Carleton University
Department of Civil and Environmental Engineering

CIVE 3204 Introduction to Structural Design (Fall 2010)

Midterm solution

Question 1(10 marks)

a) In limit states design, the typical load factor applied to specified dead load is 1.25 and to specified live load is 1.5 in factored load combination calculations of ultimate limit states. Explain what is the purpose of load factors in limit states design in general, and why there is a difference in the two load factors for dead load and live load.

Due to the long service lives of structures there is uncertainty in the magnitude of loads that are and will be applied to the structure, therefore, the purpose of load factors is to magnify the anticipated load applied to the structure in order to minimize the probability that any future load applied to the structure does not exceed the load the structure was designed to withstand safely.

The reason the load factor of the dead load is lower than the load factor for the live load is that there is more confidence in the engineer's ability to estimate an accurate dead load for the structure, then to predict an accurate live load for the structure. The self weight of concrete, steel members, ceiling tiles, flooring, electrical conduits, etc., are all well defined by physical properties such as unit weight and dimensions, which and can be calculated with higher level of certainty than other transient load effects. Whereas, the live load, due to the weight of occupants, of would have a large variation Therefore, due to the relative uncertainties of the dead and live loads, the dead load factor is smaller than the live load factor.

b) In load combination case involving earthquake, the load factors for dead load and earthquake load are both taken as 1.0, why?

For the other load cases the load factors are determined by performing a statistical analysis and then calibrating the load factors to ensure a sufficiently low probability of failure, similarly to assignment 2. Due to the fact that a major earthquake is a very rare occurrence, there is not enough data to perform a proper statistical analysis using the same methodology as the other loads, such as snow and wind, to determine the load factors. Therefore, in the evaluation of earthquake load, it is the uncertainty with regard to the earthquake load intensity, which accounts for in the seismic hazard modeling procedure by the seismologists to determine the probability and magnitude of an earthquake and their levels of uncertainty as well. Therefore, in the calculation of load combinations, the case involving earthquake load, E, a load factor of one is used. And, due to the method described for determining the earthquake load, E, the factor for the dead load cannot be properly calibrated and is therefore left as unity.

c) Explain the definition of return period in the context of limit state design of buildings for snow and wind load.

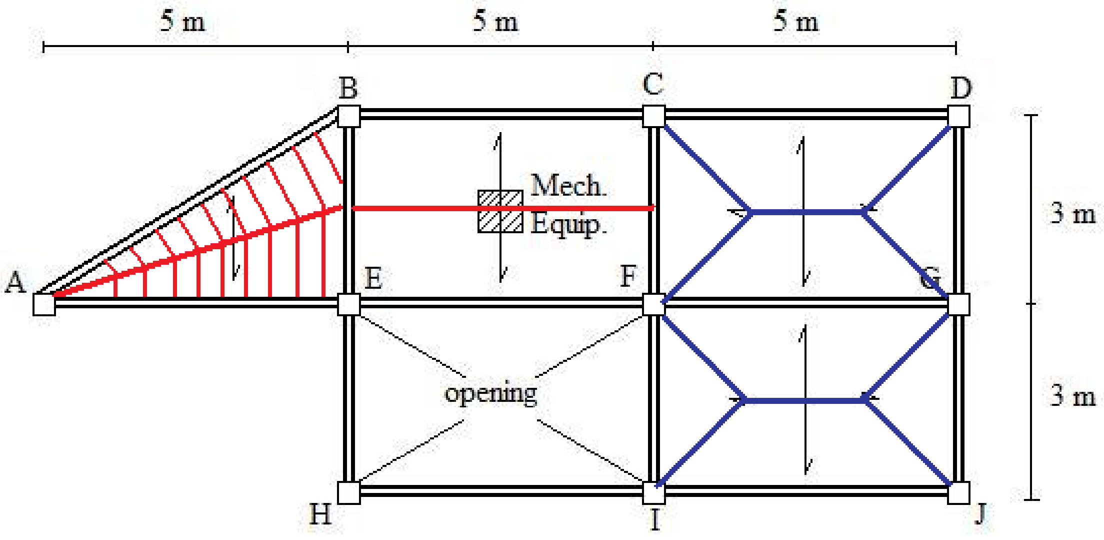
The return period for wind and snow load expressed in years, is the period of time during which there will be at least one incident that applies the maximum specified wind and snow load on the structure.

d) Explain why an importance factor of 0.9 is applied to snow load, and an importance factor of 0.75 to wind load, in serviceability limit states check of Limit State Design.

Serviceability limit states are the limit states which restrict the use and occupancy of a building (normal service loads). Ultimate limit states are the limit states which are concerned with the safety of the building (overturning, sliding and fracture). Factors used for ultimate limit states are for major events and therefore consider a large return period of 1 in 50 years for both wind and snow; this must be reduced to a reasonable return period as to check for loads which occur more frequently. Thus, the return period for snow is reduced to 1 in 30 years and the return period for wind is reduced to 1 in 10 years by using importance factors of 0.9 and 0.75, respectively.

Question 2

2-a) Tributary areas (6 marks)



Dead load calculation for the slab: (2 marks)

Vinyl floor tile finish	0.15 kN/m^2
Mechanical and electrical system	0.2 kN/m^2
Acoustic tile suspended ceiling	0.2 kN/m^2
Partition allowance	1.0 kN/m^2
Self weight of the slab	175/100*2.4 = 4.2 kN/m^2
	5.75 kN/m^2

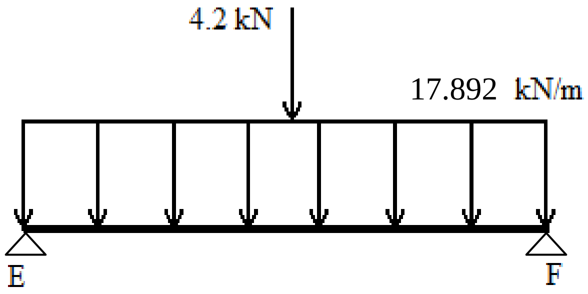
Self weight of the beams = 0.35 * 0.55 * 2200 * 9.81 = 4.155 kN/m

2-b) Beam EF (10 marks)

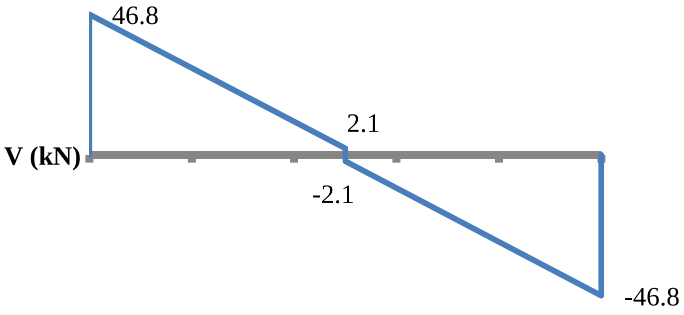
On beam EF there will be its self weight, the dead load from the slab, half of the mechanical equipment weight as a point load at mid span, and the live load from the slab, calculated as follows:

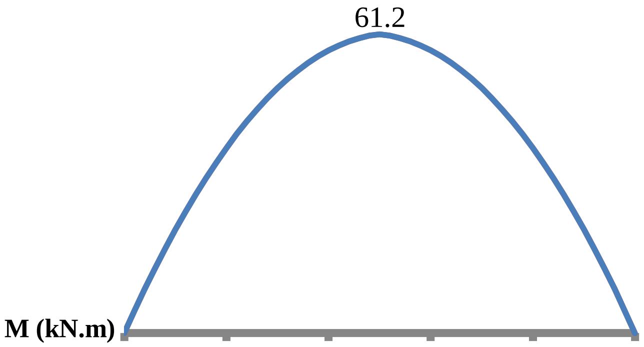
UDL dead = 5.75 * 1.5 = 8.625 kN/m
UDL live = 2.4 *1.5 = 3.6 kN/m
Point load mechanical = 6 /2 = 3 kN

<u>Case 1) 1.4 D</u>



Point load = 1.4 * 3 = 4.2 kN
UDL = 1.4 * (8.625 + 4.155) = 17.892 kN/m

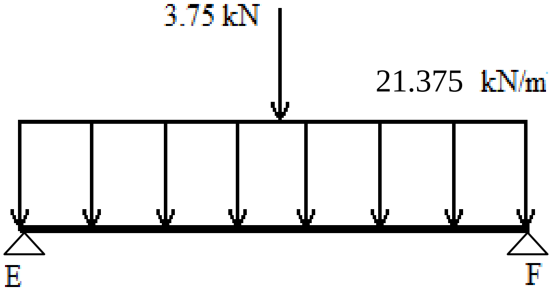




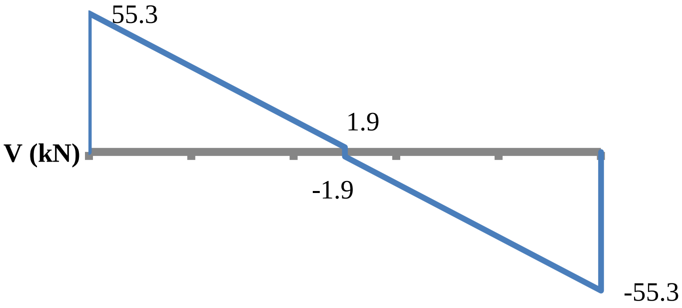
Note: In simply supported beams with symmetric geometry and loading system, maximum shear occurs at support location, and maximum bending moment occurs at midspan.

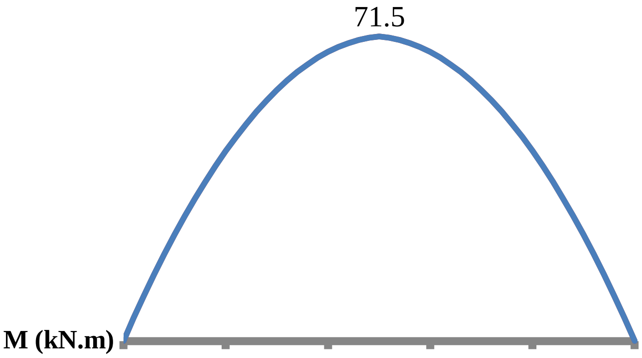
V_{max} = (4.2 + 17.892 * 5) / 2 = 46.83 kN
M_{max} = 46.83 *2.5 – 17.892 *2.5*2.5/2 = 61.162 kN.m

Case 2) 1.25 D + 1.5 L



Point load = 1.25 * 3 = 3.75 kN
UDL = 1.25 * (8.625 + 4.155) + 1.5 * 3.6 = 21.375 kN/m





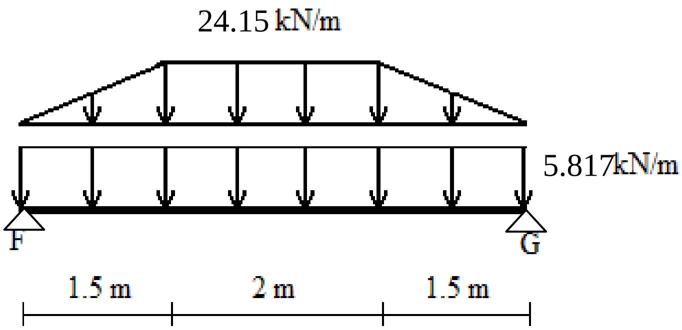
V_{max} = (3.75 + 21.375 * 5) / 2 = 55.313 kN → Governs
M_{max} = 55.313 *2.5 – 21.375 *2.5*2.5/2 = 71.486 kN.m → Governs

Maximum shear is 55.4 kN and maximum moment is 71.5 kN.m

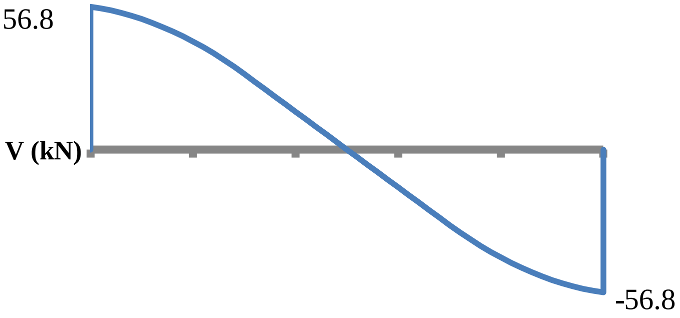
2-c) Beam FG (12 marks)

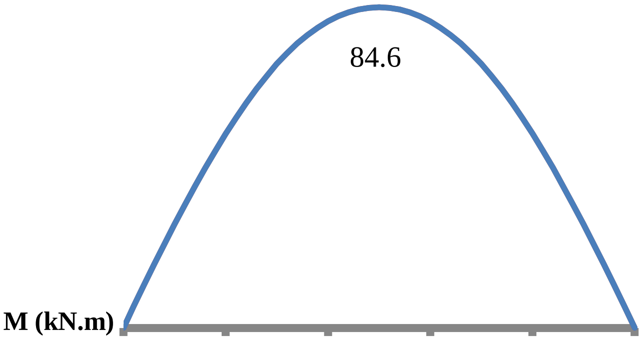
Maximum trapezoidal dead load intensity= 5.75 * 3 = 17.25 kN/m
Maximum trapezoidal live load intensity = 2.4 * 3 = 7.2 kN/m

Case 1) 1.4 D



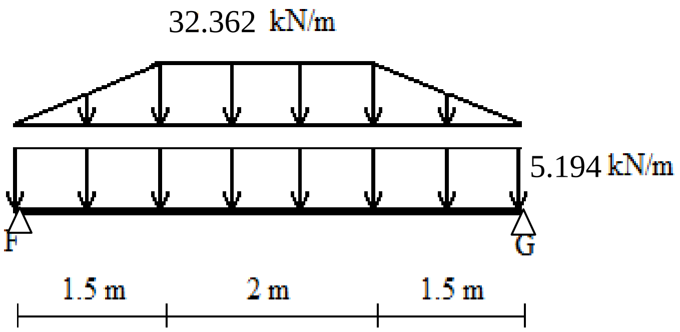
UDL due to self weight = 1.4 * 4.155 = 5.817 kN/m
Trapezoidal load intensity due to dead load= 1.4 * 17.25 = 24.15 kN/m



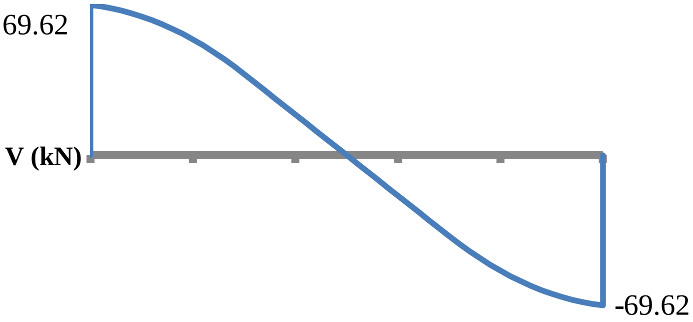


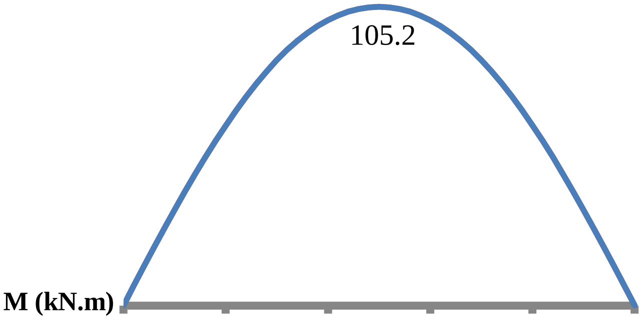
V_{max} = [5.817*5 + 24.15 * (2+5)/2] / 2 = 56.805 kN
M_{max} = 56.805*2.5 – 5.817*2.5*2.5/2 – (24.15*1.5/2)* (1+1.5/3) – 24.15*1*(1/2)
= 84.591 kN.m

Case 2) 1.25 D+1.5L



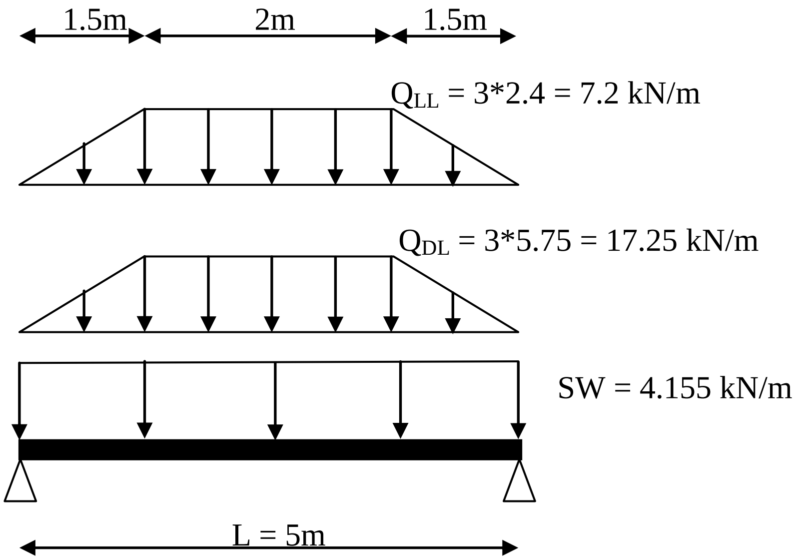
UDL due to self weight = 1.25 * 4.155 = 5.194 kN/m
Trapezoidal load intensity due to DL and LL = 1.25 * 17.25 + 1.5 * 7.2= 32.362 kN/m





V_{max} = [5.194*5 + 32.362 * (2+5)/2] / 2 = 69.619 kN → Governs
M_{max} = 69.619 *2.5 – 5.194*2.5*2.5/2 – (32.362*1.5/2)*(1+1.5/3) + 32.362*1*1/2]
= 105.228 kNm → Governs
Maximum shear is **69.7 kN** and maximum bending moment is **106 kN.m**.

2-c): (alternate solution)



R_{DL} = [SW*5+ Q_{DL} *(5+2)/2]/2 = 40.475 kN → unfactored support reaction (Dead Load)
R_{LL} = [Q_{LL} *(5+2)/2]/2 = 12.6 kN → unfactored support reaction (Live Load)

Note: In simply supported beams with symmetrical geometry and loading system, maximum shear occurs at support location, and maximum bending moment occurs at midspan.

Load Case I: $V_{I,max}$ = 1.4*(R_{DL}) = 56.805 kN
$M_{I,max}$ = 1.4*[R_{DL} *2.5-SW*2.5^2/2-Q_{DL}*(1.5/2)*(1+1.5/3)- Q_{DL}*1*1/2]
= 84.591 kN.m

Load Case II: $V_{II,max}$ = 1.25*(R_{DL})+1.5* R_{LL} = 69.619 kN → Governs
$M_{II,max}$ = 1.25*[R_{DL} *2.5-SW*2.5^2/2-Q_{DL}*(1.5/2)*(1+1.5/3)- Q_{DL}*1*1/2]
+1.5*[R_{LL} *2.5-Q_{LL}*(1.5/2)*(1+1.5/3)- Q_{LL}*1*1/2]
= 105.227 kN.m → Governs

Note: Since there is no wind, snow, or earthquake loads: load case II governs.

In the Beam: **V_{max} = $V_{II,max}$ = 69.7 kN** → Maximum factored shear
M_{max} = $M_{II,max}$ = 106 kN.m → Maximum factored bending moment