NPTEL course offered by IIT Madras

Risk and Reliability of Offshore structures

Tutorial 7: Structural Reliability

Answer all questions **Total marks: 25**

1. Explain a few set of uncertainties that are inherent to Design of offshore structures

Uncertainties in Design of Offshore Structures can be grouped as follows:

a) Fabrication

- Material availability
- Non- availability of requisite material at required time in sequence of fabrication
- Substitution with equivalent or superior material and size
- Generally a minor issue
- Handled routinely

b) Detailing In Design

- Drawings - generally captured in reviews
- Otherwise, fabricator will incorporate during preparation of shop drawings. Critical items go back to designer for review and approval.
- Fabrication Errors – Captured During Inspection and Rectified

c) Fatigue Analysis

- Stress concentration factors – empirical formulae
- Multi-planar joints
- S-n curve
- Palmgren-Miner linear cumulative damage hypothesis
- What is damage = 1?
- Crack initiation / propagation – fracture mechanics

d) Topsides Installation

Major uncertainty is in lifting, if the design does not match the lifting arrangement or if detailing is inadequate to properly transfer lifting loads the balance structure. Generally they captured in the reviews. Great attention is paid to this aspect.

Sling length tolerances – no impact in statically determinate lifts. Skew distribution in indeterminate lifts.

Routine design factors

Installation

- Rough weather / cyclone! – wait on weather
- Launch – sinking of jacket after launch – failure of buoyancy elements – damaged compartment scenario is part of routine design
- Un piled stability of jacket and mud mat design – jacket toppling during installation – particularly potential in soft soil locations
- Less serious, jacket tilting during installation – jacket lifting and rectification during piling. Standard feature
- Slopes in sea bed – generally captured during surveys – taken care in design- stepped mud mats

Pile driving – drivability-premature refusal: hammer performance, accuracy of soil information, variability of soil parameters and strata

- Overdrive – under drive allowances
- one higher size hammers is normally mobilized
- remedial equipment-pile top drilling rig mobilized
- accept without remedial action based on back calculation of capacity

Accept with reduced factor of safety because remedial action is not possible for any reason

Grouting – inadequate grout strength detected from tests

- Conservative design to cater to this scenario
- Remedial action very expensive, not normally carried out

Grouting- shear keys not available in sleeve due to under drive

- Increased grout strength-special mixtures

e) Transportation

- Rough weather / cyclone!

- Barge + structure system analysed for likely maximum sea state expected during transit through various seas – season, location
- Safe havens during transit
- Damage to barge – barge inspected and certified for seaworthiness, further inspections before mobilization
- Collision
- Grounding

2. Highlight various safe guards that exist in the classical design procedure to overcome uncertainties in the design

Safe Guards in Engineering design

- Owner's engineer reviews and approves all engineering deliverables
- Certification agency reviews selected items land fabrication
- Marine warranty surveyor review and approval of all designs and procedures related to these operations
- Installation agency review and acceptance of all items related to this work

Fabrication

- Extensive non-destructive examination and documentation of fabrication checks
- Owner's engineer, third party inspector, certification agency review & monitor fabrication work
- Any deviation from approved by engineer and owner
- Installation agency, warranty surveyor review of items of relevance to their work
- It is expected that practically all errors, mistakes or anomalies would be captured and rectified during these reviews

Installation

- Installation engineering reviewed by owner's engineer, installation contractor and warranty surveyor
- Every operation of installation is reviewed and approved by warranty surveyor.
- Commencement of any operation is approved only after review of 72-hr weather forecast

- Every operation and critical equipment has a standby / backup in order to avoid any delays due to malfunction.
- Notwithstanding these safeguards, mishaps / accidents have taken place, but generally very rarely an offshore platform is one of the most thoroughly engineered and reviewed constructions, with very stringent norms

Saving grace

- ~ 90% of joints have fatigue life in excess of 1000 years
- Actual critical joints will be 10–20, with computed fatigue life less than 100 years. These are the joints to be evaluated carefully.
- It is very easy to increase fatigue life at minimum cost
- S-n curve is conservative estimate of n2 cycles. There is a substantial reserve available.
- Factor of safety in computed life
- Periodic underwater inspection of critical joints is carried out. Arresting crack propagation, underwater wet welding just below water level in case of cracks are repair methods available.

3. A sample of study was conducted to estimate in situ strength of offshore structures. The sampling was done only on concrete platforms. Destructive testing was followed and core cuttings were made. Test standards suggest that the concrete core should be rejected if at least one out of four is not satisfactory. Estimate the probability that the core cut from the platform is accepted if 100 samples are available and gives poor results?

Let E(i) be the probability of finding that the sample is accepted. For the 4 core being cut from 100 samples, probability of acceptance is given by the following relationship:

P[acceptance] = $\frac{95}{100} \times \frac{94}{99} \times \frac{93}{98} \times \frac{92}{97} = 0.812$

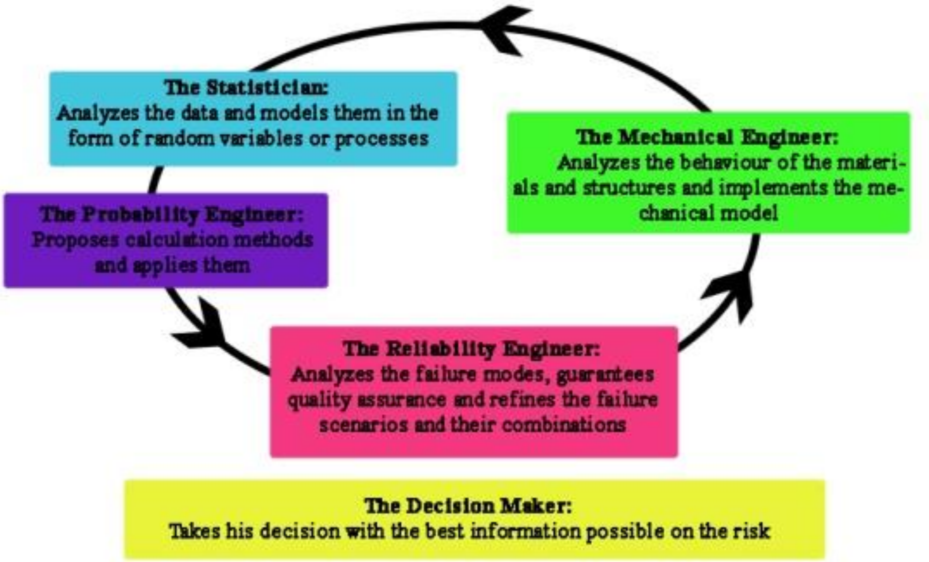
For 50 samples, P[acceptance] = $\frac{45}{50} \times \frac{44}{49} \times \frac{43}{48} \times \frac{42}{47} = 0.65$

For 25 samples, P[acceptance]= $\frac{20}{25} \times \frac{19}{24} \times \frac{18}{23} \times \frac{17}{22} = 0.38$

For 200 samples, P[200] = 0.9

4. Discuss significance of various players in Reliability analysis

Actors of reliability study depend on the nature of the problem posed, but exchanges high interaction between various specialties that collectively provide the decision maker with additional information. For example, i) the statistician analyses the data, conditions them and models them as a function of a predictable use; ii) probability engineer proposes the methods and tools for the calculation; iii) reliability engineer analyses the failure modes, guarantees quality assurance and defines the failure scenarios and their combinations and iv) structural engineer analyses the response behaviour of the materials and structures, and guarantees the proper use of the mechanical models used. Following figure shows their inter-relationship.



5. a) Why maximum correlation value is used in probability distribution?

- *It provides a method for comparing the distribution.*
- *It is also useful in identifying the best value of the shape parameter of the chosen distribution.*

b) Let P(T1) = 0.5, P(T2) = 0.3, P(T3) = 0.2, P(E|T1) = 0.3, P(E|T2) = 0.5, P(E|T3) = 0.4, Find P(T2|E).

$P(T2|E) = P(T2) \times P(E|T2) / \Sigma\, (P(Ti) \times P(E|Ti)) = 0.395.$