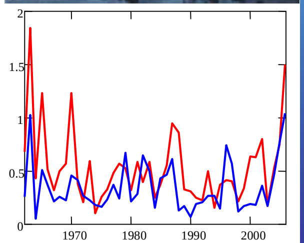
Reliability-based design of roofs exposed to a snow load

Milan Holicky and Miroslav Sykora
Czech Technical University in Prague, Klokner Institute

Introduction

- Collapses of roofs during the winter 2005/2006 – ***is the reliability of roofs exposed to a snow load adequate?***
- Major ***causes of failures*** – extreme loads due to ***snow***, insufficient ***code provisions***, ***errors*** in design, execution and use
- Available ***measurements*** of snow loads newly evaluated and ***standards revised*** - the characteristic value as the 0.98 fractile of annual extremes and the partial factor 1.5
- The study focused on a critical analysis of present ***design procedures in Eurocodes*** using probabilistic methods



Design alternatives

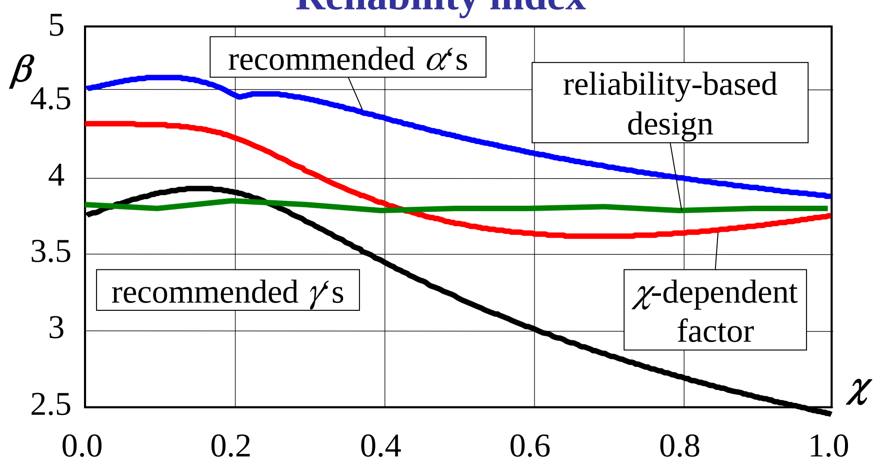
- Design of a ***generic steel member*** exposed to permanent action and snow load according to the load combination (6.10) in EN 1990
- ***Alternatives***
  - Recommended ***partial factors*** (γ's):
    γ_{M0} = 1.0; γ_G = 1.35; γ_Q **= 1.5**
  - Recommended ***sensitivity factors*** (α's) - combination (6.10a,b):
    γ_{M0} = 1.14; γ_G = 1.35(1.15); γ_Q **= 2.11**(1.33)
  - Partial factor dependent on the ***load ratio*** $\chi = s_{s,k} /(g_k+s_{s,k})$:
    $\gamma_Q = \gamma_{Sd}(1 + \chi)$
  - ***Reliability-based design*** - partial factors derived from actual sensitivity factors obtained by FORM (data)

Probabilistic analysis

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

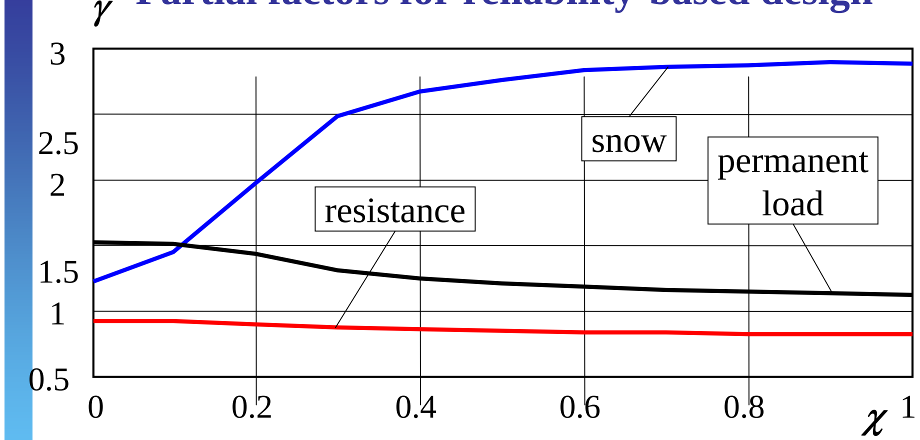
Variable	Symb.	Distr.	Mean μ_X	CoV V_X
Resistance	R	Lognormal	$R_k\exp(2V_R)$	0.08
Permanent load	G	Normal	G_k	0.10
Shape coefficient	μ	Normal	0.8	0.15
Snow load on the ground, 50-year max.	S_{50}	Gumbel	$\mathbf{s_k}$	**0.22**
Resistance uncert.	K_R	Lognormal	**1.15**	0.05
Load effect uncert.	K_E	Lognormal	1.0	0.10

Reliability index



- Recommended γ's - significant ***variation*** of the reliability index
- Partial factor γ_Q dependent on χ - ***well-balanced*** reliability
- Partial factors based on recommended α's - ***sufficient*** reliability
- Reliability-based design – ***target reliability*** achieved

Partial factors for reliability-based design



- The partial factor for ***steel*** close to the recommended value 1.0
- The partial factor for the ***permanent load*** in the range 1.1 - 1.5
- The partial factor of the ***snow load*** greater than 1.5
- Values of about ***2.5 – 3.0*** would lead to a sufficient reliability

Conclusions

- The ***constant partial factor*** for snow load leads to a significantly ***non-uniform reliability***.
- For steel roofs ***reliability*** of a structural member is ***insufficient***.
- The partial factors should be determined on the basis of actual ***sensitivity factors***.
- For steel roofs the ***partial factor*** for the snow load should be ***greater*** than ***1.5***.
- A more uniform reliability level may also be achieved using the ***partial factor*** for the snow load ***dependent on the load ratio***.
- The results are dependent on the ***assumed models***. Particularly models for the snow should be improved.

Milan Holicky, Miroslav Sykora

Reliability-based design of roofs exposed to a snow load