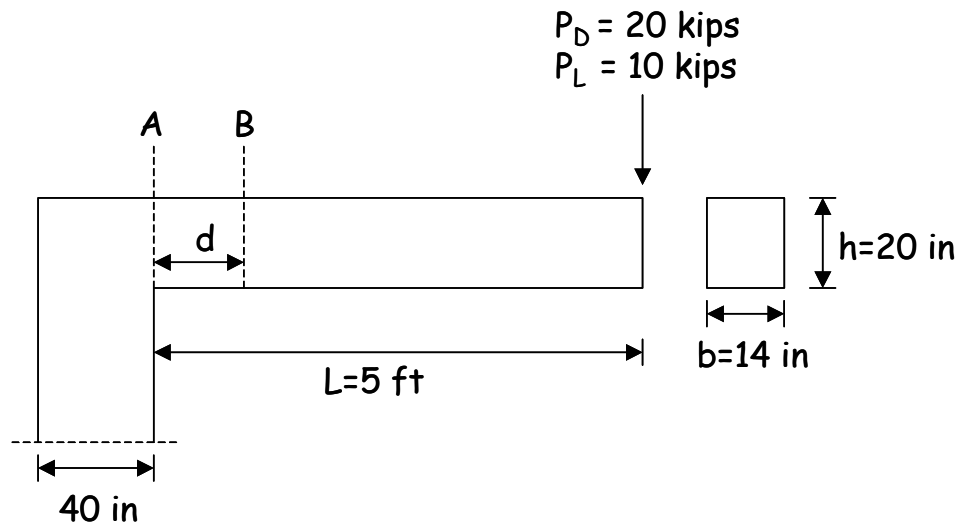# 1.051 Structural Engineering Design

QUIZ 1

Open Book & Notes – 90 minutes

QUESTION 1. – FLEXURAL DESIGN (40%)

Consider a cantilever beam shown in the figure below which is loaded at its tip with a concentrated service dead load of PD=20 kips (including self-weight) and a service live load of PL=10 kips. The beam is 5 ft long and is anchored to one end of a column having 40 in width.

The effective depth of the beam is d=17.5 in.
The material properties are: $f_c' = 4$ ksi, $f_y = 60$ ksi

(a)   Under <u>service loading</u>, what is the nearest distance to the free end where you would start seeing flexural cracks?
Consider only the gross area of concrete (neglect the steel when calculating the moment of inertia). The modulus of rupture of concrete is given by:
$f_r = 7.5\sqrt{f_c'}$

(b)   Calculate the <u>design load</u> Pu and draw the shear and moment diagrams of the beam under design loads.

(c)   Determine the minimum and maximum reinforcement ratios for the beam. Briefly explain why we impose these limits.

(d)   Assuming that the beam is underreinforced, determine the <u>required</u> reinforcement ratio, r , and the corresponding reinforcement area, A_s , in order for the beam to resist the design moment. Assume $f = 0.9$. After determining r , check if the beam is underreinforced.

(e)   Perform the reinforcement design using #11 rebars and sketch your design.

(f)   Using the <u>provided</u> reinforcement area, calculated in (e), determine the net tensile strain, e_t , and check whether the assumption that $f = 0.9$ is valid.


QUESTION 2 – SHEAR DESIGN (20%)

For the beam in Question 1,

(a)   Calculate Vc using the simple expressions according to the ACI Code. In this case, does the location of the shear critical section bear any significance? Briefly explain.

(b)   Determine if shear reinforcement is needed for this beam. If so, using the Vu and Vc previously calculated, determine the required shear reinforcement spacing using <u>#3 stirrups</u>. Would you make any changes in the stirrup spacing along the beam span?

QUESTION 3 – BOND AND ANCHORAGE (25%)

For the beam in Question 1,

(a)   What is the location of the <u>critical section for bond and anchorage</u>? For that section, determine the necessary development length required for the flexural reinforcement using the <u>simplified equations</u>. Is it possible to provide this development length at both sides of the critical section? Consider the required and provided reinforcement areas (or ratios) calculated in 1(d) and 1(e).

(b)   Assuming that the development length requirement is not met, list all possible design modifications to meet the bond and anchorage requirements (<u>no calculations required</u>).

(c)   Consider that, in addition to the end concentrated load, a concentrated moment is also applied at the free end of the beam, as shown in the figure below. Would there be any other considerations regarding the bond development length? Briefly explain (<u>no calculations required</u>).
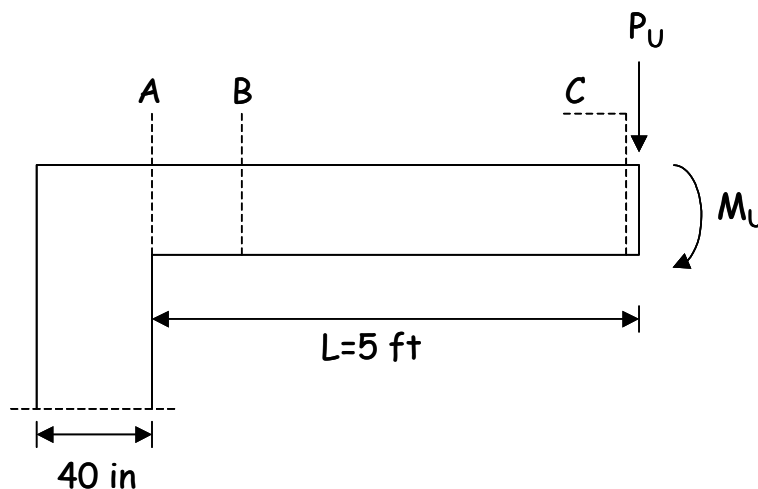
QUESTION 4 – SERVICEABILITY AND STRENGTH DESIGN (15%)

(a)   What do you understand from design for serviceability?

(b)   With the aid of a sketch, explain how the beam shown in Question 1 may be affected by the creep of concrete. How will the strains and stresses at section A vary due to the creep of concrete?