Riziková analýza požáru v silničních tunelech

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ČVUT, WP7

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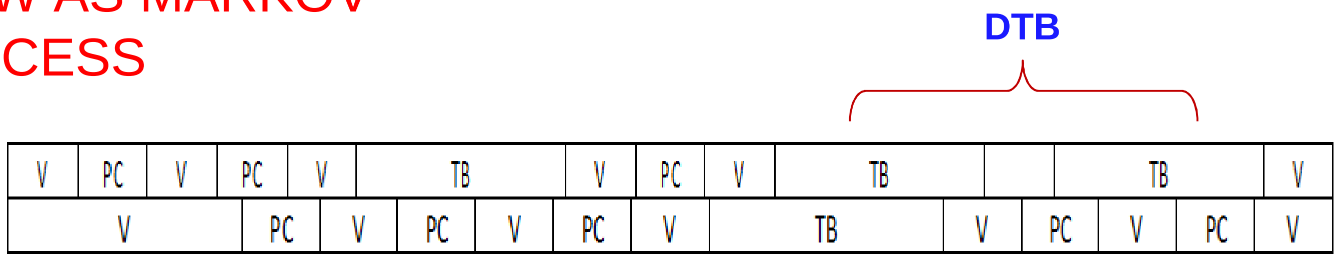
Obsah

- ÚVOD
- PRAVDĚPODOBNOSTNÍ POPIS POŽÁRU
- MATERIÁLOVÝ POPIS POŽÁRU A JEHO ÚČINKU NA OSTĚNÍ
- ZÁVĚRY

Risk analysis of fire in the road tunnels

- TWO-LANE TRAFFIC FLOW AS MARKOV PROCESS



V – Void
PC – Passenger Car
TB – Truck or Bus
DTB – Two Trucks or Buses

- FIRE INDUCED DAMAGE OF TUNNEL LINING

Heat Characteristic

- **Heat Release Rate** ***HRR* = *Q* [MW]**
- Distribution of maximum temperature in space and time
- **Fire intensities of joint states**

$$\lambda_{[i]} = \kappa_{[i]}\lambda \left[\frac{\text{N. of fires}}{\text{veh. km}}\right]$$

Risk analysis of fire in the road tunnels

- PROBABILITY OF JOINT STATES

LANE 1	V	PC	V	...	TB	TB	...	TB	DTB	...	DTB
LANE 2	V	V	PC	...	V	PC	...	TB	V	...	DTB
JOINT STATES	0	1	2	...	...	...	...	...	...	...	I

V – **V**oid

PC – Passenger Car

TB – Truck or Bus

DTB – Two Trucks or Buses

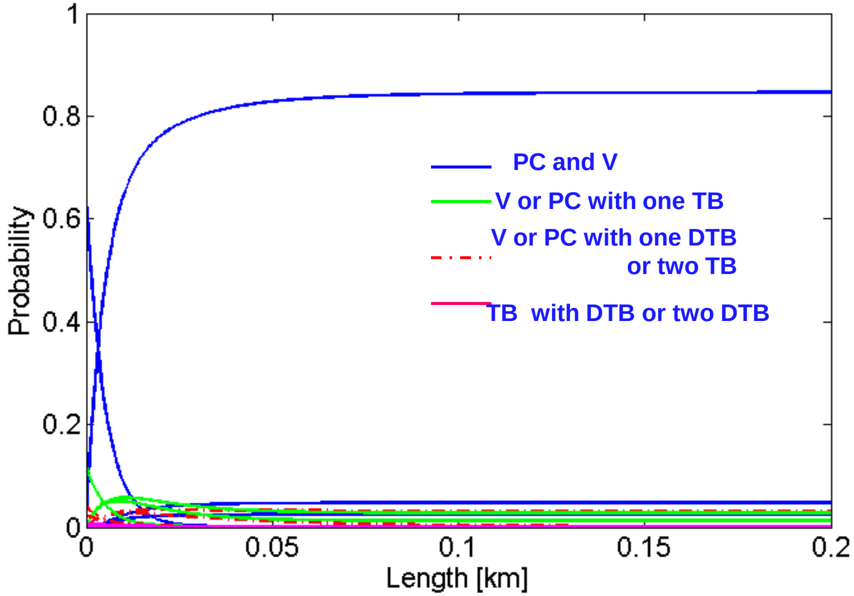
- PROBABILITY MASS FUNCTIONS FOR JOINT STATES *i*

Risk = Probable damage

- PROBABILITY OF JOINT STATES

Kolmogorov’s Equations

$$\frac{\mathrm{d}\mathbf{P}}{\mathrm{d}x} = \mathbf{AP}(x)$$



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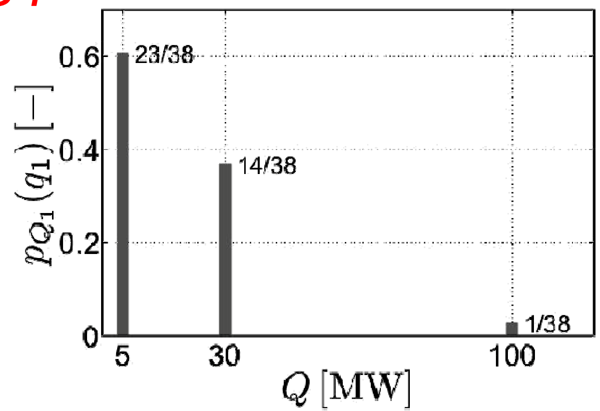

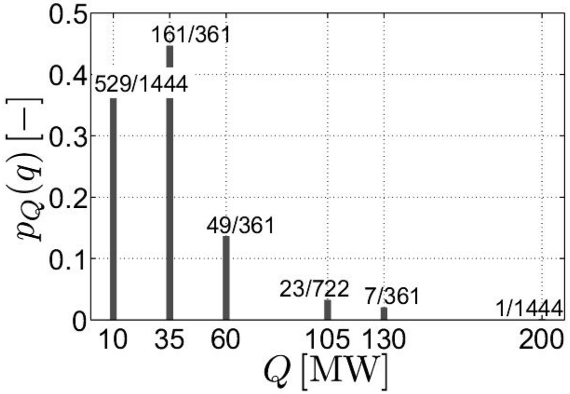

PROBABILITY OF JOINT STATES

Kolmogorov's Equations

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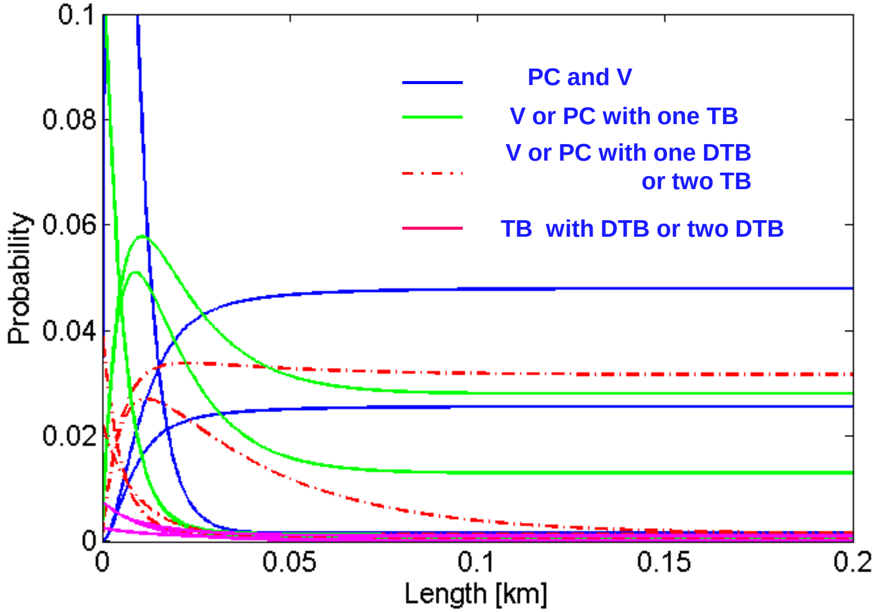

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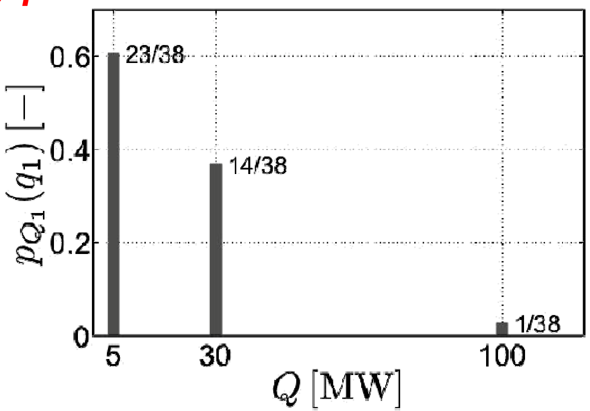

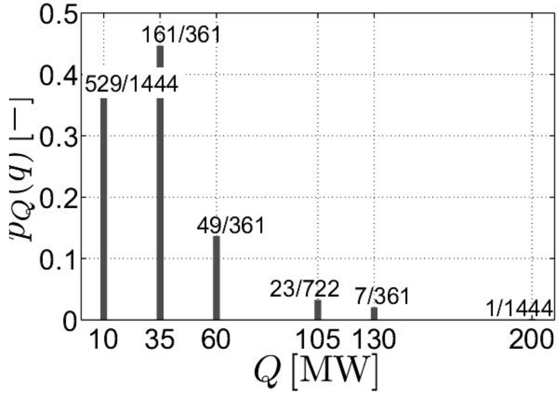

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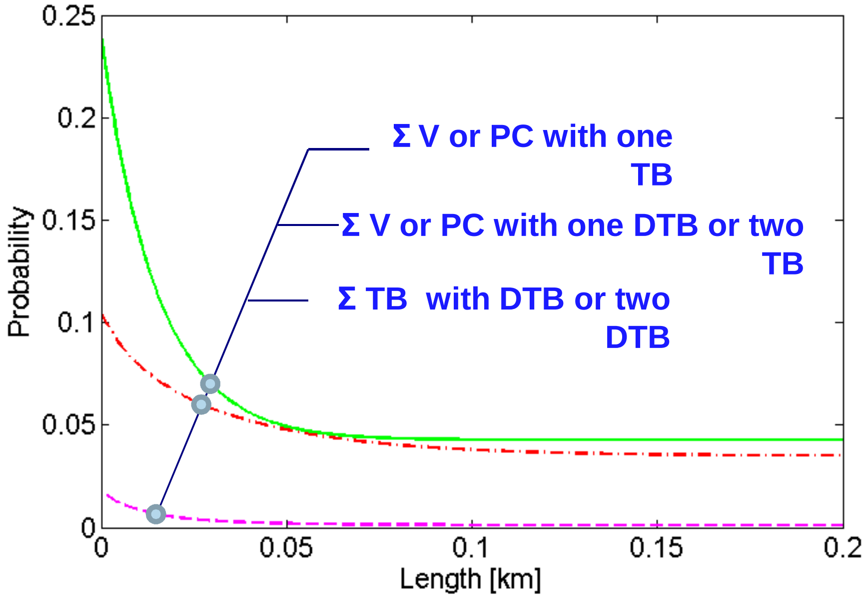

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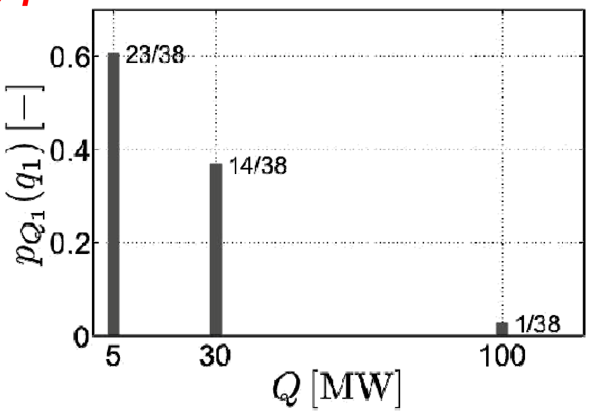
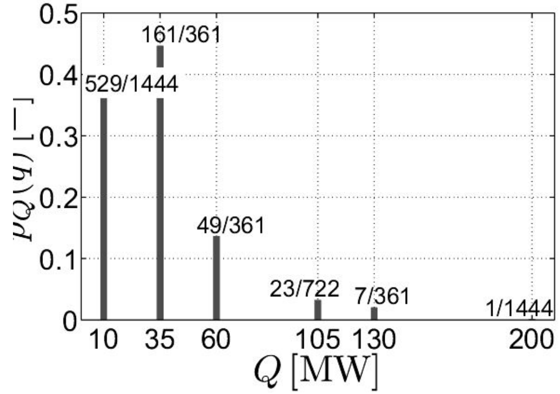




Material model of fire

- Conservation law of mass (transport of water vapor)

$$\frac{\partial w}{\partial t} = \nabla \cdot \left(\frac{\kappa}{g} \nabla p\right) + \frac{\partial w_d}{\partial t} \qquad (1)$$

- Conservation law of heat

$$\rho c \frac{\partial \theta}{\partial t} - h_v \frac{\partial w}{\partial t} = \nabla \cdot (\lambda \nabla \theta) - c_w \frac{\kappa}{g} \cdot \nabla p \cdot \nabla \theta + h_d \frac{\partial w_d}{\partial t} \qquad (2)$$

- Definition of fire-induced spalling

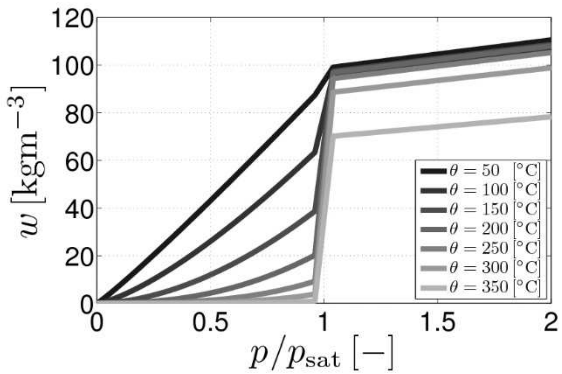
$$\phi p \geq f_t(\theta) \qquad (3)$$

Material model of fire

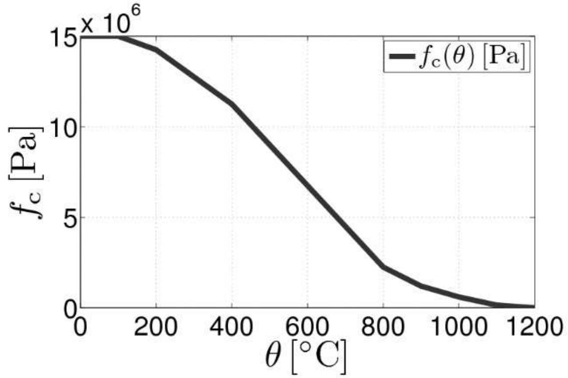
(c) temperature-dependent tensile strength ,
(d) permeability
as a function of temperature

- Material parameters

(a)

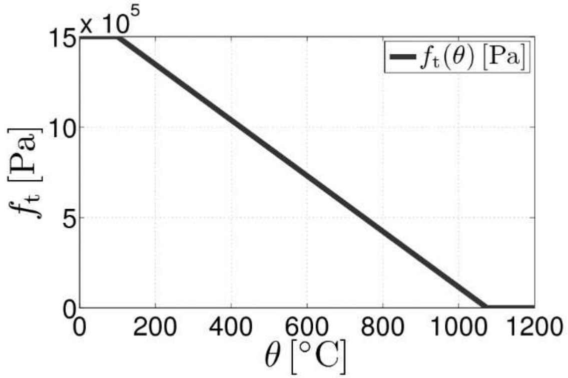


(b)

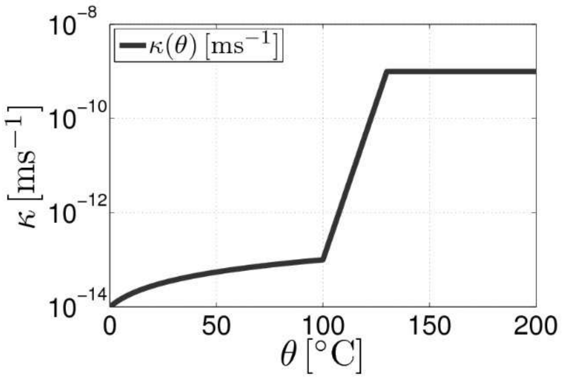


(a) Sorption isotherm, (b) temperature-dependent compressive strength $f_c(\theta)$

(c)



(d)

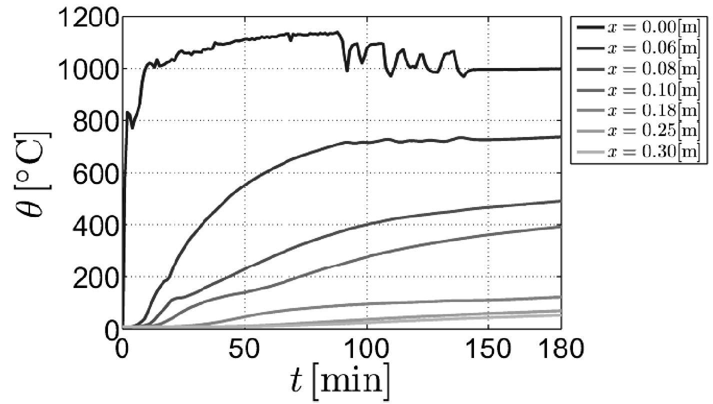


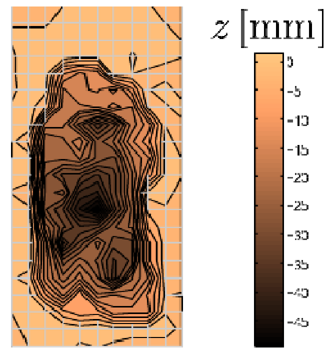
(c) temperature-dependent tensile strength $f_t(\theta)$,
(d) permeability $\kappa(\theta)$ as a function of temperature.

Material model of fire

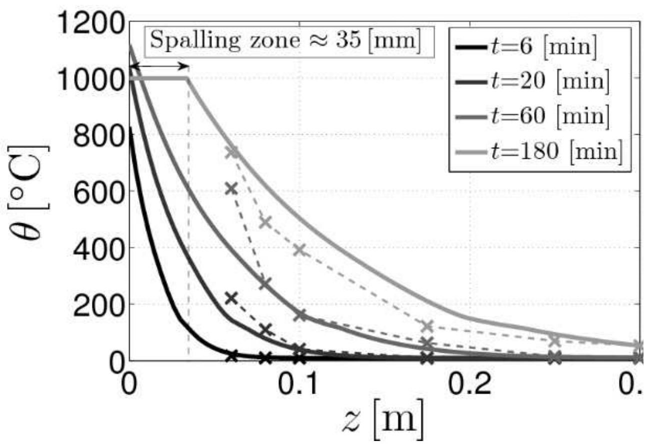
- Experimental validation against laboratory tests in furnace

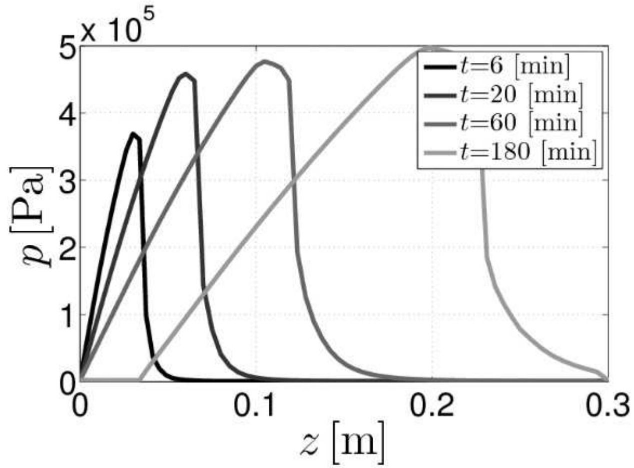
Spalling zone





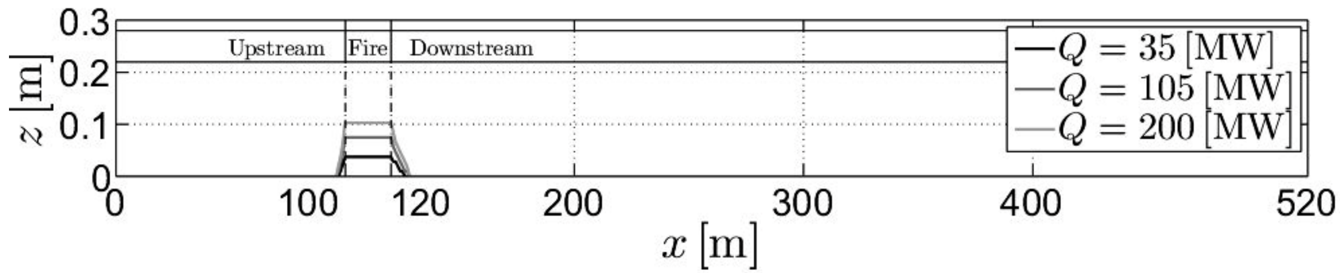
Evolutions of temperature and pore pressure



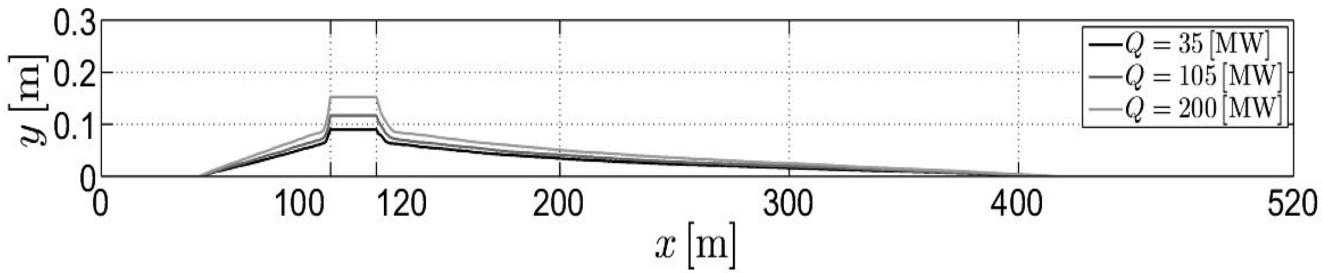


Damage of tunnel lining as a consequence of one fire accident

- spalling

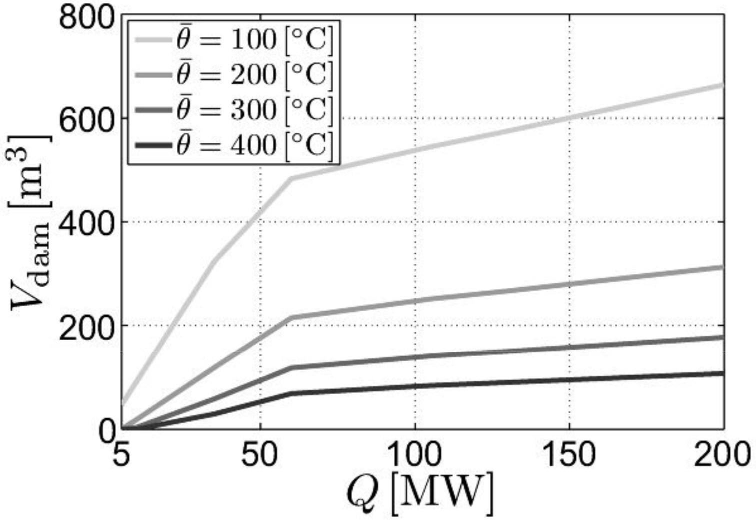


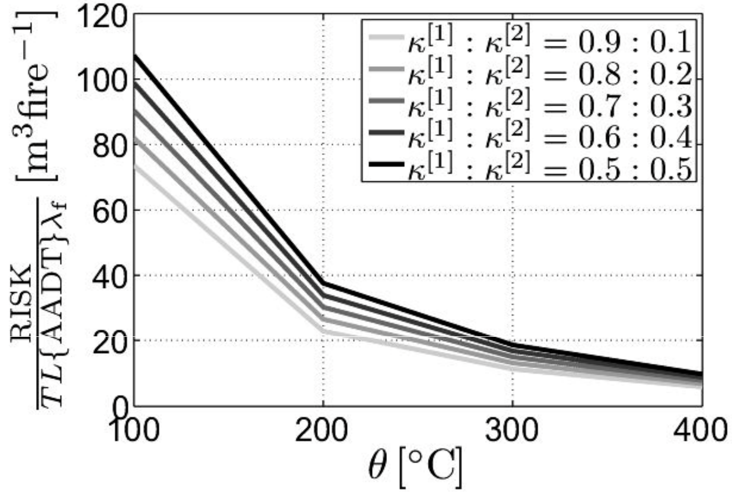
- degradation due to temperature exceeding 100℃



Damage of tunnel lining as a consequence of one fire accident

- FIRE RISK ASSESSMENT





$$\frac{\text{RISK}}{\text{TL(AADT)}\lambda_f} = \left[\left(\sum_{q=5,30,100} V_{dam}^{[1]}(q) p_{Q_1}(q_1) \right) \kappa^{[1]} P_f^{[1]} + \left(\sum_{q=10,35,60,105,130,200} V_{dam}^{[2]}(q) p_Q(q) \right) \kappa^{[2]} P_f^{[2]} \right] = \text{damage } V_{dam} \ [\text{m}^3/\text{fire}]$$

Conclusions

- For reasonably selected input data

$AADT = 17000$ [veh. day^{-1}], $L = 2$ km, $T = 1$ year,
$\lambda_f = 30 \cdot 10^{-9}$[fires(veh. km)$^{-1}$] , and $\bar{\Theta} = 150$°C

$$\text{RISK} = 19 \div 28 \text{ m}^3/\text{year}$$

For a total volume struck by a fire: $V = 3463 \text{ m}^3$

$$\text{RISK}_{rel} = (5 \div 8{,}1) \text{ ‰}$$

- Model can be improved in

  - probabilistic modeling (non-stationary process)
  - material modeling (effect of damage on permeability, effect of dry air)