Probability Methods in Civil Engineering

Prof. R. Maity

Department of Civil Engineering

Indian Institute of Technology, Kharagpur

Lecture No. # 01

Role of Probability Methods in Civil Engineering

Hello and very warm welcome to this course on probability methods in civil engineering. In this course I will try to discuss about several probabilistic method that are very useful in different disciplines of civil engineering; there are several modules in this course material namely about of seven modules are there. And in each module, there are several lectures are there and these lectures are oriented successively in such a way that it will help the audience a step by step understanding or and get some idea about the overall area of this probabilistic method that are very useful in different specializations in civil engineering.

So, today being the first lecture, and this is the only lecture of the first module, and in this lecture basically the introduction will be given and the motivation to learning this methods, and its usefulness to tackle different situation, different field condition, different data analysis will be discussed. And this will be in general for all the specializations that we can those are included in the civil engineering. To start with we will start with the overall discussion for any general problems in engineering, and then gradually we will go to the different disciplines of civil engineering.

So, today's lecture is on the on the probability, and its role in civil engineering though as I told I will start with the general discussion of engineering first. As I told that in the different lectures that will be covered in this course that for any queries - any queries that you may have my contact details are shown here you can contact me directly by email, and this is my home page address.

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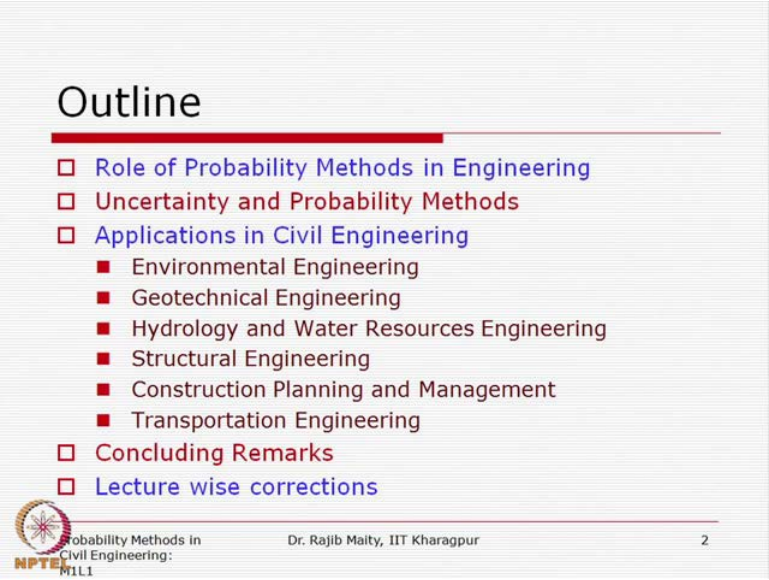

Coming to the outline of today's lecture, first I want to draw your attention to the last point of this outline, where I talk about the lecture wise corrections. So, this is very important, so I request all the audience to see this last component of this particular lecture before they proceed to the subsequent lectures. There are some typos some errors are there in the subsequent lectures, and those will be as discussed here for their corrections for their corrections.

So, after I complete that general thing of today's lecture this will be covered at the end of this lecture. So as I told I will first start with the role of probability methods in engineering in general, basically I will discuss about the concept of uncertainty and why this uncertainty is important, and how the probability methods can help in those situations.

Coming to the different applications in civil engineering, we will try to discuss is the overall view with respect to the environmental engineering, then geotechnical engineering, then hydrology and water resources engineering, structural engineering, construction planning and management transportation engineering, and etcetera.

So of course, this may not be the all the specializations that we can think of in civil engineering there could be other specializations also, but I feel that after the after discussing this things with respect to the role of the probability methods in these field,

the idea can be communicated even the some other areas in civil engineering which are not listed here.

And finally, some concluding remarks and after that the lecture wise corrections will be there, also the reference books for these course has also shown at the end and this is also uploaded in the other web pages.

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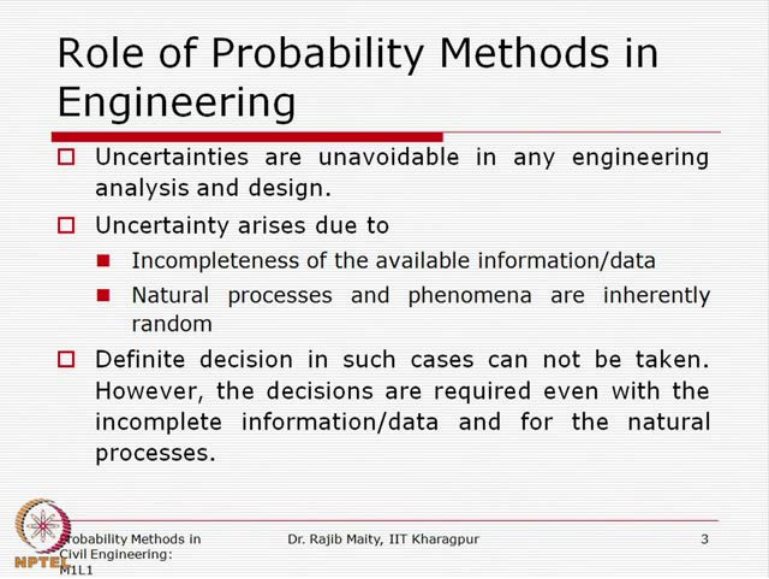

Well, so coming to the role of probability methods in engineering in general first, there are the uncertainties are unavoidable in any engineering analysis and design initially in earlier days, there are some idealized assumptions and simplification of natural processes are considered to ignore the uncertainty. And that help to add up the deterministic of or the quantitative approaches; however such assumptions or the simplifications are not sufficient in many cases, and uncertainties are unavoidable in almost all the engineering analysis and design that we can think of.

So, irrespective of degree of sophistication in the quantitative methods, because these methods are always based on some idealized assumption, so that those assumptions may not be valid under the existence of uncertainty, and this is where the role of probability methods are important.

Now, if we want to discuss about the uncertainty where it comes from and how we can tackle those things we discuss little bit, before we go to those specific discussion how to

handle it, there are there are many sources where from the uncertainty generally arises from say at the two major to broad directions are shown here. The first one is that incompleteness of the available information or data any engineering application that we think of generally based on the whatever our data base, that is available to us for any particular problem that we are handling, now that data source or that data that is available to us is generally not complete. Now not complete or complete to understand this concept in the probability theory, first the two things are discussed one is known as the population, and other one is known as the sample.

Now when you call the population that is the collection of the all feasible data that can, that is possible in that particular attribute that we are talking about say for example, if I take some say some non engineering some non engineering problem, first say that I just want to know that height of a group of the student. So, there the all possible heights that can happen for that particular targeting group of the students that we are thinking of that is giving you the population, now when you want to have some estimate of or any inference from that for that attribute, you have to first take a group of a group students. And you have to measure that that height, so that when you are considering a group of students, and collecting their heights that is your the sample that is your the sample data.

Now that whatever the large sample that you can that you can consider, that will never be the equal size of the population. So, the population is generally a concept where all feasible baloos of the data is available, so that is a concept and the sample data when we talk that is the from that population a particular subset of the data that we are talking about. Now, when we talk about the first the uncertainty, so this is the point that first comes in the in the mind in the consideration is that incompleteness of the available information or the data, so whatever the sample data whatever the information that we are that is available to us is not the complete. So that is the first source of the uncertainty that we are suppose to consider, and this is true for any engineering application that we can think of.

Secondly the natural process and phenomena are inherently random, I can take one example here is that say for example, we are we are analyzing the rainfall data now like rainfall there are several phenomena are there which are which are natural processes, and when we are talking about some engineering application many a times. We have to we have to consider the natural processes and theses natural processes are inherently

random, so you cannot deterministically state the particular value of that of the particular a natural process that we have considered, so those natural processes being inherently random. So, a source of uncertainty is also embedded in that particular data itself so when you measure that measurement, and when we take some record that length of this record, and that particular process those all are constitute if the source of the uncertainty.

So, having discussed about this source of uncertainty, where this could arise these are the two broad things that I discussed, but the so due to the existence of this uncertainty. It is not possible to take any definite decision of any problem that we are that we are thinking of because of the existence of such uncertainty, however the decisions are required even with the incomplete information or data and for the natural process for the for the natural processes. So the even if I do not have that that proper information, even if I do not have the complete data set, but still the decisions are required.

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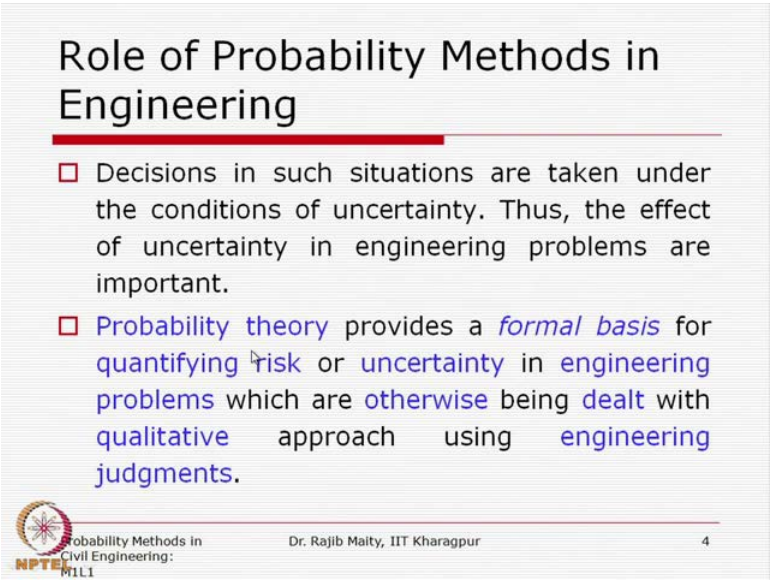

So, here when we are going for this decision, we have to first assist that how much uncertainty is involved in it, so there the probability methods are playing their roles. So, decisions under such situation are taken under the conditions of uncertainty. So, we have to consider the fact that the information that is available. If that is uncertain that assessment of this uncertainty should be carried out first and with that one with that assessment. We have to take some decision so does the effect of the uncertainty in engineering problems are very important, now the coming to this probability theory that

is a role of the probability methods in engineering first in general that it states that the probability theory provides a formal basis for quantifying risk or uncertainty in engineering problems which are otherwise being dealt with qualitative approach using engineering judgment.

So, this probability theory this probability methods that will be discussing in this course giving some concept ideas, some problems also will be discussed those are basically is providing a formal basis to quantifying to assist the uncertainty the risk associated with that particular applications. And after that assessment we can take some decision or we can infer some decision on that particular process which will help to implement some engineering project.

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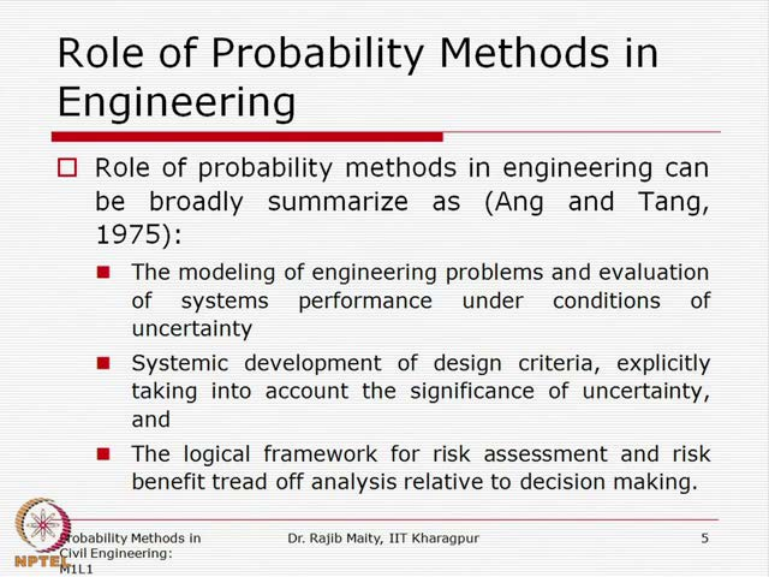

So, broadly again - broadly again the role of probability methods in engineering that we can summarize in three broad directions, and this is taken from this Ang and tang book that text book references are shown at the end, so you can refer to those books also parallel while referring to this lecture note; this lecture recordings - the first one is the modeling of engineering problem, and evaluation of system performance under condition of uncertainty. Now when we are modeling that engineering some engineering problem, and we want to evaluate the system performance so obviously as those we are dealing with some natural either some natural process, and their data involved obviously when

we want to evaluate that how the system is performing that obviously will not be deterministic, and the help of the probabilistic method should be used.

Secondly the systematic development of design criteria explicitly taking into account the significance of uncertainty; that means when we are developing some design criteria particularly when we call that the septifactor is used in all this design criteria. So, when we develop those design criteria those design criteria, which are mostly is some standard codes are developed based on that those things those criteria are based on this probability probabilistic concept, and third one is the it provides a logical framework for the risk assessment, and the risk benefit tread off analysis relative to the decision making.

Now this risk assessment and the benefit tread off is very important in any engineering application that we can think of that means that we can go for a very-very strong or very much safe structures are very much safe engineering product, but at the same time that cost will be very high or we can go we can relax some-some-some requirement, and so that will a reduce that total cost even. If going one step further is that there are two types of cost are also there one is known as the initial cost, and other one is known as the maintenance cost. Now, if the initial cost is high then it is expected that the maintenance cost will be low and vice versa, if the initial cost is low then maintenance cost will be high, so the total cost when we are determining also there is a there is a tread off, and that from the total cost to the benefit, and benefit here not only in terms of this monitory also the tangible and intangible both.

So, that when we go for a some kind of tread off analysis, we have to do that where we should fix the total cost as well as the benefit, so this type of tread off analysis. When we require due to the inherent uncertainty in several aspects of these engineering problems the usefulness of these probability methods is very-very important. So, these are the three broad directions, where the probability methods play a vital role.

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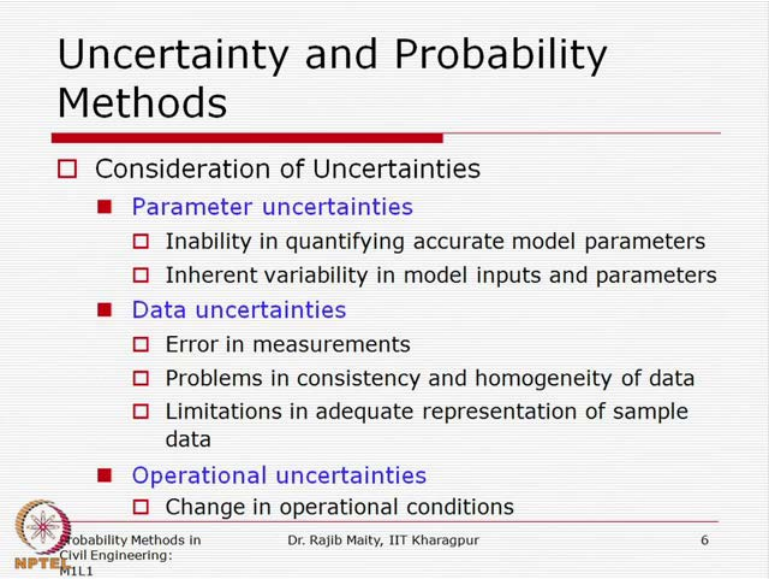

Now the uncertainty and probability method, so as we got some idea by this time is that the probability methods helps us to assess quantify, and understand the implication effect of the uncertainty on any engineering problem. So, we have to so when we talk about this uncertainty and the probability methods; first of all we have to consider the uncertainty and we have to know that where form the measures, so which are the major source of uncertainties here the three broad directions are shown here listed here, here the parameter uncertainties data uncertainties, and operational uncertainties in the parameter uncertainties inability in quantifying accurate model parameters, and the inherent variability in the model inputs and the parameters.

So, which ever model which ever mathematical of probabilistic model that we are thinking of first we have to estimate that parameter, and in that parameter as we are developing those parameters from some sample data, just now we have discussed. What is it sample? The sample data and data itself is not the representation of the complete population. So, that whatever the model parameter that we estimate those are also not definite not the not a deterministic estimates. So, those some uncertainties are involved in those model parameters itself which is known as the parameter uncertainty.

Second one is the data uncertainty, and these data uncertainty may arises from several things - first one is the error is in measurement these error in measurement means when we are talking about that the measurement of the strength of a concrete. Now, how we

are measuring that, so that measurement process may be uncertain when we are talking about the measurement of this rainfall how much rainfall has occurred. So that measurement technique may be may be uncertain, so those are the errors which are which are associated with the measurement techniques of any particular data that we are that we are dealing with, so this is the error in the measurement.

Second one is the problems in the consistency, and the homogeneity of the data sometimes some data that we take from particular location, and it is not as showed it is not guaranteed that it will be specially informed or even that or the temporarily informed. So, this is one and again some times, what happens? That we some due to some reasons-reasons that the measurement process the measurement instrument sometimes is replaced by a new one or a updated one.

So, there if we just see the data there could be problem of the consistency, so that consistency as well as homogeneity in both in the special direction and in the in the temporary direction. So, this could have some problems in this one which leads to the data uncertainty, the third one is the limitations in the adequate representation of the sample data. We will discuss this application when in detail that how from the sample data, we generally estimate the estimate the properties of the population, then it will be more clear so here now the thing is that in briefly.

I can mention that whatever the sample data that we are having having which use that data to estimate to assist that assist the properties of that particular population where from the data is drawn. Now, if the data is if the data does not represent that the population or there are some systematic. There are some systematic or some bias to a particular direction of that probability is of the associated probability distribution, then that assessment then the estimate of this entire population that will make from that particular data will be erroneous, so this is what is that limitations in the adequate representation of the sample data.

And third one is the operational uncertainties, now the some of the conditions under which the particular structural component or the particular process that we have that we have modeled, if those operational conditions are changed then the performance of that particular model or performance of the particular components will change, so this is the change in the operational conditions.

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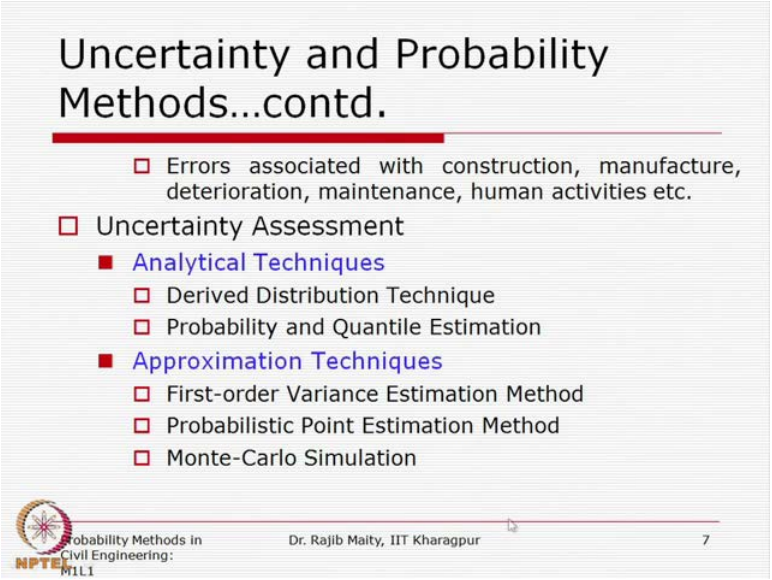

And then the within this again another is so is that the errors; those are associated with the construction, manufacture, deterioration, maintenance, human activities, etcetera, etcetera also leads to the operational uncertainties. Now the once we know the broad source of the of different uncertainty.

Now the second thing is that uncertainty assessment, and there are several techniques are there to assess the uncertainty, and these things will be discuss in details in the subsequent lectures. The first one is the analytical technique, and the approximation techniques in the analytical techniques, we generally try to derive the distribution in a different probabilistic distribution that is known as the derived distribution technique. Secondly, the probability and the quintile estimation that probability estimation from that from the data. We want to know that what is the what is the probability that the value will not exceed this particular value or the value will lie between this particular range; those are the probability estimations, and there are different quintiles' that we can estimate that give some idea about the spread of this data, and its distribution of the of the probability.

So, this quintile estimations are directly associated is a directly computed from the available data. There are other approximation techniques are also there for example, first order variance estimation method probabilistic point estimation method Monte-Carlo simulation, etcetera.

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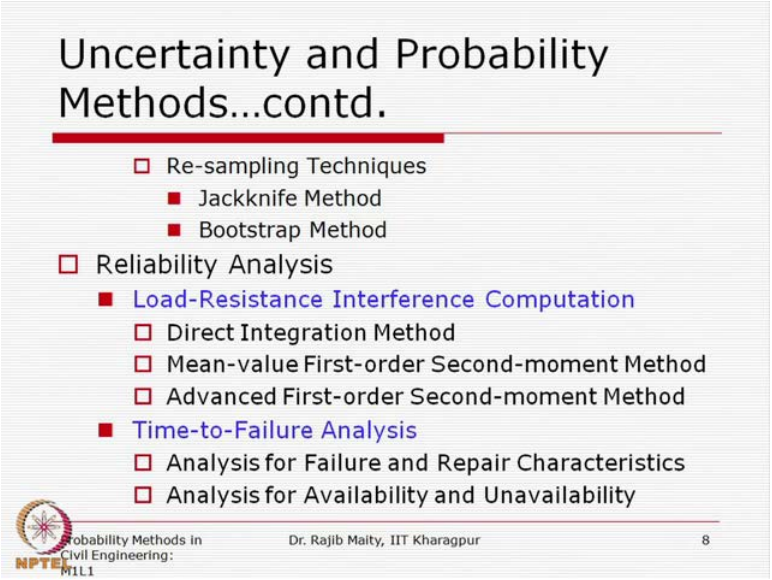

There is re sampling techniques are also available sometimes, when the data set is very small. If we want to increase the number of data points skipping the statistical properties same that time we generally use this re sampling techniques, and there are different re sampling techniques are there the jackknife method bootstrap methods are two examples for them.

Then the now we know that there is the uncertainty, and considering those those uncertainty, there are several the reliable in analysis techniques are there the load resistance inference computation to compute this one. There are several methods available the direct integration method, so this direct integration method means that I have some - some load I have some resistance, and I just want to know that how much reliable that particular system is but please note that when I talk about this load. And the resistance it is not only for any the structural component, but it is also for any other application can also happen. So, here the what we mean the load is that how much is that particular component is suppose to receive, and the resistance means that how this particular structure will stay safe against those external disturbances.

So, I think if I give some example of this water resource application, then it will be more clearer say for example, some water resource project is there on which that how much is that is that hydrologic component, that is a that is affecting that particular system is my

load here. And how long or to what extent that particular system can with stand, so that is the resistance from that system.

So, these things are generally for both for this load, and the resistance that distribution of those load, and the resistance are inferred first, and it is a it is now that from this direct integration method. We compute that to what extent that particular resistance is greater than the load, so in a probabilistic concept of course, so that is the direct integration method there are other methods are also there like mean value first order, second moment method advanced, first order second moment method in the time to failure analysis the analysis of the failure, and repair characteristics is there analysis for availability and unavailability of the different resources. That is required to execute up regular project a project that is for a specific example that I am telling now, so those things are a useful for this time to failure analysis and where the concept of probability is used.

So, coming to the applications in civil engineering as I told earlier that focus of these courses is at the roles of the probability methods in different civil engineering fields, so far we have discussed in general that what are the roles of this different methods in engineering in general now, but this course is for as you can see from the title of this course we will be discussing about the its different aspects of the civil engineering.

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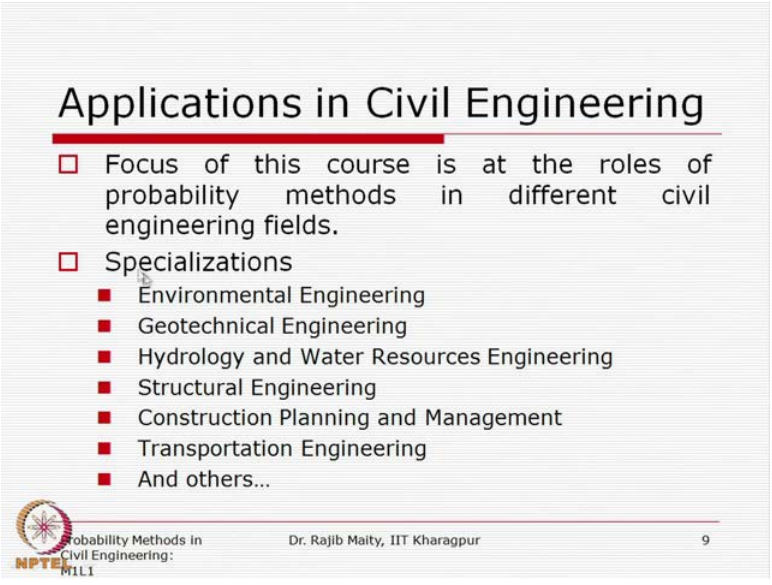

So, you know that this there are different specializations are there, environmental engineering geotechnical engineering hydrology and water resource engineering structural engineering construction planning and management transportation engineering and of course. There are others, the list may not be complete so we will be discussing some of this concept those are related to specific to this particular different specializations.

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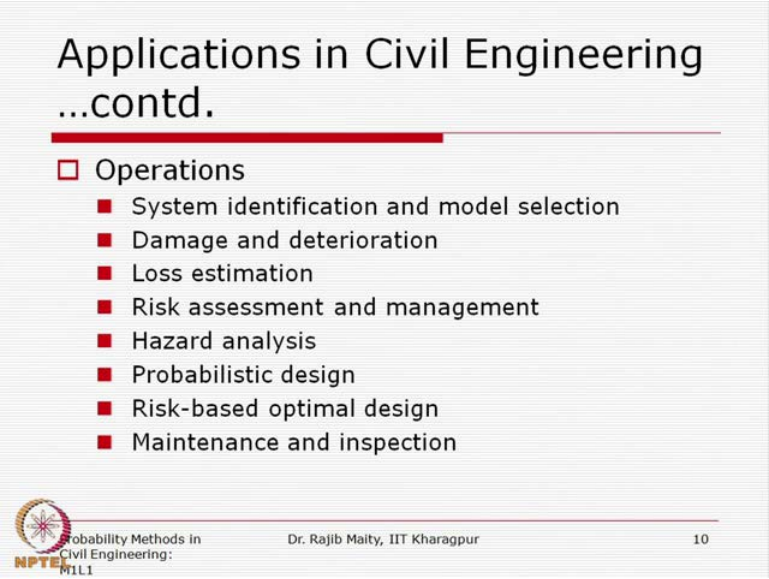

So, these are the different specialization and also that different operation, which are general for all this all this is specializations is the for different operations system identification, and the model selection, damage and deterioration, loss estimation, risk assessment and management, hazard analysis, probabilistic design risk based optimal design, and maintenance and inspection for this things that probability methods are very much used in this aspects.

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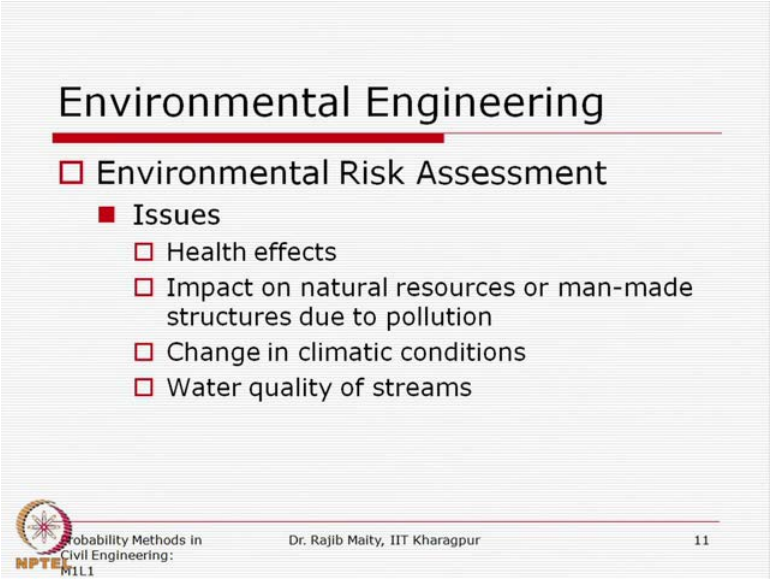

So, coming to the environmental engineering first there is environmental engineering, the environmental risk assessment that several issues are informed in it for example, that health effects impact on natural resources or manmade structures due to pollution change in climatic conditions water quality of the stress of the streams, so these are several issues which are informed in this environmental risk assessment.

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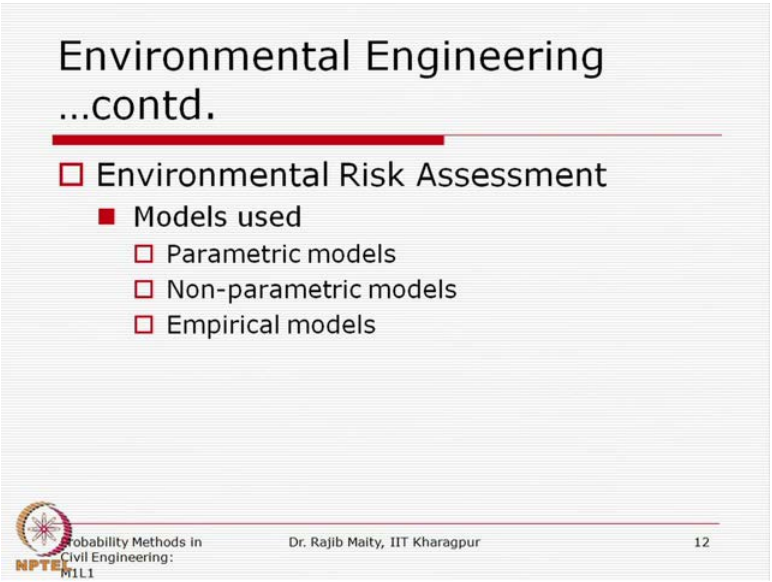

And there are different models are used. One is the parametric models, non parametric models, and empirical models. So, as you as we discuss general that for this model when

you go for some parameter estimates, and all so there the concept of probability methods are useful.

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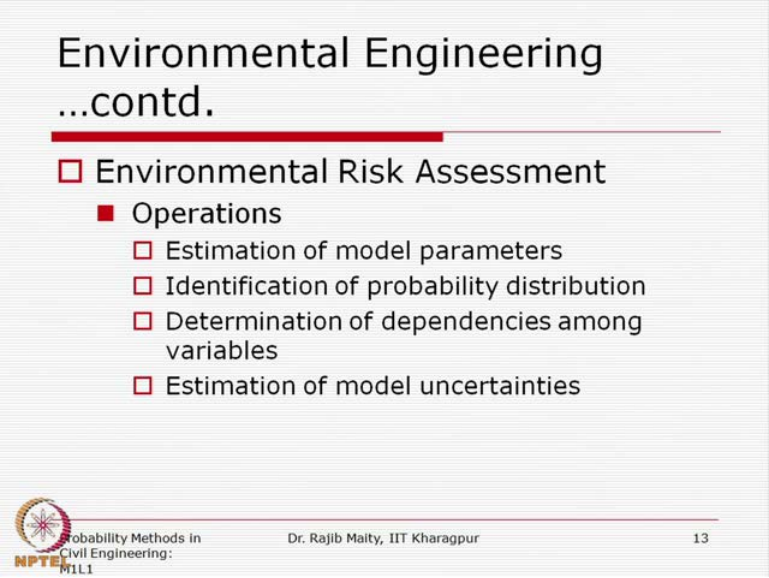

In operations under this environmental risk assessment the estimation of model parameters, then identification of probability distribution for some particular data related to this environmental application, then determination of dependences among the variables. So I, so there are different issues are there are different process which is a in this environmental engineering filled which are generally information to each other. Sometimes how they are effecting to each other whether the quantification of one particular variable can gives some assessment for the other, so this type of application, then an estimation of the model uncertainties, so these are the different operations application where the probability methods are very well used.

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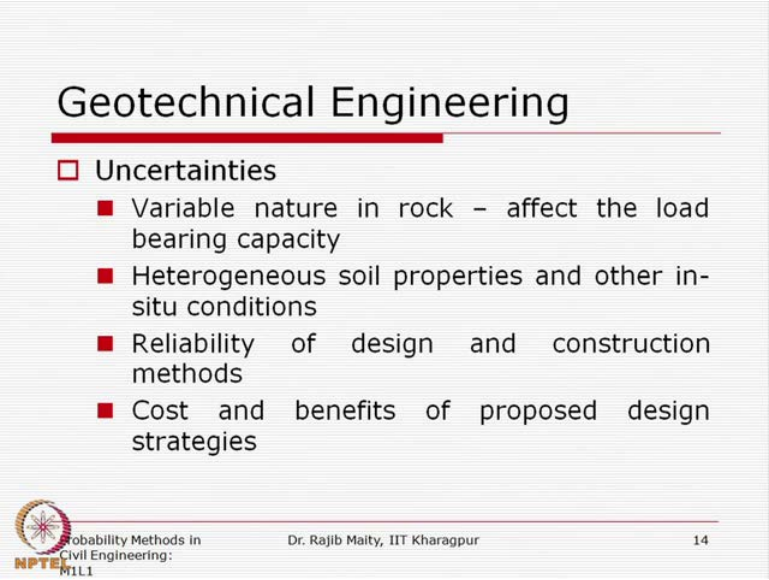

Coming to the geotechnical engineering, there are several source of uncertainties are there; first one is the variable nature in the rock that affects the load bearing capacity. Now, we know that the natural deposits of this rocks as or are having different faults, and features in it which are which are having some impact on its overall load bearing capacity. Now to assist that we cannot inspect each, and every point of the of the rough formation. So, we have to assist the overall load bearing capacity in a probabilistic in a probabilistic manner.

Secondly that when we see that there are some several layers of the deposits are there are from the foundation which are consist of this clay steels, and different layers are there, and these layers are of random, so you cannot so if you just go to the site explore the soil you. We cannot conclude that that is a thing that is having the uniform distribution across the space. So, we have very limited soil sample from the exploration result, but from there we have to assist the overall quality of the sub grid, and from where we can assist some bearing capacity and that bearing capacity will be useful for the design of the super structures.

So, the heterogeneous soil properties and other in-situ conditions so to assist; these things that so these properties are uncertain, then the reliability of the design and the construction method. There are several methods are there, which is followed in design and the construction at site, so those are also constitute the uncertainties in the overall

performance then cost, and the benefit of the proposed design strategies. So, when we adopt some particular design strategy there are some cost involve, and there are some outcome in terms of its benefit, so there is again some kind of a tread off analysis is also required to select a particular combination. And here also in this tread off analysis also the, so that that it is uncertain and the role of probability is a is used.

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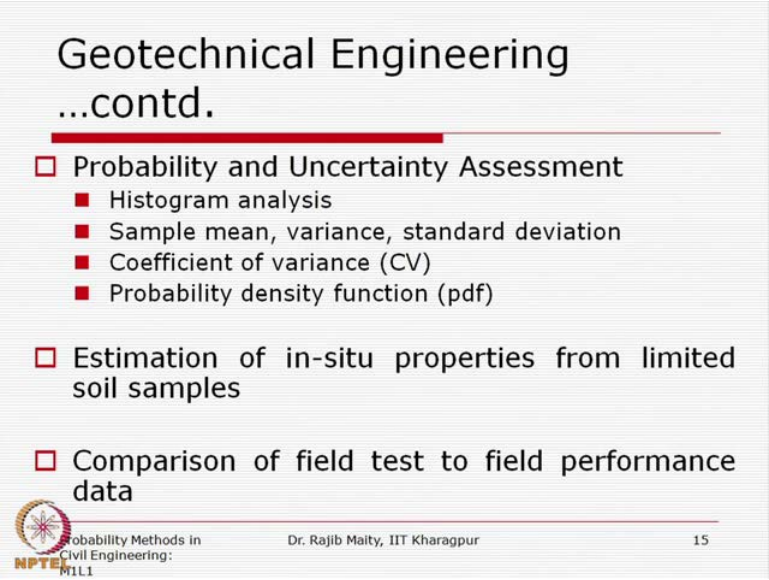

So, the probability and uncertainty assessment, this is carried out through the histogram analysis sample mean, variance standard deviation, coefficient of variance; these are the basic statistics that we use to have some idea about the data. And then the probability density a function estimate, and these things will be again discuss in detail in the subsequent lectures, and also one more point here to be mention here that even if we are discussing, now the geotechnical engineering particularly the soil sample and their exploration, but these things are used for can be used in any engineering application to any particular engineering data that is available to us to assess that overall the basic statistics for those data.

So, here that when we talk about this histogram analysis I can take minute to just tell what is this histogram.

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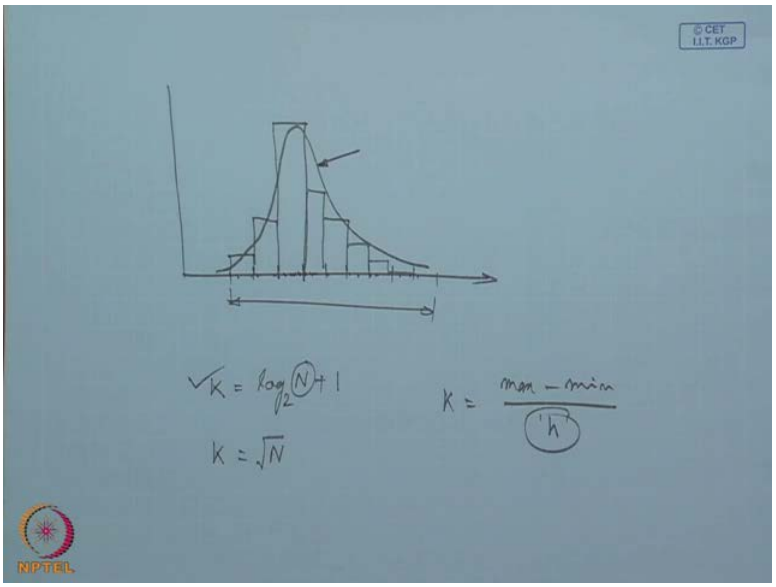

So, we take some that data that is available to us, suppose that this overall range of this data, now for this lower side there could be some there could be some area where the most of this data are concentrated, and then again some distribution is sparse and all.

So, the histogram here means that this overall range can be divided into several bins several bins which are mostly, what we considered to be that equal size. Now in within each bin we count the number of data points that is available that is available and that is divided by this overall the total number of observation. We generally plot some bars and these bar give some, so where ever there are more data set obviously the height of this bar will be will be more.

So, this is known as the histogram of this of this data with generally gives us a idea that how is the data is distributed, and from there are some techniques where we can fit some smooth line, which is known as this probability distribution function so, basically from there this one, we use as a representation of the population where from that data is taken and one small point is that so there are some there is no fixed rule that for this overall range how many bins will be will be consider in this case some times that bins there are some thumb rules are there and mostly we generally use that K equals to log of log 1 base N plus 1.

So, this N here is that total number of observations sometimes we use that K equals to the square root of n some sometimes. We decide that K is equals to that total range that is

a maximum minus minimum minus minimum divided by that some h that which of this each bin. Now these, which of these each bin is for that particular application that we are considering for that particular data that is available to us for depending on their nature. So, that is no fixed rule that how many bins that I will be using to find out this histogram mostly. We use this equation you can use, but obviously this is not that not the only equation that we generally use to decide that how many bins will be there while considering that histogram.

So similarly, that other things we will be discussing in this subsequent lecture then coming back to that, that we are discussing in this geotechnical engineering it is application, application now the estimation of the in-situ properties from the limited soil samples this in brief. I discuss few minutes before that I have very limited soil samples, because I cannot explore the soil every, everywhere in the site so from very limited soil sample. I have to estimate what is the in-situ-in-situ property that I have to assess and in that assessment procedure the probabilistic methods are used then comparison of the field test to the field performance data. So, we compare the testing and their field performance, field performance data, so these are not the one to one correspondence is not there, there is obviously some uncertainty involved in it and we use some probabilistic method.

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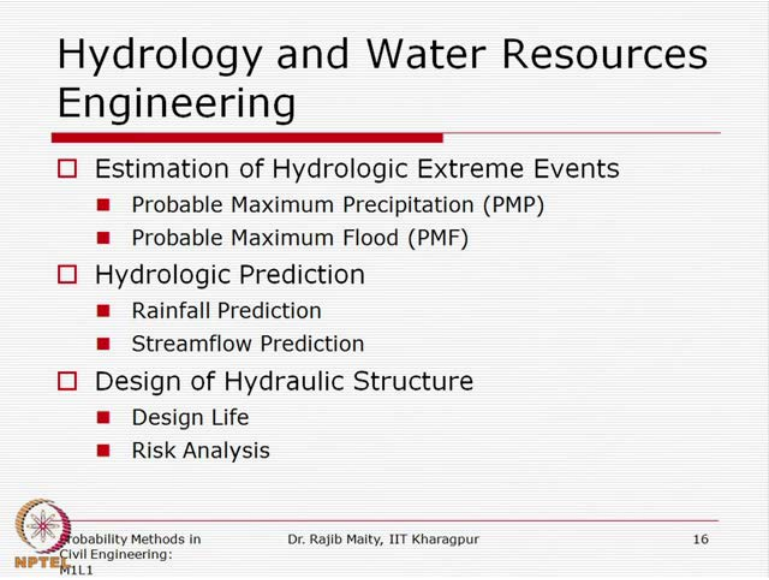

Coming to the hydrology and water resource engineering there are several issues are informed where this role of probability methods is very important, the estimation of hydrologic extreme events for assemble the probable maximum precipitation probable maximum flood. These are basically there is even, before this there is a concept called that estimated limiting value e l v, that estimating limiting value means for a particular climatic condition for a particular site what is if what is the maximum physical value of an hydrologic event that can happen in that in that particular location.

So, that is known as this estimated limiting value now when we are considering that precipitation it is that probable maximum precipitation, and when we are considering that flood there is a probable maximum flood. Now, again this is depending on that. What structure for what for what for your what for you are estimating this particular quantities now depending on the which structure. We are talking about if it is a large dam or if it is a simple drainage network obviously. Those values will change depending on their designed life and if the structure fails what is the consequence on those issues. So, when we estimate this quantities that probable maximum precipitation and probable maximum flood. So, we will have some limited data say that last thirty years, and from that data fitting some probable distribution I want to assess I want to have some idea that what could what should be the what should be my design values design values for the precipitation or the flood for the structure that that I am considering.

Secondly the hydrologic prediction and you know that being the natural process, these predictions are always associated with some uncertainty and to assess that uncertainty. We have to use that different probabilistic methods are being used and similarly, the design of this hydraulic structure when we concept, there are concepts like the design life risk analysis. The design life means that I consider that this particular structure over we suppose to give this as give service for these many years, so the more costly and more important structures which are having some implication their failure may cause a tremendous loss generally we consider very high design life for that so, so that rate of failure will be very low. So, estimation of this hydrologic extreme events hydrologic prediction design of this hydraulic structures so all these things we used that different probabilistic concept.

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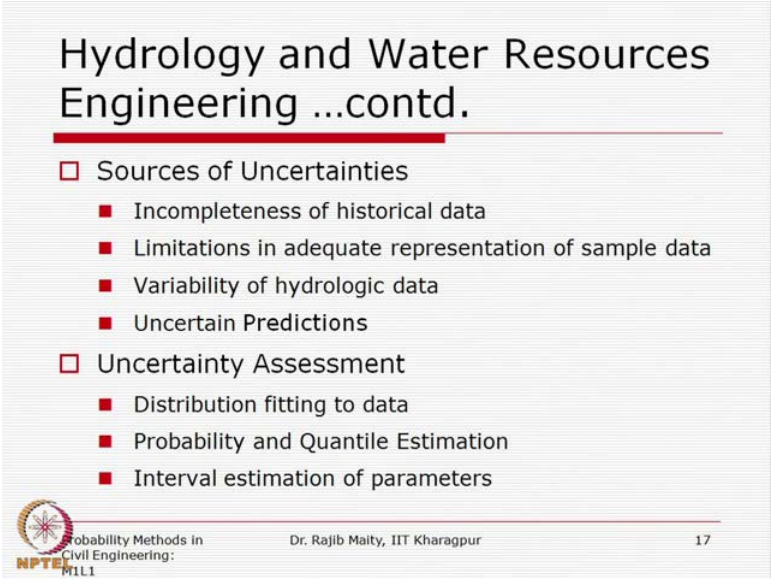

Now the source of uncertainty in different hydrologic events, and water resource engineering projects are mainly from the incompleteness of the historical data that we discuss at the starting of this lecture, then limitation of the adequate representation of the sample data. That is the data is not able to ad not able to represent its population, if it is not then the overall assessment of the population will be wrong variability of the hydrologic data and the uncertain predictions the whenever we are using some predictions from the model. Those predictions are also associated with some uncertainty now to access the uncertainty. Those are involved in this hydrology and water resources we feed that data to some distribution to some distribution means here, the probability distribution function that we are talking about we will discuss in details these things in subsequent lectures then probability, and quantile estimations and the interval estimation of the parameters which are which we can have some estimate from the data available using some probabilistic technique.

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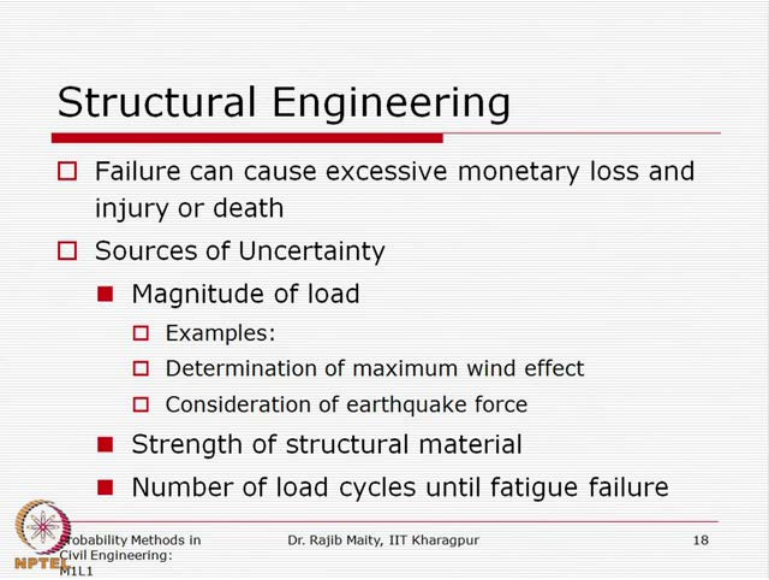

Coming to the structural engineering, we know that the failure can cause excessive monetary loss and injury or death, so this is very important to some times for some structure to keep the failure rate is very, very low. So, when we discuss about the source of uncertainty for the structural engineering there are several source are there the first one itself is the magnitude of this of the load. So, how much load I should consider for example, the determination of the maximum wind effect, if we are considering the some the effect of the hurricane on some coastal structure. The first of all the occurrence of this hurricane itself is probabilistic and once it occurs, then how much load. It should be considered. So, that depends again, again that that depends on that. If we consider that the maximum possible load obviously the cost of the structure will be very high and again, if we do not if we if we relax some of this criteria then obviously the quality of the structure or the rate or the probability of failure will be high, so here that some probabilistic assessment is required.

Similarly the consideration of earthquake force for particular location the occurrence of earthquake with different intensity is also probabilistic has to be assessed probabilistically, and then we can consider that particular load. So in that in that assessment of the load that the structure should face is itself is uncertain. Second one is the strength of the structural material say for example, whatever the quality control you, we maintain while producing the structural material, so that strength there is from one sample to another sample so the strength of structural material, whether we can talk

about anything like concrete or steel or even and composite materials their strengths are also uncertain.

Third one is the number of load cycles until the fatigue failure, so this fatigue failure means that the load that is the that the structure is suppose to it is safe under that load, but it is if there is a cycle of loading and unloading, so of the same load after some cycles the structure fails, and that is known as fatigue failure. So, the number of cycles that a particular structural component can take before it fails is that number is also uncertain, so here the number of load cycles until the fatigue failure is uncertain.

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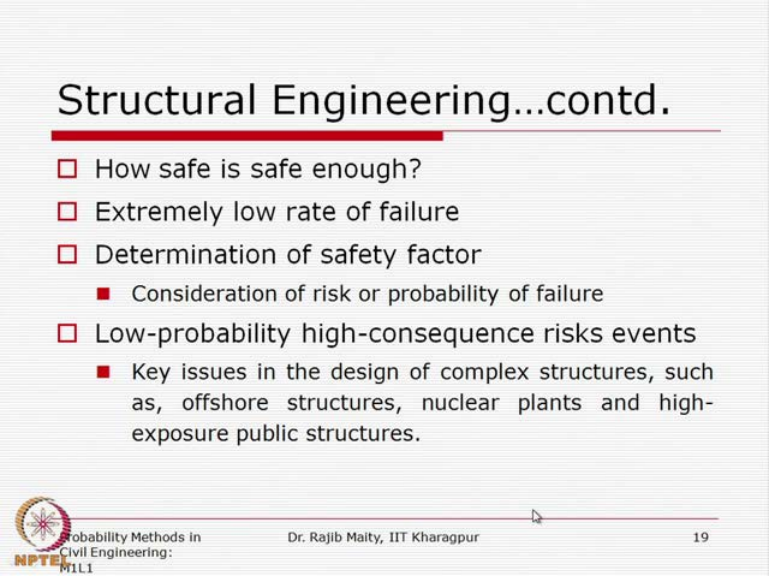

Now, when we call that the structure is safe that time we are asking that the one of the most important coastal and structural design is that the how safe is safe and enough, so thing is that we can never ask you that anything that is hundred percent safe. So, there is no such concept depending on the importance of the structure we develop some criteria based on the probabilistic concept to assess that, so that structure should be safe enough.

Now, extremely low rate of this failure of the failure, so when we quantify that the rate of failure the probability of this failure obviously, we have to use the concept of this probability determination of the safety factor. So, different safety factors are used for different components, so those when we determine that um that safety factor we consider the risk or the probability of the failure of the particular structural component, then low probability high consequence risk events the key. This is basically the key issue in the

design of the complex structure such as the offshore structure nuclear plants the high exposure to the public structure high exposure public structures, where the probability of failure is kept very, very low. Now, when you talking the probability of failure is kept very, very low obviously we are assessing we are using some probabilistic some probability concept.

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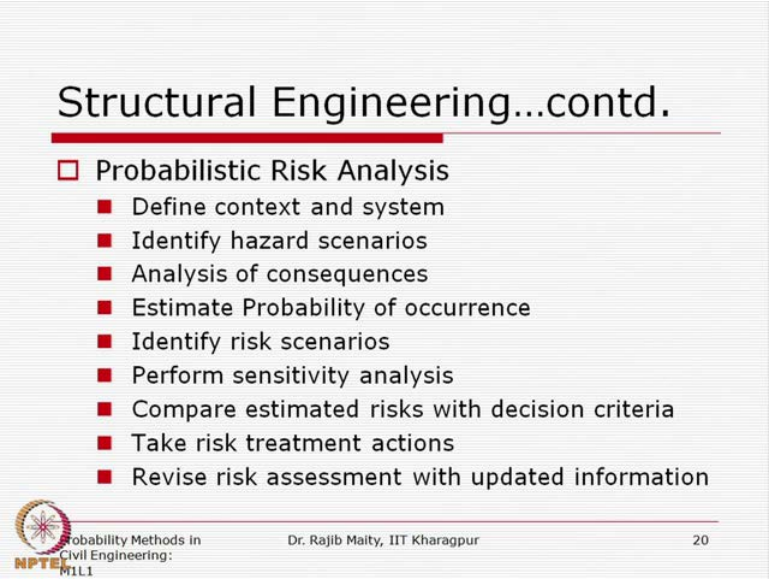

In probabilistic risk analysis their different steps are there first is that the definition of the context, and the system then the hazard scenarios identification then analysis of this consequence probability of occurrence estimation, then risk scenario identification sensitivity analysis, analysis performance of the sensitive analysis. Then the estimated risk with the with that decide , with the decision criteria is compared then the risk treatment action are taken and the risk assessment with the updated information is revised based on whatever the information is available to us. Now in this probabilistic risk analysis steps, you can now you can easily imagine that this the without the without the concept of this probability there are many steps which cannot be completed.

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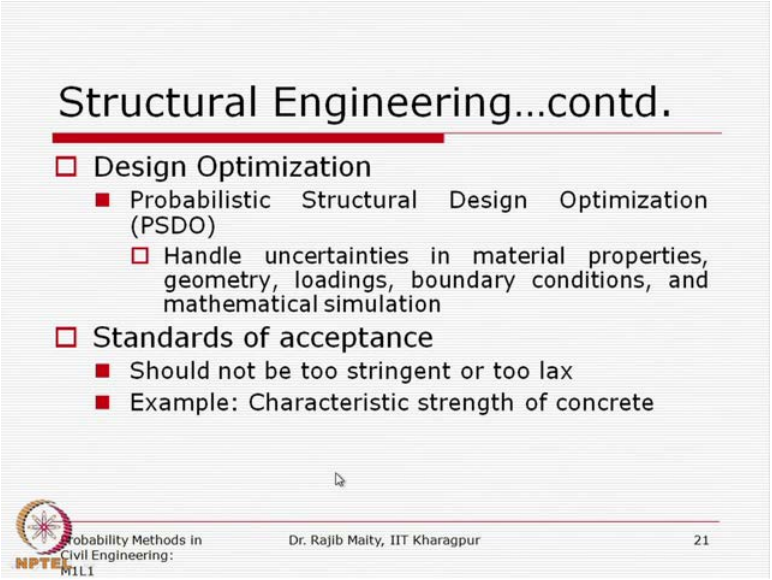

Now, thus design optimization the probabilistic structural design optimization is helps to handle the uncertainty in the material properties geometry loading boundary condition, and the mathematical simulation that we have discussed just now, and the development of the standard of acceptance. There are several codes are there are several design criteria are listed there in the in the different standards and to develop those standards. We use the concept of this probability, and it should be made clear that the criteria should not be too stringent or too lax; one example is the characteristic strength of this concrete you can take a minute on this that when we talk about that the characteristics the strength of a concrete that time.

We use that some concept of this probability again, so we develop some we add up some mixed design and develop some sample and when you test that. What is the load varying capacity for those samples, and it varies from one sample to another sample? Now it is stated in this standards that the strength which is exceeded by the 95 percent which is beyond by this 95 percent of this of the sample that is taken as the characteristic strength, now this 95 percent is the concept is the concept that is coming from the probability, so here when like this. There are several design criteria listed in this in the different standards which are based on the probability concept.

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Coming to the construction planning and management; there are several factors which are uncertain and cannot be stated in a definite a for example, that the duration of the various activities in a construction project that will take. There are several factors are involved in it to determine the duration the timely availability of the material that the time of supply. That is uncertain then availability of the required manpower, that is uncertain the weather condition weather that particular weather condition that particular job will be executed or not, so these are all several source where that, which are making this overall process is very uncertain, but we considering these uncertainty the total duration of the project or the duration of some sub project of this entire project has to be determined with some confidence level. Now with some confidence level means that at some level we have to determine, because that that in that total duration that estimation of the cost is involved.

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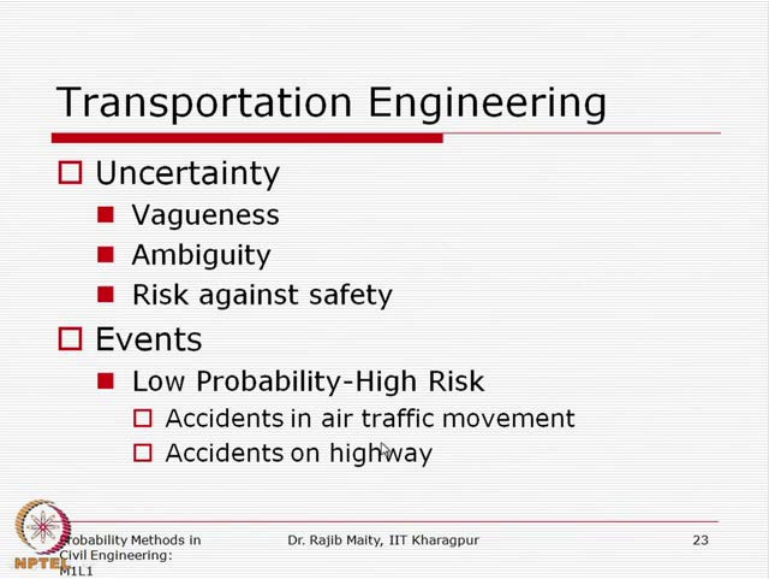

In the transportation engineering the uncertainty generally source from this vagueness ambiguity risk against safety, and the events are generally against the low probability and high risk, the accidents in the air traffic movement accidents on the highway are the examples.

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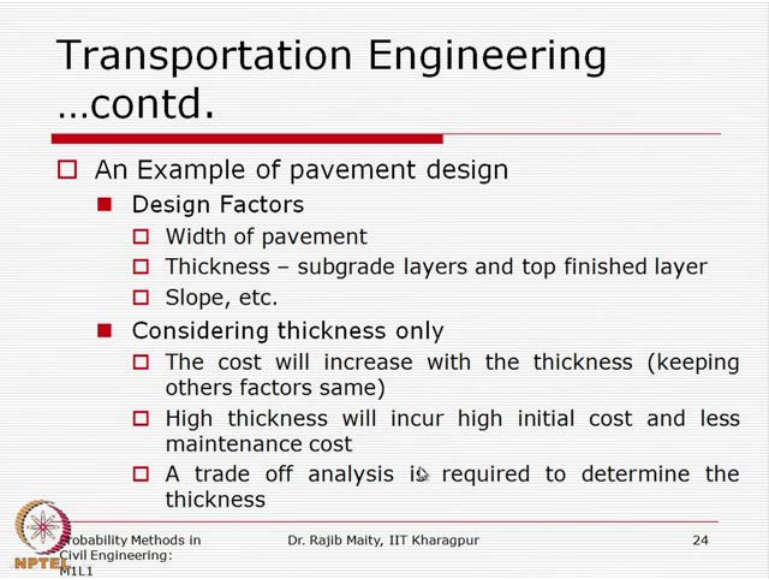

And an example of pavement design can be considered here, design factors width of pavement thickness of the sub grade layers, and also considering this thicknesses the total cost is determined, and the total cost is generally depending on this different factors

say for example, thickness. So, the when we talk about the thickness and the total cost of this pavement there in a kind of tread off analysis is considered, and in the tread off analysis that probability methods are used.

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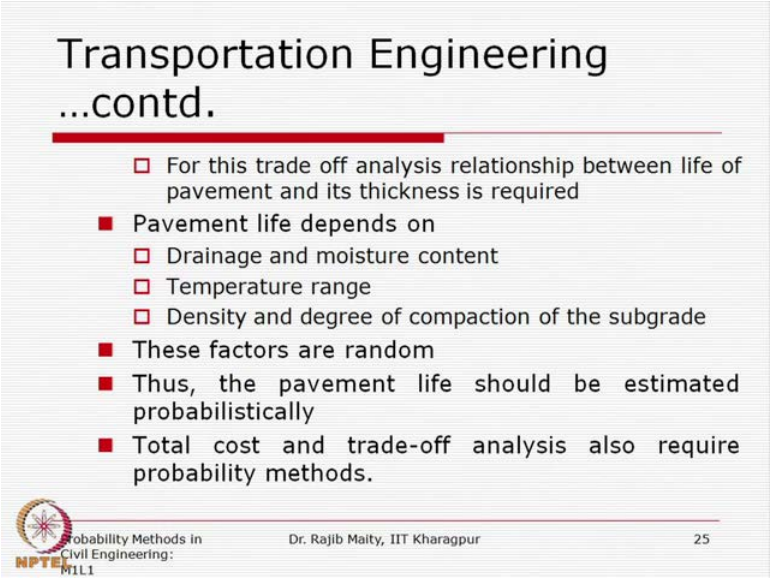

So this is that these all these factors are random that we have discussed, and their tread off analysis and the total cost estimation, we have to use that different probability method are being used.

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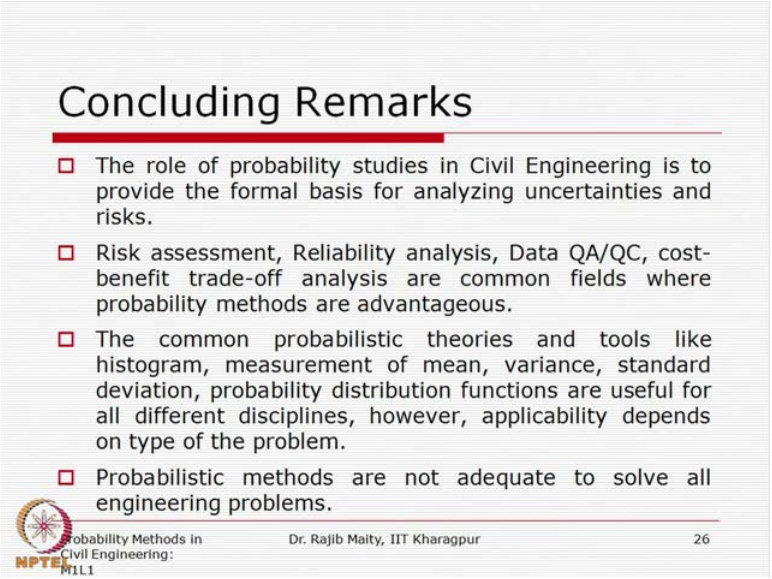

So, coming to the conclusion that role of probability methods generally lies in the generally lies in the assessment of uncertainty involved in different engineering process, and from these once we assist this uncertainty these information is useful to draw some decision to inform some decision to give some judgment based on the to the particular engineering application, and for this the different probabilistic methods are being used which will be discussed particularly with respect to the applications in the civil engineering.

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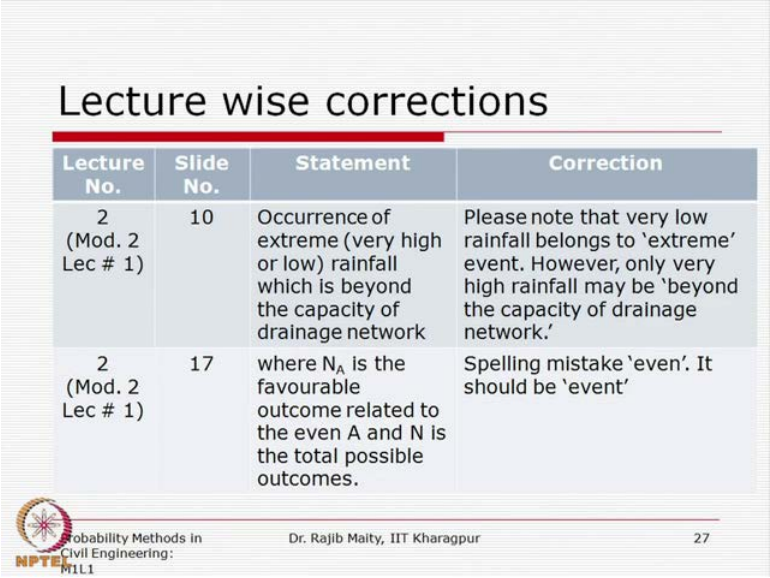

As I told at the starting and that there are some several lecture wise corrections are there, so the first column if you see that gives you the which lecture number which module and in that module what is the lecture number. So, here this number is overall lecture number, and this lecture number is that within that module what is the lecture number. Second column refers - second column refers to the slide number, third column is a what is the statement that is made, and the fourth one is that what should be the corrected one.

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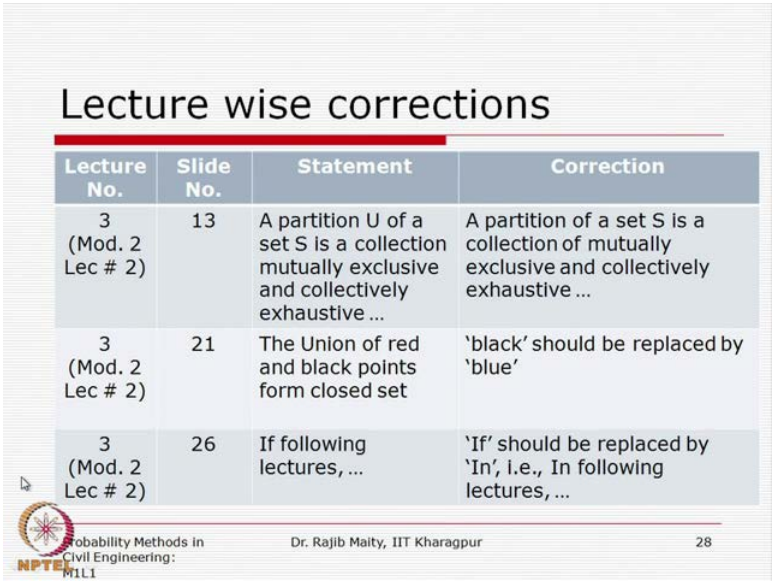

So, like this you can just refer to this few slides to there are some typos are there are there which are corrected here.

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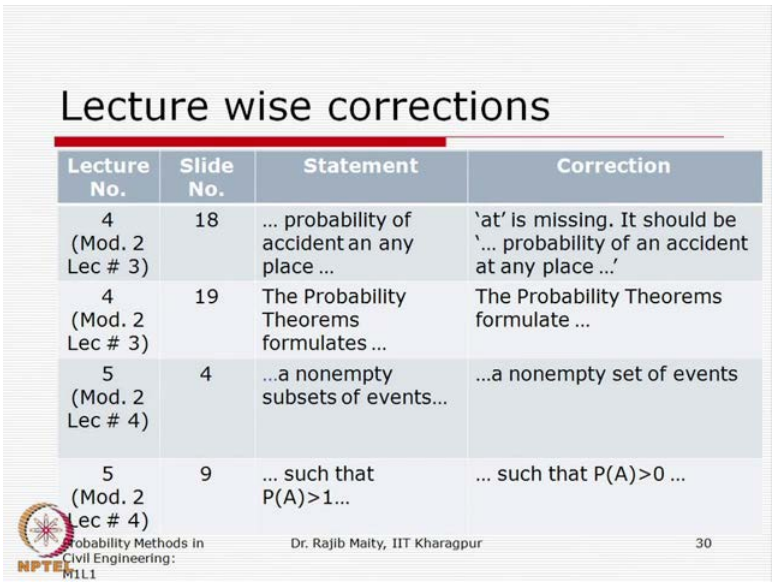

So, this thing can be referred to, to avoid any confusion well.

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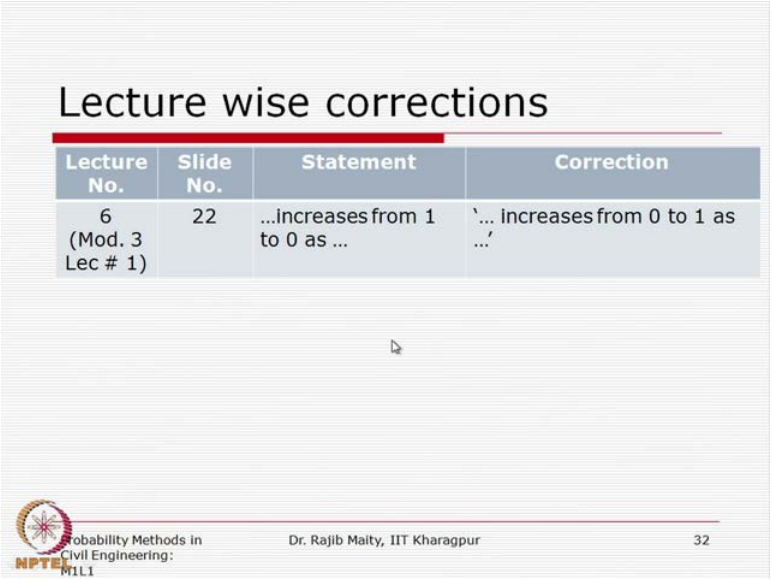

So after stating all this things I hope that you will get some idea about this mistakes or typos and all, even if I cannot tell you these are the only if are there, and I am assuming that the audience will be able to have that ability to identify those typos are there in the line of the examples that are there, but mostly it is is limited to the this few corrections.

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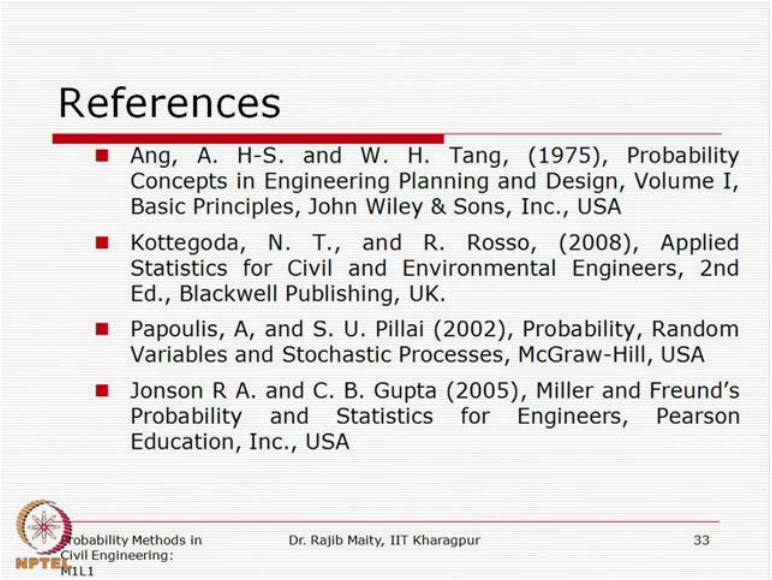

These are the references that you can refer to in parallel to the referring to these subsequent lectures, and this is all about that our today's introductory class and we will see again from the next lecture onwards, thank you.