Application 1. Design of a multi-story building

Consider the frame building shown in Figure 1. The frames are rigid at the base. On longitudinal direction, stability is provided by a brace system.

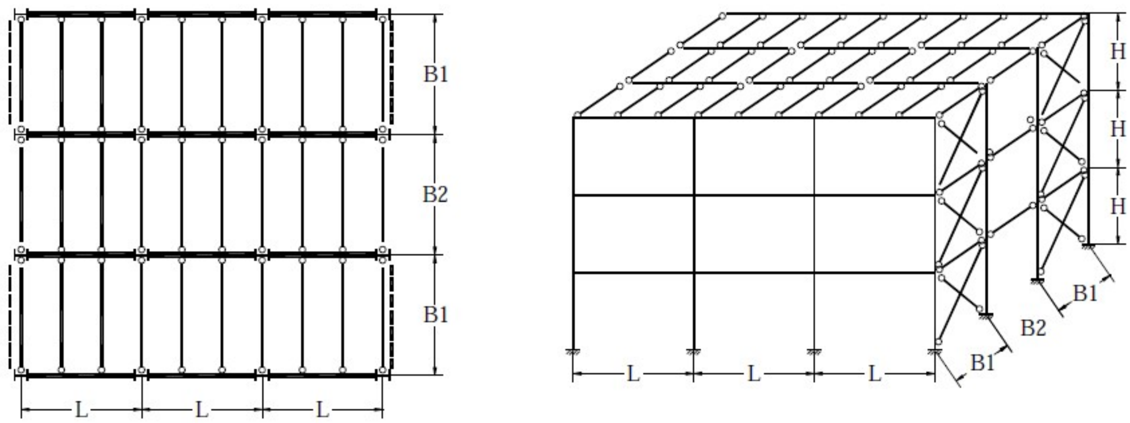


Figure 1. Plan and 3D view of the building

Description:

Location	Constanta Bucuresti Timisoara
Destination	Office building
Span (L), Bay (B1, B2), Story height (H)	• L = 6 m, B1 = 5 m, B2 = 5 m, H = 3,5 m • L = 7 m, B1 = 5 m, B2 = 5 m, H = 3,8 m • L = 8 m, B1 = 5 m, B2 = 5 m, H = 4,0 m
No of storey	• 4 • 6 • 8
Elements	• Beams / Columns I or H profiles S355 • Braces CHS S355

Requirements:

1. Evaluation of loads (permanent, live, snow, and wind)
2. Load combinations (fundamental design situation)
    a. ULS Combinations
    b. SLS Combinations
3. Cross-sections for structural components
4. Global analysis
    a. Buckling amplification factor
    b. Effects of imperfections
5. Structural analysis (3D model)
6. Structural design
    a. Column verification
    b. Beam verification
    c. Brace verification
    d. Design of beam-to-column connection, column-to-base connection
7. Drawings: frame with main details

Details about each section

1. Evaluation of loads (dead, live, snow and wind)
    a. Dead load

Material	Thickness [mm]
Sandstone	12
Support - mortar	6
Flooring screed	40
Vapour foil	0.1
Thermal insulation - min. wool	80
R.C. slab	148
Steel profile sheeting	1
Ceiling - gypsum boards	12

    b. Live load

- Office Building, see load for specific category in EN 1991-1-1.

Note:
Partition walls should be treated as an additional imposed load – equivalent uniformly distributed load.

Movable partitions are those which can be moved on the floor, be added or removed or rebuilt at another place.

According to EN 1991-1-1:2002, the uniformly distributed load is as follows:

- for movable partitions with a self-weight ≤ 1,0 kN/m wall length: q_k=0,5 kN/m2;
- for movable partitions with a self-weight ≤ 2,0 kN/m wall length: q_k=0,8 kN/m2;
- for movable partitions with a self-weight ≤ 3,0 kN/m wall length: q_k=1,2 kN/m2.

First case will be used, i.e. q_k=0,5 kN/m2

    c. Snow load

$$s = g_{Is} * m_i * C_e * C_t * s_k$$

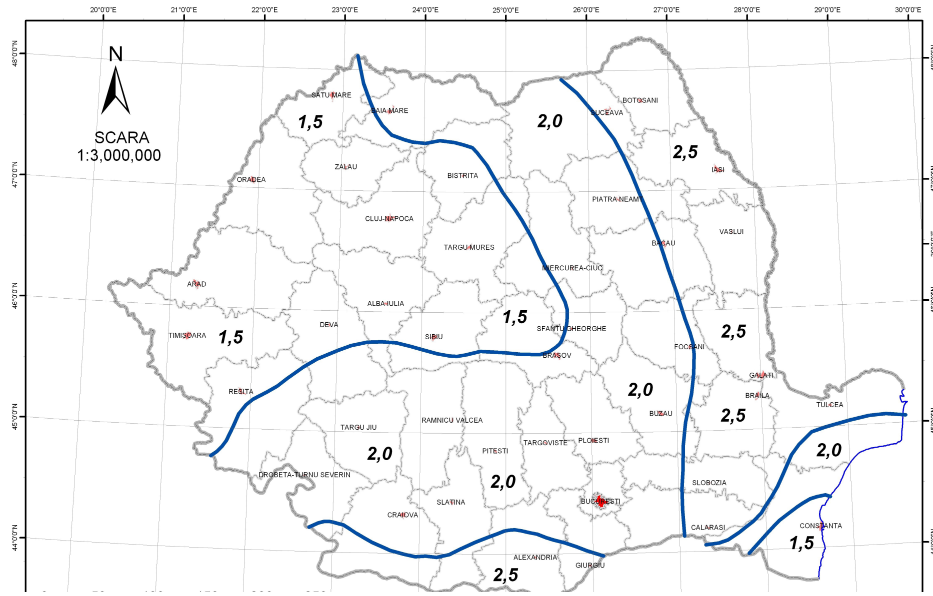
g_{Is} the importance-exposure coefficient for the snow load

m_i the form coefficient of the snow load on the roof

C_e the exposure coefficient of the building function of the location

C_t the thermal coefficient of the building

s_k the characteristic value of the snow load, function of the location



Zonation map for snow load, s_k, in kN/m2

Constanta	s_k = 1.5 kN/m2
Bucuresti	s_k =2.0 kN/m2
Timisoara	s_k = 1.5 kN/m2

d. Wind load (wind on transversal and longitudinal direction)

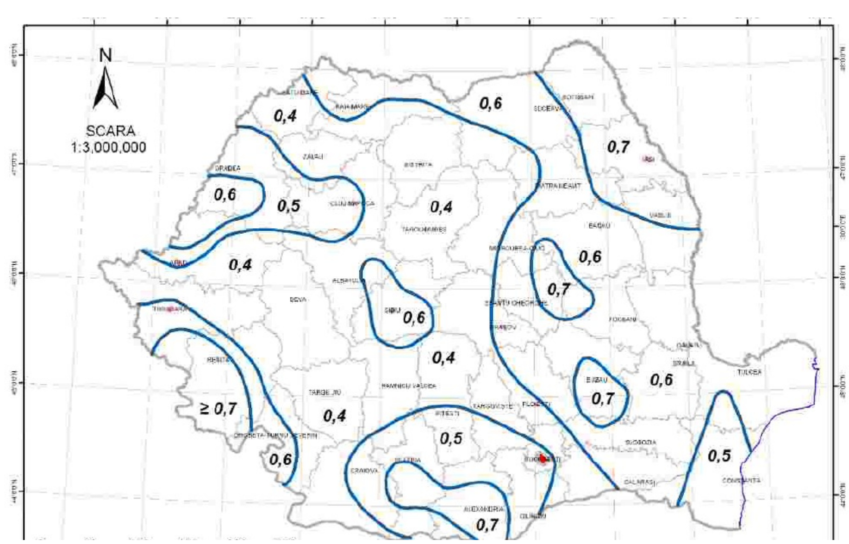
$$w(z) = g_{Iw} * c_{pe} * q_p(z_e)$$

g_{Iw} the importance-exposure factor

c_{pe} the aerodynamic pressure factor

z_e the reference height

$q_p(z_e)$ the peak wind pressure at reference height



Zonation map for wind pressure, q_p, in kN/m2

Constanta $q_p = 0.5$ kN/m2
Bucuresti $q_p = 0.5$ kN/m2
Timisoara $q_p = 0.6$ kN/m2

2. Load combinations

Partial safety factor

- γ_{Gmax} permanent loads
- γ_{Gmin} permanent loads
- γ_Q = variable loads
- ψ_0 = snow
- ψ_0 = wind
- $\gamma_{M0} = 1,0$
- $\gamma_{M1} = 1,0$

Ultimate limit state -ULS

$$\gamma_G * \sum_{J=1}^{n} G_{k,j} + \gamma_Q * Q_{k.1} + \sum_{i=2}^{m} \gamma_Q * \psi_{0,i} * Q_{k,i}$$

Serviceability limit state -SLS

the characteristic combination
$$\sum_{J=1}^{n} G_{k,j} + Q_{k,1} + \sum_{i=2}^{m} \psi_{0,i} * Q_{k,i}$$

the frequent combination
$$\sum_{J=1}^{n} G_{k,j} + \psi_{1,i} * Q_{k,1} + \sum_{i=2}^{m} \psi_{2,i} * Q_{k,i}$$

3. Select the appropriate cross-sections for structural components (column, beam, brace) and justify the decision

Columns: H, tubular, rectangular, built-up
Beams: H, built-up
Braces: H, tubular

4. Global analysis
   a. Buckling amplification factor

If the buckling factor has a value greater than 10, the structure is non-sway. This means we may perform the elastic first order analysis.

If the buckling factor has a value smaller than 10, the structure is sway. This means we have to perform either second order elastic analysis, either an equivalent first order elastic analysis with amplified effects.

   b. Effects of imperfections

$$\Phi = \Phi_0 * \alpha_h * \alpha_m$$

Φ	the global sway imperfections		
Φ_0	the nominal value		
α_h	the reduction coefficient for the height		
h	the height of the building in m		
α_m	the reduction coefficient for the number of columns		
m	the number of columns		

5. Structural analysis (3D model)
- 3D analysis using SAP2000
- Load combinations
- SLS, ULS

6. Structural design and verifications
    a. Verifications for SLS (vertical deflection, horizontal deflection)
    b. Column verification
    c. Beam (main and secondary) verification
    d. Brace verification
    e. Design of beam-to-column connection, column-to-base connection

7. Drawings: frame with main details (see Lecture 08 ÷ 10 for each type of detail).

References:

EN1990 (2002). *Eurocode – Basis of structural design*. European Committee for Standardization, Brussels, Belgium.
EN1991-1-1 (2002). *Eurocode 1: Actions on structures - Part 1-1: General actions-Densities, self-weight, imposed loads for buildings*. European Committee for Standardization, Brussels, Belgium.
EN1991-1-3 (2003). *Eurocode 1: Actions on structures - Part 1-3: General actions - Snow loads.* European Committee for Standardization, Brussels, Belgium.
EN1991-1-4 (2005). *Eurocode 1: Actions on structures - Part 1-4: General actions – Wind actions.* European Committee for Standardization, Brussels, Belgium.
EN1993-1-1 (2005). *Eurocode 3: Design of steel structures - Part 1-1: General rules and rules for buildings*. European Committee for Standardization, Brussels, Belgium (including EN1993-1- 1:2005/AC, 2009).
EN1993-1-8 (2005). *Eurocode 3: Design of steel structures. Part 1-8: Design of joints*. European Committee for Standardization, Brussels, Belgium.
Software: SAP 2000, SteelCon