Question 1:

a.

1. Show that this slab can be analyzed using the CSA A23.3 approximate frame analysis method, then determine the factored beading moments and factored shear using this method.
   Check the 5 criteria for approximate frame analysis method:
2. More than 2 continuous spans;
3. Length of each span is within 20% of the one next to it.
   (4.5/4.2=1.07 & 4.5/4.5=1.0)
3. Loads are uniformly distributed.
4. Factored live load does not exceed 2 times of factored dead load:
   $D_D = D_{self} + D_{super} = 10.4$ kN/m
   $D_L = (1\text{ m}) \times (7\text{ kN/m}^2) = 7$ kN/m
   Factored dead load: $1.25D_D = 13$ kN/m
   Factored live load: $1.5D_L = 10.5$ kN/m
   $1.5D_D < 2(1.25D_L)$ ok!
5. The slab is prismatic.

$W_f = 1.25D_D + 1.5D_L = 23.5$ kN/m

Span 1: $l_n = 3.8$ m; Span 2: $l_n = 4.1$ m; Span 3: $l_n = 4.1$ m

Factored bending moments & shear loads:

Span	1			2			3		
L_n (m)	3.8			4.1			4.1		
Sign		+	-	-	+	-	-	+	-
C_m	0	1/11	-1/10	-1/11	1/16	-1/11	-1/11	1/16	-1/11
$M_f = C_m W_f l_n^2$	0	30.8	33.9	-35.9	24.7	-35.9	-35.9	24.7	-35.9
C_v	1/2	/	-1.15/2	1/2	/	-1/2	1/2	/	-1/2
$V_f = C_v W_f l_n$	44.65		-51.35	48.18		-48.18	48.18		-48.18

b. Design the flexural reinforcement for span 2:
   Step 1: calculate d

$$d = h - cover - d_b/2 = 197.5 \text{ mm}$$

   Step 2: Strength requirement

$$A_{s,strength} = \frac{M_f}{\phi_s f_y (0.9d)} = \frac{M_f \ \ (N \cdot mm)}{60435}$$

   Step 3: Min reinforcement requirement $A_{s,min}$

$$A_{s,min} = 0.002A_g = 450 \text{ mm}^2/\text{m}$$

   Step 4: Find the required amount of reinforcement:

$$A_s = max\begin{cases} A_{s,strength} \\ A_{s,min} \end{cases}$$

Calculate the corresponding spacing: $s = A_b \frac{1000}{A_s} = \frac{200000}{A_s}$

Step 5: Check the S_{max} requirement and choose a bar spacing

$$S_{max} = min\begin{cases} 3\text{h} = 675\ mm \\ 500\ mm \end{cases}$$

$$S_{provided} \leq min\begin{cases} \frac{200000}{A_s} \\ 500\ mm \end{cases}$$

Step 6: Verify that $M_r > M_f$

$$A_{s,provoded} = A_b \frac{1000}{S_{provided}} = \frac{200000}{S_{provided}}$$

$$M_r = \emptyset_s A_s f_y \left(d - \frac{a}{2}\right) = \phi_s f_y A_{s,provoded} \left(d - \frac{1}{2} \frac{\emptyset_s f_y A_{s,provoded}}{\alpha_1 \phi_c f'_c\ b}\right)$$

Step 7: Verify that slab is not over-reinforced

$$\rho_{balance} = \frac{f'_c}{1100} = 2.73\%$$

$$\rho = \frac{A_s}{bd} = \frac{A_{s,provided}}{1000 \times 197.5}$$

C_m	-1/11	1/16	-1/11
M_f (kN·m)	-35.9	24.7	-35.9
$A_{s,strength}$ (mm^2)	594.0	408.7	594.0
$A_{s,min}$ (mm^2)	450.0	450.0	450.0
A_s (mm^2)	594.0	450.0	594.0
S (mm)	336.7	444.4	336.7
S_{max} (mm)	500.0	500.0	500.0
$S_{provided}$ (mm)	336.7	444.4	336.7
$A_{s,provided}$ (mm^2)	594.0	450.0	594.0
M_r	38.6	29.5	38.6
M_r>M_f	ok	ok	ok
ρ	0.30%	0.23%	0.30%
ρ_b	2.73%	2.73%	2.73%
ρ<ρ_b	ok	ok	ok
Design	15M @ 336 mm (Reinforcement placed at top)	15M @ 444 mm (Reinforcement placed at bottom)	15M @ 336 mm (Reinforcement placed at top)

Design the temperature and shrinkage reinforcement (15M bars)

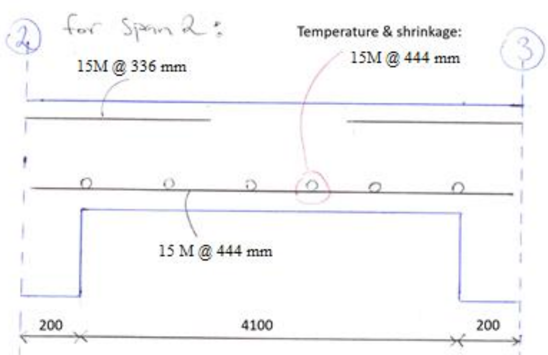
$S \leq A_b \frac{1000}{A_{s,min}} = 500\ mm$

$S_{max} = min\begin{cases} 5h \\ 444.4\ mm \end{cases} = 444.4\ mm$

$S \leq min\begin{cases} 500\ mm \\ 444.4\ mm \end{cases}$

Use 15M bars @ 444.4 mm

d.



e. Check that shear resistance is sufficient without the need to add additional shear reinforcement

$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d_v$

h < 350 mm ---- β=0.21

$d_v = max\begin{cases} 0.9d = 177.8\ mm \\ 0.72h = 162\ mm \end{cases}$

$V_c = \phi_c \lambda \beta \sqrt{f'_c} b_w d_v = 132.9kN$

$V_f < V_c$ ok!

f. Check whether the slab thickness of 225 mm is sufficient to avoid detailed deflection calculations.

At span 1: Slab is one-ends continuous.

Min. thickness = $l_n/24$ = 158.3 mm

ok!

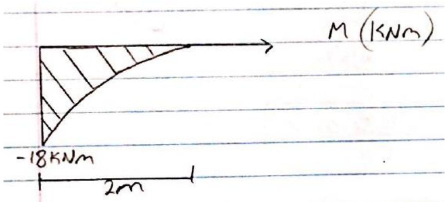
At span 2: Slab is both ends continuous.

Min. thickness = $l_n/28$ = 146.4 mm

ok!

Problem 2:

a) $M_f = \frac{w_f L^2}{2} = 18\ kN \cdot m$



$A_s = A_b\left(\frac{1000}{S}\right) = 666.7\ mm^2$

$d = 162.5\ mm$

$a = \frac{\emptyset_s A_s f_y}{\alpha_1 \emptyset_c f_c' b} = 17.22\ mm$

$\frac{c}{d} = 0.116 < (\frac{c}{d})_{max} = 0.64$

$M_r = \emptyset_s A_s f_y \left(d - \frac{a}{2}\right) = 34.88\ kN \cdot m$

$M_r = 34.88\ kN \cdot m > \ M_f = 18\ kN \cdot m$

$A_{s,min} = 0.002 A_g = 400\ mm^2$

$A_s = 666..7\ mm^2 > A_{s,min} = 400\ mm^2$

$S_{max} = min \begin{cases} 5h \\ 500\ mm \end{cases} = 500\ mm$

$S_{max} = 500\ mm > S = 300\ mm$

b)

$k_1 = 1.0$ thickness = 200 mm < 300 mm

$k_2 = 1.0$ regular uncoated bars

$k_3 = 1.0$ normal density concrete

$k_4 = 0.8$ 15M < 25M bars

$l_d = 0.45 k_1 k_2 k_3 k_4 \frac{f_y}{\sqrt{f_c'}} d_b = 432\ mm$

$EXT = max \begin{cases} 1.3d = 211.25\ mm \\ h = 200mm \end{cases} = 211.3\ mm$

$l_d + EXT = 643.3\ mm$

c)

$$l_{hb} = 100 \times \frac{d_b}{\sqrt{f_c'}} = 300\ mm$$

$$12d_b = 180\ mm$$

Assumn no modification factor.

$$l_{dh} = l_{hb} = 300\ mm$$