1.1 The building in figure P.1 is used for general office space. The slab is 8 in. thick on a beam 12 in. wide by 18 in. deep, the bay dimensions are 18'-6" in the x direction and 21'-0" in the y direction and the superimposed service dead load is 12 psf. Calculate the slab service load in psf and the beam service load in klf.. (**Solution:** *qs* = 162 psf, *wu* = 3.12 klf).

SOLUTION

From table 1.1 Office load $q_l := 50psf$

Concrete unit weight $\gamma_c := 150pcf$

Slab load $t := 8in$ $q_d := t\cdot\gamma_c = 100\,psf$

Superimposed dead load $q_{sdl} := 12psf$

Service load $q_s := q_l + q_d + q_{sdl} = 162\,psf$

The beam length is 21 feet and the tributary width is 18.5 ft. The beam is 12 x 18 in. of which 10 in is below the slab.

$$w_{beam} := (18in - t)\cdot 12in\cdot\gamma_c = 125\,plf$$

$$w_s := 18.5ft\cdot q_l + 18.5ft\cdot\left(q_d + q_{sdl}\right) + w_{beam} = 3122\,plf \qquad w_s = 3.12\,klf$$

1.2 The building in figure P.1 is used for general office space. The slab is 8 in. thick on a 12 in. wide x 18 in. deep beam, the bay dimensions are 18'-6" in the x direction and 21'-0" in the y direction and the superimposed service dead load is 12 psf. Calculate the factored column load transferred to column C3 on the 3rd floor. (**Solution:** P_u = 86.4 kips).

SOLUTION $\gamma_c := 150pcf$ $q_l := 50psf$ $q_{sdl} := 12psf$

Slab load $t := 8in$ $q_d := t\cdot\gamma_c = 100\,psf$

Tributary area $A_t := 18.5ft\cdot 21ft = 388.5\,ft^2$

$$w_{beam} := (18in - t)\cdot 12in\cdot\gamma_c = 125\,plf$$

$$P_u := 1.6\cdot A_t\cdot q_l + 1.2\cdot A_t\cdot\left(q_d + q_{sdl}\right) + 1.2\cdot w_{beam}\cdot 21ft = 86.4\,kip$$

1.3 The building in figure P.1 is used for general office space. The slab is 8 in. thick on beams 12 in. wide x 18 in. deep, the bay dimensions are 18'- 6" in the x direction and 21'- 0" in the y direction and the superimposed service dead load is 12 psf. Calculate the slab factored load in psf and the beam factored load in klf. Comment on your solution in comparison with problem 1.1.

SOLUTION $\gamma_c := 150\text{pcf}$ $q_l := 50\text{psf}$ $q_{sdl} := 12\text{psf}$

Slab load $t := 8\text{in}$ $q_d := t \cdot \gamma_c = 100\ \text{psf}$

$q_u := 1.6 \cdot q_l + 1.2 \cdot (q_d + q_{sdl}) = 214.4\ \text{psf}$

From problem 1.1 $\frac{q_u}{q_s} = 1.323$

$w_{beam} := (18\text{in} - t) \cdot 12\text{in} \cdot \gamma_c = 125\ \text{plf}$

The tributaty width is . $l := 18.5\text{ft}$

$w_u := 1.6 \cdot q_l \cdot l + 1.2 \cdot (q_d + q_{sdl}) \cdot l + w_{beam} = 4.09\ \text{klf}$

Compare to problem 1.1 $\frac{w_u}{w_s} = 1.31$

This ratio is between 1.2 and 1.6 and suggests that the majority of the load comes from long term loadings.

1.4 A slab in figure P.1 is used for lobby space. The slab is 10 in. thick on a 14 in. wide x 24 in. deep beam, the bay dimensions are 21'- 0" in the x direction and 26'- 0" in the y direction and the superimposed service dead load is 15 psf. Calculate the slab factored load in psf and the beam factored load in klf.

SOLUTION

$b := 14\text{in}$ $h := 24\text{in}$ $t := 10\text{in}$ $q_{sdl} := 15\text{psf}$

From Table 1.1 the lobbly live load is $q_l := 100\text{psf}$ $\gamma_c := 150\text{pcf}$

$q_{slab} := \gamma_c \cdot t = 125\ \text{psf}$

$w_{beam} := (h - t) \cdot b \cdot \gamma_c = 204\ \text{plf}$

$q_u := 1.2 \cdot (q_{slab} + q_{sdl}) + 1.6 \cdot q_l = 328\ \text{psf}$

The beam tributary width length is $l := 21\text{ft}$

$w_u := q_u \cdot l + 1.2 w_{beam} = 7.13\ \text{klf}$

1.5 The building in figure P.1 is used for light storage space. The slab is 10 in. thick on a 16 in. wide x 20 in. deep beam, the bay dimensions are 20'- 0" in the x direction and 25'- 0" in the y direction and the superimposed sprinkler dead load is 4 psf. Calculate the slab factored load in psf and the beam factored load in klf.

SOLUTION

$b := 16\text{in}$ $h := 20\text{in}$ $t := 10\text{in}$ $q_{sdl} := 4\text{psf}$ $\gamma_c := 150\text{pcf}$

From Table 1.1 the light storage live load is $q_l := 125\text{psf}$

$q_{slab} := \gamma_c \cdot t = 125\ \text{psf}$

$w_{beam} := (h - t) \cdot b \cdot \gamma_c = 167\ \text{plf}$

$q_u := 1.2 \cdot \left(q_{slab} + q_{sdl}\right) + 1.6 \cdot q_l = 355\ \text{psf}$

The beam tributary width length is $l := 20\text{ft}$

$w_u := q_u \cdot l + 1.2 w_{beam} = 7.30\ \text{klf}$

1.6 The roof on the building in figure P.1 has a slab 7 in. thick on a 12 in. wide x 16 in. deep beam, the bay dimensions are 19'- 0" in the x direction and 21'- 0" in the y direction and the superimposed service dead load is 6 psf. Calculate the slab factored load in psf and the beam factored load in klf.

SOLUTION

$b := 12\text{in}$ $h := 16\text{in}$ $t := 7\text{in}$ $q_{sdl} := 6\text{psf}$

From Table 1.1 the roof live load is $q_l := 20\text{psf}$ $\gamma_c := 150\text{pcf}$

$q_{slab} := \gamma_c \cdot t = 87.5\ \text{psf}$

$w_{beam} := (h - t) \cdot b \cdot \gamma_c = 112\ \text{plf}$

$q_u := 1.2 \cdot \left(q_{slab} + q_{sdl}\right) + 1.6 \cdot q_l = 144\ \text{psf}$

The beam tributary width length is $l := 18.5\text{ft}$

$w_u := q_u \cdot l + 1.2 w_{beam} = 2.80\ \text{klf}$

2.1. The specified concrete strength f'_c for a new building is 5000 psi. Calculate the required average f_{cr} for the concrete (*a*) if there are no prior test results for concrete with a compressive strength within 1000 psi of f'_c made with similar materials, (*b*) if 20 test results for concrete with f'_c = 5500 psi made with similar materials produce a sample standard deviation s_s of 560 psi, and (*c*) if 30 tests with f_c = 4500 psi made with similar materials produce a sample standard deviation s_s of 540 psi.

Solution: f'_c= 5000 psi

a) No prior results

$f'_{cr} = f'_c$ +1200 psi = 5000+1200= 6200 psi

b) 20 prior tests for concrete with f'_c within 1000 psi of f'_c of the project and s_s = 560 psi. From Table 2.1, k = 1.08 and ks_s is 1.08*560 = 605 psi.
Because f'_c = 5000 psi, use eqs (2.1) and (2.2a)

$f'_{cr} = f'_c + 1.34\ ks_s$ = 5000 + 1.34*605 = 5810 psi

$f'_{cr} = f'_c + 2.33\ ks_s$ -500= 5000 + 2.33*605 - 500= 5910 psi

USE f'_{cr} = 5910 psi

c) 30 prior tests for concrete with f'_c within 1000 psi of f'_c for the project. s_s = 590 psi and k is 1.0.

$f'_{cr} = f'_c + 1.34\ s_s$ = 5000 + 1.34*590 = 5790 psi

$f'_{cr} = f'_c + 2.33\ s_s$ -500= 5000 + 2.33*590 -500= 5870 psi

USE f'_{cr} = 5790 psi

COMMENT: in cases b) and c) the f'_{cr} would reasonably be taken as 6000 psi.

2.2. Ten consecutive strength tests are available for a new concrete mixture with f'_c = 4000 psi: 4830, 4980, 3840, 4370, 4410, 4890, 4450, 3970, 4780, and 4040 psi.
(a) Do the strength results represent concrete of satisfactory quality? Explain your reasoning.
(b) If f'_{cr} has been selected based on 30 consecutive test results from an earlier project with a sample standard deviation s_s of 570 psi, must the mixture proportions be adjusted? Explain.

Solution:

a) For f'_c = 4000 psi, the strength results indicate satisfactory concrete quality because (1) no individual test I below f'_c – 500 psi = 3500 psi, and (2) every arithmetic average of any three consecutive tests equals or exceeds f'_c..

b) For s_s = 570 psi, for 30 consecutive tests calculate f'_{cr} using equations 2.1 and 2.2a.

$f'_{cr} = f'_c + 1.34\ ks_s$ = 4000 + 1.34*1*570 = 4760 psi

$f'_{cr} = f'_c + 2.33\ ks_s$ -500= 4000 + 2.33*1*570 - 500= 4830 psi

USE f'_{cr} = 4830 psi

The average of the above tests is (4830+ 4980+ 3840+ 4370+ 4410, 4890+ 4450+ 3970+ 4780 + 4040)/10 = 4460

Because the average strength is less than the target strength, the water/cement ratio must be adjusted by adding cement or reducing water to increase the strength. If the water is reduced, a water reducer admixture would be required to maintain workability.

2.3. The specified concrete strength f'_c for the columns in a high-rise building is 12,000 psi. Calculate the required average f'_{cr} for the concrete (*a*) if there are no prior test results for concrete with a compressive strength within 1000 psi of f_c made with similar materials, (*b*) if 15 test results for concrete with f'_c = 11,000 psi made with similar materials produce a sample standard deviation s_s of 930 psi, and (*c*) if 30 tests with f'_c = 12,000 made with similar materials produce a sample standard deviation s_s of 950 psi.

Solution: f'_c= 12000 psi
a) No prior results

$f'_{cr} = f'_c + 0.1 f'_c + 700$ psi = 12000+0.1*12000 + 700= 13,900 psi

b) 15 prior tests for concrete with f'_c within 1000 psi of f'_c of the project and s_s = 930 psi. From Table 2.1, k = 1.16 and ks_s is 1.16*930 = 1079 psi.
Because f'_c > 5000 psi, use eqs (2.1) and (2.2b)

$f'_{cr} = f'_c + 1.34\, ks_s$ = 12000 + 1.34*1079 = 13,450 psi

$f'_{cr} = 0.9f'_c + 2.33\, ks_s$= 0.9*12000 + 2.33*1709 = 13,310 psi

USE f'_{cr} = 13,450 psi

c) 30 prior tests for concrete with f'_c within 1000 psi of f'_c for the project. s_s = 950 psi and k is 1.0.

$f'_{cr} = f'_c + 1.34\, s_s$ = 12000 + 1.34*950 = 13,270 psi

$f'_{cr} = 0.9f'_c + 2.33\, ks_s$= 0.9*12000 + 2.33*950 = 13,010 psi

USE f'_{cr} = 13,270 psi

3.1. A 16 × 20 in. column is made of the same concrete and reinforced with the same six No. 9 (No. 29) bars as the column in Examples 3.1 and 3.2, except t hat a steel with yield strength f_y = 40 ksi is used. The stress-strain diagram of this reinforcing steel is shown in Fig. 2.15 for f_y = 40 ksi. For this column determine (*a*) the axial load that will stress the concrete to 1200 psi; (*b*) the load at which the steel starts yielding; (*c*) the maximum load; and (*d*) the share of the total load carried by the reinforcement at these three stages of loading. Compare results with those calculated in the examples for f_y = 60 ksi, keeping in mind, in regard to relative economy, that the price per pound for reinforcing steels with 40 and 60 ksi yield points is about the same.

$A_s := 6.0in^2$

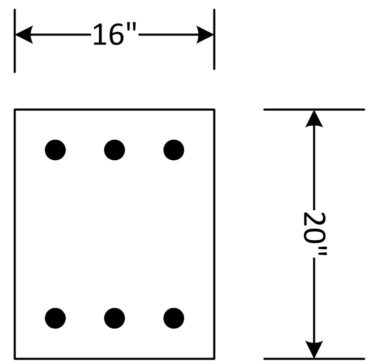
$A_g := 16in \cdot 20in = 320 \cdot in^2$

$A_c := A_g - A_s = 314 \cdot in^2$

$f'_c := 4000psi \qquad f_y := 40000psi \qquad f_{y1} := 60000psi$

$E_c := 3600000psi \qquad E_s := 29000000psi$

$n := \dfrac{E_s}{E_c} = 8.1$



Part a The solution is identical for grade 40 and grade 60 reinforcement

$f_c := 1200psi$

$P := f_c \cdot (A_c + n \cdot A_s) = 434800\, lbf \qquad P_s := f_c \cdot n \cdot A_s = 58000\, lbf$

$\dfrac{P_s}{P} = 0.133$ The steel carries 13.3 percent of the load

Part b

$\varepsilon_y := \dfrac{f_y}{E_s} = 0.00138 \qquad \varepsilon_{y1} := \dfrac{f_{y1}}{E_s} = 0.00207$

For slow loading $f_c := 3000psi \qquad f_{c1} := 3300psi$

$P := A_c \cdot f_c + A_s \cdot f_y = 1182000\, lbf \qquad P_1 := A_c \cdot f_{c1} + A_s \cdot f_{y1} = 1396200\, lbf$

$P_s := A_s \cdot f_y = 240000\, lbf \qquad P_{s1} := A_s \cdot f_{y1} = 360000\, lbf$

$\dfrac{P_s}{P} = 0.203 \qquad \dfrac{P_{s1}}{P_1} = 0.258$

Problem 3.1
Part c

$f_c := 3400\text{psi}$

$P_u := A_c \cdot f_c + A_s \cdot f_y = 1307600\ \text{lbf}$

$P_s := A_s \cdot f_y = 240000\ \text{lbf}$

$\frac{P_s}{P_u} = 0.184$

$P_{u1} := A_c \cdot f_c + A_s \cdot f_{y1} = 1427600\ \text{lbf}$

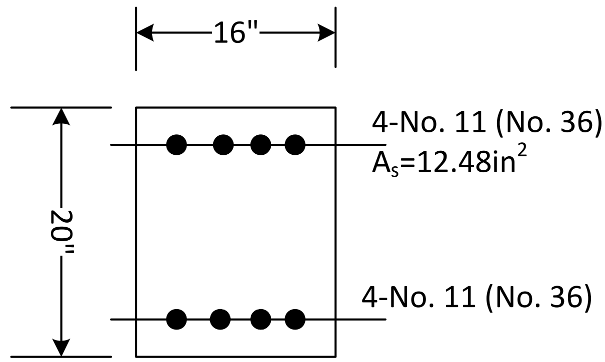
$P_{s1} := A_s \cdot f_{y1} = 360000\ \text{lbf}$

$\frac{P_{s1}}{P_u} = 0.275$

Comments

1. There is no difference at fc = 1200 psi and elastic assumptions are used
2. As the strain increases, the steel with fy = 60,000 psi contributes more to the total load and the column has a higher total capacity
3. Grade 40 and Grade 40 have the same cost, therefore Grade 60 provides a 9% increase in capacity for no increase in cost.

3.2 The area of steel, expressed as a percentage of gross concrete area, for the column of Problem 3.1 is lower than would often be used in practice. Recalculate the comparisons of Problem 3.1, using *f* *y* of 40 ksi and 60 ksi as before, but for a 16 × 20 in. column reinforced with eight No. 11 (No. 36) bars. Compare your results with those of Problem 3.1.



$A_{s11} := 1.56in^2$

$A_s := 8 \cdot A_{s11} = 12.48 \cdot in^2$

$A_g := 16in \cdot 20in = 320 \cdot in^2$

$A_c := A_g - A_s = 307.52 \cdot in^2$

$f'_c := 4000psi \qquad f_y := 40000psi \qquad f_{y1} := 60000psi$

$E_c := 3600000psi \qquad E_s := 29000000psi$

$n := \frac{E_s}{E_c} = 8.1$

Part a The solution is identical for grade 40 and grade 60 reinforcement

$f_c := 1200psi$

$P := f_c \cdot (A_c + n \cdot A_s) = 489664\,lbf \qquad P_s := f_c \cdot n \cdot A_s = 120640\,lbf$

$\frac{P_s}{P} = 0.246$ The steel carries 25 percent of the load

Part b

$\varepsilon_y := \frac{f_y}{E_s} = 0.00138 \qquad \varepsilon_{y1} := \frac{f_{y1}}{E_s} = 0.00207$

For slow loading $f_c := 3000psi \qquad f_{c1} := 3300psi$

$P := A_c \cdot f_c + A_s \cdot f_y = 1421760\,lbf \qquad P_1 := A_c \cdot f_{c1} + A_s \cdot f_{y1} = 1763616\,lbf$

$P_s := A_s \cdot f_y = 499200\,lbf \qquad P_{s1} := A_s \cdot f_{y1} = 748800\,lbf$

$\frac{P_s}{P} = 0.351 \qquad \frac{P_{s1}}{P_1} = 0.425$

Problem 3.2
Part c

$f_c := 3400\text{psi}$ both cases

$P_u := A_c \cdot f_c + A_s \cdot f_y = 1544768\ \text{lbf}$

$P_s := A_s \cdot f_y = 499200\ \text{lbf}$

$\frac{P_s}{P_u} = 0.323$

$P_{u1} := A_c \cdot f_c + A_s \cdot f_{y1} = 1794368\ \text{lbf}$

$P_{s1} := A_s \cdot f_{y1} = 748800\ \text{lbf}$

$\frac{P_{s1}}{P_u} = 0.485$

Comments

1. There is no difference at fc = 1200 psi and elastic assumptions are used
2. There is a 16% capacity increase at nominal using Grade 60 reinforcement
3. The higher steel ratio produces a higher overall capacity compared to problem 3.1

3.3. A square concrete column with dimensions 22 × 22 in. is reinforced with a total of eight No. 10 (No. 32) bars arranged uniformly around the column perimeter. Material strengths are f y = 60 ksi and f c └ = 4000 psi, with stressstrain curves as given by curves a and c of Fig. 3.3 . Calculate the percentages of total load carried by the concrete and by the steel as load is gradually increased from 0 to failure, which is assumed to occur when the concrete strain reaches a limit value of 0.0030. Determine the loads at strain increments of 0.0005 up to the failure strain, and graph your results, plotting load percentages vs. strain. The modular ratio may be assumed at n = 8 for these materials.

Using Concrete data from Figure 3.3

A_s =	10.12	in^2
A_c =	474	in^3
fy =	60000	psi
f'_c =	4000	psi

Strain	f_c (psi)	P_c (kips)	f_s (psi)	P_s (kips)	P_{total} (kips)	P_c/P_{total}	P_s/P_{total}
0.0000	0	0	0	0	0	0.00%	0.00%
0.0005	1600	758	14500	147	905	83.8%	16.2%
0.0010	2600	1232	29000	293	1526	80.8%	19.2%
0.0015	3100	1469	43500	440	1910	76.9%	23.1%
0.0020	3300	1564	58000	587	2151	72.7%	27.3%
0.0025	3400	1612	60000	607	2219	72.6%	27.4%
0.0030	3400	1612	60000	607	2219	72.6%	27.4%