Updating information on the real performance of structures – experience gained and implementation of future guidelines

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   - Flood protection
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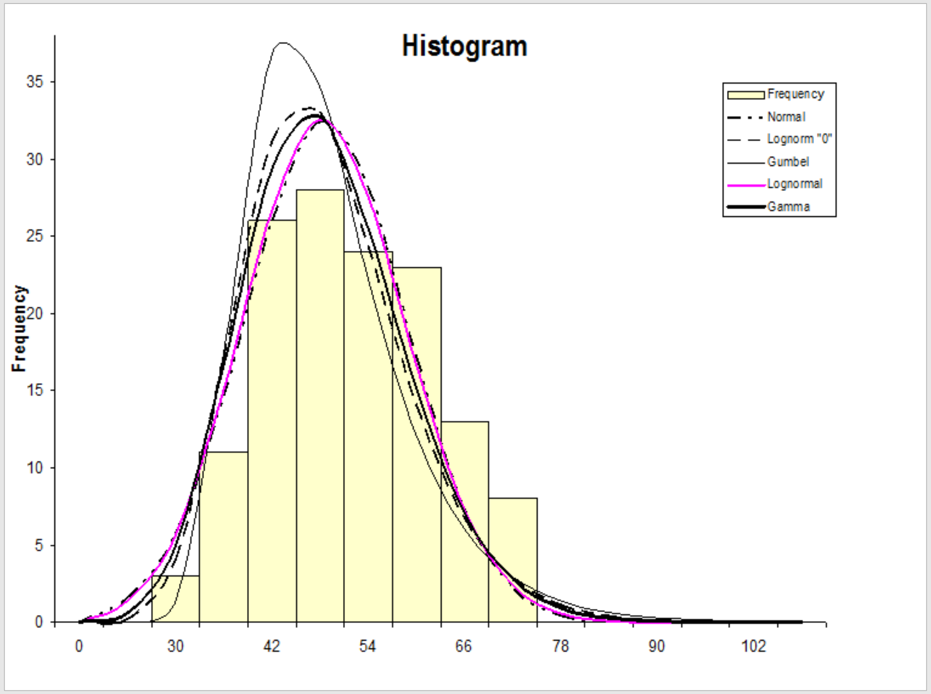
Why assess real performance?

- Deviations from original design
- Doubts about safety
- Adverse inspection results
- Changes (including change of use)
- Lifetime prolongation
- Inadequate serviceability

Typical questions

- What type of inspections are necessary?
- What type of measurements shall be taken?
- What analyses shall be performed?
- What is the future risk in using the structure?
- What is the acceptable risk?



Standards on SHM

GOST R 53778 (2010). Building and structures – Rules of inspection and monitoring of the technical condition. Moscow, Russia.

EN 15331 (2009). Criteria for design, management and control of maintenance services for buildings. ISO, Geneva, Switzerland.

ISO 14044 (2006). Environmental management – Life cycle assessment – Requirements and guidelines. ISO, Geneva, Switzerland.

ISO 14963 (2003). Mechanical Vibration and shock – Guidelines for dynamic test and investigations on bridges and viaducts. ISO, Geneva, Switzerland.

ISO 16587 (2004). Mechanical Vibration and shock – Performance parameters for condition monitoring of structures. ISO, Geneva, Switzerland.

ISIS Design Manual No. 2 (2001). Guidelines for Structural Health Monitoring. ISIS Canada, Winnipeg, MB, Canada.

SAMCO Final Report (2006). F08a – Guideline for the Assessment of Existing Structures. SAMCO, Berlin, Germany

SAMCO Final Report (2006). F08b – Guideline for Structural Health Monitoring. SAMCO, Berlin, Germany

RVS 13.03.01 (2012) – Monitoring, control and inspection of engineering structures. FSV, Wien, Austria.

Covered issues

- Permanent monitoring
- Periodic monitoring
- Spot monitoring

- sensor classification
- performance of tests
- treatment of data
- damage identification
- inspection planning

Classification of structures

Consequence Class	Description	Examples of buildings and civil engineering works
CC1	Low consequences for loss of human life, social and environmental consequences small or negligible	Agricultural buildings, silos, greenhouses
CC2	Medium consequences for loss of human life, economic, social or environmental consequences considerable	Residential and office building, public buildings
CC3	High Consequences for loss of human life, or economic, social or environmental consequences very great	Stadia, congress centers

Recommendation for Inspection intervalls VDI 6200

	Visual Check	Inspection (engineer)	Verification (expert)
CC1	5 years		
CC2	3 years	5 years	15 years
CC3	2 years	3 years	10 years

Industrial experience

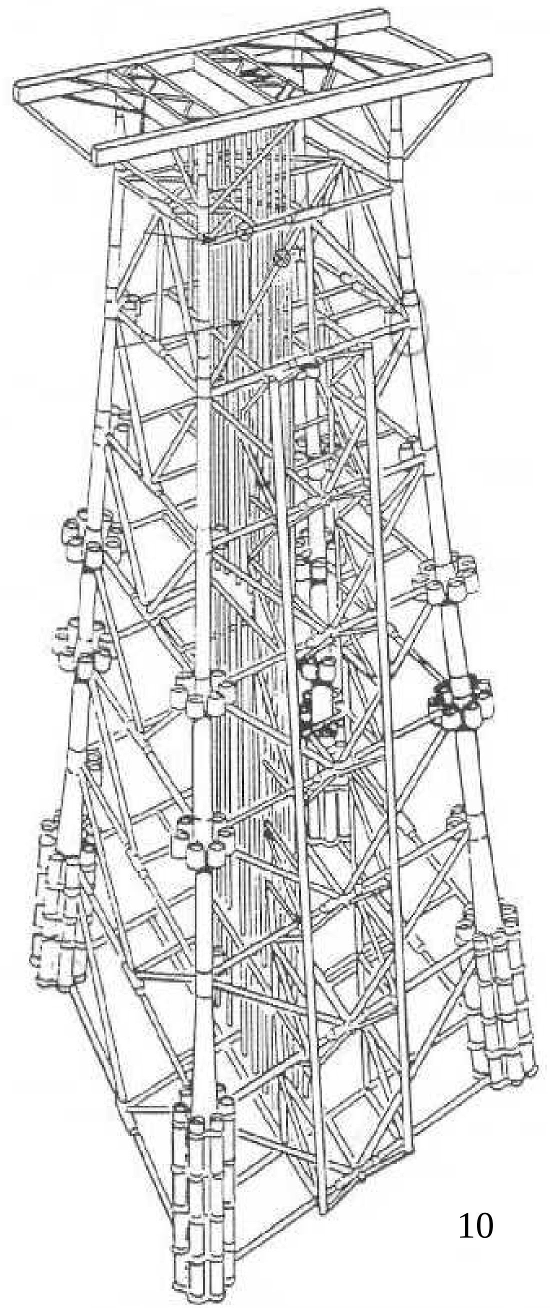
- **Offshore structures**
- **Bridges**
- **Dams**
- **Heritage structures**
- **Tunnels**
- **Buildings**

- **Waves, wind, fatigue**
- **Fatigue**
- **Flood, earthquake**
- **Live load, wind load**
- **Fire**
- **Live load, snow load, earthquake**

Steel Jacket Structures

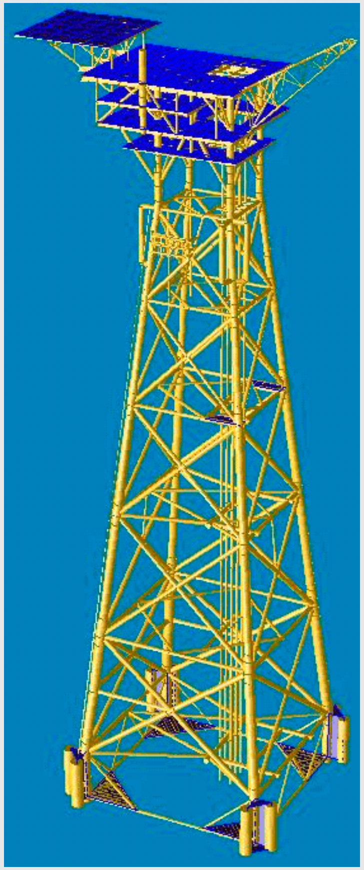
<u>**Problems (Yardsticks)**</u>

- **Fatigue of Joints**
- **Corrosion**
- **Marine Growth**
- **Scour**
- **Stiffness against impact**
- **Air-Gap**



Data collection

- Design phase
- Installation phase
- Operation phase



Data management

a) Design Phase

- Design premises (field data, geotechnical data, standards)
- Design data (material data, structural model, geometry data)
- Archives (reports, drawings)

b) Installation Phase

- Built up data (yard surveys, incidental damages)
- Transportation data (fatigue, damages)

c) Operation Phase

- Modifications (deck loads, revamping)
- Surveys (damages, corrosion, cracks, marine growth, scouring)
- Monitoring (structural displacements/stresses, meteoceanographic data, cathodic protection data
- Geotechnical data, equipment data
- Statistical regression data (correlation of damage to joint characteristics)

Structural Integrity Measures

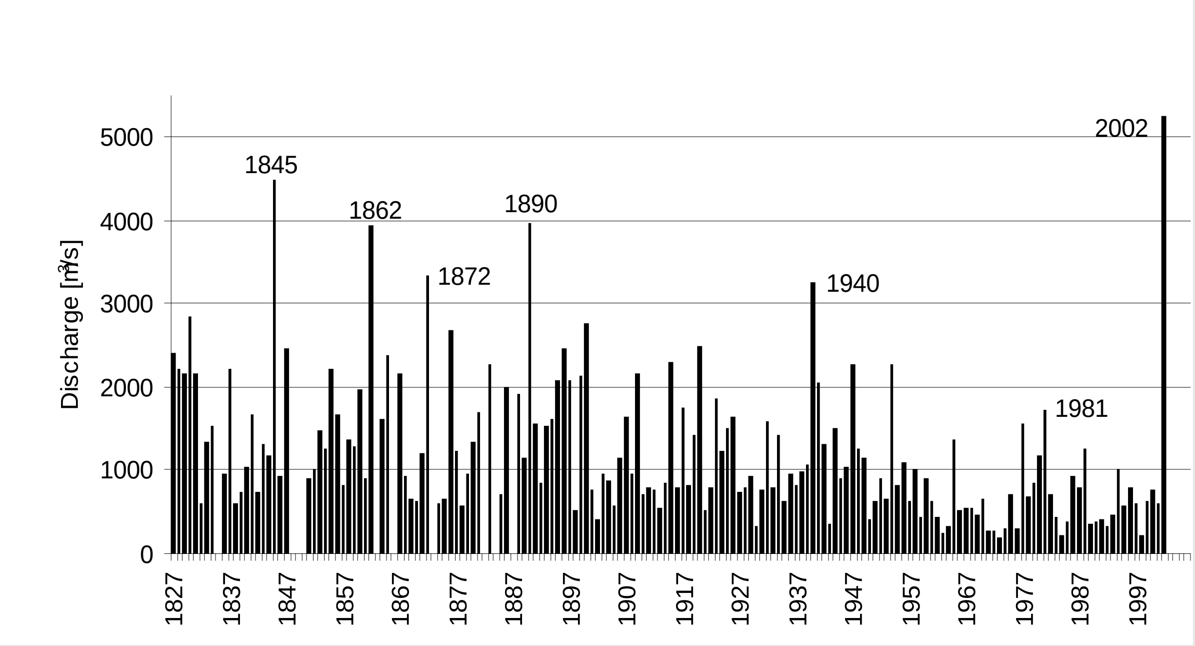
- Redistribution and reduction of deck loads
- Periodical cleaning of the marine growth
- Extensive long term inspection planning
- Inspection campaigns on critical nodes at reduced intervals

Extreme Load cases in Central Europe: Damages on roofs in Bavaria, January 2006

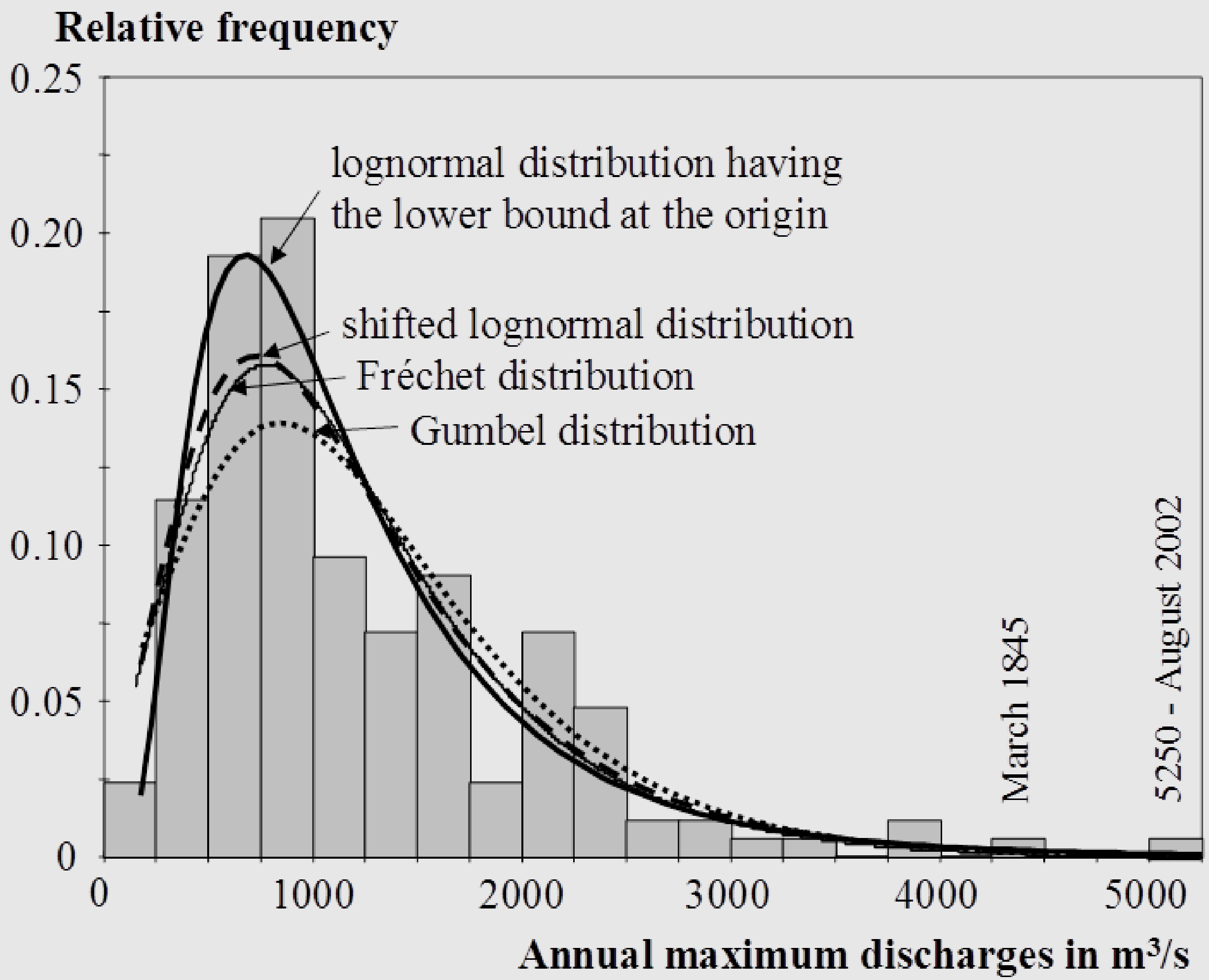
Snow load monitoring

Flood in Prag August 2002

- Highest level since 200 years
- Considerable damage
- Damage/reliability evaluation



Annual maximum discharge data Vltava river, Prague



Flood protection Danube river

(s. Rogowsky, 2012)

• Reliability assessment of a former ***factory for boiler production*** built in 1900s

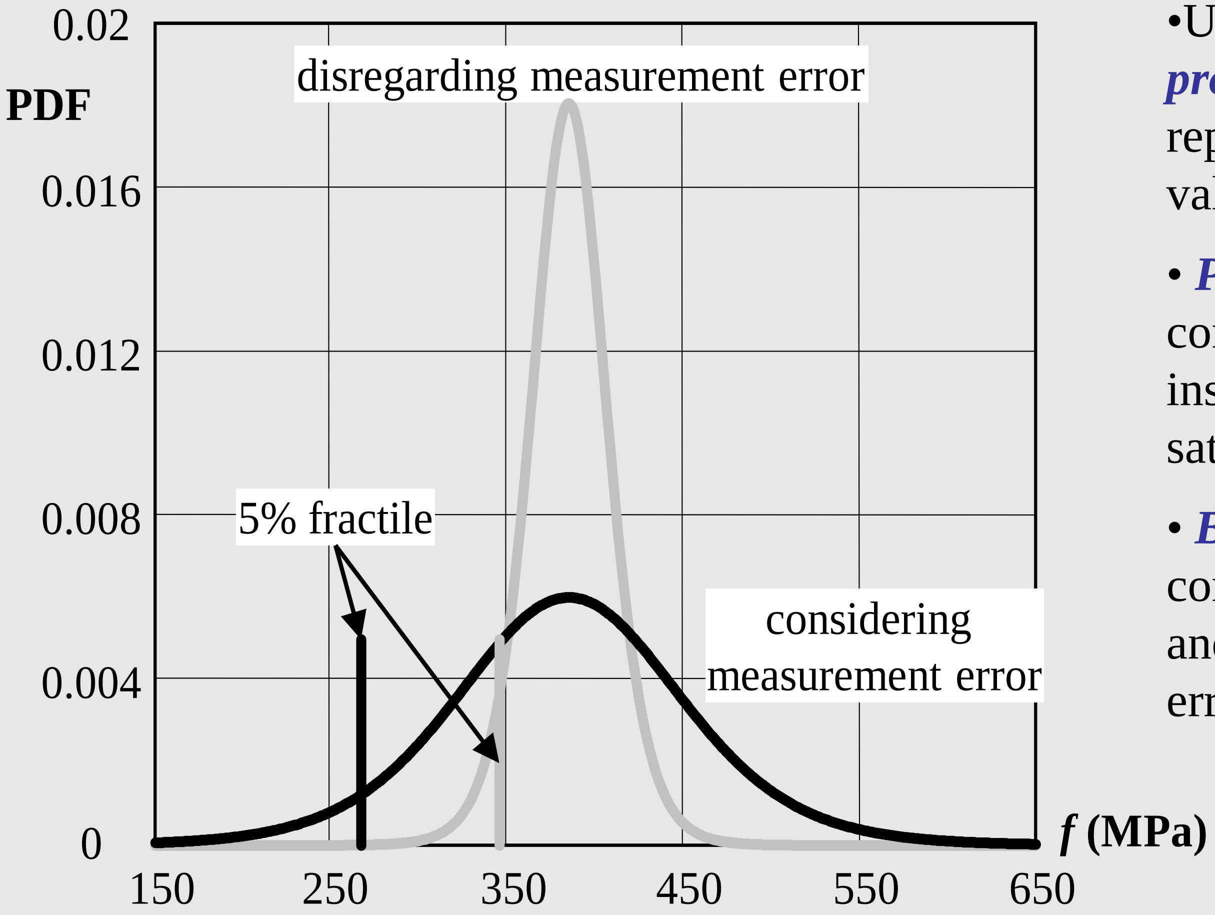
• ***Reconversion*** to adapt the building for use as the headquarters of a publishing house

• Critical structural member - ***iron truss girder***; suction due to wind yields buckling of a long-span lower chord

Heritage structure

The case study shows:
(1) development of the ***probabilistic model for iron strength*** using non-destructive and destructive tests,
(2) consideration of the ***satisfactory past performance***.

Result: resistance parameter



- Use of ***conservative design procedures*** may lead to expensive repairs and losses of the heritage value.
- ***Probabilistic methods*** allow to consider uncertainties, results of inspections and tests, and satisfactory past performance.
- ***Bayesian updating*** allows to combine results of non-destructive and destructive tests; measurement errors should be considered.

Conclusions

1) The required information to be obtained by the structural health monitoring (SHM) needs to be clearly specified before updating.
2) Present standardized approaches provide limited sufficient guidance for planning of SHM and further developments and harmonization is needed.
3) Structural reliability with respect to the Ultimate Limit States is in many cases not improved by detecting structural damage; global structural behavior and collapse should be also considered.

Conclusions

4) Further improvements should be primarily focused on:

- use of SHM results to assess similar, but not monitored structures,
- identifying value of updating of real performance as a basis of future cost optimal maintenance plans,
- developing operational methods for updating procedures and implementation of risk and reliability acceptance criteria for decision making purposes.

Recommendations

SHM guidelines should indicate:

- a appropriate methods of the SHM,
- critical structural members and cross-sections to be observed; for a group of similar structures a decision whether or not it is sufficient to observe a limited number of these structures needs to be made,
- optimum frequency of collecting data considering an observed failure mode and progress of a degradation process,
- threshold values for observed parameters.
- Implementation of updating methods including measurement and model uncertainties.

Thank you for your attention