Introduction to Engineering Seismology
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Lecture – 49
Seismic Zonation of India

So, Vanakkam. We will continue our lecture on engineering seismology. So we have been discussing about the zonation. We understand that the primary importance of the zonation is basically to give input for the building and infrastructure design.

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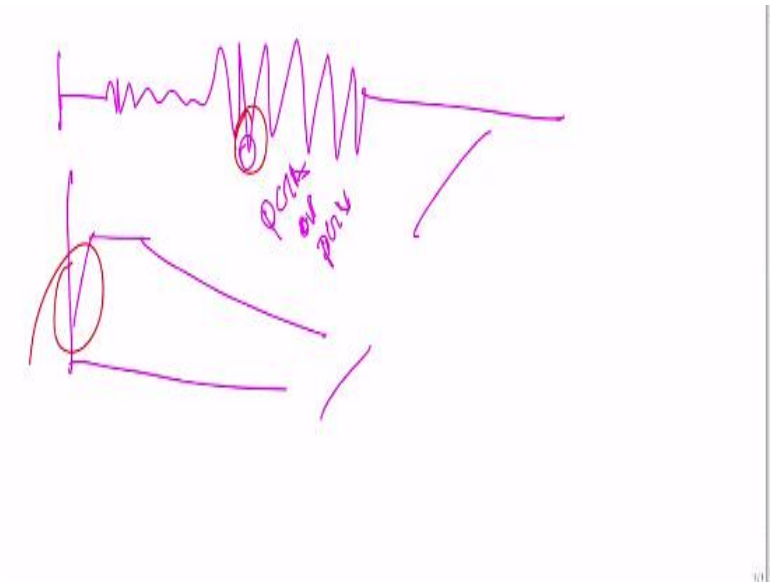

So that input will be like your acceleration time history like this whatever earthquake representing or you will get the spectrum so the design spectrum. So these are all the two input which generally given from most of the maps. So this can be represented as a PGA or PGV so depends upon the structure you can take. The primary objective of this zonation is to provide a information.

So to provide data or the building design that is what the first and foremost primary objective of this zonation mapping. So depends upon this parameter scale and consideration, the maps can vary. So we have seen that microzonation map which is basically goes for the very large level of area like continent. So Asia, South America, North America like that continental wise mapping and zoning hazard is a microzonation.

The microzonation is actually varying the regional level variation particularly accounting the soil variation in the region which is responsible for the wave modification and then the soil failure such as liquefaction and landslide. So capturing of this variation can be done at micro level that is a microzonation. As we have seen that even though the microzonation and zonation map well advanced in the several countries which was not well established in India.

So we have seen some of the microzonation study which has like done in a particular type of study not all the component of microzonation which I discussed as a methodology and claimed that as a microzonation. So such issues can be overcome when you do the systematic preparation of microzonation maps. As I told you that as of now we have the microzonation map only for the few cities which is like more reliable and good map.

Like Bangalore microzonation map one of the example you can say and then Guwahati microzonation map, Jabalpur microzonation map and then the Delhi microzonation map. So the Delhi will be more advanced than any other region because it was done by two, three times with a different group of people considering all the aspect. The Bangalore microzonation of course it has been outdated.

As we discussed with that any seismic zonation map has to be updated every 4 to 5 years or soon after the major earthquake whichever is earlier, but Bangalore we have done this microzonation around 2008 something like that the project was completed. So now we actually almost like 12 years old still it is not updated and moreover the microzonation of Bangalore done only for the old BBMP area of 650 square kilometer not for the present city which is actually extend up to I think close to 1,000 and above square kilometer area.

So which needs to be updated so it is not that whenever we prepare a map and leave it as we have seen in the global earthquake modeling they said that this map they will be keep updating frequently whenever there is a changes in the model, changes in the data. So unfortunately none of the Indian microzonation map which is developed as this kind of update possibilities.

So when you used that OpenQuake software system in the GEM which may be possible to get those kind of update frequently. So that kind of map is a more reliable and updatable frequently that is what we should target that kind of microzonation map. So the more

objective the first primary objective is to provide your input data basically we will be giving you the data of the design values for this one.

So this is one of the main objective of this microzonation. The second is this microzonation map also can be used for the city planning so the development and investment and any kind of knowing the seismic risk and vulnerability. How many people will die, how much economical loss will happen if this kind of earthquakes are coming, where it will happen more, where it happen less such kind of study and understanding the disaster management planning.

All those things are recorded this kind of microzonation map. So as I said that the microzonation map is primary objectives to give the design parameter for a normal building design in the region. So let us see what is the design parameters are recommended from Indian seismic code. So the guideline which is given from this kind of study is given in the form of codes and standards on each country.

Let us see how our Indian code gives this parameter since its origin to as of now how this values are representable. So the seismic code the Indian seismic code we are going to discuss in detail today. So, I will be telling each and every aspect of the code so I am not criticizing the code too much, but I am trying to say that it needs to be updated that is what the important message you should get or when you are constructing something you should also think what is the state of art knowledge gone to the code of development.

So that you appropriately take decision particularly the important building because a small building like ground plus 1 or ground plus 2 building collapse only 1 or 2 people or 5, 6 people die the apartments like 1,000 family and 5,000 family apartments and all constructed based on this kind of code so many people will die if the values are taken is not appropriate. So after reviewing the code yourself you will see that the values are how representative with the state of art, knowledge what we discussed earlier or what we are going to discuss in the future classes.

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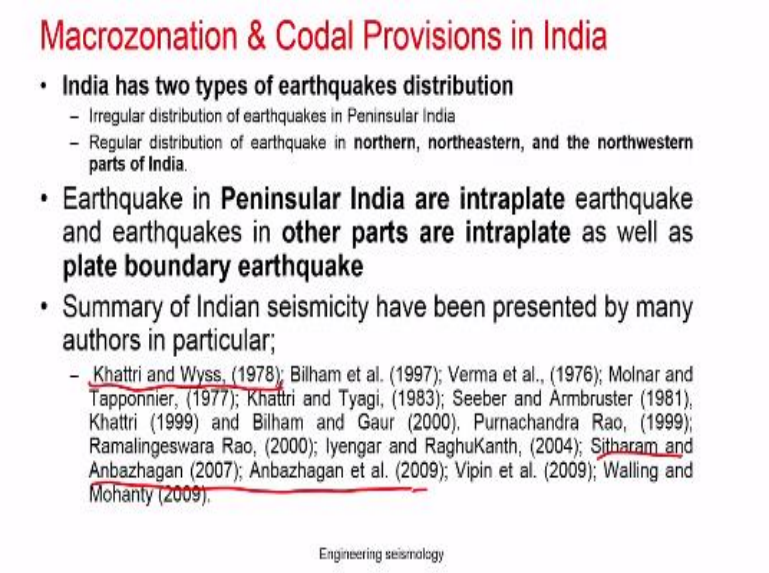

So the microzonation our code actually is a microzonation it is not a micro level because the information gone into the code development was only geology and seismicity. So as you know that when we are talking about the plate tectonics and types of plates and all so we discussed that India as majorly two classifications one is that the plate boundary which takes care of the northeastern and northwestern part of India.

So where there is a regular distribution of the earthquake so there is a frequent distribution or frequent occurrence of the earthquake in the region where which is called as a northeastern, northwestern part of India. Another one is actually the peninsular India which is irregular distribution of the earthquake which falls middle of the Indian plate that is why. So the earthquake in peninsular India are intraplate earthquake in nature.

Because the peninsular India itself far away from the plate boundary as per our types of earthquake definition if you see these are all the intraplate earthquake. So the earthquakes in the other part the northern part, northeastern part, northwestern part interplate earthquake this regions are very close to the plate boundary, but there are some earthquake which occur away from the plate boundary.

As you have seen that 10 kilometer away from the plate boundary region is considered as basically the intraplate earthquake. So the intra and interplate earthquakes are possible in the northern part of India so both. Northern part means I am starting with respect to the Delhi, Haryana, UP, Bihar so this Nepal region in Uttarakhand so then the Sikkim so this side is Tripura and then Manipur, Meghalaya and Jammu and Kashmir.

So these are all the region I am talking about more inter and intraplate earthquakes are possible. So there are several attempt has been made by the scientist to study the earthquake hazard. So the first attempt made for the assessment of the seismicity and earthquake hazard by the Khattri he was the first person to work on the seismic this one then Bilham 1997, Verma then the Khattri and Wyss.

So the Bilham and Verma and all they carried out some kind of seismicity study but not hazard Khattri work was the first one. So then there are many people spent their time on trying to describe their seismotectonic, seismology and seismic hazard including my own research group so this is our work actually. So these are all the people who contributed to the hazard analysis of the different part of India.

So even a Nath and Thinbhujam those are missing actually it was updated on 2009 then 2012 Nath and Thinbhujam work and other people work. So these are all some of the examples. You can get more details about this work in the website if you type hazard analysis in India so you can get list of papers which is published by the hazard and this one. So as I told you that there are group of scientist they work take a procedure.

Apply to particular region and produce a result without knowing that particular procedure or without worrying that the particular procedures are applicable or non applicable. So those kind of like application direct to oriental studies also you can find. There are people who do research on each and every aspect at the hazard analysis. So our group we do research on hazard analysis so why we should estimate m max in this method.

Why you should estimate magnitude conversion in this method, homozonation in this method, why we should estimate use this GMPE, why I should consider this source such kind of questions are asked in our research we tried to address that and overcome some of the limitations in the common hazard analysis procedure and try to incorporate, update a procedure as per the regional data.

We call it as a regional rupture based seismic hazard analysis which we also published couple of papers on that those kind of research on the hazard analysis, site response studies, liquefaction assessment and amplification study that is what we do part of my teaching and

research at IISc which you can see from my publication. Anything somewhere developed I do not take as such as we have seen that some of the maps are produced from the GMPE is developed elsewhere without knowing that GMPE is applicable or not.

So when I do my work I actually study those things, assess the reliability and try to incorporate most representative results. So as I told you that there were two group of scientist work like that. One group of scientist simply take the typical methodology or procedure which is adopted universally or anywhere in the world and adopt same thing to India without knowing a complex and the geology and regional variation.

So that kind of study will be more or less you can say approximate, you cannot expect more reliable results, but when you try to take a procedure and methodology and try to see that how it can be adopted to your region, how it can be suitable to your region, what are the way you can incorporate your regional level parameters to account the regional variation, seismicity then that kind of study will be more representative I work on second category actually.

The rest of the category work you can see lot of papers on that, but you have to be very cautious why I am telling that when you read about the paper whose paper you are reading also very important, who has published that paper also very important not all the paper. See everybody give you hazard map when you look at as a hazard map you can see both of them are given a hazard map which hazard map is more reliable, which hazard map is less reliable.

That depends upon what is the input and model gone to prepare that hazard. So that you have to keep it in mind otherwise you will be ending up in the referring a wrong paper and wrong equations, wrong result which will lead to a problem even though you design if you consider a wrong input your design may not be sustainable or may not withstand a load what you are considering.

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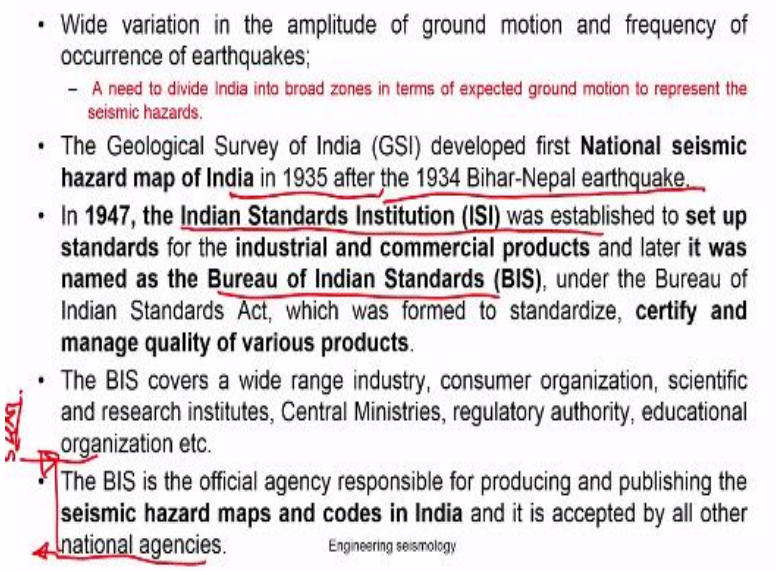

So the wide variation of amplitude of ground motion and frequency of occurrence of earthquake is possible in India because you have the very active plate boundary, you also have the stable region. So there is need to divide the India into broader zone based on the expected ground motion to represent a seismic hazard at each part of India. So that is how the zonation importance can be understood.

So this was evinced by the Geological Survey of India GSI and developed a first seismic hazard map of India in 1935 after Bihar-Nepal earthquake. So this was after 1934 Bihar-Nepal earthquake many people have died. So which made the British government to think that we should give a consideration about the developing a national seismic hazard map which shows a possible hazard of different part of India which will be useful for design of building.

So which was done and then this was developed and the committee has been formed people also worked on that and produce the seismic hazard map, but unfortunately that map was not published that time whatever is generated. In 1947 after independence the Indian Standard Institute ISI has been formed, was established to set up standard for the industrial and commercial product later it was named as a Bureau of Indian Standard BIS.

Under Bureau of Indian Standard Act which formed standardize, certify, manage quality of various product that is what ISI and BSI it does. So BSI cover wide range of industry consumer organization, scientific and research institute, central ministries, regulatory authorities and education organization. So the BIS is officially agency responsible for

producing and publishing a seismic hazard and codes in India which is accepted by all other national agency.

So basically the BIS is a responsible agency who is responsible for the current seismic hazard map of India. So the BIS they are the agency you should revise, update and publish a map and interval basis that is what BIS do. So with BIS guidance so there is a code named as a IS 1843 the part one is the seismic official code of country. So this code gives the information for the building design for the normal building. So normal building design this code produces. So the current version of this code is actually 2016.

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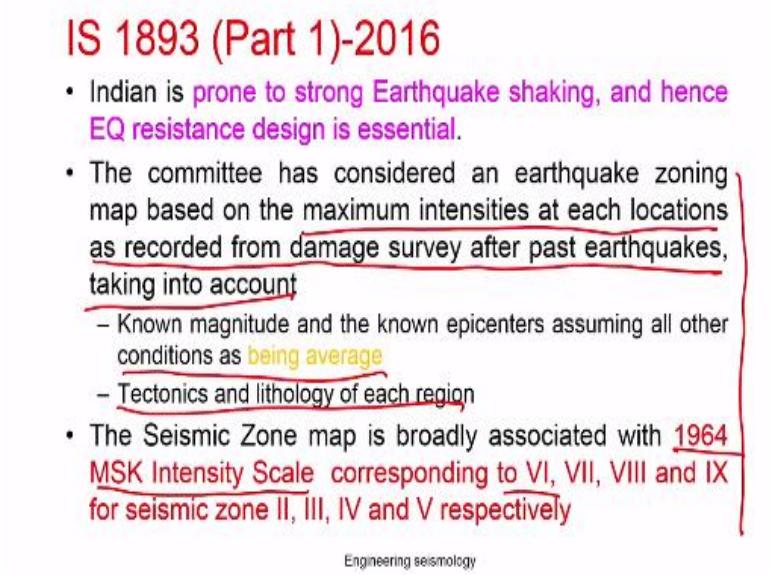

So part one specifically because this is more suitable for the essential building. For other building there is a other part so we are only going to discuss about the part one. So the committee has considered earthquake zoning map based on the maximum intensity at each location as recorded damage survey after the past earthquake taking into account of that. So this IS code given the following statement in the code which described how the code was developed.

The committee has considered an earthquake zoning map based on the maximum intensities at each locations as recorded from the damage survey after the past earthquake taking into account of the known magnitude, known epicenter assuming all other conditions are being average then the tectonic and lithology of the each region. The seismic zone map broadly associated with the 1964 MSK intensity scale corresponding to 6, 7, 8, 9 for the seismic zone 2, 3, 4 and 5.

So from here you can understand that the past earthquake damage data has been collected and people taken intensity as a reference value and then they prepared a zonation map so it was written in the code which was not my statement which was explicitly written in the highest code.

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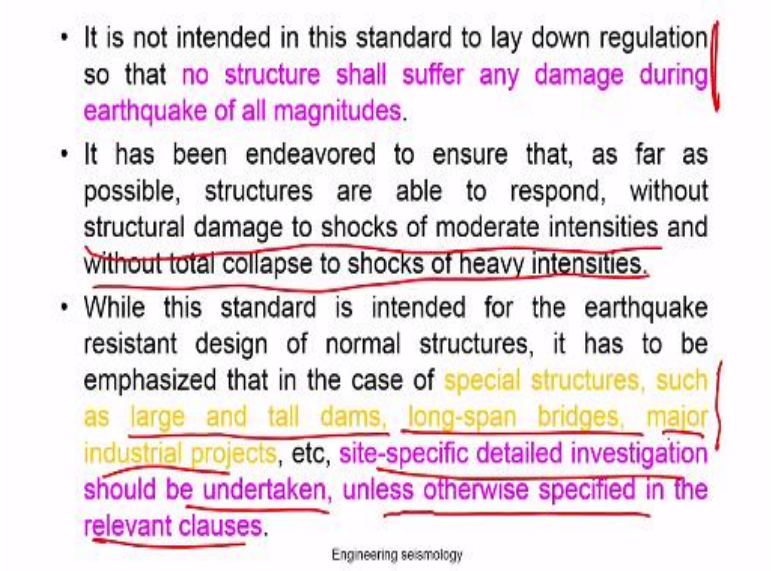

So it is not intended this standard to lay down the regulation so that no structure shall suffer any damage during a magnitude. So this code objective is to not to give you the value which will completely safe structure. So it is not intended this standard to lay down regulation such that no structures shall suffer any damage during the earthquake that means if we consider this codal values for the design.

If earthquake comes you may expect some damage, but it may not collapse so that you can escape and save your life that was the motive and definition given in the code. So it has been endeavored to ensure that as far as possible structures are able to respond without structural damage to the shocks moderate intensity without total collapse to the shocks heavy intensity. So this was the consideration gone into the development of zonation map.

So while this standard is intended for the earthquake resistant design of normal structure it has been emphasized that in the case of special structures such as large, tall dams, large span bridges, major industry project, site specific investigation should be undertaken unless otherwise specified in the relevant clauses. So that means whenever you have here special

buildings, bridges, industrial buildings you need to get site specific studies done, the value is given in the code may not be suitable that is what message convey from the code.

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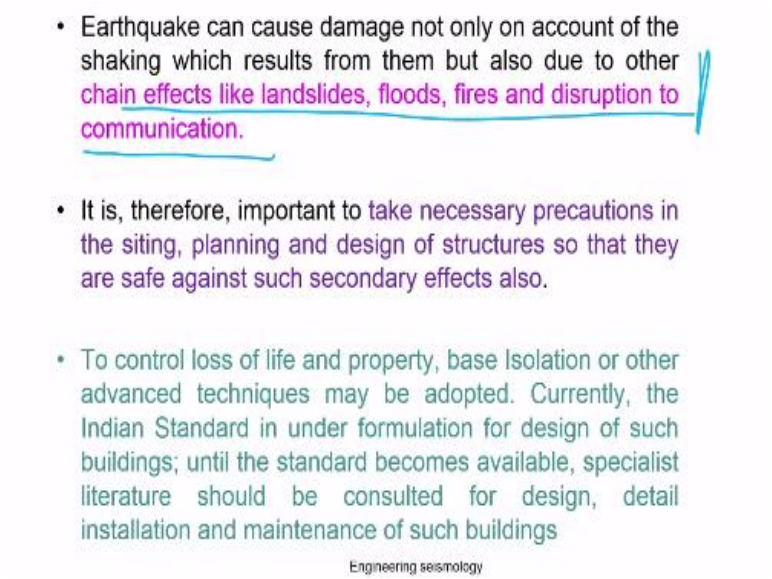

So the earthquake can cause damage not only on account of the shaking which result from them, but also due to other chain of effects such as landslide, tsunami and fire disturbance to the communication. So there all the where it can cause hazard so this hazard is not explicitly consider in the present code. So it is therefore important to take necessary precaution of the sitting, planning, design of structure such that the safe against the secondary effect also.

So you can need to consider when you do this the control loss of life property, base isolation or other advanced techniques maybe adopted. Currently the Indian standard and formation for design such building until the standard becomes available, specialist literature should be consulted for the design. They say that we should adopt a proper methodology of design to basically design your structures which can save from any future earthquake.

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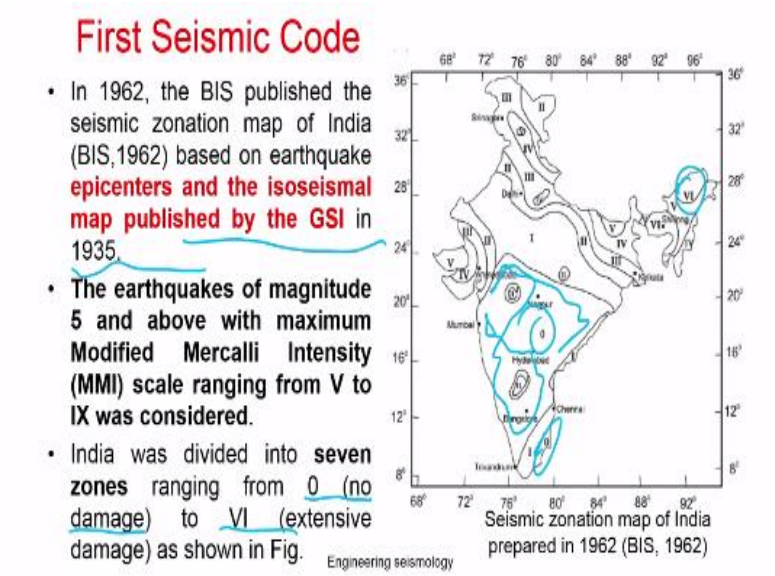

So this was the guideline given in the IS code beginning of the code forward page it has been given. So the first seismic Indian code so in 1962 the BIS published the seismic zonation map of India based on the earthquake epicenter and isoseismal map produced by GSI in 1935 you can see. So whatever work done in 1935 it has been only republished and published the first seismic zonation map.

So you can see the different zones here the earthquake magnitude 5 and above with maximum modified Mercalli intensity ranging from 5 to 9 was considered. India was divided into 7 zone ranging from 0 like no damage zone and 6 is the extensive zone. I can see the zero damaging zones so these are all the zero damaging zone. You can also see higher zone you can see here higher zone which is basically the extensive damage expected region you can see here also zero. This was the first seismic zonation map of India published in 1962 under BIS considering the work carried out by GSI all under 1935.

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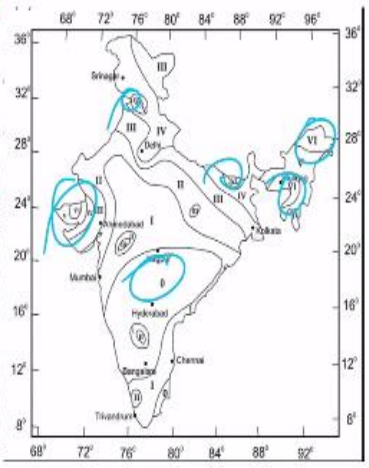
- The Deccan Plateau was considered more or less a safe zone and the hazard level was assigned 0 while a larger part of the northeastern India was assigned VI.
- The zoning was reviewed in 1966 (BIS,1966) and additional information like the **geology and the tectonic features were taken into account for modifying the zones** (See Fig) with more weightage being assigned to the tectonic maps (Tandon,1992) that delineated the fault systems.
- The 1962 and 1966 BIS zonation maps had **seven zones and each zone were assigned the maximum MMI based on the historically observed or expected intensities** for those zones as summarized in Table



Seismic zonation map of India prepared in 1966 (BIS, 1966).

So the Deccan plateau was considered more or less safe zone from the hazard value was assigned as a zero that is what you can see. While the larger part of northern India was assigned the zone 6. Okay you can see that so these are all the highest seismic zone you can see the Bhuj. So the zoning was reviewed in 1966 and additional information like geology and tectonic features were taken into account for modification of the zone.

So with more weightage being assigned to the tectonic maps and that delineates the fault. So the 1962 and 1966 BIS zonation map of 7 zone each zone were assigned a maximum MMI scale of intensity historically observed or expected intensity of the particular region okay this is the 1962 map.

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- The seven seismic zones based on BIS 1962 and 1966 with its expected maximum MMI (Prakash, 2004).

Seismic zone	Probable maximum intensities (MMI scale)
0	Below V
I	V
II	VI
III	VII
IV	VIII
V	IX
VI	X and above

Third Zonation Map

- The seven seismic zones based on BIS 1962 and 1966 with its expected maximum MMI (Prakash, 2004).
- The zonation map underwent major revision in 1970 after the 1967 Koyna earthquake (Ms=6.5) occurred in the Deccan Plateau region which was assigned as zone 0 with no seismic activity.

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There was about 7 zone this 7 zone was actually adopted in the world BIS code the first version kind of things where you can see the maximum probable intensity is expected on each 7 zone we can see seismic zone and comparatively the probable maximum intensity on each zone. So this was first map produced by the GSI and officially released by the government of India geological survey of India where this map has been given as a map for any seismic design in the country that is what they have done.

So this map where the respective you can see that the intensity of 10 and above assigned further seismic zone 6 so where the intensity of below 5 has been assigned by the zone of zero. So even though seismic zone zero means it does not indicate that there is no seismic activity it only indicates that it is corresponding to the intensity of 5 expected in the region that is what it indicates.

So after this map so in 7 seismic zone there is 1966 was expected to maximum MMI the zone map underwent a major revision in 1970s after 1967 Koyna earthquake which we have discussed that Koyna has a reservoir induced earthquake so where the Koyna is located at the Deccan plateau for which the assigned zone zero no seismic activity has on that paper. So 1970 the map was been updated considering this aspect that map basically seismic zonation map of the 1970s.

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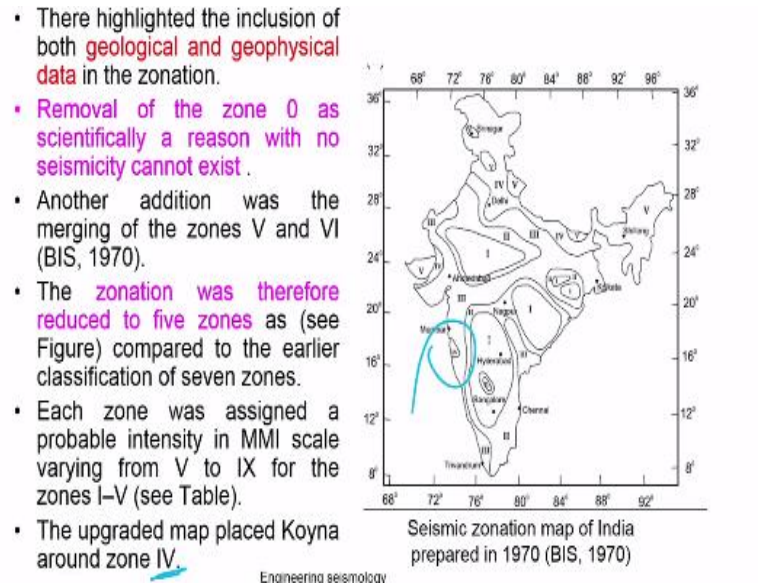

So there are highlight that includes the both geological and geophysical data in the zonation and removal of zone zero has scientifically reason with no seismicity cannot exist. So we have seen that the zero zone the Koyna earthquake was there so that means there is no point

in putting zero zone even though intensity 5 and above is expected. So that zero zone has been removed.

Therefore, the zonation reduce it to 5 so zero is removed and then 4 and 5 are merged old zone so instead of 7 zone it become a 5 seismic zone of the steady region or India. Each zone assigned a probable intensity values so based on this one again the upgraded map placed Koyna around zone 4. You can see that Koyna earlier it was in the zone zero. So this major modification done in 1970 BIS version.

So that was the third version of the code where they have developed a map and included Koyna earthquake after this. So that means the zonation map underwent a major revision soon after the Koyna earthquake this is what the message you will take it from here. So right now we discussed about the seismic zonation mapping and seismic zonation we discussed in the first seismic zonation map and second seismic zonation map.

So both of them and this map will give you the idea about how the seismic zonation changes in our country. So with this we will close this lecture so we will continue our lecture in the next class. Next class, we discussed about the next version of the seismic code and finally end up in that how the today code what are the values and implementation of today code we will be discussing in the next class. So thank you very much for watching this video we will see you in the next class. Thank you.