Background ideas related to SHM guilidelines

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discussion note

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Motivation

- What type of inspections and monitoring is necessary?
- What analyses shall be performed?
- What are the risks involved in further use of the structure?
- What type of measures shall be taken?

Answers cannot often be given by using a classical code approach.

Scope of presentation:

- **consistency with JCSS and WG 2-4 outcomes**
- **possible contents of standard**
- **examples of application**

Guideline integrated in the PMC of JCSS

- **consistent with basis of design of PMC**
- **compatible to JCSS report on existing structures**
- **material, type of structure independent**
- **reflecting results of case studies WG4**
- **on the basis of WG2 and WG3 outcomes**
- **applicable in practice (new design, existing structures) parameters**
- **providing normative references**
- **giving quantification of VoI of SHM**
- **Implementing reliability, risk, decision criteria**

Compatiblity with PMC

- §2.1 basic requirements, §2.3 requirements for durability
- §4.2 uncerainty types i.e. physical, statistical, model (SHM data analysis, Bayesian methods)
- §5 calibration of models for physical behaviour (updating)
- §6 reliability (reliability updating through SHM)
- §8 robustness (interpretation of global behaviour)
- on the basis of WG2 and WG3 outcomes (strategies, methods)
- applicable in practice (new design, existing structures)
- providing normative references
- giving quantification tools of VoI of SHM
- implementing reliability, risk, decision criteria

Consistency with JCSS report on existing structures

- §1.3 inspection and maintenance
- §1.4 decision criteria (see WG3 outcomes)
- §2.3 Bayesian probabilistic reassessment of structures (see WG1 and WG3)
- §5 decision analysis (WG1, WG2 and WG3)
- §6 updating techniques (applied in case studies of WG4)

quantification tools of VoI through reliability, risk, cost-benefit decision criteria

Possible contents (compatibility with JCSS documents)

- **General scope – field of application**
- **Normative references**
- **Definitions**
- **Basic input parameters**
- **Objectives of guideline**
- **Classification of monitoring (types)**
- **Collection of asset information**
- **Configuration of monitoring system**
- **Monitored data analysis**
- **Damage (structural) identification criteria**
- **Structural Health (Performance) analysis procedures**
- **Decision analysis (integration of monitoring system results)**

Normative references

- JCSS Probabilistic Assessment of Existing Structures
- ISO 14963:2003 Mechanical vibration and shock - Guidelines for dynamic tests and investigations on bridges and viaducts
- ISO 16587:2004 Mechanical vibration and shock - Performance parameters for condition monitoring of structures
- ISO 14044:2006 Environmental management - Life cycle assessment -- Requirements and guidelines
- ISO 13822, ISO 13824
- EN 15331:2001 Criteria for Design, Management and Control of Maintenance Services for Buildings
- ISIS Canada:2001 Guidelines for structural health monitoring (Design manual, no. 2.)
- GOST R 53778:2010 Buildings and Constructions Rules of Inspection and Monitoring of the Technical Condition
- SAMCO Final Report: F08a – Guideline for the Assessment of Existing Structures and F08b – Guideline for Structural Health Monitoring; www.samco.org
- RVS 13.03.01. Monitoring von Brücken und anderen Ingenieurbauwerken. Wien: FSV; 2012
- UNI/TR 11634:2016. Linee guida per il monitoraggio strutturale

Normative references

- ISO 2394 recognises monitoring as a safety measure
- JCSS criteria for existing structures
- VDI 6200. Standsicherheit von Bauwerken - Regelmäßige Überprüfung. 2010

Table 2. Inspection intervals proposed in [15]

	Surveillance	**Inspection**	**Thorough Investigation**
CC1	3 - 5 years	based on demand	based on demand
CC2	2 - 3 years	4 - 5 years	12 - 15 years
CC3	1 - 2 years	2 - 3 years	6 - 9 years

Definitions

- Monitoring, inspection, maintenance, risk, reliability, updating, measurement uncertainty, failure consequences, … to be prepared once a complete draft is ready

Basic input parameters

- General (different aspects)
- Type of structure and system (network) consequence class
- Stakeholder (public, private)
- Context (new structure, existing structure, obsolete structure)
- Socio-economical and political preference
- Constraints (budget, failure consequences including life safety, obsolescence and functionality, performance)
- Relations of measured parameters to performance levels (member or system level)

Objectives of standard

1. guidance related to the process:
   - selection of critical sections or members, SHM method
   - data collection, reduction, evaluation
   - choice of a structural model, calibration or updating
   - identification of damage
   - decisions related to safety measures, thresholds for observed variables (warnings, short-term exceedances)
2. criteria/requirements or choice of SHM dependent on:
   - consequence class
   - environmental conditions, static and dynamic tests
   - complexity of the structural system
   - measurement uncertainty vs. cost of SHM
   - requirements on quality of data (new structures vs. those at the end of service life, quality of prior information)
   - character of observed quantity (different frequency for snow and wind actions, deterioration rate, required remaining working life)

Objectives of standard

3. VoI-based SHM design (preliminary and detailed)

- Component/ system probabilistic reliability and sensitivity analysis; probabilistic updating
- Identification of possible monitoring strategies, estimates of acquisition and running costs and measurement uncertainty quantification
- Specification of threshold values for observed variables by cost-benefit analysis (costs of safety measures, failure consequences)
- Selection of monitoring strategy based on total cost optimisation; detailed information on time-variant process may be needed
  - methodology for statistical, reliability and risk analysis, updating, sensitivity analysis
  - guidance for groups of similar members or structures
  - large surfaces
  - proof loading?

Objectives of standard

4. Integration of SHM

- Data evaluation
- Updating procedures
- Structural performance evaluation
- Decision analysis
- Selection of inspection/maintenance or repair policy

Classification: Types of monitoring

- resistances, loads, structural response
- proactive and reactive monitoring
- spot, periodic and continuous
- section, member or structural level
- quantitative and qualitative measurements
- quality of measurements

Collection of asset information

- drawings
- Design documents
- Inspection, maintenance, repair records
- Environmental conditions
- Economical conditions (area, etc)
- Site visit specific data
- Identification of performance parameters

Configuration of the monitoring system

- General
- Structural analysis and identification of specific objectives (parameters i.e. mechanical, chemical etc..)
- Number and location of measurement locations (section, member, structural)
- Frequency of data selection
- Data treatment procedure (pretreatment, accuracy, screening)
- Measurement accuracy requirements (quality of measurements)
- Hardware and software specification
- Installation procedure
- Verification (test phase)

Monitored data analysis

- General
- Filtering (integrity of signals)
- Screening of data
- Combination of data (for example with meteorological stations, similar structures)
- Use of analytical, numerical, statistic and heuristic approaches
- Uncertainty analysis
- Relations of measured parameters to performance levels (member or system level)

Structural Health (Performance) Analysis Procedures

- General
- Calibration of acquired data
- Structural representation
- Updating of models (mechanical, statistical)
- Screening of data
- Combination of data (example with metereological stations, similar structures)
- Uncertainty analysis
- Relations of measured parameters to performance levels (member or system level)

Damage identification criteria

- General
- Identification of possible damage causes/scenarios
- Definition of associated performance indicators
- Combination of indicators
- Definition of threshold values
- Warning levels (various steps of possible intervention)

Decision analysis procedure

- General (integration of SHM in decisions such as maintenance plan)
- Compliance with standards
- Cost - benefit analysis
- Sensitivity analysis addressing uncertainties
- Presentation of alternative solutions
- Decision making recommendations

Examples of application

- impact on other standards: EN 1990: A2, guidance for existing structures, EN 1997, ISO 13822 and 13823
- high failure consequences structures: stadiums, congress halls, important bridges, structures in the energy power industry
- slightly under-designed structures (using old codes)
- novel structures (materials, systems)
- heritage structures
- considerable deteriorated infrastructure

=> Win-win situation for COST1402 - JCSS