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*

Centenario 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)

Seville

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

37,348845

Longitude

E.g. 10.3950600 for Trondheim

-5,993136

Year of construction

1991

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

Type of concrete

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

Prestressed

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 Centenario Bridge is a cable-stayed bridge in Seville, Spain. It was built in 1991 and has an average daily traffic of over 100.000 vehicles. It has five spans of 48 m, 102 m, 265 m, 102 m and 48 m. Each pylon is composed of two columns of 6 × 4.5 × 102 m, separated by 26.5 m. It has 88 stay cables of leghts between 25 and 145 m.

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.

Required reliability check (by owner, authorities)
Structural deterioration
Other

Other initiation of assessment

If other, please specify.

Corrosion in the stay cables

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

Engineering judgement

Predominant verification scale

What is the spatial boundary of the analysis?

Damage/deterioration location

Structural analysis

Structural analysis/Type of limit state

Ultimate limit state

Fatigue 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

Physical intervention

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

Repair

Operational intervention

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

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 solution adopted to know the force of the stay cables at any moment is based on a dynamic instrumentation with accelerometers. Total amount of sensors is 120. In addition to other complementary sensors, each of the 88 cables has an accelerometer continuously monitored at a rate of 100 readings per second. A volume of 900 million data is generated daily.

With this amount of data, two parallel processes are carried out in real time:

- Statistical analysis, which provides the minimum, average, maximum and RMS acceleration levels in intervals of 3 seconds (short span) and 10 minutes (long span)

- Spectral analysis, which provides the main vibration frequency of each stay cable (and, immediately, the force) obtained from the application of the FFT (Fast Fourier Transform) together

with a special algorithm developed for this purpose.

Both processes take place at the bridge, automatically and without any human intervention.

The measured values of the cable forces feed the structural model of the bridge, allowing decision making.

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

Damage
Specify all relevant damage.

General damage

NA

Concrete 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).

Displacement

Dynamic response (acceleration, damping, frequencies)

Other

Other performance indicator

If other, please specify.

Concrete, steel and air temperatures

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 2018, a campaign was carried out to assess the structural health of the bridge. Due to the signs of corrosion in the anchors and other deteriorations found, it was decided to proceed with the replacement of the stay cables. However, the time required to develop the replacement project, contract and undertake the replacement (keeping traffic on the bridge) was estimated to be over 3 years. As the bridge is a critical infrastructure and the traffic level very high, the decision was made to install a real-time structural remote monitoring system on the bridge, mainly focused on the 88 cable forces.

The monitoring system has returned the main following findings:

- The cables forces have a daily cycle oscillation due to traffic and an annual cycle due to temperature, both within the expected range. There has been no drift in their value that can be attributable to corrosion

- A phenomenon that had not been observed before on the bridge has been detected: several episodes of very high vibrations (> 2g) caused by the combined wind-rain effect have been recorded.

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?

4

Image file 1
Name the file Name_1.jpg (or any other image format)
e.g. Soderstrom_bridge_1.jpg

SectionA.jpg

(273650 bytes)

Picture caption 1

Centenario 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

SectionB.JPG

(45781 bytes)

Picture caption 2

1- Accelerometer in a stay cable

2- Real-time web presentation of the stay cable forces (Infograms)

3- Real-time web presentation of the stay cable forces (Analog dials)

4- Real-time web presentation of deck displacements

5- Real-time web presentation of other structural parameters

Section 2
To which section does the picture belong?

B

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

SectionC_1.JPG

(28726 bytes)

Picture caption 3

Figure 1: Cable-forced stability: daily and annual cycles

Figure 2: One week daily cycles

Section 3

To which section does the picture belong?

C

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_2.JPG

(29120 bytes)

Picture caption 4

Figure 1: Cable vibrations during a storm

Figure 2: Acceleration of each cable during the storm

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

Comments for development

Give feedback on the scheme (optional).

Not answered