Carleton University
Department of Civil and Environmental Engineering

CIVE 3204 Introduction to Structural Design (Fall 2015)

Midterm Examination Solution

3 November 2015

Notes: **Duration 2 hours**
Closed book and notes
Allow 2 single-sided pages of notes and calculator

Question 1: (10 marks)

a) In limit states design of structures, uncertainties in the design process are explicitly recognized. Explain the sources of these uncertainties and how they are taken care of in order to ensure a safe design structure in Canada.

Answer:

5

Uncertainties in the design of structures occur primarily from two main sources: first the variability and uncertainty in determining and estimating the various load effects on the structures, and second the uncertainties due to the determination of a member's structural resistance which relies on the material properties, dimensions, construction practices and the various types of failure mechanisms (ex. Brittle vs. Ductile) and the modelling/design assumptions. All of these uncertainties that affect a member's structural resistance and load effect determination are taken into account by consideration of the safety criteria for ultimate limit states design given by the following expression:

$$\phi R \geq \alpha U$$

Which means reduced resistance ≥ effect of load demand due to factored loads. ϕ is the resistance reduction factor which accounts for the material uncertainties, and is less than 1. α is the load resistance factor which accounts for the loading variability and uncertainties in its determination, and is greater or equal to 1.

b) In serviceability limit states calculations, explain why unfactored service loads are used for the primary transient load actions in the load combination cases?

Answer:

5

To prevent the design structure from undesirable conditions that will affect its intended use and occupancy purpose, such as excessive deflections or vibrations etc., the serviceability limit state conditions are checked with the primary transient load actions in the load combination cases calculated at a lower level (i.e. unfactored loads) which correspond to more common conditions as opposed to at the ultimate limit states of failure (i.e. factored loads).

Question 2: (20 marks)

A typical floor plan of an office building with an elevator shaft opening is shown in Figure 1. Floor slabs ABFE and FHKJ are designed as one-way with the direction shown in the figure. All the other slabs are designed as two-way. Beam B1 is supported by girders G2 and G1, while beam B3 is supported by the columns. Assume all connections are simple supports.

The self-weight of beams B1 and B3 is 2 kN/m and that of the girders is 4 kN/m. The self-weight of the floor-ceiling system which includes the weight of the concrete slab, floor and ceiling finishes, and electrical and mechanical utilities is 3 kN/m^2.

The specified live load for office occupancy is 2.4 kN/ m^2.

a) Draw the tributary area for beams B1 and B3, and girder G2.

b) Determine and show the specified unfactored load patterns in free-body diagrams of beams B1, B3, and girder G2.

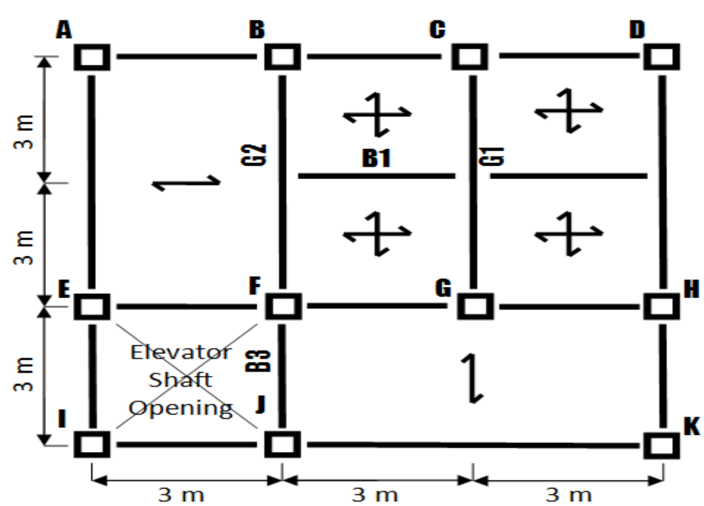
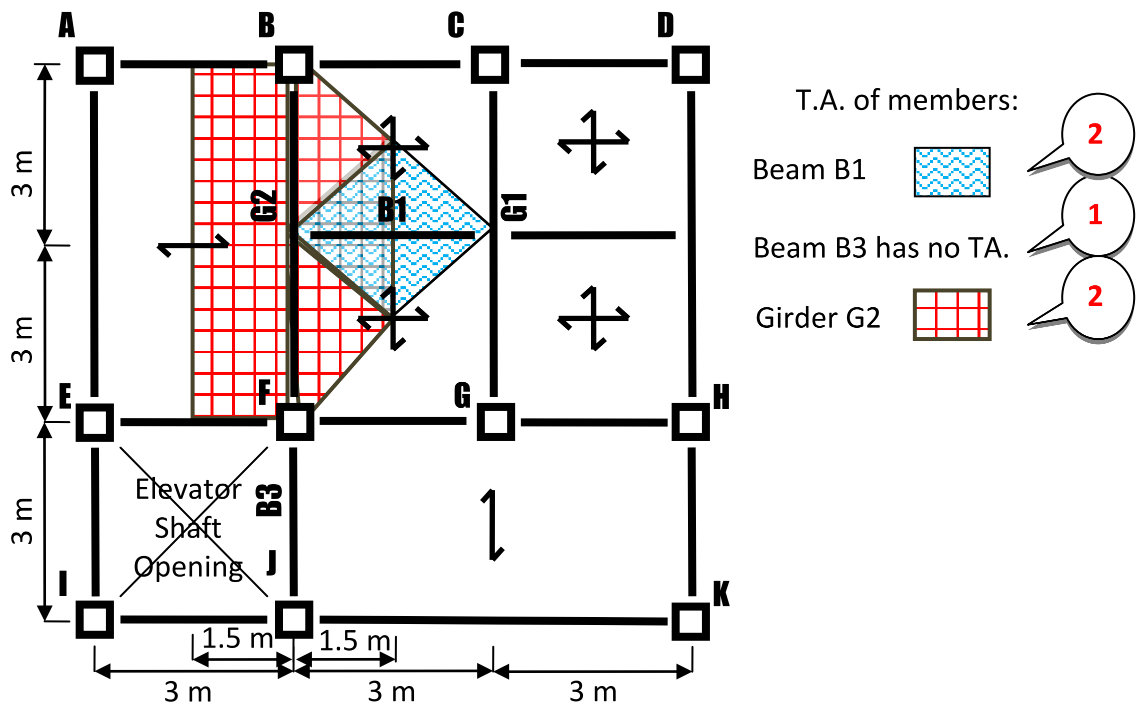


Figure 1: Floor Plan

Solution:

a) **Tributary areas:**



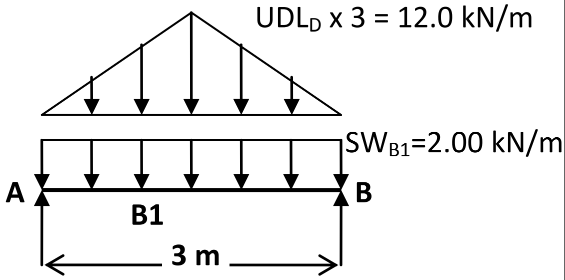
b) **Specified Unfactored Load Patterns:**

add 1 kPa for partition allowance → $UDL_D = 3+1 = 4\ kN/m^2$

Beam B1:

6

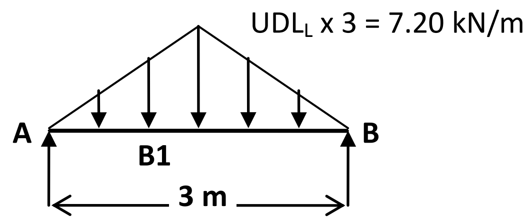
Dead Load



Ay_D = 12 kN By_D = 12 kN

Due to symmetry: $Ay_D = By_D$
ΣFy = 0 → By_D = (1/2)(3)(2)+ (1/2)(1/2)(3)(12)
= 12 kN

Live Load



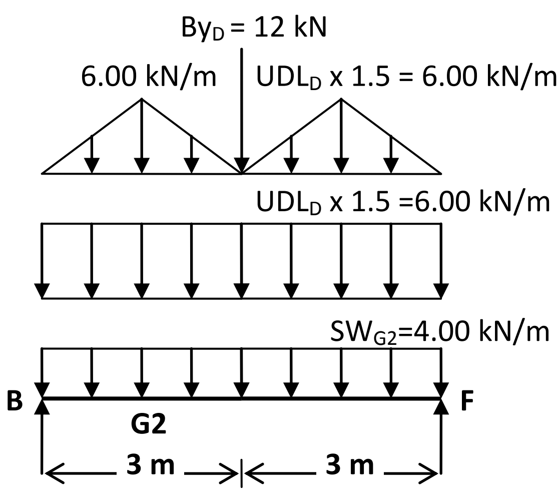
Ay_L = 5.40 kN By_L = 5.40 kN

Due to symmetry: $Ay_L = By_L$
ΣFy = 0 → By_L = (1/2)(1/2)(3)(7.2)
= 5.4 kN

Girder G2:

6

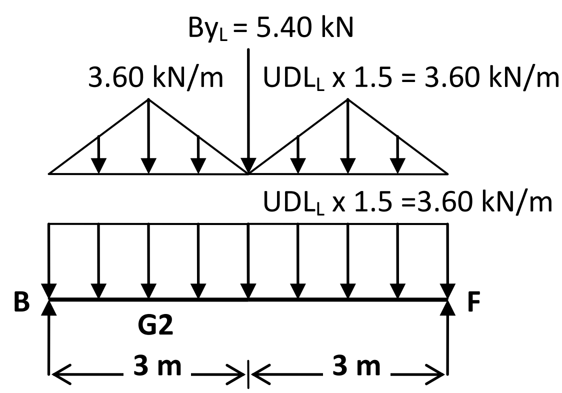
Dead Load



By_D = 45 kN Fy_D = 45 kN

Due to symmetry: $By_D = Fy_D$
ΣFy = 0 → By_D = (1/2)(6)(4+6)+
(1/2)(3)(6)+
(1/2)(12)
= 45 kN

Live Load



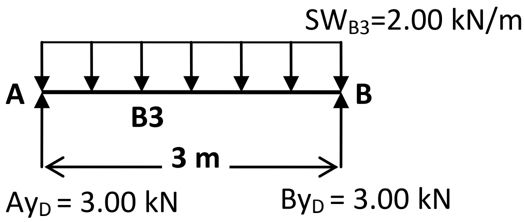
By_L = 18.9 kN Fy_L = 18.9 kN

Due to symmetry: $By_L = Fy_L$
ΣFy = 0 → By_L = (1/2)(6)(3.6)+
(1/2)(3)(3.6)+
(1/2)(5.4)
= 18.9 kN

3

Beam B3:

Dead Load



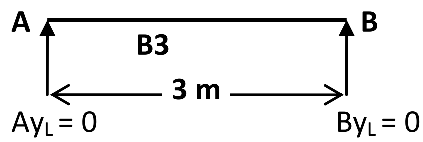
Due to symmetry: $Ay_D = By_D$

$\Sigma Fy = 0 \rightarrow\ Ay_D = (1/2)(3)(2)$

$= 3$ kN

Live Load

No live load is acting on Beam B3.



Question 3: (20 marks)

The frame shown in Figure 2 is subjected to the following specified loading:

Dead load D = 15 kN (weight of the Cantilever beam AB)

Live load W_L = 2.4 kN/m (uniformly distributed along AB)

Wind load W_W = 2 kN/m (reversible and Triangularly distributed along CD)

The self-weight of the frame CBD is negligible. The wind load may act in either direction as shown in the figure. Determine the maximum positive and maximum negative moments, and the design shear at the base support of the frame.

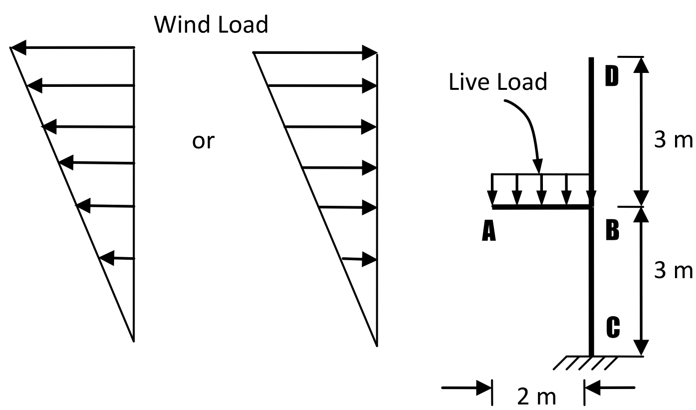
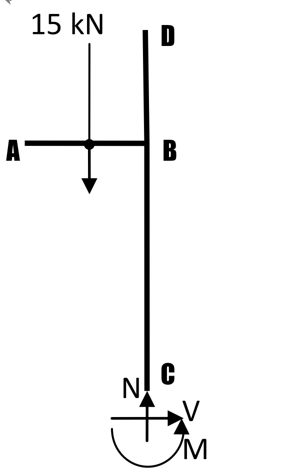


Figure 2

Solution:

Analyze the frame under each loading system separately.

1 Dead Load



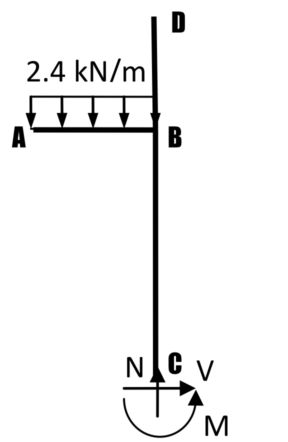
$\Sigma M_c = 0 \rightarrow$

$M_c = -15 \times 1 = -15$ kN-m

$\Sigma Fx_c = 0 \rightarrow$

$V_c = 0$ kN

1 Live Load



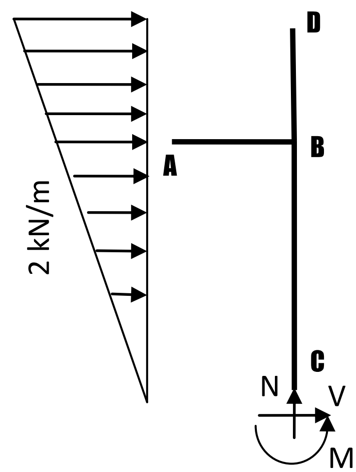
$\Sigma M_c = 0 \rightarrow$

$M_c = -2.4x2x1 = -4.8$ kN-m

$\Sigma Fx_c = 0 \rightarrow$

$V_c = 0$ kN

1 Wind Load



$\Sigma M_c = 0 \rightarrow$

$M_c = (1/2)x2x6x((2/3)x6)$

= 24 kN-m

For opposite wind direction:

$M_W = -24$ kN-m

$\Sigma Fx_c = 0 \rightarrow$

$Fx_c = -6$ kN or 6 kN

For opposite wind direction

7

Load combinations for <u>Positive moment</u>:

$D = M_D = -15$ kN-m

$L = M_L = -4.8$ kN-m

$W = M_W = +24$ kN-m

Since dead load (D) counteracts for positive moment (or simply because it creates negative moment, but we are looking for max positive moment), use factor 0.9 for dead load in cases 2, 3 and 4.

Since there is no snow load, load case 3 will not govern.

Since there is no earthquake load, load case 5 will not govern.

Case 1) $M_1 = 1.4D = 1.4 \times (-15)$ = -21 kN-m

Case 2) $M_2 = 0.9D + 1.5L + (0.5S \text{ or } 0.4W)$

= 0.9(-15) + 1.5(-4.8) + (0 or 0.4(+24)) = -11.1 kN-m

Case 4) M_4 = 0.9D + 1.4W + (0.5L or 0.5S)
= 0.9(-15) + 1.4(24) + (0.5(-4.8) or 0.5(0)) = 20.1 kN-m → Governs

Maximum **positive moment** for the design at the base support of the frame is **20.1 kN-m**.

Load combinations for negative moment:

D = M_D = -15 kN-m
L = M_L = -4.8 kN-m
W = M_W = -24 kN-m

Since dead load (D) is in agreement with negative moment, use 1.25 for dead load factor in cases 2, 3 and 4.
7 Since there is no snow load, load case 3 will not govern.
Since there is no earthquake load, load case 5 will not govern.

Case 1) M_1 = 1.4D = 1.4 x (-15) = -21 kN-m

Case 2) M_2 = 1.25D + 1.5L + (0.5S or 0.4W)
= 1.25(-15) + 1.5(-4.8) + (0 or 0.4(-24)) = -35.55 kN-m

Case 4) M_4 = 1.25D + 1.4W + (0.5L or 0.5S)
= 1.25(-15) + 1.4(-24) + (0.5(-4.8) or 0) = -54.8 kN-m → Governs

Maximum **negative moment** for the design at the base support of the frame is **54.8 kN-m**.

Load combinations for Shear:
D = V_D = 0 kN
L = V_L = 0 kN
W = V_W = 6 kN or -6 kN

3 Load combination 4 will give the maximum governing case as both the dead load and live load are 0. The maximum positive and maximum negative shears are equal in this case.

Case 4) V_4 = 1.25D + 1.4W + (0.5L or 0.5S)
= 1.25(0) + 1.4(6) + (0.5(0) or 0) = 8.4 kN → Governs

Maximum Absolute **Shear** for the design at the base support of the frame is **8.4 kN**.