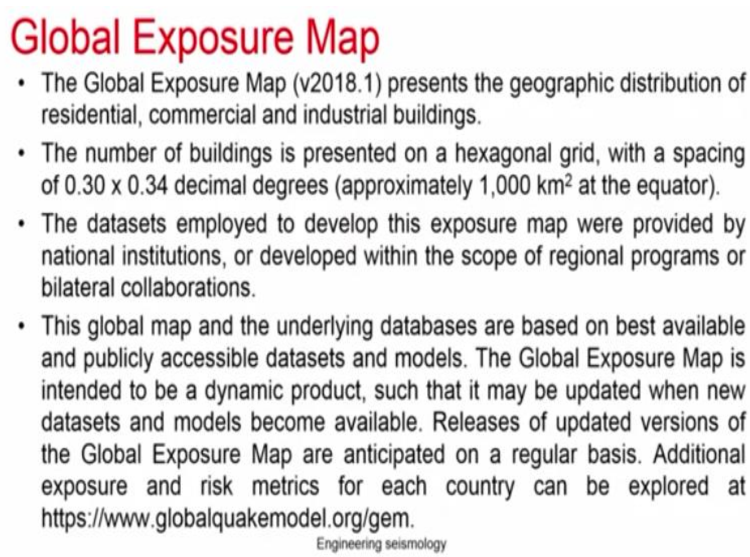

From the risk map, they also developed an exposure map. So the exposure map presents geographical distribution of residential, commercial and industrial building at a particular place. So the number of buildings present in the hexagonal grid, where the spacing of the grid as we talk about the risk basically used this exposure data. Dataset employed to develop this exposure map were provided by national institute.

So the same concept like it has been provided from the national level or they collaborated and collected from that. The global map underlying database are based on the best available, publicly accessible data. So all the data, which is accessible, they used.

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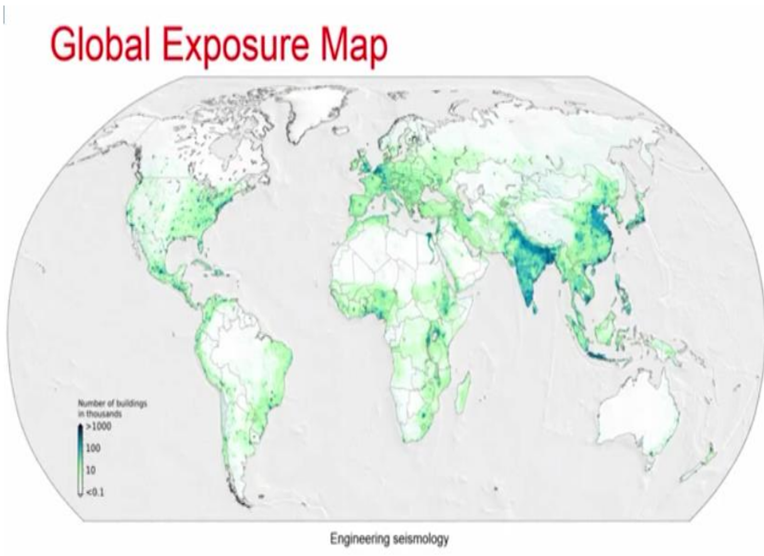

Some of the places, even though it is marked as low risk, but it may expect high risk as we said that the data or models are very important, the lack of data. So this is saying that the number of buildings in 1000s in that particular area. Exposure means, if particular hazard comes which are the buildings going to suffer more damage? How many buildings? That is, you can see here. This is basically the exposure you can see.

India actually has more exposure because of the poor building construction practice and codal provisions. That is we can see more exposure than other places. So other regions, where the building also not there, here building is there and construction practice is also problem. That is why you have more exposure.

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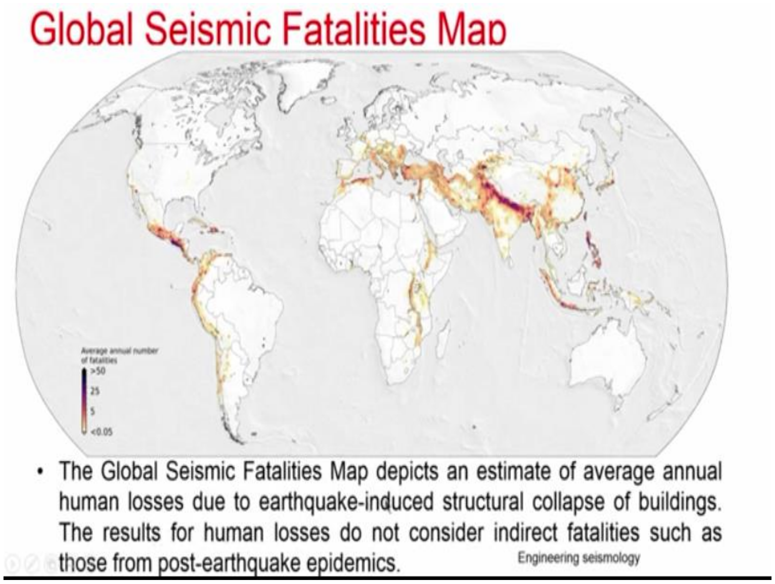

So that exposure and risk may result a number of fatality. You can see here, the global fatality map. So estimate average annual human loss due to earthquake, you can see basically the earthquake human loss. So North India, you can expect at least per year, so many people die due to the earthquake in the region.

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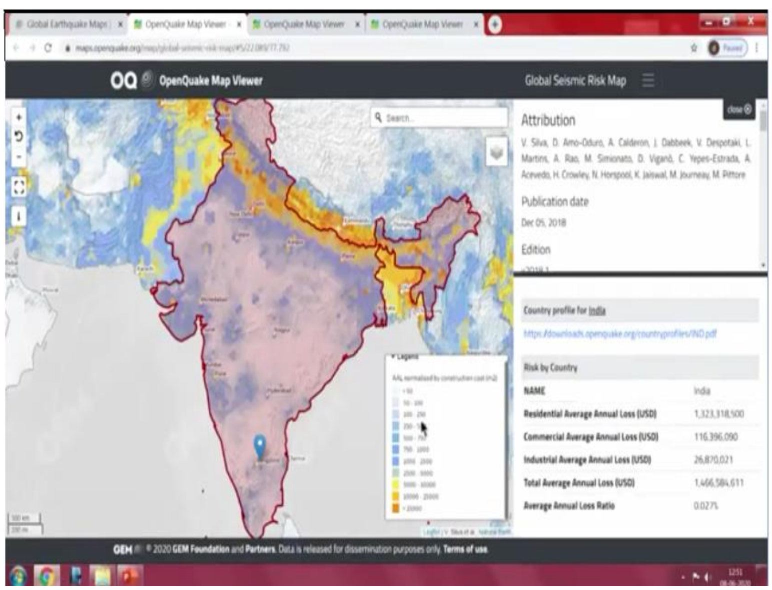

These are the details provided from the risk and analysis where they consider data from the old earthquake, which we will discuss what are the earthquake they considered for India, when we narrow down our study for the Indian region.

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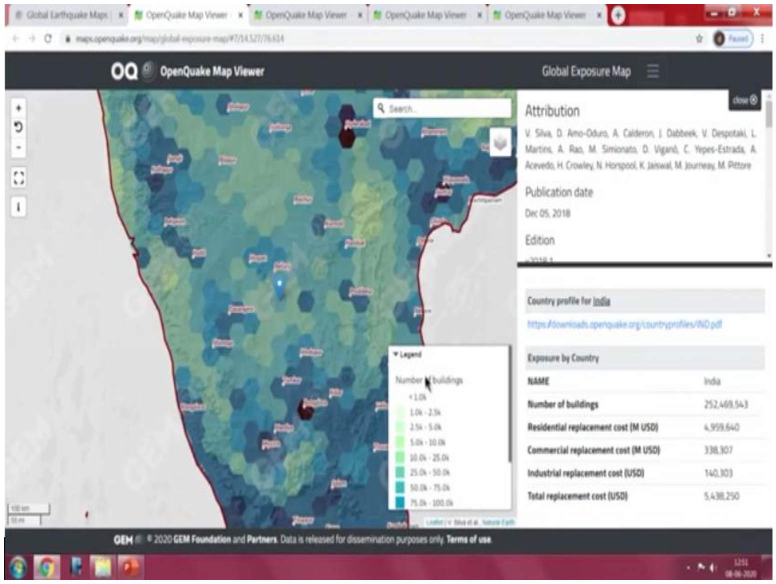

So here you can see legend. The number of buildings exposed residential, commercial, total, how these data are there, arrived and calculated using that. They say that this is risk and exposure in each region. So this model, global level, they considered and prepared throughout the globe and they published, which will be useful for different level of information. People who want to basically invest and then any kind of future planning.

Somebody want to buy a big land in India, they look for all these things, which does not have any information. They look for this one. So they then, basically accordingly will decide what is to be done.

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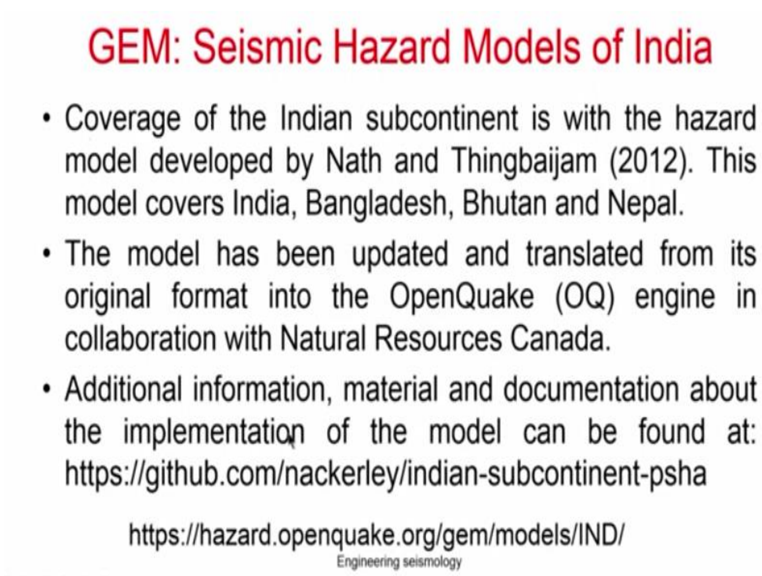

So let us see what are the information's gone into the map from India. So the Indian seismic model of India, they basically cover Indian subcontinent with hazard value estimated by the Nath and Thingbaijam during 2012. So basically, the work carried out by Nath and Thingbaijam during 2012 has been considered as a part of your global earthquake model. So this model covers India, Bangladesh, Bhutan, and Nepal.

The model has been updated and translated from the original format to the OpenQuake software, where engine, which collaborates with the natural resource of Canada. People who have taken the data and tried to incorporate them, additional information materials documentation about the implementation of the model can be found.

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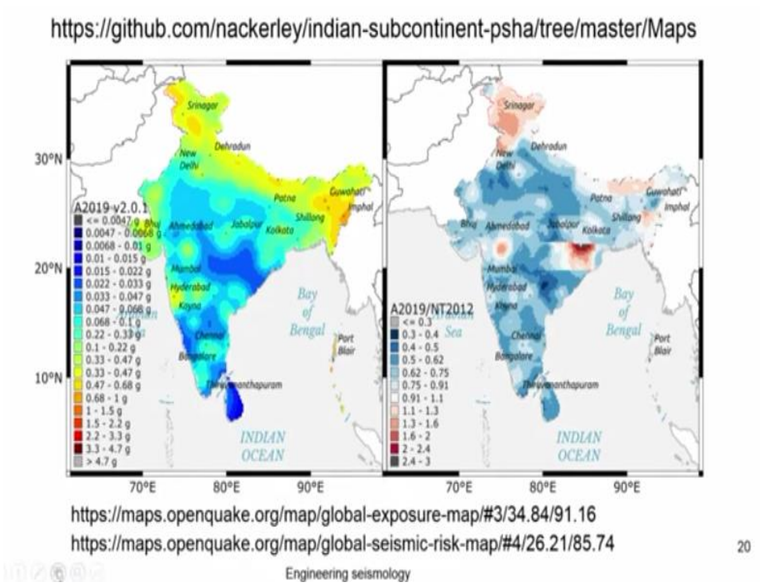

This website if you go to that website, you can fine more information about what are the models, they used. I will just show you that, because it is very important when we talk about any model, how this model is better. How far it is reliable? What are the conditions they use? So here I should also acknowledge that Thingbaijam, the scientist one of the pioneer person, who works on hazard analysis.

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Particularly he contributed, extensively in the area of this hazard analysis and seismic microzonation mapping. His contributions are extensive on this area. They are initially basically from the IISc, Iyengar, and Raghukhanth, then followed by Thingbaijam and Nath. So those are all the pioneer people who are actually senior to me, but they contributed extensively on this. So this is basically iterative map, what they produce from this study.

So where you can see that the tectonic, the PGA distribution, gridded seismicity map, you can see whatever map you have seen, this is the Indian scale, how you can see the variation. Here you can see the variation.

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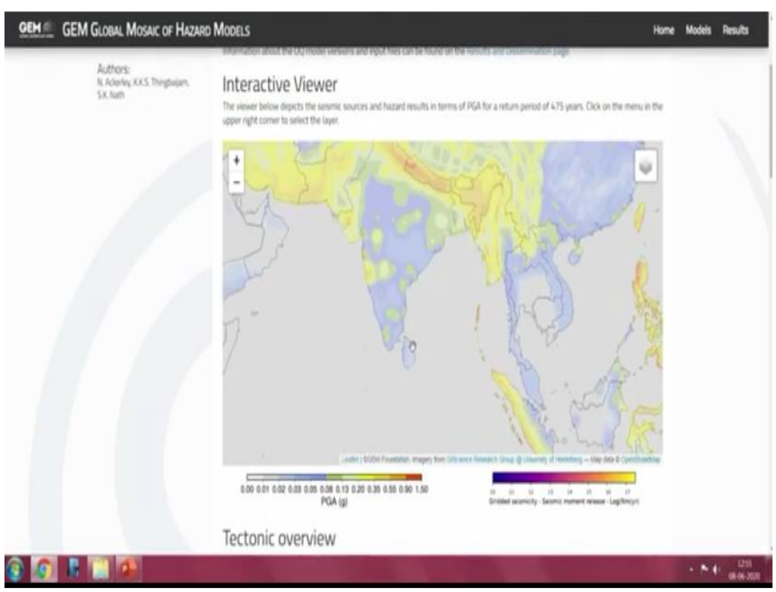

So you can get all the information, which is considered in the mapping. So that is what you can get from this iterative Indian map. You can see even the tectonic boundaries and then if I want to remove the PGA, but want to get other information. So, you can see, the tectonic boundaries, how they consider different tectonic boundaries in the consideration for arriving a particular model. So that is what it basically shows. So this information about the tectonic overview are discussed here.

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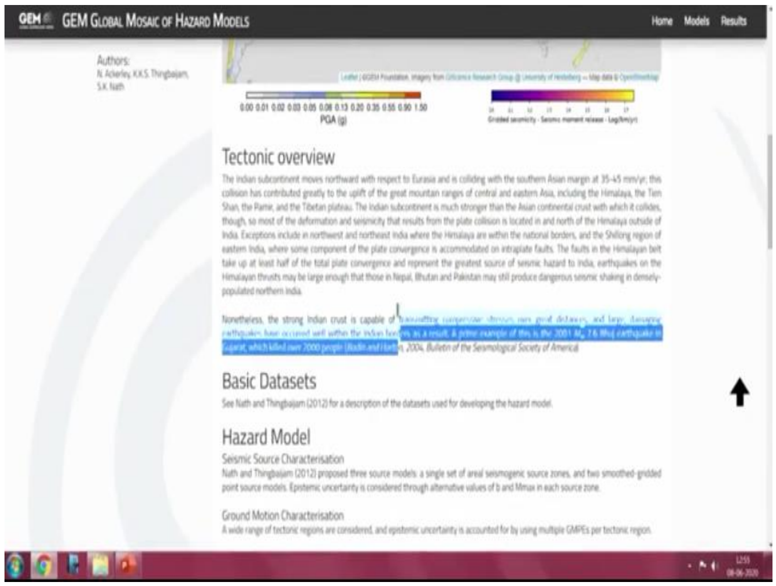

What is the tectonic overview, the hazard model, what they consider, source model. So the three source model a single set of areal seismogenic source model, two smoothed-gridded point source model. Epistemic uncertainty is considered through alternative values. So here, they did not use a linear source. They consider a point source and areal source based on the data, which is available. So this is the ground motion characteristics model, which we used to estimate a hazard value.

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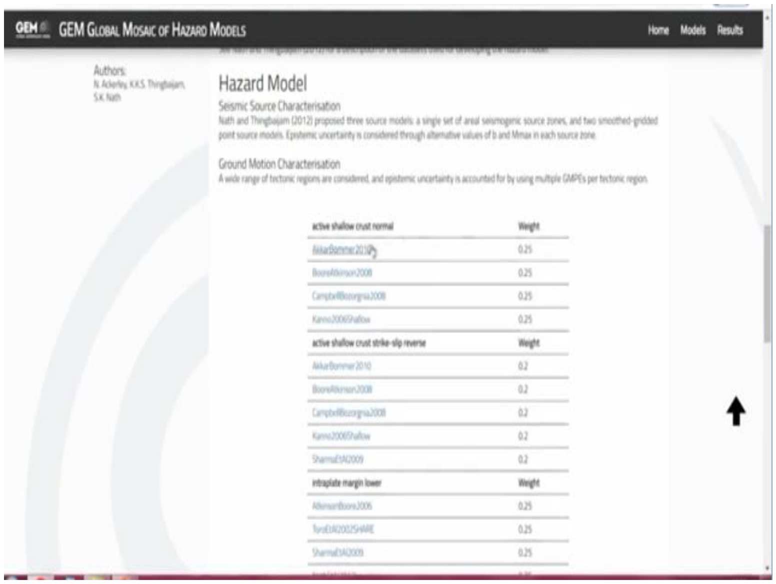

For example, active crest region, which is the North India, they used this. Active crust normal fault mechanism they used this. Active shallow crust site slip they used this model. So the intraplate regions, like Southern India, they used. These are all the ground motion model. What is the weightage factor, because in PSHA, when you have the option to combine different GMPEs with different weights.

Then the stable crust, then the subduction interface, subduction interslab and subduction intraslab, so these are all the GMPE they use and using this, they estimated the PGA value. That PGA value only you are seeing here. You can see.

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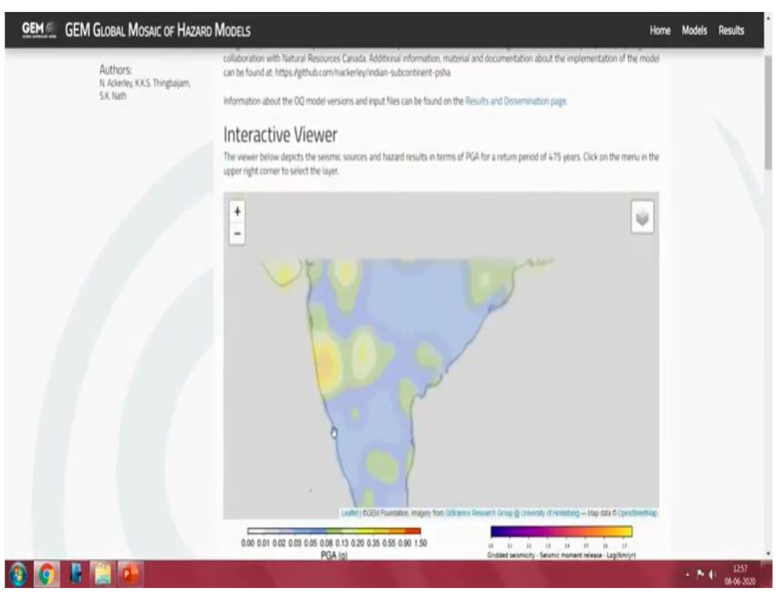

So this is the combined value. If there is a change in the model, there is an option they can incorporate and revise a map. From this website, you can get the information, what they have considered and used. So this is how your PGA distribution map. This is actually the risk value and the particular location. So you can see how the value of regional scale is estimated to represent in the global scale.

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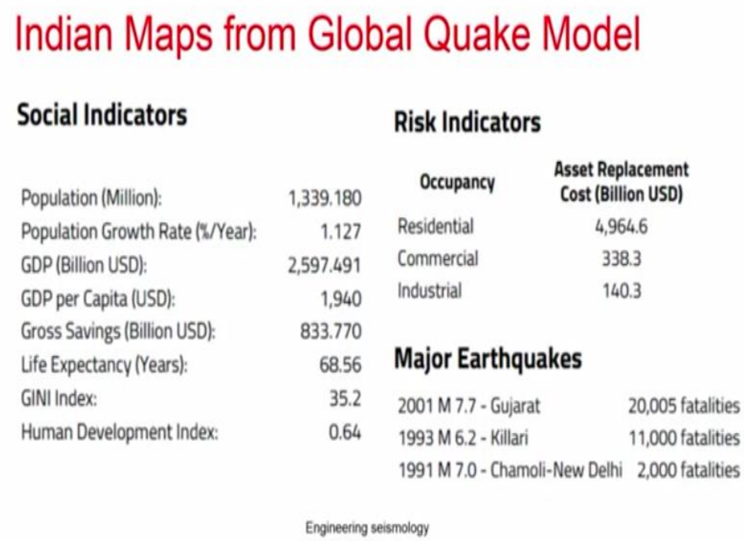

In this actually, to estimate a risk and exposure, they consider basically the data from India, what are those data. Basically, they consider when they do this analysis of 2018, the population, they considered 1333 million people. The population growth rate is so much. The GDP million is so much, GDP per capita is so much, then the total saving is billion so much, life expectancy so much, GINI index and human development index so much.

So these are all the social factors, which goes to exposure and risk. So to take a risk, they have considered residential, commercial, and industrial, so much asset replacement cost so much. Then, the major earthquake what they consider actually Gujarat 2001 earthquake, Killari earthquake and Chamoli 1991 earthquake where the number of fatalities are available with building information and other details. This is the information they used.

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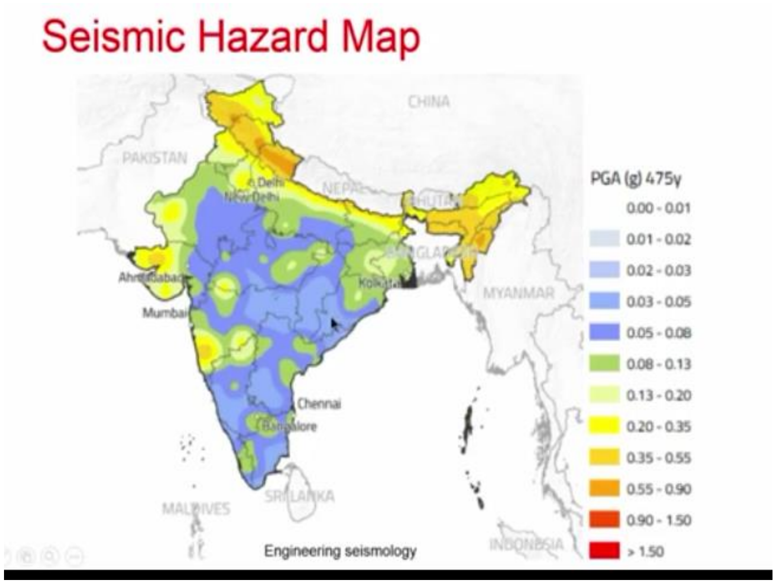

Finally, they produced seismic hazard map, which is considering the zone motion prediction equation, what we discussed earlier and this is the way of distribution of the hazard. So this map has gone to this one.

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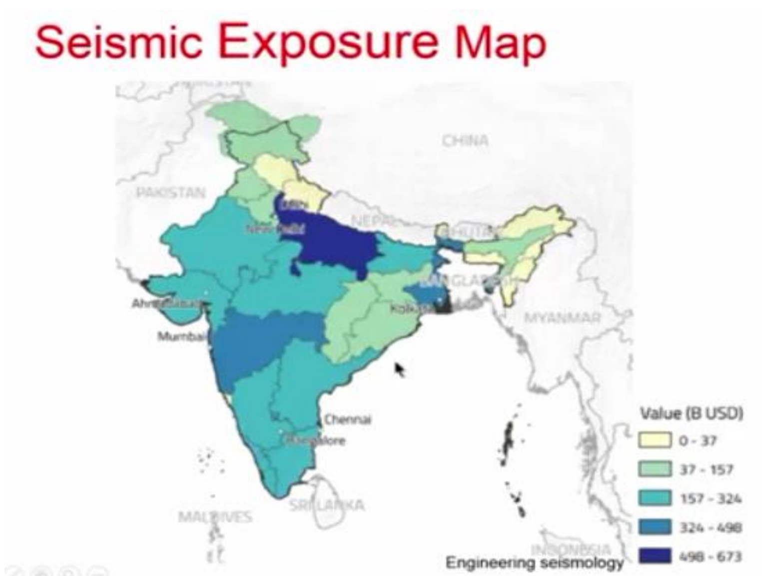

Then, the exposure map value of USD per Indian scale, you can see how much the USD in Indian scale. So there are places where the exposures of these regions are very low, even though seismically it is very high hazard. You can see that exposure and hazard.

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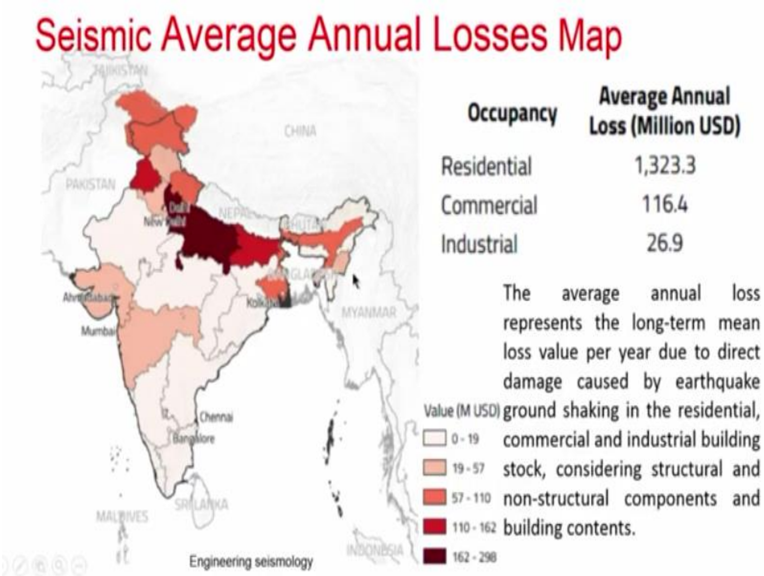

The risk, the average annual loss you can see here. This is actually combination of both exposure and risk, where some places you might have seen the higher risk, but lower exposure, some places you have seen the higher exposure and lower risk by combining this, you can see the value of USD, you can see how much. So the average annual represent long time loss value per years due to the direct damage caused by the earthquake ground shaking of residential, commercial and industrial building. Due to those 3 earthquake data, they consider and then they tried to arrive this map.

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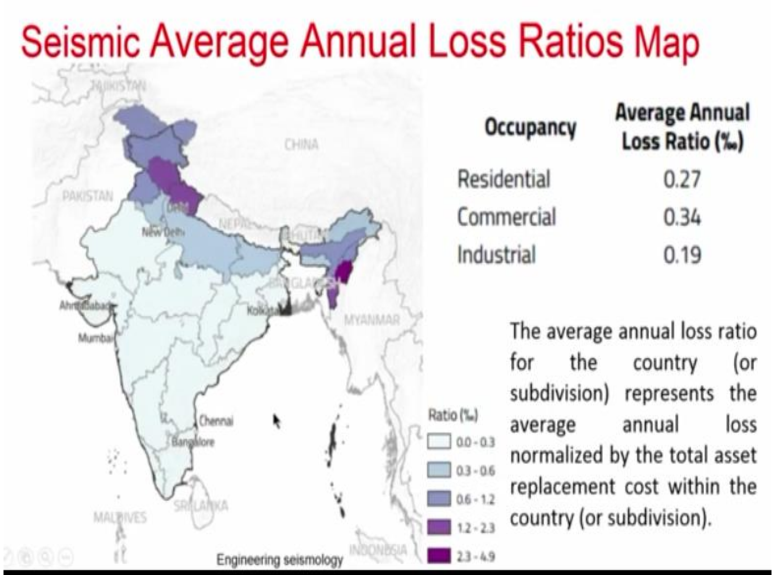

Similarly, seismic average annual loss ratios, which are the place you get more loss, which are the place you get less loss when comparing the highest and lowest in the region. So annual average loss ratio of the country or subdivision represented average annual loss normalized by the total asset replacement cost within the country. This is how they arrived. You can see the residential, commercial and industrial, how much is there. So industry actually is very less.

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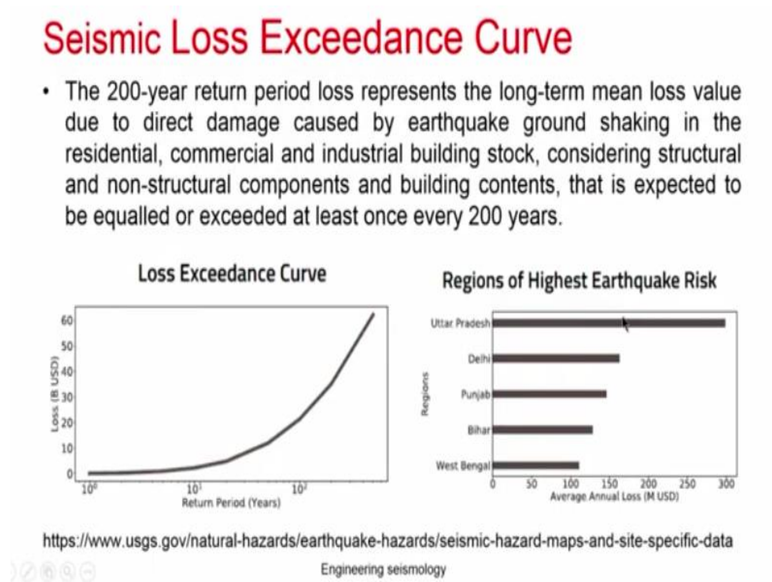

So the 200-year return period loss represented long term mean loss value due to the direct damage caused by the earthquake ground shaking, residential and commercial stock considering this one whatever non-structural component and the building content that you can see how the loss. If you want to do the long investment, you will have more loss. So people look for the short investment, they may experience revenue.

So this is again region wise how much the annual loss you can expect, West Bengal, Bihar, Punjab, Delhi, Uttar Pradesh. This is an example. So you can get like this several region level and decide where you want to invest, where you want to start your factory. As I told you that this kind of global earthquake models, GEM or all those objectives, not only to tell how your country is with respect to other countries in the world and also it gives you the risk and exposure level.

So here you can also note that this exposure level and risk level does not consider the liquefaction, tsunami, landslide kind of hazard taken into account, particularly the earthquake even though what they consider, these 3 earthquake, but these earthquake damages not explicitly account all those things in detail. So this kind of map has to frequently be updated and prepared, but this is with respect to global scale.

There is a set of community people, who work on this and then publish data and then update for the interest of the entire global community.

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So here you can see people who are involved and sponsored and developed these kind of studies, you can see. There are so many people, you see. All of them big companies on each country and then big universities, they fund and invest money on all these things, because the people who have invested from these countries are using this data.

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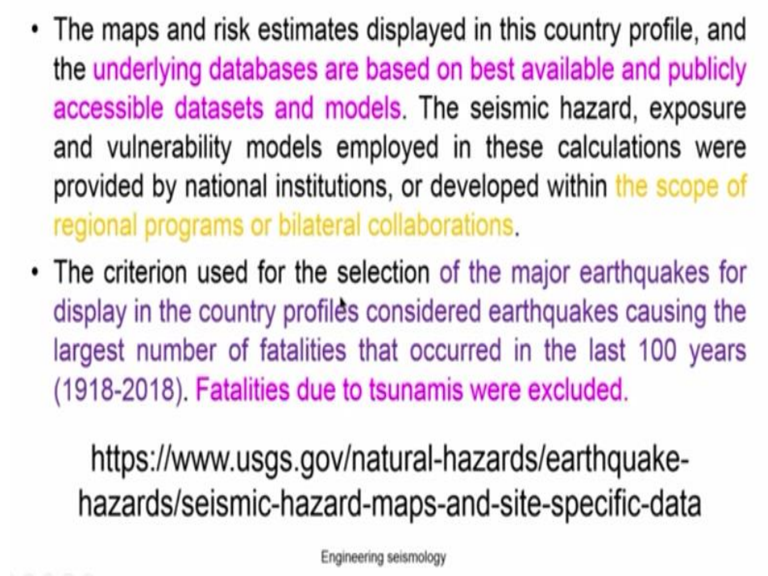

So this is the globalism, but these maps, not only with respect to the preparation, it ends. It has to be also updated frequently, that update should be consistent. So what kind of information we need to update. So the map and risk estimates displayed in a country profile, underlying database are based on the best available and public accessible data set and models, which we have seen that the seismic hazard exposure and vulnerability models employed in these calculations are provided by national institute based on the scope of regional program and bilateral collaborations, what they made.

The criteria used to select major earthquake displays the country profile considered earthquakes causing the largest number of fatalities that occurred in the last 100 years. So they considered this. Fatalities due to tsunami were excluded. So that was where the risk and fatality models are considered. There are many big earthquakes in India, which caused extensive damage and fatalities, which does not have large amount of the recorded data and the intensity maps, particularly Himalayan, Bihar-Nepal earthquake, this Shillong earthquake.

But those are all not modeled here. So obviously, the model earthquake 3, what they considered, whatever limitation they have will be carried forward in the fatality and risk prediction, but however, as on now, this is the best model data one can expect, but developing this data and models may not be sufficient. It has to be frequently updated. So frequently updated, I will give you the example, how the US system develop a model and maps similar kind of way for the US.

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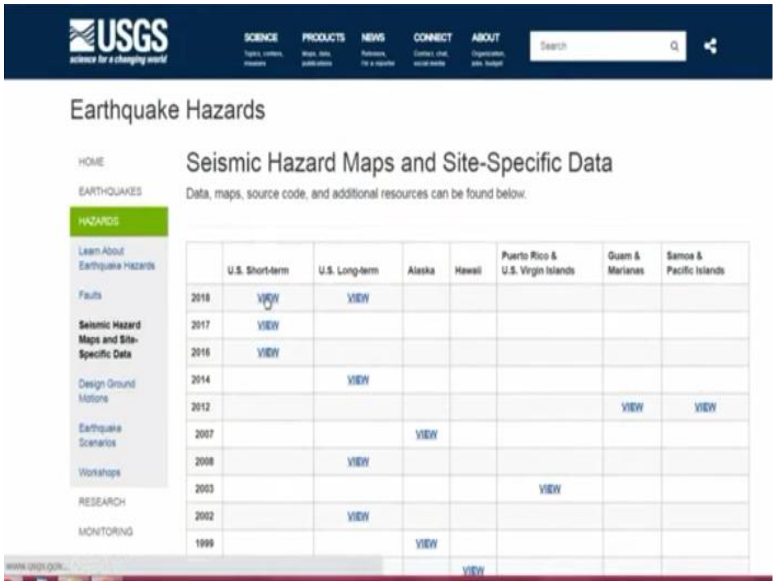

This is basically the USGS website, seismic hazard map and site-specific data, which is published every year. You can see the short term model and long term model for the entire US. The short term model, let us see for 2018.

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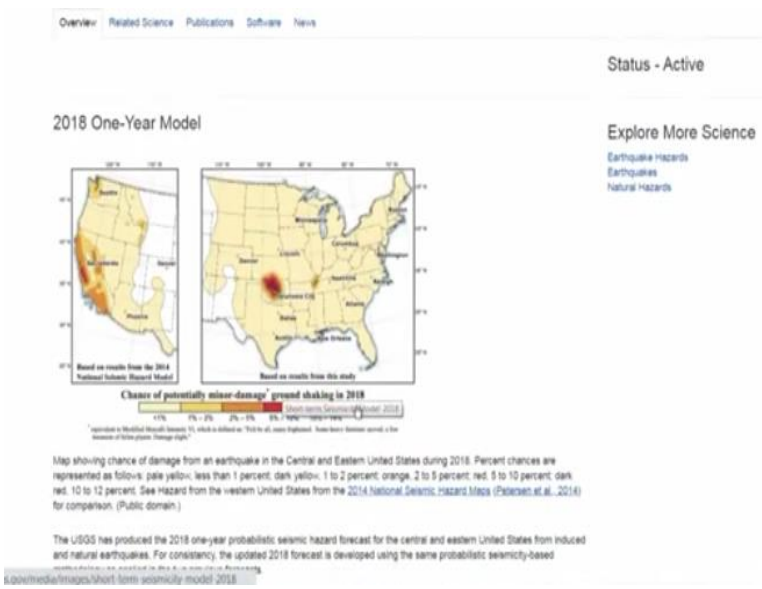

So you can see the national seismic hazard model, which gives chance of potentially minor damage ground shaking in 2018. In 2018, which are the places, how much the ground shaking potential percentage loss you can expect.

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Similarly, you can see 2007 they developed.

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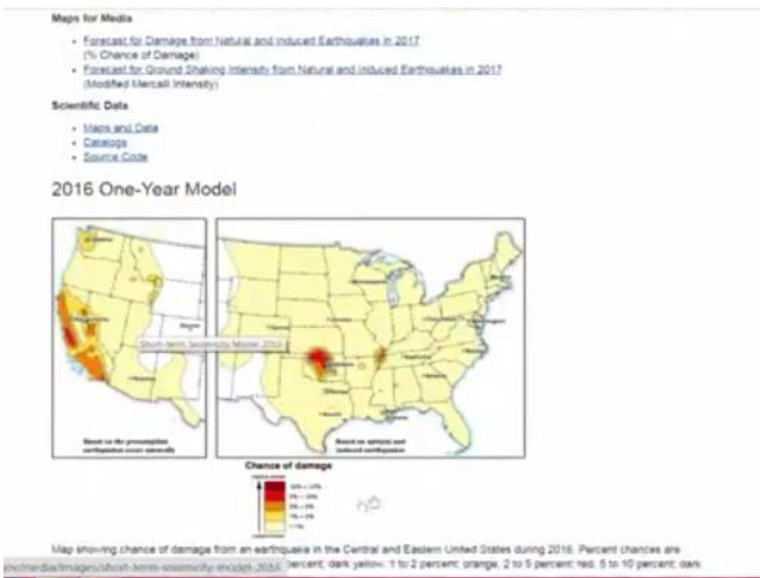

2009 they developed, which helps for the short term investment plan and other thing. So this consists of the detailed data analysis, which they collected from different sources. Long term data, you can see the long term data. You can also see that the long term data provided.

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This is the long term data. So you can see 2008 map has been given, which is valid for the next four years. You can see they developed 96, 2002, 2008, 2014 and 2018. So earlier they used to do every six years, now they are doing every four years. These kinds of microzonation maps or hazard analysis maps or exposure map or risk map need to be frequently updated. Soon after the big earthquake or soon after the four years or five years' gap depends upon the availability of tool and other things.

That means once they release a map, we should not keep quiet, saying that I have done this map, it is sufficient. So why I say this statement, next class we are going to talk about the Indian seismic zonation map. How the zonation map is prepared, what are the discussion we are going to make on that.

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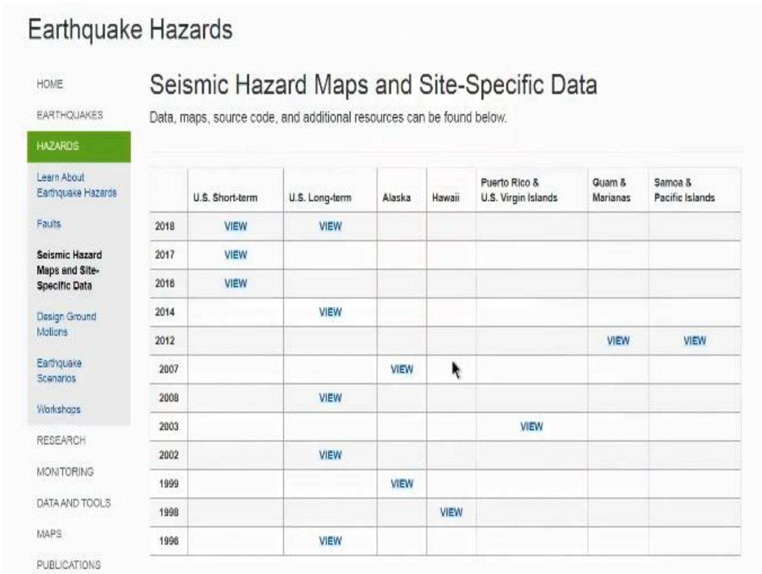

	U.S. Short-term	U.S. Long-term	Alaska	Hawaii	Puerto Rico & U.S. Virgin Islands	Guam & Marianas	Samoa & Pacific Islands
2018	VIEW	VIEW					
2017	VIEW						
2016	VIEW						
2014		VIEW					
2012						VIEW	VIEW
2007			VIEW				
2008		VIEW					
2003					VIEW		
2002		VIEW					
1999			VIEW				
1998				VIEW			
1996		VIEW					

So you can see that these people prepare a hazard zonation map and also a risk map and exposure map with time interval. Let us see how our maps are prepared in India. How these maps are reliable on the next class? We will be discussing that. Next class, I will also give you the glimpse of seismic microzonation work done in Bangalore, even though it is submitted as a report, there is no interactive map has been generated, but still the methodology steps and parameters gone to prepare a hazard index values, I will give you in the detailed way.

So that you will understand how the zonation map is very important and then followed by the Indian seismic code and zonation map discussion in the next class. Thank you very much for watching this video. We will see you in the next class. Thank you.