Introduction to Engineering Seismology

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Lecture No -34
Recapitulation - 6

So Vanakkam, so we will continue our lecture. So we have been discussing the revision of our subject, so that you will get more clear idea. So, what do we have to see? So we have been seeing the instrument seismic instrument recording seismic the cluster of the equivalent instrument. So how to space that seismic instruments. So what is the minimum spacing should be maintained what is the minimum angle orientation should be maintained?

Those are all things are the very important which we should know. So soon after the earthquake if you look at is scientific community who is handling, recording the earthquake, they release the earthquake report. So these reports consist of the several things which we have already detailed discussed but today we will be going to give you a summary of glimpse of that. So the each earthquake report will tell you that where the earthquake is occurred.

So the location of the earthquake then the nearby cities. So then that earthquake like what is the, Isosceles map, what is the magnitude. So what is the source mechanism? So what was the damage level is expected, so many fatalities are expected this kind of data generally they release. So this comes from the understanding and processing of the seismic wave recorded in the seismic instrument.

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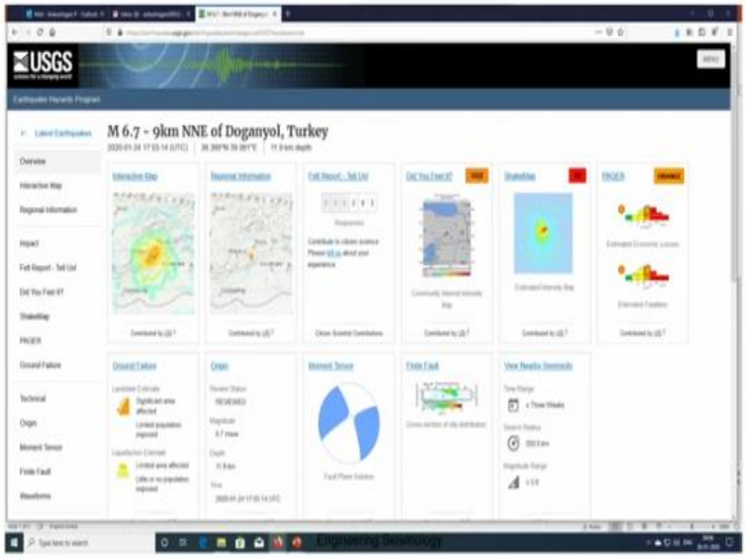

So if you look at the seismic instrument, as we discussed the records here waveform of the data. So, that waveform of the data has been used. So the quantify the earthquake so they are quantification of earthquake if you have if you do not have the waveform, how do you quantify because if you do not know the seismic instrument which was a scenario in the most of the olden days.

As I told that India the good instrumentations are started in 1960 before that that means there is not proper instrumentation even the seismic instrumentation development itself happened only on 1880s. So that means before that there is no seismic instrument in the world, except a Chinese seismoscope that also does not give you the size of that earthquake it only given the there were direction of the earthquake. So people try to quantify the earthquake by some systematic manner.

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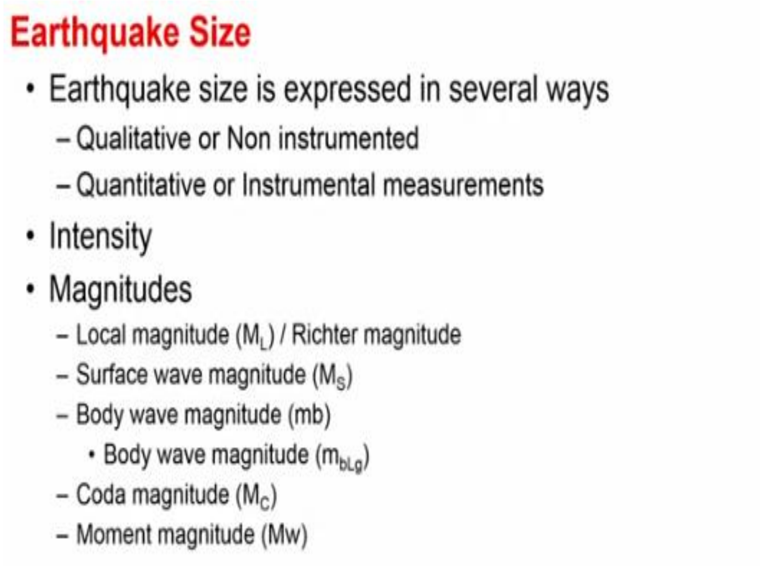

So that is basically the scaling of earthquake as I said. So the size of the earthquake is done qualitatively or non-instrumented wave, which is called as a intensity record. So we have discussed intensity record, what are the different intensities or we have and then how these intensities are useful for this one. So the another way is to get the earthquake sizes using the waveform recorded data, which is quantitative we have to estimating the size of the earthquake.

And then the instrumental measurement, this needs a recorded waveform. So depends upon the wave type you can get a different magnitude scale which we have discussed in detail.

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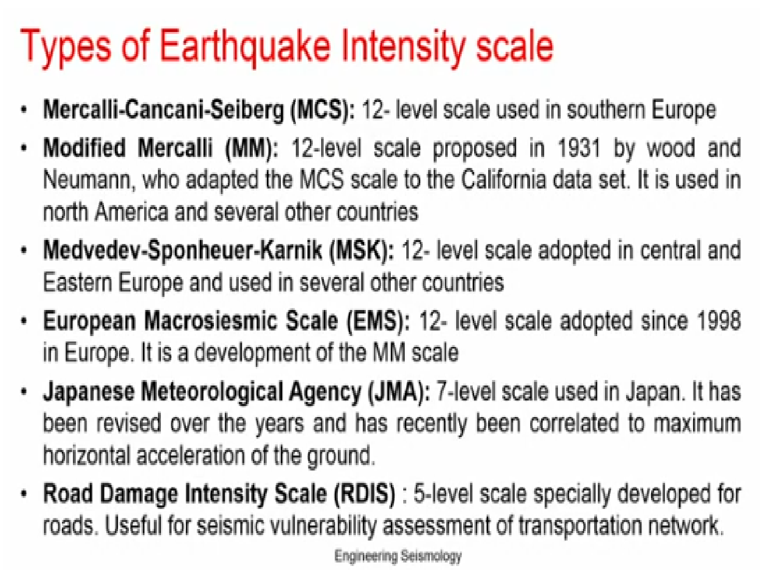

So today we will going to give the just summary of what we are done there in this class. So where you can see that the type of the intensity scale those days used basically as a 6 major category of sizing the earthquake without measuring the earthquake waveform. So this is how this is the intensity scales are used, so the Mercalli-Cancani-Seibergcan scale MCS it has a 12 level used in southern Europe.

And then modified Mercalli intensity scale MMI so 12 scales proposed in 1935 Wood and New man who adopted the MSc scale to the California data set and it is used to North America and several other countries, then the MSK which also again has here 12 level of scale adapters central and eastern Europe and then there is a European macro EMS 12 scale adapted since 1988 in Europe and is developed under the MMA scale.

Japanese meteorological stage 7 scale used to specifically in the Japan and the road damage intensity scale this is a new intensity scale developed by my research team, which is specifically used to quantify the damage the cost by the road. So all these are no need any seismic instrumented record and you can see that all the scale has been specifically modified according to location.

So in India what type of scale so they use basically so mostly India they adopted a MSK scale because this instrument concept itself brought when there was a British was ruling the in India, so basically the British were Europeans, so they brought this kind of measurement. So they use MSK scale in the India MSK or EMS scale kind of thing there is a slight variation between this scale.

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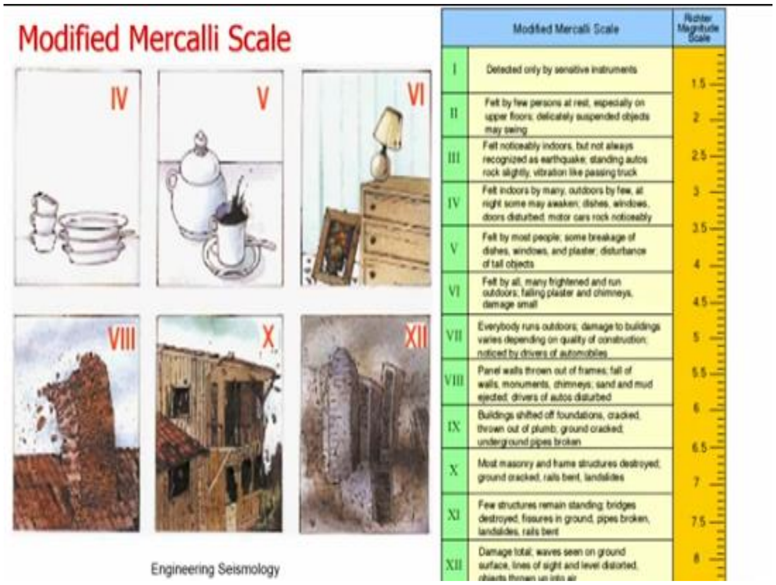

So this scale consists of the 12 level where it is given a description about so this we also discussed that the intensity measurements are only reported earthquake which is occurred in the people who are living so in the remote area earthquakes so may not be noticed because there is no building there is no human being living in the earthquake in the forest. So earthquake in the sea without causing Tsunami those are all the earthquakes are not noticed.

So the intensity scalar are moreover this is also depends upon the sensitive of the person who is basically trying to say about the earthquake or scale the earthquake. Some people is very sensitive, they may rate it higher some people less sensitive, they may rate it lower that is what the disadvantage of the intensity scale.

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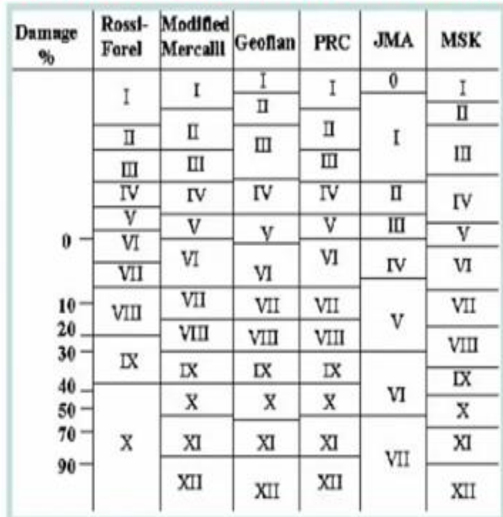
Comparison of different intensity scale



You can also see relatively the intensity scale and it is a the respective damaged level, so you can see that more or less the 12 scales are similar. So but the Japan scales are slightly different. So most of the scale the intensity is 5, so 5 and 6 onwards you can expect here damage in the building. So that is a comparison you can take it from here, so that means if you know the intensity value of a particular location, you can know what is the expected damage to the building as it is related to the damage of the building. So the damage created by the earthquake.

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- Isoseismal–Intensity scales are used to plot contour lines of equal intensity
- Peak Ground Accelerations (PGA)/Zero Period Acceleration (ZPA)- Maximum amplitude of the recorded Acceleration
- Approximate conversion from MMI to acceleration a (peak ground amplitude, PGA in cm/sec^2 or gals). The conversion is due to Richter [1935] (other conversions are also available: Trifunac and Brady, 1975; Murphy and O' Brien,1977);

$$\log a = MMI / 3 - 1/2$$

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So the intensity scale also as a conversion between the intensity to the PGA value or PGV value depends upon the place to place this is a typical conversion, which is used so the acceleration to MMI scale at a particular place.

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TABLE 4.2 Comparison of Modified Mercalli (MMI) and Other Intensity Scales

a gals	MMI Modified Mercalli	R–F Rossi–Forel	MSK Medvedev–Sponheur–Karnik	JMA Japan Meteorological Agency
0.7	I	I	I	0
1.5	II	I–II	II	I
3	III	III	III	II
7	IV	IV–V	IV	II–III
15	V	V–VI	V	III
32	VI	VI–VII	VI	IV
68	VII	VIII–	VII	IV–V
147	VIII	VIII+ to IX–	VIII	V
316	IX	IX+	IX	V–VI
681	X	X	X	VI
(1468)*	XI	—	XI	VII
(3162)*	XII	—	XII	

* Note: *a* values provided for reference only. MMI > X are due more to geologic effects.

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So this is the global comparison of the intensity scale under respective PGA value in the gals. Gals is the unit used in the US mostly you can see how the intensities scale PJ values are very drastically, even though the variation is like 6 to 7 is only one scale variation with respect to intensity but you can see the PGA variation 32 gals to 68 gals, so 32 gals to 68 gals. You can see here 32 gals to 68 density one scale. So the twice it is 32 to 147 is only 2 scale in the intensity. So this is how these scales are comparable. So this will help you basically to assess;

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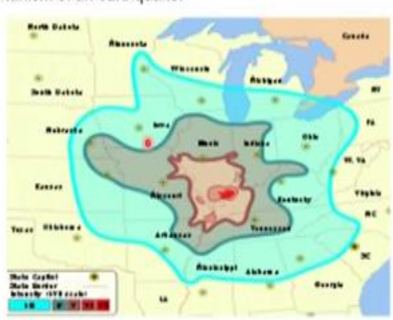
Isoseismal map

In seismology an isoseismal map is used to show lines of **equal felt seismic intensity, generally measured on the Modified Mercalli scale**. Such maps help to identify earthquake epicenters, particularly where no instrumental records exist, such as for historical earthquakes. They also contain important information on ground conditions at particular locations, the underlying geology, radiation pattern of the seismic waves and the response of different types of buildings. They form an important part of the macroseismic approach, i.e. that part of seismology dealing with non-instrumental data. The shape and size of the isoseismal regions can be used to help determine the magnitude, focal depth and focal mechanism of an earthquake.

Isoseismal map for the 1968 Illinois earthquake



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What is approximately the PGA expected what is the damage you can expect. So this intensity individual intensity value at absorbed at each location can be connected together and create a Isoseismal map. So Isointensity map or isoseismic map which is connect a equal intensity at a particular location. The line is like intensity line which is like a control line which comes like this based on the intensity recorded at a particular place.

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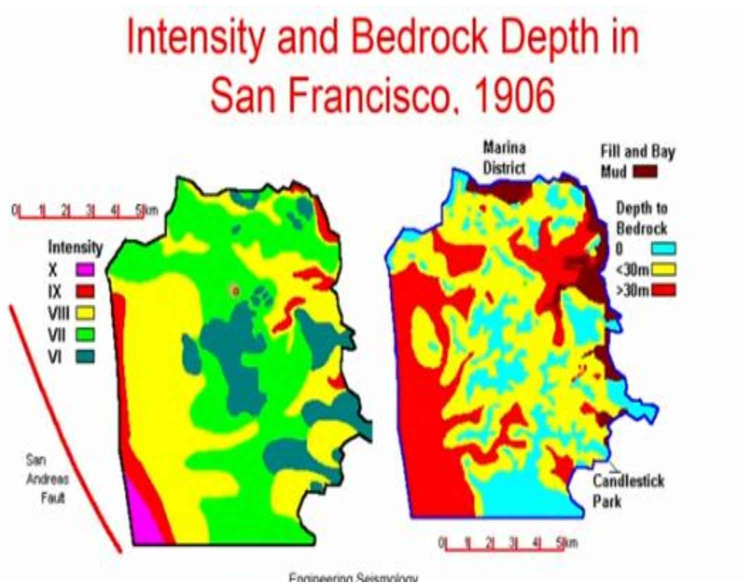

So the scientists find that the intensity value reported at a particular location is a well matches with the geological formation of the location basically geological means rock and soil type. So they observe that low intensity values are reported in the rock area, the high intensity values are reported in the soil area. So this was the earthquake observations from the San Francisco 1906, which given here initiation up thinking that the soil also plays a major role in the earthquake damage.

So where the origin of earthquake geological engineering is the starter during those observation kind of things these are typical map, you can see the this is actually a geology map which associate depth of bedrock and then the distribution in the San Francisco. So this is the intensity value observed, you can see there is a higher intensity value to the place, where is a more soil thickness.

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So those intensity scale whatever even though it is defined well and used to describe the building damage useful to convert a PGA, but that only talk about the building not the important infrastructure which also damages due to the earthquake in a road which is a place a very important role in the evacuation and disaster relief process. So this gap has been identified by my research group.

Where we put some thought try to understand how the road damages cost in the earthquake and that road damages, whatever road damages we are observed which has been used and to get here road damage intensity scale as the previous intensity scale does not talk about the damage of the road, particularly which is again become a road network. So the available road network after the earthquake and its condition scaling will help put to basically evacuate the people by controlling the traffic.

Making the one path for the ambulance so all those things are possible, if you have that kind of idea under description of the road damage and prediction of the road damage due to the earthquake which has been highlighted by the Anbuazagan Etal, so the where the road damage scale has been developed.

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Newly proposed Road Damage Scale with Description

RDS	Damage Description	MMI Scale
1	Damage is in the form of many minute cracks, one or two moderate cracks not exceeding 20 mm width, slight damage of shoulders and food path. Very little repair work is usually necessary to restore road for full traffic. This damage is seen when roads are of good quality and usually expected in road located away from epicenter for larger magnitudes.	XIII
2	Damage is in the form of settlement or moderate cracks, cracks or separation of pavement layers for width of less than 100 mm. Failure of sides and shoulder/footpath of the roads which reduces the road utility. Minor repair works have to be carried out to restore the road to its initial condition.	IX
3	A part of the road is damaged. Formation of big cracks and settlement of road is seen. Crack width may exceed more than 100 mm. Many bigger cracks in either one side or both sides of the road. Failure or crack can be attributed by liquefaction, landslide, fault rupture and failure of subgrade and sub base. Road can be used by limited traffic. Considerable road repair works should be carried out.	V, VI, VII, VII, IX, XI and XII
4	A portion of the road is rendered completely useless. Loose soil and debris is found all around. Road layers are washed away or slides. Damaged road can be used only for smooth walking or cycling. Vehicles cannot ply on the damaged stretch of the road and the stretch has to be completely rebuilt	VII,VIII, IX, X and XI
5	Maximum damage occurs to a road during an earthquake. Damage of total width of road, road may not be useful for smooth walking and cycling. The roads are completely rendered useless and are totally inaccessible. Roads are damaged structurally and debris from landslides renders the road totally inaccessible. Complete relaying and rebuilding is needed	VIII, X, XI and XII

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So this road damage is called RDS consist of the 5 description unlike other intensity level is 12 but here we are only having the 5 level ups here. So this 5 level mainly concentrated on the with respect to the road damage description nothing to do with observation or not feeling nothing. So this is the description detailed description are given for each one level, so the RDS one is actually a very light damage where you can get basically the road can be used immediately.

With slight cleaning and then doing a small repair work, so the five is the extreme level changes where you cannot use the road at all, it is completely blocked. So the respective after definition of this we collected a several data from the past earthquake where the detailed road damage photos are available descriptions are available magnitude are available distance are available, so that based on those things basically so we defined this description compared again with the original road reported in the MMI scale.

So then you can see that the scale 5, 6, 7 has been used for the RDS 3, 4, so and then the 8 is used for the 5 and 4 which it does not basically fit so that means MMI scale cannot be used. Any intensity scale other than RDS scale cannot be used to describe or quantify the road damages due to the earthquake. So that is a message we are want to emphasize.

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Correlations between Road Damage Scale and earthquake parameters

Eq. No	Equation Type	Parameter used to relate RDS	Number of data	Coefficients (90%Ci- 90% Confidence intervals)		Correlation coefficient (R^2)	RDS range	Magnitude range (Mw)	Distance range (km)
				a (90%Ci)	b(90%Ci)				
1	$RDS = aM^b$	M	7	0.12(±0.23)	1.91(±1.01)	0.81	3 - 5	5.3-6.9	-
2	$RDS = aM + b$	M	9	2.47(±0.87)	-13.87(±6.13)	0.81	2 - 5	6.6-7.6	-
3	$RDS = aM + b$	M	12	2.17(±0.87)	-13.27(±6.71)	0.67	2 - 5	7.1-8.4	-
4	$RDS = aM + b$	M	7	3.41(±1.69)	-26.58(±14.66)	0.77	1 - 4	8.1 - 9	-
5	$RDS = aED^b$	ED	21	2.32(±0.33)	0.22(±0.05)	0.80	2-5	-	1-30
6	$RDS = aED^b$	ED	7	0.14(±0.22)	0.72(±0.35)	0.87	2-4	-	49-125
7	$RDS = aED + b$	ED	7	-0.06(±0.02)	15.22(±4.27)	0.88	[illegible]-5	-	190-250
8	$RDS = aHD^b$	HD	20	1.54 (±0.65)	0.30(±0.13)	0.42	2-5	-	7-58
9	$RDS = aHD^b$	HD	18	1.67 (±0.27)	0.29(±0.05)	0.68	3-5	-	7-58
10	$RDS = aHD^b$	HD	8	0.07 (±0.13)	0.84(±0.39)	0.80	2-4	-	49-127
11	$RDS = aHD + b$	HD	7	-0.06(±0.02)	15.88(±4.46)	0.88	1-5	-	190-255
12	$RDS = a(M + ED)^b$	***M+ED***	***21***	***1.16(±0.34)***	***0.40(±0.09)***	***0.76***	***2-5***	***5.3-8.4***	***1-30***
13	$RDS = a(M + ED)^b$	***M+ED***	***7***	***0.05(±0.10)***	***0.91(±0.02)***	***0.88***	***2-4***	***6.8-9.0***	***49-125***
14	$RDS = a(M + ED) + b$	***M+ED***	***7***	***-0.06(±0.02)***	***15.58(±0.36)***	***0.88***	***1-5***	***8-8.8***	***190-250***
15	$RDS = a(M + HD)^b$	M+HD	20	1.06(±0.60)	0.39(±0.16)	0.43	2-5	5.3-8.4	7-58
16	$RDS = a(M + HD)^b$	M+HD	18	1.16(±0.44)	0.37(±0.11)	0.69	3-5	5.3-8.4	7-58
17	$RDS = a(M + HD)^b$	M+HD	8	0.05(±0.09)	0.92(±0.41)	0.82	2-4	6.8-9.0	49-127
18	$RDS = a(M + HD) + b$	M+HD	7	-0.06(±0.02)	16.31(±4.62)	0.88	1-5	8-8.8	193-253

<u>Note:</u>

RDS- Road Damage Scale, M- earthquake magnitude in Mw, ED- Epicenter Distance in km, HD – Hypocenter Distance in km, "a" and "b" are regression coefficients, 90%Ci - Coefficient in brackets are regression coefficient for 90% confidence intervals

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So this further this research group also worked on the data and collected and try to fit model the prediction equation for the road damage as has been attempted, so this is the different model. So the research found that the M and ED. ED is a epicenter distance as a very good regression relation and it gained result here reliable road damage prediction equation. So among this so many equation 12, 13 14 are the equation which is can be used to predict here road damage due to future earthquake.

So in fact that will help you to identify the which has the roads are intact which are the roads are get damaged. So an accordingly you can plan your traffic movement so other than ambulance movement evacuation process all those things.

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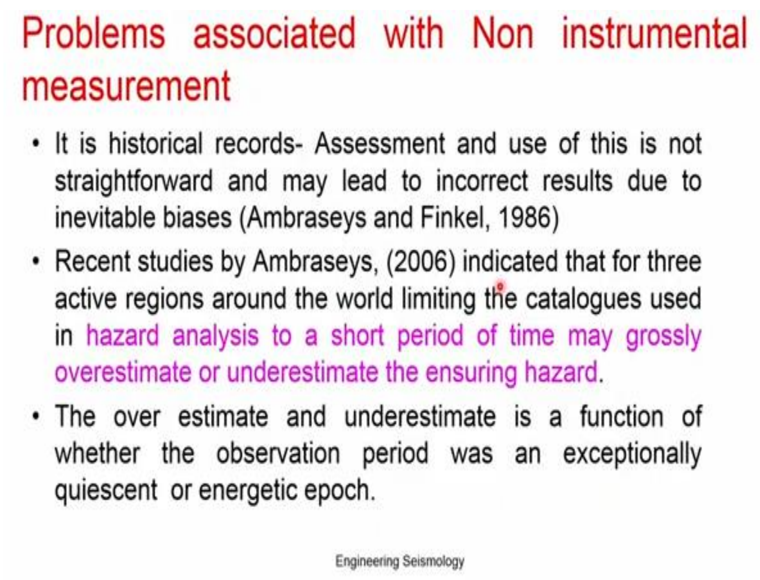

So the problem associated with this kind of non-instrumented data measurement is actually as we told that it depends upon the sensitivity of the person and then looking at a the cracks and then the description of the damage at particular person. So, there is no universal description. Some people may count some point, some people miss some point. So which is basically not appropriate.

In case the earthquakes are happening in the remote areas where there is no people no house so even though the earthquake may be strong since there is no people to feel there is no building to damage then those kind of earthquake it may not be there. But however, this scales are very important because most of the historic earthquakes are having the isoseismal map and intensity values which are very important basically to plan for the your earthquake hazard value prediction.

In form of the intensity level or you can take estimated intensity and try to convert into the peak ground acceleration peak ground velocity with there is a some equations are available on for this kind of things.

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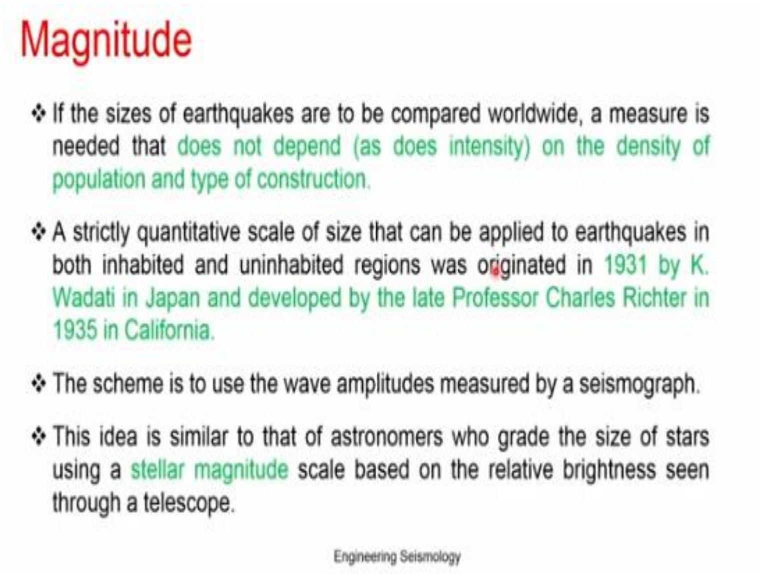

So in order to overcome this as a scientist thought, so then they come up with the concept of magnitude. So the magnitude was actually the size of the earthquake which is estimated, which is arrived based on the waveform recorded by the seismic instrument. So the waveform recorded by the seismic instrument is used to arrive a size of the earthquake that is called as a magnitude. So this was actually come from the concept of steller magnitude where people used to arrive size of the planet using its brightness.

So the similar way the wave, the wave amplitudes are bigger, the magnitude will be bigger the way duration is a bigger smaller depends on that magnitude will change this.

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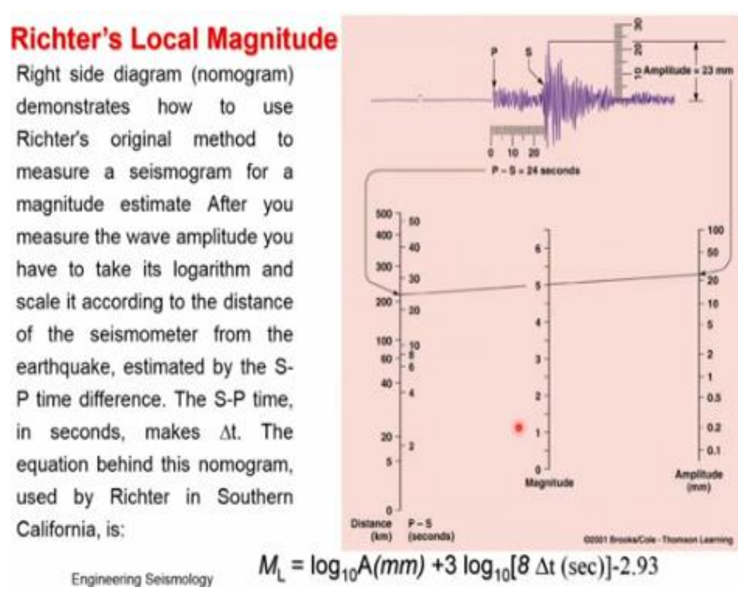

So initially the Ritcher created a first magnitude scale. So which is called as a Ritcher Local Magnitude, from the California earthquake. So where is they will record data like this, then identify a different type of wave as we discussed earlier and then take a amplitude in mm you can take this and then put it in the scale and similarly the P and S wave difference here then connected then you will get a magnitude of the earthquake or you can even use this empirical formula to get a magnitude of earthquake.

So here they used to highlight that the highest amplitude of the wave so in general the P and S wave is the most nearly recorded a data and the S wave will have the highest component that means the Ritcher magnitude scale is more of valid for the S wave kind of waves.

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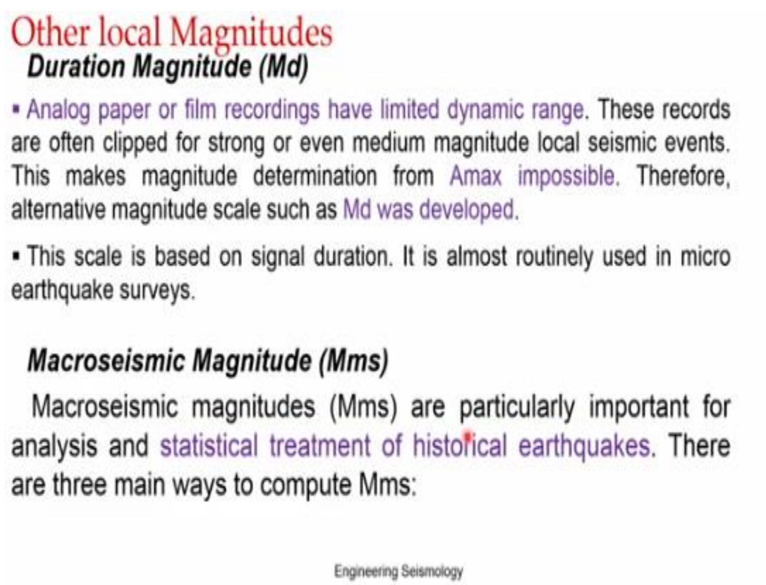

So the then sometimes if you do not have the proper this S wave recording due to long earthquake or something people use to other local magnitude, it is basically used within the region. So the duration magnitude Md, microseismic magnitude Ms. So, these are all the local magnitude people used to get a size of the earthquake. Here we should remember that, so this local magnitude varies with region to region. Some seismologists used to practice this kind of thing Md and Mms.

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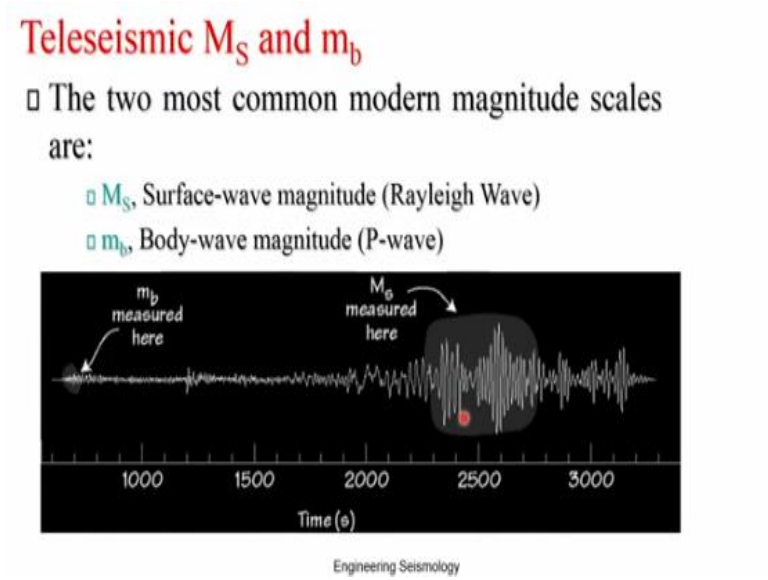

So but this when you have the very big earthquake very far away. So your broadband station may record but you may not have the your higher value as a P and S wave component. So in that case the body wave and the surface wave which is created body of the earth and far away earthquake in the surface, are used to get a magnitude which is called as a teleseismic magnitude Ms and Mb. So they use the surface wave of the earthquake.

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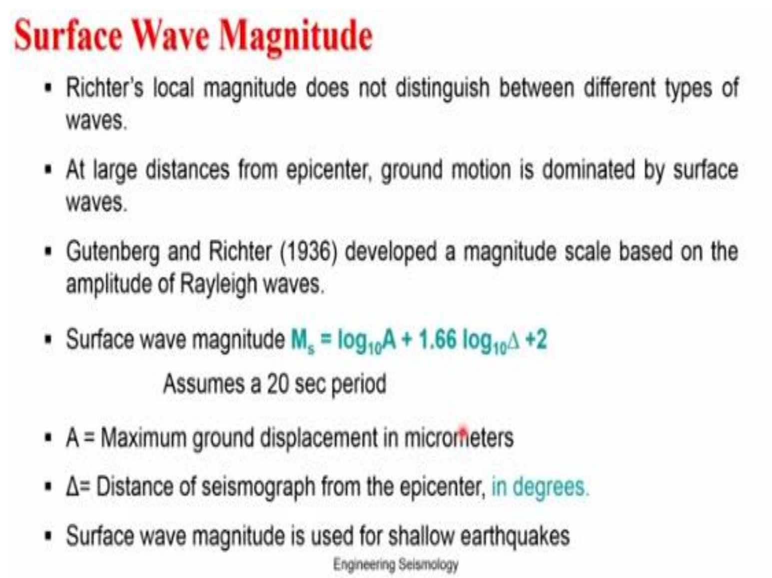

And then the P wave of the earthquake. So this is like a typical example how the Ms equations are given. So you can also see that time duration and period kind of things from here. So this if you feed that you will get a this one this was actually developed based on the so the amplitude of the Rayleigh wave by the Gutenberg and Ritcher.

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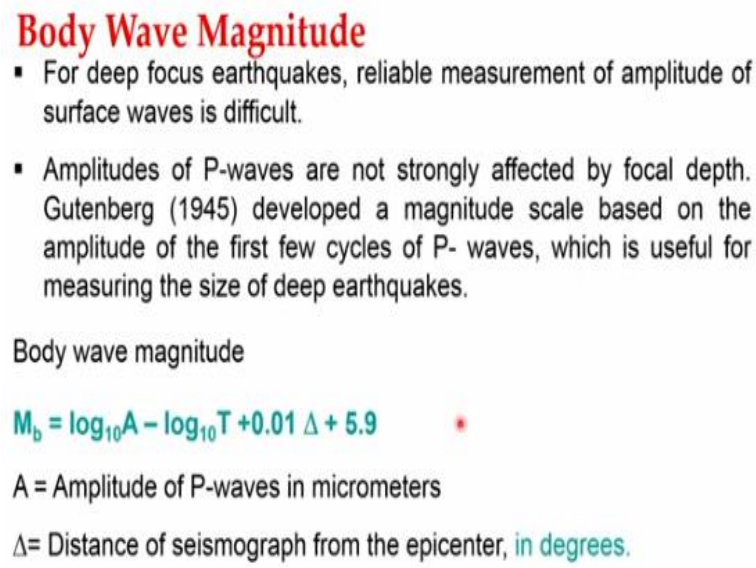

So the body wave magnitude. So there is the surface wave magnitude, the body wave with this basically the body wave amplitude and the time is has been taken into account and then the body wave relations are given. So which is useful;

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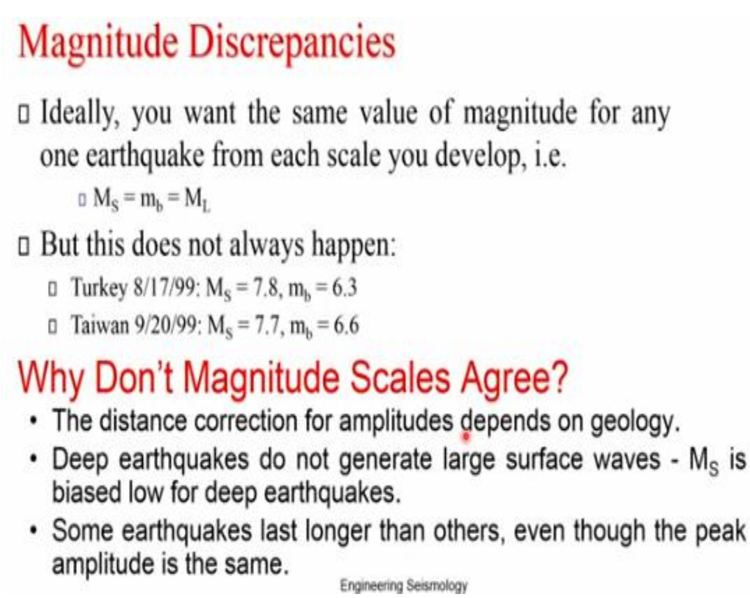

When you have the predominant record of the body wave. For example, when you are in the shadow zone of S. So the S shadow zone share wave shadow zone. So you get a body wave, so using those kind of deeper transformed seismic energy, you can get a body wave magnitude. So the scientists observed for the same earthquake the body wave and S wave and then the surface way magnitudes are uniform.

It obvious that as we have seen in the wave progression that the amplitude and the duration of the particular ground motion at a recorded site depends upon the distance and magnitude of the earthquake. So and then where it occurs and how big it is all those thing. So this phenomena not having the equal magnitude at the same earthquake is called as a magnitude saturation. So where after sometime the magnitude remain constant.

So which was identified in the olden days by the seismologists try to people try to basically get this information.

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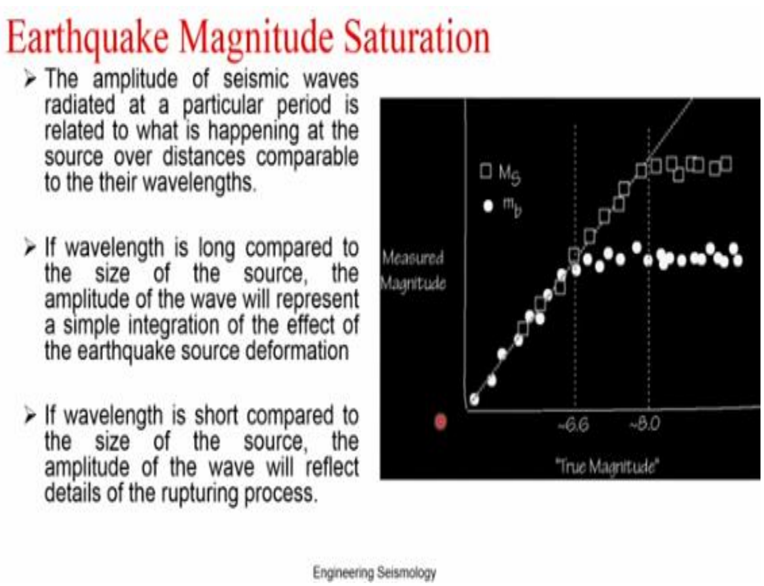

So then see that the estimations are not in this saturation zone but it is non-saturation zone. So this is how you can see the magnitude different magnitude a true magnitude and measured magnitude so you can see that this magnitudes are basically constant after reaching some point particularly the Ms Mb it has its own value of the constant values.

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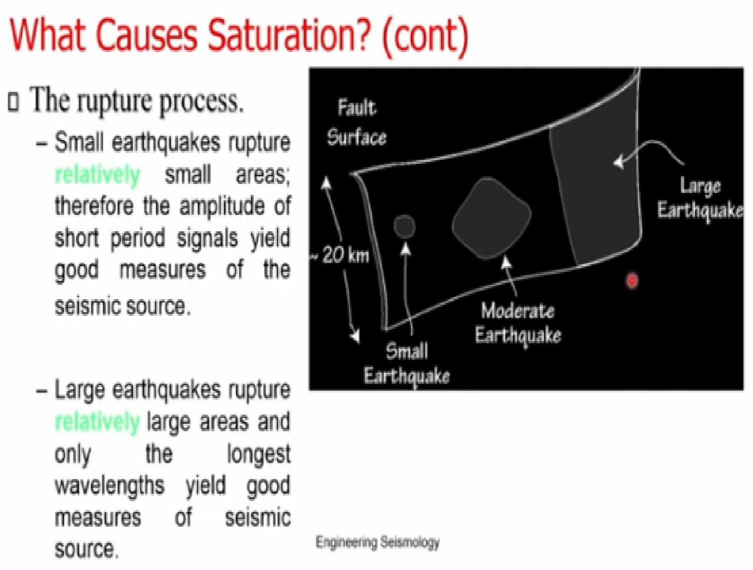

So what causes saturation? As we have seen in the seismic wave propagation, the waves are originated depends upon the fault fracture, so the larger the fracture the larger will be the wave amplitude but since it travels a very long distance, the distance from the origin of the earthquake to the your station also very important the rupture, if you know happens in the fault also very important.

These two has been considered and this is a responsible to decide the magnitude has saturation are not. So the magnitude saturations are so very important aspect one has to know what magnitude maximum that particular magnitude is applicable. You cannot be using all the scale in all the place.

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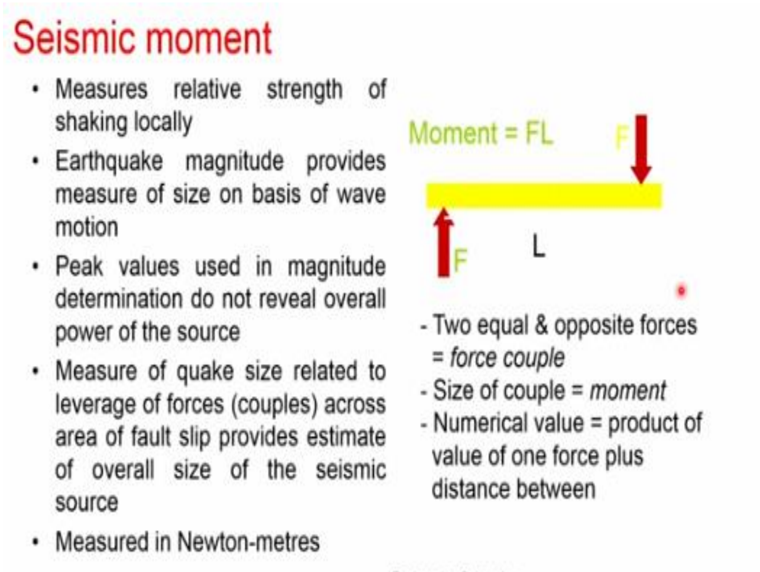

So in order to overcome this kind of magnitude related things which is the function of amplitude of the seismic waves so people come up with the concept called seismic moment, so the seismic moment the stiffness of the rock and then the slip produced by that you taken into account then the estimate here moment of the earthquake. So using this momentum, one can estimate a magnitude that is called as a moment magnitude.

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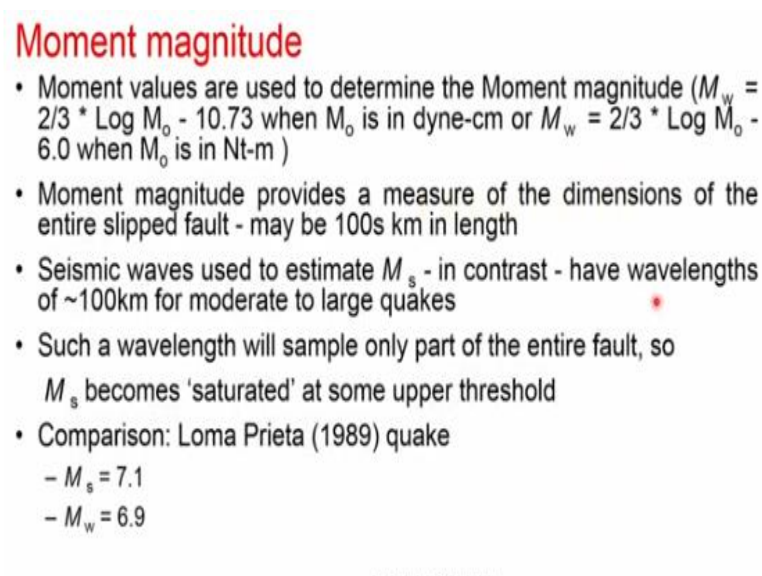

So the moment magnitude is very recent so which works for the all the range of magnitude, starting from 2 to 10 and then it also the ambiguity in the measurement of like this Ritcher because Ritcher said that beyond 100 kilometer we have to apply some kind of factor and all that so those kind of discrepancies are not there, the moment magnitude scales are very good and can be used for the any this one.

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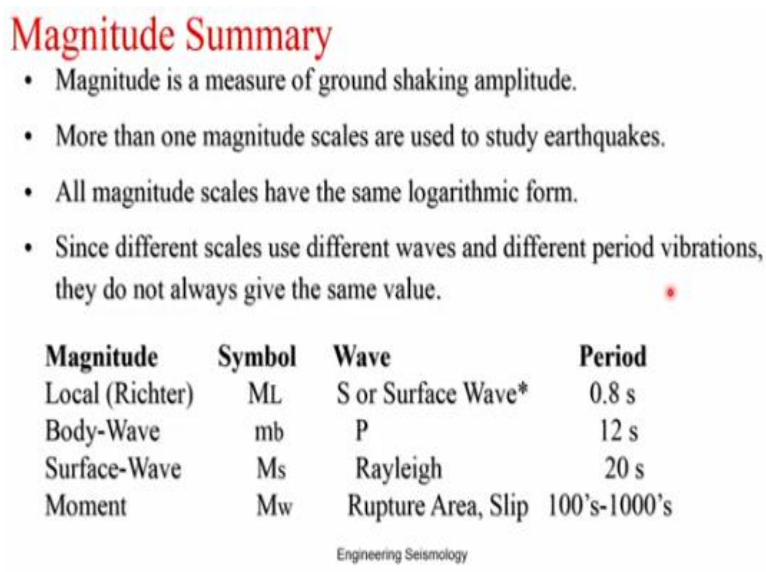

So at the Nutshell so we have studied a magnitude, quantification of the earthquake such as a intensity values and then the after intensity value RDS has been developed, so then after RDS the magnitude come into picture so then you will have the different my local body wave, surface wave, moment magnitude, so all this magnitudes are related to each other. You can also have the relation between the intensity and the magnitude which you think you have the sufficient data will be useful for a basically making some kind of prediction equation.

So here you can see the summary type of the wave and symbol and then the wave pattern and then the period at where it is being recorded so far.

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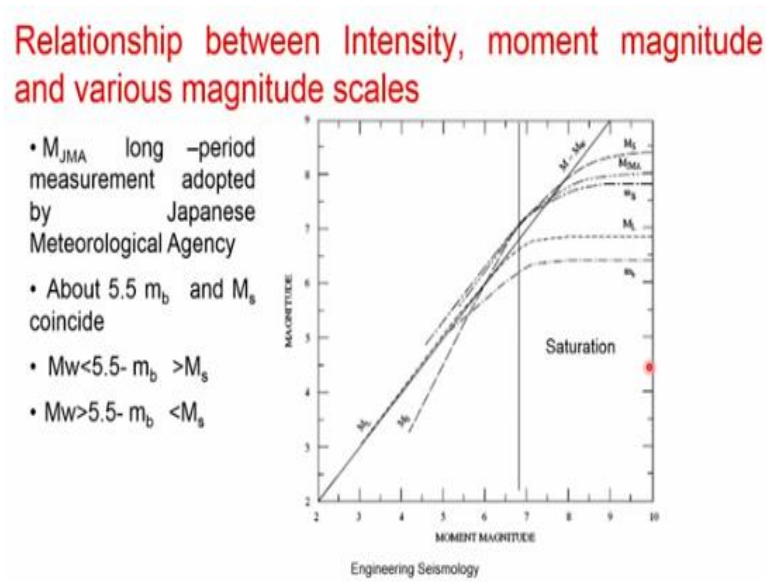

So this is a conversion equation basically the converting magnitude as we have seen that Indian any region earthquake started from the historic times where the isoseismal maps are kept then followed by the you will have instrumented record where Ml, Mb, Ms, Mw has been kept. So there is always need for homogenizing the data by removing all these ambiguity and make that all of them in a particular scale.

So that process is called as a Magnitude conversion. It give you the typical example shows how the moment magnitude and the magnitude of the earthquake how it is related.

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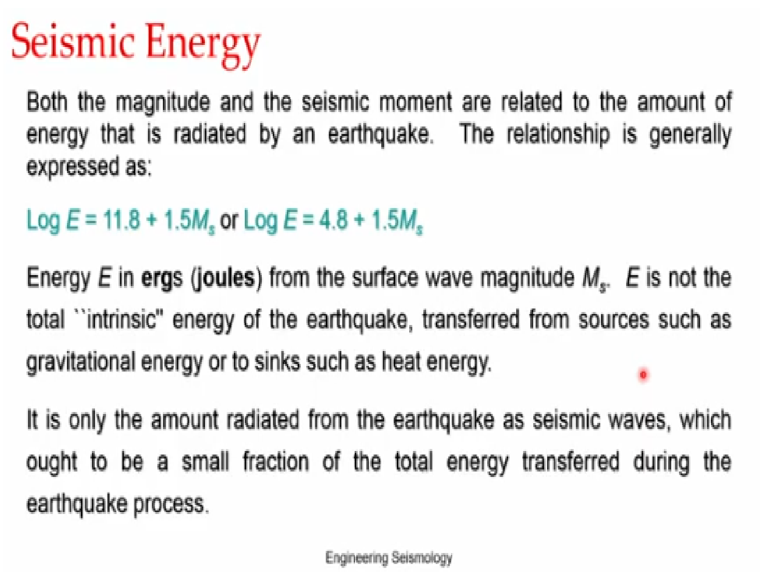

So the another important aspect in the this one is actually intensity magnitude the earthquake measurement is the seismic energy. So when the earthquakes are occurring how much the energy has been released. So that is basically the measure in terms of joules. So where the surface wave Ms and E is the minimum, is basically this will give you the idea. So the how much energy released at a particular place there is a empirical correlation between the E and the Ms directly. So that will help you that so using this understanding of the energy.

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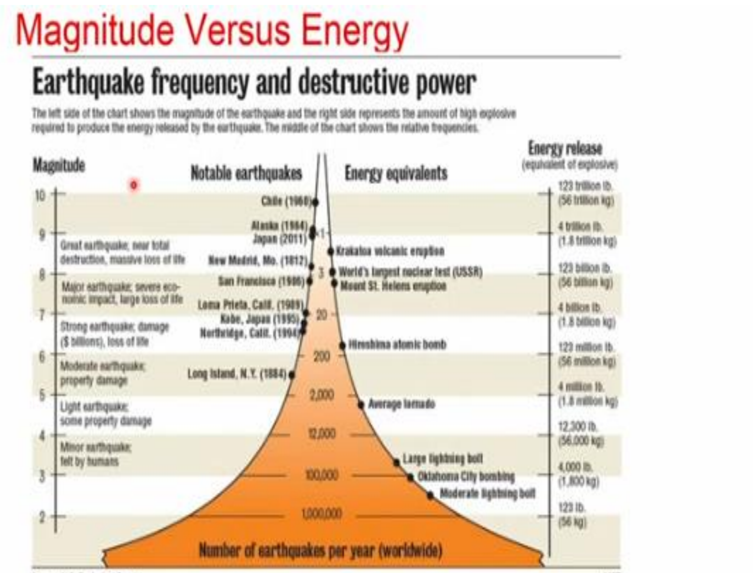

People try to see the global perspective on the different earthquake occurred in the world. So this basically gives the earthquake size based on the magnitude of the earthquake you can see minor light, moderate and strong earthquake and major and a great earthquakes. So then the notable big earthquake in the world, you can see all those earthquakes then the notable human activities. So which you can see that there are many troops are entering on this even though they are killing but still the tension is going all over the world.

You should aware when you are watching this video basically there was the issue with the getting a top portion or wave recorded in that. So because it is we did not get. So that is about the earthquake energy. So the earthquake energy plays a very important role in this graph, you can also understand that the number of earthquake per year. So you can see that the low size magnitude minor earthquakes are very large number up to 12,000 per year.

So l00000, 1000000, 12000 the larger magnitude generally occurs very rare. So the moderate magnitude occurs considerably on all the region of the world. So this energy release also related to the explosion of the particular location. So you can see the energy released by the equivalent magnitude and then the explosion recorded to create a similar kind of energy. So since it meets lot of explosion to create a magnitude.

That is why the earthquakes are not really created and did for measurement as well as the analysis in the model studies like other subject. So but you can get the computer based data and do the analysis and modeling purpose that is very widely practiced in the several places so you can see some of the atomic bomb area how much the kg explosion which is equivalent what is the magnitude.

And the this side so this is like atomic bomb where you can see how much the magnitude and what is the equivalent magnitude and what is the loss due to the so this kind of the important aspect can be obtained from the this graph. So this graph will be useful to know the energy released and how this energy how many kg of explosion if you do you will get a similar kind of seismic energy.

So this is about the earthquake sizing or estimating the earthquake magnitude there are very few people do research on this area in our country which has a very good potential for extend several things, so we have very limited homogeneous equation to convert intensity to the magnitude and then we have less intensity predictive equation with respect to the PGA as well as the spectral acceleration for considering the entire Himalaya as a different segment.

So this kind of information basically helps to identify the how the human activity based seismicity, natural based seismicity is going on so this is what we discuss in the earthquake size. So, we have seen that intensity as a one of the scale magnitude is one of the scale, so this has been widely used intensities are measured non instrumented way of quantifying the size of the earthquake magnitude or the measured and having the proof to estimate a magnitude size.

And then number of earthquake happens on the each size per year also we have discussed so this information are useful to quantify to size the earthquake at a particular location, so this information are further we can use for the other chapters and application so now after studying the GMPs and predictive equation and all you will be clear what is the intensity magnitude how you can use it in the seismic hazard analysis so with this we will close our lecture.

So thank you very much for watching we will be continuing our lecture in the next class, thank you very much.