WORK PACKAGE 9: PRACTICAL BRIDGE MANAGEMENT

Task 9.1 Bridge End-User Needs

D.9.1.2 "Identification and Analysis of Case Stories."

May 2004

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Work Package 9.1: Practical Bridge Management.
Identification and Analysis of Case Stories.

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Preface

This report is a deliverable from the Growth Thematic Network "Structural Assessment, Monitoring and Control " (SAMCO), which was initiated in October 2001.

The present report constitutes the deliverable D.9.1.2 *"Identification and Analysis of Case Stories"* under task 9.1 "Bridge end-users needs".

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1 INTRODUCTION

The SAMCO network covers many of the fields of structural assessment, monitoring and control as a part of the bridge management. The network includes a total of 9 workpackages, where WP 9 deals with Practical Bridge Management. The task 9.1 deals with the End-users needs and the present report constitutes one of the deliverables and describes essentially the End-users requirements to monitoring and control of the structures.

The end-users point-of-view and requirements are to a large extent described in the report "End-users practical bridge management requirements" [/SAMCO,2003/], where the criterias for interfacing monitoring and control were also identified.

The scope of this report is to describe how the relevant case stories are identified and analyzed from the end-users point of view. The report will also present which information the case-stories must include in order to satisfy the End-users requirements.

The report will use two of the case stories as examples, which are enclosed in the annex. These examples were chosen from the case stories from WP1 "End User Forum", WP 3 "Codes and Recommendations" or in the SAMCO-database, from which a more extensive number of examples will be available.

2 IDENTIFY AND ANALYSE A CASE-STORY

A case-story must deal with the use of monitoring to provide input, data, verification or other information, relevant to the practical bridge management.

The monitoring considered will essentially be a frequent measurement of certain parameter(s) in preselected position(s). The monitoring systems used used can therefore range from the basic monitoring (as e.g. measuring crack widths, deflections, joints widths) to the more advanced monitoring (as e.g. corrosion rate monitoring or vibration and deflection monitoring) combined with manual data collection or automatic datalogging and data transfer.

The End-user is the person, company, institution or directorate who is responsible for the maintenance, managing and eventually repairing or replacing the structure.

The End-user may have an academic interest in the behavior of the structure or the material, however, the End-user will usually not have the freedom to fund any activities based on academic interests.

The End-user is forced to choose the most cost-efficient strategy to overcome the problem and this strategy should preferably be based on known technology.

The End-user will therefore need to see the following information in any case-story:

1. End-users benefits from monitoring.
2. Basic information about the structure.
3. Clear description of the problem.
4. The alternative, traditional strategy.
5. Scope of the monitoring
6. Identification of the applied sensors and equipment.
7. Evaluation of the monitoring.

Each of these points needs to be identified and analyzed in a proper case-story, but the case-story must no be too long (preferably 2-4 pages).

Any case-story, which fails to do this, will be judged to have only academic interest (and can therefore not be used in practice).

Each of the points listed above will be described in more detail in the following, along with the information or text extracted from the example shown in italic.

2.1 End-users benefits from monitoring.

The benefits from the monitoring must be clearly identified, especially from the End-users point-of-view.

These benefits will usually be economical benefits and may include the traffic delays, were a reduced traffic delay may reduce the traffic delay costs substantially. The reduction in traffic delay costs will always beneficial for the consumers (who use the bridges), but may also lead to increased income for the owner or operator of toll roads.

> *Example: "The use of monitoring of a critical part of the highway bridge over a busy railway have lead to a cost reduction of the inspection. .... The monitoring will verify the safety of the structure until a planned replacement can be performed in 2010-2012 where an additional lane is required."*

2.2 Basic information about the structure.

The basic information about the bridge must be presented in 10-20 lines, covering type of structure, age, spanwidth etc. as well as its precise location and history.

An overview photograph and a photograph of the problem must be included.

The owner or operators must be clearly identified with address, email etc. must also be available, either in the case-story itself or in the SAMCO database.

> *Example: "The Skovdiget bridge was constructed between 1965 and 1967 and consists of two parallel bridges, each with 12 spans and a total length of 220 m. The bridges are post-tensioned concrete box-girder bridges with serious deterioration of the concrete, reinforcement and cables......."*

2.3 Clear description of the problem.

The problem must be described briefly, e.g. that the reinforcement has corroded to a severe extend in the identified, critical areas or that the structure is being exposed to traffic load well above the original design load.

> *Example: "The bridge deck and the water proofing over the deck are both defective and allow the water and the de-icing salt to leak into the structure. .... The probalistic assessments of the load-carrying capacity have shown that the longest span in the bridge (over the railway) is in a critical condition."*

2.4 The alternative, traditional strategy.

The traditional strategy must be described. It must also be described why this alternative strategy was not used.

> *Example: "The traditional approach would be to carry out a more frequent and intense NDT-mapping of the corrosion risks and rates. This would require frequent blocking of the railway for each inspection and was abandoned, since it would be too expensive."*

2.5 Scope of the monitoring

The scope and the expected outcome of the monitoring must be clearly identified. This could e.g. be to verify the simulated behavior of the structure or to log the variations in the corrosion rates or similar.

> *Example: "The scope of the monitoring is to log the development of the corrosion rates in selected, representative positions in the cell in order to provide an assessment of the variations of the corrosion rates mapped by the NDT-mapping and thus to predict the loss of reinforcement."*

2.6 Identification of the applied sensors and equipment.

The sensors, equipment or programs used in the project must be identified, but not in great details.

The detailed identification should be listed in the SAMCO database. The listing in the SAMCO database should include not just the type, but also the actual trade name of the sensors or equipments and the supplier's address, so other projects can apply the same. This must be checked for any case story.

> *Example: "A test version of the sensor (Corro-Eye) for monitoring corrosion risk and standard sensors (HUM) for monitoring humidity were used in combination with batteri-driven datalogger and the portable NDT-equipment (GalvaPulse)"*

2.7 Evaluation of the monitoring.

It must be described how good the monitoring actually worked and how the results from the monitoring were verified.

Example: "The use of surface mounted sensors (HUM and CorroRisk) is fast and easy and very suitable for installations in difficult positions or with critical and unflexible time schedules. .... The use of battery-driven dataloggers reduce the costs significantly and makes the installation easier, as the cables are shorter, the power supply not required and the dataloggers are more weather resistant than the normal datalogger."

2.8 Length of the case-story.

The length of the case story must not exceed 7 pages and should preferably be kept shorter.

A good case story will provide references to where additional information can be obtained.

3 TYPICAL END-USER QUESTIONS

The case-stories and the analyses should not only answer the scientific and technical questions, but should also provide examples on projects, where the monitoring actually worked and was worth the investment.

The analysis of the case-stories should check if the following typical End-user questions have been answered:

1. What are the benefits from using this monitoring system or equipment on that structure?
2. How can the system or equipment reduce the costs ?
3. Has is been documented that these sensors/this system/this equipment works reliable – both on a short term and a long term basis ?
4. Is there a reference list for these sensors/equipment etc. and of your experience with this approach ?
5. Where do the sensors/system not work ? (there will always be some situations, where they do not work or are not worth the price)

Failure to answer these questions will lead to rejection of the monitoring project.

4 REFERENCES

/SAMCO,2003/ "Deliverable D.9.1.1: End-users practical bridge management requirements", SAMCO, July 2003, downloaded from http://www.samco.org.

Annex A.

Copy of case stories used in the examples.

The following case-stories are used as examples in the report:

1. Skovdiget bridge over railway – Denmark
2. Svinesund bridge– Norway/Sweden
3. Putlitz bridge – Germany

The first case is written by the partners in WP9 and focuses therefore mainly on the practical bridge management seen from the end-users point of view, the second is an owners report of the actions taken to verify the design and the casting planning of a new bridge, whereas the third case-story is written for WP3 and therefore focuses on the recommendation for the monitoring assessment and structural control from the technical point-of-view. This leads to major differences in the setup of the case-stories and in the order, in which the information is presented.

The case stories used are listed in the following, but can also be found on the SAMCO projectweb at http://www.samco.org/. The case stories are always shown in the latest version on the SAMCO site, whereas the versions used in this report may not have been fully updated.

The precise addresses of owners, suppliers, institutes and other referred to in the case-stories are listed on the projectweb.

The details of the monitoring systems, equipments and sensors used are also listed on the projectweb.

Annex A.1. Skovdiget bridge over railway - Denmark

Owner of structure: Danish Road Directorate

Reported by: Per Goltermann, Rambøll

A.1.1 End-users benefits from monitoring.

The use of monitoring of a critical part of the highway bridge over a busy railway have lead to a cost reduction of the inspection. The inspection is normally carried out at night from 1.00 AM to 4.30 AM, where there is no passenger train service, but this still requires assistance and personnel from the Danish rail Service and disrupt the transport of goods.

A reliability-based management plan was established in 1999. An extensive special inspection was performed and detailed analyses of the current and future safety resulted in a remaining lifetime of 12-14 years before replacement or strengthening was required. This means that the required safety for the bridge can be secured until at least 2010-2012.

However, the future safety depends deterioration rate, which have to be monitored. Though additional safety has been included in the prediction of future safety, it is essential that the deterioration rate is not significantly higher than the deterioration rate predicted in 1999.

It is there required that the deterioration rate must be followed closely - either by frequent NDT-mapping and breakups - or by monitoring.

The monitoring will verify the safety of the structure until a planned replacement can be performed in 2010-2012 where an additional lane is required by the Danish Road Directorate.

A.1.2 Basic information about the structure.

The Skovdiget bridge was constructed between 1965 and 1967 and consists of two parallel bridges, each with 12 spans and a total length of 220 m. The bridges are post-tensioned concrete box-girder bridges with serious deterioration of the concrete, reinforcement and cables.

In the late 70'ies and early 80'ies, substantial damage was registered on both bridges. For the eastern bridge, major repairs including application of new waterproofing, and partial concrete replacement and repair of prestressing, bearings and expansion joints in the superstructure were initiated in 1978.

These repairs proved so costly that it was decided to leave the western bridge unrepaired and instead monitor the development of deterioration closely to determine when the safety is no longer acceptable based on frequent inspections and test loadings. Since the 80'ies, the eastern bridge has been inspected according to the normal guidelines for bridge inspections whereas the western bridge has been monitored closely with visual inspections four times a year. In addition, the movement of selected points on selected structural parts has been measured once a year for the western bridge. The last general inspection was carried out in 2003 for the eastern bridge and the last special inspection was carried out in 1999 for the western bridge. Test loadings of the western bridge were carried out in 1984, 1988 and 1993.

A probality-based evaluation of the load-carrying capacity of the western bridge has been carried out in 1999, leading to a probability-based inspection planning. This has also identified the span over the railway as being the critical span and requested a close monitoring of the deterioration rate in this span.

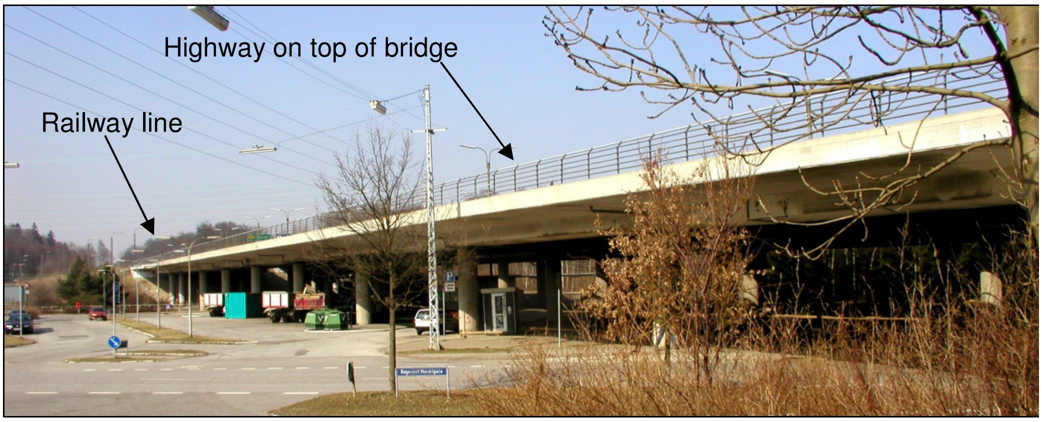


Fig. A.1.1. View of the western bridge

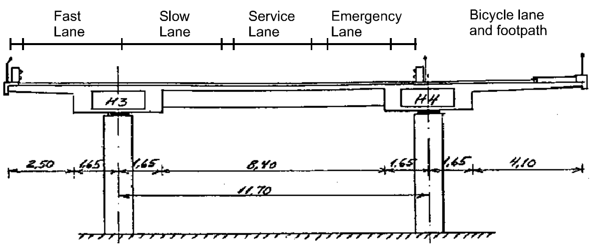


Fig. A.1.2. Cross-section of the western bridge.

The bridge carries a highway with app. 60 000 persons passing daily over an electrically powered railway with app. 10 000 daily passengers. The bridge span over the railway is therefore a keypoint in the transport infrastructure and could affect a substantial number of passengers daily.

A.1.3 Description of the problem.

The bridge deck and the water proofing over the deck are both defective and allow the water and the de-icing salt to leak into the structure. This leads to frost-damages and to a high corrosion rate in some positions in the structure. The concrete contains in addition to this an amount of alkali-reactive aggregates, which leads to substantial cracking and increased water and chloride ingress. The workmanship during the construction has been poor and the cover varies therefore from 3 to 100 mm in the structure.

The probalistic assessments of the load-carrying capacity have shown that the long-est span in the bridge (over the railway) is in a critical condition. It is therefore neces-sary to have an improved registration of the deterioration rates and degrees, in order to ensure the safety of the bridge and to keep the bridge in function until 2010-2012, where the scheduled enlargement may require strengthening or replacement of parts of the bridge.

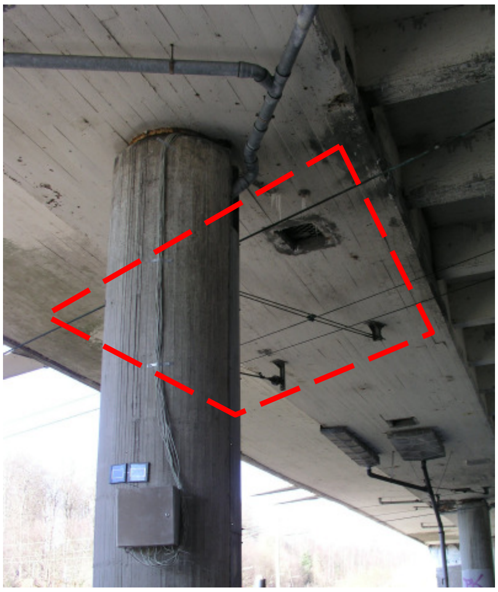


Fig. A.1.3. View of the main girder over the railway.

The position of the critical cell is marked with the dashed line.

Notice the rain water basins under the girder; these collect the water, running through the concrete girder, the icicles and the cables from the monitored cell, which leads down to the steel box with the data loggers and the solar cells.

Fig. A.1.4. View of the interior of the cell over the railway facing north (Left: western side, right: eastern side of cell).

A.1.4 The optimal, traditional strategy.

The traditional monitoring of deflections cannot be used as an indication of the deterioration rates as the structure is prestressed and as the bridge's load-carrying capacity is limited by the shear force capacity. The corrosion rates will vary substantially due to variations in temperature and moisture and leads to uncertainty of the loss of shear force capacity, as this depends significantly on the amount and condition of the shear reinforcement.

The traditional approach would therefore be to carry out a more frequent and intense NDT-mapping of the corrosion risks and rates. This would require frequent blocking of the railway for each inspection and was abandoned, since it would be too expensive.

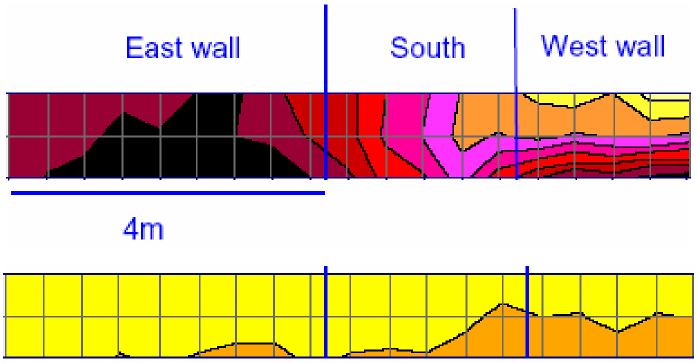


Fig. A.1.5. Mapped corrosion potential (top) and rates (bottom) in cell walls above the railway.

A.1.5 Scope of the monitoring

The scope of the monitoring is to log the development of the corrosion rates in selected, representative positions in the cell in order to provide an assessment of the variations of the corrosion rates mapped by the NDT-mapping and thus to predict the loss of reinforcement The logged corrosion rates will identify the seasonal variations and thus identify the variations by the mapped corrosion rates.

The corrosion rates provide information about the loss of reinforcement, which contributes to the shear capacity in the main girders.

The temperature and the moisture contents influences the corrosion rates significantly and therefore logged in order to support the logged corrosion rates.

A.1.6 Identification of the applied sensors and equipment.

The reinforcement in the cell is already corroding and it was therefore not required to monitor the corrosion risk in different depths, but only to monitor the corrosion rates in the depth of the reinforcement.

The easy and speed of installation was a major requirement, as the installation of the sensors had to be carried out under difficult conditions and with a very short time schedule (3 hours). The precise monitoring positions, the positions of the reinforcement the installation of the sensors and their cables had to be carried out during this 3 hour period.

It was therefore decided to use a test version of a new type of sensor “CorroEye”, which could be mounted on the surface, instead of more traditional sensors (as the CorroRisk-sensors combined with a Combisensor).

Fig. A.1.6. Installation of sensors in cell over parking lot
(the third person is behind the camera).

Fig. A.1.7. The cell over the railway after the sensor installation.

The moisture is monitored with HUM-sensors, as their signals would have a minimum of temperature dependence and as they are easy and fast to install. Standard temperature sensors were installed.

The cables are mounted on the walls in the cell and lead through a drilled hole at the bottom, down to a stainless steel box 2-3 m below the main girder. The data collection of the moisture and temperature is carried out by battery-driven dataloggers and are powered by a battery, which is loaded by solar cells. The corrosion rate sensors are logged manually, using the same NDT-equipment (GalvaPulse) as were used for the NDT-mapping of the corrosion rates.

This minimizes the length of the cables and reduces the electrical noise (important as the railway is 1-2 m from the column). The cost of the monitoring system (cables, loggers, power, communication) is reduced substantially by this used of solar cells and batteries.

It was decided to install monitoring in the critical cell and also in a reference cell, as the monitoring system used a test version of the sensor for monitoring corrosion rates. The reference cell has the same condition and deterioration as the critical cell, but is placed over the parking lot, where the access is easy and will not require any traffic regulation.

The sensors were installed in the reference cell, as this allowed a preliminary 3 months testing of the monitoring system prior to the installation in the critical cell.The reference cell and the sensors in this cell are also available for additional tests, sampling or comparisons with the NDT-mappings.

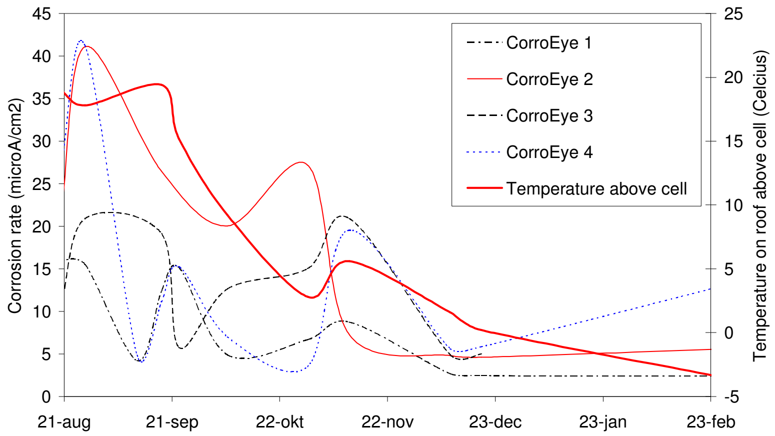


Fig. A.1.7. Corrosion rates logged in the reference cell.

A.1.7 Evaluation of the monitoring.

The use of surface mounted sensors (HUM and CorroRisk) is fast and easy and very suitable for installations in difficult positions or with critical and unflexible time schedules.

In cases, where the installation conditions are easier and the time schedule more flexible, it would be preferred to install CorroRisk sensors and a Combisensor in the concrete, as this would provide a more robust installation and still be able to monitor the corrosion rate.

The results of the two sensors correspond to the NDT-mapping, but provide a good registration of the variation with time and temperature. The HUM-sensor require calibration on this concrete in order to provide a precise translation of the mapped signals into moisture content in percentage by weight of concrete.

The use of battery-driven dataloggers will reduce the costs significantly and also make the installation easier, as the cables are shorter, the power supply not required and the dataloggers are more weather resistant than the normal datalogger. The battery-driven dataloggers should preferably be powered by solar cells as this increases the length of the time, where the dataloggers can function without maintenance.

A.1.8. References

"Bro M13 1021, UF af Skovdiget, Vestbro A) Løbende overvågning ifølge Driftsplan B) Opfølgning/kontrol af driftsplan", F. Jensen and P. Goltermann, Rambøll, May 2004 for the Danish Road Directorate.

"The owners perspective in probability-based bridge management", J. Bjerrum, F. Jensen and I. Enevoldsen, Proc. IABMAS02, Barcelona, Spain, July 2002.

"Safety-based Bridge Maintenance Management", I Enevoldsen and F. Jensen in International conference on Safety, Risk and Reliability - Trends in Engineering, 2001, Malta.

"Probalistic-based Bridge Management Implemented at Skovdiget West Bridge", F. Jensen, A. Knudsen and I. Enevoldsen in Fourth International Conference on Bridge Management, 16-19 April, 2000, University of Surrey, UK.

"Load Testing as an Assessment Method", A. J. Mondrup, J. O. Frederiksen and H. H. Christensen, IABSE symposium "Durability of Structures", 1989.

Annex A.2. New Svinesund bridge – Norway and Sweden

Owner of structure: NPRA

Reported by: Ian Markey, Norwegian Public Road Authorities

A.2.1 End-users needs for monitoring

The New Svinesund Bridge that is under construction between Norway and Sweden is an elegant but structurally complicated bridge as it combines a very slender construction with a special structural form. The bridge will be opened in 2005 and will be the world's largest single-arched bridge.

The world's largest bridge with a single arch is being built across the Ide Fjord at Svinesund. The design of the new road bridge is a result of an international design contest. The bridge will form a part of the European highway, E6, which is the main route for all road traffic between Gothenburg and Oslo and currently has an Average Annual Daily Traffic (AADT) of 8,000 vehicles, whereof 15 per cent are heavy goods vehicles.

Fig. A.2.1. An artist's impression of the New Svinesund Bridge joining Sweden and Norway. The main span is a single arch with a bridge deck on either side of the arch.

Due to the uniqueness of design and the importance of the bridge and as monitoring is an effective way to understand the real behaviour of the bridge, a monitoring project was initiated. The instrumentation of the bridge has been developed following the principles laid out in the handbook (Statens vegvesen, 1999) and in accordance with the method described therein as Instrumentation, Documentation and Verification, abbreviated IDV.

The monitoring program was required and designed to monitor critical construction stages as well as to acquire data needed for design verification studies and long-term performance assessment.

The case-description has been based on the published information in a paper (Karoumi and Markey, 2004), just as additional information can be found at the website http://www.byv.kth.se/svinesund and in the report (James, G., and Karoumi, R., 2003).

A2.2. Basic information about the bridge

The New Svinesund Bridge, Figure 1, has a total length of 704 m, and is to be built in only 36 months. The main span of the bridge between abutments is approximately 247 m and consists of a single ordinary reinforced concrete arch which carries a multiple-cell steel box-girder: double-cell on either side of the arch, which carries two twin double cell steel box-girder bridge deck, one double cell on either side of the arch. The concrete arch has a rectangular hollow cross-section that tapers in two directions reducing the section of the arch from the abutment to the crown in both width and height. The superstructure is joined to the arch at approximately half its height. The steel bridge deck is monolithically connected at the junction to the arch and assists in providing lateral stability to the arch.

Fig. A2.2. Photograph of the arch under construction.

The construction of the arch uses a climbing formwork and is done in parallel on the Norwegian and Swedish sides. During the construction phase, the arch is supported by cables, which are anchored to temporary auxiliary back-stayed towers, see Figure 2. The towers will be dismantled after completion of the arch. More information on the bridge structure and the construction process can be found in (Brürger, O., 2003).

A2.3. Scope of the monitoring

The primary objective of the monitoring programme is to check that the bridge is built as designed and to learn more about the as-built structure. This will be achieved by comparing the measured structural behaviour of the bridge with that predicted by theory.

A2.4. DIdentification of the sensors and system

The data acquisition system consists of two separate data sub-control units built up of basic MGC Digital Frontend modules from HBM (Hottinger Baldwin Messtechnik). The units are located at the base of the arch on respectively the Norwegian and Swedish side. The sub-control system on the Swedish side contains the central rack-mounted industrial computer and is connected with ISDN telephone link for data transmittal to the computer facilities at KTH for further analysis and presentation of data. The logged data on the Norwegian side is transmitted to the central computer on the Swedish side via a radio Ethernet link.

The selected logging procedure provides sampling of all sensors continuously at 50 Hz with the exception of the temperature sensors, which have a sampling of once per 20 seconds or 1/20 Hz. At the end of each 10 minutes sampling period, statistical data such as mean, maximum, minimum and standard deviation are calculated for each sensor and stored in a statistical data file having a file name that identifies the date and time period when the data was recorded. Raw data, taken during a 10 minutes period, is stored in a buffer if the “trigger” value for calculated standard deviation for acceleration is exceeded.

The instrumentation of the arch is composed of:

- 16 vibrating-wire strain gauges, 4 at arch base and 4 just below the bridge deck, Norwegian and Swedish side
- 8 resistance strain gauges, 2 at arch base, 2 in a segment just below bridge deck, and 4 at the crown
- 4 linear servo accelerometers, installed pair-wise and are moved to new arch segments as construction of the arch progresses. When the arch is completed, 2 accelerometers will be moved to the arch mid point and 2 to the arch’s Swedish quarter point
- 28 temperature gauges, at the same sections as the strain gauges
- 1 outside air temperature gauge, and 1 3-directional ultrasonic anemometer for measuring wind speed and direction at deck level close to the first support on the Swedish side.

All the 24 strain gauges and 28 temperature gauges are embedded in the concrete section. In some sections both vibrating-wire and resistance strain gauges are installed side by side for instrument verification and quality control purposes.

In addition to the above listed sensors, the suspended part of the bridge deck will be instrumented with 6 linear servo accelerometers: 3 at mid point and 3 at quarter point. At each section, 2 of the accelerometers will monitor vertical deck acceleration and 1 for horizontal deck acceleration. Furthermore, it is also intended to monitor the forces in the first hangers as well as the transverse movement of the bridge deck at the first bridge pier supports on both sides of the arch.

A2.5. Typical results of field measurements

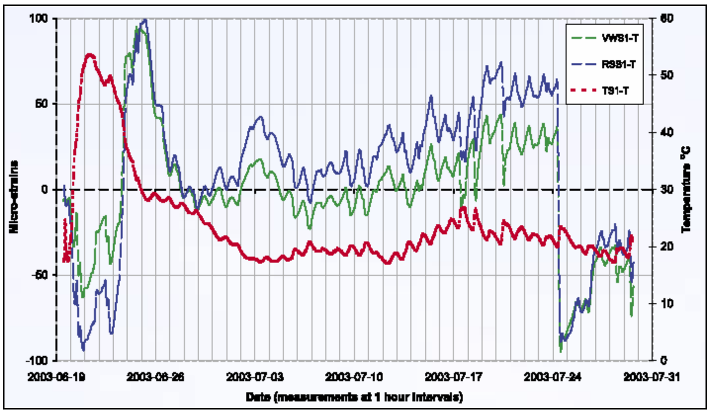


Fig. A2.3. Early age temperature-strain behaviour. The gauges are installed at the roof of an arch segment close to the arch base on the Swedish side. (VW) vibrating wire gauge, (RS) resistance strain gauge, (T) temperature gauge.

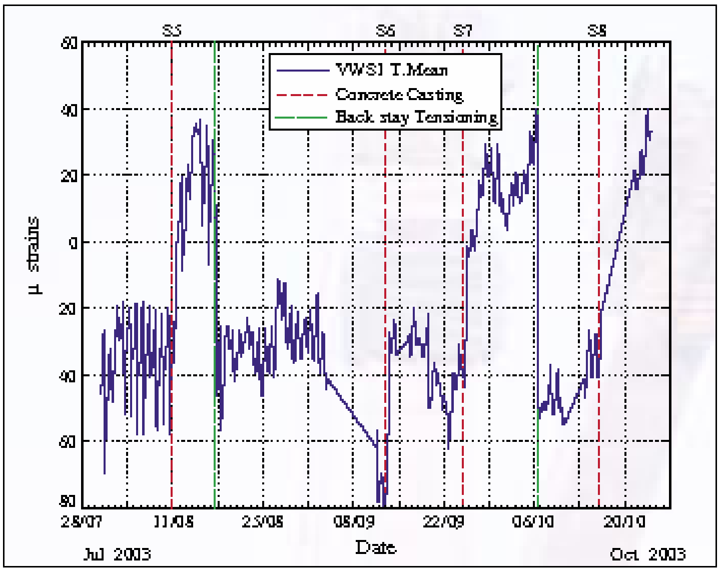


Fig. A2.4. The above figure shows how the work on site is mirrored by the measured strains. The casting dates for segments are represented by dotted red lines. Segment numbers are shown at the top of the figure. The dates when tensioning of the temporary support cables occurred are shown in green.

Figure 3 shows the complex temperature-strain behaviour of the hardening concrete from casting until an age of five weeks. The strain and temperature gauges are positioned in the roof of a segment close to the arch base on the Swedish side. At the start of the monitoring period the gauges are mounted alongside the main reinforcement with no concrete present. The concrete is then poured into the formwork and hardening takes place causing an increase in temperature to approximately 55 °C. Another point to be observed from Figure 3 is that on the 24th July 2003 a temporary stay-cable support was removed by the contractor. This can be seen as a sudden drop in the strains at that time.

The events on-site obviously play an important role in interpreting the results from the strain gauges. Figure 4 shows the strains measured at the roof of a segment close to the arch base on the Swedish side. The casting of each subsequent segment causes an elongation of the reinforcement bars. This is to be expected as the arch behaves as a cantilever and the extra weight at the end of the structure caused by the newly cast arch segments will cause tension in the top of the section at the base of the arch. In a similar manner, tensioning the temporary support cables, represented by the green dot-dashed lines, causes a contraction of the same reinforcement bars.

A2.6. Evaluation of the monitoring

On the whole, the sensors and data acquisition equipment appear to be operating satisfactorily and provide reasonable results. The stored statistical data will be used to identify raw data files of interest. Verification and analysis of these raw data files will be presented in future reports.

A2.7. References

Olaf Brürger, (2003). ”Nya Svinesundsbron får slank båge i betong”. Betong, Vol. 1, (In Swedish).

James, G., and Karoumi, R. (2003). “Monitoring of the New Svinesund Bridge, Report1: Instrumentation of the arch and preliminary results from the construction phase”, TRITA-BKN. Rapport 74, Brobyggnad 2003, ISSN 1103-4289, ISRN KTH/BKN/R--74--SE, Royal Institute of Technology (KTH), Stockholm.

Statens vegvesen, (1999). “Metodikk for instrumentering, dokumentasjon og verifikasjon av konstruktioner”. Handbook Nr. 212 in Vegvesen’s handbook series, (In Norwegian).

Karoumi, R. and Markey, I.: “Instrumentation for monitoring the new Svinesund bridge”, Nordic Road & Transport Research No.1, 2004.

Annex A.3. Putlitz Bridge - Germany

Putlitz Bridge - Germany

Project Description:

The Putlitz Bridge in Berlin, Germany, opened in 1977, is part of a main route for urban traffic, which is also used for heavy loads. Currently the bridge is stressed by the transport of heavy gas turbines with maximum loads of 500 t, which is much more than the design loads. To ensure the bearing capacity experimental investigations including SHM have to be carried out.

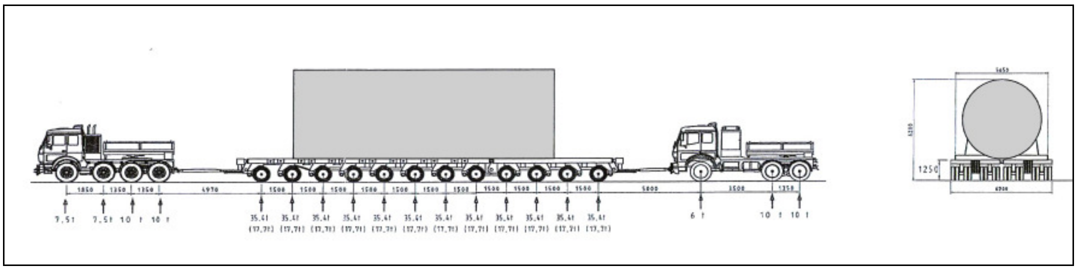
Putlitz Bridge, Berlin, Germany

Quick Facts:

- **Name and Location:** Putlitz Bridge, Berlin, Germany
- **Owner:** City of Berlin, Germany
- **Structure category:** medium span bridge
- **Spans:** 9 spans: 25.1/ 34.7/ 31.5/ 30.2/ 32.6/ 30.1/ 30.2/ 30.4/ 29.2 m
- **Structural system:** Steel box girder with orthotropic deck and steel columns
- **Start of SHM:** September, 2001
- **Number of sensors installed:** 21
- **Instrumentation design by:** BAM, Division Buildings and Structures, Berlin,Germany

Description of Structure:

The superstructure comprises of two steel box girders and an orthotropic deck plate. The bridge with a total length of 270 m consists of two parts, separated by a lengthways joint. A roadway is led with two lanes of traffic each on every bridge part. Every bridge part is 14 m wide. For the heavy load transports the western part is of use for the bridge.



Heavy load transport 490 t

Purpose of Inspection:

Static calculations show that the ultimate limit state of the bridge is reached under those heavy loads. These results have to be verified by experimental investigations measuring continuously maximum strains due to heavy loads und temperature. Additional fatigue stresses at endangered points of the bridge are of interest. Furthermore it is important to know the real static and dynamic loads which can be calculated from the results of the available stain measurements.

Sensor Details*:

Type of sensors	Number	Location
Strain gauges	11	at the main girders and the orthotropic bridge deck
Velocity transducers	4	all sensors are fixed at the main girders
Position Sensitive Detectors	2	
LVDT	2	
PT100	2	

Measurement Equipement and Data Management:

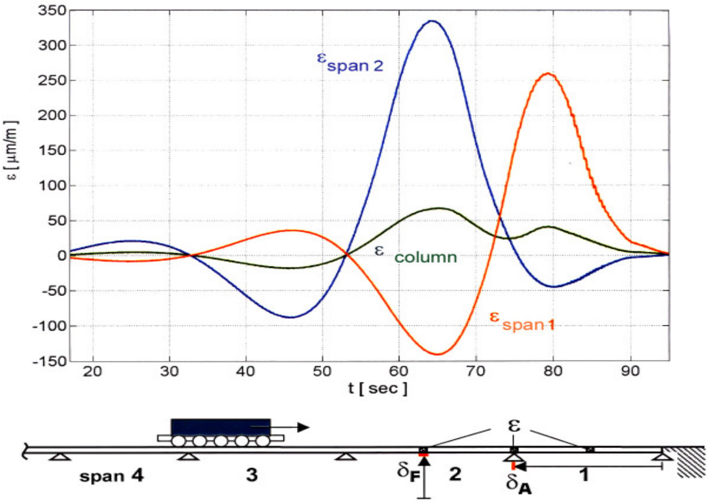
Type of system	Data Management	CMS
PC based meas-urement system	▪ data pre-analysis (statistics,frequency analy sis) on site ▪ main analysis, graphical presentation and docu-mentation in office ▪ data transfer via modem ▪ long term data base	y

Data Analysis Procedures:

Type of analysis	Software	Additional features
Statistics, ambient analysis, rainflow analysis, damage indicators	Self made software	▪ adjustable trigger levels for different alert phases ▪ no expert system

Examples of Outcomes:

It could be affirmed that the dynamic loads, as assumed for the static calculations, can be neglected. Within the time of observation no exceeding of the limit state could be noted. The global condition state of the bridge is not yet affected.



Strain distribution at a main girder during the crossing of a heavy load vehicle measured by SHM

Benefits of Using SHM Technologies in the Project:

All data from stress measurements due to normal and heavy traffic loads as well as temperature loads is available so that the exceeding of limit states and the occurrence of damage can be detected immediately.

References:

R.G. Rohrmann, S. Said, W. Schmid, "Load and condition monitoring of the Putlitz Bridge in Berlin-Moabit", Proc. Symposium Topics from civil and bridge engineering, BAM, Berlin 2003 (in German)

Submitted by:

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