Carleton University
Department of Civil and Environmental Engineering

CIVE 3204 Introduction to Structural Design (Fall 2020)

Final Examination

14 December 2020

Notes:

- **2 hours open-book exam (2:00 pm-4:00 pm) and another 20 minutes for submission (4:00 pm-4:20 pm).**
- **Submissions should be started before or at 4:00 pm in case of internet connection or any other unforeseeable problem.**
- **Answers are to be submitted to cuLearn in PDF format.**
- **No late submissions (after 4:20 pm). Submission link will be turned off at 4:20 pm.**
- **NO EXCEPTION will be granted including scanning and/or connection problems.**

Question 1: (10%)

a) In limit states design of buildings, briefly explain why two different sets of load factors are used in the load combination calculations of ultimate limit states and serviceability limit states?

b) In the equivalent static force procedure for seismic design of buildings, an importance factor is used to increase the lateral earthquake design force for buildings in the high and post-disaster importance categories. Explain whether this will achieve the intent and objective of the design of higher importance buildings in the context of the new concept of performance-based design (PBD).

The following general description of a multi-storey building is applicable to Questions 2 to 5.

The elevation and typical floor plan of an 5 storey **office building** located in **downtown urban area of Pembroke**, Ontario are shown in Figure 1. All the concrete floor slabs and structural framing system of the building are designed as two-way slab systems as shown in the figure.

The concrete floor slab is 150 mm thick of unit weight 0.24 kN/m^2 per 10 mm thick.

For preliminary design purposes, the total weight of the floor-ceiling sandwich system, including the floor slab and floor finishes, and ceiling fixtures etc., may be taken as the weight of the floor slab plus 0.65 kN/m^2. Additional allowance for mechanical and electrical equipment may be taken as 0.25 kN/ m^2. Allowance for moveable partition can be assumed to be 1 kN/m^2. The roofing materials on the roof may be assumed to have the same weight as the floor finishes.

The weight of all beams and girders is the same and given as 4 kN/m.

The Live load due to occupancy is 2.4 kPa.

Question 2: (30%)

The building shown in Figure 1 has a commercial sign on the roof weighting 300 kN. It is supported by 3 columns at locations B2, B3 and B4 on the roof. The roof has no public access. Assuming snow load governs the design of the roof, there is no need to consider live load for roof area. For the determination of axial load of columns of the building, you may ignore the influence of the commercial sign on snow load distribution on the roof. The weight of the columns is small compared to the weight of the floor and roof slab, the beams and girders of the building, and thus they can be ignored in the calculation.

Ignoring all other types of loading, determine the factored axial load of column line **B4** due to all possible combinations of dead, live and snow loads required for the strength design of the column at the **ground floor level**.

Question 3: (30%)

The commercial sign spanning between column line B2 to B4 on the roof is 4 m high.

The roof is flat with a parapet of 1.2 m high surrounding its perimeter. Note the building location is in downtown urban area.

Determine the specified unfactored snow load for the design of the girders along the line between A4 and C4 by specifying the snow load intensity values (i.e. load/unit length of girder) at points a, b, c, d, e, f, g, h and i equally spaced at 2m as shown on Figure 1.

Question 4 (30%)

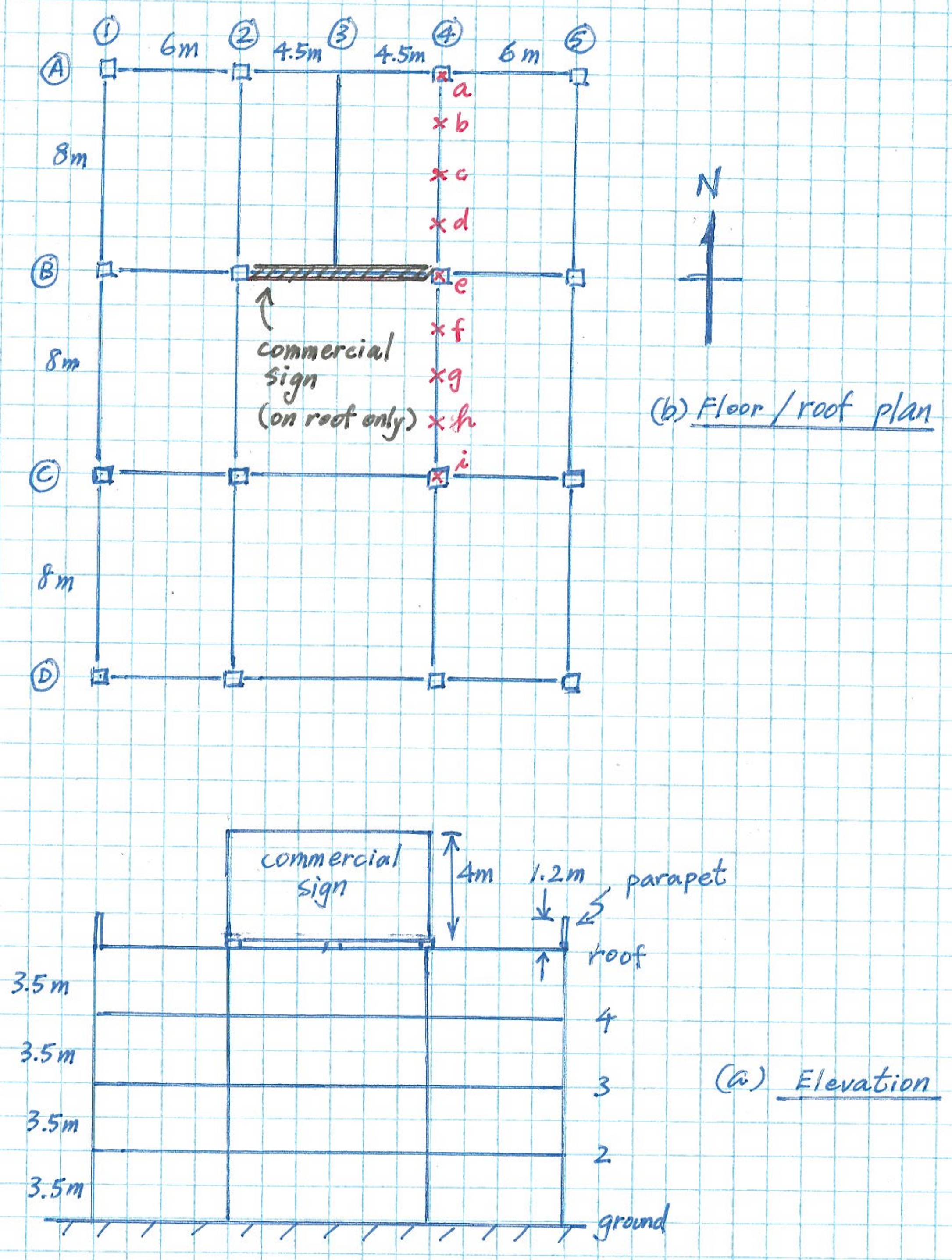
For earthquake load calculation, the total weight of roof and floors of the **steel** building located in Cornwall, Ontario shown in Figure 1 may be assumed as follows

Floor	Dead weight (kN)
Roof	5,800
2 to 4	6,500 per floor

For earthquake load determination only, the seismicity at the city of Pembroke can be assumed to be similar to Ottawa, so you may use the given hazard curve of Ottawa for the seismic load calculation of building in Pembroke. Also, you may ignore the effect of the commercial sign and parapet fence for earthquake load calculation.

The building is founded on foundation soil classified as **Soil Type D stiff soil**. The building derives its stability against lateral forces by the action of moderately ductile steel moment-resisting frames in both East-West and North-South directions.

Calculate the specified design base shear for earthquake forces in the **North-South** direction.



① ② ③ ④ ⑤
6m
4.5m
4.5m
6 m
Ⓐ Ⓑ Ⓒ Ⓓ
8m
8m
8m
a b c d e f g h i
commercial sign (on roof only)
N
(b) Floor / roof plan
commercial sign
4m
1.2m
parapet
roof
4
3
2
ground
3.5m
3.5m
3.5m
3.5m
(a) Elevation

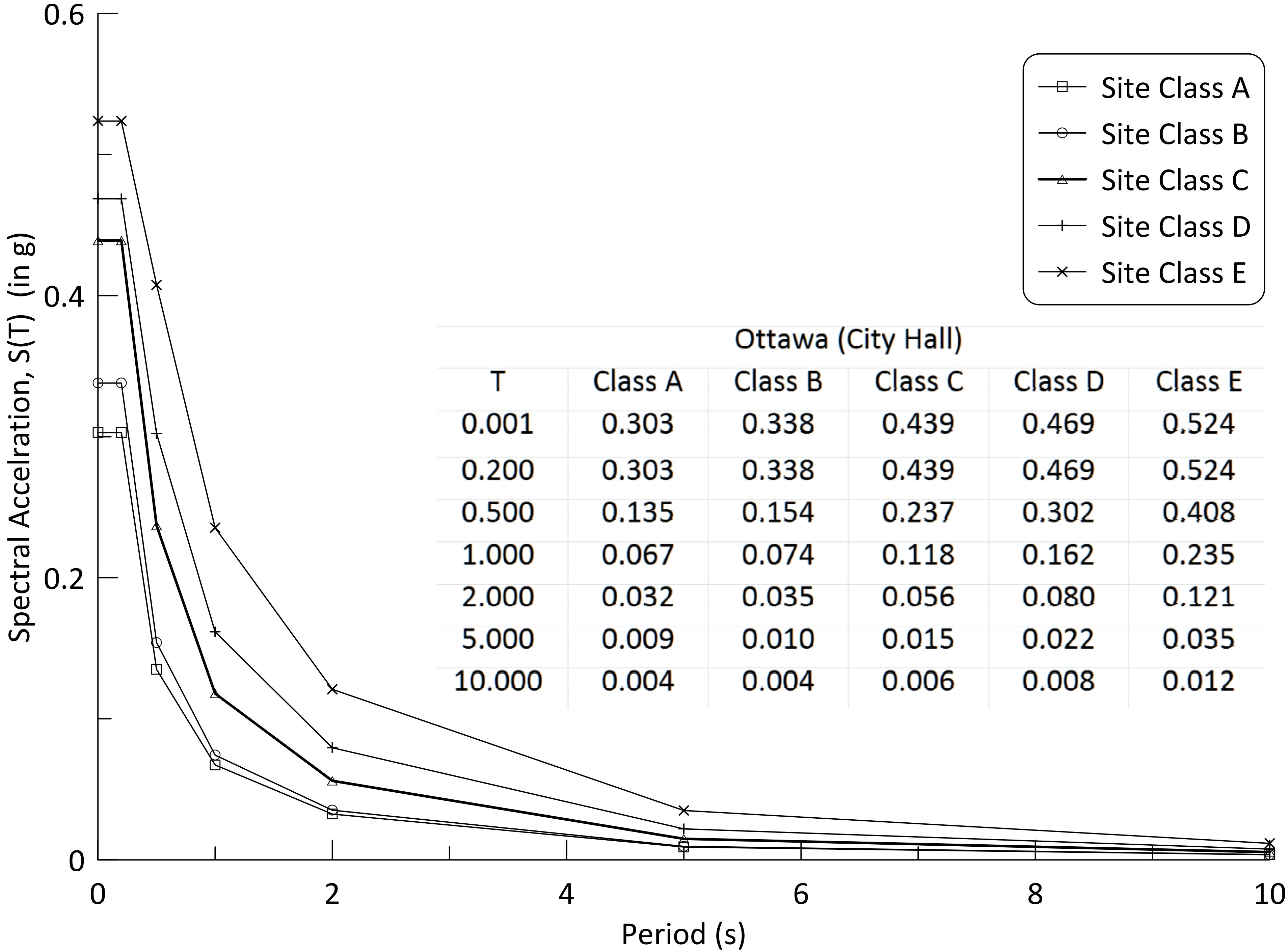
FIG. 1.

DESIGN DATA FOR PEMBROKE, ONTARIO

Table C-2 (Continued)

Province and Location	Elev., m	Design Temperature January 2.5% °C	January 1% °C	July 2.5% Dry °C	July 2.5% Wet °C	Degree-Days Below 18°C	15 Min. Rain, mm	One Day Rain, 1/50, mm	Ann. Rain, mm	Moist. Index	Ann. Tot. Ppn., mm	Driving Rain Wind Pressures, Pa, 1/5	Snow Load, kPa, 1/50 S_s	S_r	Hourly Wind Pressures, kPa 1/10	1/50
Mount Forest	420	-21	-24	28	22	4700	28	103	740	0.87	940	140	2.7	0.4	0.32	0.41
Nakina	325	-36	-38	28	21	6500	20	86	540	0.76	750	100	2.8	0.4	0.23	0.30
Nanticoke (Jarvis)	205	-17	-18	30	23	3700	28	108	840	0.95	900	160	1.4	0.4	0.37	0.48
Nanticoke (Port Dover)	180	-15	-17	30	24	3600	25	108	860	0.98	950	140	1.2	0.4	0.37	0.48
Napanee	90	-22	-24	29	23	4140	23	92	770	0.90	900	160	1.9	0.4	0.33	0.43
New Liskeard	180	-32	-35	30	22	5570	23	92	570	0.75	810	100	2.6	0.4	0.33	0.43
Newcastle	115	-20	-22	30	23	3990	23	86	760	0.90	830	160	1.5	0.4	0.37	0.48
Newcastle (Bowmanville)	95	-20	-22	30	23	4000	23	86	760	0.90	830	160	1.4	0.4	0.37	0.48
Newmarket	185	-22	-24	30	23	4260	28	108	700	0.81	800	140	2.0	0.4	0.29	0.38
Niagara Falls	210	-16	-18	30	23	3600	23	96	810	0.94	950	160	1.8	0.4	0.33	0.43
North Bay	210	-28	-30	28	22	5150	25	95	775	0.93	975	120	2.2	0.4	0.27	0.34
Norwood	225	-24	-26	30	23	4320	25	92	720	0.84	850	120	2.1	0.4	0.32	0.41
Oakville	90	-18	-20	30	23	3760	23	97	750	0.90	850	160	1.1	0.4	0.36	0.47
Orangeville	430	-21	-23	29	23	4450	28	108	730	0.84	875	140	2.3	0.4	0.28	0.36
Orillia	230	-25	-27	29	23	4260	25	103	740	0.88	1000	120	2.4	0.4	0.28	0.36
Oshawa	110	-19	-21	30	23	3860	23	86	760	0.90	875	160	1.4	0.4	0.37	0.48
Ottawa (Metropolitan)																
Ottawa (City Hall)	70	-25	-27	30	23	4440	23	86	750	0.84	900	160	2.4	0.4	0.32	0.41
Ottawa (Barrhaven)	98	-25	-27	30	23	4500	25	92	750	0.84	900	160	2.4	0.4	0.32	0.41
Ottawa (Kanata)	98	-25	-27	30	23	4520	25	92	730	0.84	900	160	2.5	0.4	0.32	0.41
Ottawa (M-C Int'l Airport)	125	-25	-27	30	23	4500	24	89	750	0.84	900	160	2.4	0.4	0.32	0.41
Ottawa (Orleans)	70	-26	-28	30	23	4500	23	91	750	0.84	900	160	2.4	0.4	0.32	0.41
Owen Sound	215	-19	-21	29	22	4030	28	113	760	0.90	1075	160	2.8	0.4	0.37	0.48
Pagwa River	185	-35	-37	28	21	6500	20	86	540	0.76	825	80	2.7	0.4	0.23	0.30
Paris	245	-18	-20	30	23	4000	23	96	790	0.90	925	160	1.4	0.4	0.33	0.42
Parkhill	205	-16	-18	31	23	3800	25	103	800	0.93	925	180	2.1	0.4	0.39	0.50
Parry Sound	215	-24	-26	28	22	4640	23	97	820	0.95	1050	160	2.8	0.4	0.30	0.39
Pelham (Fonthill)	230	-15	-17	30	23	3690	23	96	820	0.94	950	160	2.1	0.4	0.33	0.42
Pembroke	125	-28	-31	30	23	4980	23	105	640	0.80	825	100	2.5	0.4	0.27	0.35
Penetanguishene	220	-24	-26	29	23	4200	25	97	720	0.87	1050	160	2.8	0.4	0.30	0.39
Perth	130	-25	-27	30	23	4540	25	92	730	0.84	900	140	2.3	0.4	0.32	0.41
Petawawa	135	-29	-31	30	23	4980	23	92	640	0.80	825	100	2.6	0.4	0.27	0.35
Peterborough	200	-23	-25	30	23	4400	25	92	710	0.83	840	140	2.0	0.4	0.32	0.41
Petrolia	195	-16	-18	31	24	3640	25	108	810	0.89	920	180	1.3	0.4	0.36	0.47
Pickering (Dunbarton)	85	-19	-21	30	23	3800	23	92	730	0.88	825	140	1.0	0.4	0.37	0.48
Picton	95	-21	-23	29	23	3980	23	92	770	0.91	940	160	2.0	0.4	0.38	0.49
Plattsville	300	-19	-21	29	23	4150	28	103	820	0.93	950	140	1.9	0.4	0.33	0.42
Point Alexander	150	-29	-32	30	22	4960	23	92	650	0.82	850	100	2.5	0.4	0.27	0.35
Port Burwell	195	-15	-17	30	24	3800	25	92	930	1.05	1000	180	1.2	0.4	0.36	0.47

Ottawa, ON
Design Spectral Response Acceleration, NBC 2015



Ottawa (City Hall)					
T	Class A	Class B	Class C	Class D	Class E
0.001	0.303	0.338	0.439	0.469	0.524
0.200	0.303	0.338	0.439	0.469	0.524
0.500	0.135	0.154	0.237	0.302	0.408
1.000	0.067	0.074	0.118	0.162	0.235
2.000	0.032	0.035	0.056	0.080	0.121
5.000	0.009	0.010	0.015	0.022	0.035
10.000	0.004	0.004	0.006	0.008	0.012