Geotechnical Earthquake Engineering

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Module - 7
Lecture - 23
Seismic Hazard Analysis

Let us start our today's lecture on this NPTEL video course on Geotechnical Earthquake Engineering. Let us start our next module which is module 7, let us look at the slide, so module 7 is on Seismic Hazard Analysis.

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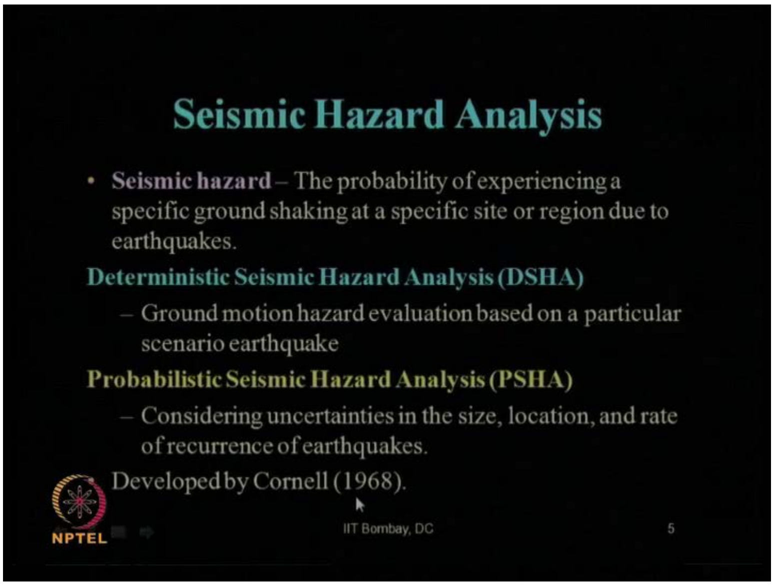

So, what is seismic hazard? Let us see seismic hazard is nothing but the probability of experiencing a specific ground shaking, at a specific site or region due to earthquake; so that is the probability by which at a particular site, the earthquake will be felt or shaken. So, that seismic hazard analysis can be done through basic two major methods, what are those two major methods? These are two major methods, one is called Deterministic Seismic Hazard Analysis, in short it is called DSHA. Taking their initial letters that is DSHA which is nothing but ground motion hazard evaluation based on a particular scenario earthquake, on a particular scenario earthquake; that is the important part we should note.

And another type of seismic hazard analysis is called, Probabilistic Seismic Hazard Analysis or PSHA, taking again the first letter of each word that is Probabilistic Seismic Hazard Analysis, PSHA. In this case we considered the uncertainties involved in the size of earthquake, in the location of earthquake, and at the rate of recurrence that is in the interval through which earthquake repeats or reoccur that of earthquake. Considering uncertainties involved in all these parameters, then this PSHA or Probabilistic Seismic Hazard Analysis is done, that was initially developed by Cornell in 1968.

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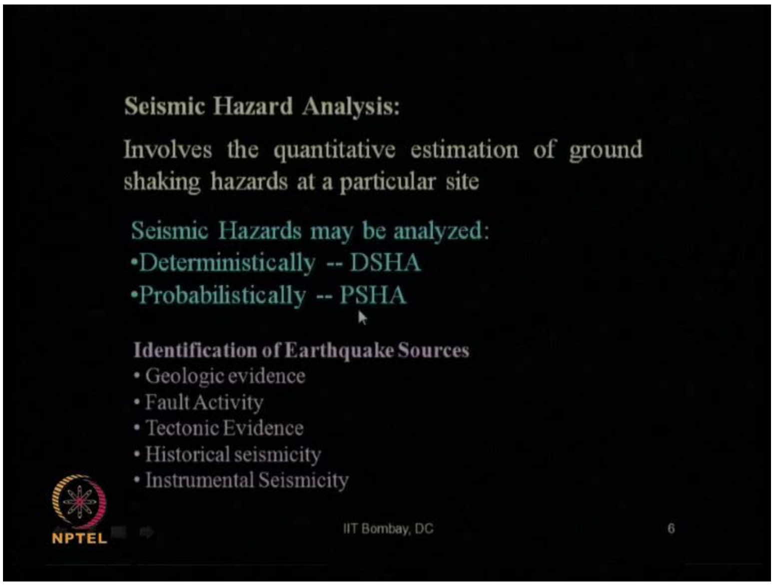

So, the seismic hazard analysis, it involves the quantitative estimation of ground shaking hazards at a particular site, and it can be analyzed through deterministically, and probabilistically or probabilistically that is these are the two ways, through which seismic hazard can be analyzed that is DSHA and PSHA. So, how we go ahead further, first step to do the seismic hazard analysis is to identify the earthquake source, that is the very first step. So, to identify the earthquake sources, what are the characteristics we should look into like, geologic evidence of the earthquake that is from the historical earthquake, the fault activity we should note down the fault activity for past earthquakes.

Tectonic evidence, any tectonic movements etcetera, historical seismicity at that particular site or in close vicinity, what are the various previous earthquake, and instrumental seismicity that is through the recording stations, what it the recorded values of seismicity of a particular site over the years. So, these all together will help us to identify what are the various earthquake sources, for a particular site for which we are going to do the seismic hazard analysis.

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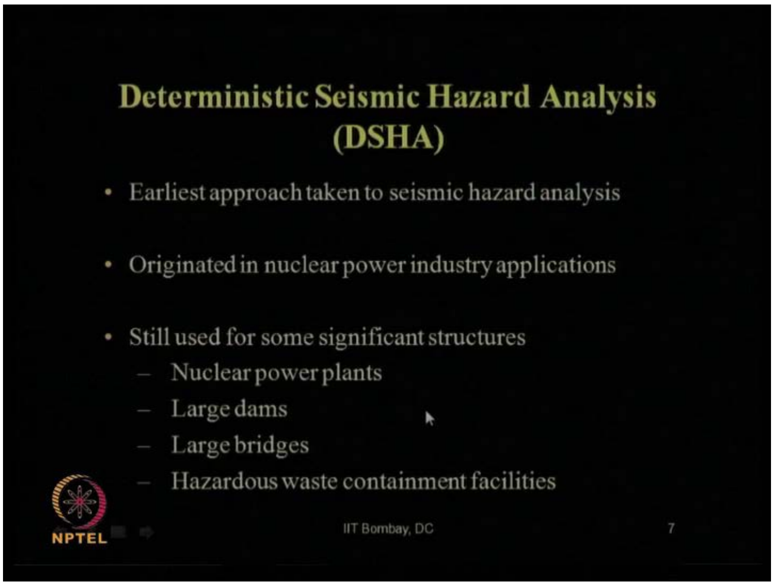

Say in the deterministic seismic hazard analysis, it is the earliest approach taken for the seismic hazard analysis, it is originated in nuclear power industry applications, and still it is in use for significant structures that is for nuclear power plants, for large dams, for large bridges, for hazardous waste contaminant facilities etcetera. That means, you can see all the important or very important structures, where the destruction of these structures during earthquake can be a huge disaster, in that area also in an area surrounding that particular area, for those cases we should consider or we should apply this Deterministic Seismic Hazard Analysis or DSHA.

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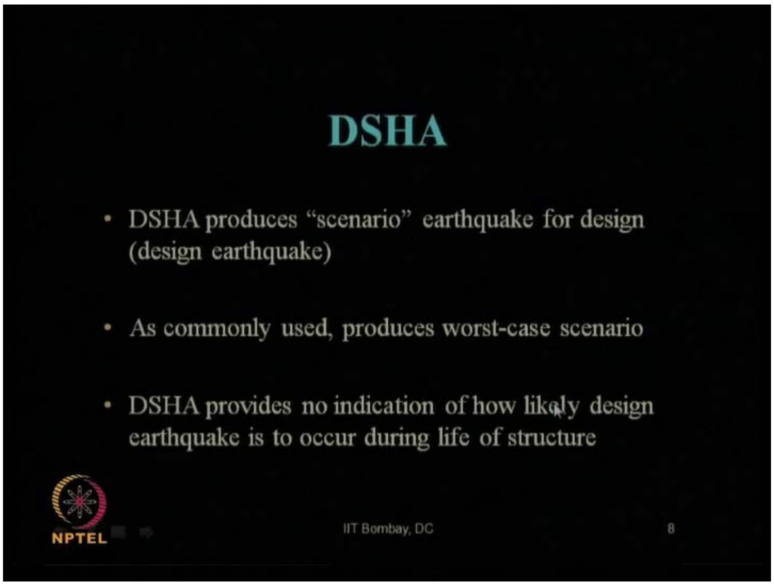

So, DSHA it produces a scenario earthquake for design that is the design earthquake. So, DSHA considered only one particular earthquake, as we have mentioned it is based on one particular earthquake which is nothing but a design earthquake or scenario earthquake for a particular region.

So, as commonly used it produces the worst case scenario, so obviously, when we are trying to do the design of this seismic hazard analysis, through the deterministic approach. We should take the worst case that is, what is the maximum magnitude in that region it occurred, so that what it meant that it is commonly used produces the worst scenario case. The DSHA provides no indication of how likely the design earthquake is to occur, during the lifetime of the structure.

So, this is one disadvantage of DSHA why, because when you are considering the worst case scenario or the highest value of earthquake, you never know that whether that design or worst case or the highest value of earthquake will ever occur, during the life span of your structure or not. It may happen that from the past historical earthquake of say, several of 100's of years, you have chosen the highest value of earthquake for designing your nuclear power plant or large bridge etcetera.

But you never know, suppose the life span of that structure is 100 years or so in that highest magnitude of earthquake may never come. So, that is one of the limitations or because it never provides any kind of indication that, it should be considered based on the likelihood of that occurrence of the design earthquake.

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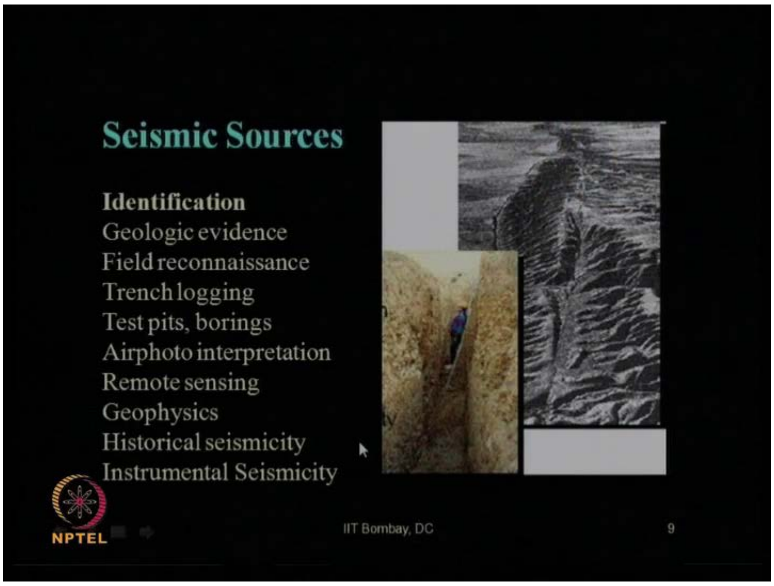

Now, let us come to the seismic sources that is identification of seismic sources, through various methods as we have already mentioned, like geologic evidence. You have to find out what are these seismic sources of this fault etcetera, geologic evidence of past earthquake, field reconnaissance that is field survey you can do, trench logging you can do the trench logging at a particular site to identify a fault. Test pits and borings method, air photo interpretation, you can have aerial photograph of a particular region to identify an open fault or the surface fault stress. Remote sensing through the process of remote sensing, using the geophysics geophysical methods, non destructive methods you can identify the fault.

Historical seismicity from the past earthquake historical records, which you may have for that particular location, and based on the instrumental seismicity of current days, you can use the recorded earthquake motions etcetera, from the motion seismograms. And those seismograms data you can use to identify the seismic sources, so these are the various ways, so either you have to use the combinations of them or a particular of them, it is always better to apply a combination of these methods to identify the seismic sources.

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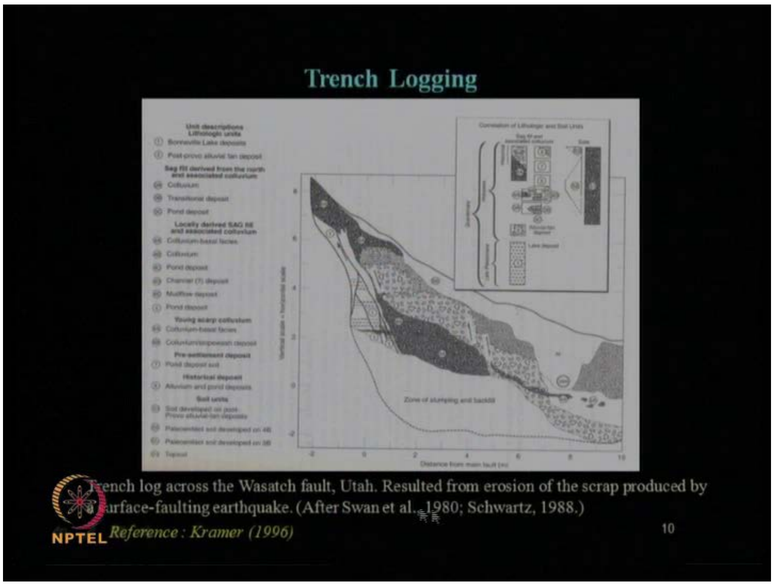

So, coming to the trench logging, this is the picture which is presented by Swan et al in 1980, and modified after Schwartz in 1988. This is various trenches looking at the zone of slumping, and the backfield, and the material property etcetera, you can see the pond deposit (( )), Viam, transitional deposit etcetera depending upon types of material, you can comment on the previous seismicity using this lithologic unit behavior; and distance from your main fault in this directions fine.

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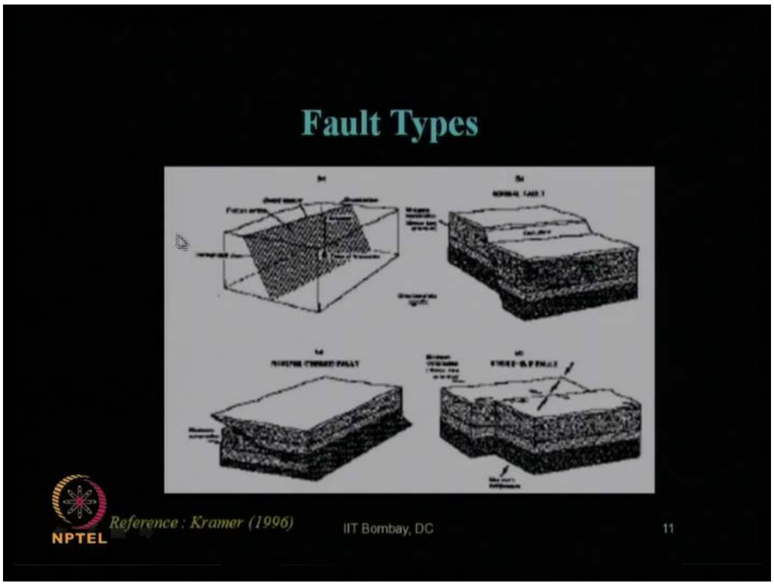

Also we have seen earlier what are the various types of fault, like normal fault, reverse fault, strike slip fault, oblique fault etcetera. So, depending on the fault type you have to identify, what type of or what are the chances of seismic sources you may have at a particular site.

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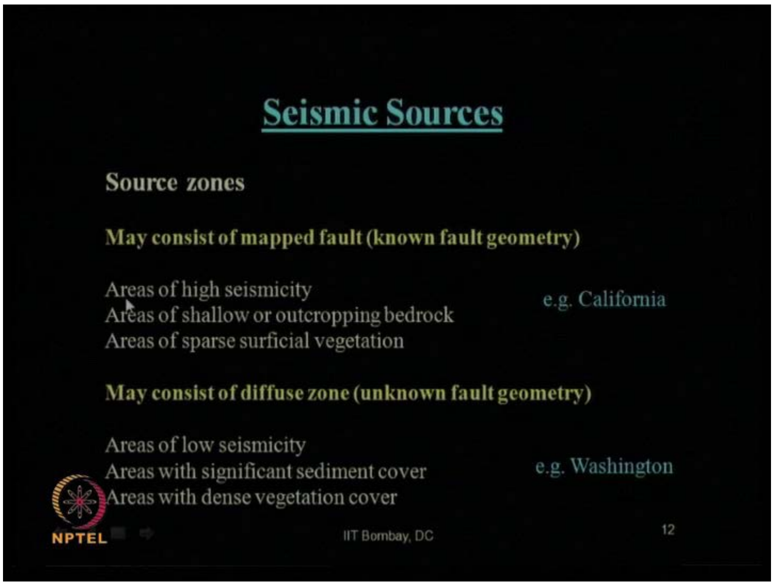

So, when we talk about these various seismic sources, so source zones may consist of a mapped fault, which is known from your fault geometry. Like areas of high seismicity where for a particular area you have a fault, which is already mapped that is you know the geometry completely, depending on area of high seismicity, area of shallow or outcropping bedrock. Because if the bedrock is outcrops means that bedrock comes open or to the ground surface, that is called outcropping of the bedrock.

So, those areas and areas of sparse surficial vegetation, in these areas you will have a mapped fault, which from the known fault geometry, which can be considered as a identification for your seismic source. For example, for California region we have already available this mapped fault, whereas you may have another type of region or source zone, where your fault geometry may not be known, that is called as diffuse zone. What are those areas; those areas are nothing like areas of low seismicity, where earthquake is not that frequent or common, and that high magnitude.

Areas with significant sediment cover, where you have large thick cover of earth soft sediment layer, and areas with dense vegetation cover, here you have less vegetation cover, here you have dense vegetation cover. So, those area it is very difficult to identify your fault or surface trace of the faults, so those area it will be considered as diffuse zone; but there also we need to identify the source zone, someway or other we will see the various ways. For example, such type of diffuse zone can be considered like Washington is considered as a diffuse zone, where fault geometry is somewhat unknown compared to the California region.

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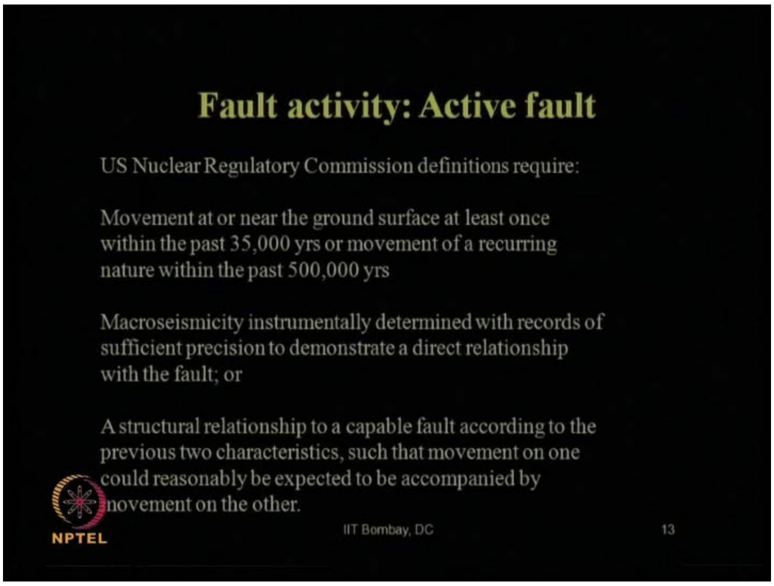

Coming to the fault activity, we need to check whether that fault various types of fault what we have seen, whether it is an active fault or a dormant fault, what is active fault, that is where still the occurrence of earthquake is keep on happening. Now, let us see what are the guidelines available in various specifications or codal guidelines or stipulations like, US nuclear regulatory commission; they define the active fault means movement at or near the ground surface, at least once in the past 35000's of years, or movement of a recurring nature within the past 500000 years, then they called it as a active fault.

That means, you will see most of the fault which you will get are nothing but active fault because these period automatically shows it is in the human era of what we are considering as years of civilization, we have to consider almost all fault as an active fault, all identified fault as an active fault, as per this US nuclear regulatory commission. Also another statement they made, macro seismicity instrumentally determined with records of sufficient precision to demonstrate a direct relationship with the fault; that is suppose there is no such definite fault activity.

But, you have some macro seismicity which is recorded instrumentally, which is not may be perceptible or noticeable to the human being, but noticed by the instruments. Even those faults also US nuclear regulatory commission, they are considering as an active fault, though they generate a very minor or small magnitude of earthquake; or a structural relationship to a capable fault, according to the previous two characteristics like this. Such that, the movement on one could reasonably be expected to be accompanied by the movement of the other, so any kind of movement on the structural relationship between two plates between two fault plane can be considered as the active fault based on their fault activity.

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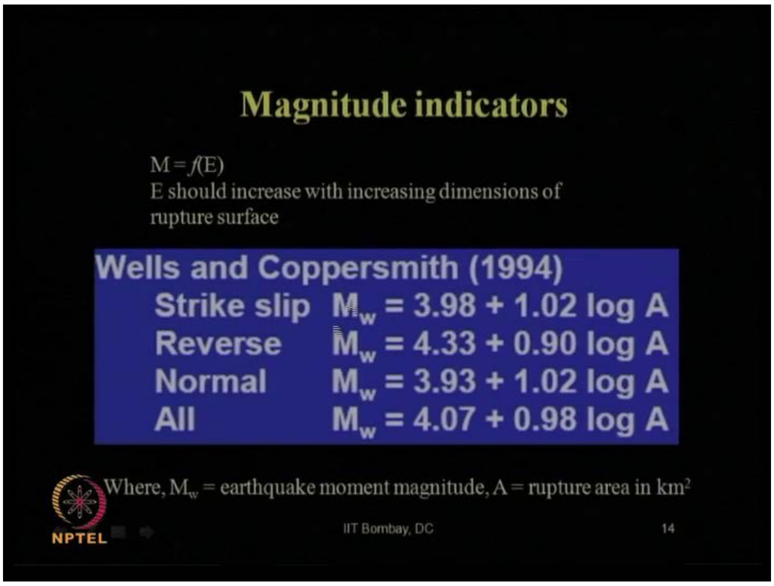

Now, coming to the magnitude indicators, next step we need to find out how to estimate the earthquake magnitude, for this seismic hazard analysis, this magnitude is nothing but a function of this energy released; that we know that is the best magnitude, which is that magnitude we already have mentioned that is the moment magnitude. So, E should increase with increasing dimensions of the ruptured surface, because if during an earthquake, energy release is more that means, more rupture will occur, am I right?

The seismic energy gets erupted more, means more opening or more rupture of the fault will occur, will take place, so that shows the relationship as proposed by wells and coppersmith, in 1994 for various types of faults. How to estimate the moment magnitude of earthquake, based on the area of that fault rupture, so what are the equations they proposed, for all over the world, they mentioned that for strike slip type of fault. M w can be calculated the earthquake moment magnitude can be calculated, if we know the how much (( )) fault rupture area is having that is knowing the fault rupture area, in kilometer square unit in this empirical relation that is why, we have to be careful about this unit, it is in kilometer square.

If you put this value of a, when it is a strike slip type of fault you will get what is the value of your earthquake magnitude. Similarly, if it is a reverse fault, what should be the M w can be used, can be obtained using this equation, similarly if it is a normal type of fault it can be estimated using this expression. If it is any type of fault that is all types of fault, that is if you are not sure about what type of fault, then you should use this equation, that is which is valid for all type of faults like this.

Now, you should know what is the origin of this development of these equations, wells and coppersmith collected several historical earthquake, available before this 1994 knowing their fault rupture pattern. What type of fault, and combining them, he did, they did a combined analysis of assembling all these historical earthquake data, and plotted them in this form.

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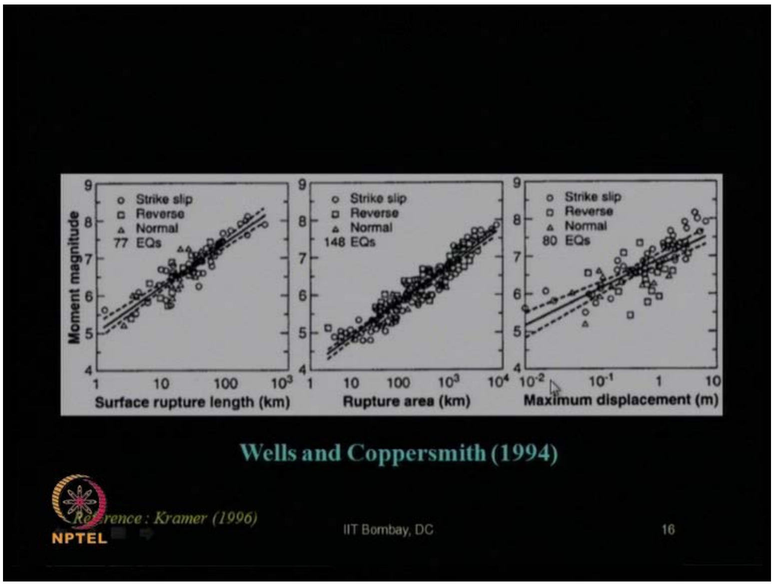

We will see this slide moment magnitude versus surface rupture length in kilometer, this is for length, for various strike slip reverse fault and normal fault, for 77 recorded earthquake. They proposed, they put all the points and then they used this regression equation, which best fit those points. Also for the earthquake moment magnitude versus rupture area, it should be in kilometer square it is a wrongly shown it should be kilometer square, you can correct it.

For all types of strike slip reverse and normal fault, from 148 recorded earthquake data, also from moment magnitude versus maximum displacement of the fault, that is the maximum slip of the fault which is in meter unit. That for various strike slip reverse, and normal fault for 80 recorded earthquake points, and then using the regression relation they have proposed the equation.

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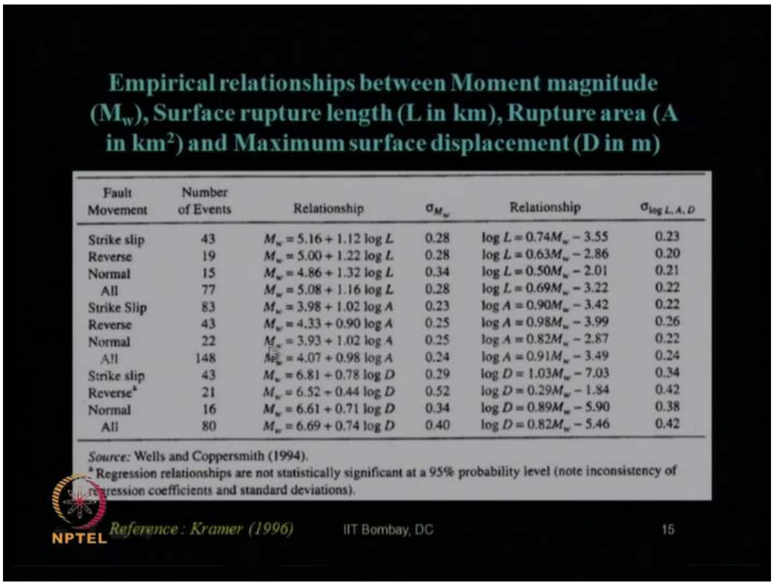

Now, let us come back to this slide, these are the equations which are proposed by wells and coppersmith in 1994; these are empirical relationships, between moment magnitude M w of earthquake. And surface rupture length L in the unit of kilometer, rupture area A in kilometer square, and maximum surface displacement or surface slip in the unit meter, we generally use the symbol D. So, these are the equations you can see, they have also mentioned how many number of events they considered to propose that semi empirical relationship, so for strike slip fault 43 events to propose this M w versus that rupture length relationship.

What is the sigma M w that is nothing but the standard deviation which occurs for all the 43 points with respect to this proposed relation right, and this is the relationship in log scale that is after reshuffling this. So, what is the standard deviation of this log of value of this length, in terms of A and D that is for this first equation is log of L is this much value, say in log scale the standard deviation is lesser. So, that is why one can use this equation, though it is a rearrange in this format that is what it is shown in the log scale, the points are pretty close to the proposed equation, can you see?

Now, if we compare this three relationship, three sets of relationship that is one set is for with respect to rupture length L, another set is for rupture area kilometer square, another set is for maximum displacement or slip in terms of D; which one is the best one in terms of the scatter is concerned, we can see the rupture area is the best one. Because here it all are clustered through that best fit equation, which they have proposed, that is why if you look at here, first four equations strike slip fault, reverse fault, normal fault, and all fault this is for length based, surface rupture length.

Then next four is for rupture area based, and last four are for surface displacement based, and among them the least value of standard deviation he will get for this rupture area, because the scatter is less, can you notice here, it is clearly shown. Whether you consider the standard deviation of M w in normal scale or standard deviation of that log of either length or area or slip in this log scale. So, in both the cases we found this portion of equations, in terms of surface rupture length surface rupture area of the fault in terms of kilometer square is the best fit equations, compared to the length and displacement.

Now, if we want to see what is the next best or next better proposed semi empirical relationship, as given by wells and coppersmith that is with respect to the rupture length, that is with respect to L. Suppose, at some fault you do not have the information about rupture area, you know only the surface trace of the rupture fault length, you can use that length and you can compute the M w. If you are sure about what type of fault movement, otherwise use the equation for all fault equation, which can be used for estimation of M w. That is why in this slide we have mentioned that, these are the best recommended equations of wells and coppersmith, for magnitude calculation for a particular earthquake, using the fault geometry, using the fault rupture area and types of faults also.

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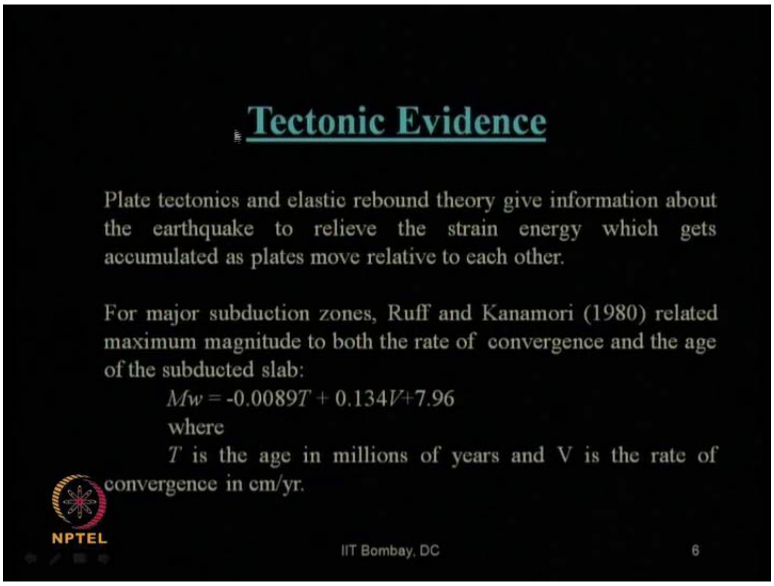

Now, let us move to tectonic evidence, for tectonic evidence how we can compute the magnitude of earthquake like, we have seen now through the fault characteristic that is either from the fault length or rupture area or surface displacement, we can compute the moment magnitude of earthquake. Now, we are looking at through the tectonic evidence or plate movement, how we can find out this moment magnitude of earthquake. So, plate tectonics and elastic rebound theory, give information about the earthquake to relieve the strain energy which gets accumulated, as plates move relative to each other; so that is what happens, during the plate movement in plate tectonic theory, we have learned that.

Now, for major subduction zone, Ruff and Kanamori in 1980 related the maximum moment magnitude to both the rate of convergence, and the age of the subducted slab. So, what is the proposed equation by Ruff and Kanamori that is M w equals to minus of 0.0089 of T plus 0.134 times V plus 7.96, again this is semi empirical relationship or empirical equation, so we have to be careful about the unit of this T and V. So, what are these things let us see, where this T is the age in the millions of years, age of that tectonic slab; and V, this V is the rate of convergence through which two plates are converging with respect to each other right.

So, that rate of convergence expressed in the unit of centimeter per year, so if from the geologist, one can get these two information that is, what is the rate of convergence between two plates, and what is the age of that plate in millions of year’s unit. Then we can easily put those values in this equation, and compute the possible values of maximum M w which can come from that major subduction zone using this relationship.

So, either you can use the maximum available historical earthquake data value, from that you can take M w for your hazard analysis or estimation or if you do not have very well documented historical data, what you can do? From the recent data given by the geologists, you get the values of this T and V, use this equation to get the maximum possible value of earthquake which can occur, in that subduction zone due to the plate tectonic movement that is what it shows clear.

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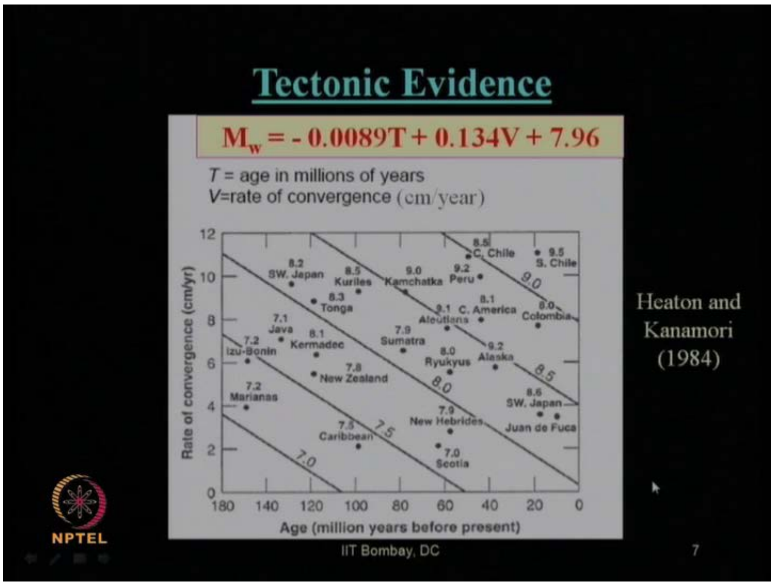

So, the same equation, so this tectonic evidence how it was proposed and further modified, like this first equation you can see, it was proposed by Ruff and Kanamori in 1980. Then later on it was slightly modified by Heaton and Kanamori in 1984, what was the change they incorporated more number of earthquake data during this 4 year period. So, that is what you can see over here, they proposed this figure through which they have shown all the collected data of earthquake till that time, rate of convergence in the y axis in the unit of centimeter per year, and in the x axis the age of that plate tectonic in millions of years before the present.

So, if 0 is the present day that is suppose in 1984, they have proposed that they considered as the present age, then age of that plates in those many millions of years. Then they proposed different demarcations of area to highlight, what are the values of various magnitude of earthquake, which they have recorded all over the world you can see, New Zealand earthquake, Sumatra earthquake, Chile earthquake, South Chile earthquake, Columbia earthquake, American earthquake, South West Japan earthquake etcetera; so using those points they have proposed finally, this equation.

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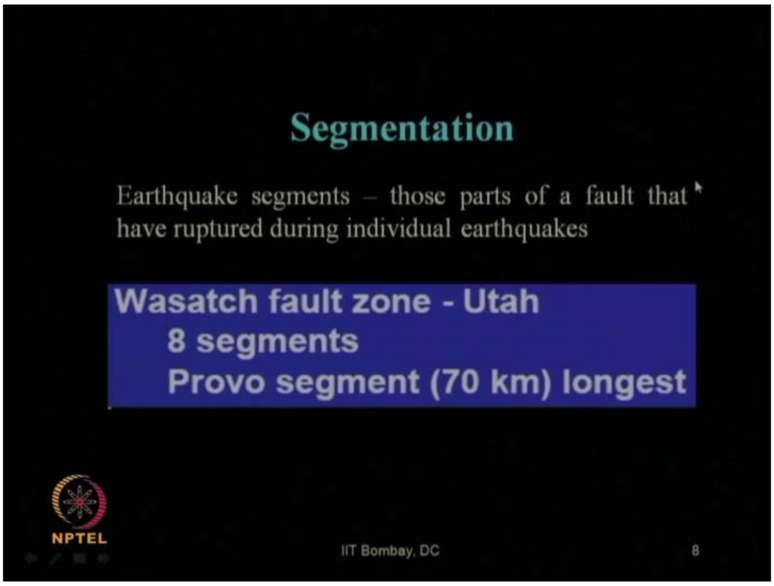

Now, let us come to next important part of this hazard analysis, which is known as segmentation. First is a magnitude indicator that is first we have to find out the magnitude of earthquake, which we have done using either the fault characteristics, if it is a fault based earthquake or we have done it through the plate tectonic movement, if it is a plate tectonic based earthquake right.

Now, we have to segment the earthquake that is earthquake segmentation. Let us see how we do this earthquake segmentation, that is those parts of the fault that have ruptured during individual earthquake are nothing but the earthquake segments. That is within the active fault, only those parts of the fault which have ruptured during your period of consideration, like for deterministic seismic hazard analysis, we have seen almost every fault is active fault. Because they say some several of 1000’s of years ago whichever earthquake fault was responsible for earthquake that can be considered as active fault; so from that fault characteristics one can find out, what are the earthquake segments of a particular fault.

So, for example, one example is given over here that is Wasatch fault zone of Utah region in US, they are 8 segments have been found and Provo segment which is 70 kilometer is the longest one among those 8 segments within a fault. That is among those ruptured portion of the fault which are nothing but the segments you have to identify how many segments are responsible for your hazard analysis, and accordingly you have to take the values of those.

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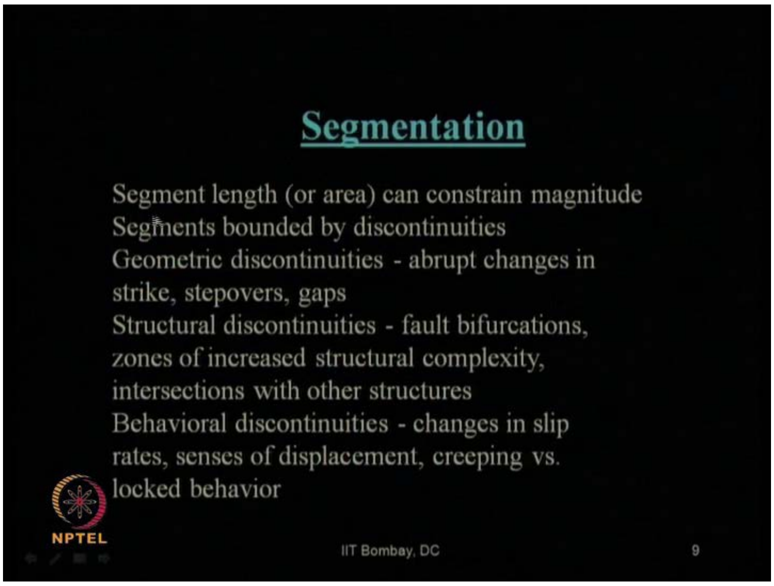

So, in this slide we are now looking at segment length or area, can constrain magnitude segments bounded by discontinuities, then geometric discontinuities like suppose, there is an abrupt change in the strike, stepovers, gaps etcetera need to be considered. Then structural discontinuity of this segment, like fault bifurcations suppose, there was a fault going in a particular direction, then there is a bifurcation from that fault there is another sub fault or another sub rupture has been formed.

So, that bifurcation that segment also needs to be taken care of zones of increased structural complexity, intersections with other structures, behavioral discontinuities, changes in slip rates, senses of displacement and creeping versus logged behavior. So, all these characteristics or properties need to be considered, when we are trying to identify a segment, earthquake segment clear.

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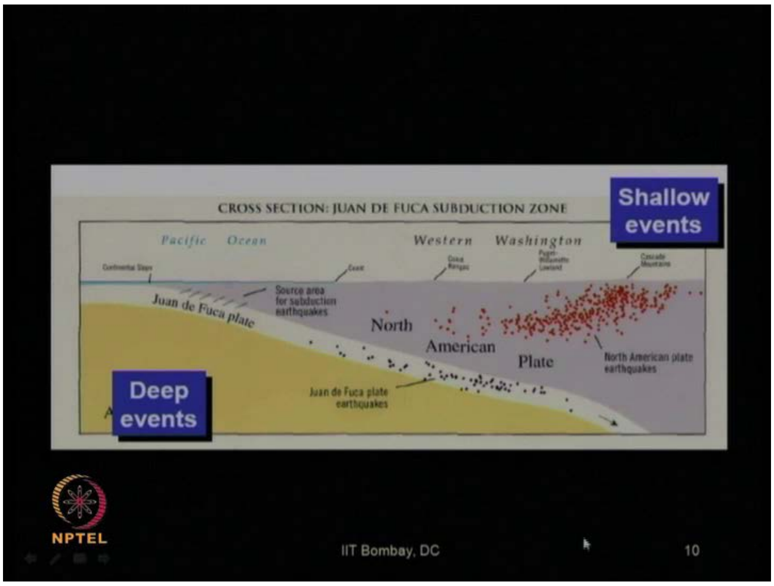

So, this is the picture which shows the cross section of Juan de Fuca Subduction zone, you can see over here, this is Juan de Fuca plate of earthquake, this is that plate. And this is North American plate, this is Pacific Ocean over here, you have source area for subduction of earthquake, this is the portion. Now, North American plate earthquakes are clustered, these are typically the shallow events whereas, here you have the deep events at these locations, below the sea Pacific Ocean over here.

And this is the western part of the Washington, so that is how you have to find out the subduction zone; and once you get the subduction zone. Then next step will be to identify which portion or which segments are responsible for particular earthquake.

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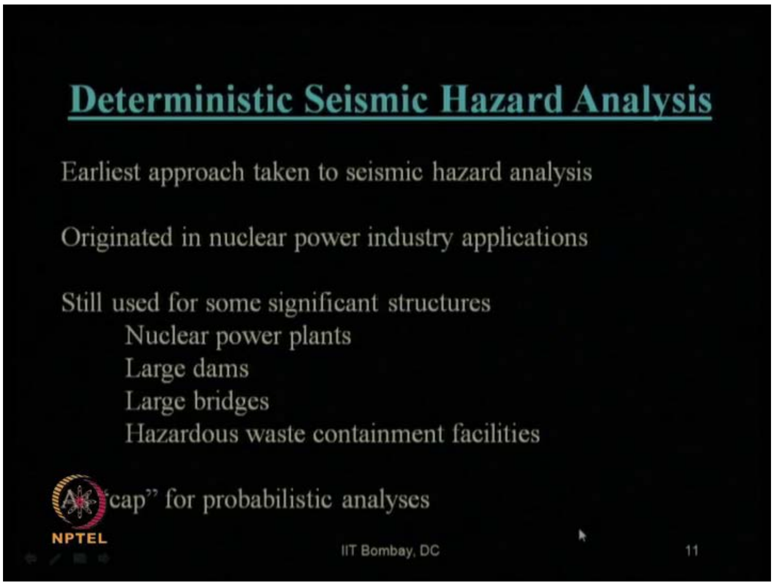

Now, these deterministic seismic hazard analysis whereas, we have initiated we have seen that earliest, this is the earliest approach taken for any seismic hazard analysis, this is the oldest approach, and this is the simplest approach that we have mentioned. It is originated in nuclear power industry applications, like we have seen what are the areas we can apply, what are the important structures, where the deterministic seismic hazard analysis is still used even today also, so this originated from that design consideration of a nuclear power plant.

So, still used for some significant structures or important structures those are nuclear power plants, large dams, large bridges, hazardous waste containment facilities. So, any kind of very important structures as you can see, damage of which is associated with a very severe amount of loss of property and human being, like suppose if a dam breaks; obviously, you can expect there will be a big amount of loss on the downstream of the dam. Because there will be a probably a society entire society may live, on the downstream of a particular dam which is quite possible at some places.

So, that is the reason, why for this mentioned structures one needs to be taken at most caution or maximum caution that is why, though this is the earliest and simplest approach considering the worst case scenario. We have mentioned that already, it considers the worst case scenario to estimate the hazard analysis, or to estimate the design. But still today also it is in use for design, for this particular structure or these particular sites where these structures will come up in future.

Like for India suppose, if we plan for a proposed nuclear power plant at a particular site, if you want to go for seismic hazard analysis, you have to go for deterministic seismic hazard analysis only. Probabilistic will be more logical technically yes but that can be considered as a subsection or just a kind of a looking from the technical point of view how much it vary from your design value, which is proposed through the deterministic seismic hazard analysis.

So, you can see over here, it is mentioned as a cap for the probabilistic analysis, why it is mentioned as a cap, cap means there is nothing beyond that. Because in the deterministic analysis what you are proposing the design data, say suppose design seismic acceleration, peak horizontal acceleration or design value of peak horizontal velocity for a particular site. After doing the hazard analysis taking all the nearby faults into consideration segments etcetera, magnitude indicators everything, then whatever value we will get from this deterministic seismic hazard analysis, that will be the maximum possible or the worst case or design basis value based on this maximum case.

Whereas, probabilistic value considering several uncertainties involve in this process will give you obviously, little lower than or maybe at maximum to that level value, but not beyond that; that is the reason why deterministic seismic hazard analysis values are called as cap of the or maximum of the probabilistic seismic hazard value. That is why you can see over here, it is mentioned in the slide it is the cap for probabilistic analysis. That is suppose, after doing the analysis you get your result as probabilistic seismic hazard value is giving you the higher one than deterministic seismic hazard analysis, that shows you have made a mistake in your calculation, that is the only consideration or output or conclusion one can draw from the results.

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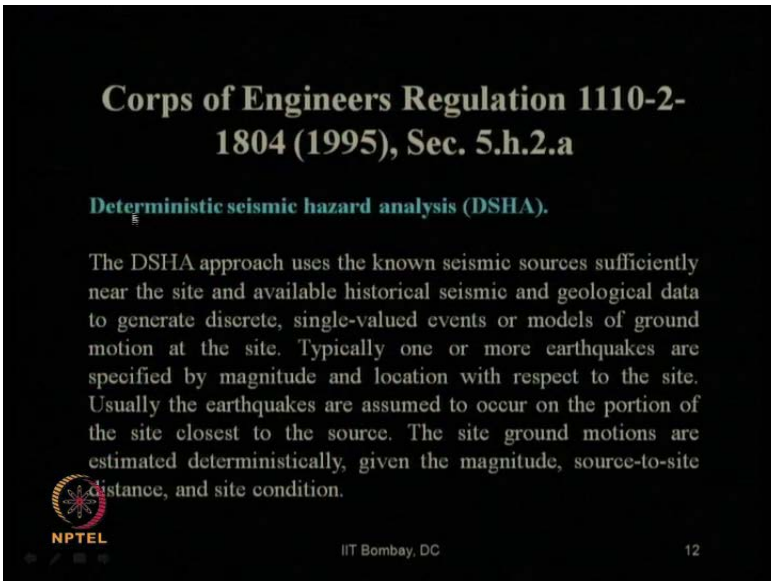

Now, let us see what the guidelines are proposed by this Corps of engineer's regulation of USA, through this clause number and section, number of their manual, which is of 1995 version. Deterministic Seismic Hazard Analysis or DSHA, the clause says the DSHA approach uses the known seismic sources sufficiently near to the site, and available seismic and geological data to generate discrete, single valued events or models of ground motion at the site.

So, first of all it considers all the known seismic sources, known seismic sources means wherever you have identified the fault or if you know what are the plate tectonic movements are involved, or close to that proposed site. So, these are sufficiently near to the site that how much sufficient that quantification depends on your analysis, sometimes some people say it is within 100 kilometer, some people say within 200 kilometer, some people say within 250 kilometer, some people say 300 kilometer; so that depends on your designers choice or the decision of a of an engineer who is going to find out the design value for construction of a structure.

So, near to the site and remember these, near ranges in terms of several kilometers not few meters only, because fault etcetera, geologic fault etcetera can run for several kilometer that we have seen already; that is the reason why it is not only few meters, it has to be in several kilometers. Now, from available historical seismic and geological data, also should be available which should be used to generate discrete, and single valued events of the model of ground motion at the site. So, it should be independent from all the different sources and finally, you should get a single value should be proposed for that site; we will further discuss when we will carry out the analysis, and steps and also example problem very soon.

So, the typically one or more earthquakes are specified by magnitude, and location with respect to the site, so with respect to your proposed site where you are going to design a construct. Your new structure with respect to that you have to find out possible near sources, and for all sources we have to find out how much magnitude of earthquake can occur in those sources, and their location of those sources that is what it means. So, usually the earthquakes are assumed to occur on the portion of the site closest to the source. The site ground motions are estimated deterministically, given the magnitude source to site distance, and the site condition.

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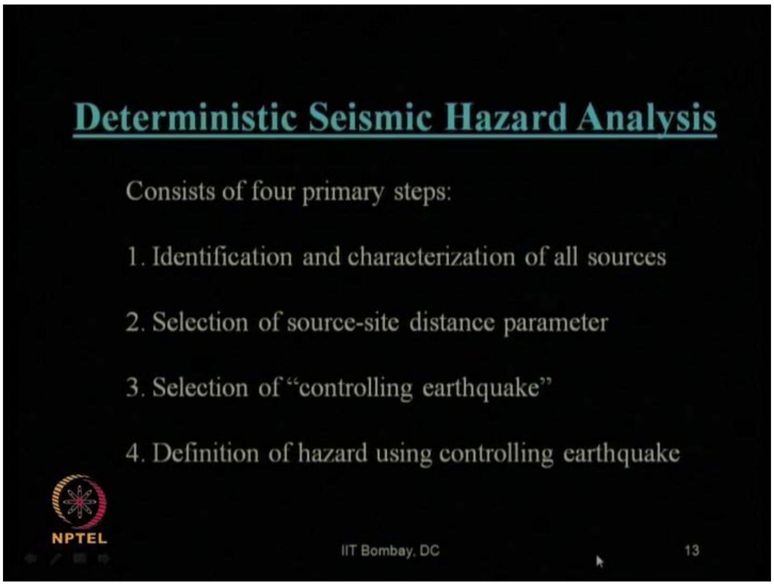

So, let us see what are the various steps of doing this deterministic seismic hazard analysis, there are major 4 steps involved in this deterministic seismic hazard analysis, what are those four major steps, first step is identification and characterization of all sources. That is you first identify all seismic sources close to your proposed site, and characterize them that is what type of source, I will come to that very soon. Next step is selection of source to site distance parameter that is from your proposed site to the earthquake sources, what are the distance parameters, what are the relevant distances you should consider etcetera.

3 rd point is selection of controlling earthquake, means among all the sources which source earthquake controls for your chosen or proposed site that you have to identify. And 4 th step or last step is definition of the hazard, using that concept of this controlling earthquake for your proposed site, so that will give you the final hazard value, for your proposed site.

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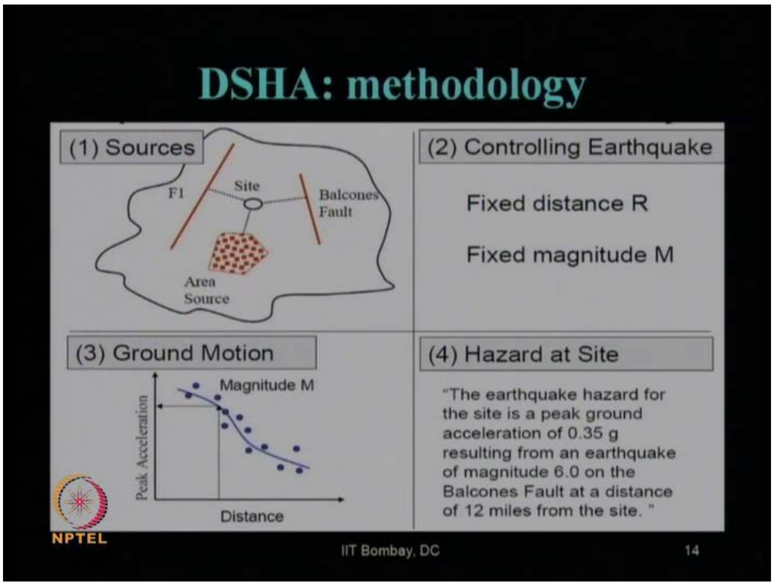

Now, let us see pictorially how it looks like all this 4 steps which I've mentioned just now, so DSHA methodology involves this 4 steps, step 1, step 2, step 3, and step 4. So, step 1 is identification and characterization of sources, suppose this is your proposed site you may have several types of faults, close to that you have to identify all those faults; that is what are the sources of earthquake, from past historical data. And if it is a plate boundary from the tectonic plate movement, from plate movement theory you have to find out their magnitude, you need to find out, and from the fault characteristics everything you need to find out after identifying faults.

Now, these faults can be sometimes like this which is linear fault, sometimes it can be like this which is called as area fault, sometimes it can be a single point which is a point source or point fault, so several types of shapes of this faults are possible (Refer Slide Time: 43:14). So, next what you need to do, you need to identify which one is the controlling earthquake, to identify the controlling earthquake you need to do two things. One is fix the distance R, what is that distance from this site to all these sources, you need to find out all these distances.

When you are talking about distance, which distance you should take like from this site to this fault, there will be this is one distance, this is another distance, this is another distance this is another distance there can be several possible distance (Refer Slide Time: 43:57). Obviously, you have to take the minimum of those all distances, right that gives you the worst case scenario or design scenario, which we consider for our deterministic seismic hazard analysis.

So, you have to take the minimum distance from that site to all these sources, and you have to fix the magnitude of earthquake, that is for each of the fault there will be certain magnitude maximum magnitude of earthquake, which either you can get using that wells and coppersmith equation. Using the fault dimensions or using the plate boundary you can use that Kanamori's equation, (( )) and Kanamori's equation to find out the magnitude of earthquake, which are possible in these sources or from historical data you will have the maximum value recorded at those faults.

So, using all those data, you have to fix what is the maximum of all those values of the magnitude of earthquake; now, next step is ground motion, now ground motion it depends which parameter you are looking at, suppose you want to get the design value of peak acceleration. If somebody wants peak velocity it can be peak velocity, if somebody wants intensity it can be intensity, so it depends on which parameter you want to find out as your hazard parameter right.

For that, you need to use the proper attenuation relationship that is with respect to distance, how that parameter is changing from your particular source. That is from each source, you will have for that particular locality, a particular attenuation relationship available for a hazard parameter, say peak acceleration like this. Then within that depending on your site source distances, maximum magnitude and minimum distance, you can identify what is your that hazard value or design parameter for your site.

So, in the 4th step you report that hazard at the site, which needs to be considered for your design of the structure at this proposed site. So, the earthquake hazard, for the site is a peak ground acceleration, because we are showing here peak acceleration that is why it is mentioned peak acceleration. Just a value is shown say for acceleration of 0.35 g resulting from an earthquake magnitude of say 6 which is the controlling earthquake, on say some fault at a particular distance at 12 miles, which is a minimum distance from the site. So, this is just a typical example is shown, how final data or final output of the result is reported for your design; so this is the final output of your seismic hazard analysis, using this deterministic approach.

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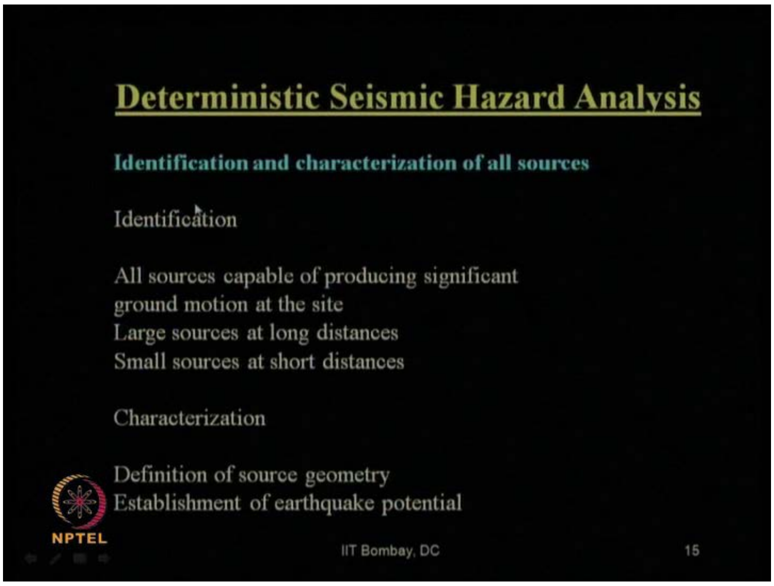

So, now let us see again this identification and characterization of all sources like, all sources are capable of producing significant, ground motion at the site that is one major assumption in this deterministic seismic hazard analysis. Remember, it is considering all sources are equally important, it is not that suppose among those sources, may be few sources are showing very active events in the near future; you cannot give more weightage to those sources, which are more active in the near future.

In deterministic approach you cannot give different weightage to different sources that is what it shows, that all sources are assumed to produce the significant ground motion at the site. That means, all sources has to be taken care of with equal weightage, large sources at long distances, small sources at short distances, all these should be considered.

Now, how that is fixed I will come to that very soon, characterization like definition of the source geometry, definition of source geometry means what type of source it is, as just few minutes back I mentioned, it can be a point source, it can be an area source, it can be a line source, it can be a volume source etcetera. So, that definition of source geometry should be characterized, and the establishment of the earthquake potential needs to be changed.

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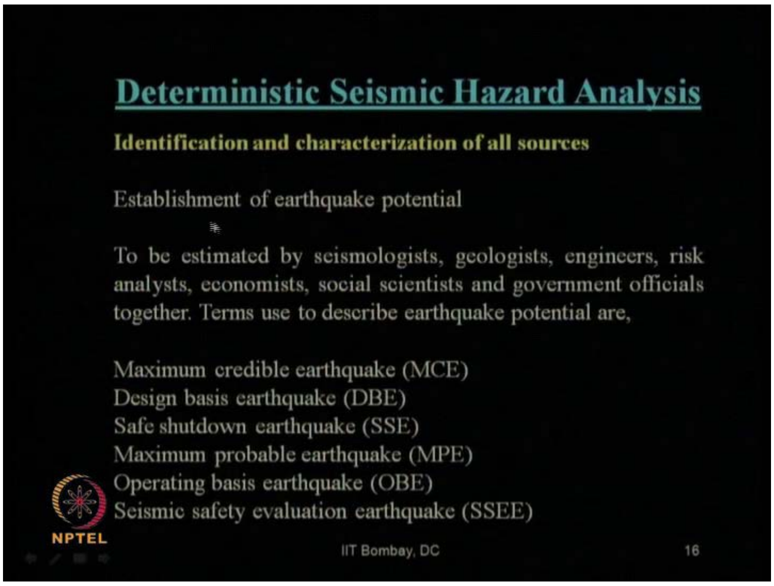

So, now for the establishment of that earthquake potential, it is to be estimated by the seismologist, geologists, engineers, the risk analyst, economist, social scientist, and government officials together. Remember that, what is that earthquake potential for a particular site or for a particular source, that needs to be estimated or identified by all these people involved, it is not only the job of a particular community, it is a job of all together seismologists, geologists, engineers, risk analyst, economist, social scientist and government officials.

Why, because of course, the seismologist, geologist, engineers, they will give the technical values; now the risk analyst will check, whether those values are really admissible or feasible for that particular site. Suppose, engineers and seismologist gave some value of earthquake potential, at a particular location, where there is no inhabitants, like there is no mankind in staying there. Then what is the risk involved, you understood the point, why the role of an risk analyst also come into picture, so risk analyst is supposed to do the risk estimation.

Economist that is also very important, because they have to they need to provide the data, how the economy of that particular region where you are proposing a new site for the calculation of this hazard analysis, how it is changing. Suppose, if it is a stable economy obviously, in that case they can probably take a little extra risk then at a particular location where economy is not stable, not good economy. If it is a poor economy, then it is very difficult to take a risk for a major say nuclear power plant is going to get commission or starting at a particular site, they cannot take risk, so that economist's role is also important, can you see that.

Social scientist, what the social scientist do? Social scientist also see all the social aspects related to the mankind, like their usage pattern of that proposed utility or structure, suppose whether a nuclear power plant or a large dam, which is proposed to be commissioned at that place, how much need for that at a particular location for the human being. From the social point of view they will take all the possible data and information. Then government officials they are obviously, required to provide the all not only the all government support, but also they are the policy makers.

Suppose all these people have proposed something, and suppose government officials do not allow it to occur, then obviously finally the project will not run. So, that is the job of all these group of people together to establish the earthquake potential for source to site to do the deterministic or any kind of seismic hazard analysis.

Now, to do that what are the various terms, technical terms which are used to describe the earthquake potential, these are listed over here, these are common terms which are used to describe this earthquake potential. First one is called Maximum Credible Earthquake, which is the short form is MCE, next is called Design Basis Earthquake which is called DBE, another terminology is Safe Shutdown Earthquake which is the short form is SSE.

Maximum Probable Earthquake the short form is MPE, Operating Basis Earthquake OBE, Seismic Safety Evaluation Earthquake, SSEE; so these are the common terms which are conventionally used to estimate or to describe the earthquake potential of a particular source. So, we will see their definitions and application in our next lecture, so with this we have come to the end of today's lecture, we will continue further in our next lecture.