IM-SAFE WG1 Case Studies

Introduction

This is a form for case study collection and review within IM-SAFE WG 1.2. It follows the internal working document *Guide to Data Acquisition*.

Before submitting a form, please make sure the object is not already submitted by someone else by reviewing this list. Your contribution will be added automatically to the list when you submit the form.

The form consists of the following sections:
Section A - Description of the object
Section B - Description of the analysis
Section C - Description of the state of the object
Section D - References and pictures

If there is no suitable option, select *other* and specify. If the question is not applicable or you don't have the information, select *NA*.

At the end of each section A, B and C you are asked to write a text summarizing and extending the information given in that section. This is the text that will comprise the one-pager in the final deliverable. Please make sure the text is self-contained.

If you want to modify your answers you can navigate between the pages without loosing any information. When you have submitted the form, you will recieve a link by email that allows you to edit or delete your submission.
To submit several case studies, reuse the link you used to access this form.

If you have questions, please contact frida.liljefors@ntnu.no

Respondent's information

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Section A - Description of the object

In section A the following information will be extracted:

- Basic information
- Structure type
- Network type
- Material
- Summary

Basic information

Name

Name of the object, e.g. *Söderström bridge*

Constitution of 1812 Bridge

Country

Give the name of the country in English.

Spain

Country code

Two-letter country code according to ISO 3166.

ES

Location

(City, area)

Cádiz

Coordinates for the object

given in decimal degrees (DD), WGS84

E.g. coordinates for Trondheim: 63.4304900°, 10.3950600° (lat, long)

Latitude

E.g. 63.4304900 for Trondheim

36,523423

Longitude

E.g. 10.3950600 for Trondheim

-6,262603

Year of construction

2015

Structure Type

Type of structure

Bridge

Network type

Type of traffic network

Specify the main useage of the structure

Road

Material information

Material

Select all structural materials that are relevant for the assessment.
Further options will be given when selecting concrete or timber.
For composite structures, select *composite* and the comprised *materials.* E.g. for a concrete steel composite structure, select *concrete, steel, composite*.

Concrete

Steel

Composite

Type of concrete
For concrete, select the type(s) of concrete.

Reinforced

Type of composite
For composite material, select the type(s).

Not answered

Summary section A

Summary A
Write approx. 700 characters text describing the structure. The text should contain the main information of this section A, and provide further details.

The Constitution of 1812 Bridge is a cable-stayed bridge, linking Cádiz with Puerto Real over the Mediterranean sea.

The main span, 540 m, is the record in Spain and the third largest in Europe among cable-stayed.

The two pylons are 185 m high. The vertical clearance is 69 m, that is the second height of navigation channel in the world, after the Verrazano-Narrows Bridge, in New York. Moreover, the bridge includes a 150 m removable span over the bay that means no limit to the maritime navigation if necessary.

The total length of the bridge is 3.092 m (1.440 m over the sea).

The deck, 34 m width, is distributed between the motorway with two lanes in each direction and another carriageway of two lanes reserved for metropolitan public transport.

Section B - Description of the analysis

In section B the following information will be extracted:

Case type

Verification type and scale

Initiation of the assessment

Structural analysis

Information updating

Intervention

Summary

Case type
Specify whether the main driver of the case study is to produce original research content (research) or to support real, practical decisions (consulting).

Consulting

Initiation of assessment
NB. Assessment can include monitoring.

Anticipated change of design working life

Other

Other initiation of assessment
If other, please specify.

Control during contruction and surveillance during service life

Predominant verification type

Choose from:

Risk-based (due account of consequences and event probabilities, explicit representation of uncertainties)

Reliability based (due account of event probabilities and assessment of reliability criteria, explicit representation of uncertainties)

Design value criteria (structural capacity and demand expressed as design values, implicit representation of uncertainties)

Qualitative criteria (e.g. damage classes, consequence classes, ranking based on indicators, etc.)

Engineering judgement

Other

Other

Other verification type

If other, please specify.

Design Value Criteria & Engineering judgement

Predominant verification scale

What is the spatial boundary of the analysis?

Other

Other verification scale

If other, please specify.

Structural System wind effects on traffic

Structural analysis

Structural analysis/Type of limit state

Serviceability limit state

Proxy limit state (e.g. corrosion initiation)

Information updating

The structural performance is described by a limit state (LSF)/design equations (DE) that contains variables representing relevant properties related to resistance, stiffness, dimensions, loads, etc. The information from inspection or monitoring is somehow utilized in the LSF/DE, but how?
Direct information means that a relevant property contained in the LSF/DE is directly measured. If only an indicator for the relevant property is measured, it is referred to as **indirect** information. Then a model is necessary to connect the information to the relevant property (in COST TU1406 this is called "Performance Model").
Bayesian methods combine prior information and new data from inspection/monitoring into posterior information. **Non-bayesian** methods refers to classical statistical methods where only the new data is evaluated.

Direct bayesian

Direct non-bayesian

Physical intervention

Here, all physical interventions that have been considered as possible options should be selected.

Other

Other physical intervention

If other, please specify.

Physical intervetion is not foreseen. Just if any anomaly is detected during working life it will be considered

Operational intervention

Here, all operational interventions that have been considered as possible options should be selected.

Maintenance

Monitoring

Summary B

Write approx. 700 characters text describing the analysis. The text should contain the main information of this section B (structural, probabilistic and decision analysis), and provide further details.

The bridge is monitored, since the construction, with 424 sensors, most of them static but some dynamic.

The static system consists of 154 strain gages embedded into the fresh concrete, 127 strain gages on the steel surface, 55 thermocouples, 17 tiltmeters, 40 load cells in the stay cables and 4 sensors on bearings at the piers. Every five minutes, all these parameters are recorded.

19 accelerometres, 4 anemometers and another 4 weather vanes integrate the dynamic monitoring system, which is triggered automatically when certain threshold values are exceeded.

To assess the structural behavior, the measurements are compared with the theoretical values and its evolution is look out. Moreover, the wind measurements are used to regulate the traffic on the bridge.

Section C - Description of the state of the object

In section C the following information will be extracted:

Deterioration process

Damage

Investigation

Summary

Deterioration process

Specify all relevant deterioration processes.

Concrete deterioration process

NA

Steel deterioration process

NA

Damage

Specify all relevant damage.

General damage

NA

Concrete damage

NA

Steel damage

NA

Investigation

Prior information

Select all prior information that was (available, used, specified...?)

Design standard

Drawings

Design documents

Previous inspections

Monitoring

Numerical model

Performance indicator

Select all physical parameters measured/monitored (performance indicators).

Deformation

Displacement

Dynamic response (acceleration, damping, frequencies)

Other actions (wind, temperature, earthquake...)

Inspection/monitoring method

Select all inspection/measuring/monitoring methods used in the case study.

Other

Other inspection/monitoring method

If other method, please specify.

Electronic sensors with static/dynamic data acquisition system, real-time transmission system and cloud web platform.

Summary C

Write approx. 700 characters text describing the state of the structure. The text should contain the main information of this section C (deterioration process, damage, inspection/monitoring method), and provide further details.

In order to have a first reference of the stay cable forces before the bridge was open to traffic in 2015, a dynamic auscultation of them was performed. The forces were obtained through the vibrating string analogy (see figure below). As planned, this auscultation has been repeated in 2020, five years later, finding minor differences in the forces.

The monitoring system inherited from the construction phase has been kept almost entirely for the monitoring of the bridge in service. This system allows controlling both the actions (thermal and wind) and the structural response (gradients, forces, accelerations, etc.). In addition, it is useful to maintain a service of automatic alerts based on 10-minute average wind speeds.

Since the bridge was open to traffic, a large amount of data has been recorded that is periodically analyzed from different points of view (statistical-descriptive, correlational and spectral) to verify through this experimental analysis the correct structural behavior.

Section D - References and pictures

All cases studies are documented in publicly available documents.
If the document is open access you can upload it as a pdf file.

Documents
Give 1-3 references for the case study.
For each document, write the reference in Harvard referencing style. If open access, upload the document.

Number of references

How many documents do you want to make reference to?

Not answered

Pictures
Upload in total 1-5 pictures that illustrate (if available):

Section A. Description of the structure.

Section B. Analysis.

Section C. State of the structure (deterioration process, damage, inspection/monitoring method.)

For each picture, confirm that we have the right to publish it, give reference when applicable and write a caption.

Number of pictures

How many pictures do you want to upload?

5

Image file 1

Name the file Name_1.jpg (or any other image format)
e.g. Soderstrom_bridge_1.jpg

SectionA.png

(1412599 bytes)

Picture caption 1

Constitution of 1812 Bridge

Section 1

To which section does the picture belong?

A

Copywrite 1

Do we have the right to publish the picture?

Yes

Image reference 1

Not answered

Image file 2

Name the file Name_2.jpg (or any other image format) *e.g. Soderstrom_bridge_2.jpg*

SectionA_1.png

(290250 bytes)

Picture caption 2

Constitution of 1812 Bridge Scheme

Section 2

To which section does the picture belong?

A

Copywrite 2

Do we have the right to publish the picture?

Yes

Image reference 2

Not answered

Image file 3

Name the file Name_3.jpg (or any other image format)

e.g. Soderstrom_bridge_3.jpg

SectionB.JPG

(24697 bytes)

Picture caption 3

Distribution of sensors

Section 3

To which section does the picture belong?

B

Copywrite 3

Do we have the right to publish the picture?

Yes

Image reference 3

Not answered

Image file 4

Name the file Name_4.jpg (or any other image format)

e.g. Soderstrom_bridge_4.jpg

SectionC_1.JPG

(31896 bytes)

Picture caption 4

Figure 1: Example of auscultation of a stay cable: registered accelerogram (red), zoom of the accelerogram (blue) and frequency spectrum (green). In this stay cable, the measured frequency is 0.8667 Hz, f (0.9091 Hz was the theoretical value). The assessed logarithmic damping was 0.0678

which is equivalent to a critical damping rate of 1.08%.

Figure 2:Concrete deck temperatures at the moment of maximum gradient

Section 4
To which section does the picture belong?

C

Copywrite 4
Do we have the right to publish the picture?

Yes

Image reference 4
Not answered

Image file 5
Name the file Name_5.jpg (or any other image format)
e.g. Soderstrom_bridge_5.jpg

SectionC_2.JPG

(44808 bytes)

Picture caption 5
Figure 1: Wind polar diagram

Figure 2: Envelope of maximum acceleration on pylons

Section 5
To which section does the picture belong?

C

Copywrite 5
Do we have the right to publish the picture?

Yes

Image reference 5
Not answered

Comments for development
Give feedback on the scheme (optional).

Not answered