THE UNIVERSITY OF CAPE TOWN
DEPARTMENT OF CIVIL ENGINEERING
CIV 3048F – STRUCTURAL ANALYSIS II
May 2024

LOADING PROJECT

WIND ANALYSIS & LOADING (PORTAL FRAME & FRAME)

Due Date: **Wednesday May 15**, 2024 (by midnight on Amathuba Assignments).

Late submissions get a mark of zero.

**All working must be presented on a properly formatted calculation sheet. Plagiarism will NOT be tolerated*

The design of a buildings requires that the designer consider several aspects in producing a concept that is functional, safe and meets aesthetic requirements. Some of the important aspects that need to be considered are choices of:

- Floor construction/type
- Frame construction/type
- Resistance to wind/lateral loads
- Aesthetics
- Integration of structure with building services

All structures must be able to withstand some horizontal loading; whether it is an imposed load such as wind, a seismic load or a notional horizontal load stipulated in a design standard. The engineer must ensure proper load paths so that all loads are transferred safely to the foundation.

In the first part of this project (Part - A) you are required to determine the loads, including wind load, on an industrial structure consisting of several portal frames spaced at 5m. The portal frame is clad with IBR sheets on the roof and sides. Insulation material is provided on the roof only. The structure has the following key dimensions: **30m long, 20m wide, 4.475m** overall **height** to apex and **3.6m height** to eaves. This gives a shallow roof slope of 5^0. You are required to determine the wind pressure acting on the building. You will then analyse a typical internal portal frame for both gravity and wind load with appropriate load combinations. You will be required to use software to conduct the analysis. In the second part (Part - B), you will be required to determine the loading on a frame and conduct an analysis using software. You will then perform a similar analysis using hand calculations and compare results from the hand calculation to those from the software analysis.

PART – A

(a) Determine the wind pressure on the structure for both 0^0 and 90^0 wind. The structure is located in the outskirts of Worcester in the Western Cape. The site altitude is 220m above mean sea level. It is in an area with regular cover of vegetation and buildings. At a distance of 1.2km away the terrain changes to one of low vegetation and isolated obstacles. (*Hint: consider influencing terrain category*). Assume that the structure has no dominant openings, therefore Note 2 of SANS 10160-3 clause 8.3.9.6 should be used. For the 0^0 roof load use $C_{pe,10}$ with the case of (-ve) values for F,G,H, I & J. This is one of four possible combinations (see Note at bottom of Table 10). [40]

(b) For this part consider only the results from an internal pressure coefficient (C_{pi}) of +0.2. Having found the wind pressure determine, for the <u>90^0 wind only</u>, the characteristic loads on an interior portal frame for the case of wall region '**C**' combined with region '**I**' on the roof. Purlins and girts are simply supported between frames. The portal frames are spaced at 5m as indicated. Sketch the resulting wind load on the portal frame rafter and column as point loads on the purlin and girt positions. Do this also for the Dead and Live loads on the frame given the following:

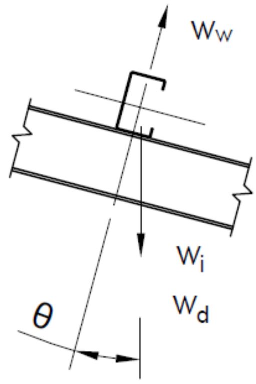
<u>Dead Loads:</u>

Roofing sheet: 5.42 kg/m^2

Insulation (roof): 185 g/m^2
Purlin/Girt self-weight: 5.82 kg/m *(*Please take note of units!!)*

Live Load
See SANS 10160-2 (Table 5) for an inaccessible roof (Case H2). Use the rafter tributary area. [20]

- *Purlin spacing is 1100mm c/c along rafter slope and Girt spacing is 1200mm c/c on column. Assume no roof overhang. Purlins and girts are simply supported on frames.*



W_W = *Wind Load*

W_i = *Imposed Load*

W_d = *Dead Load*

**Wind load perpendicular to surface*
**Dead and Live load act vertically downwards*

Figure 1: Purlin Loads (vector application)

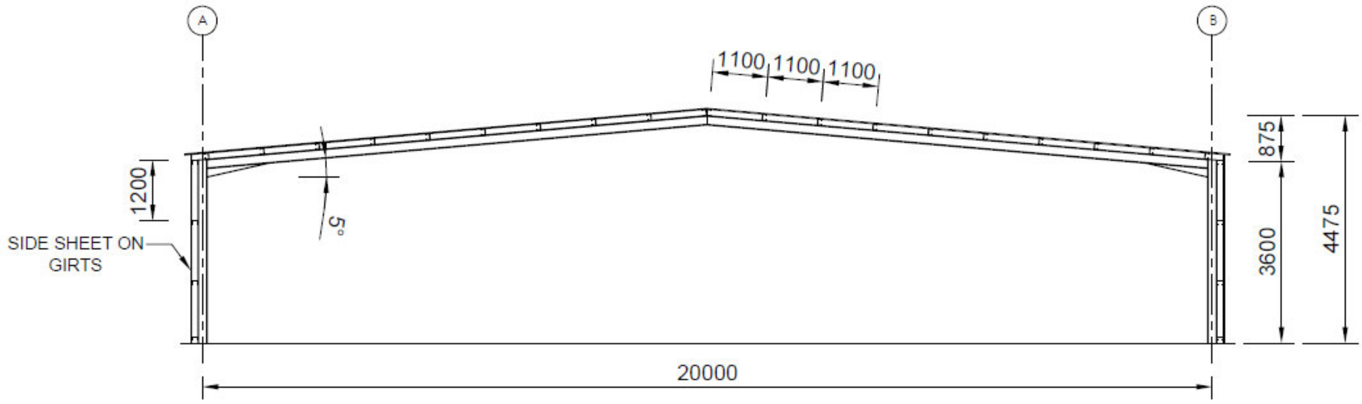


Figure 2: Portal Frame - Typical Section

(c) Having found the characteristic loads, use analysis software to determine the resulting bending moment diagram for the load combinations given below. In the software, place the appropriate ultimate limit state (ULS) and service limit state (SLS) factors. Do this only for the STR case for this exercise. Take the **supports** at the bottom of the column as **pinned.**

(i) Dead + Live
(ii) Dead + Wind

**Since combinations with more than one variable load must be considered (i.e., adopt a leading and accompanying variable load) a combination factor (ψ) = 0 is used here as per Table 2 of SANS10160-1.*

Carry out an analysis using Prokon (or similar) software to obtain the bending moments for each of the two load combinations given: (c)(i) and (c)(ii). For the software analysis assume a **steel** column and rafter size of **203x133x30** (I_x = 28.9 x 10^6 mm^4, self-weight 30kg/m). Orient the members correctly in your model so that bending occurs about the major axis (axis with I_x value). If an alternative software is used ensure that it has the South African (or similar UK) section library for steel members so that you can make use of the sections given for the column and rafter. In the software **include self-weight** of the column and rafter. In your submission present software bending moment and shear force diagram output together with the input file.

NOTE: Dead & Live load both unfavourable (same direction). For Wind load unfavourable make Dead load favourable. [20]

(d) Indicate the maximum horizontal deflection at the eaves level (top of column) and state for which load case it is obtained. Remember to include the 'SLS' factors for this. [5]

PART – B

A frame supporting a 150mm thick concrete slab ($\gamma_c = 24kN/m^3$) is shown in Figure 3. Determine the characteristic line load on an **internal frame** for the one-way spanning slab. The live load on the slab is category 'E1' in Table 2 of SANS10160-2 (light industrial). Frames are spaced at 2800mm. Take supports at 'A' and 'D' as fixed and 'C' as pinned.

(i) Determine the design (factored) Dead + Live load (use greater of STR or STR-P) case. [5]

Taking columns as 152x152x37 members (I_x = 22.1 x 10^6 mm^4) and beams as 254x146x31 members (I_x = 44.3 x 10^6 mm^4). The beam has twice the second moment of area of the column. Self-weight for the beam is 31.1kg/m and for the column 37kg/m.

(ii) A software analysis of the frame reveals the bending moment diagram in Figure 4.

(iii) Use the moment distribution method to find the bending moment diagram for the frame. [5]

(iv) Compare the result from (ii) with (iii) [5]

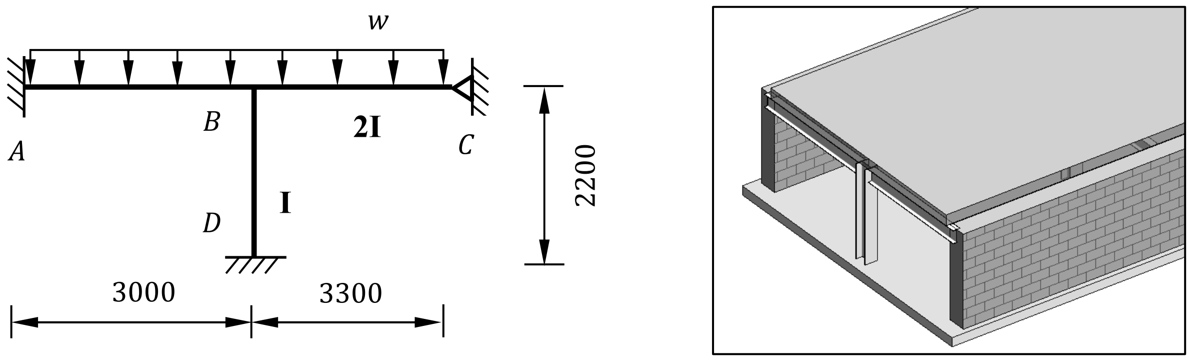
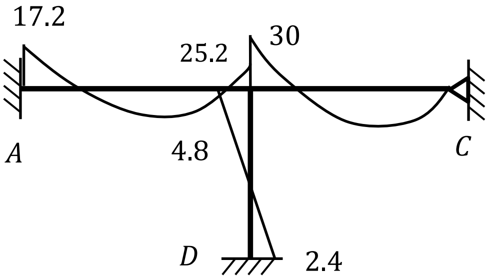


Figure 3: Frame Details



$\boldsymbol{BMD}\ (kNm)$

<u>Figure 4: BMD from software analysis</u>

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