NPTEL CERETIFICATE EXAMINATION

Offshore structures under special loads including fire resistant design- SET 2

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 unique by *innovative design* and *functional requirements*.

2. Fixed structures triggers *brittle* mode of failure.

3. In SPAR platform, helical strakes are provide around the cylinder to reduce *Vortex induced vibration*.

4. Wave direction does not influence the response of triceratops platform. State true/false.
   True because the legs of the platform are symmetrically placed.

5. Airy's theory is valid only up to *mean sea level* and stretching modifications should be accounted for *the actual level of submergence*.

6. The wind spectra applicable for the offshore structures are *Kaimal spectrum and API spectrum.*

7. If the return period of the event is reduced, the probability of exceedance of the event will *increase.*

8. Any sample from the process which represents the average statistical properties of the entire process is said to be *ergodic*.

9. Earthquake loads affects the super structure of the tension leg platforms indirectly by inducing *tether tension variation.*

10. Triangular geometry of TLP is advantageous compared to square geometry. Why?
    - *Increased tolerance for the position of foundation.*
    - *Increased drought and heat tolerance.*

11. Pitch response of triangular TLP is *lesser* than the square TLP.

12. *Freak wave model* is used for the simulation of the extreme waves in square TLP.

13. Due to unsymmetrical bending, thin sections will undergo *twisting* under transverse loads.

14. If a section has one axis of symmetry, the shear centre will lie on *the axis of the section*.

15. Write the Winkler-Bach equation.

$$\sigma = \frac{M}{AR}\left[1 - \frac{1}{m}\left(\frac{y}{R+y}\right)\right]$$

16. *Central stud* should be introduced in the chain link when the stress in the links are greater than the permissible limits.

17. The inner metal surface of the layered riser is called *carcass*.

18. AIT is also known *as self-ignition temperature and kinding point of the material*.

19. If the ignition source is present, and the vessel is in contact with the ignition source, then it will result in the formation of *fire ball*.

20. Rear wall load tends to *reduce* the overall blast wave force.

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Section B: Each question carries TWO marks. Answer briefly

1. Elaborate the following*:*

   DPS – *Dynamic Positioning System.*
   BLS – *Buoyant Leg Structure.*
   VIV – *Vortex Induced Vibration.*
   BLEVE – *Boiling Liquid Expanding Vapour Explosion.*

2. Explain the structural action of the spud can arrangement with neat sketch.
   - *Spud can is similar to the inverted cone placed under suction.*
   - *When the spud can arrangement is placed on the sea bed with high pressure, partial vacuum will develop inside the cone arrangement.*
   - *The partial vacuum space is the filled by the soil particles surrounding the spud can and hence high pressure is required to remove the spud can from its position.*

3. Find the stiffness and time period of the spar platform of 30 m diameter and mass in heave degree of freedom is 60000t.

   Stiffness = $\rho g \pi R^2 = 1025 \times 9.81 \times \pi \times (15)^2 = 7.1 \times 10^6 N/m$

   $$m = 6 \times 10^7 kg$$

   $$\omega = \sqrt{k/m} = 0.344$$

   $$T = \frac{1}{\omega} = 2.907\ seconds$$

4. Platforms remaining stiff in heave degree of freedom is advisable. Why?
   - *For operational convenience.*
   - *To reduce the change in tension in the tethers and to avoid fatigue failure.*
   - *To reduce the consequences of change in buoyancy by the added mass.*

5. Write the expression for horizontal and vertical water particle velocities based on Airy's theory.

   $$\dot{u}(x,t) = \frac{\omega H}{2} \frac{\cosh ky}{\sinh kd} \cos(kx - \omega t)$$

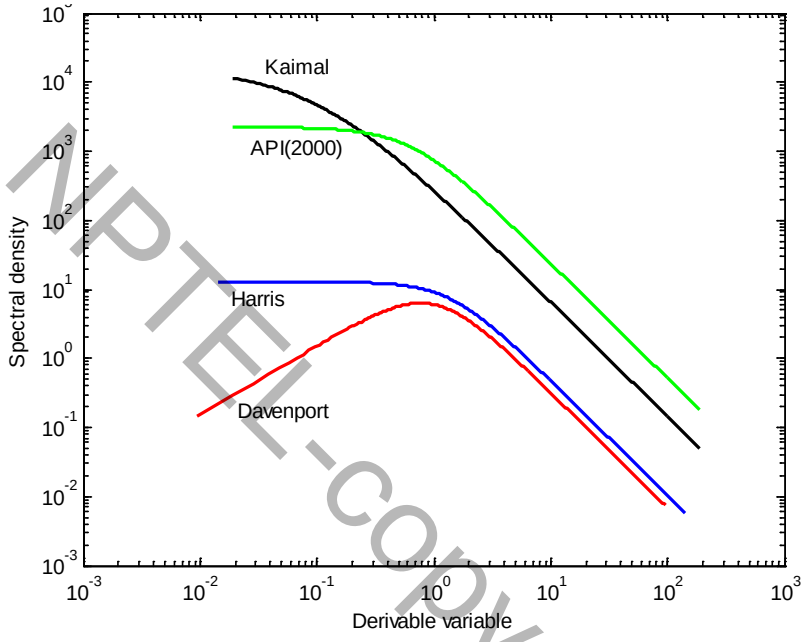
   $$\dot{v}(x,t) = \frac{\omega H}{2} \frac{\sinh ky}{\sinh kd} \sin(kx - \omega t)$$

   where,

   $\dot{u}$ *= horizontal water particle velocity*
   $\dot{v}$ *= vertical water particle velocity.*
   k *= wave number =* $2\pi/\omega$.
   H *= wave amplitude.*
   d *= water depth.*
   Y *= depth at which the velocity is measured.*

6. Why aerodynamic admittance function is used? State the reasons.
    - *Aerodynamic admittance function is used to find the equivalent total wind load acting on the members.*
    - *It is used to by-pass the rigorous random variable.*
    - *The value can be found experimentally.*

7. State the inferences for the following wind spectra.



    - *The variation among the spectrum is considerable at lower frequencies.*
    - *The variation between API and Kaimal spectra is considerably low.*
    - *Davenport spectrum and Harris spectrum are not applicable to offshore structures and they found to have lower peak value.*

8. How uncertainties in the analysis and design of the structures are grouped?
    - Group I: related to material characteristics.
    - Group II: related to load estimation.
    - Group III: arises due to mathematical modelling and method of analysis.

9. What are the assumptions made in the earthquake analysis of the offshore structures?
    - *Sea bed movement is horizontal.*
    - *The movement of sea bed is very low and second order forces generated due to the sea bed movement is generally neglected.*
    - *Radiation damping is neglected for the slender structures.*

10. Write the classification of loads.
    - *P class loads – permanent loads.*

- *L class loads – Live loads.*
- *D class loads – Deformation loads.*
- *E class loads – Environmental loads.*
- *A class loads – Accidental loads.*

11. Mention the effect of impact waves and non-impact waves on TLP.

Impact waves:

- *Cause ringing response.*
- *Pitch dof is influenced.*
- *Challenges the operability of the platform.*
- *Leads to tether pull-out and stability issues.*

Non-impact waves:

- *Cause springing response.*
- *Heave dof is influenced.*
- *Leads to fatigue failure of tethers.*

12. What are the consequences of transverse loading on the structural members?
    - *Members will have premature failure due to twisting before bending.*
    - *Plasticization of twisted members.*

13. What is the advantage of using buoyancy modules in the risers?
    - *They are helpful in reducing the top tension force, which is required in the installation of the risers.*
    - *They make the risers neutrally buoyant.*

14. What are the ways through which, VIV suppression can be achieved in the structure?
    - *Surface protrusion – helical strakes*
    - *Helically wounded wire.*
    - *Projected plates.*
    - *Shrouds.*
    - *Proper design.*
    - *Smooth surface.*

15. Differentiate fire and explosion.

Fire:

- *It is a rapid exothermal oxidation of the ignition fuel.*

Explosion:

- *Rapid expansion of gases resulting from the pressure waves or shock waves.*
- *Explosion releases energy very rapidly.*

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16. Arrange the following in ascending order based on their temperature.
    Oxyhydrogen fire, simple candle, air acetylene fire, blow torch under welding operation.
    2-4-3-1

17. How the consequences due to the explosion damage can be measured?
    - *One of the common method used to measure the consequences of explosion damage is TNT equivalence method.*
    - *TNT is an important explosive, which rapidly changes its form from solid to hot expanding gas.*

18. List the general design requirements of fire protection in the offshore platforms.
    - *They should be compact in size and weight.*
    - *They should be easy to operate.*
    - *They should be rapid activation systems.*
    - *They should be accessible.*

19. Define peak reflected pressure and peak dynamic pressure.
    Peak reflected pressure:
    - *When the blast wave hits the surface of the bluff body, it reflects back.*
    - *The effect of this reflection depends upon the surface characteristics of the body.*
    - *Surface will experience more pressure than the incident side-on pressure.*
    - $P_r = C_r P_{so}$
      where,
      C_r *is the reflection coefficient.*

    Peak dynamic pressure:
    - *Blast wave moves due to the air movement.*
    - *Wind pressure depends upon the magnitude of peak over pressure of the blast wave.*

20. Name the different types of fire.
    - *Pool fire*
    - *Jet fire*
    - *Fire ball*
    - *Flash fire.*

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

1. Match the following:

1	Fixed structures	A	Exploratory drilling
2	Articulated towers	B	Deck isolated platforms
3	Tethers	C	turret mooring
4	Guyed towers	D	Tethered SPAR
5	Compliant structures	E	Attract more forces
6	FPSO	F	DPS
7	Jack up rig	G	Skirt piles
8	Drill ships	H	Position restraint
9	Gravity Based structure	I	Recentering is gentle
10	Jacket Platforms	J	Spud can
11	BLS	K	Sea bed scouring
12	Triceratops	L	Better under cyclic loads

1-e, 2-i, 3-h, 4-j, 5-b, 6-c, 7-a, 8-f, 9-k, 10-g, 11-d, 12-b

2. Explain the structural action of TLP.
   - *The structure is vertically restrained while it is compliant in the horizontal direction, permitting surge, sway and yaw motion. The structural action results in low vertical force in rough seas, which is the key design factor.*

     $$W < < < F_B$$
     $$W + T_o = F_B$$

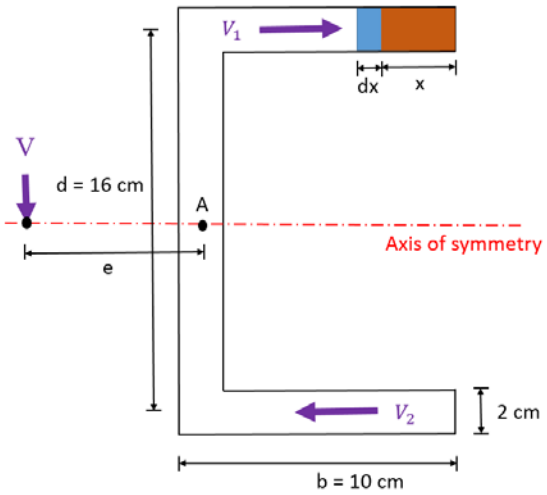
     Where,

     $W \rightarrow$ *weight of the platform.*

     $T_o \rightarrow$ *initial axial pretension which was set initially in the structure to hold the platform down (20% of total weight).*

     $F_B \rightarrow$ *buoyancy force.*
   - *Due to lateral forces, the platform moves along the wave direction. Horizontal movement is called* ***offset.***
   - *Due to horizontal movement, the platform also have the tendency to have increased immerse volume of members. Thus, the platform will undergo* ***set-down*** *effect.*
   - *The lateral movement increases the tension in the tethers. The horizontal component of tensile force counteracts the wave action and the vertical component increases the weight which will balance the additional weight imposed by set down.*

3. Locate the shear centre for the channel section shown in the figure.



Consider a section of thickness 'dx' on the flange at a distance 'x' from the end.

$$V_1 = \int \tau \, da$$

$V_1 = \int \frac{VA\bar{y}}{It} \, da$

where, $A = t\,x$

$da = dx\,t$

$\bar{y} = d/2$

$V_1 = \frac{V}{It} \int_0^b (t\,x)\,(dx\,t)\,\frac{d}{2} = \left[\frac{V}{It}\frac{t^2 d}{2}\frac{x^2}{2}\right]_0^b$

$= \frac{Vtb^2 d}{4I}$

By symmetry, $V_1 = V_2 = \frac{Vtb^2 d}{4I}$

Neglecting the shear taken by the web and taking moment about the point A on the web,

$Ve = V_1 \frac{d}{2} + V_2 \frac{d}{2}$

$Ve = \frac{Vtb^2 d}{4I} \times d$

$e = \frac{tb^2 d^2}{2I}$

Moment of Inertia, $I = 3.031 \times 10^7\ mm^4$

$e = 8.44$ *cm.*

4. Write a short note on different type of risers.

Low pressure risers:

- *Large diameter risers that are open to the atmospheric pressure at the top end.*
- *They are useful for drilling.*
- *They also have a lot of peripheral lines.*
- *Kill and choke lines are useful to circulate the fluid when kick occurs.*

- *They are also useful in communicating with the well about the closure of BOP.*
- *Booster lines are useful to inject fluid at the lower end and to accelerate the flow.*
- *When the risers are installed at greater water depth, they need top tensioning.*

High Pressure Risers:

- *These risers are installed when the blow-out preventer is located closer to the surface.*
- *These risers do not require any additional peripheral lines which are essentially useful for communicating with the BOP.*
- *These risers are designed to operate at full pressure.*

Flexible risers:

- *They are useful as production risers.*
- *Flow lines.*

Top tension risers:

- *These are required to ensure stability.*
- *They connect the sea bed through a stress joint.*
- *In addition, these risers will also have keel joint, which is located at keel level of the platform.*
- *As these risers are highly flexible in terms of its cross section, they undergo large deformation.*

5. Describe the steps involved in the identification of explosion damage.

One of the common method to estimate the consequences of explosion damage is TNT equivalence method. The steps involved are as follows:

- *Calculation of total mass of the fluid involved.*
- *Calculation of explosion energy.*
- *Computation of TNT equivalence.*

$$m_{TNT} = \eta \frac{m\Delta H_c}{E}$$

- *Calculation of scaled distance.*

$$Z_e = \frac{r}{\sqrt[3]{m_{TNT}}}$$

- *Calculation of peak overpressure.*

6. Mention the basic problems in the offshore platforms that makes fire protection very difficult.

- *Offshore platforms generally have congested layout of topside module.*
- *They operate in a very confined and compact space.*
- *Offshore production equipment are not laid horizontally but laid vertically.*
- *They impose extensive weight and space limitation for fire protection equipment to be provided on board.*

- *Usage of sea water for fire protection may lead to corrosion.*
- *Pure water to be used for fire protection system in offshore platforms.*

7. Compute the front wall loading due to blast waves travelling horizontally on the building module of offshore platform. Length = 15m, breadth = 30m, height = 5m and the blast wave approaches the building in the direction parallel to the length of the building. The peak side-on overpressure is 50 kPa for the duration of 0.06 s.

   (i) shock wave parameters:

   a. shock wave velocity, $u = 345(1 + 0.0083P_{so})^{0.5}$ *= 410.39 m/s.*

   b. length of the pressure wave = $u.t_d$ *= 24.623 m.*

   c. peak dynamic wind pressure, $q_o = 0.0032(P_{so})^2$ *= 8 kPa.*

   (ii) front wall loading:

   Reflected over pressure, $C_r = 2 + 0.0073P_{so}$ *=2.365*

   $P_r = C_r P_{so}$ *= 118.25 kPa.*

   Clearing distance is the least of B_H *= 5m and* $B_W/2$ *= 5m.*

   S=5m

   Reflected overpressure clearing time, t_c *= 3S/u = 0.0366.*

   Drag coefficient = 1.0

   Stagnation pressure, $P_s = P_{so} + C_d q_o$ *= 58 kPa.*

   Front wall impulse, $I_w = 0.5(P_r - P_s)t_c + 0.5P_s t_d$ *=2.84 kPa.s*

   Effective duration, $t_e = \frac{2I_w}{P_r}$ *=0.048 s.*

8. Write a case study on the piper alpha accident and deep water horizon accident.

   Piper alpha accident:

   - *July 6, 1998 in the North Sea.*
   - *Fire and explosion occurred.*
   - *The consequences are highly severe. 167 people died and financial loss of about 3.4 billion US dollars in 1998.*
   - *Accident occurred due to human error during operation/ maintenance and faulty design of the platform.*

   Deep water horizon:

   - *It is a semisubmersible MODU.*
   - *Accident occurred on April 20, 2010 in Gulf of Mexico.*
   - *It caused severe human and environmental impact.*
   - *Fire and explosion occurred which leads to capsizing of the vessel and oil spill.*
   - *Reason for the explosion is faulty design.*