Monitoring of cooling towers and industrial chimneys

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Introduction

- Cooling towers and industrial chimneys are reaching ***service life***

- Maintenance plans should be based on credible ***estimates of remaining lifetime***

- Present monitoring systems provide ***great amount of information*** on performance of key energetic devices

- Contribution provides an overview of:
  - Operational statistical tools for ***data analysis***
  - Procedure of residual ***lifetime estimation***
  - Challenges for ***optimising monitoring*** systems

Current practice

• Parameters observed for concrete, masonry and steel structures:

- cracking, spalling of concrete, carbonation depth, concrete cover
- deterioration of masonry units and mortar
- steel corrosion
- irreversible deformation, settlements of foundations

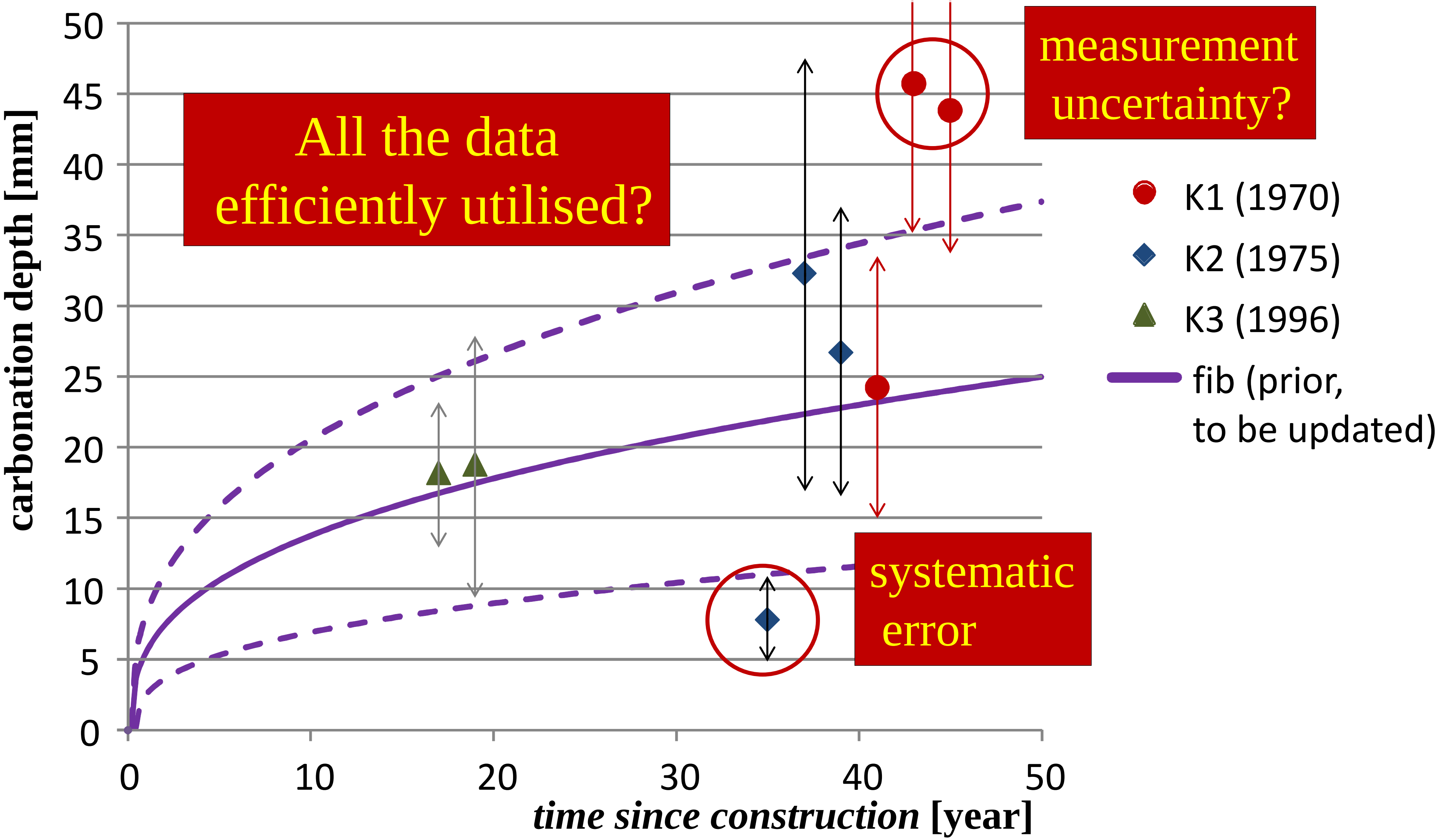
• Structures divided into ***components***:

- outside and inside surfaces of shell, columns, supports of cooling system, inspection galleries

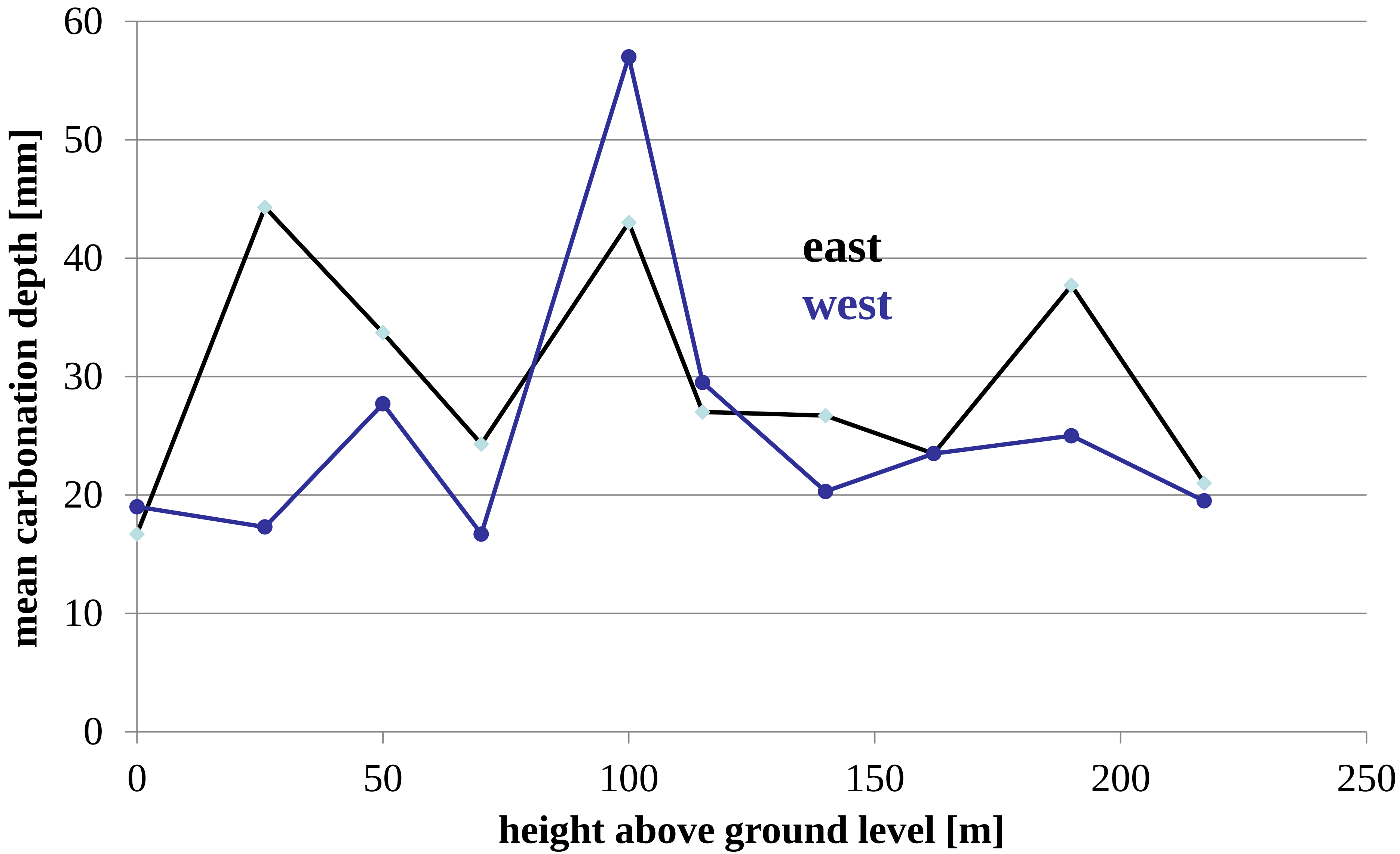
Current monitoring seems to be ***sufficient for detecting*** serious damage, but often provides redundant information.

Available data

- Monitoring data for the last ten years (each two years)
- Reference areas (identical for all the time instants)

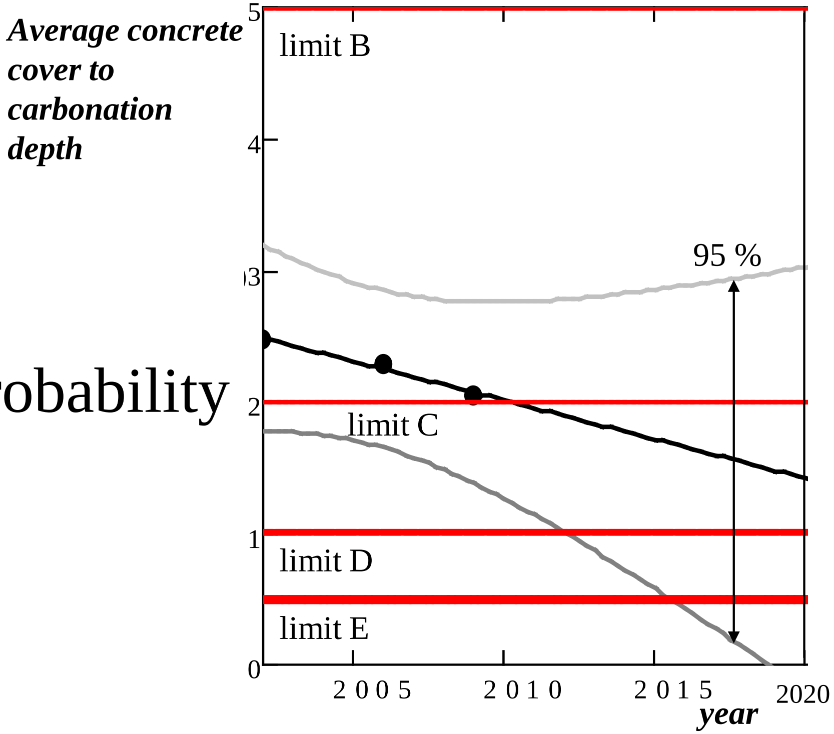


Available data



Statistical analysis

1. Tests of outliers
   If the cause of an outlying observation is non-statistical, the outlier is removed from the sample.
2. Correlation analysis
   indicates if a number of observed parameters can be reduced.
3. Regression model
   is selected on the basis of experience and fit to empirical data.
4. Confidence intervals
   of the regression curve indicate probability of exceeding a limiting value.



Residual lifetime estimation

- Estimates linked to durability, serviceability and ultimate limit states (severe failure and damage distinguished)
- Five deterioration levels recognised

Example for carbonation depth *d* and concrete cover *c*

Cooling tower – outside and inside surface of shell, inspection galleries	Technical parameter - ratio of carbonation depth *d* and mean value of concrete cover *c*
Deterioration level	Criterion
A	$0 < d / c < 0.1$ for less than 90 % of surface area AND $0.1 < d / c < 0.5$ for less than 10 % of surface area
…	…
D	$0.1 < d / c < 0.5$ for more than 70 % AND $0.5 < d / c < 1$ for less than 60 % AND $d / c > 1$ for less than 20 %.
E	Whenever one of the criteria for Level 4 is exceeded.

Challenges

1. Selection of observed ***deterioration processes and threshold values***

   Correlations between cracking, carbonation and corrosion progress? Threshold values reflecting optimal maintenance plans?

2. ***Appropriate method for monitoring***

   Balance between related costs, uncertainty in outcomes and required precision.

3. Amount of ***observations at a time*** for components of different areas

   Spatial variability – distinction between shell and columns of cooling tower, zones in shell.

Challenges

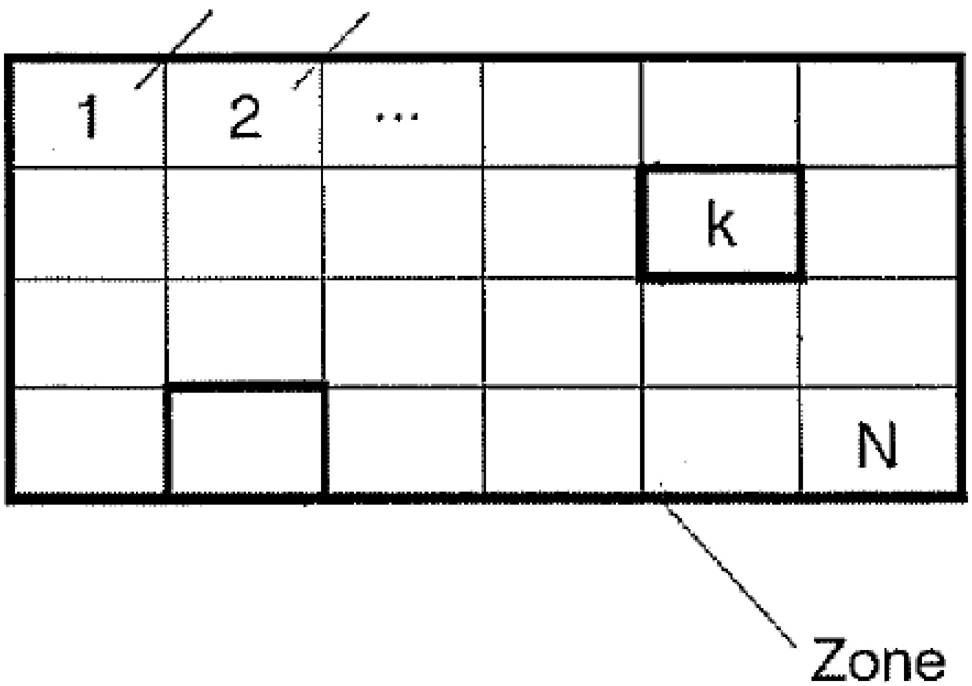
4. Optimal time ***interval between measurements of*** different degradation processes.

5. Monitoring of ***similar structures***
   Group of cooling towers, chimneys, structures in a power plant.

Tools to be applied – spatial deterioration

- simplified deterioration model according to ***fib Bulletin 59***
- structure divided into ***zones*** (similar exposures)
- within a given zone → a homogeneous ***random field*** **X** + ***hyperparameters*** **Ω** (random variables common within the zone)
- the zone ***discretized*** into *N* zone-elements (a component *X* of **X** in an element *k* is a random variable X_k independent of other elements)

Zone-elements (0,5 – 3 m)

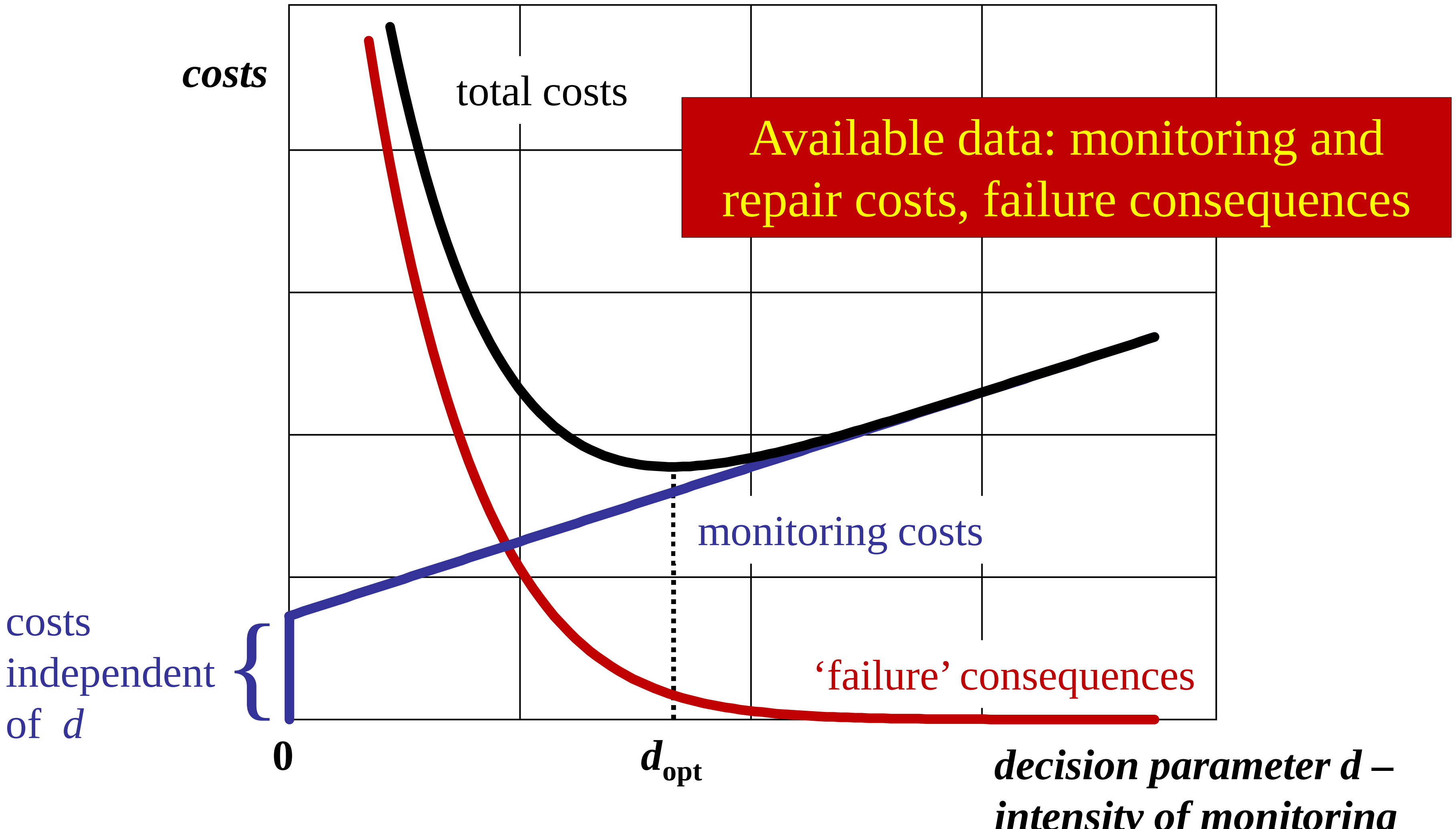


- RC structures: zone-element ~ square with the side 0.5-3 m
- Steel structures: ~ 3 m

Sykora - Holicky. Durability Assessment of Large Surfaces; ICOSSAR 2013

Tools to be applied – balance of costs and benefits of monitoring

total costs ≈ monitoring costs + repair (failure) costs



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Thank you for your attention.

Another study offered for next meetings – reliability-based monitoring of a stadium roof in Italy by D. Diamantidis