NPTEL course offered by IIT Madras

Risk and Reliability of Offshore structures

Tutorial 4: Levels of Reliability

Answer all questions **Total marks: 25**

1. **Identify a few practical difficulties in applying theoretical reliability methods in offshore structures**

The failure of offshore structures is a consequence of decisions made under uncertain conditions. This shall deduce to different type of failures such as temporary failures causing shut down of the platform, maintenance failures resulting in temporary uphold of the oil and gas production, failures in design causing decrease in payload or insufficient operational conditions etc. which need to be addressed. In all such cases, definition of failure becomes important. In dealing with design, uncertainties are unavoidable. As the question of uncertainty and randomness of data is central to design and analysis, decisions are made on the basis of information which is limited or incomplete. It becomes therefore necessary to supplement the traditional deterministic methods of analysis by methods which use the principles of statistics and probability. Practical experience, applied with engineering judgment is vital in design of offshore structures. Failure is therefore a simple combination of complex components rather than a complex combination of simple components. The latter case is more frequently encountered when dealing with system reliability. Should all the failure modes be possible in design, relations between elementary variables, components and system are necessarily to be examined. This preliminary analysis becomes a vital step, since identification of potential failure implies the implementations of measures for minimizing the risks, even without any particular reliability calculations.

2. **Explain different levels of Reliability**

There are different levels of reliability analysis, which can be used in any design methodology depending on the importance of the structure. The term 'level' is characterized by the extent of information about the problem that is used and provided. The methods of safety analysis proposed currently for the attainment of a given limit state can be grouped under four basic "levels" (namely levels IV, III, II, and I) depending upon the degree of sophistication applied to the treatment of the various problems.

In level I methods, the probabilistic aspect of the problem is taken into account by introducing into the safety analysis suitable "characteristic values" of the random variables, conceived as fraction of a predefined order of the statistical distributions concerned. These characteristic values are associated with partial safety factors that should be deduced from probabilistic considerations so as to ensure appropriate levels of reliability in the design. In this method, the reliability of the design deviate from the target value, and the objective is to minimize such an error. Load and Resistance Factor Design (LRFD) method comes under this category.

Reliability methods, which employ two values of each uncertain parameter (i.e., mean and variance), supplemented with a measure of the correlation between parameters, are classified as level II methods.

Level III methods encompass complete analysis of the problem and also involve integration of the multidimensional joint probability density function of the random variables extended over the safety domain. Reliability is expressed in terms of suitable safety indices, viz., reliability index, β and failure probabilities.

Level IV methods are appropriate for structures that are of major economic importance, involve the principles of engineering economic analysis under uncertainty, and consider costs and benefits of construction, maintenance, repair, consequences of failure, and interest on capital, etc. Foundations for sensitive projects like nuclear power projects, transmission towers, highway bridges, are suitable objects of level IV design.

3. How errors are classified in Reliability analysis? How are their departure controlled?

Errors departures from acceptable practice are an inevitable part of all human activities. They add a considerable degree of uncertainty to design and construction activities.in fact, surveys indicate that human errors are a dominant cause of structural failure in buildings and bridges. Errors can be categorized according to causes and consequences. Structural reliability is determined by error control. There are two approaches to control errors.

1) By reducing the error frequency

2) By minimizing the consequences

Calculations are checked and jobs are inspected to control the quantity of errors

Classification of errors on the basis of causes and consequences may be useful in the selection of efficient control measures. The analysis of causes may allow for identification of the occurrence mechanisms and lead to a reduction in the frequency. The consequential errors can be prevented by additional control measures and by special design methods.

Errors can be considered with regard to person involved, phase of the building process, place, reason and mechanism of occurrence. There are three fundamental types of errors

1) Errors of concept: conceptual error is an unintentional departure from the accepted practice due to insufficient knowledge.

2) Errors of execution: This is an unintentional departure from what one believed to be accepted practice.

3) Errors of intention: This is an international departure from the acceptable practice.

4. Explain the uncertainties inherently present in the design of offshore structures

Reliability analysis of offshore structures implies estimation of the limit state probabilities of a structure under adverse/environmental loading for its intended period of use. There is a synonymous nomenclature, called safety, which is used to indicate reliability. However, safety is a more traditional concept, while reliability is a relatively new one and offers a probabilistic meaning to the traditional concept. Similarly, risk and reliability analysis of structures are simultaneously used in many literature for expressing their probabilities of failure. But they are not actually one and the same thing. Risk analysis of structures is an extension of the reliability analysis to include the consequences of failure. Despite these finer distinctions, seismic risk, reliability and safety analysis of structures are loosely used in the literature to denote the seismic probability of failure of structures, failure being defined by different limit state conditions. Most important aspect of the reliability analysis is the consideration of uncertainties which make structures vulnerable to failure for a predefined limit state. Accuracy of the reliability analysis depends upon how accurately all the uncertainties are accounted for in the analysis. Firstly, it is practically impossible to identify all uncertainties; however, important ones can be identified.

Secondly and most importantly, methods for modelling and analysing them are not easy and some amount of uncertainty always remains associated with their modelling. Finally, analytical formulation of the limit state surface and integration of the probability density function within the domain of interest are complex resulting in various approximations. As a result, different degrees of simplifications are made in the reliability analysis leading to the development of different reliability methods. Therefore, it is not possible to obtain exact probability of failure of a structure for any event except for very simple ones.

5. Explain the uncertainties that are inherently present in seismic reliability analysis

Generally there are three types of uncertainties, which are dominant in seismic reliability analysis namely, a) randomness and variability of excitation, b) statistical uncertainty which arises due to estimation of parameters describing statistical models, and c) model uncertainty which arises due to imperfection of mathematical modelling of the complex physical phenomena. Mostly, the uncertainty arising due to (a) is irreducible but those arising due to (b) and (c) can be reduced. For example, collection of more data or samples helps in providing better statistical parameters. Likewise, use of more refined model may reduce the uncertainty due to (c). An unified approach for treating statistical and model uncertainties in the reliability analysis is by employing Bayesian updating rule. Model parameters and likelihood functions are updated based on the prior information (knowledge status). With the help of these functions, posterior parameters or models are obtained from prior ones. The posterior ones are supposed to have less uncertainty as they are developed using more data and more observations.