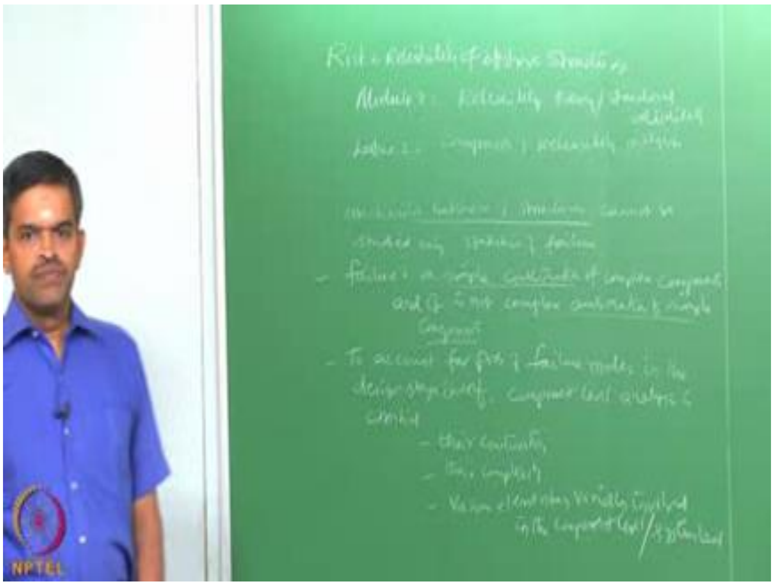
Risk and Reliability of Offshore Structures
Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module – 02
Reliability theory and Structural Reliability
Lecture – 02
Components of Reliability Analysis

(Refer Slide Time: 00:29)



Welcome friends to the second lecture on second module title course on Risk and Reliability of Offshore Structures. So, in module-2 of the course on Risk and Reliability of Offshore structures in module 2, we are focusing on reliability theory and structural reliability.

In this lecture, which is the second lecture in module 2, we will talk about components of reliability analysis, what are the various components which take part in the reliability analysis. We already said in the last lecture that mechanical behavior of structures cannot be generally studied using statistics of failure. So, mechanical behavior of structures cannot be studied using statistics of failure.

Even if you have a data let say about 10, 15 structures of offshore structures, where you have got a data how they are fail what are the material degradation happened, what are the cases where the overloading occurred, where are the cases reporter for accidents and shocks etcetera. Even if you have a good statistics of data which resulted in failure of those structures based on that statistics you cannot infer mechanical behavior of the present set of structures that is not a fair idea.

Therefore, we already said that failure is a simple combination of complex components; instead and it is not a complex combination of simple components. So, the complexity essentially arise at the component level when they assemble together then we try to combine them as simple as possible. So, the combination is simple, but the components participating in the combination are used to combine or complex in nature. So, essentially complex combination of simple components is what actually seen in system reliability.

So, this will lead with system reliability of course, this will lead with the component reliability. So, therefore, to account for probability of failure, which may happen or to account for probability failure modes, let us say various failure modes. In the design stage itself, it is important that the elementary variables and relationships components and system are required to be examined in detail. So, component level analysis is essential because this will give hint about their combination, their complexity and various elementary variables involved in the component level and system.

(Refer Slide Time: 05:26)

Therefore, such preliminary analyses become very important, and why tell for identifying the potential failure. So, what is it mean this implies that if component level analysis accounts for various factors that arise from the elementary variables, then this can result in reduction of this, you can rather minimize risk. If you are able to do this then one can proceed with a design even without reliability analysis. So, if I able to do a preliminary level analysis very effectively which takes care of various factors that arise from the elementary variables this will obviously, result in risk reduction. If we are able to achieve this goal at the preliminary level analysis at the component stage itself then a detail reliability analysis may not even necessary.

Therefore, theoretical reliability is calculated or is performed based on the ideal representation and modeling which are ideal representation. Whereas, practical reliability will be use to address the quality control issues which we discussed in the last lecture, so we said reliability can be also connected to quality control so that is where the practical reliability comes into play. However, if we are able to use an ideal situation of the data sampling and modeling then that will lead to theoretical reliability analysis. Let us quickly compare various components in the design level in the construction level and see where we talk about theoretical reliability and where we can talk about practical reliability.

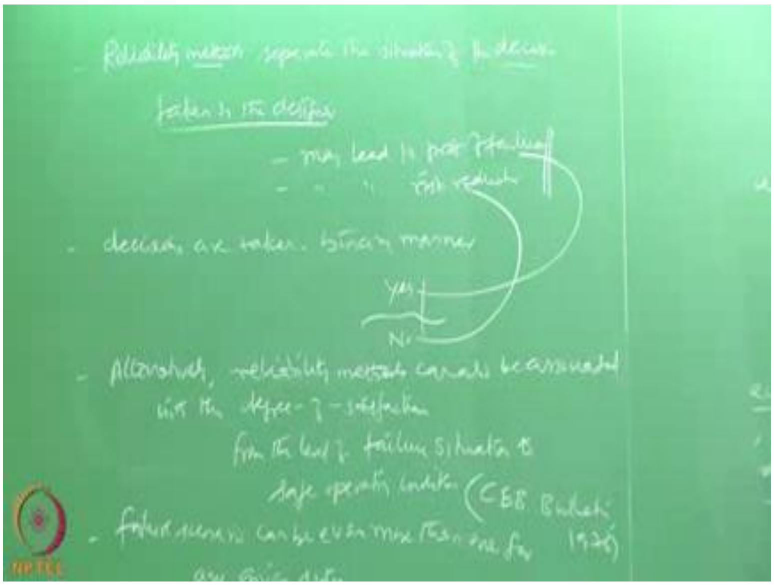
(Refer Slide Time: 09:21)

So, let us say table, which is indicating theoretical and practical reliability. In the design stage, it is important to analyze all possible failure modes which arise which are the elementary variables because in failure analysis the variables could be the failure modes. It can also come from component level analysis because you know elementary variables, which lead to the failure mode or essentially at the component level, it can also lead to system level analysis, which will ultimately lead to risk reduction, so these can all happen at the design stage.

When you come to the construction and maintenance stage, then we are more worried about the quality assurance. So, it is necessary to verify the construction process for its clearance with that of the design proposed. So, whatever design has been proposed exactly that should be constructed. So, whatever assumptions we are made in the design they are got to be ideally followed all those things have to happen. So, since we are now checking whether the construction process is going to follow the same as assumed or as proposed in the design procedure, we call this as quality assurance. Of course, this is also a reliability analysis only. We are anyway in both the cases be it a design stage or be it in construction-maintenance stage we are only aiming at risk reduction or avoiding the probability of failure.

Therefore, practical reliability is essentially quality assurance and quality control. Theoretical reliability essentially is conditioned by practical reliability. So, theoretical reliability is condition verified updated by practical reliability. So, one can say theoretical reliability is therefore index or measure so it is indicate. Whereas, practical reliability is no more an indicator it is a verification process; it is quality control or quality assurance; you have to implement. So, this is more or less related to the routine job where as this more or less related to the innovative stage that a difference between practical and theoretical reliability states is.

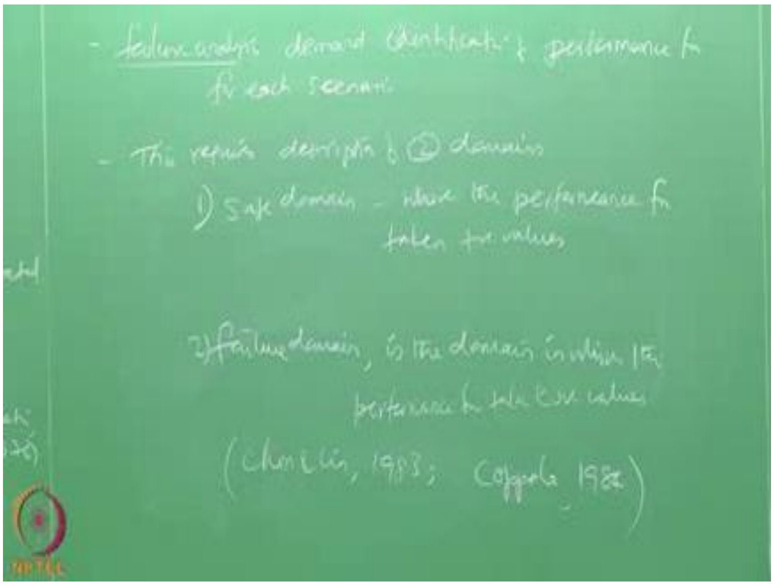
(Refer Slide Time: 14:48)



Now, reliability methods which are we are going to discuss in detail. Various reliability methods are referred the literature, they actually separate the situation of the designer or let us say of decisions taken by the designer. So, now, the decisions taken by designer may lead to probability of failure or on the contrary may also lead to risk reduction. So, even verifying this is also a reliability method. So, depending upon what is the method you are choosing which will always lead to validating or assessing or checking even the decisions taken by the designer at the preliminary stage or even the decisions taken construction manager during the construction processes.

Now, it is very clear that decisions are generally taken in a binary manner what you mean by binary manner binary manner means whether it is yes or no, there is nothing in between. So, it may lead to either a probability of failure or this reduction we really do not know. So, it is of going for this there is an alternative technique also; alternatively, the reliability methods can be also associated with degrees of satisfaction from the level of failure situation to safe operating condition. It is very interesting suggestion made by CEE Bulletin in 1976. Therefore, there can be more than one failure scenario in a given system. So, failure scenarios can be even more than one for any given system.

(Refer Slide Time: 18:14)



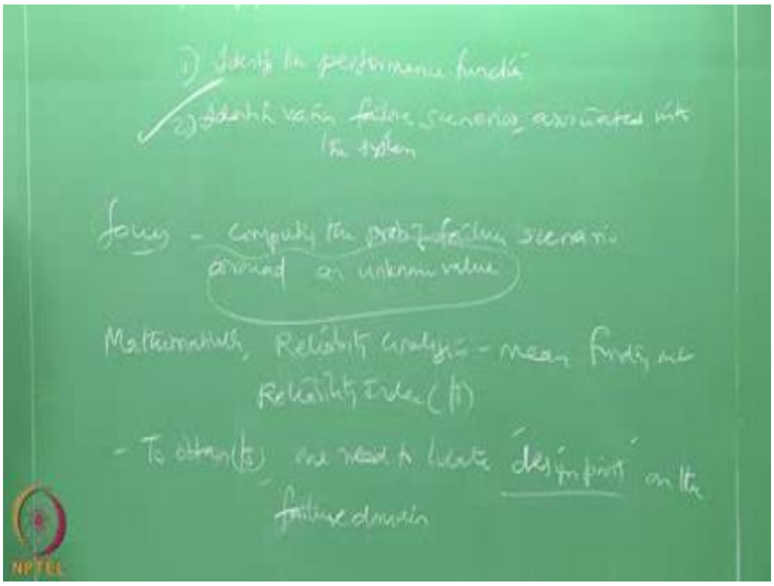
Therefore, for every failure scenario, there should be a corresponding performance function what we mean by performance function it is that function which checks or assesses whether the performance is satisfactory on demand or not. Because we know if we look at the definition of failure back again we already said failure is defined as the non-functional criteria of a given system when required to function on demand for a specific period of time under specific conditions. It is not a structural failure or catastrophic failure or disaster etcetera. It is only non fulfillment of the commitment of the system to deliver or perform a function so performance function for each failure should be identified. So, it is very interesting that the failure analysis which is of course, indirectly the reliability analysis because 1 minus probability of failure is what we call as reliability because reliability is converse of failure.

Failure analysis demand identification of performance functions for each scenario. So, probably that could be the first step in reliability analysis. So, the moment I talk about performance function then I must discuss two domains are describe two domains. So, this requires description of two domains, what are these domains; one is what is called safe domain; other is what is called failure domain.

If the performance function falls in the failure domain then one can say it is going to fail; or on the other hand, it is going to be safe. So, safe domain is the domain where the performance function takes positive values mathematically. Failure domain is a domain in which the performance function takes negative values. So, can one easily understand mathematically, in the failure analysis or reliability analysis in terms of identifying a performance function for each scenario? Why, each scenario in a given system there can be more than one failure scenario.

Therefore, for each single failure scenario, one needs to identify a performance function. If the performance function takes a positive value then we can say it is lying on the safe domain; if it takes a negative value then we can say it is lying on the failure domain. On the other hand, one can infer that is it going to be safe or going to fail, this what Chen and Lin, 1983; Coppala 1984 suggested in simple terms for identifying the probability of failure or essentially reliability method.

(Refer Slide Time: 22:41)

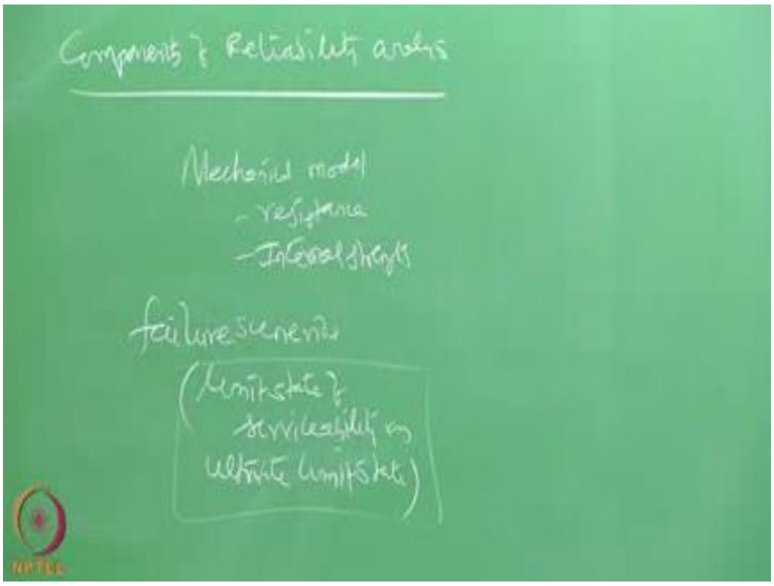


Now, in a whole set of discussions so far we are introduced or focusing on two issues. To do a reliability analysis these set we need to first identify the performance function. This performance function will be associated with each failure scenario. Therefore, we should also need to identify various failure scenarios associated with a system. So, this an additional requirement now we so far we need not bother about we always thought probability of failure can be identified for a given system, because failure is different as non-performance of an intended function adequately on demand under given specific period of time under specific conditions.

But now we have introduced a new statement that performance function will qualify the failure statement or non-performance of a given function, by assuming either a positive value or a negative value, which we say on the other hand safe domain or failure domain.

To identify this one need to actually now recognize or assess or declare or state an additional scenario what we call failure scenarios. So, reliability analysis requires an addition a failure scenario. So, therefore, computing probability of failure scenario around the unknown value is the focus of reliability analysis. So, reliability analysis focus could be computing the probability failure of probability of failure scenario around an unknown value. Mathematically, reliability analysis means finding out what we call reliability index indicated as beta. What should be the basis for this, to obtain beta or to obtain reliability index, one need to identify or one need to locate around an unknown value what we call as design point in the failure domain or let say on the failure domain.

(Refer Slide Time: 26:23)



Therefore, in nutshell reliability analysis will lead to estimating the limit state function, which is a zero performance function. So, one can easily say the complexity in reliability analysis or methods are all only leading to identifying or deriving or declaring this limit state function. Say, if the variables which are participating in the failure domain which are nothing but failure scenarios; if they are bivariant, if they are univariant then depending upon the presence of this or the cross correlation or the dependence of these variables to each other will make the limit state function complex. So, the whole complexity will start in readability analysis and start from identifying what is a limit statement function which is nothing but a zero performance function.

Let us now come to components of reliability analysis. What are different components, which will play a role in reliability analysis? First could be the mechanical model, which will indicate the resistance offered by the material by the system etcetera, which we say internal strength that is one set. The second could be alternatively the failure scenarios to identify the failure scenarios one can obviously, say is it going to be limit state of serviceability or ultimate limit state on what limit state we are looking at. So, there can be failure scenarios. There are various limit states available.

(Refer Slide Time: 29:21)

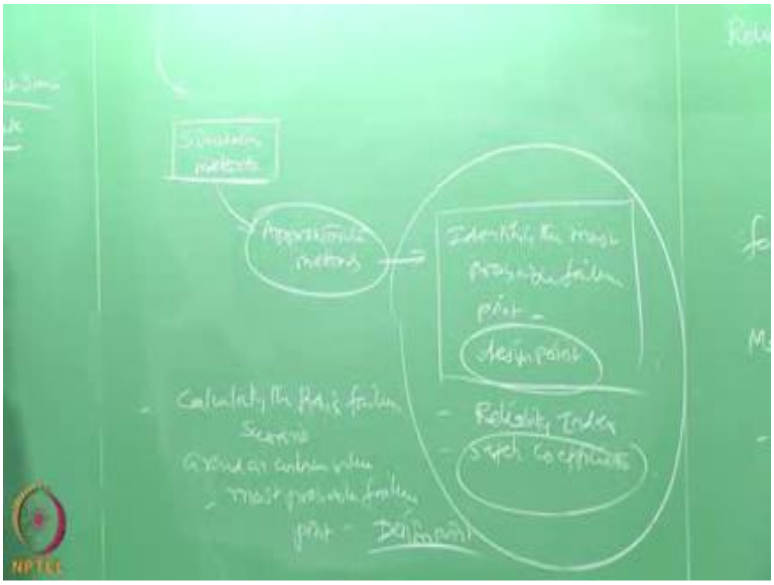
You can refer to my book, Srinivasan Chandrasekaran, 2015 Advanced marine structures by CRC press, Florida. In this book, we explained in detail what are the various limit states, which can be applicable to offshore structures. Now, the two set of data now; one is mechanical model which describing the resistance and internal strength offered by the component as well as the system.

The second is leading to identification of failure scenarios. To identify them I have to compare and say that failure has occurred or not because failure is related to nonperformance of an intended function therefore, I must say what is that intended function is it related to limit state of serviceability or ultimate limit state so we have to declare this in advance. So, let us say this is my one operator or one component so that is going to be a random variable which may have a specific kind of distribution, so the random variable can be let say mu which going to compare these two.

(Refer Slide Time: 30:31)

So, I need a data for this I mean what are the material modeling, what is resistance of the material or internal strength of the material, what are the intended functions the system should perform, so I need a data. So I should be able to generate the statistical information connecting these two and have a distribution model like this so that is going to be one component.

(Refer Slide Time: 31:15)



Now, connecting to this you can generate I will continue here, you can generate various simulation methods, you can generate different simulation techniques can also lead or have approximate methods. So, identify various failure scenarios and then you can say safety or you can check whether the scenario is safe or not. Now, these will lead to identifying the most probable failure point, which we call as design point so that is going to be other component in reliability analysis.

So, one estimate reliability index depending upon the location of the designing point or the value of the design point if you know the value of design point location or coordinates of design point in a given distribution system based on that one can always estimate the reliability index. Then one can always say or estimate safety coefficients I mean it safe by what level one can estimate safety coefficients.

So, all these put together can be another component reliability analysis the first component is of course, the material or the strength from model and the level of performance desired by the user. So, you can either do simulation methods or approximate methods to get this connect this to identify the most probable failure point what we call as a design point.

Once the design point is located one can easily compute the reliability index form the reliability index one can always lead towards what we call safety coefficients. Therefore, in the whole scenario one can see reliability analysis focus towards calculating the probability of failure. We should say probability of scenario let say probability of failure scenario around an unknown value, which is called the most probable failure point in literature these referred design point. So, friends very interesting definition define a design point; design point is the most probably failure point around which the reliability analysis generally is focused.

(Refer Slide Time: 34:36)

Therefore, reliability analysis binds two independent functions; one which is the internal strength offered by the material; second is evaluation of resistance offered with structure of form. For example, let say an offshore structures, let us take for example, a tension leg platform. The structural form actually controls a design we had already discussed this in first module. So, if form dominated design, it is not function dominated design. So, it is important to know the resistance offered by the structural form or the weakness offered by the external forces in the given system. So, in addition to the resistance or the strength offered by the material in offshore structures we have one more complexity because of a system or form dominated designs.

Therefore, one should be also able to deduce the weakness, which is exerted on the system by external forces because of the form for example. The form is highly flexible it undergoes large deformation, therefore that is going to be the weakness of the form under external loads or the structural form is so rigid let say jacket structures for example. They are not affected or lay lie in sensitive to the external forces so the resistance offered by the structural form against the external loads are very great.

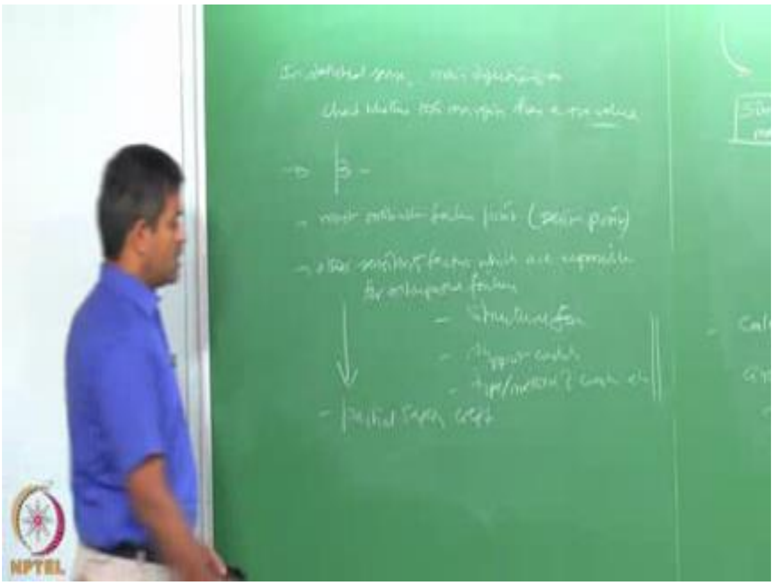
Therefore, the second part of evaluating resistance offered by the structural form is also predominantly important in offshore structures, because offshore structures essentially form dominated design in the present scenario. Because already saw that as an introduction in the first module lectures how offshore structures have been generated from the first phase in early 1920s to in the latest recent trends how the structural form has dominantly change and how the form dominates a design instead of function dominate a design so that is very important.

In offshore structures, in reliability analysis applied to offshore structures there are two issues which are very important of course,, one is common to any kind of structure which nothing but the resistance or the internal strength offered to the material which is required to understand whether the material is not able to function properly or not that is one of the important player even in the reliability analysis.

In addition to this, in offshore structures very specifically, we also look into the evaluation offered by the resistance offered by the structural form because it is form-dominated design; it is not function dominant design in the present scenario. Therefore, there are two complex issues here one is the material strength which will also vary dependent on the directions, modules of elasticity, dynamic modules, temperature, pressure, size, length, etcetera so that is a variable there as we saw in the first set of lectures in first module.

Again we have one more complexity large displacement effects let say the supporting system like hinged joints, ball joints, present in (Refer Time: 39:05), hinged joints present in articulated towers, fairly connectors present in guide towers there are many complexities arising because of the form itself. Therefore, there are many variables, which is going to now affect even one part of the player in the reliability analysis. Therefore, random variables are used to model the uncertainties, but one has got to realize that there is going to be a marginal difference between internal strength of resistance. There is going to be only a marginal difference between internal strength offered by the material and the resistance offered by the structural form so that difference is going to be marginal, but however we must realize that there wills a difference that is needs to be looked into.

(Refer Slide Time: 40:30)



In statistical sense, main objective reliability analysis is to evaluate the probability that this margin has a positive value. Because if it has a positive value then it is safe, lies going to lying this safe domain; otherwise going to lie in the failure domain. So, based on the data certain to external forces structural form and the resistance offered by the form are expressed in appropriate reliability models. So, therefore, it all amounts working out or determining reliability index beta which will check to lie either in safe domain or in failure domain that is first objective in reliability analysis.

In addition to this we should also have to locate the most probable failure point because then only beta can be computed it means beta estimate and location of most probable failure point what we call design point or inter related. Mainly relate this when you come out to exactly the model we will talk about this a design point or inter connected.

In addition to this, there are other sensitivity factors, which are responsible for anticipated failure and these factors can arise because of structural form or let say geometry because of the support conditions, because of the type of construction or method of construction etcetera, there are many. So, therefore, one will not be able evaluate absolute safety factor. So, one looks for partial safety coefficient. So, from this one can easily find out the safety coefficient, but the associated term partial to this because other than these two there are many other factors which are also lead to the failure.

Friends, in this lecture, we are able identify the components represent in reliability analysis. We have also understood what would be the main objective of reliability analysis in qualitative terms, in statistical terms. And therefore, we also said ultimately identifying reliability index which is going to tell me whether the resistance is more than the applied load or not so whether the system is going to fail or going to pass the intended function. But still we associated term partial to that safety coefficient because there may be other factors which will also contribute to the failure which may not be included or inclusive in the mathematical model which consist of the resistance and the internal strength.

Thank you very much.