MASSACHUSETTS INSTITUTE OF TECHNOLOGY
13.10J/1.573J Structural Mechanics

Problem Set 5

Assigned : October 2, 2002
Due : October 11, 2002 (in Recitation)

1. From your book : 7.14,7.21,7.22,7.27

2. A Design Problem :

   2A An FPSO (Floating Production, Storage and Off-loading) system under operation at a water depth $D = 1000m$ is moored by steel cables as shown in Figure 1. It has a riser for drilling and oil production so that the maximum excursion of the ship should be restricted to a certain range to prevent the riser from breaking. The fluid force (horizontal force) on the ship due to ocean currents, waves and wind is resisted by the steel cables. Here we are analyzing one cable AB which resists a horizontal force $H = 20kN$ (part of the total drag on the ship). The maximum allowed horizontal excursion of the ship is $X_M = 60m$. Fluid forces on the cable, added mass effects and other dynamic phenomena are neglected. The structure is in static equilibrium. We are also given the following data.

   - diameter of steel cable : $d_s = 0.05m$
   - density of steel : $\rho_s = 7040kg/m^3$
   - modulus of elasticity of steel : $E_s = 200GPa$
   - Poisson's ratio of steel : $\nu_s = 0.3$
   - yield stress of steel : $\sigma_y = 250MPa$
   - density of sea water : $\rho_w = 1025kg/m^3$
   - acceleration of gravity : $g = 9.81m/s^2$

   (a) Determine the vertical and horizontal forces from the anchor on the mooring cable and the length of the cable.

(b) Plot $x(s)$, $z(s)$, $\phi(s)$ and $T_e(s)$ where arc length s is measured from the anchor. (Use of Matlab is suggested).

(c) What are the tension forces in the material at $s = 0$ and $s = L$?

(d) Estimate the maximum axial strain, maximum axial stress and total elongation of cable under the given conditions.

(e) Estimate the maximum shrinkage of the cable diameter.

(f) Estimate the strain energy of the entire cable under the given condition.

(g) Given your answer on a) calculate the spring constant of the cable AB under small horizontal motions of the top end A. The spring constant is defined as the change of the horizontal force divided by the corresponding small change in the horizontal displacement of point A.

2B For the above problem assume that the structure is at rest and the mooring lines are in perfect symmetry. Consider a small vertical displacement and calculate the spring constant in the vertical direction (the rate of change of the vertical force on the cables divided by the change of the small vertical displacement). Please derive a closed form formula for the spring constant as a function of d_s and D.

Plot the spring constant in the vertical direction as a function of d_s and D in one dimensional and two dimensional plots.

You may use MATLAB, MAPPLE, MATHEMATICA or any other program to do this Problem Set. Please present the results CLEARLY in a COMPLETE report.

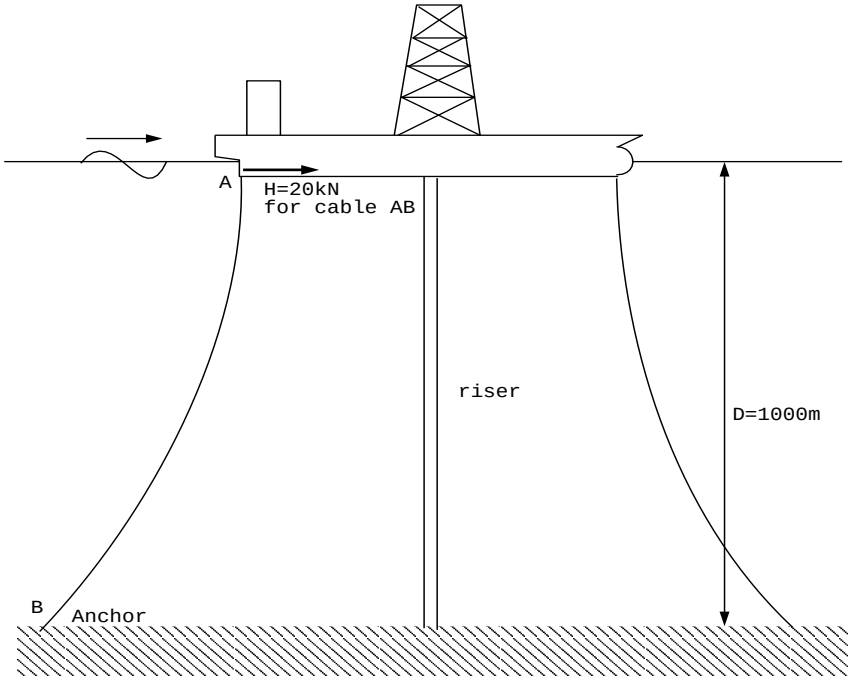

Figure 1: A diagram for Design Problem 2