DEPARTMENT OF CIVIL ENGINEERING, IIT DELHI

I SEMESTER 2008-2009 MAJOR EXAM Time limit: 2 hrs.
CEL 731 PRESTRESSED CONCRETE & COMPOSITE STRUCTURES Max Marks = 40
Course Coordinator: Dr. Alok Madan

Instructions: *1. This is a 'closed book' exam. Only design codes may be referred.*
2. Make suitable assumptions where necessary and state them.
3. Attempt any combination of questions with their maximum marks totaling 40

1. A singly reinforced prismatic rectangular beam with a width of 300 mm and an effective depth of 500 mm and overall depth of 600 mm is provided with high strength steel strands with a total cross-sectional area of 200 mm^2 that are uniformly prestressed to an initial strain of 0.002. The beam is simply supported and subjected to a mid-span concentrated force. The prestressing steel has a yield strength f_y of 1400 MPa and a modulus of elasticity E_s of $2x10^5$ MPa. Assuming (a) plane sections remain plane after bending, (b) an elastic perfectly plastic stress-strain relationship for steel (bilinear curve with flat post-yielding branch), (c) tensile strength of concrete is negligible, (d) steel is perfectly bonded to neighboring concrete, and (e) M40 concrete with a parabolic stress-strain relationship in compression as follows:

$$f_c(\varepsilon_c) = f_{ck}\left[2\left(\frac{\varepsilon_c}{\varepsilon_c'}\right) - \left(\frac{\varepsilon_c}{\varepsilon_c'}\right)^2\right]$$;where f_{ck} is the characteristic compressive strength of concrete

and ε_c' is the corresponding strain that equals 0.002

Obtain the short-term non-linear **force-displacement** response of the prestressed concrete beam at the mid-span under an axial load P of 200 kN using closed form analytical integrals of the compressive stress-strain function of concrete. Plot the moment-curvature response using at least five representative points. The yield strain of concrete in compression may be assumed as 0.0005 if required. (20 marks)

2. Obtain the axial load- bending moment (P-M) strength envelope (N-M interaction diagram) in non-dimensional terms for the prestressed concrete section in Problem 1 using equivalent uniform stress block factors. Assume that the ultimate moment (flexural strength) is reached when the concrete strain at the extreme compression fiber is 0.003. Determine five points on the strength envelope including points corresponding to zero axial force, tension failure, balanced failure and compression failure. (20 marks)
3. (a) Illustrate the step-by step methodology of predicting the non-linear shear response of a prestressed concrete section using compression field theory. Briefly explain why only equilibrium equations are not sufficient for a unique solution of the stresses due to shear. (4 marks)
   (b) Illustrate using neat flowcharts the computational algorithm for numerical solution of the non-linear flexural (moment-curvature) response of a prestressed concrete section under an axial load using Newton-Raphson method. (6 marks)

4. A four-walled workshop building with plan dimensions of 24 m by 12 m is located in seismic zone V and is constructed with a flexible timber roof on 3 meters high reinforced concrete masonry unit (CMU) bearing walls with 300 mm wall thickness. The walls are reinforced vertically as well as horizontally. The dead and superimposed load on the roof diaphragm is 2.0

kN/m^2. Assuming all the connections between the walls, roof and foundation to be pinned, for a design earthquake load as per IS: 1893-2002 acting along the shorter dimension of the building:

(a) Calculate the roof diaphragm-to-wall shear for the shorter wall for design of the diaphragm-to-wall connection. (4 marks)

(b) Calculate the maximum chord force in the bond beam at the top of the longer wall and design the reinforcement in the bond beam. (2 marks)

(c) Obtain the horizontal shear in the shorter wall at a point 2.0 meters above the foundation. (2 marks)

(d) Check the wall thickness for adequacy. (2 marks)

5. A beam with a T shaped section shown in Figure 1 has a simply supported span of 24 m and is subjected to uniformly distributed load. The prestressing steel consists of 20 No.s 10 mm diameter strands with a triangular profile having an effective eccentricity from the centroidal axis of 400 mm at end span and 600 mm at midspan. The sectional and material properties of the beam are as follows:

$A = 442580\ mm^2$ $I = 3.1054 \times 10^{10}\ mm^4$ $y_b = 694$ mm $y_t = 221$mm

$f_{ck} = 35$ Mpa $\gamma_c = 24.0\ kN/m^3$ $f_{pu} = 1620$ Mpa $Es = 2.1 \times 10^5$ Mpa

Assuming that the prestress in the strands after all losses is 800 Mpa,

(i) Estimate the shear capacity due to contribution of concrete alone prior to web shear cracking (diagonal web cracking). Use IS: 1343-1980 code provisions. (6 marks)

(ii) Design the shear stirrups for the beam using staggering design concept assuming that the member carries a superimposed dead load of 4.5 kN/m and a service live load of 12.0 kN/m in addition to the self weight of the beam. Use the relevant load factors. (4 marks)

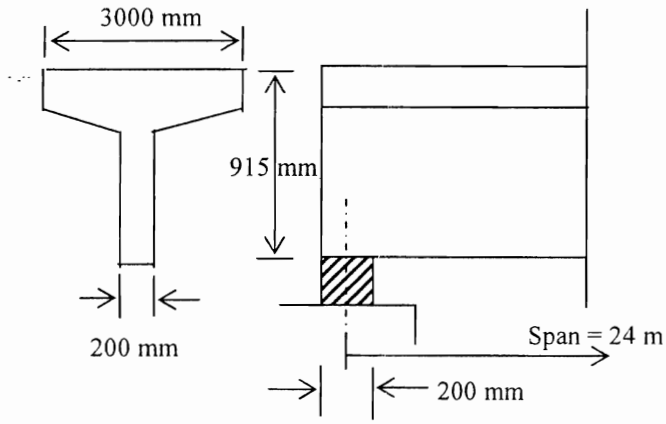

Figure 1