Models for exposure conditions – a review of available data for snow and flooding in the Czech Republic

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Introduction
Snow load
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Concluding remarks

Introduction

- ***Robustness*** - complicated concept, not understood uniformly
- ***Two possible concepts***:

→ **Indicator of the ability of a structure**

→ Indicator of the ability of a system containing a structure

- ***Exposures*** to be considered - climatic effects such as ***snow falls*** and ***flooding***
- Exposures of structures having insufficient robustness in the Czech Republic

→ Structural failures during the ***winter period 2005/2006***, reliability analysis, failure causes

→ ***Flooding in 1997 and 2002***, evaluation of discharges, investigation of structural failures

Snow load

Stadium in Humpolec, Czech Republic

Lack of robustness

Reliability analysis of roofs

- Design of a ***generic member*** in accordance with the load combination (6.10) in EN 1990

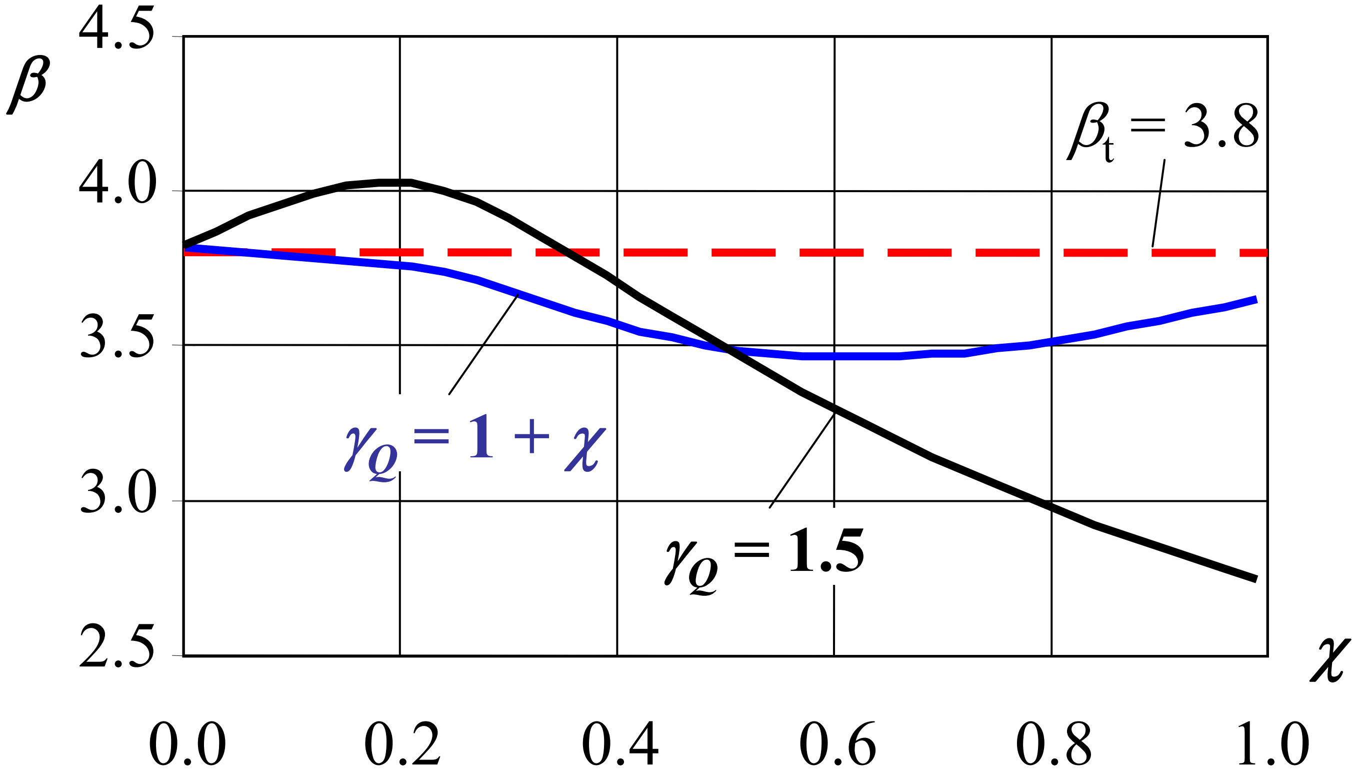
  Alternative (1): $\gamma_M = 1.15$; $\gamma_G = 1.35$; $\boldsymbol{\gamma_Q = 1.5}$

  Alternative (2): $\chi = s_{s,k} / (G_k + s_{s,k})$; $\boldsymbol{\gamma_Q = 1 + \chi}$

- ***Limit state function***: $g(\mathbf{X}) = K_R\, R - K_E\, (G + S_{50})$

Variable	Symb. X	Distr.	Char. val. X_k	The mean μ_X	CoV V_X
Resistance	R	LN	From (6.10) + χ	$1.25R_k$	0.10
Permanent load	G	N	From (6.10) + χ	$1.0G_k$	0.10
Snow, 50-years max.	S_{50}	GU	$\boldsymbol{s_{s,k}}$	$\boldsymbol{1.02s_{s,k}}$	**0.22**
Resistance uncertainty	K_R	N	-	1.0	0.05
Load effect uncertainty	K_E	N	-	1.0	0.10

Results of the reliability analysis



- For $\gamma_Q = 1.5$ the reliability index β significantly varies with the load ratio χ; for $\chi > 0.4$ rather ***low reliability level*** is obtained.
- ***More uniform*** reliability level is achieved for the partial factor $\gamma_Q = 1 + \chi$.

Structural failures due to snow

- Extreme ***exposures***:
  - extraordinary ***snow load*** (where snow was required to be removed, combination of snow and ice)
  - ***additional loadings*** (incompetent intervention into structures, installation of new facilities, water on a roof)

- ***Low resistance*** of a member (structural vulnerability):
  - insufficient ***code provisions*** (increasing load ratio $\chi \rightarrow$ low reliability; improved heat insulation $\rightarrow$ accumulation of snow)
  - ***errors*** in design and defects in execution (inadequate quality control of design and construction)

- The most severe damage in case of ***insufficient robustness***:
  - no ***tying***
  - low resistance of ***key members***
  - vulnerable ***detailing***

Flooding

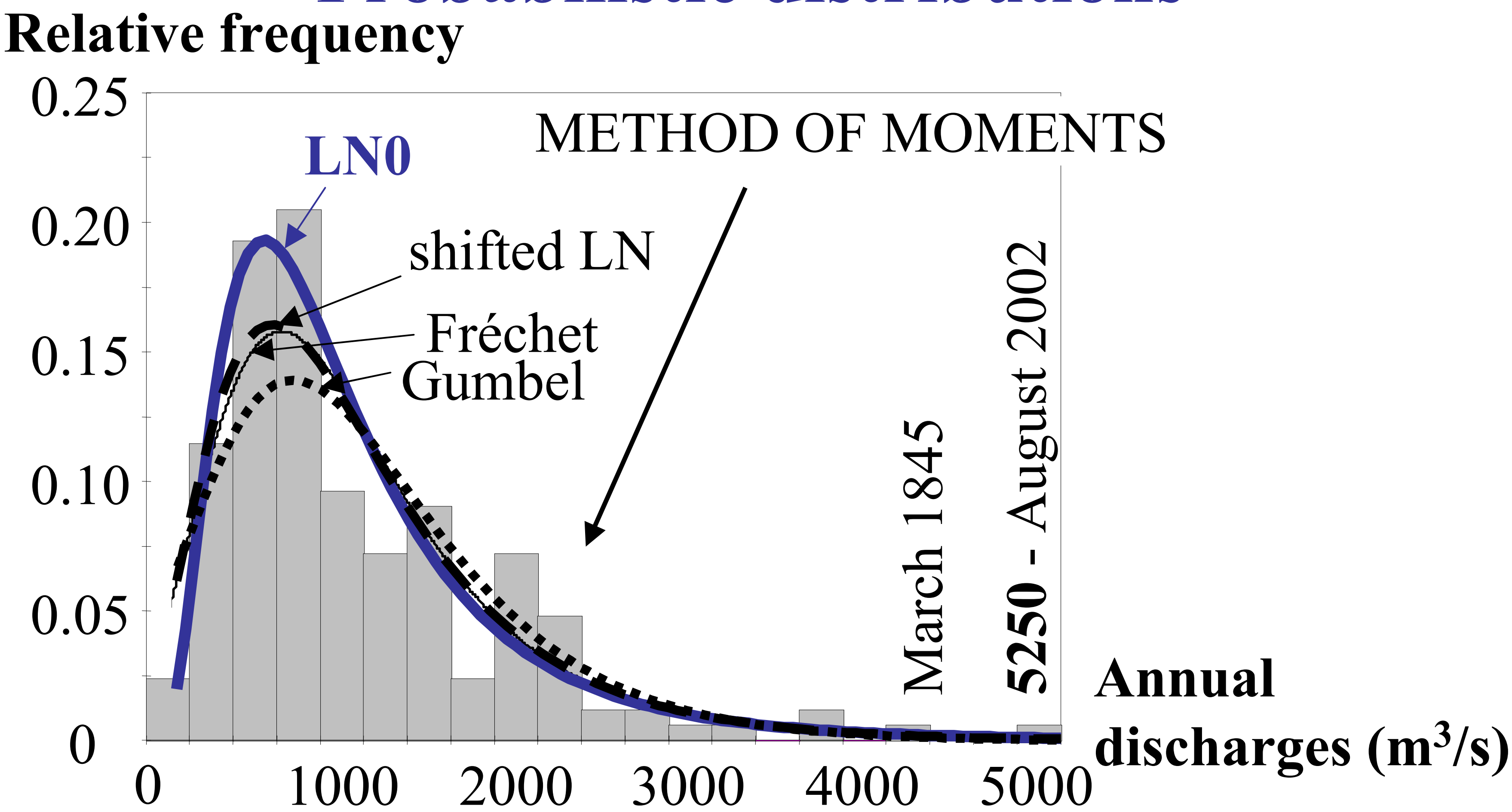
in July 1997 in Moravia and in August 2002 in Bohemia

Structural failures due to flooding

- Extreme ***exposures***:
  - Underground ***transport of sediments*** and man-made ground
  - Increased ***earth pressure*** due to elevated underground water
- ***Structural causes***:
  - Insufficient ***foundation*** (depth, width)
  - Inadequate ***construction materials*** (unfired masonry units)
  - ***Material property changes*** due to moisture (volume, strength)
- The most severe damage in case of ***insufficient robustness*** (no tying)

Was the flooding really so exceptional and unpredictable?
→ evaluation of annual discharges (in Prague since 1827)

Probabilistic distributions



- Statistical tests together with empirical experience indicate that the ***lognormal distribution*** with the lower bound at the origin could be a suitable model.

Evaluation of discharges

- Parameters alternatively estimated by the ***maximum-likelihood method***

- Estimates of the ***mean*** independent of the applied method

- Estimates by the ***maximum likelihood*** method ***increased***:
  - standard deviation by about 10 %
  - characteristic value (≈ 3800 m^3/s) by about 8 %
  - design value (≈ 11500 m^3/s) by about 16 %

- ***Partial factor*** $\gamma_Q \approx 3.0$

The discharge in 2002 corresponds to a considerably long return period of approximately 210 years.

Conclusions

- ***Lack of robustness*** seems to be a significant factor of structural failures due to snow and flooding.
- ***Exposures*** include:
  - extreme snow load and additional loadings,
  - transport of sediments and earth pressure.
- Low ***resistance*** may be caused by:
  - insufficient code provisions, errors in design and execution,
  - inadequate foundation and construction materials.
- ***Reliability of light-weight roofs*** exposed to a snow load may be rather ***low*** - the partial factor γ_Q should be greater than 1.5.
- Extreme discharges predicted by the ***maximum-likelihood method*** are greater than those by the method of moments (by about 10 %).
- The ***partial factor*** $\gamma_Q = 1.5$ recommended in EN is considerably lower than the value derived from the data ($\gamma_Q \approx 3.0$).
- The ***discharge*** observed ***in 2002*** corresponds to an exceptionally ***long return period*** and could be hardly expected.

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Thank you for your attention.