DEPARTMENT OF CIVIL ENGINEERING, IIT DELHI

CVL 443: PRESTRESSED CONCRETE AND INDUSTRIAL STRUCTURES

2nd Semester 2023-2024 ASSIGNMENT #1: Fundamentals and Idea of Prestressed Concrete

Assigned on: 15.01.2024 (Monday) *Submission due on: 29.01.2024 (Monday)*

Course Coordinator: Dr. Alok Madan

1. A prismatic prestressd concrete (PSC) concrete bar of length L with a rectangular cross-section of dimensions of width b and depth D (gross Area Ac = b x D) composed of **M45 grade concrete** and prestresssed with a high tensile prestressing steel bar of area A_s located concentrically at centroid of the cross-section is subjected to an externally applied concentric axial tensile force T:

   (a) Calculate the design value of the prestress σ_{cp} required to ensure that the PSC bar with a steel area ratio $\rho = A_s/A_c = 0.4$ % of prestressing steel remains uncracked in the **working stress range (i.e. range of externally applied average tensile stress under working or service loads) σ_{av} = 0.0 to 6.5 MPa**. Given the cracking stress or fracture strength of plain concrete σ_{cr} = 5% of characteristic compressive strength σ_{ck} of concrete, cracking strain of concrete ε_{cr} = 0.0002 and Elastic Modulus of concrete $E_c = \sigma_{cr} / \varepsilon_{cr}$.

   (b) Plot the uniaxial average stress-stress strain curve (plot of average uniaxial stress $\sigma_{av} = T/A_c$ with average uniaxial strain $\varepsilon_{av} = \Delta L/L$) of the PSC bar as the externally applied axial tensile force T is increased from 0.0 at the prestressed state of concrete to the ultimate tensile force at failure due to rupture of prestressing steel. Assume that the average tensile strain in the PSC bar is measured prior to the prestressing operation while the average applied tensile stress is measured as $\sigma_{av} = T/A_c$ where T is the external tensile force applied after the prestressing operation. Mention the average uniaxial tensile stress and strain values for the PSC bar at the important limit states of cracking of concrete, yielding of steel and ultimate failure (rupture) of steel on the plot. Compare the measured cracking strength of concrete in the PSC Bar with the fracture strength of plain concrete. Also, mention the uniaxial stress and strain state of the concrete in the PSC bar in the prestressed state prior to the application of the external tensile force T. Given the yield stress of the high tensile prestressing steel σ_{sy} = 1660 MPa, the ultimate tensile stress or tensile strength of the prestressing steel $\sigma_{su} = 1.25\ \sigma_{sy}$, ultimate tensile strain of steel at rupture ε_{su} = 0.01 and Elastic Modulus of steel E_s = Young's Modulus = $2x10^5$ MPa.

   (c) Plot the uniaxial average stress-stress strain curve (plot of average uniaxial stress $\sigma_{av} = T/A_c$ with average uniaxial strain $\varepsilon_{av} = \Delta L/L$) of the corresponding Reinforced Concrete (RC) Bar of identical geometry and grade of concrete reinforced with HYSD (high yield strength deformed) steel reinforcement (r/f) provided as a single steel rebar of cross-sectional area A_s such that the steel area ratio $\rho = A_s/A_c = 1.6$ % for the RC Bar while the normalized steel ratio $\rho_{norm} = A_s.\sigma sy /(A_c .\sigma_{ck})$ of the RC Bar equal to that for the PSC Bar. Superimpose the plot for the RC bar on that for the PSC Bar for comparison of the important limit states mentioned in Part (b). Given the ultimate tensile stress or tensile strength of the reinforcing steel $\sigma_{su} = 1.25\ \sigma_{sy}$, ultimate tensile strain of steel at rupture ε_{su} = 0.01 and Modulus of Elasticity of steel $E_s = 2x10^5$ MPa,