Introduction to Engineering Seismology

Prof. P. Anbazhagan
Department of Civil Engineering
Indian Institute of Science – Bangalore

Lecture – 47
Seismic Microzonation of Bangalore

So, vanakkam; so we will continue our lecture on engineering seismology. So last class we have been discussing about the seismic microzonation So the different studies done on seismic microzonation in India particularly we have seen that even though there are so many people carried out seismic microzonation topics studies, but only the city which has wroth to be climbed is Guwahati and Chennai and Delhi microzonation and Bangalore microzonation.

So we have seen that basically the earthquake create a lot of ground shaking related hazard which includes like a ground shaking directly, amplification of the seismic waves, liquefaction, landslide so these are all the ground shaking hazard. So the microzonation is done basically to delineate the similar area which has this kind of effect or similar. So, we also seen that the microzonation has carried out on macroscale and microscale and nanoscale.

So macroscale we discussed the global earthquake model GEM we discussed. So we have seen that how that models are useful particularly we have seen that those models they basically assess the exposure level of the infrastructure in the each country particularly residential building, commercial building, industrial building. So that you know what is a risk and loss going to incur if such kind of earthquake are coming.

And what is the return period of this risk and loss for every year. So that is what we try to understand particularly they highlighted that taking a typical earthquake damage in the past in the country and data and models and then they developed a user interfacable maps where you can zoom in and find out each grid what is the value. They also given a risk financial loss associated with the damage and how much you can expect on each places.

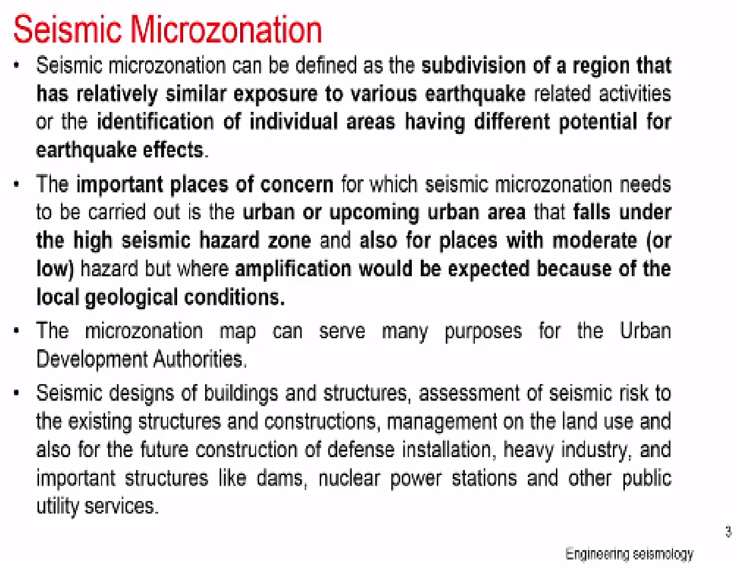
So the people want to invest and do a business so they basically get all this details from this map and fatality rate also they included. So all those things are part we also discussed that the microzonation basically gives a wider perspective. So in the global level we have seen that global seismic hazard analysis carried out on 1992 to 1999 where we have seen how the hazard analysis and other things are done.

Then followed by the GEM 2014 to 2018 where we have seen the India map like Nath and Thinbhujam data has been modified and they have been using that and this one. We have also seen that it is a broadly country level estimation it is not narrow down to each city level because there is a lot of information need to go. So they also clearly mention that the fatality rate or the economic loss or the hazard index what they have given is not considered the tsunami.

Liquefaction, landslide, amplification phenomena which happens locally so, which necessitate that if you want to prevent and plan properly and then execute something safer way in each city in India there is a need for seismic microzonation of studies. So that is why we have seen that after Bhuj 2001 earthquake and even the Jabalpur area has been taken as a classical example.

And people have done microzonation of Jabalpur and then Delhi, Guwahati these are all the regions where specifically done extensive work on this angle. So we also noticed that there are many other people who do hazard analysis and other cities claiming to be a microzonation, but which is not really microzonation according to the methodology what we discussed. So we discussed that a microzonation is a delineation of area.

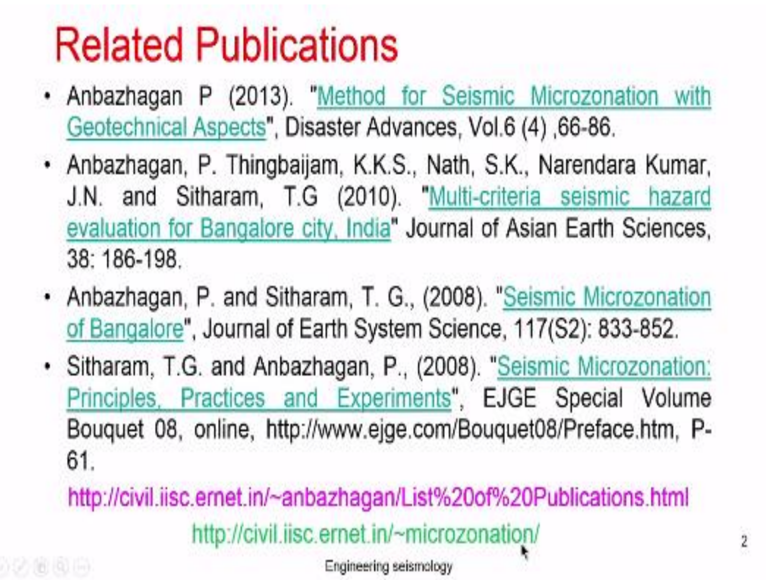
(Refer Slide Time: 04:20)



So the region will be subdivided based on the exposure of various earthquake effects that is what we have seen. So with that definition so any grid or any area what you delineate that has spelled out what are the different possible earthquake is expected on this and how accurately that is associated. So that is the main way the microzonation map has to be represented. So the global scale maps are macrozonation not microzonation.

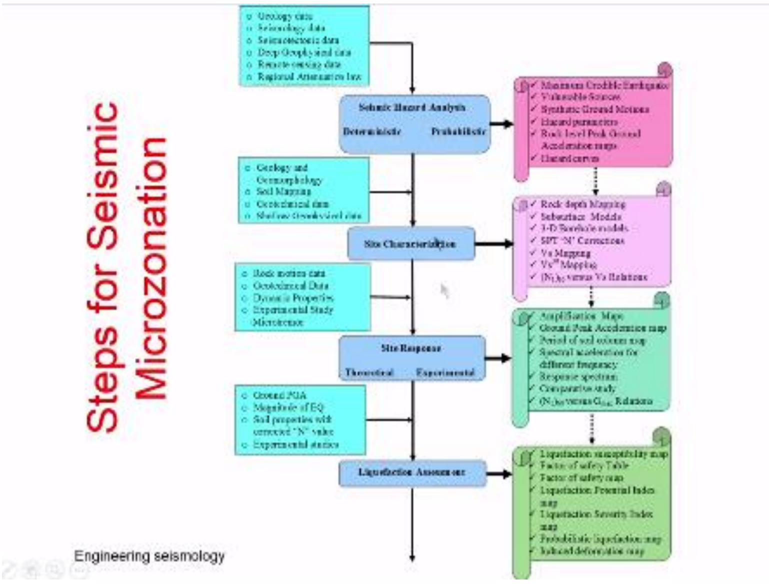
When you come to the city level it should be micro level has to be done. So, today class as I told you last class that I have done extensive work for the Bangalore region. So today I am going to discuss what I have done for the microzonation of Bangalore city which was actually part of my Ph.D I carried out this report also officially released by the MoES so you can get the entire full report about details and all those things.

(Refer Slide Time: 05:19)



So you can also see the related publication which I am going to discuss. So these are some of the publication which published part of microzonation. So you can see basically these publications are updated from 2008 to 2010 the better improvement from 2010 to 2013 there is a improvement. So you can also visit the website given here if you want to download some of this papers, softcopy whatever I do and also this website were to get lot of information. But note that the microzonation website was not updated long time, but I will be updating soon. So this is a reference we are going to discuss today the microzonation aspect.

(Refer Slide Time: 05:58)



So we have seen that the microzonation consists of here 6 major components which is like analysis and producing a map and the 7th one will be the integrating all the results and then getting the final output. So we have seen the direct ground shaking at bedrock level as we have seen the GEM global earthquake model even estimated the hazard at bedrock condition. So similarly the bedrock level estimation of the hazard is the first and prime most important for microzonation.

Which is applicable to all the; city irrespective of where the city is located so that step has to be carried out in the first part. So which can produce here PGA distribution map and then synthetic ground motion and response spectrum, probabilistic and deterministic hazard level indication like 2% probability in 50 years, 10% probability in 50 years so all those things. So we will be discussing this hazard analysis to end up our lecture.

How to do hazard analysis by deterministic and probabilistic with the case studies up to that we will be carrying out actually. So once you are done that as I told you that the seismic waves travels from the bedrock when it comes to the soil the waves get modified based on the soil static and dynamic properties. So that modification has to be captured. If you want to capture that first you have to characterize the site on what type of soil it is present.

What is his stiffness, what is the Young’s Modulus? So that kind of study is here part 2 as a site characterization which will help you to produce basically the stiffness average map in the particular region, thickness of the soil at a particular region and other related issues, other related parameters and the rock depth and 3D modeling all those data can be produced from this kind of studies which is called as a site characterization.

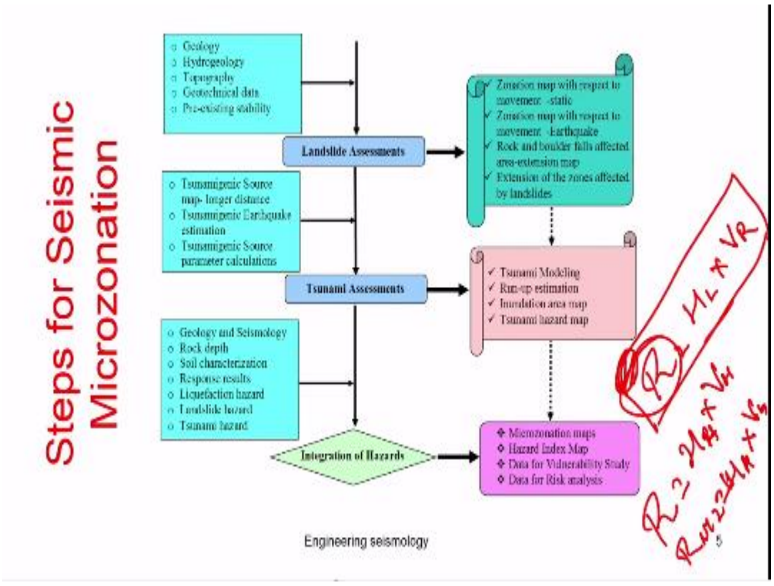
Once you are done that by clubbing the hazard analysis and soil property you can estimate and quantify how much the amplification and modification going to take in the region. So that is called as a site response studies and which can be done theoretically as well as experimentally so using the data obtained from the step 1 and step 2. So in that third step you produce amplification map of the region PGA distribution at a surface level at different level considering the regional variation in the soil properties.

Then the response spectrum considering the soil amplification so these are all the typical study then predominant frequency of the fundamental frequency and predominant frequency of the soil column so that when you design your structure you should keep your structures not matching with the fundamental frequency of the soil column in the region. So these map are produced as a part of step 3 analysis in the microzonation methodology which was developed by IISc Bangalore.

So once you are done that the amplified ground motion will cause us a permanent deformation in the soil. So when particularly on un-cohesion less soil where the particles are tendency to move very easily so that analysis called as a liquefaction assessment. The liquefaction assessment takes input from the second and third part; the amplified ground motion and soil data and do the detailed analysis.

And identify which are the areas are liquefiable, which are the areas are non-liquefiable. The liquefiable again what severe it is. The factor of safety is low it will be very severe it is close to 1 it is okay more than 1 it is partially. So such kind of deviation should be done and map has to be prepared a part of liquefaction assessment. So this will be both part of seismic microzonation. So mostly when the clays soil region liquefaction may not happen other three will be fine.

(Refer Slide Time: 10:07)



So similarly once you have done the liquefaction the regions or cities which is located on the hill so hilly terrain. So those kind of hilly terrain will causes a addition hazard called landslide hazard which is due to the seismic activity. So the next step is to estimate a landslide hazard which is caused due to the earthquake and then map here landslide factor of safety or landslide hazard map saying that which are the landslide take place what PGA kind of things.

So, that kind of map only applicable to the cities or regions which is in the hilly terrain. So then the cities which is next to the coastal regions as we have seen that 2004 tsunami caused huge amount of the DESS and financial loss in the east and west coast of India. So considering tsunami as a part of the seismic zonations are very important for the cities which is lying on the coastal.

Particularly where there are some places even the install nuclear power station kind of things and all so where they prepare a tsunami inundation map so how much tsunami depth you can expect and then what is the velocity it will hit so then the height of wave so all those things will be taken and mapped in the tsunami hazard assessment. So it can be noted here that a regular other parameter assessment you should consider the seismic data within the seismic study area.

Generally, 500 kilometer per southern Indian and 750 kilometer for the north India which I will discuss why we take such area for the study and the tsunami assessment you need to take the source a tsunamigenic source which is up to 2,500 kilometer that means if you want to do the tsunami hazard analysis of the Chennai coast then you should consider 2,500 kilometer radius around that whatever fault and fold as well as the plate boundaries are located on the sea side so that was very important.

Once you are systemically estimated all this parameters the next step is basically to integrate all of them appropriately based on the weights and rank and finally developed a zonation map so which is called as a microzonation map which reflect a hazard index value. So this hazard index values are once you decide that you will know that which are the places are highly risk, which are the place of low risk with respect to considering all the possible seismic hazard.

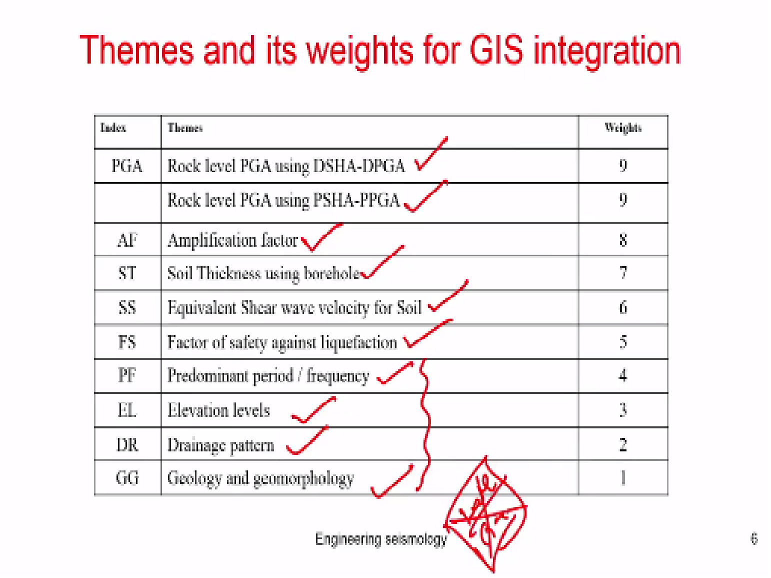
Then you take a account of the building in that area how much buildings are exposure and what is the vulnerability. Sometimes your hazard maybe high the building is consider and designed for earthquake then it will be low vulnerability. So like that you should do a systemic analysis of the study a building and map their vulnerability key scale. So that is vulnerability analysis.

So once you map a building then you will know how many people living in that building, what is the income of per capita income. So based on the vulnerability and the hazard you can multiply both you will get a risk. So generally the vulnerability high vulnerability, high hazard value will result in the high risk. So the risk will be higher your hazard is high and your vulnerability also high.

So both are high so the risk will be sometime moderate your hazard maybe high, but vulnerability will be less the buildings are safe. So, similarly the risk vary with like it will vary the low hazard and vulnerability high then your risk will vary. So this is the composite so this risk will give you so this seismic risk will give you how much financial loss you can expect, how many people will die what are the level of disaster you can expect due to the typical earthquake.

So this was very important particularly for the disaster management planning and disaster minimizing the disaster. So that is why the macro scale map soon after they prepared a bedrock level hazard values they also estimated the exposure and number of fatality and financial loss expected from the different earthquake. So this is the whole objective of microzonation mapping and the steps involved under.

(Refer Slide Time: 14:51)



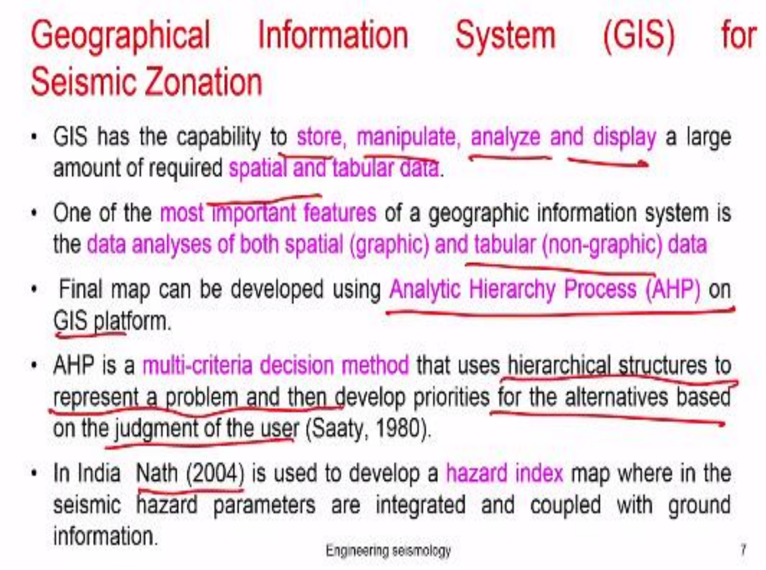
Index	Themes	Weights
PGA	Rock level PGA using DSHA-DPGA	9
	Rock level PGA using PSHA-PPGA	9
AF	Amplification factor	8
ST	Soil Thickness using borehole	7
SS	Equivalent Shear wave velocity for Soil	6
FS	Factor of safety against liquefaction	5
PF	Predominant period / frequency	4
EL	Elevation levels	3
DR	Drainage pattern	2
GG	Geology and geomorphology	1

So which means that any microzonation study which consider in a particular region should have a systematically listed parameters which has to be consider in the mapping hazard index value. So we will not talk about the risk and vulnerability only we will talk about up to zonation mapping for the discussion here, but we stop at only estimation up to the hazard analysis.

Because that you need a geotechnical knowledge from the civil engineering so which generally not minimum requirement for essential requirement for this course so we are only stopping at a hazard values which will be discussing in the future classes how to estimate hazard. So as I said that so you will be estimating a direct hazard so in the form of deterministic and probabilistic and then amplification from this one.

And then which is also related with the soil thickness. So then the soil stiffness, liquefaction factor and then predominant frequency elevation level, drainage pattern and topography basically these parameters so all clubbed together will represent somewhere the side effect or amplification. So here we did not include a landslide hazard as well as the tsunami because this is the case study of Bangalore where the landslide and tsunami is not possible. So that is why we did not include a landslide and tsunami part of the themes and weights needed for this one.

(Refer Slide Time: 16:22)



So this entire process we should do it on the geographical information system for the seismic zonation. So, why we have to do the geographical information system? So the GIS as a capacity to store, manipulate, analyze and display large amount of the required spatial and tabular data. So the GIS basically is a mapping tool so whatever you are seeing a Google map so this kind of map where can be produced GIS.

This has a capacity to store and manipulate and analyze and display and then data in the spatial and tabular form. So that means we can give input as a spatial as well as a tabular form this will store a data and manipulate so that is how the manipulation is taking place. I do not know how many of you noticed that when you use your Google map so when you use a Google map in your mobile you go like somewhere you go one to grocery shop, market and then movie theater something like that.

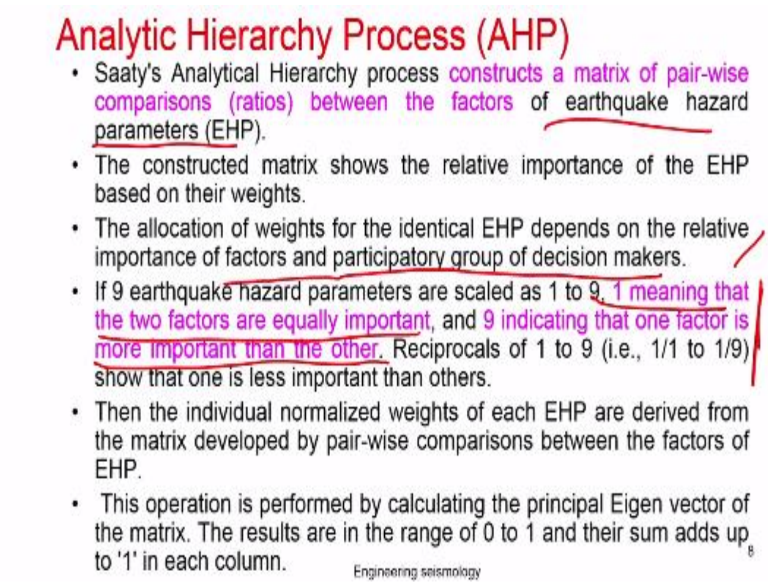
So after a month or a week Google will tell you these are all the places you visited, you want to rate. So it will tell you then based on your purchase if we take some photos or something like purchase and visit some particular shop it will remind you that in the shop there is something cheaper you want to buy. So such kind of advertisement, manipulation and process and analyzed data and display to the user.

So that kind of the larger activity is possible in the GIS in the spatial as well as tabular form. Spatial form means a data form which is map form you can give or a tabular form. So, one of the most important features of geography information is data analysis on both spatial and tabular form. So the tabular form is basically non graphic data, spatial form is graphic data. So the final map can be developed using the analytical hierarchy procedure in GIS form.

So this analytical hierarchy procedure we will discuss in the next slide. So which is a user friendly way you can describe the weights of the parameters, analytical hierarchy process. So the analytical hierarchy process is a multi decision method that uses hierarchy structures okay you can rank parameters based on the importance then develop a priority an alternate based judgment of the user. So which was developed by the Saaty in 1980s.

So the first time the analytical hierarchy procedure are incorporated in the seismic zonation work by the Nath for the Sikkim microzonation work before that people are not using this kind of technique in the preparing zonation map in India. So that is for your information.

(Refer Slide Time: 19:22)



So the analytical hierarchy procedure so Saaty's analytical hierarchy process construct a matrix of pair wise comparison ratio between the factor of the different earthquake hazard parameters. So the earthquake hazard parameters what we mean here the bedrock hazard, amplification, liquefaction, landslide, tsunami. So these are all the factors which is responsible to cause earthquake hazard and death and damage those are all the parameters called as a earthquake hazard parameters.

So this will take a basically constructs a matrix pair wise comparison and take ratio between these factors that is very important in the analytical hierarchy process. The construction of matrix shows the relative importance of the each earthquake parameters based on their weight. So allocation of the weights identical to the EHP depends upon the relative importance of the factors and participatory ground decision makers.

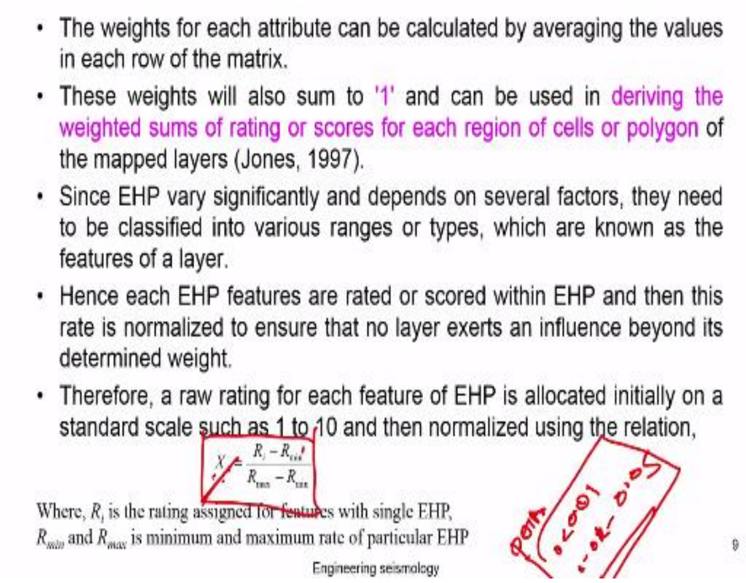
So this assigning the weight of particular factors depends upon the user or participation group. For example, some place the tsunami will be given higher weight, some place the landslide will be given higher weight, some place the liquefaction may be given as higher weight, some place the ground shaking hazard can be given as a higher weight. So this depends upon the group decision makers who is involved on the making a analytical hierarchy process.

So for example 9 earthquake hazard parameters are selected which you have discussed in the last slide. So in the scale of 1 to 9 so 1 meaning that two factors are equally important and the 9 indicating that one factor is more important than other. So the reciprocal of 1 to 9 1 / 1 1 / 9 so 1 is less important than the others. So that is how the analytical hierarchy procedure works. So then the individual normalized weights of each EHP are derived from the matrix developed by the pair wise comparison between the factors and EHP.

This operation is performed by calculating the principle Eigen vector matrix. The results are range from 0 to 1 their sum adds up to the 1. So finally even though you prepare a different ranking and then assigned a different weights to each parameters you make a Eigen vector estimation and make each parameter as a normalized weight and some of the parameters finally to the unity.

That means the highest hazard index can be expected on any zonation map should be unity the lowest will be 0. So in between it varies depends upon its level and position and all those things.

(Refer Slide Time: 22:15)

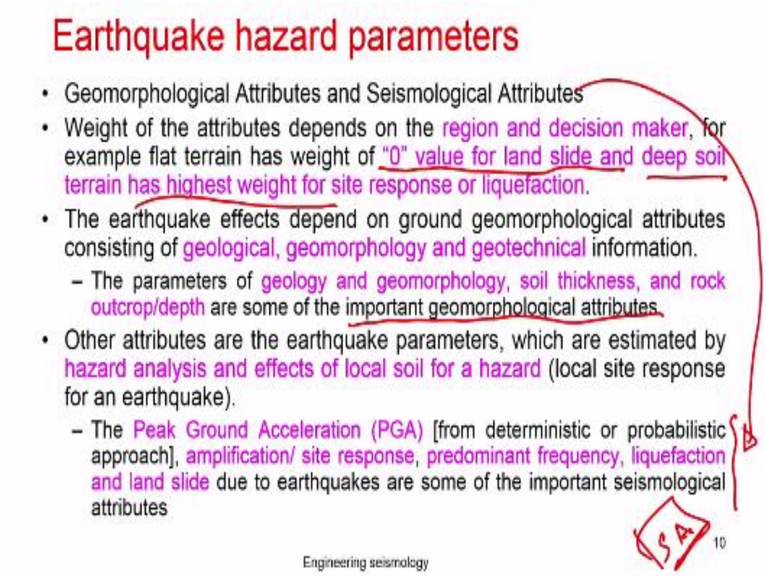


So the weight of each attribute can be calculated by averaging the value of each row of matrix which we will discuss in the next slide. So this weight will be sum to 1 can be used deriving the weight sum of rating or score of each region cell or polygon in the mapped domain. So since EHP vary significantly and depends on the several factors they need to be classified into two ranges of type which known as a features of layers.

Each earthquake hazard parameter features are rated or scored within the EHP then this. So we have seen that each parameter would describe, but that parameter has a sub range. For example, if you take a PGA estimation. As you know that one place the PGA will be 0.01 low another place 0.01 to 0.05 so something like that you will have a different group depends upon the region.

So this each individual group within the earthquake hazard parameter need to be ranked and a normalized ranking weight has to be estimated so that is the formula where you can estimate a normalized weight of each parameter you can see that so the R is the ranking of individual parameters R minimum is the lowest ranking, maximum is the highest ranking then you can get a normalized weight using this formula. So this will give you the normalized weight.

(Refer Slide Time: 23:43)



So the earthquake hazard parameters can be broadly classified as a two category. So one is the geomorphological attributes, another is the seismological attributes. So what is the geomorphological attributes? Geomorphological attributes is a parameters which responsible from the geology and morphology of the region. So the geology means like the soil formation, soil elevation level so that is a geomorphology.

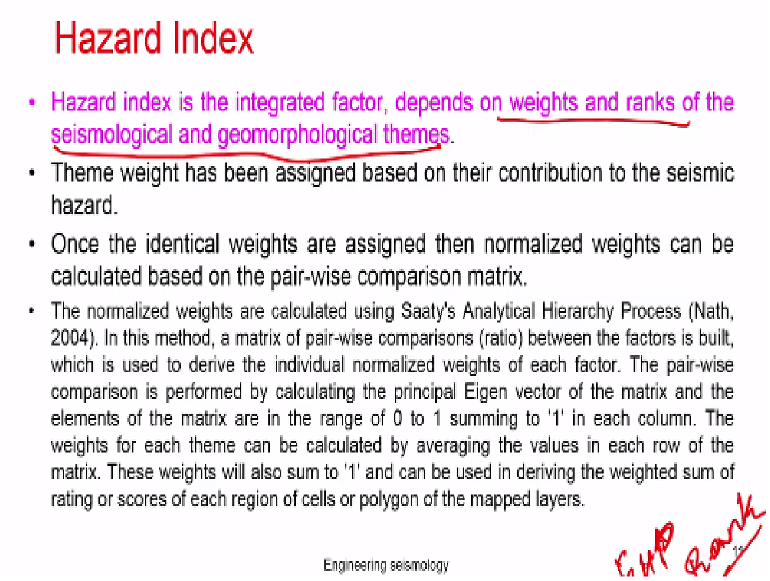
So the soil type it is a geology so those are all the geological attributes which varies like bedrock depth. Seismological attributes are the parameter which is estimated considering the earthquake so for example amplification, predominant frequency. So then the liquefaction where you need earthquake data as a input to arrive this parameter. So the entire parameter whatever we have we can group as a geomorphology attributes and seismological attributes.

So the weight of each attribute depends upon the region and decision maker which we have discussed earlier example flat terrain has a zero weight for a landslide and a deep terrain has highest weight for the site response and liquefaction you can see here. So if you want to take a landslide so the parameters which is given for the flat land is zero. At the same time if you want to do the liquefaction and site response deep soil has a favorably high weight.

So this is how the ranking and weighting has to be assigned. So earthquake effect depends upon the ground geomorphological attribute consisting the geology, geomorphology, geotechnical information. The parameters of geology, geomorphology, soil thickness, rock outcrop depth are the most geomorphological attributes. So these are all the parameter which varies with respect to the geomorphology, geology features.

The other attributes which we have discussed that the seismological attribute which is the function of earthquake, occurrence or earthquake data the peak ground acceleration which maybe from deterministic, probabilistic, amplification which is again earthquake data as input, site response, predominant frequency, liquefaction, landslide due to earthquake and tsunami. So these are all the parameters for the seismological attributes. So this is the seismological attribute where you can see that these are all the function of earthquake data.

(Refer Slide Time: 26:27)

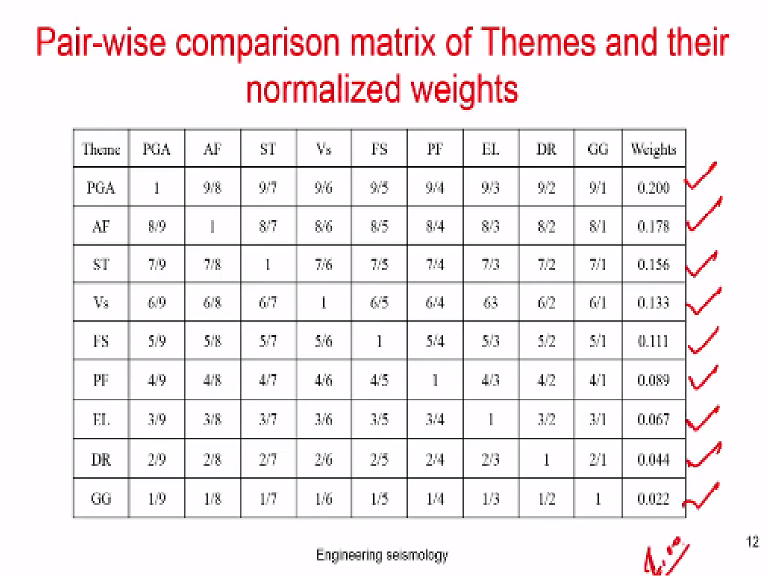


So this parameter has been ultimately combined such that you can generate a final hazard index value which is integration of all this parameter depends on the weight and rank of the seismological and geomorphological theme. So the theme weight has been assigned based on their contribution and to the seismic hazard at a particular region. So based on the past earthquake you will get a idea like what are the parameters of contributed more hazard from the isoseismal and intensity map.

So based on that you can decide that this is the parameter where you can assign a more weight and less weight are based on the experience in case if you do not have much data from the previous year. So once the identical weights are assigned and normalized weights can be calculated based on the pair-wise comparison matrix. So once; the weight has been calculated for each earthquake hazard parameters.

So then you can estimate a rank, assign a rank, rank of each parameters division subdivision and then calculate a normalized rank within the parameter. So that is what you will be getting then you can multiply all of them systematically and then estimate your hazard index value.

(Refer Slide Time: 27:55)

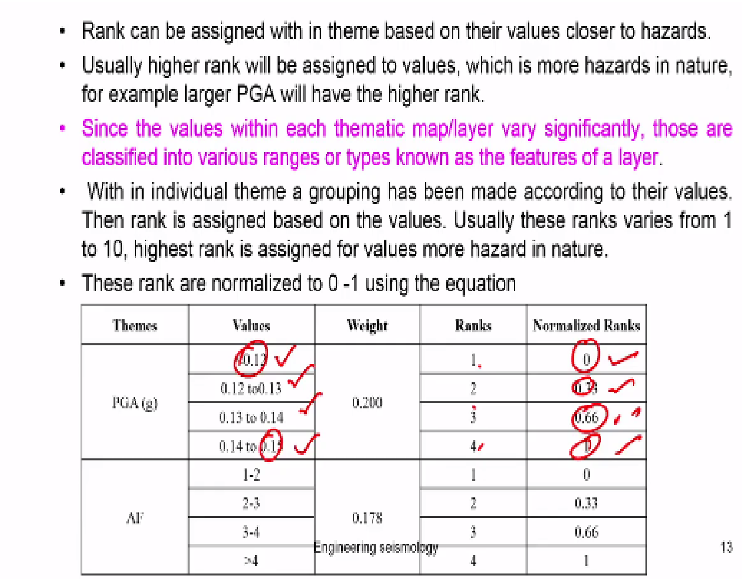


Theme	PGA	AF	ST	Vs	FS	PF	EL	DR	GG	Weights
PGA	1	9/8	9/7	9/6	9/5	9/4	9/3	9/2	9/1	0.200
AF	8/9	1	8/7	8/6	8/5	8/4	8/3	8/2	8/1	0.178
ST	7/9	7/8	1	7/6	7/5	7/4	7/3	7/2	7/1	0.156
Vs	6/9	6/8	6/7	1	6/5	6/4	63	6/2	6/1	0.133
FS	5/9	5/8	5/7	5/6	1	5/4	5/3	5/2	5/1	0.111
PF	4/9	4/8	4/7	4/6	4/5	1	4/3	4/2	4/1	0.089
EL	3/9	3/8	3/7	3/6	3/5	3/4	1	3/2	3/1	0.067
DR	2/9	2/8	2/7	2/6	2/5	2/4	2/3	1	2/1	0.044
GG	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	0.022

So how to estimate a pair wise matrix I was telling you this is actually you take a 9 parameter which we discussed earlier and this is how. So you can divide by each parameter by its own parameter in the first. For example, PGA so which is assigned as a 9 so 9 / 9 PGA amplification 8 divided by 9 so 7 / 9 so like that you can see the unity. So you can prepare this kind of this one and finally you arrive here weight based on the normalized value of each weight systematically calculated.

So this weight will indicate that how each parameter is given a weight in your final hazard index value. So this is about the individual parameter and weight estimation. We have taken a 9 parameters here so if you cumulatively will be unity basically if we cumulate and see you can get the unity or the values.

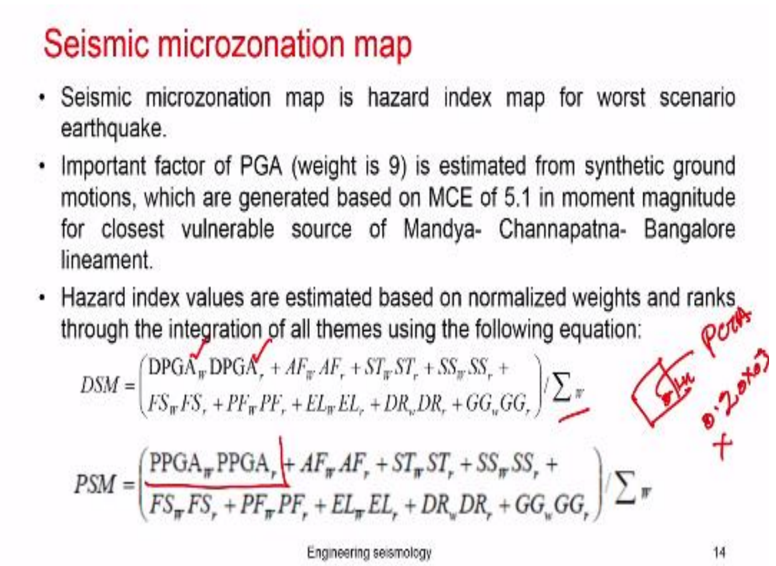
(Refer Slide Time: 28:54)



So once you are done that as I told you that each parameter you will have a subgroup division for example PGA. PGA can be divided depends upon the value, range produced in the region. For example, this particular region this is the four classification we can get as PGA varies from this to this then each one you will rank 1, 2, 3 the highest rank is given for the more hazardous dangerous value so 4, 3, 4.

Then you estimate a normalized rank using the formula what we discussed. You can see that the ranking so like this so similarly amplification factor this is the typical example so this can be repeated for 5 group, 4 group, 2 group, 3 group depends upon the number of group what you use for each earthquake hazard.

(Refer Slide Time: 29:43)



So once you are done that finally the hazard index map can be developed by multiplying the weight and rank. So that means each grid point you know what is the PGA. So you know what is the weight of PGA which estimated as per table it is 0.2 and then this value I got a 0.44 my ranking will be so here you can see so 0.12 this one also 2 my ranking and 0.33 so this will be 0.2 into 0.3 so like that one parameter similarly the other amplification.

So each grid all the parameters whatever we estimated multiplied and added and divided by some of the weights generally this is the unity so you will get a value that value is called as a seismic hazard index. So this hazard index can be estimate two cases. One is that deterministic hazard index where the worst scenario for the one earthquake and the another is probabilistic hazard index.

So we have seen that global seismic hazard map program they use a probabilistic way here also when you estimate a PGA with different probability of exceedance in given period then you get your microzonation map also deterministic and probabilistic. So this microzonation map is a map of zonation of each region which represents all the possible scenario in the region.

So this is your methodology detailed discussion of how each hazard component will be taken the weights will be taken and ranking will be taken then finally how the hazard index values are estimated. So yesterday we have discussed about the hazard index value when we are talking about the microzonation of some of the Indian cities and all those things. So now next we are going to discuss how this can be really applied for the microzonation of Bangalore in the next class. So, thank you very much for watching this video so we look forward again in the next class. Thank you.