FINAL EXAMINATION

Open books, notes and any other material.
Time of Examination: 3 Hours

READ following notes:

1. The total number of points exceeds 100 points. However, your score may not exceed 100.

2. There will be no credits for correct "answers" which are not relevant to the question. There might be even deductions for such attempts.

3. Budget your time according to your strength. The questions are not in order of their difficulty. Start and solve in order of their difficulty for you, starting from the easiest.

4. Each problem should be solved starting a new odd page in the exam book.

5. Optional. At the end of the examination, please answer a few questions on the enclosed form (on the back of this page). Do not sign it and submit the page separately from your examination, if you wish to do so. Add additional pages if you think you need it. Your feedback is very important to us.

SUCCESS TO YOU IN YOUR EXAMINATION

and

SUCCESS IN YOUR ENGINEERING LIFE.

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Have a nice holiday and winter vacation!!
Problem #1 TWOWAYSLAB (30 pps.)
Using load distribution method (based on equal deflections in mid span), determine the load
distribution in each direction, determine the maximum moments and design the reinforcement for
all directions of ONE panel of the slab supported by beams (along all axes lines) shown in Fig 1 below.
Assume a 4" thick slab and a service live load of 159 psf. The concrete is 3500-psi strength and the
steel is GR50. [You may approximate the maximum moments using the suggested envelopes – see
below - and you may assume k=0.2 for all cases to reduce computations] Indicate all your
approximations!

Fig 1 - Floor layout for Problems 1 (not in scale)

SUGGESTED APPROXIMATIONS FOR HORIZONTAL ENVELOPES
Problem #2 EVALUATION OF BEAMS (40 pts.)

For the 15" x 28" rectangular beam, reinforced with 4#/8 at both supports, and 3#/8 in midspan as shown below, determine:

a) Determine the moment capacity in each of the critical sections (10 pts).

b) Determine how much total ultimate uniformly distributed load can be supported on this beam (5 pts).

c) Assuming that the dead load is 35% of the total, determine the service live and dead load which can be supported by the beam (5 pts).

d) Determine the amount of camber that you need in the forms during the casting of the beam such that the beam will be perfectly flat under half of the live load. Use equivalent moment of inertia determined using midspan moment of inertia only (c1=c2=0; c3=1) (20 points).

Data: Concrete: 3000 psi, Steel: GR60; Cover: 3", E/E₀=9

Fig 2 - Beam end moment diagram for Problem 2
Problem #3 Columns (30 pts).

1) Determine the ultimate capacity interaction diagram for the column below defined by two (optional three) points:
   a) Axial capacity without any moments (5 pts)
   b) Balanced failure of the column (15 pts)
   c) (Optional for 5 more points) Failure of the column with tension strain at extreme tensioned fiber equal to the double the yield strain of steel. ($\varepsilon = 2 \varepsilon_y$) - extreme tension fiber is at the edge of the column

2) Determine the design space derived from the capacity diagram developed in (1) above. (7 pts)

Notes:

Moments should be calculated about the symmetry axis of the section. Assume a tied column (no spiral reinforcement)

Data for the column:

Concrete: 4,000 psi, $\varepsilon_y = 0.004$ !!!!! Steel: 1269 of GR60.

Cover of reinforcing bars form the center of the bar (including the hoops): 3" - from axis of reinforcement to the outside surface is all places.

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Fig 3 - Cross section of column in Problem #3
Problem #4 - CONCEPTS AND DETAILING (20 pts.)

For the retaining wall shown below indicate:
1) The expected deflected line of the retaining wall (5 pts)
2) The expected moment diagram due to lateral soil pressure. Assume in the lower level embedment is 9 times bigger than the pressure in the high level soil. (5 pts)
3) The location of the needed reinforcement (only the reinforcement required to compensate for tension in concrete) (5 pts)
4) The detailed required reinforcement and the details of the bars to be able to construct the wall. (5 pts)

ONLY APPROXIMATIONS ARE ALLOWED FOR THIS QUESTION. POINTS WILL BE DEDUCTED FOR ANY DETAILED COMPUTATIONS APPLIED HERE.

Fig 4 - Cross section for Question #4
The distributions will follow:

\[ W_X = \left( \frac{1}{\lambda_X} \right)^4 e^{-\lambda_X X} \]

\[ W_Y = \left( \frac{1}{\lambda_Y} \right)^4 e^{-\lambda_Y Y} \]

**Panel (a):**

\[ \lambda_X = 26/0.6 \quad \lambda_Y = 0.8 \times 26 = 21.6 \]

\[ \lambda_Y = 20/0.5 \quad \lambda_Y = 0.8 \times 20 = 16.0 \]

\[ \eta_X = \frac{16}{20} = 0.8 \quad \eta_Y = \frac{16}{20} = 0.8 \]

\[ \frac{\eta_X}{\eta_Y} = \frac{0.8}{0.8} = 1 \]

\[ w_X = w_Y = \frac{1}{220 + 1} = \frac{w_{DR}}{4.7} \]

\[ w_Y = w_{DR} \quad \frac{3.2}{4.2} = 0.762 \]

\[ = 0.298 \times w_{DR} \]

**Panel (b):**

\[ \lambda_X = 26 \quad \lambda_X = 0.6 \times 26 = 15.6 \]

\[ \lambda_Y = 20 \quad \lambda_Y = 0.5 \times 20 = 10.0 \]

\[ \frac{\lambda_X}{\lambda_Y} = \frac{16}{15.6} = 1.025 \]

\[ \frac{w_X}{w_Y} = \frac{1.025}{1.107} = 0.926 \quad \frac{w_Y}{w_{DR}} \]

\[ \frac{1}{210} = 0.474 \times w_{DR} \]
\[ X_L = \frac{4}{12} \times 150 = 50 \, \text{gal} \]

\[ W_L = 120 \, \text{psf} \]

\[ W_{107} = 1.9 \times 50 + 170 \times 17 = 2790 \, \text{lbf} \]

\[ W_s = 210.2 \]

\[ W_s = 210.2 \]

\[ W_s = 199.8 \]

\[ w = 144.1 \]

\[ w = 2.37 \]

\[ w = 114.1 \]

\[ w = 129.8 \]

\[ w = 114.1 \]

\[ w = 210.2 \]

\[ w = 129.8 \]

\[ w = 144.1 \]

\[ w = 114.1 \]

\[ \Delta_s_{ml} = 0.018 \times 5 \times 12 = 0.065 \, \text{in/lb} \]

\[ \Delta_s = 0.1 \times 1057.9 = 105.79 \, \text{in} \]

\[ \Delta_s = 0.60 \, \text{in} \]

\[ \Delta_s = 0.78 \, \text{in} \]

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Problem #1 TWO WAY SLAB (30 pts.)
Using load distribution method (based on equal deflections in mid spans), determine the load distribution in each direction, determine the maximum moments and design the reinforcement for all directions of all panels of the slab supported by beams (along all axes lines) shown in Fig 1 below. Assume a 1/4" thick slab and a service live load of 1500 lb. The concrete is 3500-psi strength and the steel is GR60. [You may approximate the maximum moments using the suggested envelopes – see below - and you may assume k=0.2 for all cases to reduce computations] Indicate all your approximations.
**Problem 12**

(a) **Mental Capacity**

\[
A = \frac{g}{3} \quad f_{v} = 3 \text{kr} \quad A_{1} = 6 \text{kr}
\]

\[
\Delta = 28^\circ 
\]

\[
A_{s} = 4 \times 0.79 = 3.16 \text{kr}
\]

\[
A_{d} = 2 \times 0.79 = 1.58 \text{kr}
\]

\[
K = \frac{6}{0.8 \times 3.3} \frac{3.16}{2 \times 15} \frac{1.58}{2 \times 15} \frac{1 - 2.85}{6.0} = 0.103
\]

\[
\gamma' = 0.0032 \left( \frac{0.08 - 0.85 \cdot (0.82 / 2)}{0.103} \right) = 0.0002 \approx 0.003 \left( \text{watt} \cdot \text{K}^{-1} \right)
\]

Recalculate \( L \):

\[
K = \frac{5.0}{0.20 \times 3} \frac{3.16}{2 \times 15} = 0.192
\]

\[
M = 3.16 \times 60 \times 25 \left( 1 - \frac{0.192}{2} \right) = 4260 \text{ km} = 386 \text{ K} \cdot \text{ft}
\]

\[
M_{1234567} = 2.27 \text{ kN} \cdot \text{m} = 2.37 \text{ kN} \cdot \text{m}.
\]

\[
K = \frac{6.0}{0.8 \times 6} \frac{3.16}{2 \times 15} = 0.158
\]

\[
M = 2.27 \times 60 \times 25 \left( 1 - \frac{0.158}{2} \right) = 3288 \text{ kN} \cdot \text{m} = 274 \text{ k} \cdot \text{ft}
\]

(b) **Ultimate Load**

\[
W_{b} = 10 \text{ ft} \cdot 20 \text{ ft} = 200 \text{ k} \cdot \text{ft}
\]

\[
W_{k} = \frac{355 + 214}{629} = 0.59 \text{ k} \cdot \text{ft}
\]

\[
W_{D} = \frac{8 \times 629}{20^2} = 125.8 \text{ k} \cdot \text{ft}
\]
\[ W_B = 0.35W \quad W_L = 0.65W \]

\[ W_{tot} = 4.4 \times 0.35 + 1.7 \times 0.65 \]

\[ W = W_{tot} / (1.4 \times 0.35 + 1.7 \times 0.65) = 0.63 \quad W_{tot} = 0.63 \times 12.73 = 7.89 kN \]

\[ W_B = 0.35 \times 7.89 = 2.77 kN/lit \]  
\[ (0.35 \times 0.63)w_{ml} = 6.14 \times 12 \frac{kN}{lit} \]

\[ W_L = 0.65 \times 7.89 = 5.12 kN/lit \]

### Deflections Due To Dead Load

\[ M_{dB} = 0.35 \times 0.63 \times 350 = 783 \]

\[ M_{dL} = 0.65 \times 0.63 \times 274 = 60.4 \]

\[ M_{BL} = 0.65 \times 0.63 \times 350 = 145.3 \]

\[ 0.65 \times 0.63 \times 274 = 117.2 \]

\[ M_c = \frac{15 \times 45^3}{12} + (15 \times 15) \]

\[ M_{eq} = \int M_c \text{ d}y = \frac{25 \times 45^2}{12} + 1951 = 564.3 \text{ kNm} \]

\[ = 641.8 \text{ kNm} = 641.8 \text{ kN.m} = 53.48 \text{ kN} \cdot \text{m} \]

### All Cases: Section will be cracked checked in flexure only

\[ f_{cr} = \frac{0.0063 \times q + 0.0063 \times q + 0.0033 \times q}{15 \times 2.5} = \frac{2.37}{15 \times 2.5} = 0.003 \times 2500 = 0.745 \]

\[ f_{cr} = 0.125 \times 25 \approx 3.75 \]

\[ f_{cr} = 0.25 \times 25 \approx 6.25 \]

\[ \begin{align*}
I_{cr} & = 15 \times 15 \times \left[ \frac{0.025}{3} + 0.0063 \times q \cdot (1 - 0.285)^2 \right] = 86.26 \text{ in}^4 \\
I_{eq} & = \left( \frac{535}{604} \right)^3 \times 1951 + \left[ -\frac{535}{604} \right]^3 \times 86.26 = 1604 \text{ in}^2 \end{align*} \]

\[ \text{not necessary} \]
$$I_{eq} = \left( \frac{53.5}{116} \right)^3 \times 19.531 + \left[ -\left( \frac{12.5}{116} \right)^3 \right] = 0.294 \text{ in}^4.$$  

$$\delta = \frac{L^2}{48EI_{eq}} \times (5M_o - 3M_c - 3H_o) =$$  

$$= \frac{(200)^2}{48 \times 2.5 \times 10^{6} \times 9.81} \times \left( 5 \times (116 + 102.5) - 3 \times (102.5 + 116) \right) =$$  

$$= 0.17 \text{ in}.$$  

CARNEGIE THE ENGINEERS BY \sim 0.17; SAY \sim 0.2\text{ in}.$$
(a) Axial compressive load:

$$N = (45 \times 45 - 4 \times 15) \times 0.35 \times 4.0 + 12 \times 1.0 (6.0 - 0.35 \times 4.0) = 450 - 100 \text{ kips}$$

$$M = 0$$

(b)

$$\varepsilon_p = \frac{60}{290} = 0.00207 \approx 0.002$$

$$\varepsilon_s = 0.004$$

$$\varepsilon_e = \frac{15 + 15 + 15}{(15 + 15 + 15)} (0.004 + 0.002) - 0.002 = 0.0036$$

$$\varepsilon_a = \frac{15 + 15}{42} (0.004 + 0.002) - 0.002 = 0.00143$$

$$\varepsilon_2 = \frac{15}{42} - 0.002 = 0.00115 \approx 0.0$$

$$\varepsilon_3 = 0.002$$

$$F_1 = 0.002 \times 29000 \times 2 = 60.2 \times 2 = 120 \text{ kips}$$

$$F_2 = 0.015 \times 29000 \times 4 = 16.5 \text{ kips}$$

$$F_4 = 0$$

$$F_5 = 0.015 \times 29000 \times 2 = 60 \times 2 = 120 \text{ kips}$$

$$F_{e Bray} = (2 \times 45 - 2 \times 15) \times 0.60 = 2601 \text{ kips}$$

$$N = 2601 + 120 + 16.5 - 120 = 2497.5 \text{ kips}$$

$$M = 4131 \times (22.5 - 15.5) - 14.5 \times (22.5 - 18) + 120 \times (22.5 - 3.5) + 14.5 \times (22.5 - 18) + 120 \times (22.5 - 3.5) = 18983 \text{ kips} - 152 \text{ kips}$$
\( E_1 = 0.60 \pi \)

\( E_2 = \frac{12 \times 0.08}{4} = 0.192 \pi \)

\( E_3 = \frac{7 \times 0.08}{4} = 0.112 \pi \)

\( E_4 = E_5 \)

\( E_6 = E_7 \)

\( F_1 = 60 \times 2 \times 1 = 120 \pi \)

\( F_2 = 0.008 \times 8 \times 2 \times 1 = 9.6 \pi \)

\( F_3 = 0.2 \pi \)

\( F_4 = 0.7 \pi \)

\( F_5 = 0.4 \pi \)

\( F_6 = 0.3 \pi \) (Note: This seems to be a typo, as it should be \( F_6 = 0.3 \pi \) for the calculation.)

\( F_7 = 0.5 \pi \)

\( F = 22.5 \times 4.5 \times 0.25 \times 14.3 = 3443.5 - 1530 = 1913.5 \pi \)

\( N = 1912 + 120 + 92 \times 2 - 92 \times 170 = 1477.5 \pi \)

\( M = 3443.5 \left( 22.5 - \frac{22.5}{2} \right) + 120 \left( 72 \times 2 - 7 \right) + 92 \times (22.5 - 18) = -1530 \left( 22.5 - 7.5 \right) = -1530 \times 15 = -23050 \pi \)

Diagram

Design values:

- \( 450 \times 0.75 \times 3 \pi \)
- \( 264 \times 0.75 \times 12 \pi \)
- \( 191 \times 0.75 \times 18 \pi \)
- \( 191 \times 0.75 \times 18 \pi \)
- \( 18 \times 0.75 \times 20 \pi \)