# Exercise 7: Ice ring roof structure

Updating variables by a semi-probabilistic analysis and verification of structural safety

## Background and objective

The structure is a single-pitch flat roof (with a pitch angle < 30°) of a sports hall.

The aim of this exercise is to check the structural safety of the main beam (truss in steel construction) using a step-by-step approach (steps 1 and 2).

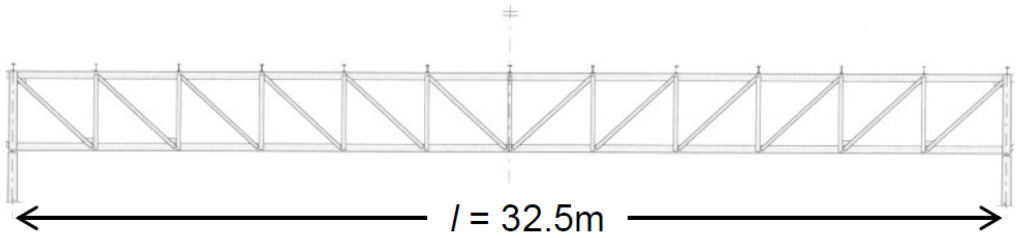


*Figure 1: Geometry of the main truss beam.*

In the context of this exercise, only the structural safety (type 2) of the tensioned chord at mid-span of the truss is to be verified, considering:

- The results of the condition survey, which showed a structure corresponding to drawings
- The roof and its structure are in good condition. There is no ongoing deterioration that could reduce the strength of the load-bearing elements.
- Lattice truss (see Figure 1):
  - Span: $l$ = 32.5 m;
  - Height: $h$ = 3.25 m;
  - Static height: $d$ = 3.0 m;
  - Spacing between 2 trusses: $e$ = 5.0 m;
- Area of the chord in tension, at mid-span of the truss: $A_a$ = 110 cm$^2$;
- Year of construction: 1952. Structural steel with a nominal strength $f_{yk}$ = 240 N/mm$^2$ (as indicated on the construction drawings);
- Self-weight of the truss, leading permanent action, as executed, recomputed as: $g_a$ = 1.5 kN/m;
- The lightweight roof "skin", accompanying permanent action, consists of a metal construction with thermal insulation and gravel. Nominal imposed load as indicated on the construction drawings: $q_{roof}$ = 2 kN/m$^2$;

- The sport hall is located at an altitude of 1575 m.
- Required safety level: $\beta_0 = 4.6$ (following an assessment of the required safety level);
- The sports hall is expected to remain in service for a long time (≥ 50 years).

Step 1: Structural safety check using characteristic values (deterministic methods)

**Question 1.1**

*Determine the examination value of the resisting moment of the truss at mid-span.*

*Hint: use SIA 269/3, chap. 5*

**Question 1.2**

*Determine the examination value of the effect of the actions for the hazard situation with snow as the leading action (wind can be neglected here).*

*For the unchecked self-weights, a conservative CoV value of 0.12 can be assumed. Use the typical relationship between $\beta_{tgt}$ ,$V_i$ and $\gamma_i$ given in course 7 to deduce the corresponding (conservative) value for the load factor to be used.*

*Discuss the applicability of the $\beta_{tgt}$ ,$V_i$ and $\gamma_i$ relationship.*

**Question 1.3**

*Determine the degree of compliance and discuss the result, also discuss the safety level required.*

Step 2: Structural safety check using updated values with a semi-probabilistic analysis

**Question 2.1**

*Determine the examination value of the resisting moment of the truss at mid-span, assuming that the mechanical properties of the structural steel (year of construction: 1952) were determined by means of a laboratory test campaign and a literature study. For the yield point, the results are as follows:*

*$f_{y,m} = 273$ N/mm$^2$ (mean value)*

*$v_{fy} = 0.03$ (coefficient of variation)*

**Question 2.2**

*Determine the examination value of the imposed load considering that the load due to the roof "skin" has been updated by gravel thickness measurements. Including these results, the uniformly distributed imposed load should be taken as:*

*$q_{roof,m} = 2.45$ kN/m$^2$ (mean value)*

*$v_{roof} = 0.18$ (coefficient of variation)*

**Question 2.3**

*Determine the examination value for the moment due to the snow (as the leading variable action) by considering the snow load is updated by exploiting the results of a measuring station located in the same village as the sports hall. The following results were obtained from an 85-year measurement campaign (measurement of the maximum snow load per year, based on the water content):*

$q_{snow,m}$ = *3.15 kN/m²* *(mean value)*

$v_{snow}$ =*0.24 (coefficient of variation)*

**Question 2.4**

*Determine the sum of the examination values of the acting moments for the hazard situation with the snow as the leading action.*

**Question 2.5**

*Determine the degree of compliance and discuss the result.*

**Question 2.6**

*Determine the degree of compliance for $\beta_0$ = 4.2 and discuss the result.*

Reminder: Snow load

Characteristic value of snow load on roofs, referred to the horizontal surface covered:

$$q_k = \mu_i \cdot C_e \cdot C_T \cdot s_k$$

with:

- $\mu_i$ the roof shape coefficient, for single-pitch flat roofs pitched at less than 30°: $\mu_i$ = 1.0;
- $C_e$ the wind exposure coefficient of the structure, for normal wind exposure: $C_e$ = 1.0;
- $C_T$ the thermal coefficient, generally equal to 1.0;
- $s_k$ the snow load on horizontal ground (return period of approximately 50 years), valid up to 2'000 m altitude:

$$s_k = \left[1 + \left(\frac{h_0}{350}\right)^2\right] \cdot 0.4\,\text{kN/m}^2 \geq 0.9\,\text{kN/m}^2$$

$h_0$ the reference altitude (in m), depending on location and taking account of regional climate where applicable.

**Note: this document is a translation, corrected of the exercise 4, lecture notes Prof. Eugen Brühwiler "Structures existantes I : Examen et interventions – Bases", 2022 edition, course CIVIL-436, courtesy of Prof. Brühwiler.**

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