Introduction to Engineering Seismology
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Lecture – 50
IS 1893 Version 2002 and 2016 Explained

Welcome. So we will continue our engineering seismology lectures. So we have been talking about the Indian code. So we told that the prime importance of any seismic zonation is to provide design of parameters, design parameters for the normal buildings in the country. So that is how the Indian code also is being developed. So I am not very sure we have discussed in our class what was the first recorded earthquake or instrumented earthquake in India.

So I think we have discussed about the Shillong earthquake and then the (()) (00:55) studies and followed by the first seismic instrument deployed in India. So if we see the first seismic instrument installed in India and the code released you can see almost there is a huge gap since historic times, but there is no codal provision was developed until or after independence only we had a first code provision.

So that means before that whatever the construction happened in the country these are all happened based on the experience gained by the people whatever buildings which was constructed long back so such as our heritage, temples and then old buildings these are all based on the experience gained by the people not the engineered structures which claimed to be a civil engineers today.

And where there is a lot of calculation and mathematics they talk and all those things, but in fact many of the historic structures are intact and not failed due to the natural hazard. You can see that there are temples which are 1,000 years old several 1,000 years old, dams 1,000 years old like there was a dam colony where it is almost like more than 2,000, 3,000 years old nothing was happened to any of the natural hazard.

So the practice was based on the experience gained by the people which has very intact, but still the new way of civil engineering which was a modern concrete and then the reinforcement all those things which was developed elsewhere and also adopted in India. So

those kind of technology design needs a seismic code to be consider because our traditional practice if we adopt a traditional practice and design a building or construct a building.

You will sure that your building may not get affected by the earthquake whatever traditional practice, but you should adopt that was practiced about maybe 200, 300 years old technology you should adopt not the modern technology. So the modern technology is basically RCC framed structure, concrete structures all those things like cement so many things. So where this needs some kind of systematic engineering calculation and adaptation for the sustainability.

So this is the basis for creating a seismic code to recommend a seismic zonation map and also give the input for the design of building. As we have seen that the first code work was started in 1935 by geological survey of India so then it was basically prepared a zonation map of the country by considering the 7 zone okay the 7 zones starts from 0 to 6 the 6 is actually as a intensity reported or expected as a 11 so where the 0 is actually 5.

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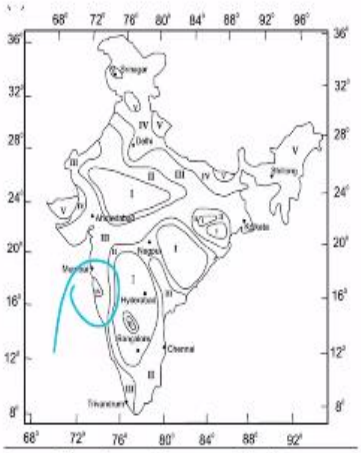
- There highlighted the inclusion of both geological and geophysical data in the zonation.
- Removal of the zone 0 as scientifically a reason with no seismicity cannot exist .
- Another addition was the merging of the zones V and VI (BIS, 1970).
- The zonation was therefore reduced to five zones as (see Figure) compared to the earlier classification of seven zones.
- Each zone was assigned a probable intensity in MMI scale varying from V to IX for the zones I–V (see Table).
- The upgraded map placed Koyna around zone IV.



Seismic zonation map of India prepared in 1970 (BIS, 1970)

Engineering seismology

But after the preparation of release of that zonation map in 1965 there was a earthquake in Koyna it was 1967 that Koyna earthquake happened in the so zone 0 seismic zone 0 that earthquake was happened. So that created a fuzzle people found that the seismic zonation what we are adopted based on whatever way okay the old wave seismic zone map how it was prepared there was not a clear details are available.

It is only written that it is based on the intensity value reported in the different part of India. So that means whatever we had a limited knowledge about the earthquake in the last 50 years or 100 years has been taken as a input to prepare a seismic zone map which was released as a codal provision of IS 1893 zonation map of one during the 1960 to 165 that is the period of first zonation.

So then they felt that there is a need to revise a code. So what they did basically the Koyna they pushed into the zone 4. So they removed zone 0 so what they did they tried to also include a geology and geophysical data which was done at selected location in Bangalore. So removal of 0 zone scientifically reason with no seismicity cannot exit. There is no seismic zone 0 in the country that was the zonation map update has been done.

Another addition was that merging of zone 5 and 6 as a one category. So now the seismic zonation version 3 which was published in 1970 is as a 5 zone starting from zone 1 to zone 5 where the one indicates that there is some kind of seismic activity. So then each zone was assigned probably intensity respective scale so the 5 close to the intensity 9 and zone 1 close to the intensity 5. So the upgraded map placed Koyna around zone 4 so that is what update has been done.

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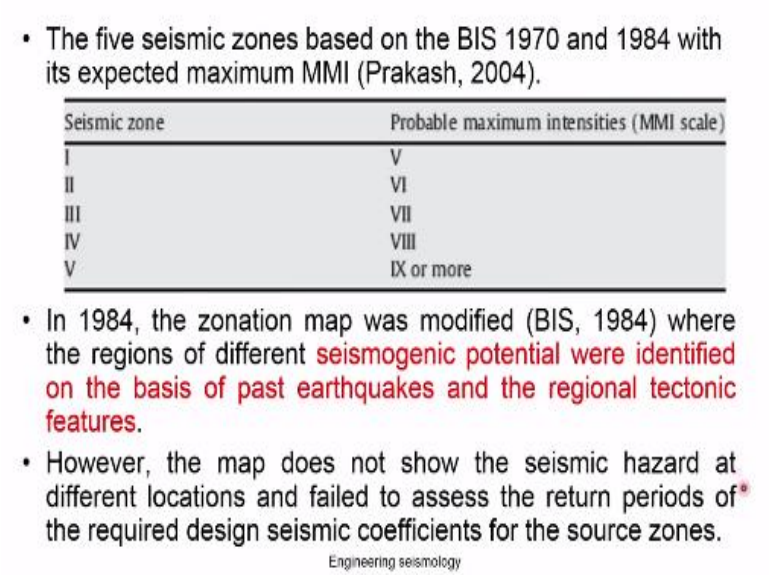

So this is basically your table indicating your seismic zone respective maximum probable intensity. You can see that until 1970 also we have been talking with intensity as a basis for your code, but in 1935, 45 itself the seismic moment concept has been developed universally

people started using the magnitude as a scale. So in 1984 the zonation map was modified again.

So where the regions different seismogenic potential were identified on basis of the past earthquake and regional tectonic features. So the regional tectonic feature has been incorporated in the code in 1984 however the map does not show the seismic hazard at different location and failed to assess return period record design seismic coefficient for the source zone.

So we did not estimate a systematically the hazard values and we did not assess the return period which was one of the mandatory requirement for (()) (07:59) seismic zonation map. So until 1984 zone map also so during that period people even talk about doing the probabilistic seismic hazard analysis so that is what they start talking in the world. So this was done.

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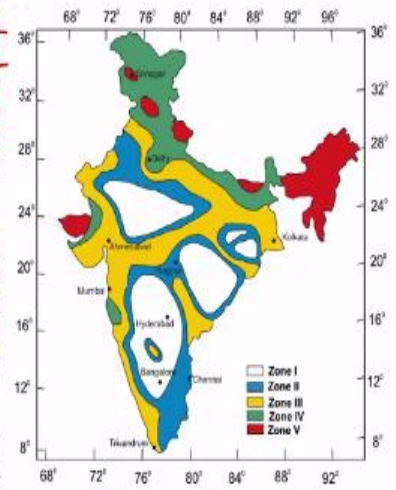
- The occurrence of the 1993 Latur earthquake (m_b: 6.3) caused an intensity of IX damages in MSK scale in seismic zone I highlighted the limitation of BIS 1984 seismic zonation and a need for revision.
- Other earthquakes including 1997 Jabalpur (mb=6.0) and 2001 Bhuj (Mw=7.6) put question mark of the credibility of BIS 1984 particularly for peninsular India.
- This further led to the revision of the seismic zonation map and in 2002, only four zones were identified: II, III, IV and .V



Seismic zonation map of India prepared in 1984 (BIS, 1984).

The occurrence of 1984 after the 84 codal revision there was a earthquake of magnitude 1993 there was a earthquake of magnitude 6.3 which was mb which is accorded to Latur. So the Latur there was a earthquake where the intensity 9 MSK scale has been reported in that region where the intensity 5 was basically expected. So this was Latur Washim zone 1 as per 17 revision, but the earthquake occurred was 6.3 and caused intensity of 9.

So this put a question mark and reliability of the seismic zonation map in 1984 question. So then followed by there was another earthquake in 1997 in Jabalpur there was a magnitude of 6 then 2001 the Bhuj earthquake all this put the pressure and then the country tried to revise

their seismic zonation map. So which was the fourth revision of the seismic zonation map which is done on 2002. So this map basically has been modified as from the 1984 map where they removed basically the zone one completely.

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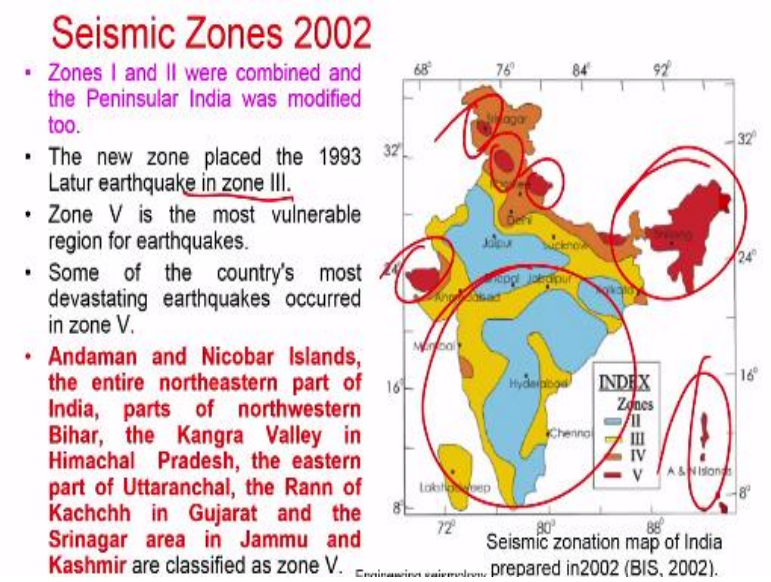

So the seismic zonation map 84 has been updated in 2002 where the zone 1 and 2 are combined together peninsular India was modified too. So now you can see the difference. So this is the older seismic zone of the peninsular India, this is the newer seismic zone you can see the pattern of distribution of the zone itself. The new zone placed the 1993 Latur earthquake into zone 3 earlier it was zone 1.

Zone 5 has been the most vulnerable of the region which is generally north eastern part and then the Bhuj region and some of the country most devastating earthquake occurred in zone 5 or Andaman Nicobar Islands there are all the regions then the entire northeastern part this one so part of northwestern Bihar, so the Kangra valley and Himachal Pradesh eastern part of Uttarakhand so all these places. The Kachchh region and Kachchh Jammu and Kashmir which you have already so has been classified as a zone 5. So this was released on 2002.

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- Two major metropolitan cities, with a high population density, i.e. Delhi, lie in zone IV, and Kolkata, at the boundary of zone III and IV of the zonation map.
- The four seismic zones of India are assigned peak ground acceleration (PGA) values ranging from 0.1 g to 0.4 g (See Table 5).

The seismic zones and the expected PGA (BIS, 2002).

Seismic zone	PGA
II	0.10 g
III	0.20 g
IV	0.25 g
V	0.40 g

- Besides the ground motion, the expected maximum intensity of shaking in each zone was also estimated (See Table) based on the Comprehensive Intensity Scale (

The seismic zones and the expected Intensity in Comprehensive Intensity Scale (CIS-64) (Prakash, 2004).

Seismic zone	Intensity
II	VI and below
III	VII
IV	VIII
V	IX and above

Two major metropolitan cities high population density like Delhi zone 4 and Kolkata boundary of zone 3, 4 in the zonation map. Four seismic zones of India were assigned a peak ground acceleration of so much. So you can see that from intensity we upgraded to the PGA by conversion or by linking if you recall your global seismic hazard map what we discussed which was developed in 1992 by the (()) (11:42).

So where you can see this discussion was matching in that so where that PGA was gone as a reference the zone wise PGA has been given. You see zone 2 0.1, zone 3 0.2, zone 4 0.25, zone 5 0.4. Besides the ground motion expected minimum intensity of shaking in each zone also estimated and this is the value. You can see the zone 1 6 and below zone 2 and zone 3 is a 7, zone 4 is 8, zone 5 is actually 9 and above.

So this is the expected intensity one can expect from the each seismic zone. So this intensity values also converted as a PGA and used here. So this map further updated in 2016 as a seismic zonation map of the country. So in this actually there is no update of map honestly speaking. It is only changing up color and then some information are added there is no map has been updated. You can see both the map actually has a similar pattern you can see this one color pattern only basically changed you can see that color pattern are changed.

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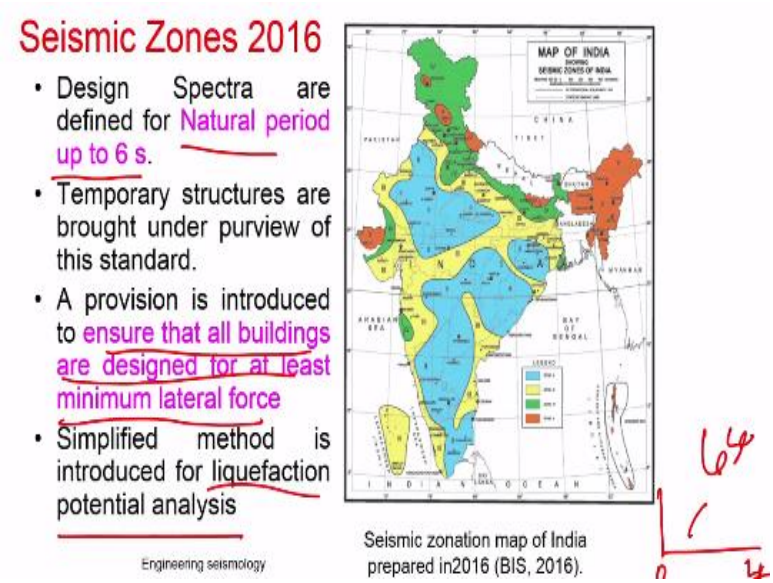

So here also the same 4 zone concept has been extended so here modification what they have done was the previous version of the code, the design spectrum given up to 4 seconds, the highest of that is 4 second here they made it to 6 second so that was one of the modification. So then as a previous version actually does not include necessity of temporary structure to design for seismic provision for its temporary structures mean like this some kind of Kumbh Mela or some kind of meeting are any temporary structures during the construction stage.

All those things are temporary structures that is earlier no need to design for the seismic provision, but now they made that as a mandatory for all the temporary structure should also follow a seismic design requirement. So that is also one of the revision it is taken by the provision to introduce and ensure that all the buildings are designed at least minimum lateral force which is given in the code.

Simplified method is introduced for the liquefaction you can see that the first time the liquefaction term has been introduced in the code only on 2016 version so where 2016 is the era throughout the world liquefaction obtained a stage where there is no more further development needed in the estimation of liquefaction potential where we started introducing the liquefaction potential.

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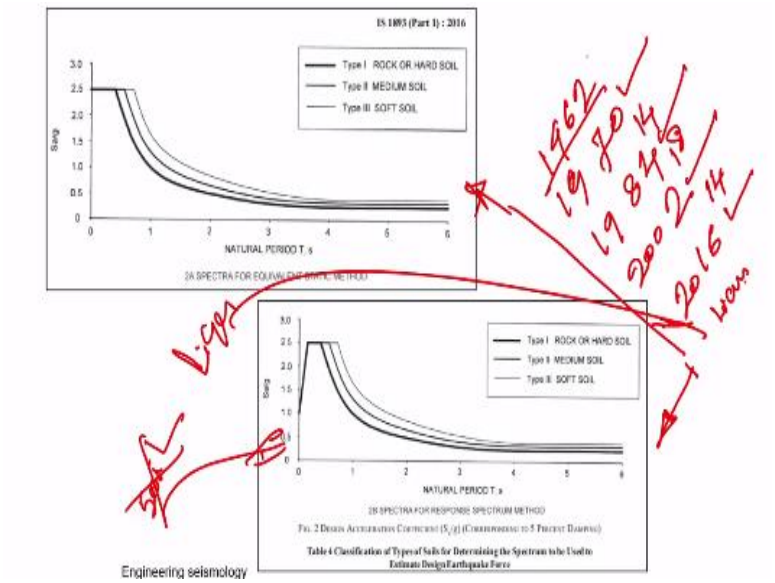

So this is the typical design spectrum given in the code so this design spectrum identical in the older version there is not much change. Here we can also see that they give Sa / g so Sa / g and natural period. There are 3 classifications these are soil, rock and soil medium soil, soft soil and rock. So this is the rock or hard soil this is the medium soil this is hard. So here you can also observe that there are two type of pattern.

One is for the equivalent static method analysis they have given horizontal force up to this period will be equal. When the soil comes you should increase only this period. So when you want to talk about the design acceleration coefficient based design or response spectrum. So you can see that this is the acceleration zone, velocity zone this one then the displacement zone.

So three zone was given, but still the values are kept 2.5 most of the modern countries they use different value for the different soil based on the analysis and recorded data estimated. So this as such the spectrum given in the code. So we had chance to review this spectrum this was actually developed way back during 1930, 40s based on some earthquake data for western countries that shape has been adopted in the older version that has been retained even today.

So that means there is no systematic design spectrum developed for India considering the Indian data. So there is one more thing also you can see that entire 4 zone even though we classified the seismic zones in India as a four major category. The entire four zone the same

spectral shape has been used there is no change. For example, the peninsular India and active region north India may have different spectral shape.

Because of the change in the source, path and the site which is not explicitly represented or reflected in the design spectrum given in the code you can see that. So those information if you want to study more about that recently we have done the extensive work on this and tried to develop how the design spectrum of North India and South India by active region and intraplate region varies by carrying out a systematic regional input based analysis.

And published a design spectrum those who are interested you can basically verify those publication and check. So as and now this is the design spectrum given in the code which classify soil as a three major category where all the PGA was kept 2.5. So that is the reason when they talk about the seismic code they said that when you design as per the seismic code it does not ensure that no damage will occur.

It is ensured that there may be a damage that only there is no collapse that is what discussed in the seismic code. So there may be earthquake damage can occur if we design as per IS code, but it will not prevent a complete damage, but even though IS code categorically specified that for any important structures which has a tall structures many people living like apartments, dams, bridges.

And then the nuclear power plant there should be site specific study has to be taken up, but as per my knowledge none of the apartments people were 5,000, 4,000 people are living nobody does any site specific studies. They construct as per IS code even though it is very categorically mentioned. So all reliable whatever you do so now you can think of your Delhi earthquake.

As I told you that if there is earthquake in Delhi if somebody designed their code building they transfer the code somebody designed their building as per code you can expect that no collapse scenario happens. In case if they do not design then there may be issue. Now you can also see that the liquefaction concept has been introduced in the code only on 2016 that means before that whatever building design the liquefaction is happening since historic times.

Nobody can prevent that if the soil is liquefiable the earthquake comes liquefaction will happen. There is no way one can prevent, but the design (()) (19:54) is not given in the code olden days. So how that is taken care nobody knows it does only people who are constructed, people who are living has to take care. So in US based system what they do that is why they categorically revise a code every four year once.

In India you can see that the first version of the code come into picture 1962, 1970, 1984, 2002 and 2016. So all this revision happened after major earthquake not the periodical because you should see this is the 8 years, 14 years. So this will be again 10 + 6 so the 18 years so this will be again 14 years so this is our code of revision. So in US based system what they do soon after they release a new code now one of our gap they start working under new code for the next year next revision.

So they incorporate each and every component which is responsible and causing a damage at any dwelling in the urban area, but India the liquefaction is introduced only on this one and the soil classification you can see the classification three major category of soil which is nowhere represent a amplification happens actually. So this shape has to be arrived based on the regional data like you should have the recorded earthquake data from each region.

And try to extract the data for different site condition or you can create synthetically data at bedrock condition and the steady response at different soil and try to generate a spectrum that will be more representative then this spectrum. So presently some of my research group team we are working on basically developing a design spectrum for North and South India separately.

So maybe we will come up soon with the spectrum which maybe recommended for the codal provisions also. So when I talk about the liquefaction again there was a set of well established criteria for the liquefaction assessment at the site. So there are so many factors which affects a liquefaction, but as on now estimating that factors itself a question in India. For example, for the liquefaction analysis one has to calculate a corrected SPTN value because there was a liquefaction resistant.

Cyclic resistance of soil that is cyclic resistance of soil which is based on the SPTN value which is basically N measured for 60% energy because these correlations apply for the 60%

energy. In India nobody measures hammer energy as on recently up to 2019 nobody measure SPT energy during the SPT test. So first time we have developed a SPT hammer energy measuring apparatus.

And measured hammer energy which was yesterday one of my student actually defined his M Tech research. We noticed that the energy varies from 20% to 65% based on the equipment manpower. So this place value in N 60 which is again responsible for the cyclic resistance ratio and liquefaction. So this is what so this liquefaction criteria even though mentioned in the code which is not explicitly discusses what is the state of art, knowledge has to be consider for the liquefaction assessment.

That was one of the major drawback and the second the landslide and tsunami is silent in the code there is no provision for accounting the landslide and tsunami. So as such the code given so if we observe very closely the code development actually you can see that our code been developed soon after the major earthquake except 2016 version which was developed after gap of 14 years, but most of the other previous version was developed after earthquake.

So India like peninsular India consider as a stable and low seismic region once because there is no earthquake, but after 1960 there was a Latur earthquake, Jabalpur earthquake, Koyna earthquake, this Bhuj earthquake this earthquake damages are much more than the any earthquake in the last 50, 60 years in India that means the damage caused by this earthquake or the damage experienced by the South India is much, much larger than the north India in the last 60 years of earthquake history.

So that means if we use this data to predict earthquake risk and fertility model basically end up in the less earthquake damage from North India more earthquake damage in the South India because the history data we have we do not have the complete history. There was some major earthquake which is reported in golden days, but that damage is (()) (25:54) and isoseismal maps are limited particularly damaged data are limited.

Because the 2001 earthquake and then the Jabalpur Koyna earthquake are the well known and well studied earthquake where many scientist add a knowledge to do research on that and then also study this kind. So that means whatever model so which we consider based on the

(()) (26:21) to be very cautious. So using this kind of South Indian based data if you predict a model so in the north India you will end up in this one.

And you can also see that even today our seismic zonation map not prepared for the future seismicity that means you can estimate hazard assessment systematic procedure like I have shown a seismic hazard map, deterministic and probabilistic map of Bangalore similar way there is no estimated hazard for the zonation. Zonation map was based on the past seismicity and intensity reported values not based on the estimated values that is one thing.

Second most of the modern code in the world they have given the seismic zonation map for the based on the probabilistic, seismic hazard analysis they say that like 10% probability in the 50 years which is roughly return period of 475 years this we will discuss later class what it mean really then 2% probability in 50 years. So they say that the reoccurrence model has to be represented.

So you can take like I want to take 98% non occurring so the 90% non occurring, 50% non occurring like that you can define different probability of occurrence of particular G value which you want to decide, but that kind of provisions are not made in Indian code as on now. Even though there was some studies by the NDMA. NDMA basically did a systematic hazard analysis of the entire India by carrying out a seismic hazard analysis and developing a new GMPE.

But unfortunately all the GMPE developed by NDMA is only considered a synthetic ground motion data which is not considered the recorded data only for the validation purpose they consider because of that the validity of that NDMA map itself a question which is not directly incorporatable in the IS code. There was a objections people like me I have been told that the GMP is what you consider may not be appropriate.

So that is the reason the NDMA 2010 even though they published probabilistic, seismic hazard map of India which is not explicitly consider for the Indian zone map represented, but not on (()) (29:02). Some of represented the entire India in a larger scale and used state of art the GMPE model and data and produced a zonation map. So now you can compare a current seismic zone map and then the north and (()) (29:22) map you can see there is a similarities and dissimilarities between this two maps.

So the one was basically predictor systematic hazard analysis another was based on the past seismicity. So here I can also say that the prediction of seismic hazard as on today whatever world follows basically considers more weightage to the places where already earthquakes are occurred. So there was earthquake before 100 years or 50 years on particular location it gives more weightage.

But I believe that giving more weightage to the recent earthquake location may not be appropriate when you want to consider your future earthquake design. For example, I am sitting in the Bangalore, Bangalore has a average return period of magnitude of 6 and above more than 300 years. So there was earthquake before 50 years next to somewhere near to some region.

So if I consider that and estimate a hazard I will get more hazard, but since it was happened before 50 years next 50 years I am giving this map or next 5 years basically that is what we should do not 50 years. In that case the structural life maybe the 50 years that from 5 years people who have designed they consider the life of building as a 50 years. So this map what we give for next 5 years at least should consider the 50 years return period of the those earthquake.

So the earthquake already occurred next 50 years may not occur because it has a return period of 300 years. So considering same location more weightage may not be appropriate that is what I believe. So that concept we actually need to be incorporated in the hazard analysis, but the conventional hazard analysis that kind of concept has not been included. So they take probabilistic by variation of the different source and the distance which is somehow indirectly taken care of this.

But still you can do explicitly analysis particularly DSHA which is not explicitly included. You can come up with the new method of hazard analysis which we call it as a rupture based seismic hazard analysis. So right now we discussed about the Indian code so the next few classes we are going to talk about the seismicity of India, seismotectonic of India, the seismic models developed in India or applicable to India.

And then followed by the seismic hazard analysis deterministic and probabilistic procedure so that we are going to discuss in the next couple of classes which are very important. So during seismic hazard analysis of any region by different way of approach itself you can publish as a general paper. So most of the discussion what I make in the classes which has been taken directly from the different publications and updated research.

You may not find any text books directly, but my PPT will give the details if you prepare that for the exam point of view this data are more sufficient to fulfill your requirement for the exam. So as we have seen that the Indian code the first Indian code was released on 1962 so 1962 so then followed by it was updated in the 70 and 84 and 2002 and 2016. So all this versions the design spectrum remains same.

This is the design spectrum most of the version it has been used there is no change only the zone is changed. So this design spectrum does not consider a soil, soil consideration not gone to the design spectrum. Second the liquefaction introduced only on the 2006 version so there is no other version talk about the liquefaction that means code which people who design the building 2016 may not even thought about the liquefaction.

But liquefaction is one of the major hazard particularly the apartments the people multi store construction of buildings this code has been extensively used particularly the architect. So the architect they say that we follow IS code they model and they do, but without having a knowledge of all this information whoever designed that building as per even IS code that has a question on is stability.

So it is a individual responsibility to know and enhance their knowledge and before you invest or construct your house you should be ready and see that your house is safe against earthquake particularly people who were living in the high seismic zones such as Delhi, northern India several part of the north India and Bhuj and other related areas. So as I told you that earthquake can occur anywhere.

There is no this one only the return period varies. As we do not know many of the earthquakes actually occurred places where there is no identified fault, there is no identified zone activity. For example, 62 zone for some place marked as a zero seismic zone there was a

big earthquake occurred and caused intensity of 8, 9 where it was intensity 4 and 5 was expected.

So something like that kind of mismatching of the representation of the data or we have less data to show the complete activity. So in that case taking risk is always not good or not advisable better we be prepared. So the construction caused due to the seismic design will increase only marginally not so much. When you consider your life actually that cost is nothing, but you should also know that what you should consider.

As I told you that if some people say that I designed as per IS code, but if the design without considering liquefaction even if we design a building, the building will be intact because of the foundation soil failure the building will fall. So such kind of scenarios has to be accounted. Right now that process is going on as a preparation of microzonation map. So hopefully the future I do not know how many years future it will take to produce a most reliable zonation map which consider all the part of microzonation component.

And give the zonation map state of art knowledge and upgradable as we have seen in the OpenQuake software the map should be upgradable. So that we can do and then produce a most reliable map that will be useful for the design. So as I said that we have discussed the concept and methodology and importance of the engineering seismology, several aspects. So next couple of classes we are going to talk of specific to Indian seismicity.

Seismic hazard analysis for the typical area deterministic, probabilistic and a new way of rupture based analysis which was we are talking and we have discussed and published in those papers. So these aspects will be discussed in the coming classes. So thank you very much for watching this video. So we will see you in the next class with discussion on the seismicity of India.

What is the seismicity of where earthquake are occurred when it is occurred what are the places are active, how it is active, what are the evidence they shown, what are the source zone all those information we will be discussing in the coming classes. Thank you very much for watching this video we will see you in the next class. Thank you.