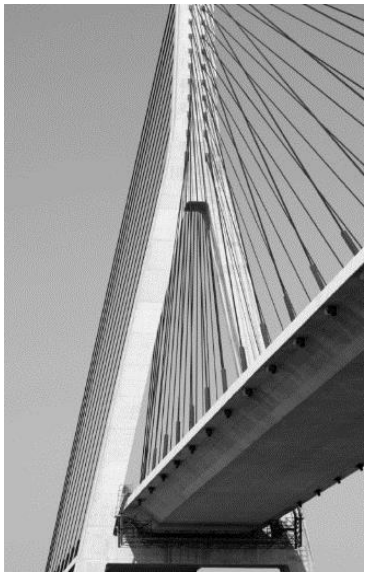
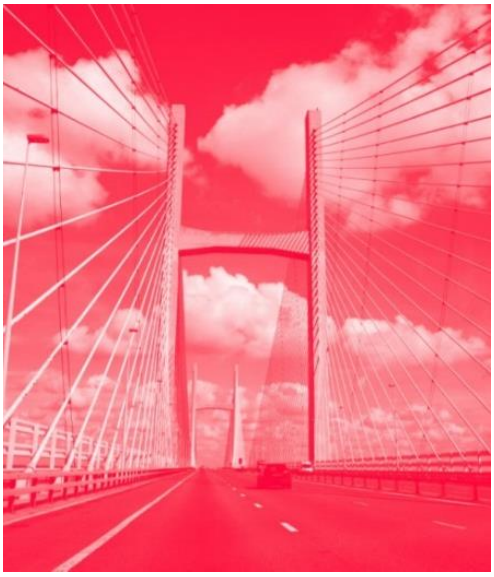
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

NEWSLETTER #01
- May 2017 -





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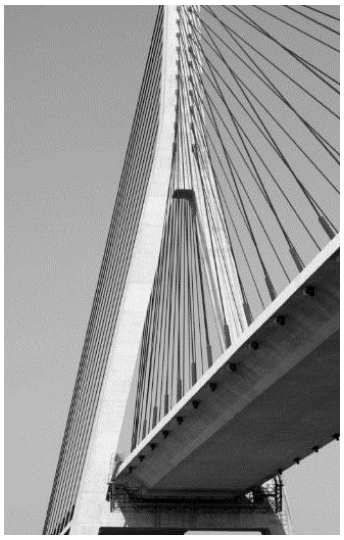
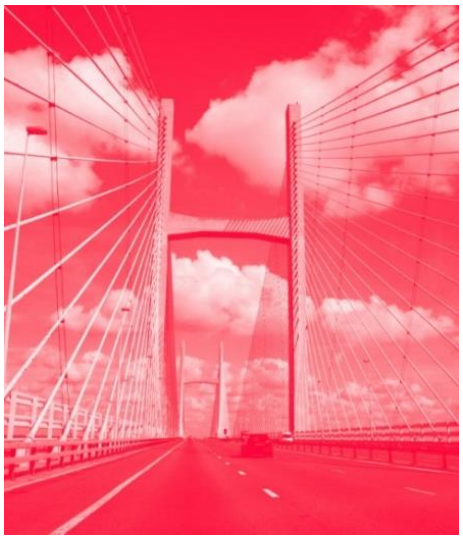
THE INFRASTAR PROJECT

INFRASTAR provides multi-disciplinary and intersectoral training in innovative solutions to asset management of civil infrastructures. Focus is on the prediction of **concrete infrastructure behaviour under fatigue**, currently one of the most critical issues in the field. **INFRASTAR** considers two representative types of concrete infrastructures: **bridges** and **wind turbine** towers and foundations.

The network partners provide **12 Early Stage Researchers** (**ESRs**) with a system-wide understanding of structure management on bridges and wind energy technology. This outstanding research training offers ranges from knowledge in **materials** to design loads, **design** of structures, **monitoring** of existing structures, **development** of **sensors** and innovative **calculation methods** for structural analysis, optimal and reliable management of structures.

Through these innovative activities, **INFRASTAR** contributes to extend the service lifetime of structures, reduce overall costs and develop risk-based life-cycle approaches for future designs.

IFSTTAR, French institute of science and technology for transport, development and networks, is the **project coordinator**.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

OBJECTIVES

INFRASTAR aims to develop **knowledge**, **expertise** and **skills** for optimal and reliable management of structures. The generic methodology will be applied to **bridges** and **wind turbines** in relation to **fatigue** offering the opportunity to deal with complementary notions (such as old and new asset management, unique and similar structures, wind and traffic actions) while addressing 3 major challenges:

- advanced **modelling of concrete fatigue** behaviour,
- new **non destructive testing** methods for early aged damage detection,
- **probabilistic approach** of structure reliability under fatigue.

INFRASTAR proposes innovative solutions for civil infrastructure asset management so that young scientists will acquire a **high employment profile** in close dialogue between industry and academic partners.

Benefit of cross-experience and inter-disciplinary **synergies** will create **new knowledge**. Modern engineering methods, including **probabilistic approaches**, **risk** and **reliability assessment** tools, will take into account the effective structural behaviour of existing **bridges** and **wind turbines** by exploiting **monitored data**. Existing methods and current state-of-the art are based on excessive conservatism, which produces high costs and hinders sustainability.

INFRASTAR will improve knowledge for **optimising the design** of new structures, for more realistic verification of structural safety and more **accurate prediction** of future lifetime of the existing structures. That is a challenge for a sustainable development because it reduces building material and energy consumption as well as CO2 production.

Within the global framework of optimal infrastructure asset management, **INFRASTAR** will result in a **multi-disciplinary** body of knowledge covering generic problems from the design stage process of the new civil infrastructures up to recycling after dismantlement. This approach and the proposed methods and tools are new and will allow a step forward for innovative and effective processes.

Breaking News

One of our Senior Scientist, during its stay as a visiting research fellow at the University of Technology in Sydney, found out the way Australia deals with fatigue issues.

Discover it at the end of the newsletter…

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

KEY FIGURES

EU Contribution: **3 161 113** €

8 Beneficiaries - 4 academic & 4 non-academic

IFSTTAR · EPFL École Polytechnique Fédérale de Lausanne · Aalborg Universitet · BAM · COWI · PHIMECA · NeoStrain

2 Partner Organisations

bast · EIFFAGE

3 Scientific Work Packages

WP1: Monitoring & auscultation

WP2: Structure & action models

WP3: Reliability approaches for decision-making

12 ESRs from 10 different countries

1 Advisory Board & 6 Members from Academia and Industries

University of Surrey · Politechnika Wrocławska · TNO innovation for life · Total · DB · DNV·GL

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WORK PACKAGE 1: MONITORING & AUSCULTATION

The Work Package **Monitoring and Auscultation** (WP1) focuses on **advanced monitoring** and **non-destructive testing** (NDT) techniques for **stress** and **strain** measurements and **fatigue damage** assessment.

The aim is to benefit from novel **sensors** and improved physics based **data processing** methods to "smarten" the structures. These new techniques will be used to make monitoring much **more efficient**. By enabling the optimisation of preventive and corrective maintenance strategies, the project will help **increase infrastructure availability** and **implement cost-efficient asset management**.

WP1 Leader:

Dr Ernst Niederleithinger

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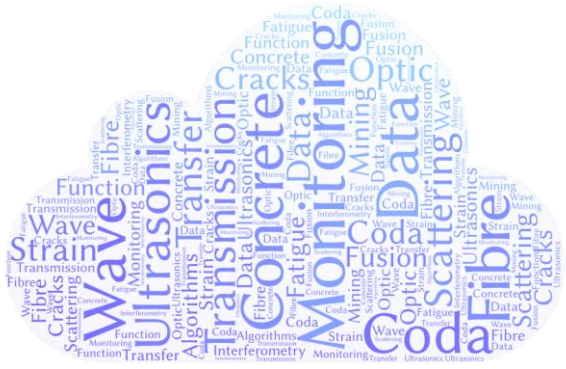
4 ESRs (Early Stage Researcher) are involved in **4 different PhD projects**:

- **ESR1 / Project 1:**
  Advanced ultrasonic instrumentation for interferometric monitoring.
- **ESR2 / Project 2:**
  Fibre-optic sensor for fatigue monitoring.
- **ESR3 / Project 3:**
  Sensor integration, data fusion and information management for industrial monitoring systems.
- **ESR4 / Project 4:**
  NDT parameters for fatigue damage identification in structural elements.



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Project 1: Advanced instrumentation for interferometric monitoring

ESR1 @ BAM

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Project webpage

Recent research results have shown the capabilities of new data processing techniques in detecting subtle changes in materials and structures. Among these concepts, **active and passive interferometric methods** such as **Coda Wave Interferometry** (CWI) for ultrasonic data, originating mostly from seismological research, are the most promising.

However, up to now, neither the full possibilities and limitations have been investigated, nor has the instrumentation been fully adapted for practical implementation.

Main aim is to improve **ultrasonic sensor** networks to monitor **concrete structures** under dynamic loads. This includes **simulation** of effect of certain damage/fatigue scenarios on ultrasonic wave propagation including sensitivity analysis, development of optimised sensors networks, **test** and further **optimisation** based on laboratory size concrete models and implementation on real structures.

Project 2: Fibre-optic sensor for fatigue monitoring

ESR2 @ IFSTTAR

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Project webpage

Strain and crack width measurements are primary concerns for health monitoring and damage assessment of large concrete structures. The effective **detection of damage**, its **localisation** and its **quantification** are essential for an optimised maintenance. **Distributed fibre optic sensing techniques** is a promising alternative.

However, some technological challenges must still overcome. Indeed, the **reliability** of fibre optic measurements and the mechanical **durability** of fibre optic sensors for long term monitoring continue to raise interrogations.

Main aim is to improve the understanding of **strain transfer** between a host material in concrete and an **embedded fibre optic** for more accurate strain and **crack** width measurements. This includes **numerical simulations**, **experimental tests** of different types of fibre optic cables embedded in laboratory size **concrete** models and further **optimisation** and implementation on **real structures**.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Project 3: Sensor integration, data fusion and information management for industrial monitoring systems

ESR3 @ NeoStrain

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Project webpage

One of the main challenges of **Structural Health Monitoring** (SHM) remains the transfer of sensing and damage detection technologies from the laboratory to field applications (including wireless sensors). This requires an industrial approach to system integration and validation.

It is important that data from each measurement system is collected and managed in a coherent way and that the **data management** and **decision making tools** can access straightforwardly all data.

Prototype sensors and new methods of measurement will be developed during this project. Specific **data fusion** and **data mining algorithms** must be developed, implemented and tested in order to verify their effectiveness in real field conditions and under different environmental and operational disturbances.

Project 4: NDT parameters for fatigue damage identification in structural elements

ESR4 @ EPFL

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Project webpage

The service duration of structures like **reinforced concrete** bridges and wind turbines depends on the **fatigue** of structural components due to respectively traffic loading and wind action. In order to realistically evaluate fatigue damage, **Non-Destructive Testing** (NDT) methods are a real asset.

In this project, **ultrasonic sensor** networks shall be used to **detect** and **monitor** fatigue damage in reinforced concrete of bridges subjected to traffic induced fatigue loading.

The focus is to establish **correlations** of NDT parameters (e.g. ultrasonic velocity, attenuation) to fatigue related phenomena and parameters to identify any **fatigue damaging process** (microcracks in concrete, slow microcrack progagation in steel elements) in structural elements and components at the earliest possible stage.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

WORK PACKAGE 2: STRUCTURE & ACTION MODELS

The Work Package **Structure and Action Models** (WP2) focuses on **structural and fatigue loading models**.

The aim is to examine more precisely (than currently used conservative methods) structural behaviour of elements and components of wind turbines and bridges **under natural (wind and wave) loading** and **traffic loads** (live loads) using results from WP1 "Monitoring and Auscultation".

Probabilistic methods as well as action and **structural behaviour models** will be used as input for WP3. Deterministic and probabilistic approaches for **fatigue safety verification** will be investigated and implemented. These tools will retroactively guide NDT and monitoring (WP1). A strong interaction between wind turbine and bridge structural aspects will generate novel knowledge as well as research areas to explore.

WP2 Leader:

Prof. Eugen Brühwiler

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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

4 ESRs (Early Stage Researcher) are involved in **4 different PhD projects**:

- **ESR5 / Project 5:**
  Fatigue of reinforced concrete structural element.
- **ESR6 / Project 6:**
  Reliability of structures exposed to traffic loads and environmental loading.
- **ESR7 / Project 7:**
  Lifetime cyclic behaviour of gravity base foundations for offshore wind turbines.
- **ESR8 / Project 8:**
  Fatigue of wind turbine concrete structures.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Project 5: Fatigue of reinforced concrete structural element

ESR5 @ EPFL

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Project webpage

The service duration of structures like **reinforced concrete** bridges and wind turbines depends on the fatigue of structural components. In order to realistically evaluate the **fatigue safety**, precise data regarding the fatigue action effect due to traffic loading and wind respectively are needed.

The objective is to investigate the fatigue behaviour of structural elements in reinforced concrete of bridges and wind turbines including novel cementitious materials like **Ultra-High Performance Fibre Reinforced Concrete** (UHPFRC).

The research findings will provide the necessary knowledge for establishing a novel **engineering approach** based on monitoring by inspections or continuous measurements cross-validating fatigue damage model for concrete and UHPFRC including **stochastic aspects**.

Project 6: Reliability of structures exposed to traffic loads and environmental loading

ESR6 @ IFSTTAR

Mariia Nesterova
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Project webpage

Civil engineering structures are subjected to various actions, like traffic loads or climatic actions. The extreme values of these actions are of utmost importance, as they govern the design or the re-assessment of the structures.

In Eurocode 1, the actions (wind, snow, traffic) for the structures assessment have been chosen with extrapolation of measured values, for a given value of the return period. Are these extrapolated values still valid? Are the extrapolation methods suitable?

The objective is to investigate **extreme traffic loads** applied on bridges over **long time periods**, and to assess the extreme load effects by **extrapolation**, taking into account updated heavy vehicle weight distributions. This methodology will also be applied to the natural loading applied on **on- and off-shore wind turbines**. The **safety margins** and reliability indexes may then be assessed for extreme load effects and fatigue limit states.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Project 7: Lifetime cyclic behaviour of gravity base foundations for offshore wind turbines

ESR7 @ GuD

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Project webpage

Due to the highly cyclic nature of loading of offshore wind turbines **gravity base foundations**, the soil structure interaction comprises complex effects such as pore pressure development, compaction and liquefaction.

Furthermore, the long-term behaviour of gravity base and suction bucket foundations of offshore wind turbines is not yet fully understood.

The aim is to develop **analytical and empirical engineering models**, simplifying the problem of implicit modelling of gravity base foundations for offshore wind turbines by means of a defined number of state variables such as density, permeability, stiffness etc. all depending on the **loading history**, i.e. number and amplitude of previous loading cycles.

Project 8: Fatigue of wind turbine concrete structures

ESR8 @ COWI

Joey Velarde
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Project webpage

This project mainly focuses on fatigue loading effects on structural elements in reinforced concrete of wind turbines. It is very important to capture the various and complex interactions of the environment and individual subsystems within **offshore wind turbines**, e.g. leading to a pronounced aero-elastic behaviour.

Adequate consideration of these interactions requires an **integrated modelling approach** for offshore wind turbines, their foundations and the environmental conditions.

The main aim is to investigate and develop new methods for assessment of the **fatigue load** and **resistance for reinforced concrete** in gravity based offshore wind turbine foundations. The influence of various design driving effects for fatigue will be investigated in order to optimise the current design philosophy and minimise the total cost of energy.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

WORK PACKAGE 3: Reliability Approaches for Decision-Making

The Work Package **Reliability Approaches for Decision-Making** (WP3) has the objective to apply the theoretical basis for reliability analysis and risk-based optimal decision making for **life cycle analysis** to **concrete foundations** and towers for wind turbines along with bridge elements.

For formulation of the **stochastic modelling** the JCSS Probabilistic Model Code1 will be used as basis. Further, **fatigue mitigation** of the structures will be considered. Methods for coupling monitoring information (throughout the life of the systems) with structural reliability models will be developed in order to establish cost-efficient and safe maintenance planning. These methods will be based on **Bayesian statistics** and optimisation of maintenance scenarios.

WP3 Leader:

Prof. John Dalsgaard Sørensen

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AALBORG UNIVERSITET

4 ESRs (Early Stage Researcher) are involved in **4 different PhD projects**:

- **ESR9 / Project 9:**
  Fatigue reliability of concrete wind turbines and bridge elements.
- **ESR10 / Project 10:**
  Optimal maintenance planning of existing structures using monitoring data.
- **ESR11 / Project 11:**
  Development of methods for risk assessment of wind turbine support structures and bridges.
- **ESR12 / Project 12:**
  Quantification of the value of monitoring information for deteriorated structures.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Project 9: Fatigue reliability of concrete wind turbines and bridge elements

ESR9 @ Aalborg University

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Project webpage

The **fatigue** properties of **reinforced** and **pre-stressed concrete** structures are dependent on the fatigue properties of the concrete, the steel reinforcement and the pre-stressing steel.

The **inhomogeneous** and complex structure of concrete, along with large spatial variations, the **steel reinforcement** and pre-stressing initial defects and the interaction between the steel and concrete, introduce significant **uncertainties**.

Main aim is to develop a probabilistic framework for **reliability assessment of reinforced concrete structures** with respect to fatigue. This includes applications within the wind turbine industry where reinforced concrete structures are used widely for onshore foundations, but also for new, innovative designs of concrete towers both for **onshore and offshore applications**.

Project 10: Optimal maintenance planning of existing structures using monitoring data

ESR10 @ PHIMECA

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Project webpage

In the last decades, **maintenance optimisation** of civil engineering structures has gained increasing attention since the number of ageing structures is large and the available budget dedicated to maintenance is constrained in European countries.

In this context, it becomes important to **optimise the maintenance strategy** using a cost/benefit analysis.

The ESR will take advantage of the type of monitoring information obtained from the **sensors** developed in WP1 and will include this additional knowledge in the **structural model** using **Bayesian** techniques. Various types of criteria related to the results of monitoring will be proposed together with an estimation of the associated costs. The overall procedure will then be optimised so as to minimise **inspection/ monitoring/maintenance** costs all over the life time of the structure.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

Project 11: Development of methods for risk assessment of wind turbine support structures and bridges

ESR11 @ Aalborg University

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Project webpage

For both new and existing structures, it is important to be able to take **rational decisions** on **inspections**, **operations**, **maintenances** and **repairs** accounting for both uncertainties and consequences.

The decisions can be related to both planning at the design stage, as well as decisions during the lifetime of the structure. This can be performed using methods for **risk assessment**. The framework described in the **JCSS** (Joint Committee for Structural Safety) guideline for risk assessment, will be used as basis.

The main aim is to develop methods for **risk-based assessment for bridges and wind turbines**, using information from **inspections**, **sensors** and **condition monitoring**, i.e. to apply data from measurements in **rational decision making**.

Project 12: Quantification of the value of monitoring information for deteriorated structures

ESR12 @ BAM

Lijia Long
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Project webpage

An efficient **structural integrity** management of **deteriorated structures** is of high societal value. **Monitoring** can be very beneficial as it is well developed with diverse technologies, algorithms and systems.

However, the value or the utility of monitoring is seldom quantified and infrastructure owners and operators may be reluctant to invest in large systems for which the benefit is not clearly specified.

This project focusses on **deteriorated structures** such as bridges and wind turbines and the **development of monitoring** strategies to most efficiently plan the structural integrity management. The expected results comprise the documentation of efficient monitoring strategies and the quantification of their utility in terms of **risk reduction**, expected **cost reduction** and service life benefits for industrial application and for the value of society.

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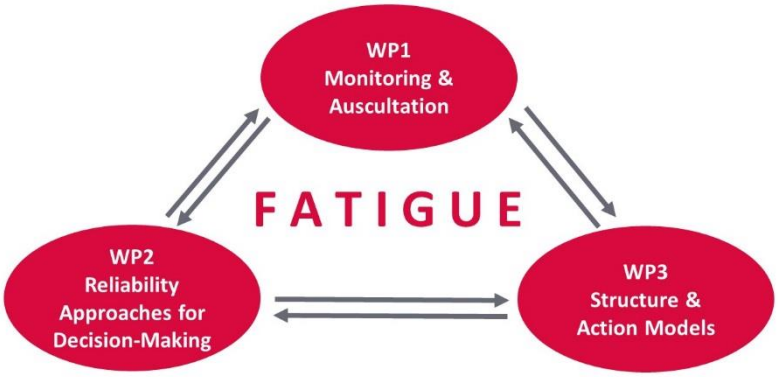
THE SYNERGETIC NETWORK

The 12 ESRs benefit from a **unique network** whom the goal is to better understand the **concrete infrastructures behaviour under fatigue** from different prospects but complementary. To do so, the ESRs of the 3 work packages exchange inputs and outputs with each other through data and "**shared objects**".



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THE PARTNER ORGANISATIONS

The partner organisations provide **additional training** and host researchers during **secondments**.

The Federal Highway Research Institute is the practice-oriented, technical-scientific research institute of the German Government in the field of road engineering.

Dr Peter Haardt (haardt@bast.de)

EIFFAGE is a leading figure in the European concessions and public works sector.

Dr Ziad Hajar (ziad.hajar@eiffage.com)
Sandrine Chanut (sandrine.chanut@eiffage.com)

THE END USER ADVISORY BOARD

The **End User Advisory Board** (EUAB) provides INFRASTAR with a **strategic guidance** on training and exploitation of the results. It is composed of 6 members from both **academia** and **industries**:

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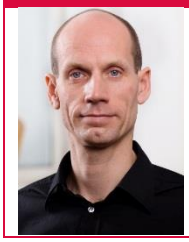

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139.

TRAINING WEEKS

A series of **3 training weeks** will be held. The ESRs will be offered a progressive in-depth knowledge in asset management through both intensive scientific modules and complementary skills.

The first training week was held at **BAM** in Berlin from the 27th until the 31st of March 2017. It put emphasis on the current state-of-the-art and best practices.

Scientific lectures:

- Experimental investigation of damage evolution in concrete under high-cycle fatigue (BAM)
- Non Destructive Testing overview (BAM)
- Practical trainings at the Non Destructive Testing test and validation centre of BAM at BAM-TTS/Horstwalde
- Structural Health Monitoring: state-of-the-art (NeoStrain)
- Extreme value probabilistic theory (IFSTTAR)
- Monitoring road traffic loading (IFSTTAR)
- Value of Information and Structural Health Monitoring (DTU)
- The Millau Viaduct: design, construction and monitoring (EIFFAGE)
- Wind turbines: basic principles (Aalborg University)
- Wind turbines: design for extreme loads and fatigue (Aalborg University)
- Uncertainty framework for sensitivity or reliability purpose (PHIMECA)
- Fatigue behaviour of reinforced concrete EPFL)

Complementary skills:

- Open access, open data, open source (IFSTTAR)
- Effective tools to write peer reviewed articles

Technical visit at the Pergamon Museum.

The second training week (November 2017) at **EPFL** will address the challenge of the shift from lab to real in situ conditions.

The third training week (July 2018) at **Aalborg University** will put into relief considerations such as decision, normalisation and qualification.

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GET INVOLVED IN THE "IMPLEMENTATION DAYS"

The purpose of the **implementation days** is to invite small and large companies, administrations, local authorities, academic experts in the fields of INFRASTAR in order to get their feedback on the progresses and **to boost the networking** opportunities.

Three implementation days are scheduled:

- At **BAST** (Germany), the 20th and 21st of March 2018, and organised with the **National Symposium on Smart Structures**. **More information soon… Stay tuned!**
- At **EIFFAGE** (France) in October 2018
- At **COWI** (Denmark) in June 2019

MORE INFORMATION ON INFRASTAR WEBSITE, STAY TUNED…

INFRASTAR TEAM
First Meeting at GuD, Berlin, Germany
4th November 2016

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https://www.researchgate.net/profile/Infrastar_Itn

Breaking News

Dr Ernst Niederleithinger found out the way Australia deals with fatigue issues.

"Only sleep cures fatigue"…