NPTEL CERETIFICATE EXAMINATION

Offshore structures under special loads including fire resistant design- SET 1

Instructions to candidates

- ***This question paper contains three sections, printed in FOUR pages. Answer all sections.***
- ***No codes and additional support material is allowed for reference.***
- ***Any data missing, may be suitably assumed and stated.***
- ***Use of calculators is permitted.***

Time: 3 hrs **Total Marks: 100**

Section A: Each question carries one mark. Use appropriate key words to answer

1. Offshore structures are preferably function dominant. State true/ false and validate the statement.
   False. Offshore structures are form dominant.

2. Compliant structures and fixed structures resists the lateral loads by *self-weight* and *relative displacement* respectively.

3. Continuous rotation of the spud can arrangement in the guyed towers will lead to *fatigue failure of the joint*.

4. Give the expression for the resisting moment in articulated towers.
   $$Resisting\ moment = \{[(B\rho - M_B)gl_B] - [M_D g l_D]\}\theta$$
   Where,
   B = Buoyancy provided by the buoyancy tank.
   l_D *= Distance of CG of the deck from the articulated joint.*
   l_B *= Distance of centre of buoyancy from the articulated joint.*
   Θ *= degree of freedom.*
   M_B *= Mass of the buoyancy tank.*
   M_D *= Mass of the deck.*

5. Ball joints restrains *rotation* and allows translation from the buoyant leg to the deck.

6. When the mean square value is unique across the ensemble, the process is said to be *stationary process.*

7. Ice loads on conical structures cause less response. State true/ false and validate the statement.
   True. Well defined cone can change the ice failure mode from crushing to bending.

8. The interaction of ice on the structure will cause *ice induced vibration*, which is measured by monitoring *the acceleration of the deck*.

9. *Kanai-tazimi power spectrum* is used for the analysis of the offshore structures under earthquake loads.

10. *Springing response* is caused by second order waves in mild and severe sea state; and *ringing response* is caused by extremely high steep waves.

11. Non-impact waves cause *heave* response on TLP which will lead to *fatigue failure*.

12. When the trace of the plane of applied moment does not coincide with any of the principal axes of inertia, then the bending is said to be *unsymmetrical*.

13. Write the expression for finding the shear stress on the section.

$$\tau = \frac{Va\bar{y}}{It}$$

14. Winkler-Bach equation is useful in estimating the stresses in the curved beams with large initial curvature only at *the extreme skin layer*.

15. When risers are exposed to the fluid flow, *flow separation* takes place which results in the formation of *vortex shedding*.

16. *Top tensioning* is required to maintain the stability of the riser, when installed in greater water depth.

17. *Flash point* is the lowest temperature at which the liquid gives up enough vapour to maintain the continuous flame.

18. *Deflagration arresters* reduces the risk of flame propagation.

19. High strength steel do not have a *well-developed yield point* and the yield region is *non-linear*.

20. A turbulent diffusion of flame resulting from the combustion of the fuel, and propagates in a particular direction with significant momentum is called *jet fire*.

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Section B: Each question carries TWO marks. Answer briefly

1. List the uncertainties in estimating the environmental loads.
   - *Estimation of direction of approach.*
   - *Estimation of magnitude of loads.*
   - *Return period of the maximum event.*
   - *Non availability of data.*

2. Does the lateral load acting on the compliant platforms get reduced by the structural action of the platform? Explain.

   The lateral loads get reduced. Since the compliant platforms are position restrained by tethers or tendons, the horizontal component of the tension in the deflected tendon will reduce the lateral load acting on the platform.

3. Write the following degrees of freedom in descending order based on the time period of the SPAR platform: Pitch, heave, Surge
   - *Surge: 100-120s*
   - *Pitch: 60s*
   - *Heave: 25-40s*

4. Find the time period of a Tension Leg Platform in surge degree of freedom. The platform has 8 tethers made up of steel, with 1.5 MN initial pretension each and 250 m long, 0.9m diameter. The mass of TLP in surge is 1.5x10^7 kg.

$$(T)_{surge} = 2\pi\sqrt{\frac{m_{surge}\ l_t}{n\ T_t}} = 111.07\ seconds$$

5. Name the essential features of Buoyant Leg Structure that makes the structure insensitive to ultra - deep waters.
   - *Deep draft*
   - *High stability*

6. Compare the different wave spectra and write the inferences based on the following spectral density curves.

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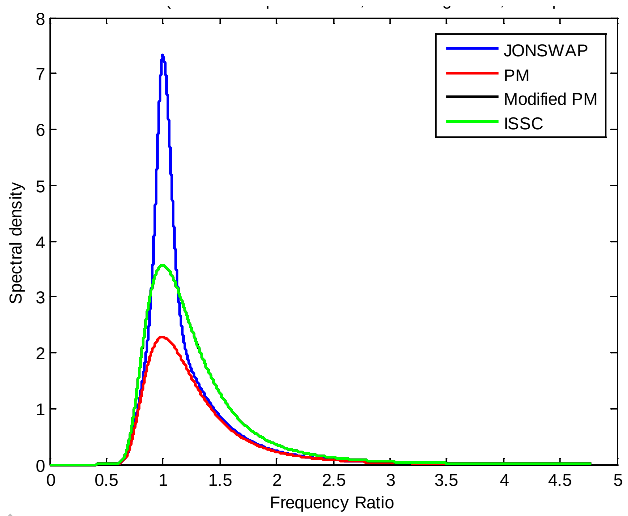

- *The peak value of all the spectrum lies on the same frequency.*
- *JONSWAP spectrum exhibits the highest peak value.*
- *PM spectrum describes a fully developed sea condition and it has the lowest energy.*

7. List the various ice conditions.
   - *Level ice*
   - *Broken ice*
   - *Ice ridges*
   - *Ice bergs*

8. What are the factors that affect the dynamic modulus of elasticity?
   - *Material on which the experiment is carried out.*
   - *Type of test used to find the dynamic modulus of elasticity.*
   - *Shape of the specimen used in the experimental setup.*

9. How the orientation of the platform is chosen based on the wave approach angle?

   The orientation is chosen in such a way that the members should have less projected area on the encountered wave direction.

10. What is the effect of springing and ringing waves on the structures?
    - *Generation of high frequency force.*
    - *Builds up resonance type responses within the period of TLP.*
    - *The frequency of the ringing waves seems closer to the natural frequency of the tension leg platforms.*

11. When symmetrical bending occurs in the members?

- *The plane containing one of the principal axes of inertia, plane of applied moment and plane of deflection should coincide.*
- *The neutral axis should coincide with the principal axis of inertia.*

12. How do you classify the curved beams? What is the condition for the classification?
    - *Beam with small initial curvature.*
    - *Beam with large initial curvature.*
    - *For the beams with small initial curvature, the ratio of the initial radius of curvature to the depth of the section should be greater than10.*

13. What are the types of failure that may occur on the chain links used as moorings in the offshore structures?
    - *Failure due to fatigue crack at the inter-grip area.*
    - *Distortion in the dimensions of the chain along the length.*
    - *Fatigue damage at the weld.*
    - *Erosion at the inter-grip area.*

14. List the different group of risers.
    - *Bundled risers.*
    - *Flexible risers.*
    - *Top tension risers.*
    - *Steel catenary risers.*
    - *Hybrid risers.*

15. What are the consequences of vortex induced vibration?
    - *They can cause alternating pressure field on the surface of the riser.*
    - *Reduction of service life of the system.*
    - *Fatigue damage.*
    - *Induce large transverse motion.*
    - *Causes operational difficulties.*

16. Write the expression for Reynolds number and reduced velocity.

    $$Re = \frac{\rho u D}{\mu}$$

    $$Reduced\ Velocity = \frac{uT}{D}$$

17. Define BLEVE and what are the primary causes of it?

    BLEVE – Boiling Liquid Expanding Vapour Explosion.

    This is caused due to the sudden release of large amount of vapour through a narrow opening under pressurized conditions.

18. Explain blast wave structure interaction.
    When the blast wave hits the structure, the following occurs:
    - *Reflection of waves.*
    - *Refraction of waves.*
    - *Vortex formation.*
    - *Diffraction of waves.*

19. Differentiate the terms blast proof and blast resistant.
    - *Blast proof is the non-realistic term and it is difficult to provide a system with complete blast protection.*
    - *Blast resistance should aim to protect the functional requirements of the critical systems from any irreparable damage that leads to catastrophic damage.*
    - *The platform should remain functional even after the blast event.*

20. Name the principal parameters of the blast wave that has to be defined to estimate the blast load.
    - *Peak side-on overpressure.*
    - *Phase duration.*
    - *Impulse.*
    - *Peak side-on negative pressure (suction).*
    - *Negative phase duration.*
    - *Associated negative impulse.*

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Section C: Each question carries 5 marks. Answer in detail. Draw figures, wherever necessary to support your answer

1. Elaborate the following:
   FEED – *Front End Engineering Design.*
   FPSO – *Floating Production Storage and Offloading system.*
   FSRU – *Floating, Storage, Regasification Unit.*
   BLSRP - *Buoyant Leg Storage and Regasification Unit.*
   JONSWAP - *Joint North Sea Wave Project.*
   AIT – *Auto Ignition Temperature.*
   CVCE – *Confined Vapour Cloud explosion.*
   TNT – *Tri Nitro Toluene.*
   PSV – *Platform Support Vessels.*
   NFPA – *National Fire Protection Association.*

2. Mention the advantages and disadvantages of SPAR platform.
   Advantages:
   - *It is a free floating system more or less, the response in heave and pitch are lesser.*
   - *The drilling risers are protected by the cylinder of the SPAR from the wave action.*
   - *Simple fabrication.*
   - *Unconditional stability because the mass centre is always located lower than the centre of buoyancy.*
   - *Stability is ensured even when the mooring lines are disconnected.*

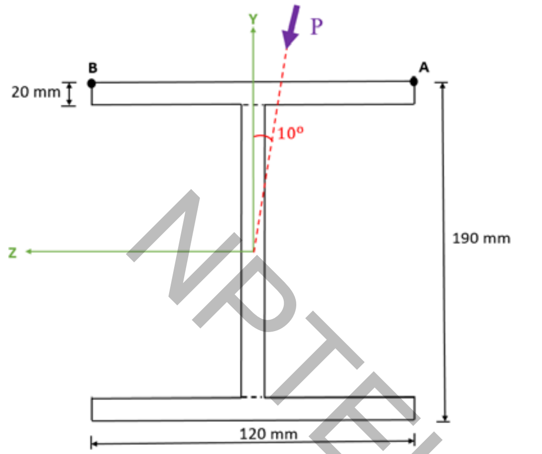
   Disadvantages:
   - *Installation is difficult compared to other platform, because the topside of the platform can only be placed after upending the cylinder of the spar.*
   - *Little storage capacity.*
   - *Spar can be used only for storage and offloading.*
   - *It is prone to corrosion.*

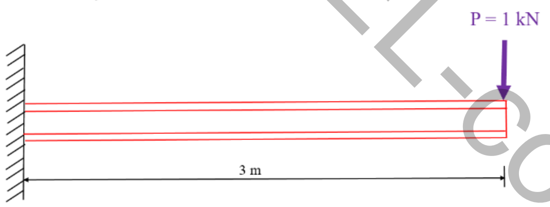
3. How do you calculate the total wave force acting on the pile of the jacket leg platform?
   - *On a pile member, combined inertia and drag forces will act.*
   - *Forces on the pile member arises due to velocity and acceleration components of the water particles.*
   - *The forces vary with time.*
   - *The combined inertia and drag forces can be found out from the Morison's equation.*
   - *In order to find the maximum forces, the phase angle at which this will occur should be calculated first, which can be calculated by,*

$$\frac{dF_t}{d\theta} = 0$$

- *The maximum force can now be calculated from Morison's equation for the above value of phase angle.*

4. Find the stresses on the cantilever beam (l= 3m) of I section at points A and B, shown in the figure. The load of 1 KN acts at angle of 10^o from the vertical axis.





(i) Calculation of I_Z, I_Y and I_{ZY}:

$$\bar{y} = \frac{\sum ay}{\sum a} = 95\ mm$$

$$\bar{z} = \frac{\sum az}{\sum a} = 60\ mm$$

$$I_Y = \frac{2\times20\times120^3}{12} + \frac{150\times20^3}{12} = 0.586\times10^7\ \ mm^4$$

$$I_Z = 2\left[\frac{120\times20^3}{12} + 120\times20\times(85)^2\right] + \frac{20\times150^3}{12} = 4.046\times10^7\ \ mm^4$$

(ii) To locate principal axes (u,v):

Since I section is symmetrical, ZZ and YY axes are the principal axes UU and VV respectively.

$$I_U = 0.586\times10^7\ mm^4$$

$$I_V = 4.046\times10^7\ mm^4$$

(iii) To find the stresses:

Moment about Z-axis = load x perpendicular distance = 1 x 3 = -3 kNm.

$$M_U = M_Z\cos\alpha = -2.954\ kNm$$

$$M_V = -\,M_Z\sin\alpha = 0.521\ kNm$$

$$\sigma_X = -\left(\frac{M_U}{I_U}\,v - \frac{M_V}{I_V}\,u\right)$$

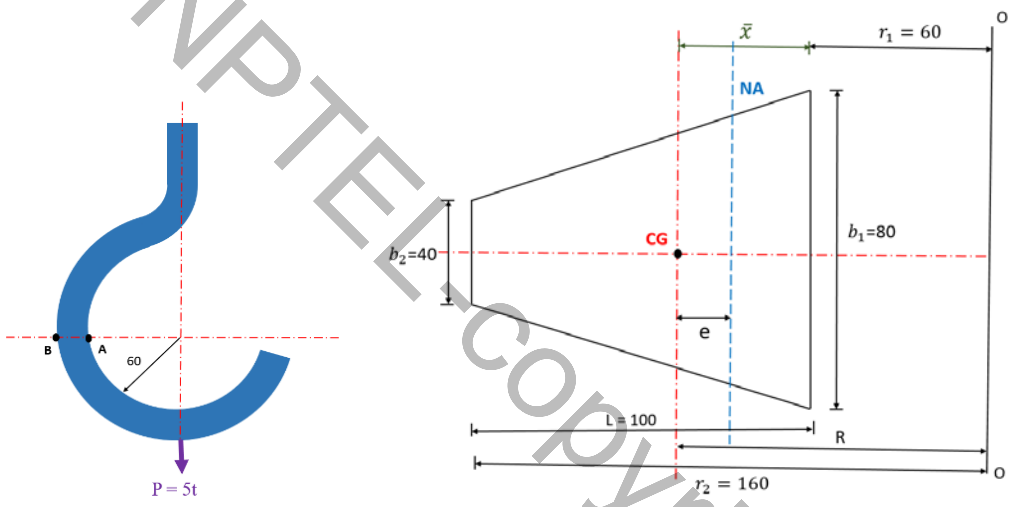
For point A,

$$u_A = -60\ mm$$
$$v_A = +95\ mm$$
$$\sigma_A = -\left(\frac{M_U}{I_U} v_A - \frac{M_V}{I_V} u_A\right) = 1.602\ N/mm^2\ (tension)$$

Similarly for point B,

$$u_B = 60\ mm$$
$$v_B = 95\ mm$$
$$\sigma_B = -\left(\frac{M_U}{I_U} v_B - \frac{M_V}{I_V} u_B\right) = 12.28\ N/mm^2\ (tension)$$

5. A 10 ton crane hook is used to lift an object during commissioning of an offshore deck. Find the stresses at the intrados and extrados using Winkler –Bach equation and Straight Beam formula. The details of the cross section is shown in the figure.



A. Winkler Bach Equation

(i) Calculation of Geometric properties:

b_3 = 20 mm

Location of the neutral axis, $\bar{x} = \frac{\sum A\bar{x}}{\sum A}$ = *44.44 mm*

h_i = x = 44.44 mm

h_o = h-x = 55.56 mm

1. Radius of the curved beam, R = r_1 +x = 104.44 mm

2. Outer radius of the curved beam, r_2 = r_1 +h = 160 mm

3. CS area of the section, A = 6000 mm²

4. Sectional property, $m = 1 - \left(\frac{R}{A}\right)\left\{\left[b_2 + \frac{r_2(b_1-b_2)}{(r_2-r_1)}\right].\ ln\left(\frac{r^2}{r^1}\right) - (b_1 - b_2)\right\}$ = *-0.0794 (no unit)*

5. Eccentricity, $e = \left(\frac{m}{m-1}\right) R$ = *7.679 mm (The positive value of 'e' indicates that the Neutral axis will shift towards the centre of curvature)*

6. Moment of Inertia, I = 4.814 x 10^6 mm^4

(ii) Section AB:

$r_i = r_1$ = 60 mm
$r_o = r_2$ = 100 mm

(a) Direct Stress, $\sigma_d = \frac{P}{A}$ = 8.333 N/mm²

(b) Moment at CG, M = -P x R = -5.222 kNm

(c) Stress at intrados, $\sigma_i = -\frac{M}{Ae}\left(\frac{h_i - e}{r_i}\right)$ = 69.442 N/mm² (tensile)

(d) Stress at Extrados, $\sigma_i = \frac{M}{Ae}\left(\frac{h_o - e}{r_o}\right)$ = -44.79 N/mm² (compressive)

(e) Total stress at intrados, $\sigma_A = \sigma_d + \sigma_i$ = 77.775 N/mm² (tensile)

(f) Total stress at extrados, $\sigma_B = \sigma_d + \sigma_o$ = -36.457 N/mm² (compressive)

B. Straight Beam Formula:

$\sigma = \frac{M}{I}\, y$

y_i = 44.44 mm
y_o = 55.56 mm

(a) Stress at intrados, $\sigma_i = \frac{M}{I}\, y_i$ = 48.205 N/mm² (tensile)

(b) Stress at Extrados, $\sigma_o = \frac{M}{I}\, y_o$ = -60.256 N/mm² (compressive)

(c) Total stress at intrados, $\sigma_A = \sigma_d + \sigma_i$ = 56.539 N/mm² (tensile)

(d) Total stress at extrados, $\sigma_B = \sigma_d + \sigma_o$ = -51.923 N/mm² (compressive)

6. Describe Vortex Induced Vibration and the ways to suppress the effect of it on the structure.
   - *As the fluid passes the body, flow separation occurs. This results in the formation of vortex behind the body.*
   - *Vortex shedding frequency tries to lock-in with the natural frequency of the riser, which leads to resonating condition.*

   Consequences of VIV:
   - *They can cause alternating pressure field on the surface of the riser.*
   - *Reduction of service life of the system.*
   - *Fatigue damage.*
   - *Induce large transverse motion.*
   - *Causes operational difficulties.*

   VIV Suppression:
   - *By providing Surface protrusion – helical strakes*
   - *By attaching the projected plates called near wake stabilizers.*
   - *By providing shroud, which is a perforated cover around the member.*
   - *Changing the geometric shape of the platform.*
   - *By ensuring smooth surface of the members.*
   - *By connecting external dampers.*

7. List the best practices for fire safety in offshore platforms.

- *Fluid should be used above the flash point temperature and the fire point temperature, but not above AIT.*
- *Fluid can be used up to their maximum bulk temperature, which is higher than the flash and fire point temperature of the fluid.*
- *Avoid designing confined space with the presence of ignition source, because that can result in flash fire easily.*
- *Through proper system design, one can ensure that no oxygen content is available at the heat source.*
- *Fluid should be well contained within the system.*
- *Fluid containment should not have direct contact with the external ignition source.*

8. Describe the different types of blast waves.

   Shock wave:
   - *Leads to instantaneous shoot up of pressure above the ambient temperature.*
   - *The peak side-on pressure then gradually returns to the ambient conditions.*
   - *This also results in negative pressure wave, following the positive phase of the shock wave.*

   Pressure wave:
   - *Gradual rise in the pressure to reach the peak side-on over pressure.*
   - *It then gradually decays without any negative phase.*
   - *Shock waves are the consequences of extremely energetic vapour cloud explosion.*
   - *Vapour cloud deflagration will result in rise of pressure waves in the near field.*
   - *They will further propagate to the far field as a shock wave.*
   - *Negative phase of the shock wave is weaker but sometimes a suction pressure can also cause significant damage.*