Fragility of structures due to extreme actions

Key topics

Stractural damage, consequences, cost optimization, sustainability

Prepared for power producing plants

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The limit state function - simple example

$$G = KR \times R - KS \times S - p = KR \times R - KS \times (g + q) - p$$

Deterministic factors (units/dimensionless):

p: intensity of action (0 to 100 units, wind, tornado, earthquake)

KR, KS: factors (0 to 2) of the resistance R and load effect S

Random variables, distributions LN, N (units/dimensionless):

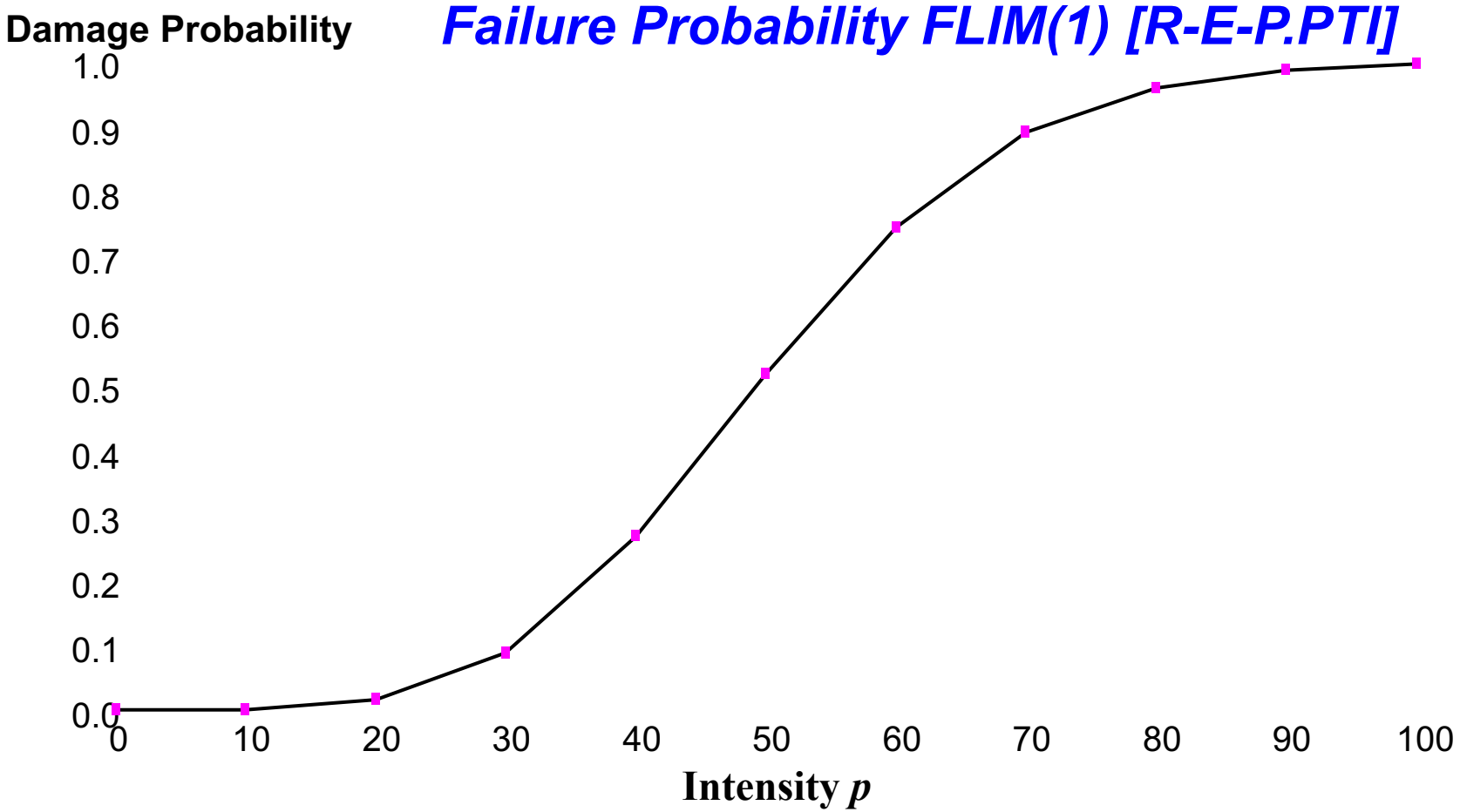
R, LN: $\mu_R = 100$ units, $\sigma_R = 15$ units, $V_R = 0{,}15$

g, N: $\mu_g = 30$ units, $\sigma_g = 3$ units, $V_g = 0{,}10$

q, LN: $\mu_q = 20$ units, $\sigma_q = 4$ units, $V_q = 0{,}20$

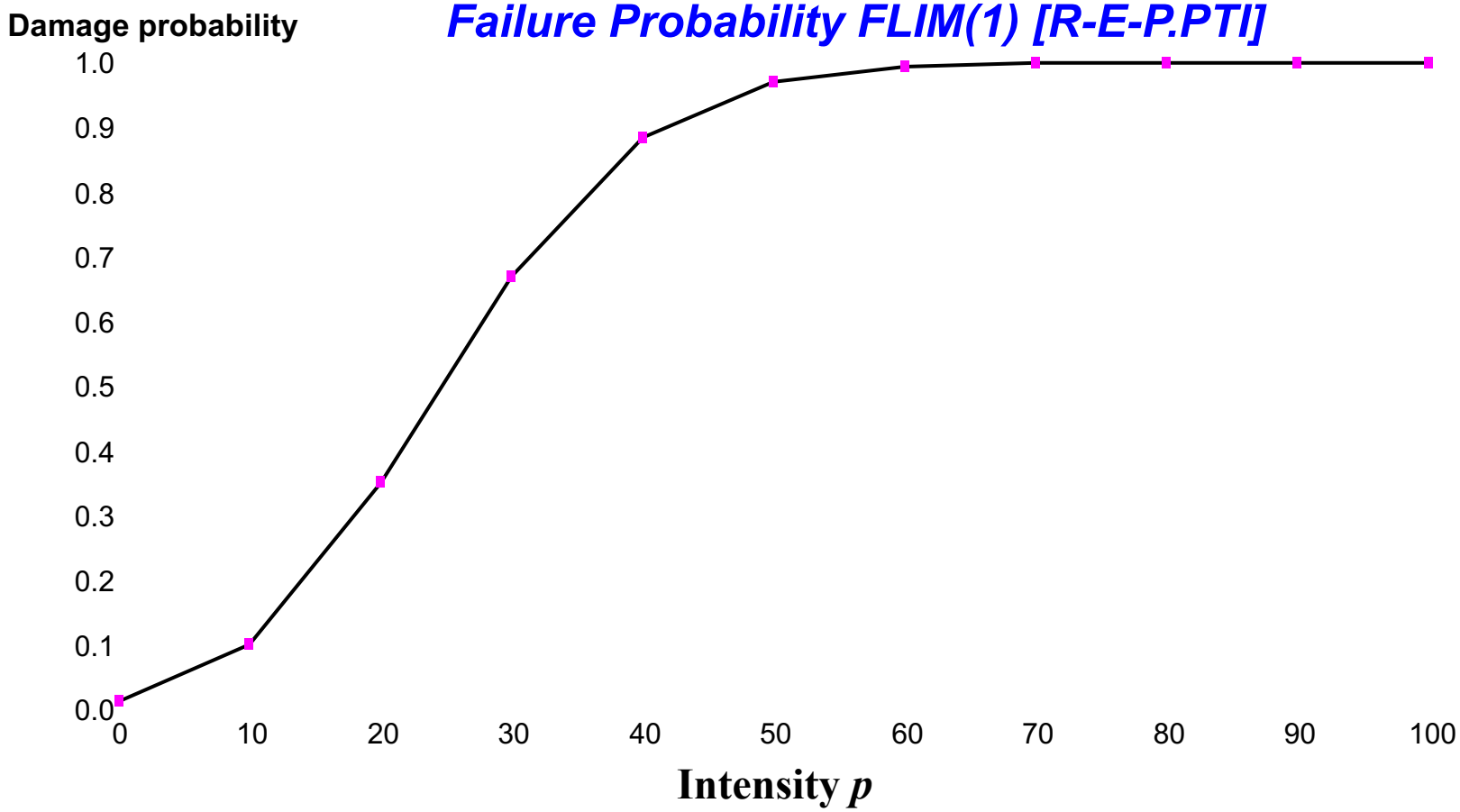
$S = (g + q)$, LN: $\mu_S = 50$ units, $\sigma_S = 5$ units, $V_S = 0{,}10$

Fragility curve



Variation of the failure probability with the intensity p (0 to 100) of extreme action for 100 % of the resistance R (KR = 1,00).

Fragility curve



Variation of the failure probability with the intensity p (0 to 100) of extreme action for 75 % of the resistance R ($KR = 0{,}75$)

Risk assessment and cost optimization

C_{marg} represents the cost due to the factor KR
H denotes the cost due to structural damage

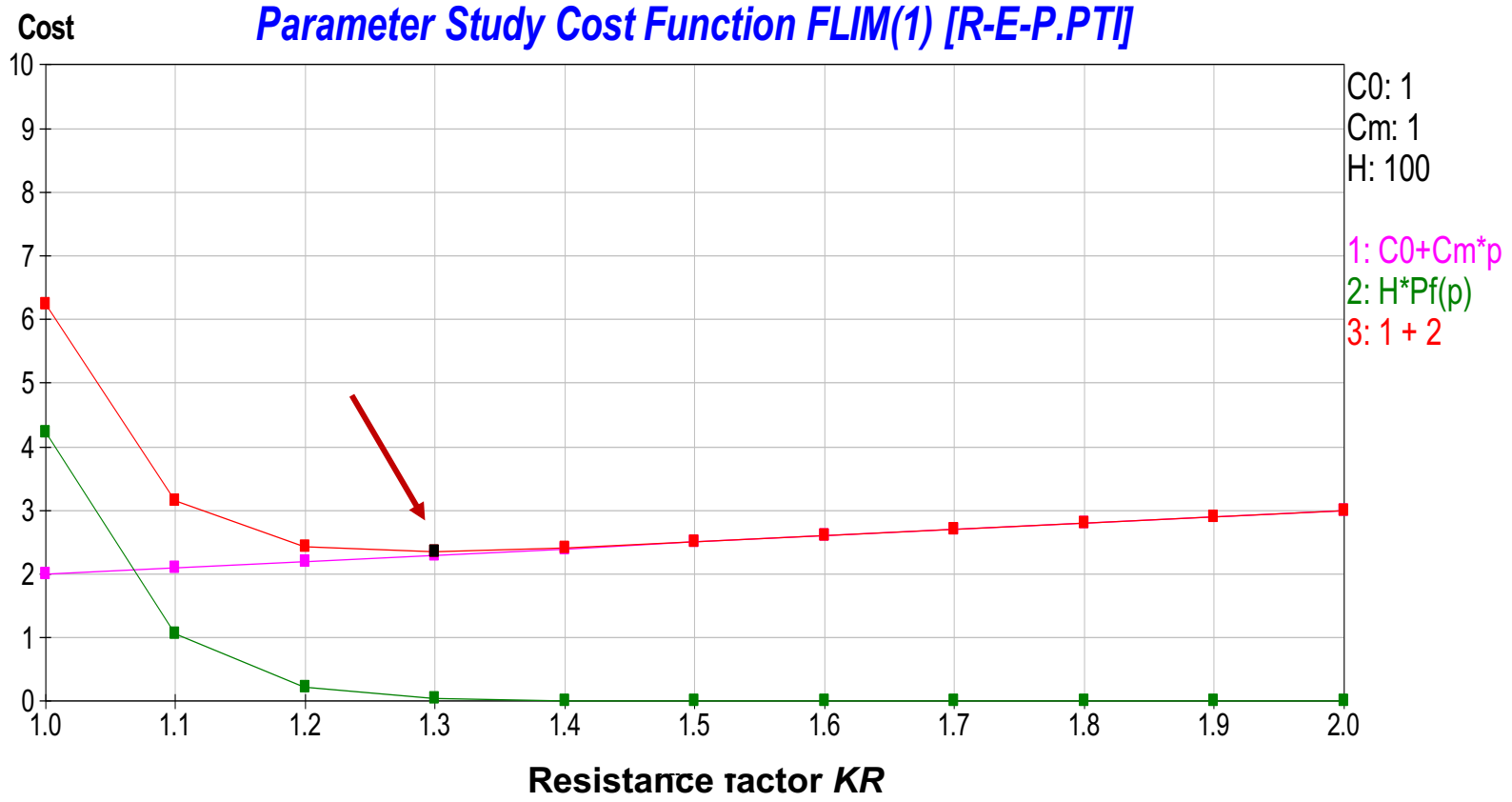
The total cost

$$C_{\text{tot}} = C_0 + C_{\text{marg}} * KR + H * \text{P}_\text{f}(p,KR)$$

The optimum factor KR

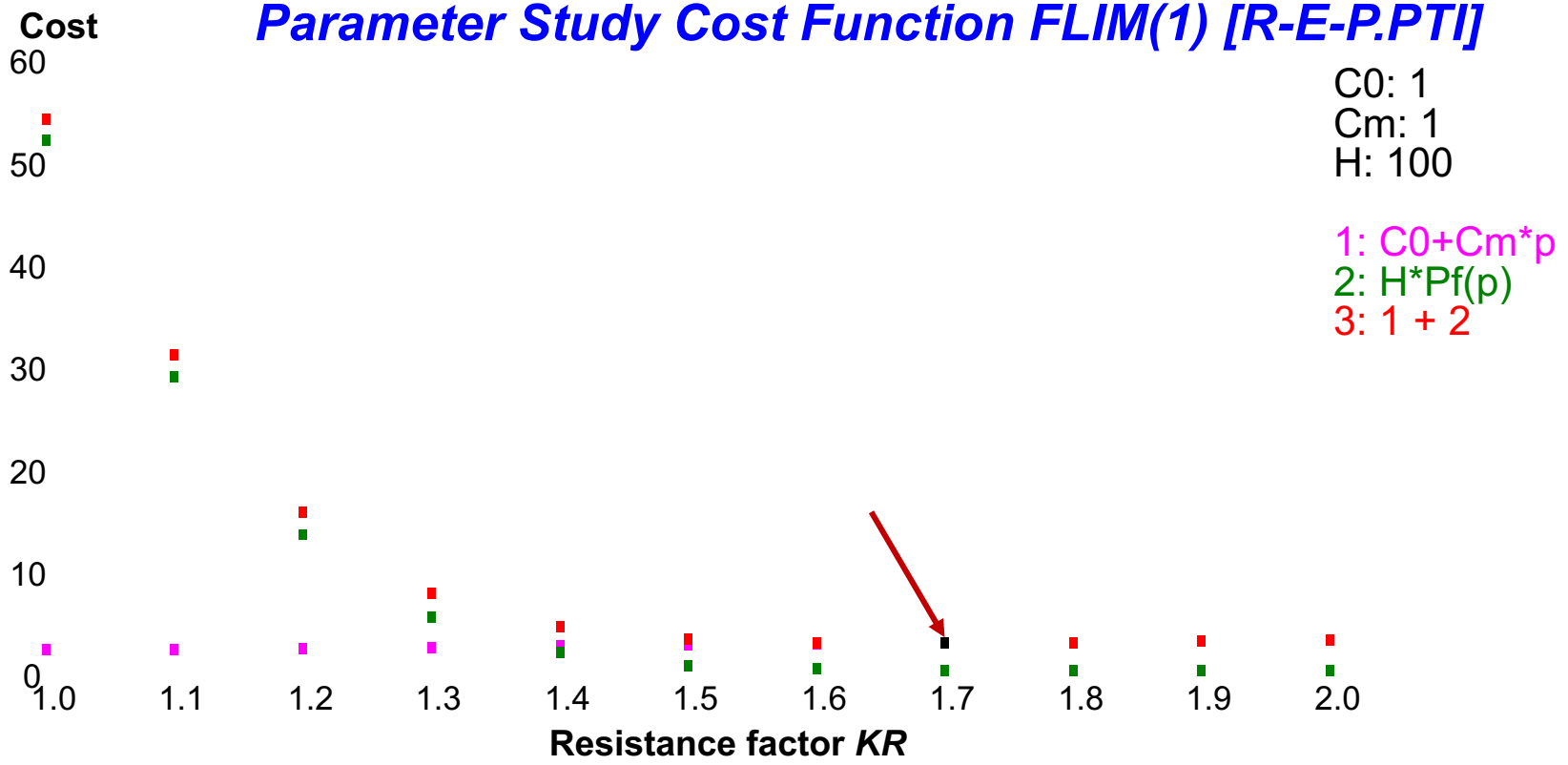
$$\frac{\partial C\text{tot}}{\partial KR} = C_{\text{marg}} + H * \frac{\partial \text{Pf}(p,KR)}{\partial KR} = 0 \rightarrow C_{\text{marg}}/H = \text{?} \frac{\partial \text{Pf}(p,KR)}{\partial KR}$$

The optimum resistance factor *KR*



Variation of the costs with the factor *KR* for the intensity of extreme action $p = 25$, $H/C_{\text{marg}} = 100$

Optimum resistance factor *KR*



Variation of the costs with the factor *KR* for the intensity of extreme action $p = 50$, $H/C_{\text{marg}} = 100$

Concluding notes

(1) The fragility of a structure depends strongly on the expected extreme actions and relevant situation.

(2) The probability p_{f} of structural damage and sustainability depend on the intensity of extreme action p and the resistance factor KR.

(3) Cost optimization bearing in mind structural fragility may lead to significant savings.

(4) The optimum resistance factor KR is determined by the negative derivative $\frac{\partial \mathrm{P}(p,KR)}{\partial KR}$ equals to the cost ratio C_{marg}/H.

(5) The optimum resistance factor KR enlarges with the increasing cost ratio H/C_{marg} and the intensity of extreme action p.