Introduction to Engineering Seismology
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Lecture – 51
Seismicity, Tectonic and Geology of India

Vanakkam. So we will continue our lecture on Engineering Seismology. So last class we have been discussing about the seismic zonation map of India and also we talked about the micro zonation of Bangalore, so how the systemically the micro zonation has been done. And we also looked that what are the essential component which is basically decided based on the city, okay. So you will not get all the earthquake hazard parameters similar throughout the country.

So if you are in coastal region you will get different earthquake hazard parameters, if you are in the hilly region you will get different earthquake hazard parameters, if you are in the middle of the any of the part of India then you will get different earthquake hazard parameters so which has to be systematically geomorphological attributes and a seismological attributes. So the geomorphological attributes we have seen that the soil thickness okay so the tomography, rock type geology of the material, water bodies.

So these are all the geomorphological attributes one has to basically consider and estimate systematically and then weigh them accordingly, give the weightage. Okay, so considering the importance of that particular factor to contribute to the final seismic hazard in the region. Then the another parameters seismological attributes which is basically function of earthquake, okay so the direct ground shaking, amplification as well as the liquefaction and then predominant frequency okay so then the landslide, tsunami so these are the seismological attributes.

So all these parameters needs to be systemically estimated; each parameter estimation is a crucial role, okay people has to have the expertise. This is not possible to estimate just like that but for the mapping purpose I have shown you the parameters and described like how does parameters are estimated. But in general so each parameter estimation requires a; the in-depth knowledge of that particular parameters, how it is associated in your region and passed history, all those things you have to consider and then take that parameter and estimate precisely and map it.

So if you map all those parameters geomorphological attributes and then seismological attributes then finally you can integrate all of them in the JAS platform. We have seen that JAS has a unique opportunity to integrate okay and the like handle the data, analyze the data like multiply, add, divide so all those things are possible in the JAS platform in tabular form as well as the graphical form.

So you can do the calculation and finally produce Hazard Index map, so that hazard index map can be estimated deterministically as well as the probabilistically. So data deterministically means it is the worst scenario in the region so that is that beyond that there is nothing you can expect. So that kind of worst scenario is the deterministically approach, okay the probabilistically is specify what is the probability of accidents in the given period.

Generally, they take 50 years. The 50 years basically the building life of the; any normal building, so in that 2% probability, 10% probability, 50% probability so like that you can divide that into a different probability and estimate and map hazard index for this estimation that is called as a probabilistic seismic hazard index map or a seismic micro zonation map of the region. So this is how you can map.

So we have also discussed that the Indian code, okay so we have seen that the first version of the Indian code was released 1962 then it has been subsequently updated on the, so 1970 okay 1984, 2002 and 2016 with the gap of roughly more than 10 years, okay. Sp we have seen that. But most of the update okay so only people added the new earthquake location as a severe zone, okay. So this Indian code basically arrived based on the past seismicity in the region or experienced intensities at the region, okay.

We can also here think that the intensity experienced, intensity predicted. There is a two difference term. Okay, so the intensity experienced means based on the past earthquake okay based on the observed it from the people or from the damage, scientist are went, geologist are went, seismologist are went, they collected a data and they noted down what is the intensity as per the intensity scale what we have discussed earlier. Okay, that is the intensity observed.

The intensity predicted means there is a intensity predictive equation for the region based on the observed data then that intensity predictive equation is used to estimate a intensity values and mapped, okay. So this way these two are the different but Indian code based on the past observed intensity not the predicted intensity that is also we should know. And we also discussed that these intensity values are converted as a PGA.

Okay so during 1984 or 2020 version, so where they consider intensity and PGA conversion and they given in the form of zonation factor okay that each zone. So currently India has a totally 4 zone, earlier the South India most of the South India was first version it was a zero zone then became a Zone 1 then now most of the lowest zone expected in India is 2. So which indicate that our understanding okay and our prediction of a earthquake is not so accurate, okay.

So that is why this zonation maps are keep updated frequently after the earthquake not based on the predicted values. So even though there are here and there some studies are done by the experts like we have seen that Macro Zonation was done by (()) (06:33) in NDMA, they released probabilistic seismic hazard map of the India in 2010. But all these maps what happens actually, there was a consistent the inaccuracy.

Because of the model what they use, the parameter what they consider, the result what they deliver so the group of scientist or the people who are in the country not anonymously agreeing that this is the best way to represent okay. So we also seen that the Indian code provided a response okay spectrum or a design spectrum which considers basically the acceleration velocity and displacement sensitive region.

When we are talking about the response spectrum (()) (07:14) I told you that this shape the cut-off period for the acceleration sensitive, velocity sensitive and displacement sensitive depends upon the recorded data at a region. As on my knowledge okay so as per also the literature what I have gone through our spectrum what we use actually 99% may not be derived from the past earthquake recorded in the India.

Why because, the spectral shape okay, so we gone through the literature and found that it was actually the new mark and all spectral shape which was based on the some western countries earthquake okay, so if you are interested and doing research on that, that is the one of the potential area you can consider and contribute to that. So by considering that and also the current spectrum okay.

We have three classification okay where the basically the velocity and displacement regions are divided as a; are shown a difference for the rock or very dense soil, medium soil, lose soil not on the acceleration and velocity posture. Okay. So that also is another concern. If you look at a modern seismic code okay if you want to see the modern just type it in Google, find out a design spectrum map, international building code, IBC or Euro code okay.

So all those code if you see their given design spectrum shape okay based on the different soil classification which accounts the acceleration region, velocity region and displacement region, right now our code does not account that. We also seen that until 2016 our code is silent about the talking about the liquefaction. There is no discussion on liquefaction until 2016, okay. That; 2016 version they given a liquefaction estimation a part of the code but still the procedures and methodology given okay is actually borrowed from the foreign countries without verifying that it is applicable for Indian scenario or not, but at least it has been incorporated.

That means people who have designed their building before 2016 may not be consider liquefaction as a part of assessment in the building construction. The code also categorically specifies that any important buildings such as a tall structure, multistory buildings, dams, nuclear power plant okay bridges, size specific study has to be taken into account and the minimum value given in the code should be consider as a minimum value.

The zonation factor given in the code should be considered as a minimum value in case if you get the lower hazard, so that is what code specifies. But most of the apartments okay in the many of the urban cities including Delhi, Bangalore, Mumbai and all nobody does size specific consideration of the design of structures. It is very unfortunate. Particularly why it is very important because these are all the apartments; the large number of people live okay.

So in the order of like a 5000, 10000 people live at a small area okay so which has to be accounted because together like a 4-5 villages if you count to the size of the Indian village typically so which has to be safe, okay and also these structures are multistoried, multistoried means like say minimum 10, 15, 20, 25 kind of things say where the huge corporate area like four area has been covered so which always has a potential for any small disaster can trigger a massive financial and fatality loss, okay so in order to prevent that these building should be safe against any nature disaster, okay.

So there was again; I was also keep telling that there was a drummers; Delhi even during this courses we have been telling that; even yesterday when there was a micro earthquake has been reported in the NCR Delhi. So I am not very sure to comment critically that it is a potential for the big earthquake or not potential for the big earthquake but it indicates that we should some kind of precursor study or a prediction study.

We have seen that VP VS ratio okay will change before earthquake and during the earthquake, so that kind of indication people can do and also they can try to see the any geological evidence in the past and match with the present epicenters and try to pinpoint which location it ruptures okay. So then based on that if there is any associated nearby fault, if it is associated it is already ruptured or not okay that seismic history one can see.

And then based on that one can be come to conclusion that there is a possibility of bigger level earthquake, bigger level means above 5.5 anything which harm your structure, okay 5, 6, 7 does not matter. Okay, so bigger earthquakes are possible or not, okay so that you can rule out. But I can see that many scientists are exchanging their view somebody says that there is a; this maybe a (()) (12:23) big earthquake can be expected; big means anything which causes a damage.

Somebody says that no, no this not the place where big one can expected, big one is only expected on plate boundary not on the interior of the plate because the Delhi is; where the NCR is actually slightly like far away from plate, I think maybe more than 300-400 kilometer away

from the plate boundary. They are telling that no, no such big earthquake may not occur. So there are two ways we should look at it.

One is that very large earthquake which has to which is expected to occur in the plate boundary so that is like 8 and above 7.5, 8, 8.5 and above those kind of magnitude. Even that does not occur it does not matter, okay. The next is the moderate earthquake which is generally occur in the interior of the plate so which is starting from like 4.5, 5, 6 okay so 6.5 so up to 7.5 you can take as a moderate or big earthquake kind of in the scale.

So those earthquake occurring also trigger a lot of problem depends upon the place and the building construction type okay and then way of modification. So particularly I hope I told you that so the 5.7 magnitude okay which is occurred in Tripura okay so in the Manu River caused very extensive liquefaction in the agriculture lake. Okay. So there are 2,500 buildings are damaged due to that earthquake and some of the mud buildings even collapsed, there are about 2-3 fatality was identified, many injuries are identified.

Luckily the epicenter was closed to the agriculture area and the liquefaction also occurred in agriculture area so not much devastation has been reported in the urban area. But in NCR we cannot ignore like that, okay. Because the NCR is like where the earthquakes are occurring and nearby many urban settlements are there. It maybe the warning we should take it as a; the foreshock kind of data and try to look at a seismic signal, okay.

Try to understand your seismic signal and look at geology and seismotectonic and then study okay a very quick study can be done and then people try to report that what is a possible magnitude if at all it going to occur. Okay if that is occurring how the; in that area what are the consequences can be expected okay how much the ground motion you can expect; can the liquefaction take place or not.

If that ground motion, the buildings are safe or not. If it is not safe you should advice those people saying that you take care that, if this earthquake occur at anytime your building is not safe, okay. So if you want to safely live move to other location or do something retrofitting or

something so that it will become safe. So that kind of warning at least safe the life of the people around the region.

But I am not very sure when you are watching this video what will happen because you may watch this video after 2-3 months so by the time the earthquake may occur may not occur we do not know, but this is how one can take is a prediction, okay so prediction, forward, informing people to reduce a risk. So this is a significantly similar to the, the prediction of the; our cyclone, okay.

So cyclone what we do, so we soon after cyclone forms we will see that what is the speed it moves, okay if that comes how the; which are the area going to affect. Then people accordingly will evacuate the people and then it comes actually then it trashes away. So cyclone what happens you are basically seeing after formation of the cyclone so that is why the prediction okay the cyclone prediction the consequences due to cyclone is you are able to understand well and also you able to tell the people warning.

And more or less the damage whatever prediction happens more or less it matches except there was a slight difference in the time and a slight difference in the area but more or less it happens many people life saving are happening because prediction. But unfortunately the earthquake does not do like that because it once break it suddenly reaches to the place where the cyclone take long time because depends upon the velocity and distance where it forms, so because of that sometime this warning goes even wrong does not matter.

At least people aware, okay we are in the region of this one what to do when earthquake comes, so that kind of identity will give. So by looking at all these scenario okay, so we need to understand that estimating and mapping up seismic hazard at the particular regions are very, very important for the new design as well as a retrofitting the existing structures. Okay. So this estimation again it has to be on the regional scale, okay.

So why a regional scale I am talking when you are seeing a Global Earthquake Model, GEM we have seen, so we have seen that they consider the macro scale models and data and try to predict.

So but we should do in on the regional scale which is like a country code as to be in the regional scale but unfortunately our earthquake need further improvement and update that is why we discussed that the micro zonation of the urban centers, okay are under progress, we there try to develop a zonation map of the each city particular where people are 5,00,000 and above so try to generate a; so the micro generation map that will be more robust way in the future.

So if you want to predict a regional level accurate hazard, okay, so what we should do basically we should go try to understand regionally what happens, okay. So what are the seismicity pattern? What is the tectonic pattern? What is the geology of the region? What is the soil in the region? So that is what we should do. So in order to the hazard estimation okay part of the course so we need to understand first what is the seismicity, tectonic and geology in the India.

So in our class from today onwards we are going to talk about specific to India all these parameters, how it varies, what are the different studies are done so far. So I try to summarize or discuss most of the studies but what I am describing is not only limited it is only the indication that what are the factors we should look forward. When you are going for; doing hazard analysis at a particular location you should consider all these factors even though I may not discuss.

For example, if you want to do some area which I may not highlight in my study but since I am highlighting in general as an India so you should also look a similar kind of studies in your region. If it is not done even, then it may be necessary to carry out the study before estimating the hazard values. So we are going to discuss that from today class onwards. So we will also look at what is the government says about the Indian Seismic Code. So the NDMA, National Disaster Management Authority, they are the nodal agencies basically to discuss the seismic hazard at any particular location.

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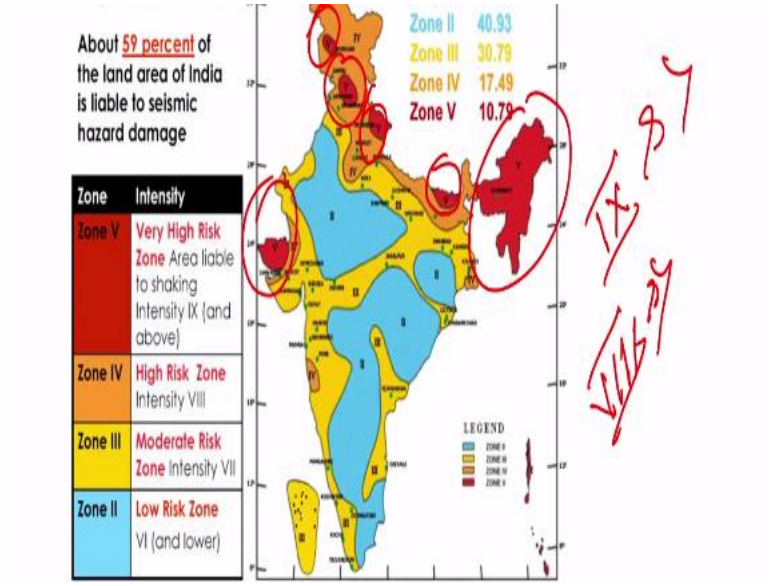

So they say that basically, the India as we have seen that it is divided as a four major zone. They say that about 59% of the land area in India liable to seismic hazard damage. So how much 59%, it is almost 60%. So they divide based on the zonation map they discussed that, the Zone V okay, say which is very high risk zone, area liable to shaking intensity of 9 and above, okay. So the Zone V wherever Zone V is there basically the entire North East region see here, okay.

So these are all the Zone V. So these are all the places where you can expect a intensity of 9 and above. Okay, so this is what you can expect. So the; another is a high risk zone so those are called as a very high risk zone, the; another is high risk zone which is Zone IV, okay. So basically the orange color in the map, if you look at a very closely map so basically this part, okay so then the part here okay so next to the red and then all these part okay so a part around.

So those are all the zone where you can see these are all the zone basically consider as a high risk where the intensity are 8 and above is expected, intensity are 8 and above, okay so is expected. So the third is a moderate risk zone, so this moderate risk zone basically yellow in color, so you can see all these areas again this is followed by this one, so again this regions intensity 7 is expected or intensity 7 is occurred.

So as I told you that this map based on the past history of the earthquake in the region so this is also experienced region we can say. So Zone II, the low risk zone, so which is 6 and a lower can

be expected. So the overall the past seismic intensity value has been used to prepare a zonation map of the country so that is what we discussed.

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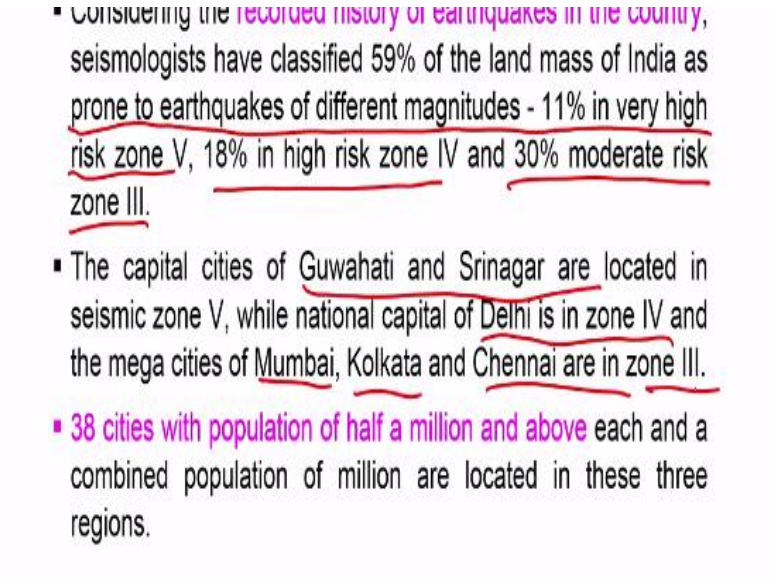

Okay. So the considering recorded history of the earthquake in the country, that is what; it is the actually the message whatever I am discussing now has been taken directly from the NDMA website. So they written very categorically saying that the considering the recorded history of the earthquake in the country, seismologists have classified 59% of the land mass of India as prone to earthquakes of different magnitude, okay.

And 11% in the very high risk zone and 18% in the high risk zone and 30% in the moderate risk zone. So the capital city of Guwahati and Srinagar basically comes in the very high risk zone, say lets Zone V, while the national capital of Delhi comes under the Zone IV. Okay, the mega cities like Mumbai, Kolkata, Chennai in the Zone III, okay. So the Bangalore is basically on Zone II.

So about 38 cities with a population of half a million and above okay, so and the combined population of million are located in this region. So more than 38 urban centers are located, okay on the different part of this zonation which is very risk okay or these cities need to estimate what is the expected risk in detail, okay that is why the micro zonation of Indian city where they are basically planning on the future studies and this combining all these 38 cities.

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occurrence of earthquakes for last 110 years.

Seismic Region	No. of Earthquakes of Magnitude				Return Period
	5.0-5.9	6.0-6.9	7.0-7.9	8.0+	
Kashmir & Western Himalayas	25	7	2	1	2.5-3 yrs.
Central Himalayas	68	28	4	1	1 yrs.
North East India	200	128	15	4	<4 months
Indo-Gangetic Basin and Rajasthan	14	6	-	-	5 yrs
Cambay and Rann of Kutch	4	4	1	1	20 yrs.
Peninsualr India	31	10	-	-	2.5-3 yrs.
Andaman & Nicobar	80	68	1	1	<8 months

https://nidm.gov.in/safety_earthquake.asp

So the table 1 basically shows, okay the table 1 shows. So the region where, okay region wise frequency of the occurrence of the earthquake based on the last 110 years data, so here also you should note that this 110 years okay, basically the instrumented data plus historic data, okay. It is not the only instrumented data. As we know that the proper instrumentation in India started only after 1960s.

So this side which basically gives a seismic region, okay so which are the region you can classify. The number of earthquake magnitude occurred okay in the 110 years are given here, okay. So the Kashmir and Western Himalaya, so 5.0 to 5.9 magnitude about 25 earthquakes are occurred in the 110 years. So 6.0 to 6.9 magnitude 7 are occurred, 7.0 to 7.9 2 are occurred, 9 magnitude, 1 is occurred.

So even though the Kashmir and Western Himalaya is here very active region seismically but in the last 110 years okay only one earthquake was reported, okay. So similarly this was also old earthquake actually. Similarly, the Central Himalaya okay so 5.0 to 5.9 magnitude 68 and 6.0 to 6.9 28, 7.0 to 7.9 4 and here 8+1, okay. So the North East India okay so 200 and the lower magnitude the moderate actually 128 okay so the high magnitude 15 mega earthquake 4.

So then Indo-Gangetic Basin and Rajasthan, so 14 in the moderate okay so magnitude so the big earthquake 6, so the greater earthquake nil and this one also nil, so similarly the Cambay Rann of Kutch this is a Bhuj region so 4 5.0 to 5.9, 6.0 to 6.9 4, 7.0 to 7.9 1 and 8 1. So Peninsular India, 31 say 5.0 to 5.9 and the 6.0 to 6.9 10 above 7 basically nil. Andaman and Nicobar so 80, 68 and above 7 1 and above 8 1.

So here you can see that this data whatever is reported here based on the past observations, okay. So people are observed this data in the past and as well some of them maybe recorded, okay. So sometime if you do not have any people to observe, if you do not have the seismic instrument, okay kept on this region then there maybe chances that the earthquake occurred you may not be noticed, okay.

So you can also see that the number of earthquake okay the smaller to this range basically this two combinedly so this two combinedly will indicate that how well the seismic energies are been released in the region, okay. If the; many earthquakes are not occurring there is a chances that the storing up energy is happening in those places. So that is what you can see, the North East so you will see many place, but the West and the Central there is not much earthquake.

Three of them are in the plate boundary, okay. So these all the information which we can get from this, so this data actually taken from NDMA website, those who are interested you can go and check the NDMA website and then get clarified. I hope this data they will also update because this is quite old now, okay.

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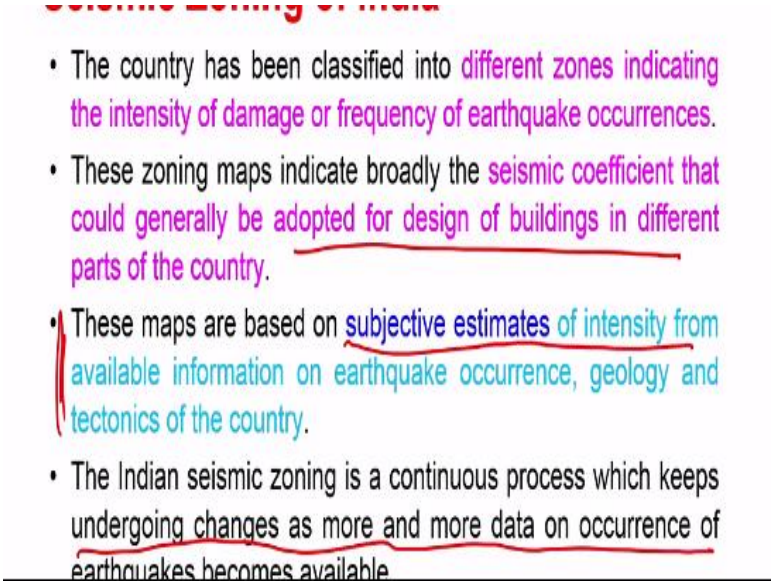

So the overall the seismic zoning of India, country has been classified into different zone indicating that intensity of damage, frequency of earthquake occurrence, okay. So these zoning maps indicate that broadly seismic coefficient could generally adopted for the design of; design of buildings in different part of the country. Okay, so code gives a seismic coefficient. These maps are based on the subjective estimate of the intensity you can see subjective estimation. Okay available information of the earthquake occurrence, geology and tectonic.

So this is the statement which is made in the NDMA website, okay as I keep telling you that this data was taken from there. So Indian seismic zoning continuous process which keeps undergoing a changes as more and more data occurrence of earthquake become available, so this zonation map are keep updated after the earthquake not based on the predictive hazard at a particular location, okay. So that is what the message you can take it from here.

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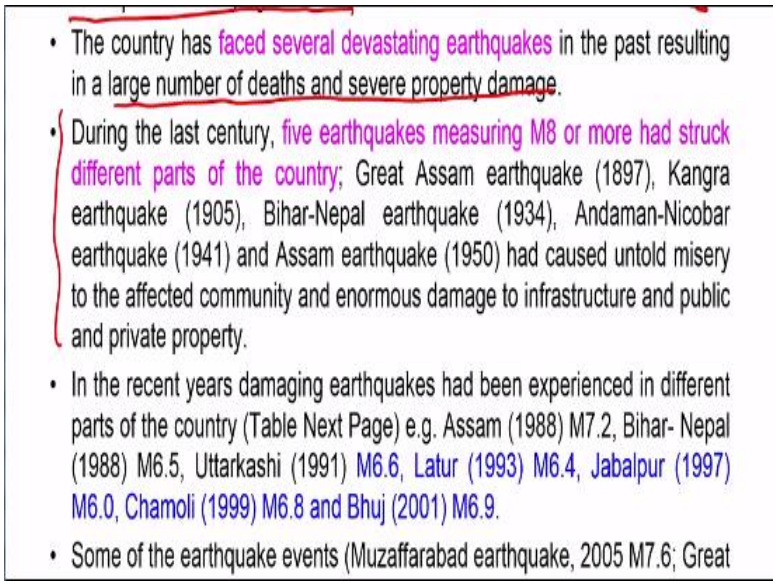

So India on a account of unique geophysical setting okay. So the India as a unique geophysical setting, so what is the geophysical setting will be discussing in coming classes; an highly prone to earthquake of various intensities. Okay, so basically it should be written as a varying magnitude but since code uses intensity as a value to describe the zonation so they also written as intensities.

So the country as faced several devasting earthquakes in the past resulting in a large number of death and severe property damage. So this is the evidence from many of the past earthquake. So during the last century, okay the five earthquake measuring M8 and more had struck different part of the country so the Great Assam earthquake 1897, Kangra earthquake 1905, Bihar-Nepal earthquake 1934, Andaman-Nicobar earthquake 1941, Assam earthquake 1950 had caused untold misery to the affected community and enormous damage to the infrastructure and public-private properties are reported due to these earthquake.

But all these earthquake if you see, these all occurred okay, so more or less okay so before our independence okay except that Assam earthquake which is soon after the independence. So because of those period there is no seismic instrument in the country which we have seen. There was only one or two earthquake instrument was kept throughout the country to record something. So in the recent years damaging earthquake had been experienced in the different part of the country.

For example, Assam 1988 earthquake 7.2, Bihar-Nepal earthquake 6.5 in again 1988, Uttarkashi 1991 6.6, Latur 6.4, Jabalpur 6, Chamoli 6.8 and Bhuj 6.9. So these are the, the recent earthquake after 85; 1985 where the third revision of the code 1984 after this earthquakes are occurred. So some of the earthquakes events like there is a Muzaffarabad earthquake in 2005 7.6, Great Mathura earthquake 2001 9.1, so even though these earthquakes are not part of India.

But these earthquakes are caused severe economic and a fatality damage or loss; severe economic and a fatality loss to the India. So that means the earthquake which not only occurred in Indian within Indian boundary we should concern, we should also concern that the earthquakes are occurred anywhere within the; I mean anywhere near okay to our country okay depends upon the, the radius of damage is expected to cause. Okay. That is what we need to understand.

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Year	Month & Date	Region		Magnitude/Intensity	Loss of lives
1255		Kathmandu Valley	India		1,00,000
1555		Srinagar	India		60,000
1737		Kolkata	India		1,00,000
1819	16-Jun	Kutch,	India	8.3	1,543
1885	30-May	Srinagar,	India	IX	3,000
1897	12-Jun	Shillong,	India	8.7, XII	1,500
1905		Kangra	India	7.8	19,800
1934	15-Jan	Bihar,	India	8.4	10,700
1950	15-Aug	Assam,	India	8.7	1,500
1967	10-Dec	Koyna	India	6.7, IX	180
1991	20-Oct	Uttarkashi,	India	6.6, IX	1,500
1993	30-Sep	Killari,	India	6.4, IX	8,000
2001	26-Jan	Bhuj,	India	7.7, X	20,000
2004	26-Dec	Sumatra	India	9.3, X	3,00,000
2005	8-Oct	Kashmir	India	7.8, X	80,000
		India, Myanmar			

So these are the some of the major earthquakes we reported so far. So we will discuss this earthquake and continue our discussion in the next class. So we have been discussing about the seismicity of the India because the understanding of seismicity is very important to predict seismic hazard in the region. Without understanding the seismicity and the past earthquake you cannot predict a earthquake hazard precisely in the region.

So with that aspect we are discussing the seismicity of India. We will continue our discussion in the next class. Thank you very much for watching this video. So we will see; meet you in the next class. Thank you.