IABMAS

FOUNDED 1999

Meeting Minutes

IABMAS Technical Committee on Bridge Load Testing

Online, Zoom https://usfq.zoom.us/j/84240253010

Wednesday April 13th 2022, 8am – 10 am EDT (US Eastern) / 2 pm – 4 pm CEDT (Central European)

Mission: *Bridge Load Testing is a field testing technique that can be used to obtain more information about the performance of bridges. In particular, diagnostic load tests can be used to quantify elements of structural performance such as transverse distribution, unintended composite action, repair effectiveness, etc. and the information of a diagnostic load test can serve to develop field-validated models of existing bridges that can be used to develop a more accurate assessment of the bridge's performance. Proof load testing can be used to demonstrate directly that a bridge can carry a load that is representative of the code-prescribed live load, provided that the bridge does not show signs of distress. Other types of load testing include testing for dynamic properties, and parameter-specific tests. Load test data as well as the analytical assessment of the data can be used to make more informed decisions and manage the life-cycle performance and maintenance of bridges.*

Aspects of bridge load testing that are of particular interest to bridge owners are having an overview of the typical uses for bridge load tests, the decision on when to load test or not, which information to obtain from the load test, and how this information can be used to reduce the uncertainties regarding the tested bridge. This committee is eager to learn about and disseminate the potential for applying new technologies for bridge load testing through learning from technologies used in other industries.

Associated with bridge load testing, the following topics are also of importance to this committee: instrumentation used during load testing and the interpretation of the obtained measurements during the load test, determination of required load, method of load application, methods of updating assessments using collected field data, the link between load testing and structural health monitoring, the uncertainties (probabilistic aspects as well as risks during test execution) associated with load testing, the interpretation of load test results, laboratory testing of bridge components to improve assessment methods in the field, and optimization of related costs keeping adequate reliability to spread their use worldwide.

The IABMAS Bridge Load Testing Committee aims to be an international committee of participants from academia, industry, and bridge owners, which provides a forum for the exchange of ideas on bridge load *testing. Best practices as well as the insights from the development of national codes and guidelines will be exchanged among participants from countries that use load testing for the assessment of their existing bridges, those who are exploring the possibilities of this method, and those who are in the process of standardizing the procedures or developing guidelines.*

Goals:

- *Organize dedicated sessions to the topic of load testing at IABMAS conferences.*
- *Develop national IABMAS group events on the topic of load testing.*
- *Exchange information on the use of load testing in different countries.*
- *Exchange lessons learned and best practices.*
- *Inform about case studies of bridge load testing.*
- *Communicate load testing guides or standards that have been developed.*
- *Provide a forum for new ideas and applications of technology.*
- *Identify potential research topics.*
- *Establish international collaborations.*
- *Liaise with relevant committees internationally outside of IABMAS and liaise with the national IABMAS groups.*

Committee Members

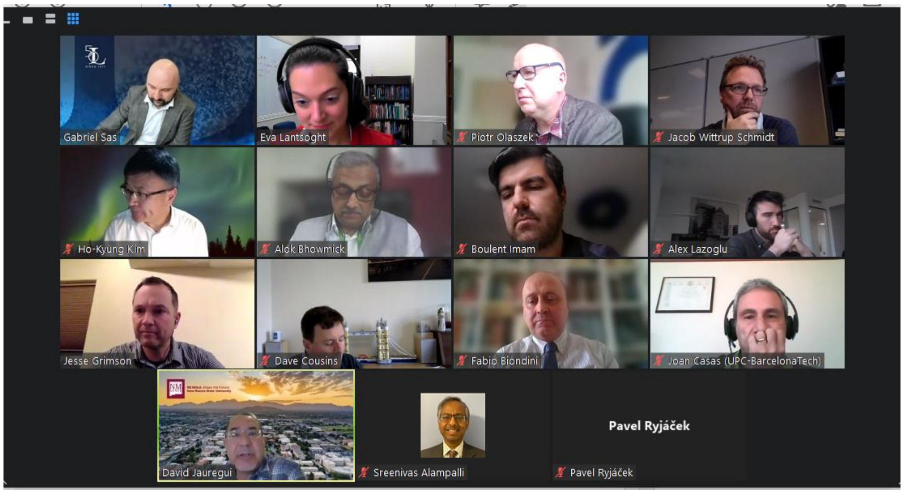
Eva Lantsoght
Jesse Grimson
Mitsuyoshi Akiyama
Sreenivas Alampalli
Fabio Biondini
Alok Bhowmick
Jonathan Bonifaz
Anders Carolin
Dave Cousins
Dan Frangopol
Boulent Imam
David Jauregui
Ho-Kyung Kim
David Kosnik
Marcelo Marquez
Johannio Marulanda
Piotr Olaszek
Joan Ramon Casas
Pavel Ryjacek
Gabriel Sas
Marek Salamak
Gregor Schacht
Jacob Schmidt
Tomoki Shiotani
Matias Valenzuela
Esteban Villalobos Vega
David Yang

Guests: Alex Lazoglu to replace Gregor Schacht
Regrets: Mitsuyoshi Akiyama, Anders Carolin, David Kosnik, Gregor Schacht, Esteban Villalobos Vega, David Yang

1. Administrative [10 min]

1.1. Welcome and introduction

All those present introduced themselves with their name and affiliation.



1.2. Review and approval of agenda

The agenda was reviewed and no comments were mentioned.

2. Strategic Planning and Discussion

2.1. Membership

Lantsoght welcomed new member Sas.

Lantsoght informed about potential members from the owner side. Schmidt will liaise with the Danish road directorate for a member. Sas will reach out to colleagues in Norway and Finland. Bhowmick will contact engineers at the bridge owner side in India.

2.2. Website

On the IABMAS website, the committee information is included. Lantsoght showed the committee members where to find the information on the website, including the approved minutes of the inaugural meeting.

3. New Business

3.1. Technical presentations

- Kalix bridge proof loading and demolition – Gabriel Sas
- Field testing of a full-scale riveted railway bridge removed from service - Boulent Imam
- Research on bridge load testing in Denmark - Jacob Schmidt

Grimson introduced the speakers and chaired the discussion. We had three technical presentations and resulting discussions. The slides are attached to these minutes.

3.2. Opportunities for collaboration

TRB AKB40 liaison Kosnik sent his regrets for the meeting. Committee members were invited to reach out to relevant organizations and committees to establish liaisons.

3.3. Upcoming conferences and events

- IABMAS USA will meet virtually on May 13th. Alampalli mentioned there will be a one-hour long webinar by Limongelli followed by the business portion of the meeting.
- IALCCE 2023 will be held in July 2023 in Milan. Biondini will provide further updates in the upcoming committee meetings: https://ialcce2023.org/
- IABSE Congress 2023 will be in New Delhi – Engineering for Sustainable Development. More information here. Bhowmick is part of the organizing committee and invited all to send in their contributions.
- IABMAS 2022 will be in 11-15th of July in Barcelona. Website. Casas mentioned the keynotes of committee members Lantsoght and Alampalli, as well as the MS organized by these members, which received good interest in terms of abstracts and papers.

4. Adjournment

The next meeting will be held on the 12th of July 2022, at IABMAS in Barcelona. We will explore the possibility of setting up a Zoom link for hybrid participation.

KALIX BRIDGE PROJECT

Bridge testing – A solution to the sustainability challenge?

Gabriel Sas
Chair Professor in Structural Engineering

https://www.linkedin.com/company/byggkonstruktion

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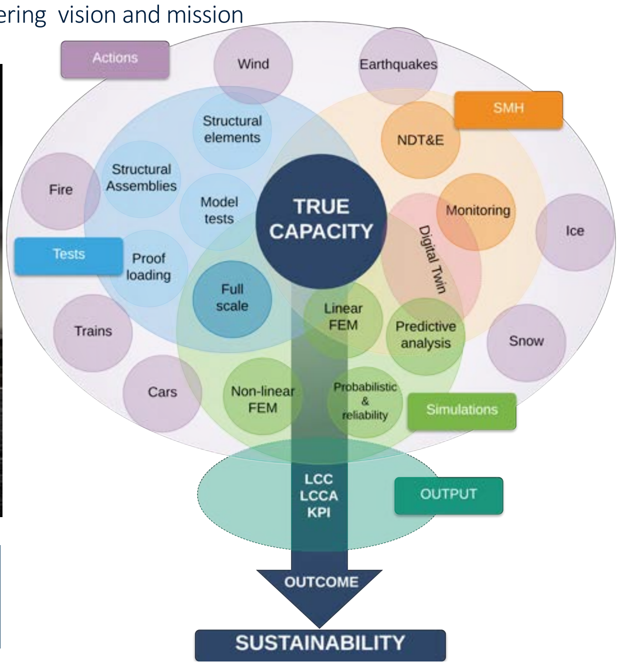
LTU's Structural Engineering vision and mission



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14 BRIDGES TESTED AT LTU DURING THE LAST 3 DECADES – SOME EXAMPLES

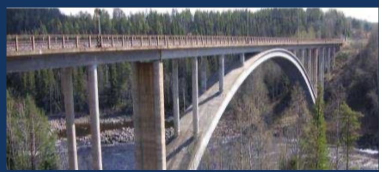
Lautajokk, 1967, trough bridge, 7 m, railway.
FAT test – 6 mcycles, axle from 250 kN to 350 kN, no damage. Then ULS.

Åby, 1955, truss, 33 m, railway.
ULS: buckling, 11 MN. Code prediction: 3,8 MN.

Kiruna, 1959, PC bridge, 5 spans=121.5 m, road.
ULS: shear, 13.4 MN. Best code prediction 3 MN.

Ö-vik, 1955, trough bridge, 11.9+12.2 m, railway.
ULS: shear, 11.7 MN. Best code prediction 9.1 MN.

Haparanda, 1959, trough bridge, 12.5 m, railway.
Strengthen to increase axle to 300 kN from 250 kN.



Vindelälven , 1954, RC arch , 110 m, railway.
SLS test to increase axle to 250 kN, successful.

3

Bridges in Sweden

- 16 000 road bridges
- 4 000 railway
- 10 000 more owned by municipalities
- Bridge stock is getting old
- We are building faster and transporting heavier loads
- First generation of prestressed bridges reach design life

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4


Kalix bridge – Testbed and Demolition
STRUCTURAL & FIRE ENGINEERING
Improve the performance and life length of bridges by identifying their "reserve" internal capacity.

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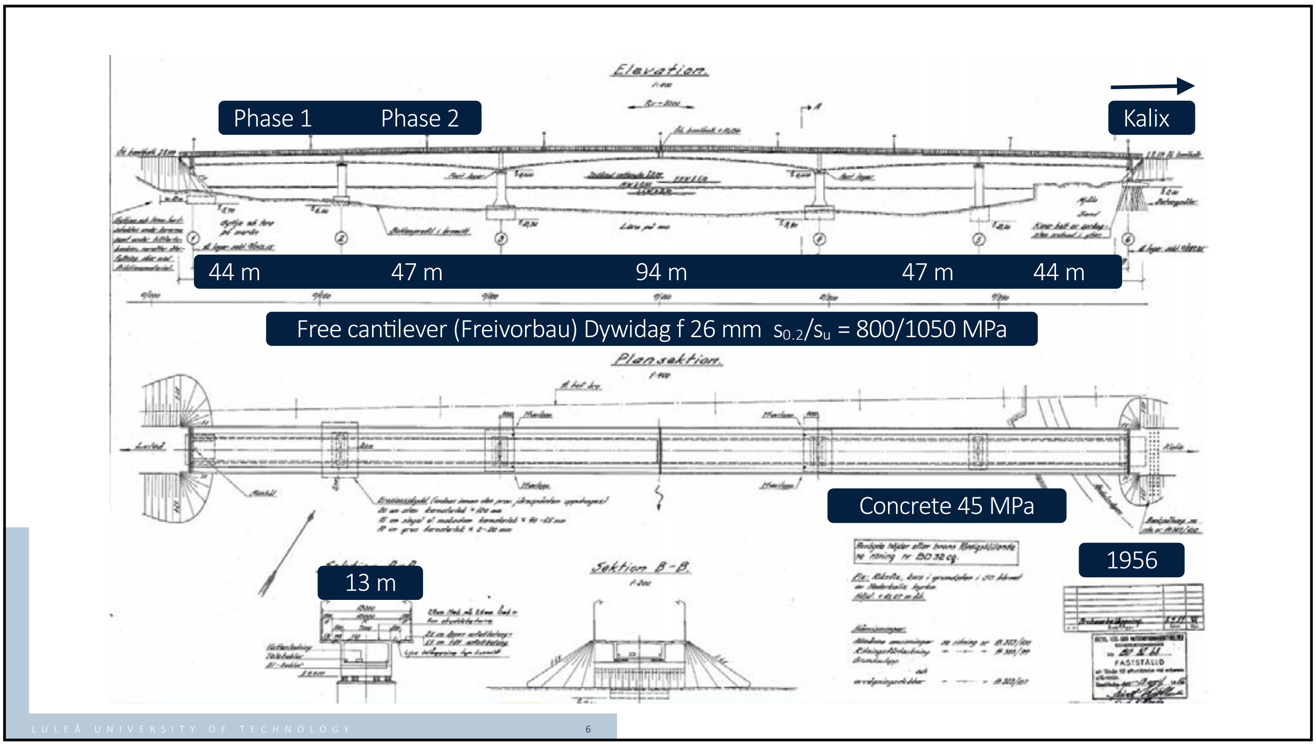
Elevation
Phase 1
Phase 2
Kalix
44 m
47 m
94 m
47 m
44 m
Free cantilever (Freivorbau) Dywidag f 26 mm $s_{0.2}/s_u$ = 800/1050 MPa
Plansektion
Concrete 45 MPa
Sektion B-B
13 m
1956
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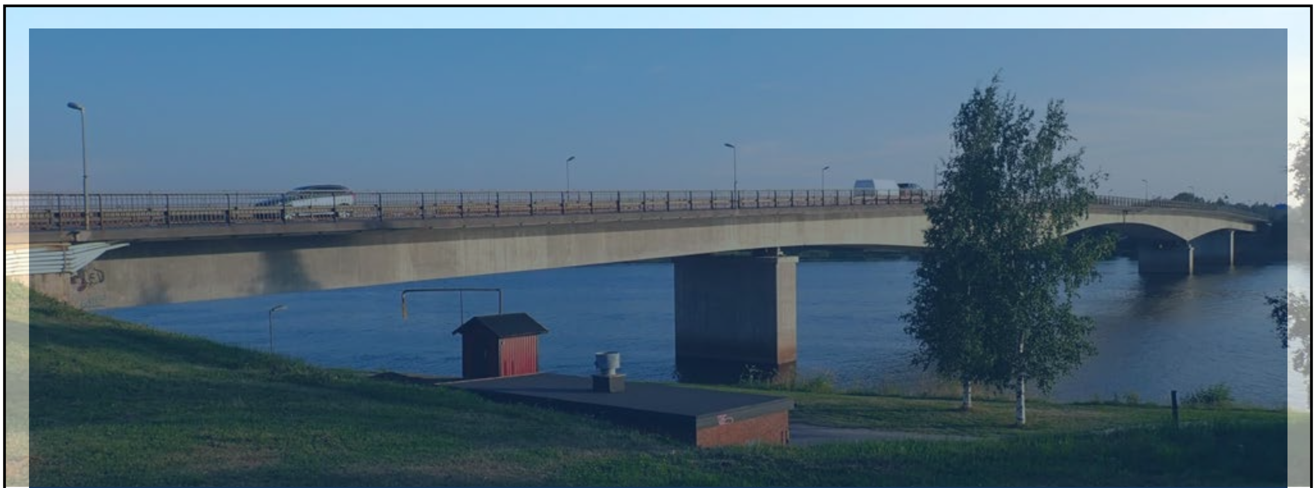

Objectives:

1. Develop proof loading test method for similar bridge type
2. Demonstrate condition assessment methods (TRL)
3. Test methods to measure prestress forces
4. Suggest method for controlled demolition

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Kalix Bridge projects

FOI BBT

SBUF

2021-2022 Phase 1

2022-2023 (Phase 2)

2024-2025 (Phase 3)

2021-2022

Data collection

- Proof loading
- Structural heath monitoring
- Non-Destructive Testing

Data analysis

- Analysis of results
- Laboratory testing
- Forensic investigation on removed parts of the bridge

Data evaluation

- Technology Readiness Levels (TRLs)
- Recommendations

Demolition

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KTH VETENSKAP OCH KONST
TRAFIKVERKET
LULEÅ UNIVERSITY OF TECHNOLOGY
Statens vegvesen
CHALMERS
NCC
SINTEF
LUND UNIVERSITY

Vejdirektoratet
elop THE BIG PICTURE
AALBORG UNIVERSITET
UNIVERSITY OF OULU
INVATOR AB
TIMEZYX DIGITAL TWIN
SAVONIA UNIVERSITY OF APPLIED SCIENCES

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Kalix Bridge projects

FOI BBT			SBUF
2021-2022 Phase 1	2022-2023 (Phase 2)	2024-2025 (Phase 3)	2021-2022
Data collection	Data analysis	Data evaluation	
• Proof loading • Structural heath monitoring • Non-Destructive Testing	• Analysis of results • Laboratory testing • Forensic investigation on removed parts of the bridge	• Technology Readiness Levels (TRLs) • Recommendations	Demolition

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Phase 1 - planning and data collection at Kalix Bridge– main processes

Instrumentation	Convoy loading	Condition assessment with NDT&E	Demolition

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Phase 1- planning and data collection at Kalix Bridge– main processes

Instrumentation	Convoy loading	Condition assessment with NDT&E	Demolition

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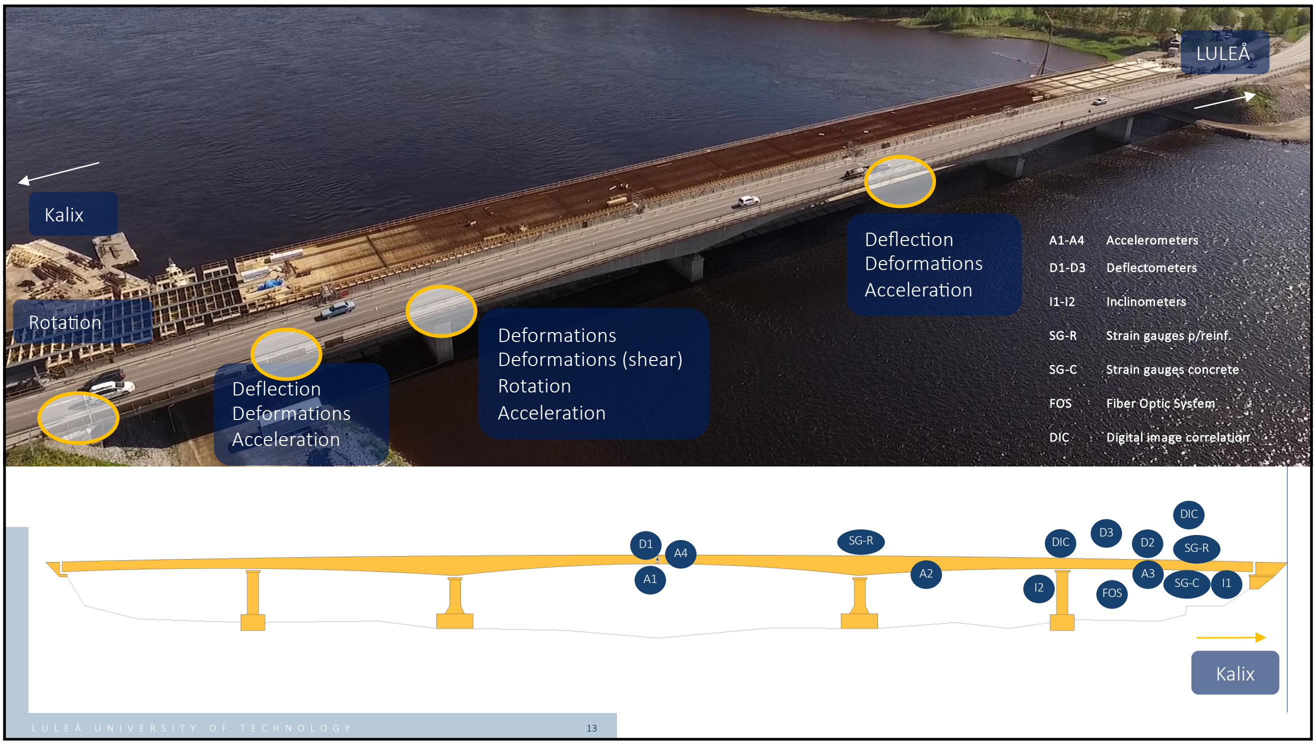

LULEÅ
Kalix
Rotation
Deflection
Deformations
Acceleration
Deformations
Deformations (shear)
Rotation
Acceleration
Deflection
Deformations
Acceleration
A1-A4 Accelerometers
D1-D3 Deflectometers
I1-I2 Inclinometers
SG-R Strain gauges p/reinf.
SG-C Strain gauges concrete
FOS Fiber Optic System
DIC Digital image correlation
D1 A4 A1 SG-R A2 DIC I2 D3 FOS D2 A3 DIC SG-R SG-C I1
Kalix
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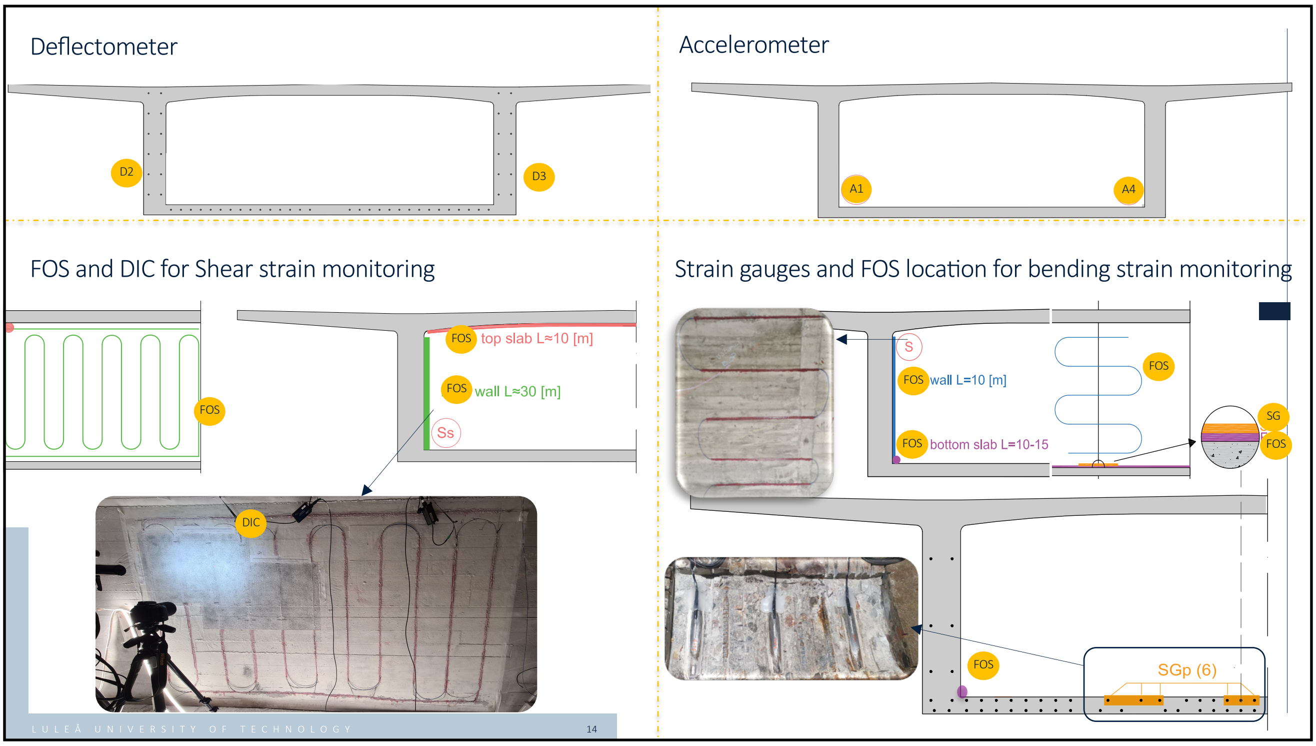

Deflectometer
D2
D3
Accelerometer
A1
A4
FOS and DIC for Shear strain monitoring
FOS
FOS top slab L≈10 [m]
FOS wall L≈30 [m]
Ss
DIC
Strain gauges and FOS location for bending strain monitoring
S
FOS wall L=10 [m]
FOS bottom slab L=10-15
FOS
SG
FOS
FOS
SGp (6)
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14

14

Phase 1 - planning and data collection at Kalix Bridge– main processes

- Instrumentation
- Convoy loading
- Condition assessment with NDT&E
- Demolition

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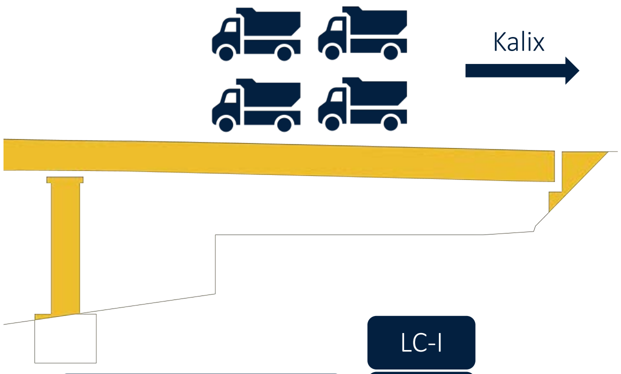
Loading configuration and levels

Standard Volvo trucks + lorry



Three load cases

- LC-I
- LC-II
- LC-III

Three load levels:

- 23 t – Empty – 0%
- 43 t – Half full – 50%
- 63 t – Full – 100%

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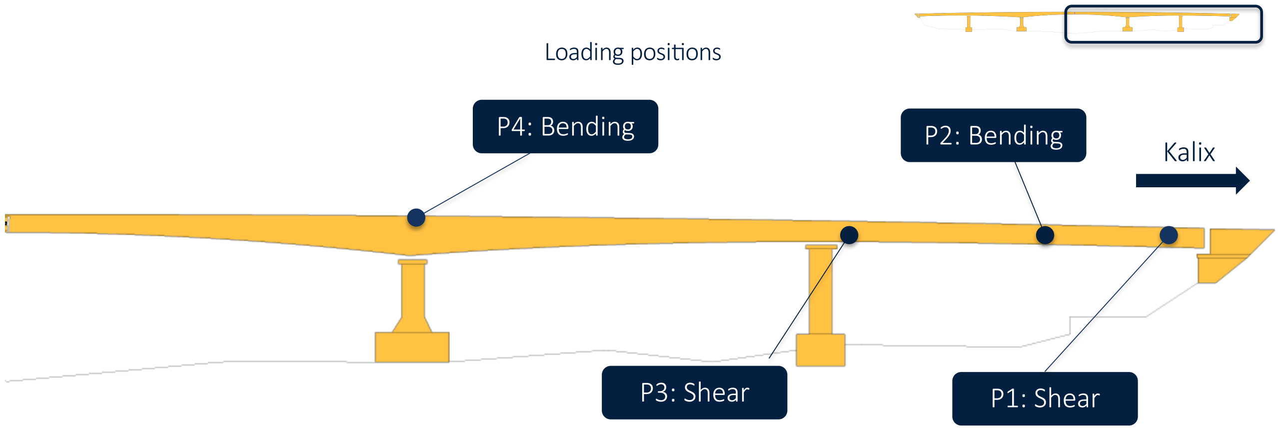
Loading positions



3 loading levels x 3 loading configurations x 4 positions
36 load tests
(3 days)

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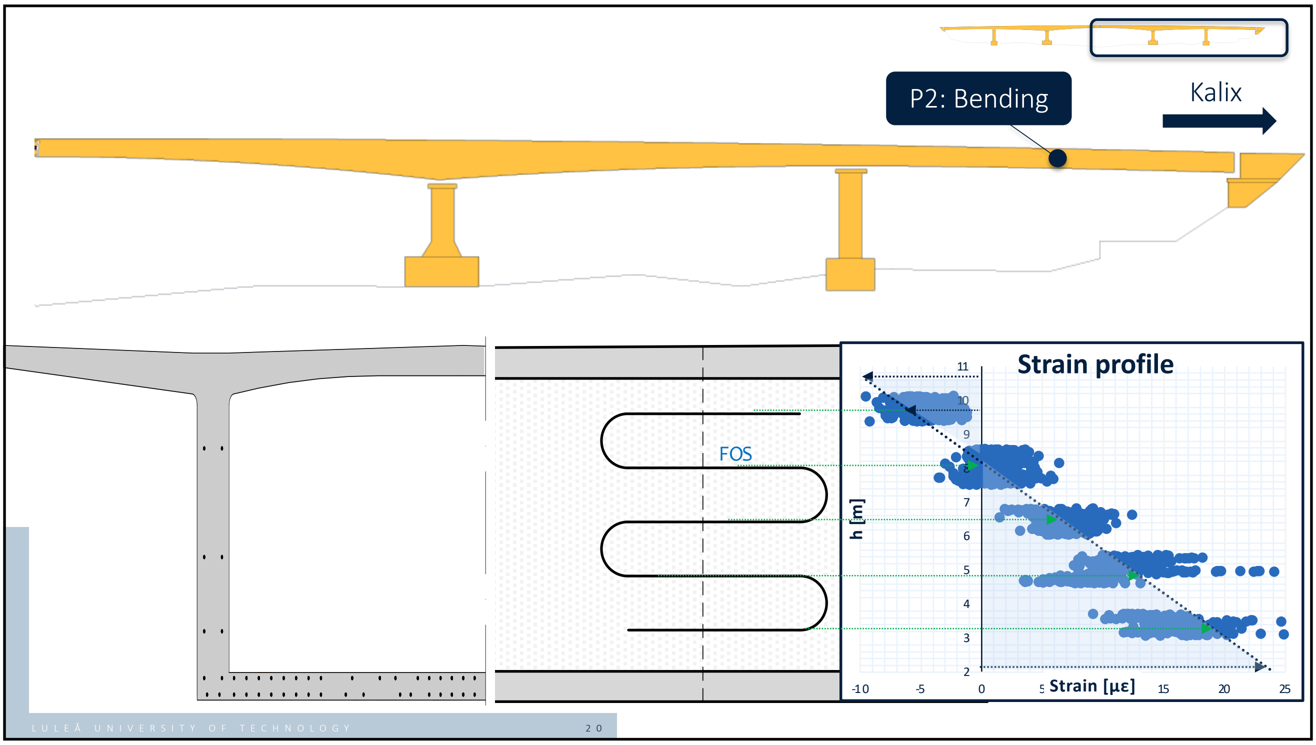
P2: Bending
Kalix
FOS
Strain profile
h [m]
Strain [με]
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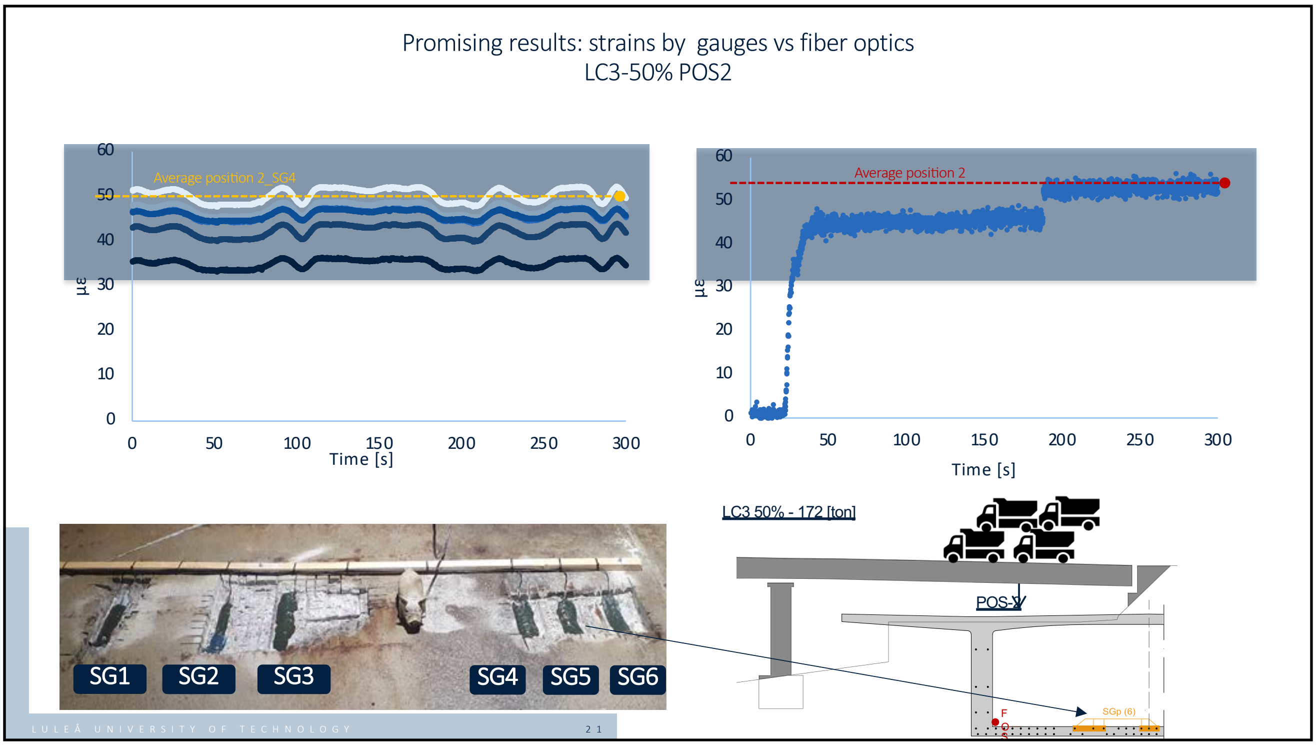
20

20


Promising results: strains by gauges vs fiber optics
LC3-50% POS2
Average position 2_SG4
με
Time [s]
Average position 2
με
Time [s]
LC3 50% - 172 [ton]
POS-2
SG1
SG2
SG3
SG4
SG5
SG6
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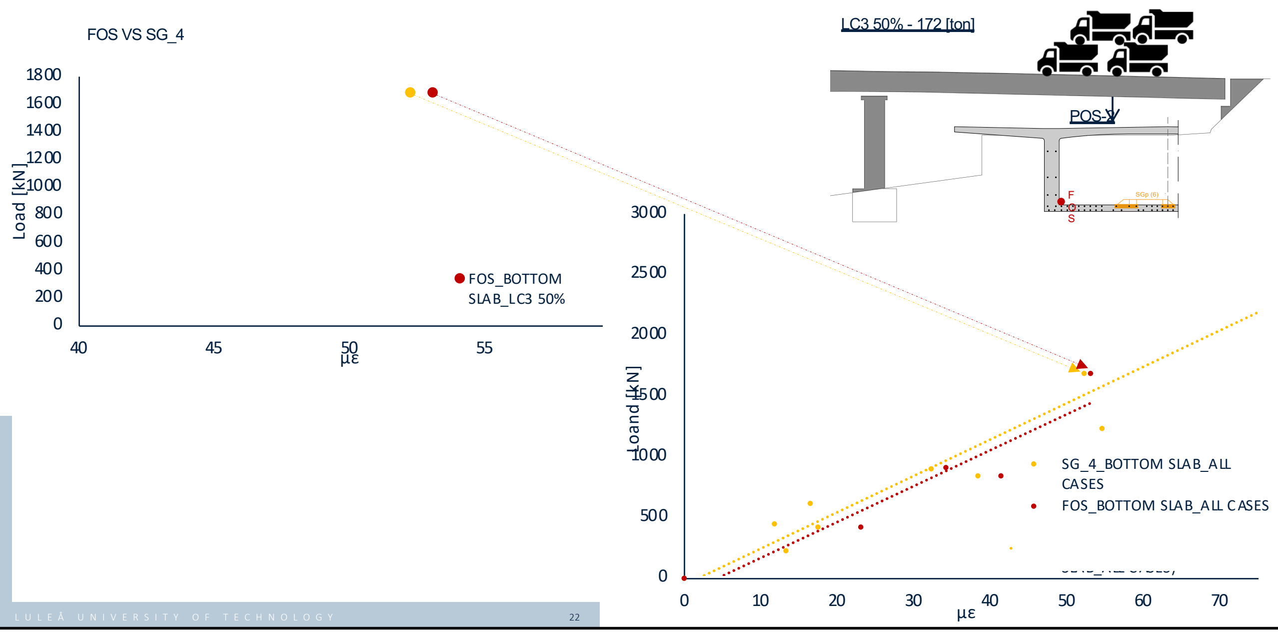
Response of the bridge – Average axial strains in the bottom slab
LC3-50% at position 2



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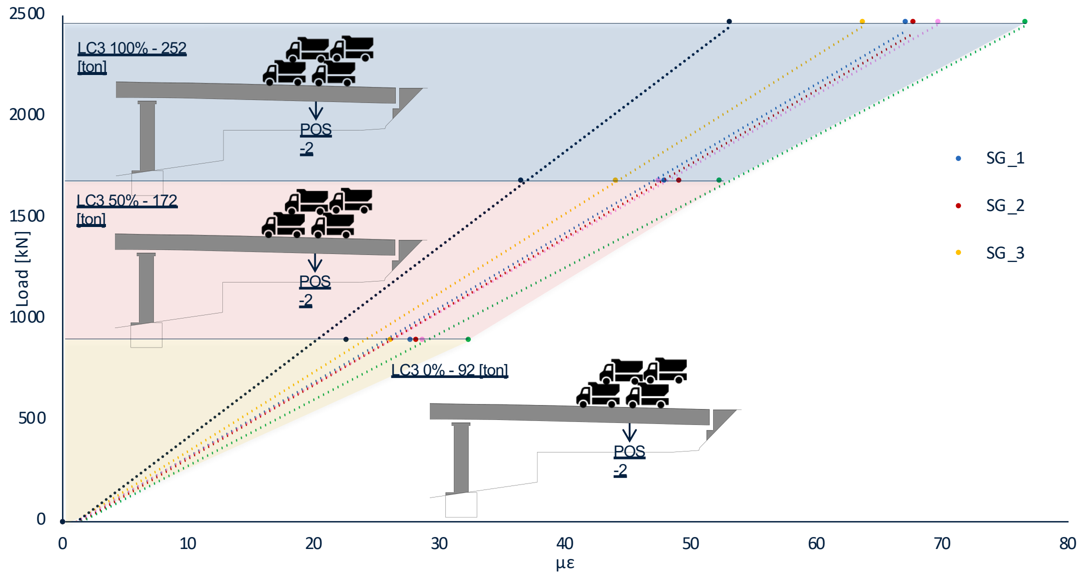
Axial strains in the bottom slab(span 6)
all strain gauges for LC3 at position 2



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Phase 1 - planning and data collection at Kalix Bridge– main processes

Instrumentation

Convoy loading

Condition assessment with NDT&E

Demolition

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Non-destructive tests

- Parameters investigated
  - Concrete uniformity (rebound hammer)
  - Concrete compressive strength (rebound hammer)
  - Surface reinforcement – spacing and concrete cover (covermeter)
  - Integrity check of the tendons (MIRA-Ultrasonic shear-wave tomography, Impact echo)
  - Location of tendons (ground-penetrating radar)
  - Crack depth estimation

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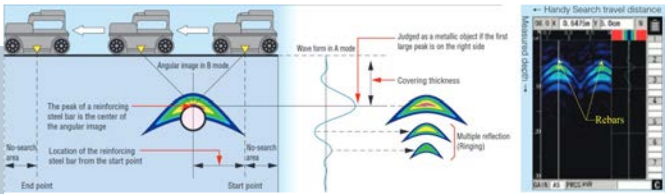
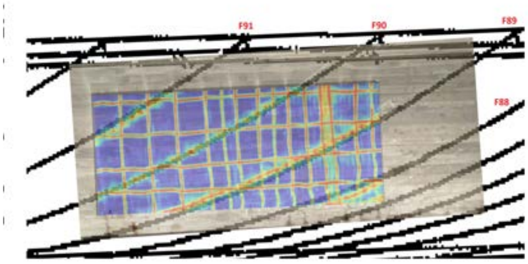
Non-destructive testing of Kalix Bridge

- Ground penetrating radar (Surface reinforcement + depth reinforcement/tendons)
  - Line scans and area scans performed







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Future work

FOI BBT			SBUF
2021-2022 Phase 1	2022-2023 (Phase 2)	2024-2025 (Phase 3)	2021-2022
Data collection	Data analysis	Data evaluation	
• Proof loading • Structural heath monitoring • Non-Destructive Testing	• Analysis of results • Laboratory testing • Forensic investigation on removed parts of the bridge	• Technology Readiness Levels (TRLs) • Recommendations	Demolition

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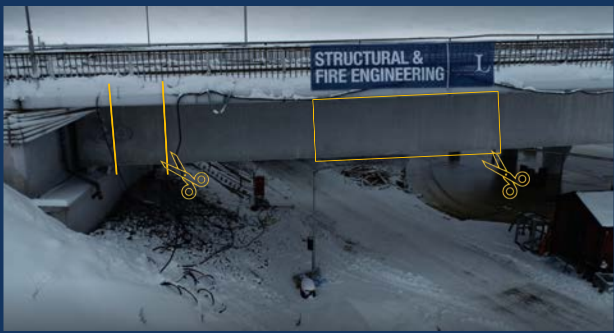
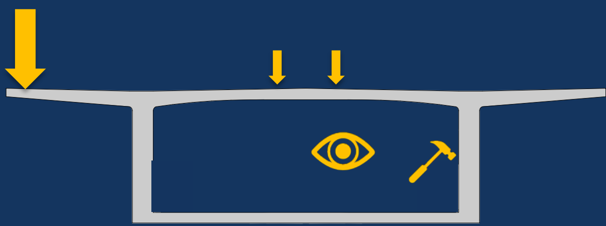
Future work



- Material samples (cores and reinforcement)
- Section cutting and transporting to LTU, approx. 40 tones
- Small size cuts (2x2m)
- Test prestressed cantilever
- Measure prestressed forces



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Events and dissemination

- Final project workshop: 8^{th} of June, Luleå (potential site visit to Kalix)
- IABSE – Prague - May
- IABMAS – Barcelona – July
- NCR – Stockholm – August
- IABSE – Nanjing – September

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https://www.linkedin.com/company/byggkonstruktion

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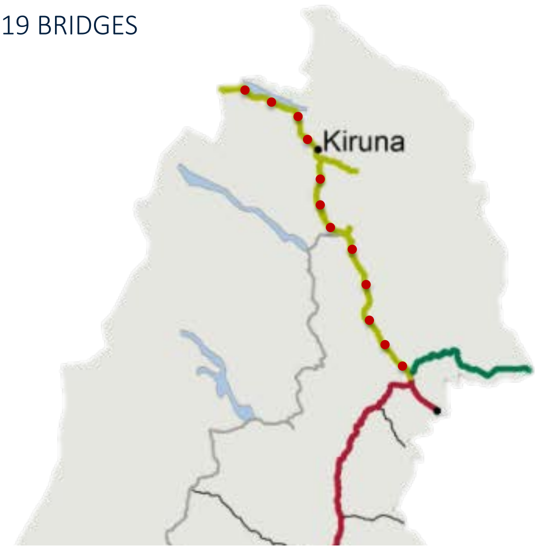
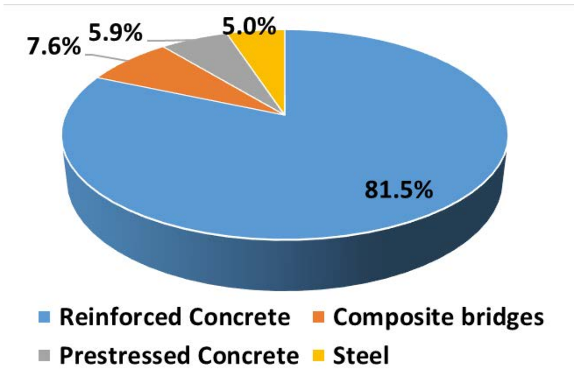
Bridges on the Iron Ore Line ?

- 119 BRIDGES





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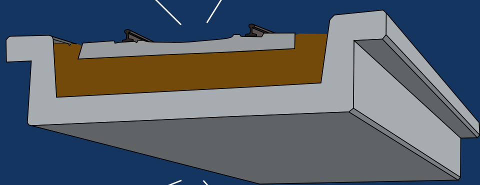
Trough Bridges on the Iron Ore Line

Around 50% of the total railway bridge population on the Iron Ore line

Average age: 48.5 years old



Average span length: 5.54 m

Average total structure width: 4.5 m

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What if ?

We could tell how much they hold and for how long ?

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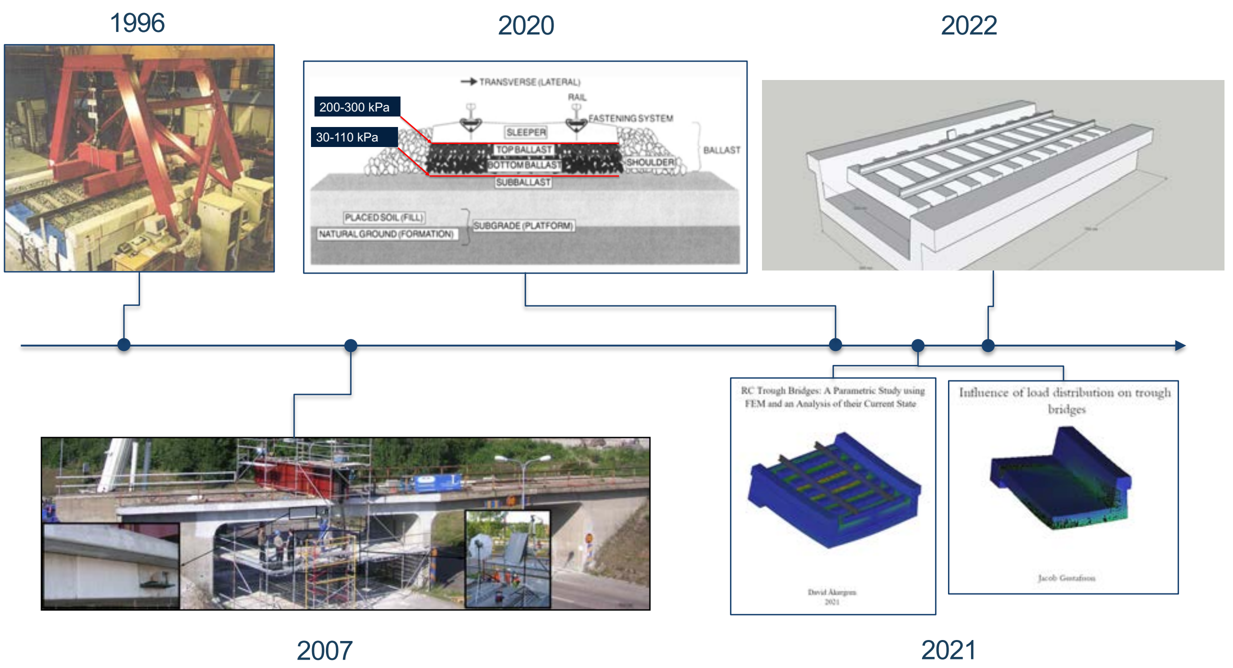

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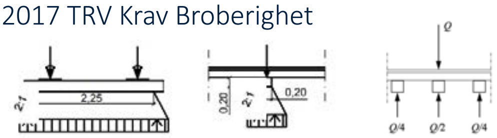
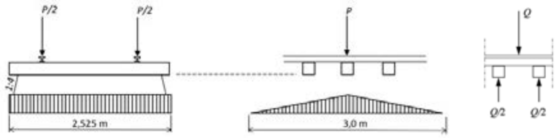
Objectives

1. **Measure the pressure distribution**

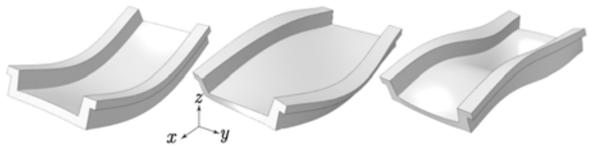
2017 TRV Krav Broberighet



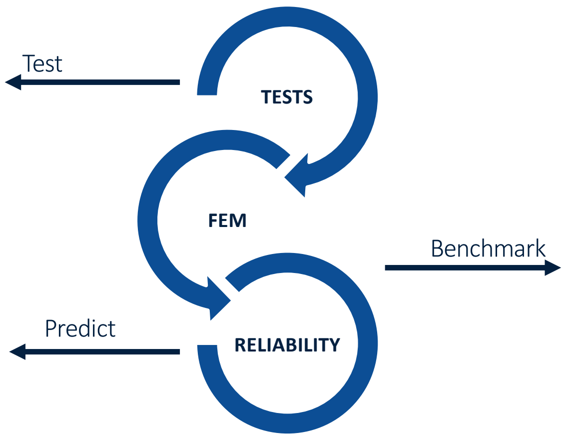
2019 TRV Krav Brober (EC1-2)

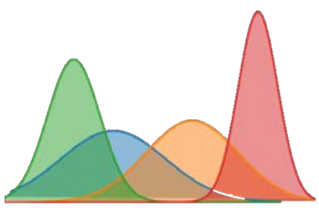


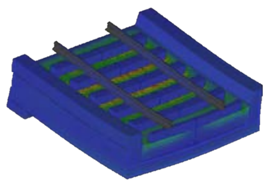
2. **Characterize the dynamic behavior**



How?







The bridges

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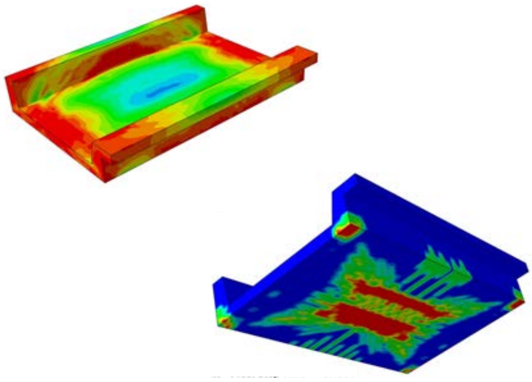
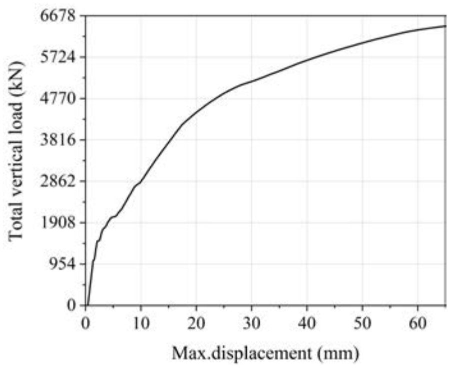
ULS estimates





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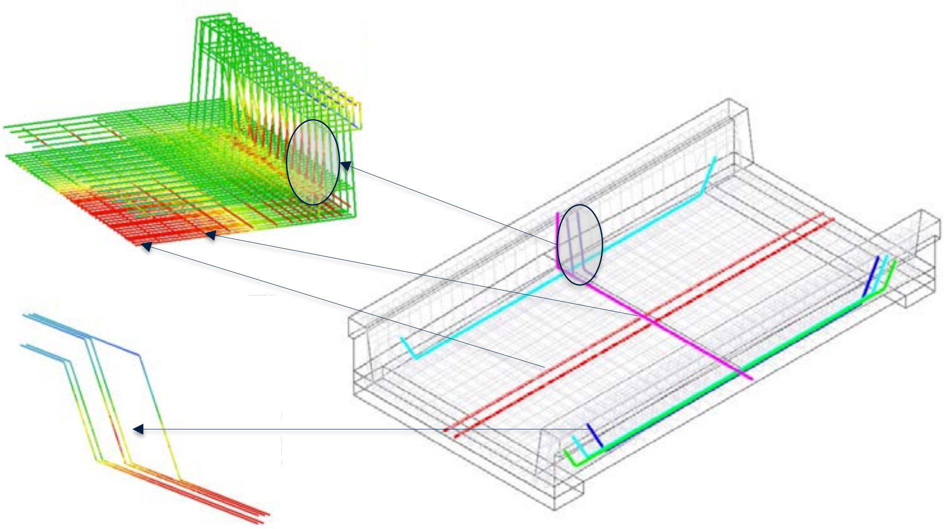
Instrumentation: Fiber Optic Sensors (FOS)



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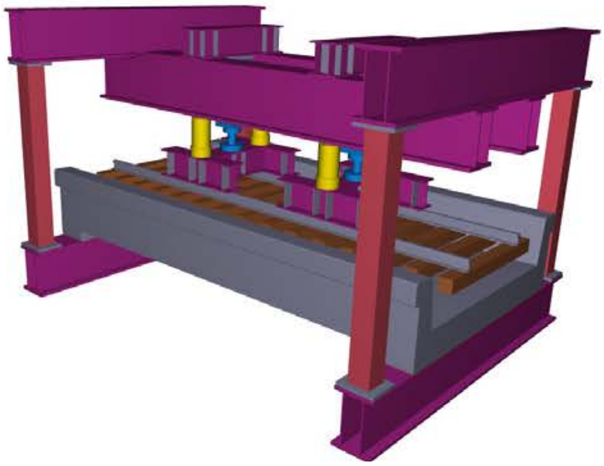
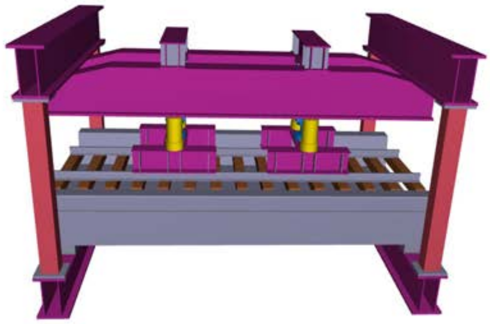
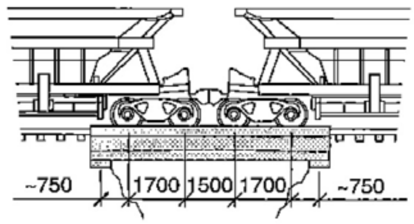
Test setup

1. Loading frame – static & dynamic up to 800 t
2. Bridge - ballast – sleepers – rail – boogie







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IABMAS Technical Committee on Bridge Load Testing

Field testing of a full-scale riveted railway bridge removed from service

Dr Boulent Imam

Department of Civil and Environmental Engineering
University of Surrey, UK

b.imam@surrey.ac.uk

Project Objectives

- Understand U-frame action on metallic riveted railway bridges (especially with offset stiffeners) and factors affecting it
- Assess fatigue criticality of double-angle riveted connections and developed advanced assessment methods
- Contribute to updating of metallic railway bridge rules for the assessment of existing bridges
- Partners include Mott MacDonald, James Fisher & MISTRAS

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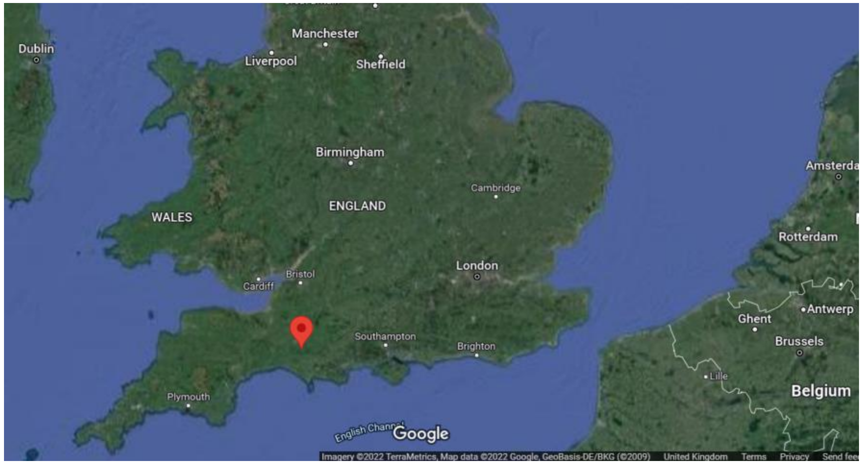
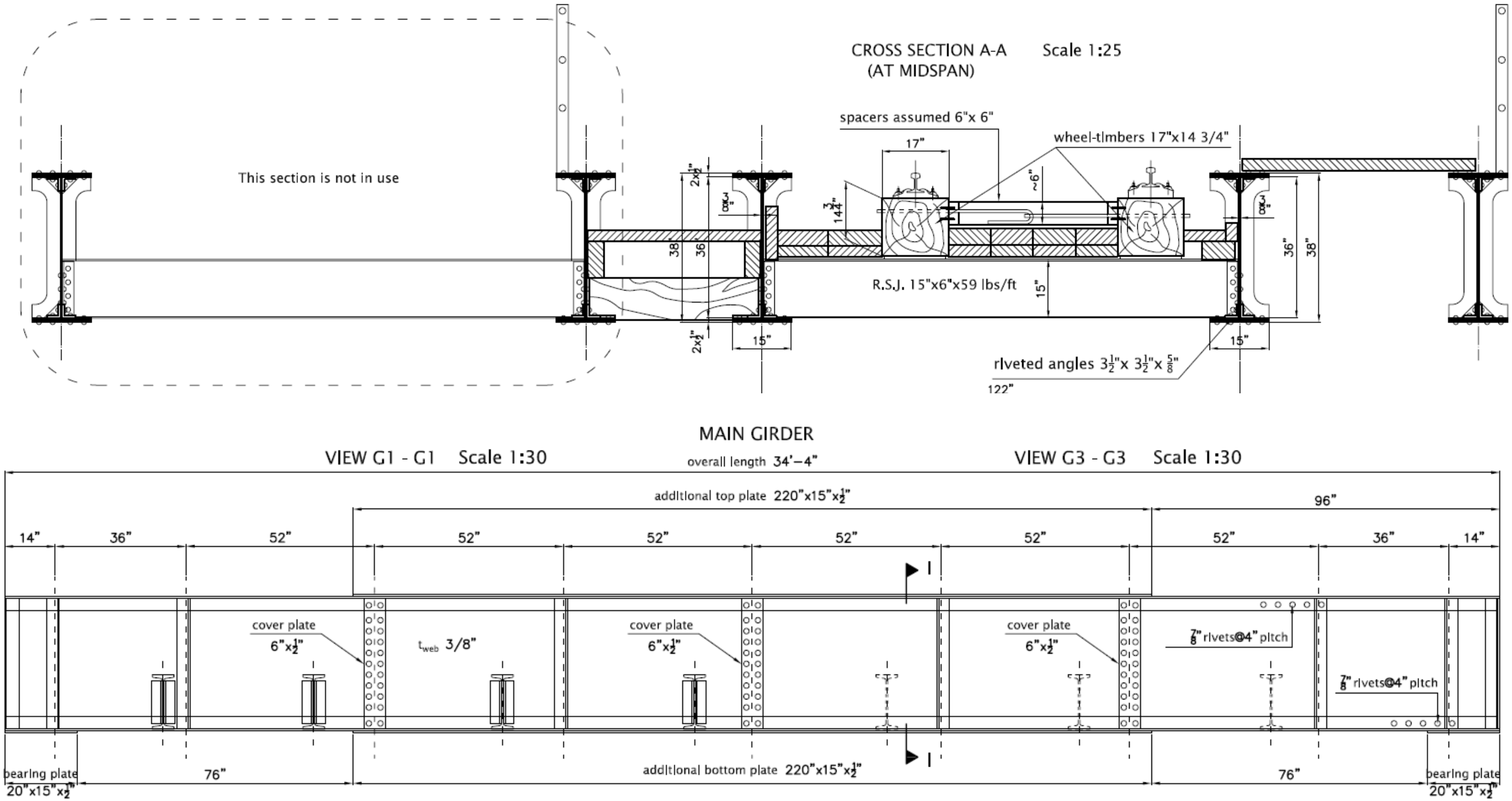
Yetminster Bridge

- Located in Dorset, SW UK
- Constructed in 1892
- Removed from service in 2020
- Riveted metallic bridge
- Wrought-iron main girders
- Old mild steel cross-girders
- Timber girders carrying railway line
- Approximately 9.4m span
- Offset stiffeners
- Transported to University of Surrey as a whole for testing



Yetminster Bridge

Yetminster Bridge



Testing Regime

- In-service monitoring before removal
  Deflections, accelerations
- Controlled field testing of entire bridge at University of Surrey
  Deflections, strains
- Modal testing of entire bridge at University of Surrey
  Accelerations
- Cutting bridge into components
- Static testing of components to understand U-frame action
- Fatigue testing of components to obtain fatigue life
- Small-scale tests for mechanical property characterisation

In-Service Monitoring

- Carried out before the bridge was removed from service by James Fisher
- 1 iMetrum Video Gauge (viewing 23 targets on the bridge)
- 6 single axis accelerometers
- Focus on behaviour of off-set U-frames
- Measurements under 4 passenger train passages

In-Service Monitoring

- 1 iMetrum Video Gauge (viewing 23 targets on the bridge)

IABMAS

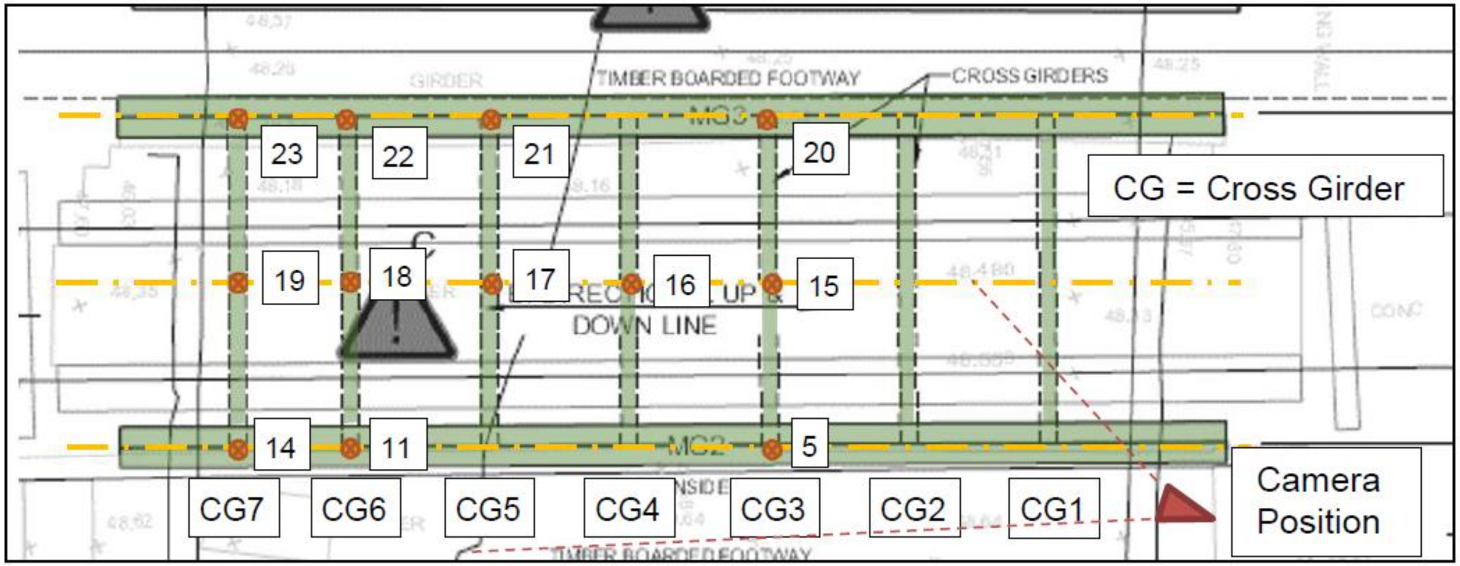
James Fisher
Testing Services

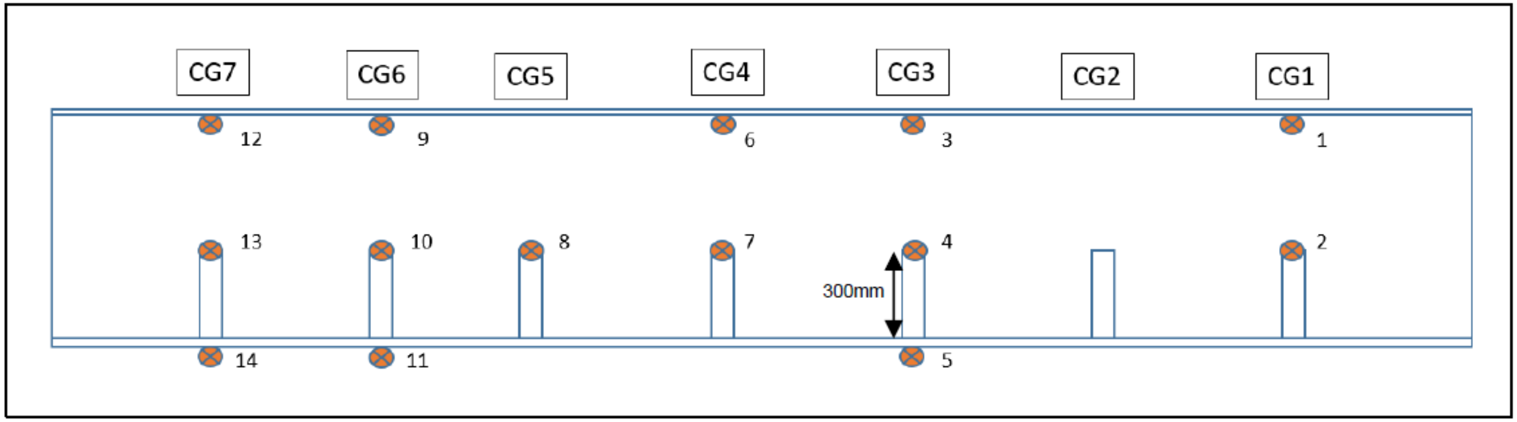
Fisher

UNIVERSITY OF SURREY

In-Service Monitoring

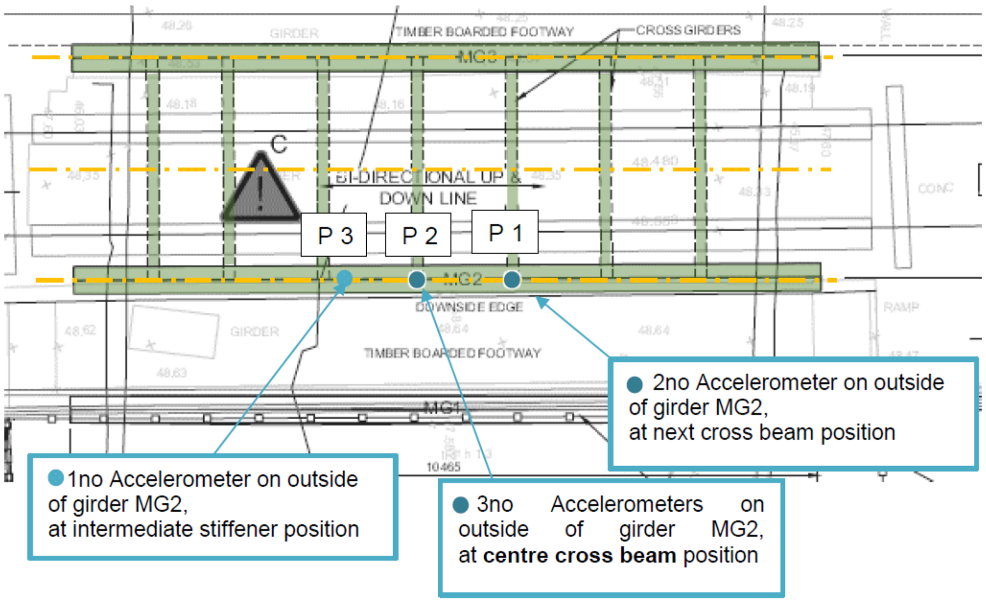
- 1 iMetrum Video Gauge (viewing 23 targets on the bridge)

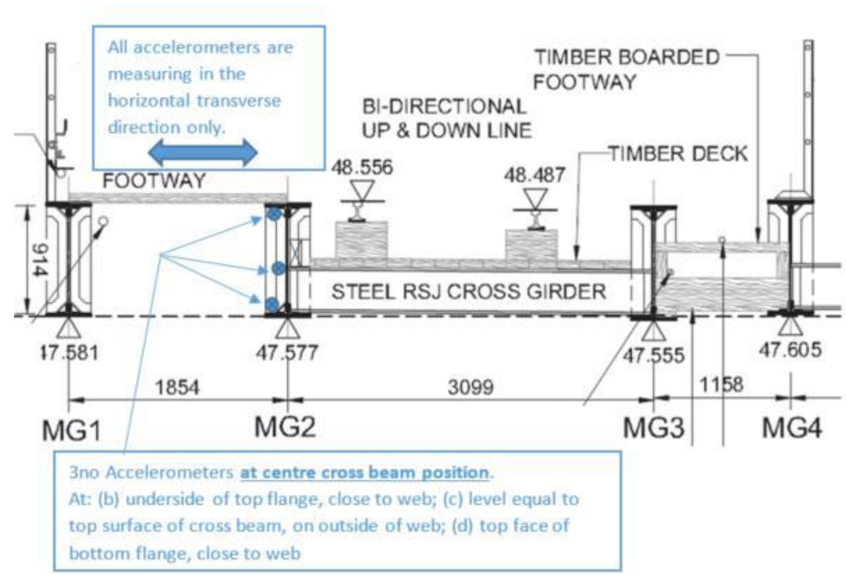




In-Service Monitoring

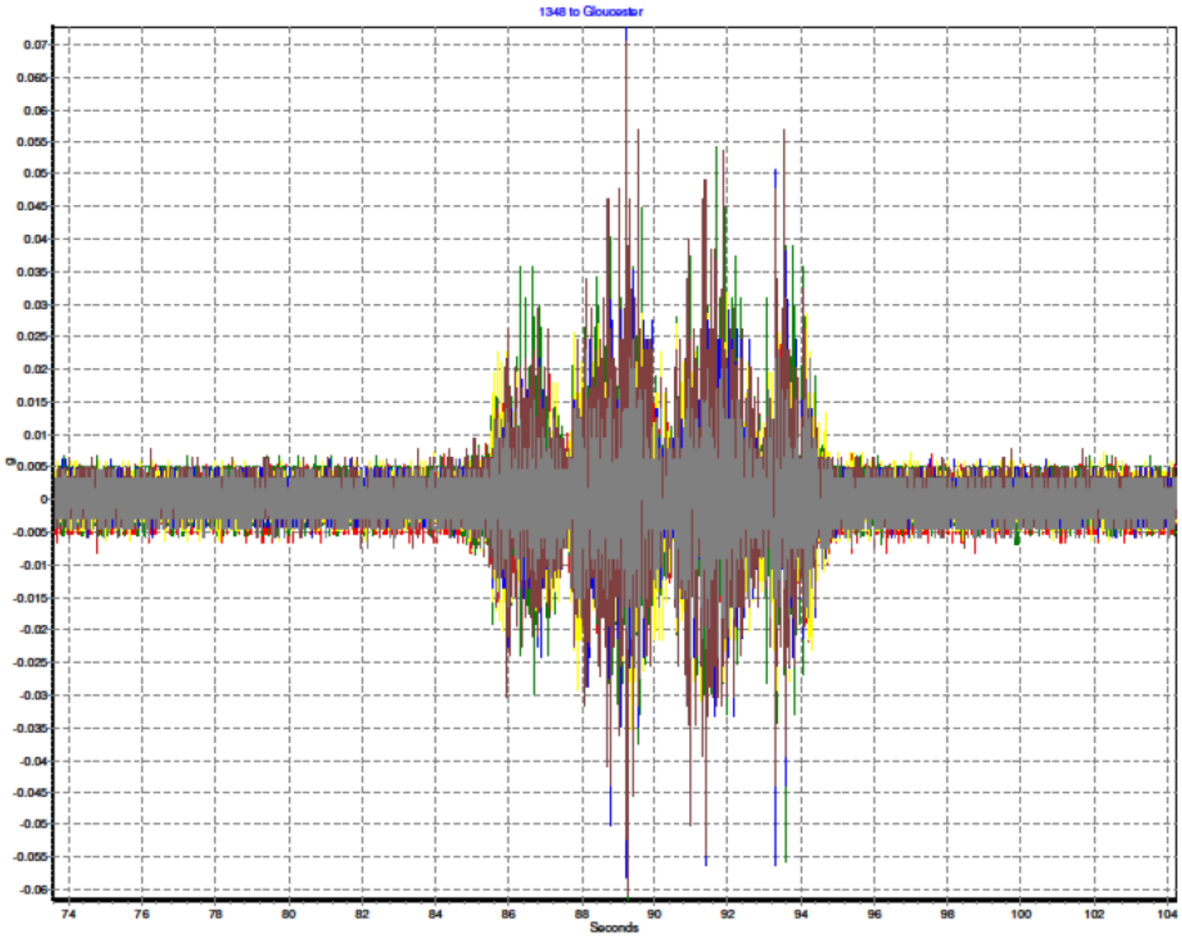
- 6 single axis accelerometers





In-Service Monitoring

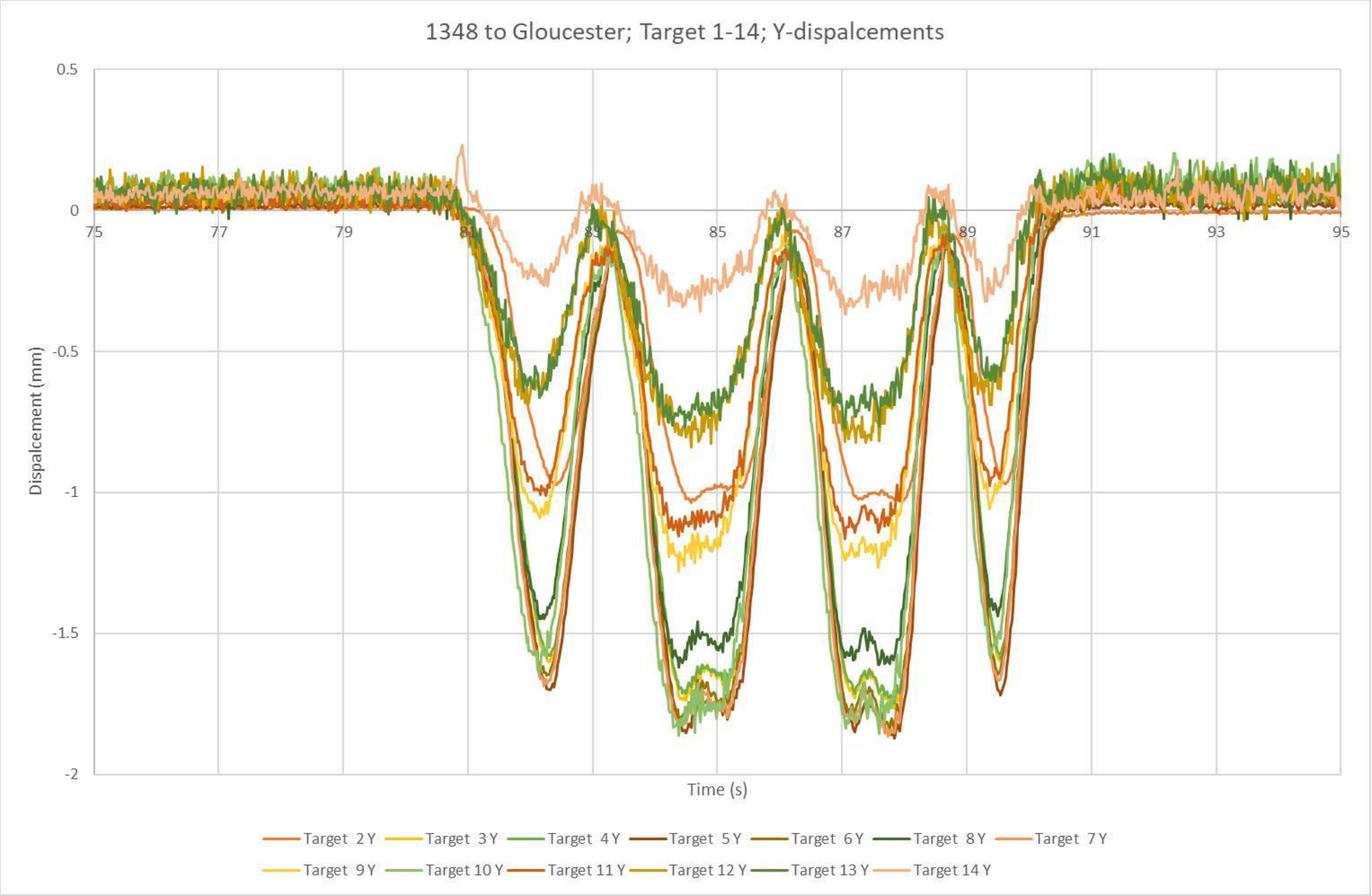
- Acceleration measurements



James Fisher
Testing Services

In-Service Monitoring

- Displacement measurements



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James Fisher Testing Services

Fisher

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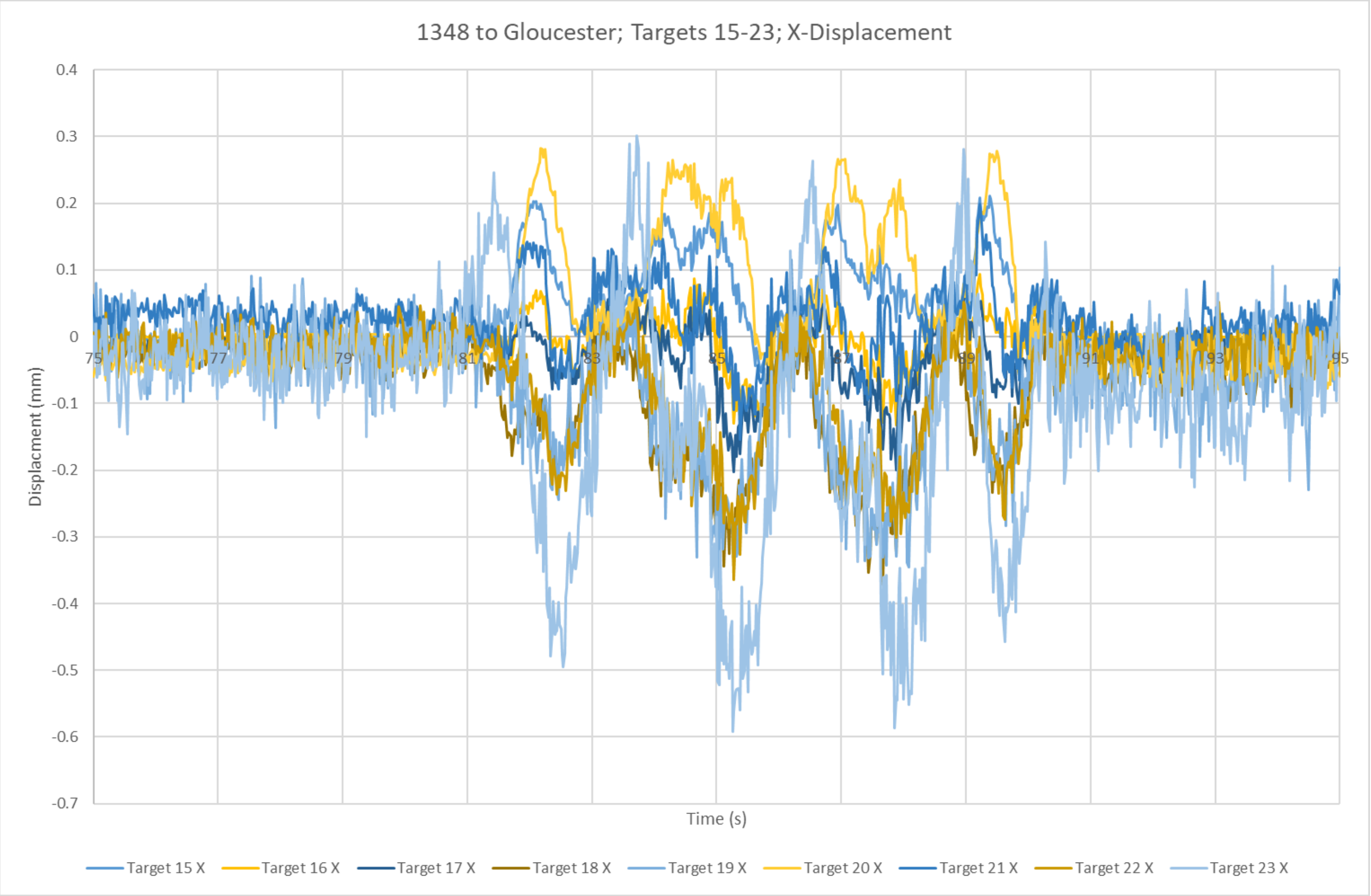
In-Service Monitoring

- Displacement measurements



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James Fisher Testing Services

Fisher

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Bridge Removal

- Removed from service in February 2020 and replaced with new bridge

Bridge Delivery to UoS

Bridge Delivery to UoS

- Understanding concrete surface bearing strength and pull-out strength

Bridge Delivery to UoS

Bridge Delivery to UoS

Bridge Delivery to UoS

- Bridge unloaded on concrete surface for the field testing

Bridge Delivery to UoS

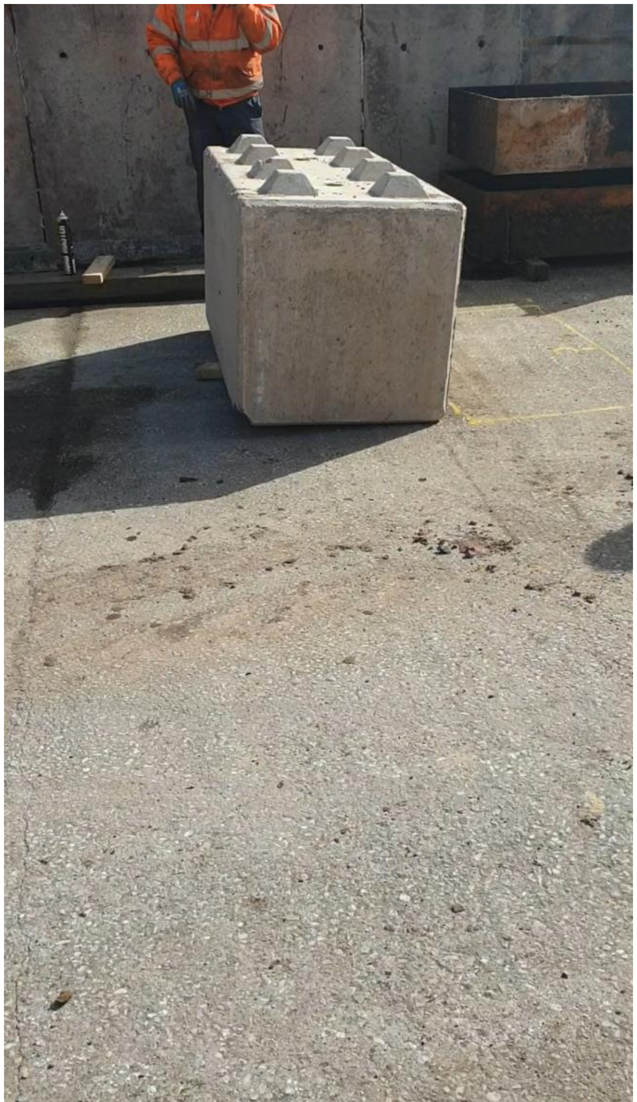
- Bearing plates retained for seating the bridge on supports

Bridge Delivery to UoS

- Preparing the bridge supports

Bridge Delivery to UoS

- Preparing the bridge supports



Bridge Delivery to UoS

- Lifting the bridge to position

Bridge Delivery to UoS

- Lifting the bridge to position

Bridge Delivery to UoS

- Bridge supports

Bridge Delivery to UoS

- Bridge supports

Bridge Delivery to UoS

- Bridge supports

Bridge Delivery to UoS

- Bridge supports

Bridge Delivery to UoS

- Bridge deck

Bridge Delivery to UoS

- Bridge deck

Bridge Delivery to UoS

- Bridge deck

Bridge Delivery to UoS

- Timber girder pre-camber

Bridge Delivery to UoS

- Offset stiffeners

Bridge Delivery to UoS

- Double-angle riveted connections

Bridge Delivery to UoS

- Bridge deck

Bridge Field Testing

- Reaction frame construction

Bridge Field Testing

- Reaction frame construction

Bridge Field Testing

- Reaction frame construction

Bridge Field Testing

- Reaction frame construction

Bridge Field Testing

- Reaction frame construction

Bridge Field Testing

- Instrumentation – 39 LVDTs for horizontal and vertical displacements

Bridge Field Testing

- Instrumentation – 39 LVDTs for horizontal and vertical displacements

Bridge Field Testing

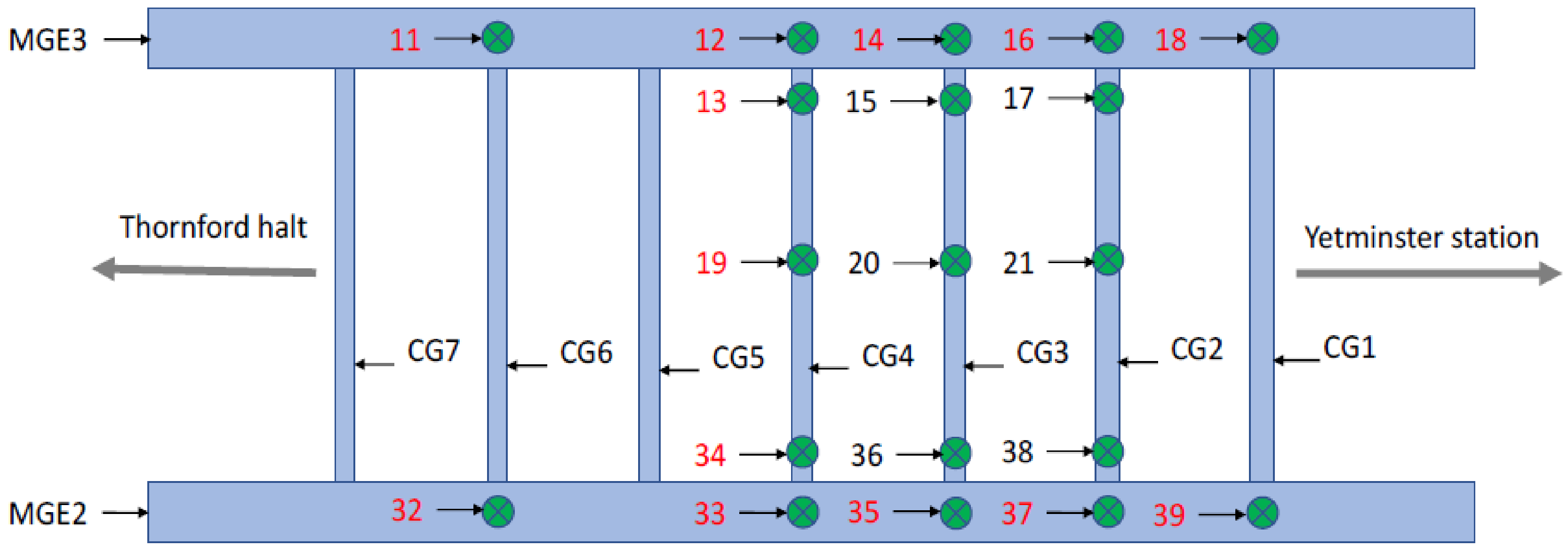
- Instrumentation – 39 LVDTs for horizontal and vertical displacements

Bridge Field Testing

- Instrumentation – 39 LVDTs for horizontal and vertical displacements

Bridge Field Testing

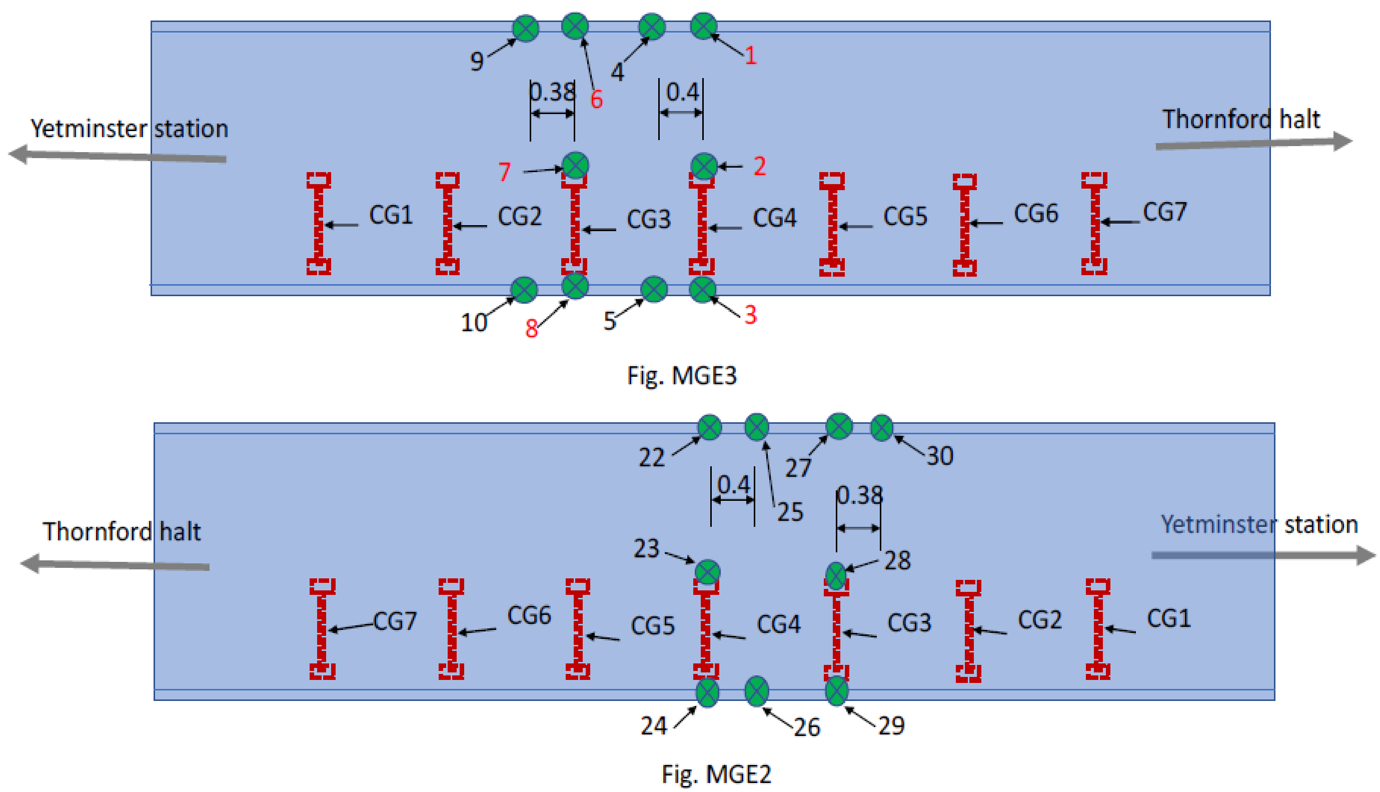
- Instrumentation – 39 LVDTs for horizontal and vertical displacements



LVDT locations for vertical displacement measurement.

Bridge Field Testing

- Instrumentation – 39 LVDTs for horizontal and vertical displacements



LVDT locations for horizontal displacement measurement (all dimensions in m).

Bridge Field Testing

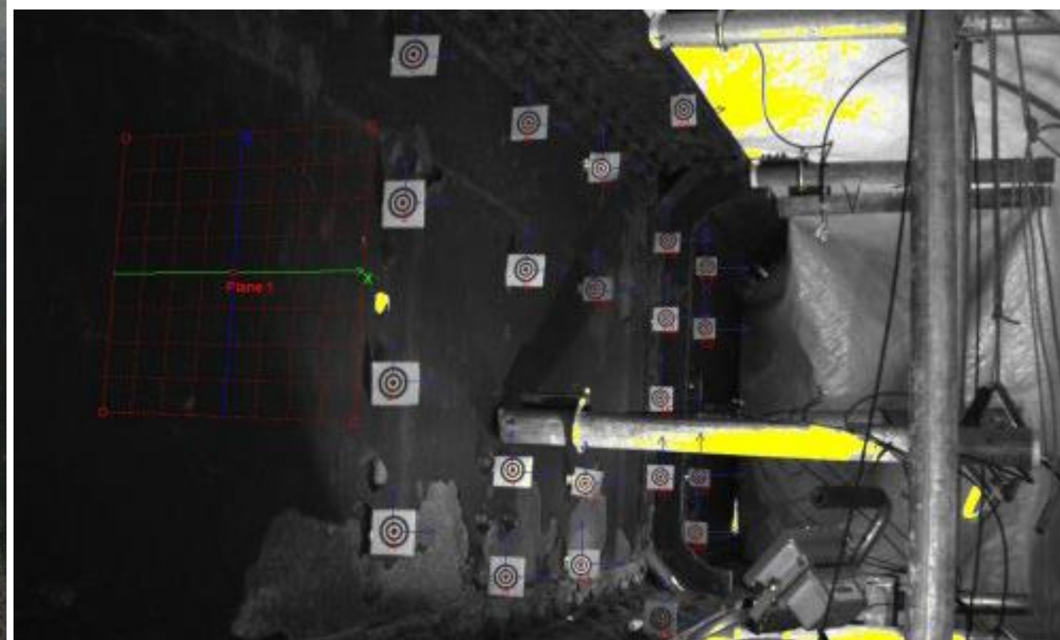
- Instrumentation – 30 strain gauges (linear + rosettes)

Bridge Field Testing

- Instrumentation – 30 strain gauges (linear + rosettes)

Bridge Field Testing

- iMetrum Video Gauge



Bridge Field Testing

- 4 Load cells & hydraulic jacks

Bridge Field Testing

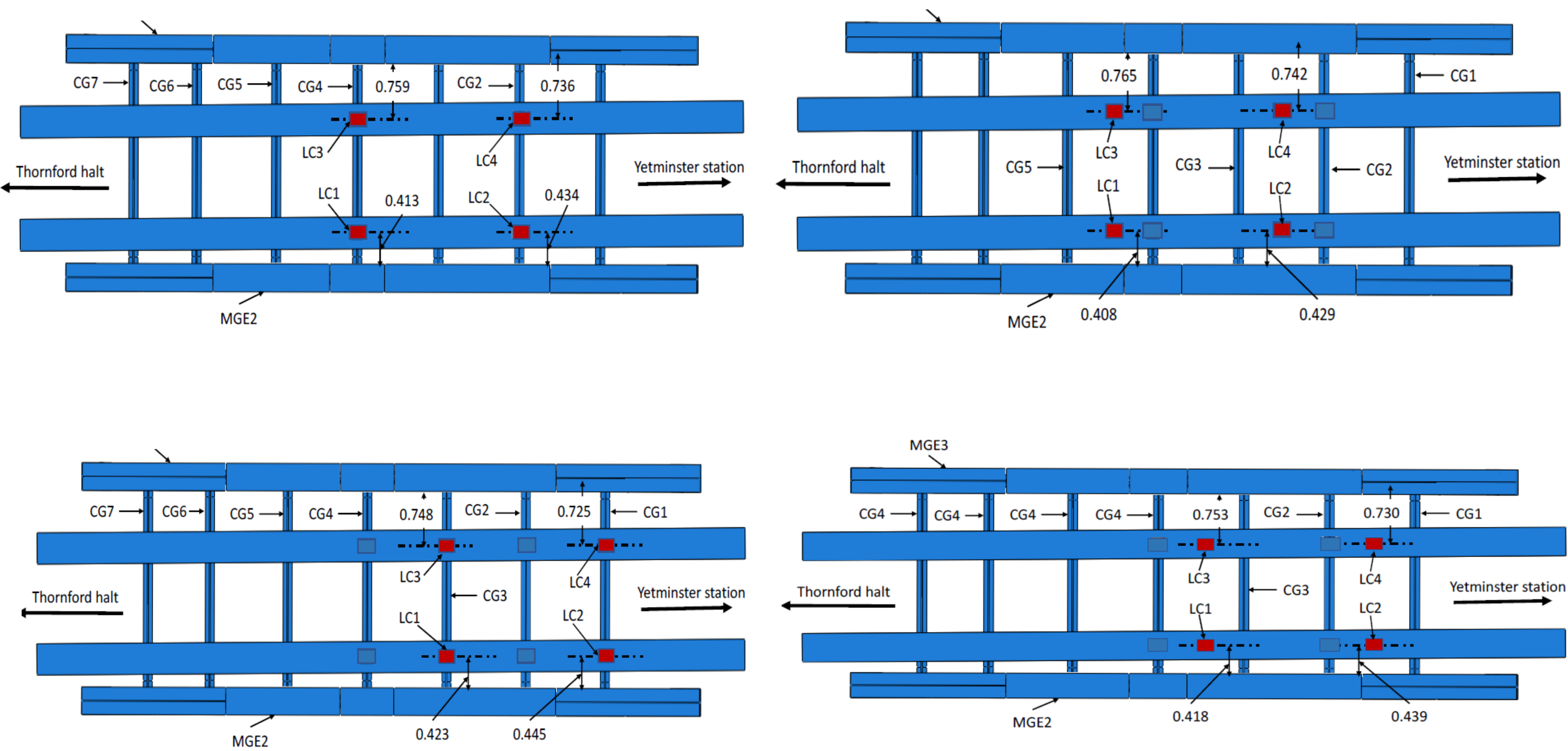
- 4 Load cells & hydraulic jacks

Bridge Field Testing

- Field testing was carried out over 3 days
- Load cells and hydraulic jacks were placed on the timber girders.
- 4 loading scenarios representing different train positions
- Loading in 10kN increments, with a pause of 5 minutes between loadings to check for creep, up to 50 kN each
- Timbers girders subsequently removed to investigate load distribution

Bridge Field Testing

- Loadcases (with timber girders)



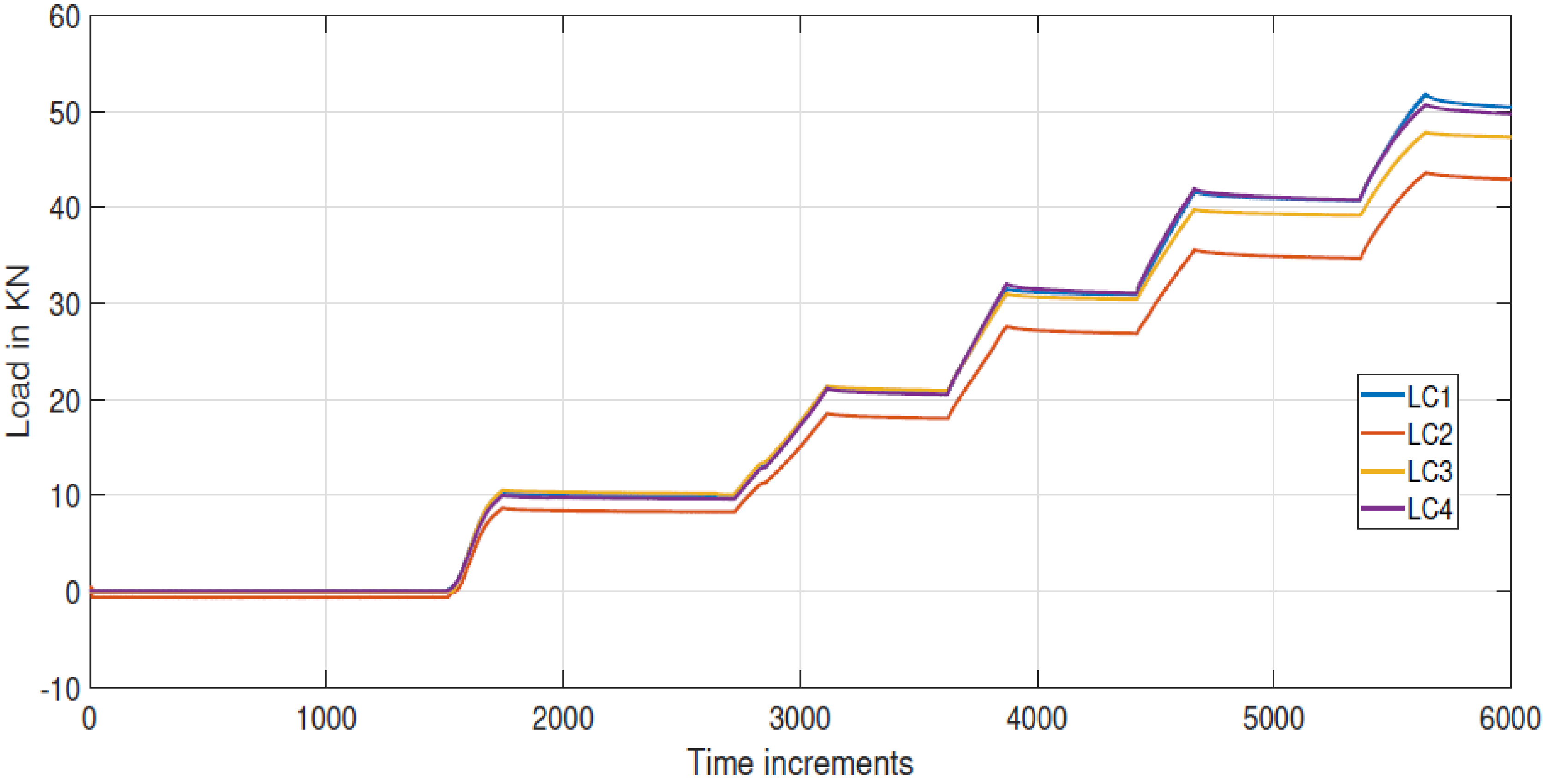
Bridge Field Testing

Some challenges encountered:

- Reaction plate breakage
- Hydraulic jack reaching full extension before full load
- Ground anchors slackening
- Unequal distribution of applied loads due to stiffness variation of the reaction frame

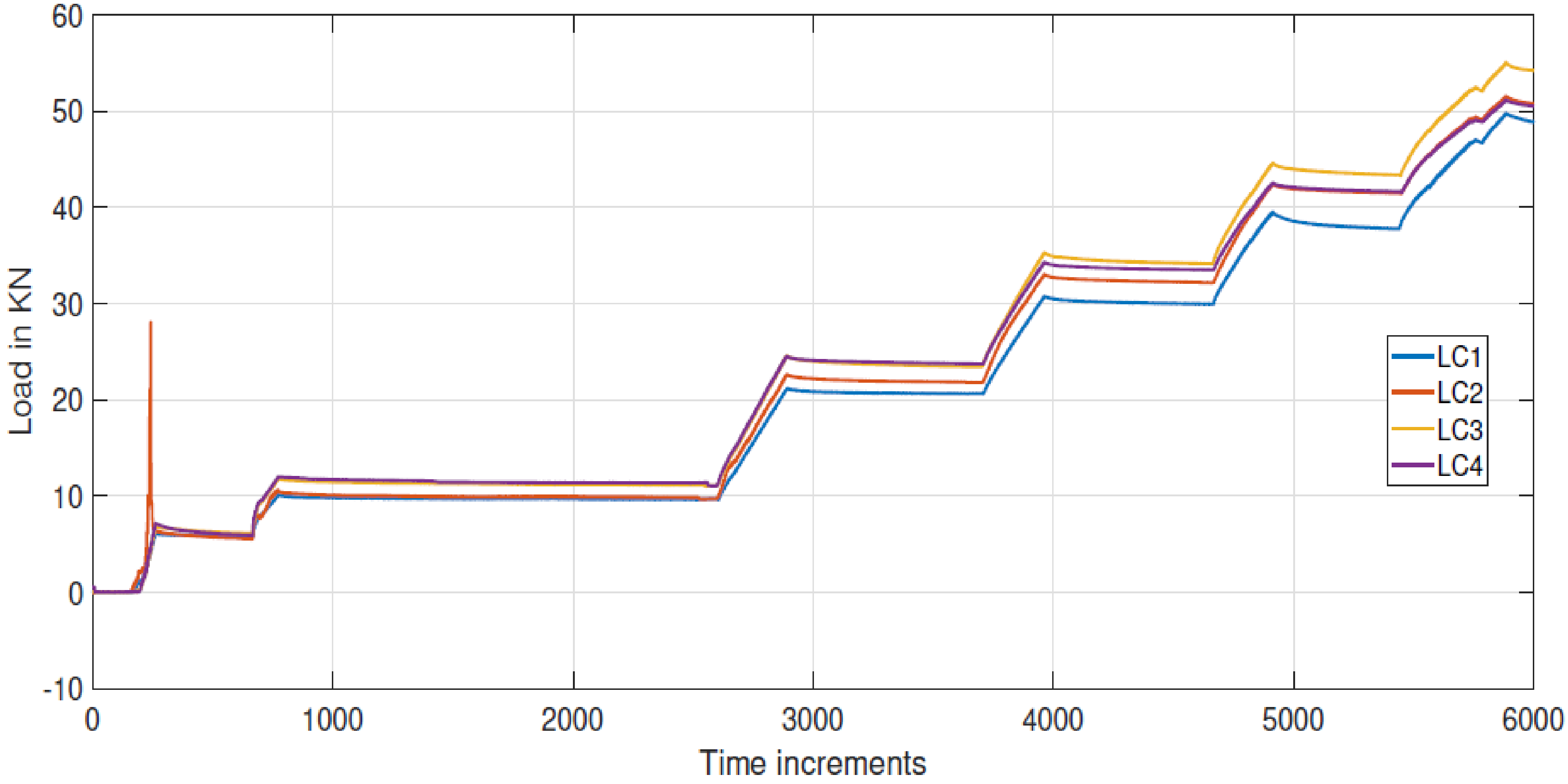
Bridge Field Testing

- Applied load time histories



Bridge Field Testing

- Applied load time histories



Bridge Field Testing

- Removal of timber girders

Bridge Field Testing

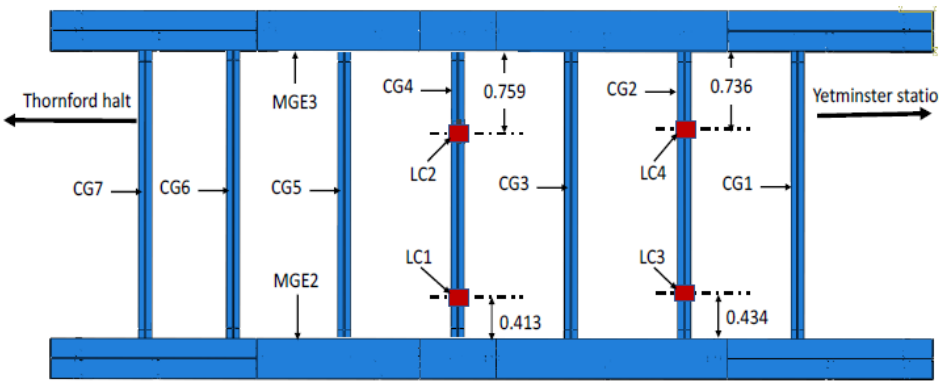
- Removal of timber girders

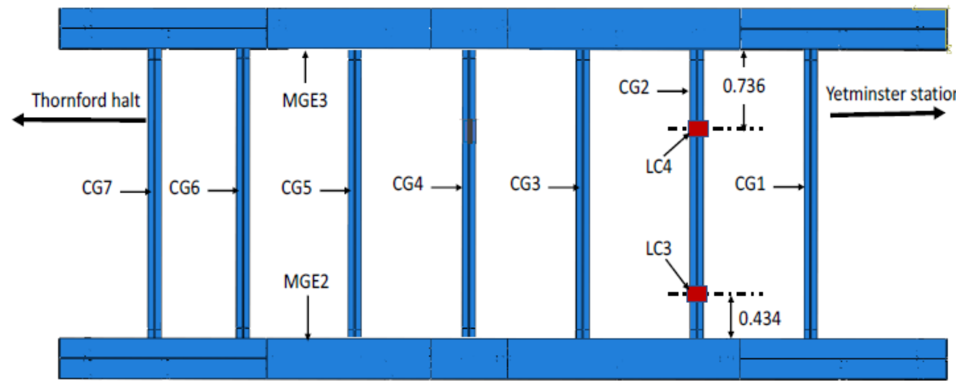
Bridge Field Testing

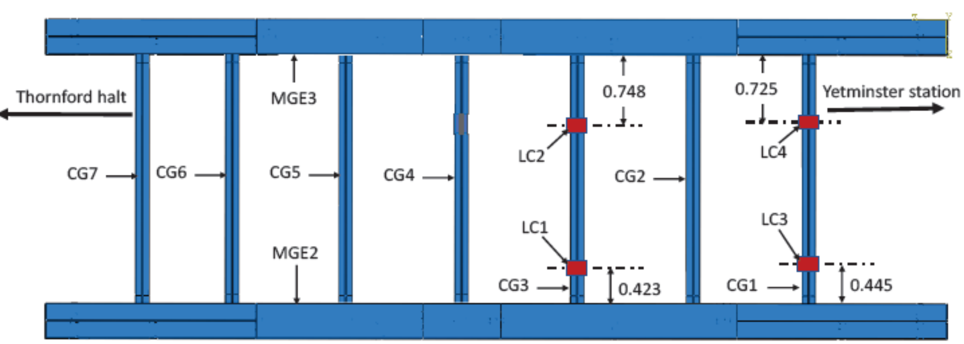
- Removal of timber girders

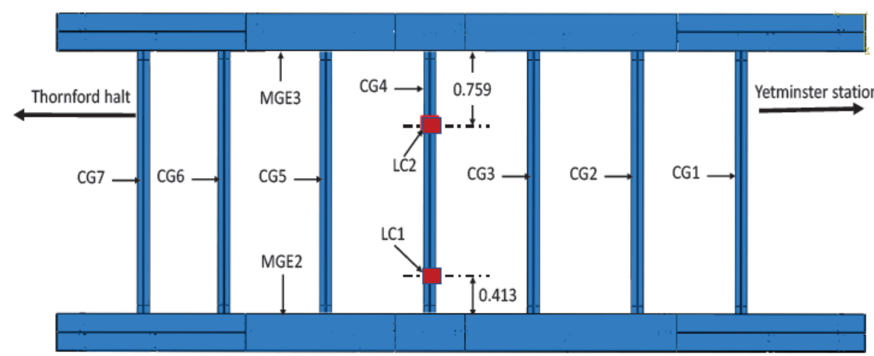
Bridge Field Testing

- Loadcases (without timber girders)



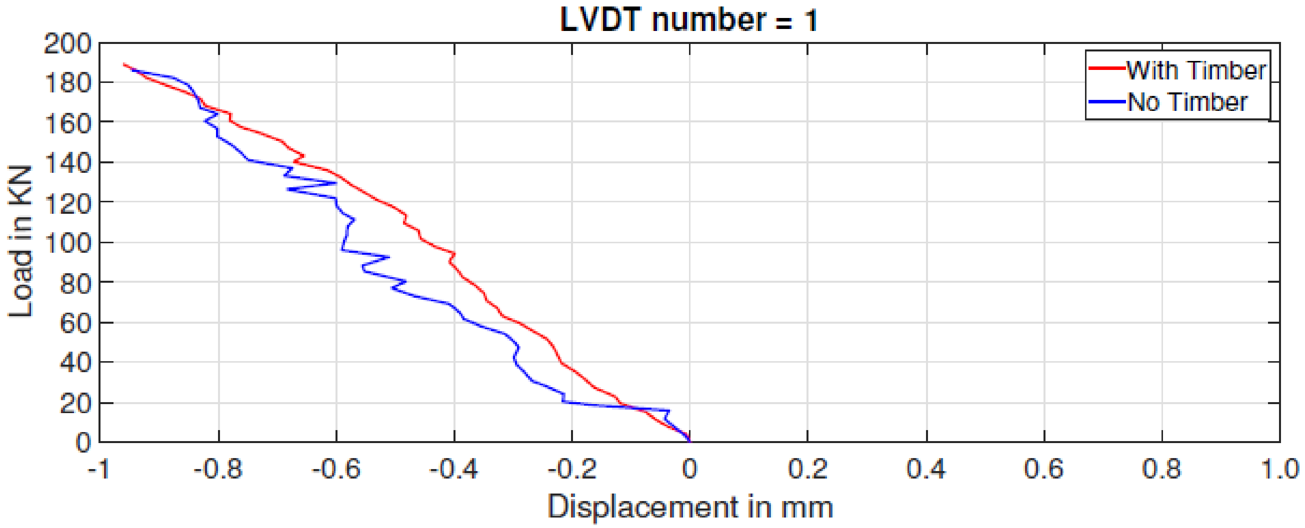


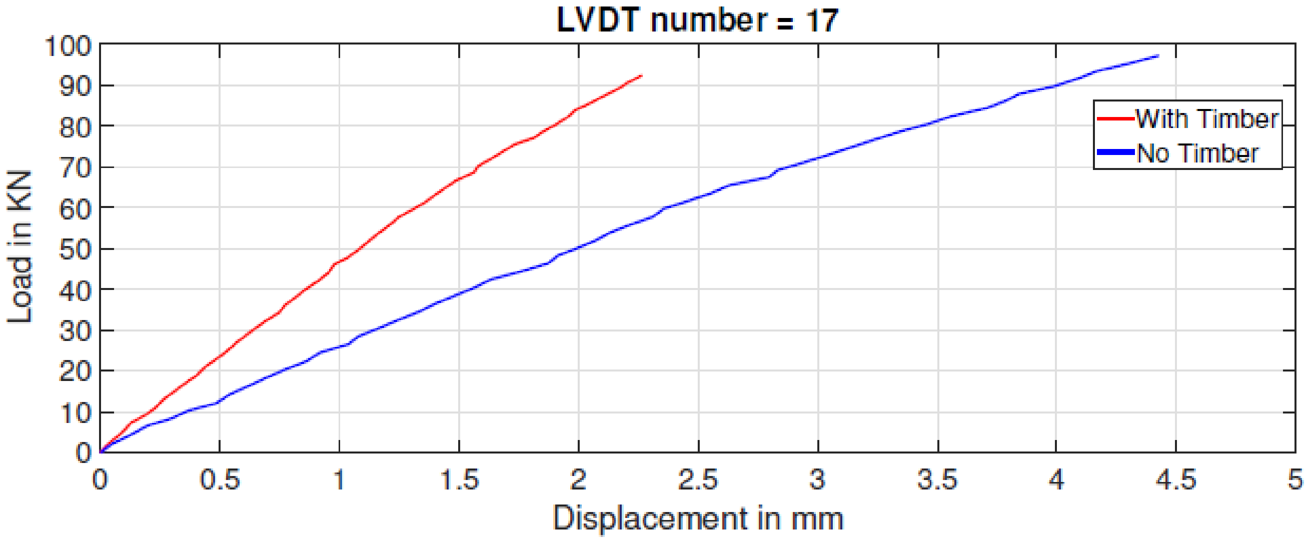




Bridge Field Testing

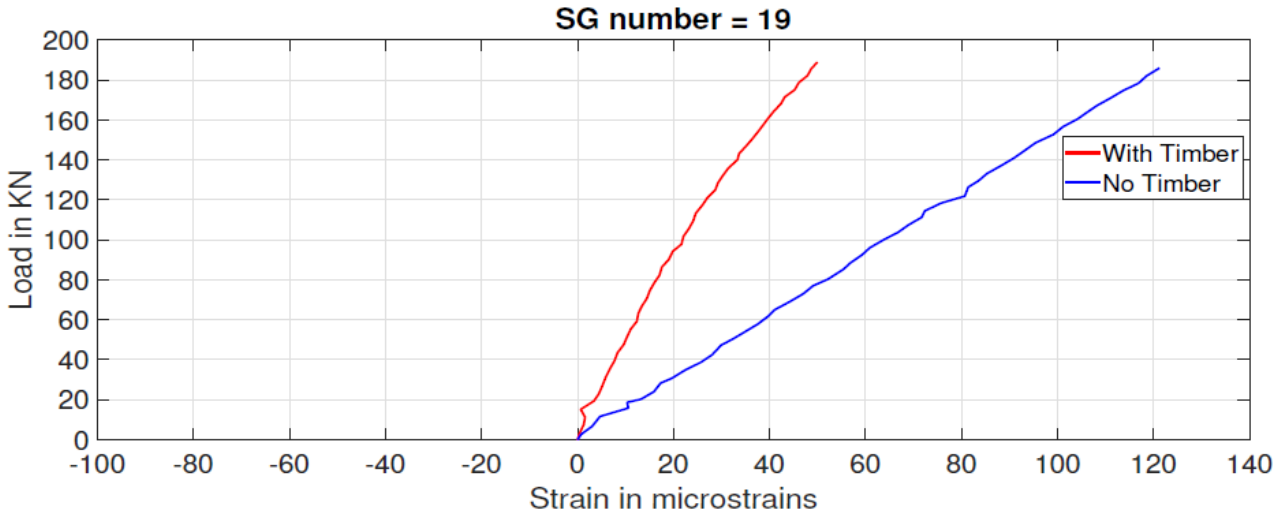
- Displacement measurements

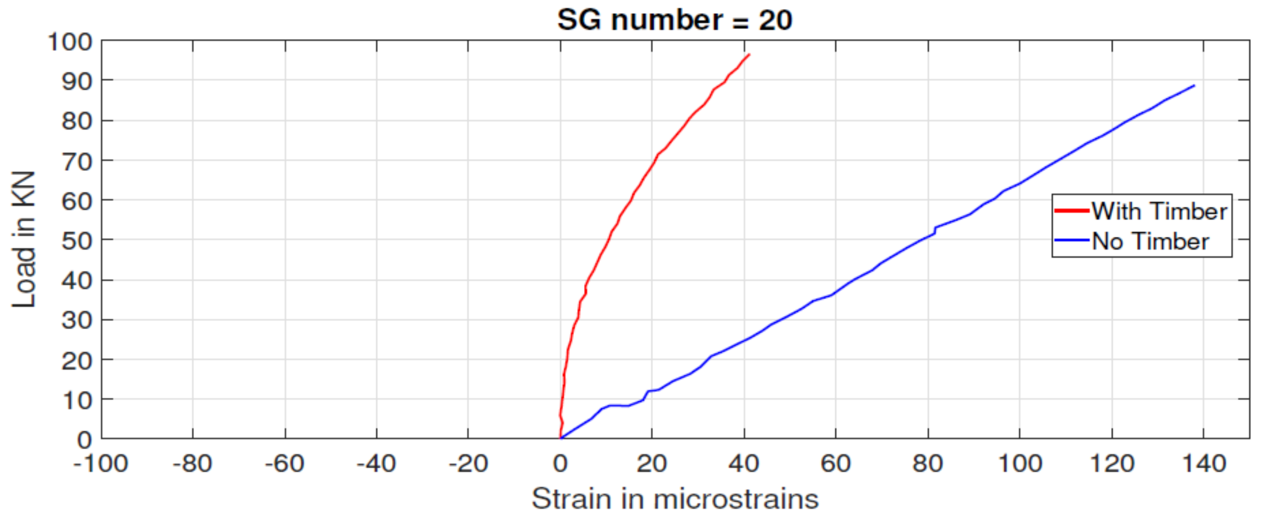




Bridge Field Testing

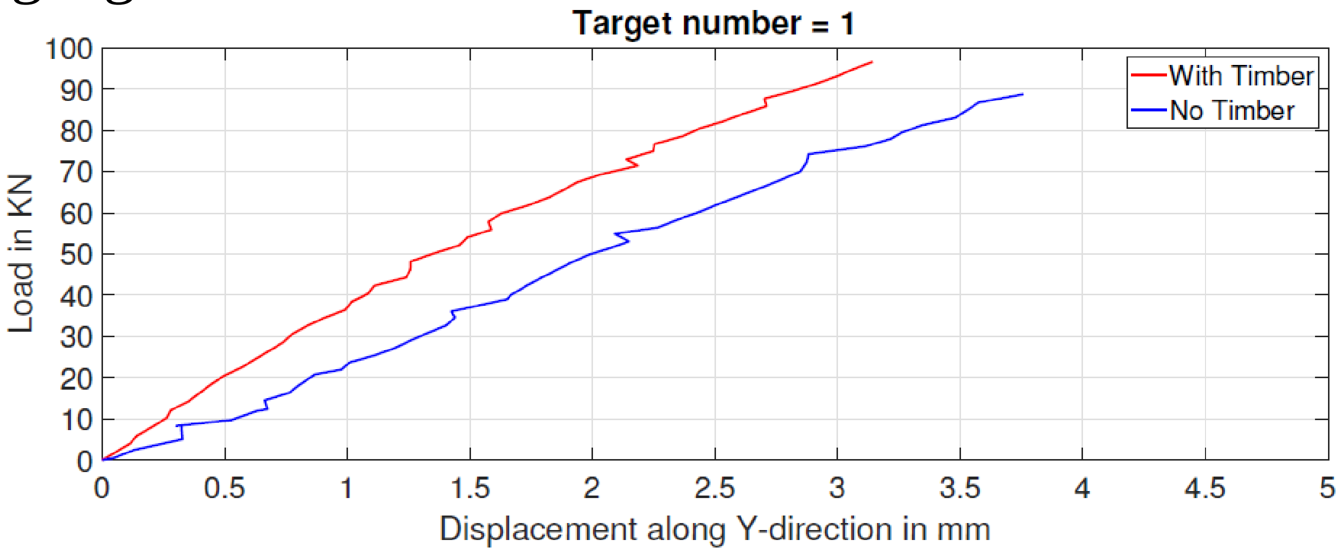
- Strain measurements

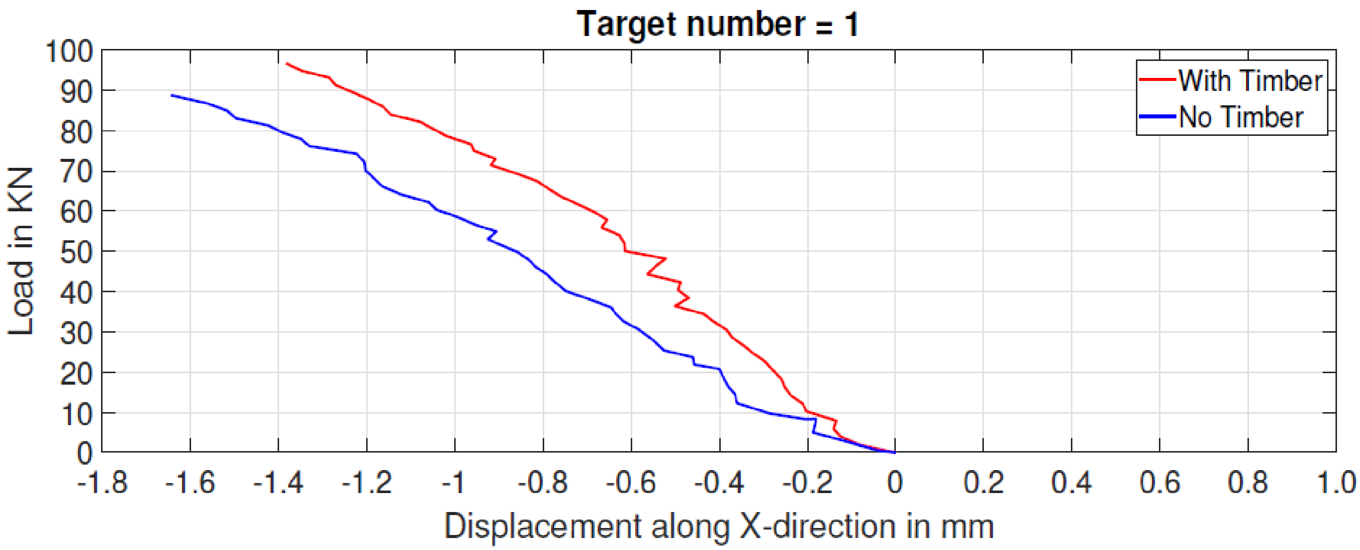




Bridge Field Testing

- Video gauge measurements

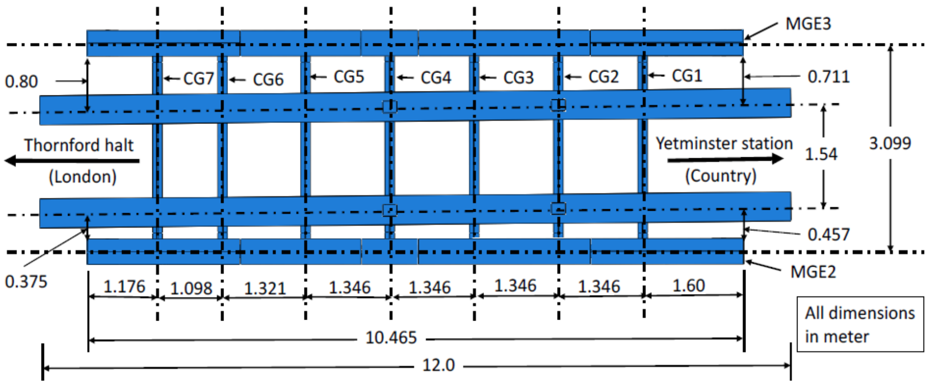




Bridge Field Testing

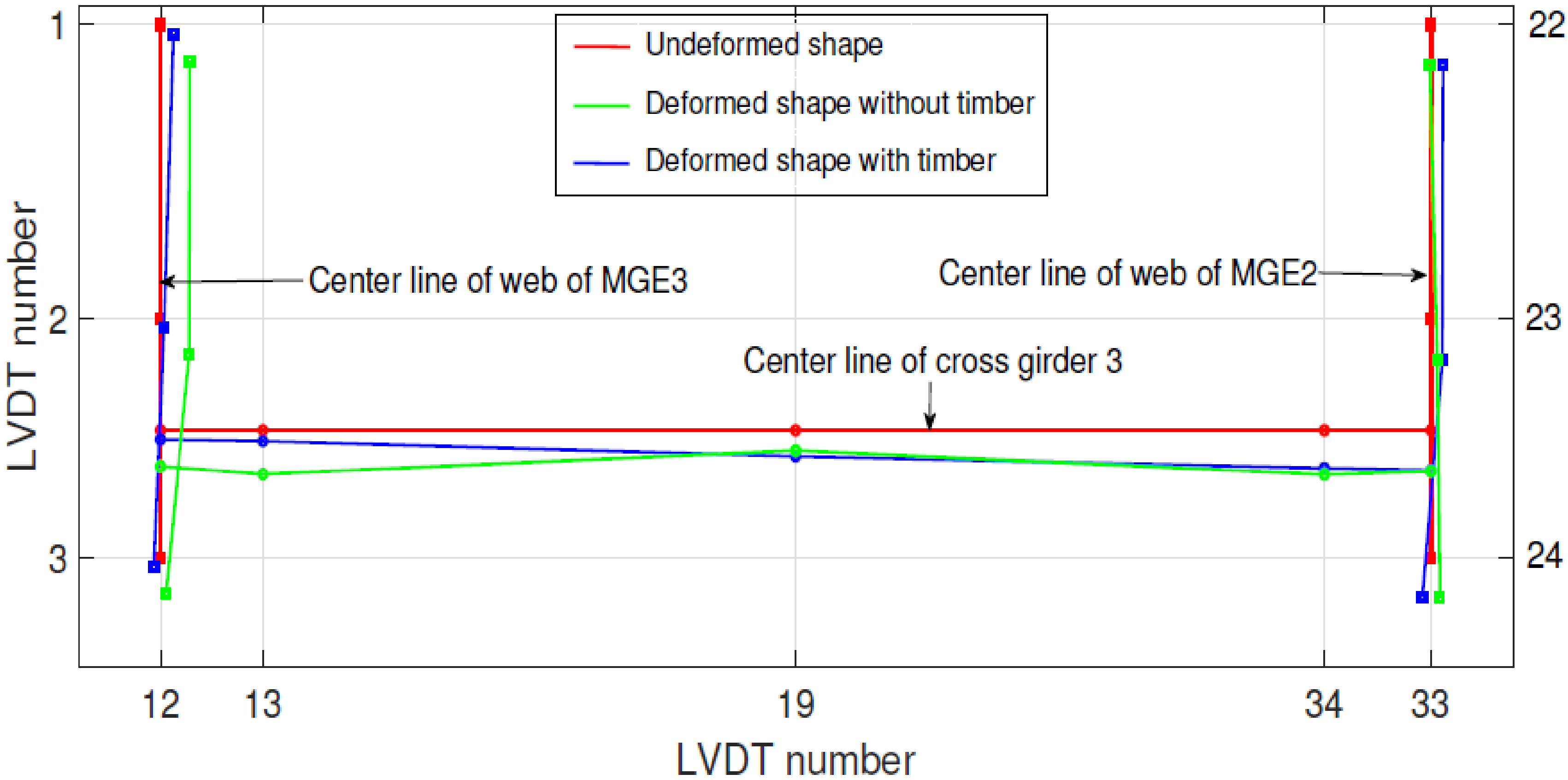
- Load distribution from timber girders

Loading identifier	Loading type	Strain in CG2 in microstrains	Strain in CG3 in microstrains	Strain in CG4 in microstrains
I	Loading scenario 8 (Two 50 KN loads on CG4 (without timber), Fig 1.13)	4	16	164
II	Loading scenario 5 (Two 50 KN loads on CG4 (with timber), Fig 1.10)	79	12	8
III	Loading scenario 6 (Two 50 KN loads on CG4 and two 50 KN loads on CG2 (without timber),Fig 1.11)	150	32	153
IV	Loading scenario 1 (Two 50 KN loads on CG4 and two 50 KN loads on CG2 (with timber), Fig 1.6)	115	78	42
V	Loading scenario 9 (Two 50 KN loads on CG3 and two 50 KN loads on CG1 (without timber), Fig 1.14)	22	143	5
VI	Loading scenario 2 (Two 50 KN loads on CG3 and two 50 KN loads on CG1 (with timber), Fig 1.7)	90	71	8
VII	Loading scenario 7 (Two 50 KN loads on CG2 (without timber), Fig 1.12)	153	15	2
VIII	Loading scenario 4 (Two 50 KN loads mid-length between CG4 and CG3 , and two 50 KN loads mid-length between CG2 and CG1 (with timber), Fig 1.9)	100	73	25



Bridge Field Testing

- U-frame behaviour



Bridge Blasting

- Removal of paint to better determine condition

Bridge Blasting

- Corrosion at connections

Bridge Blasting

- Corrosion on members

Bridge Blasting

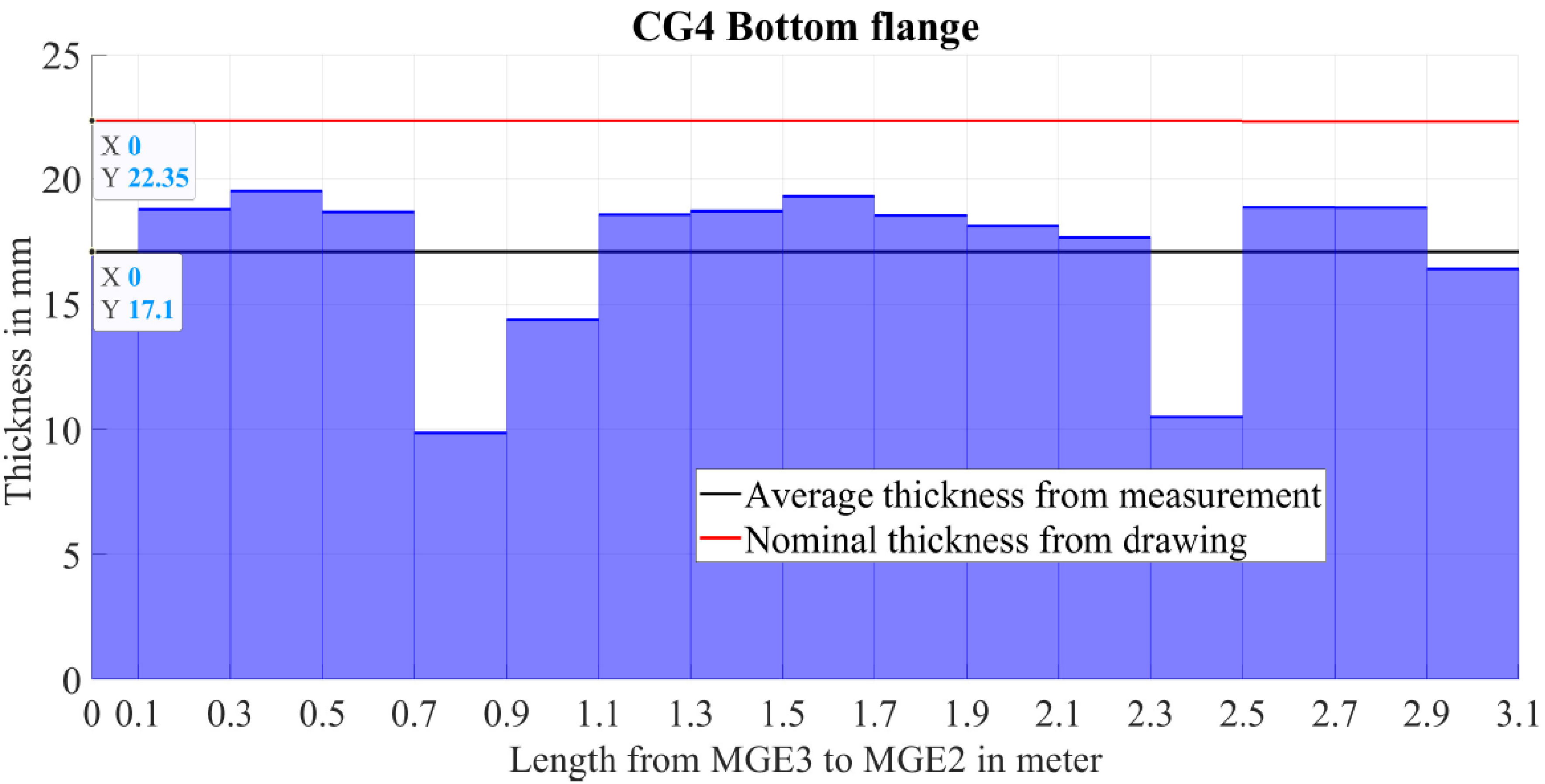
- Corrosion on members

Bridge Blasting

- Missing rivets

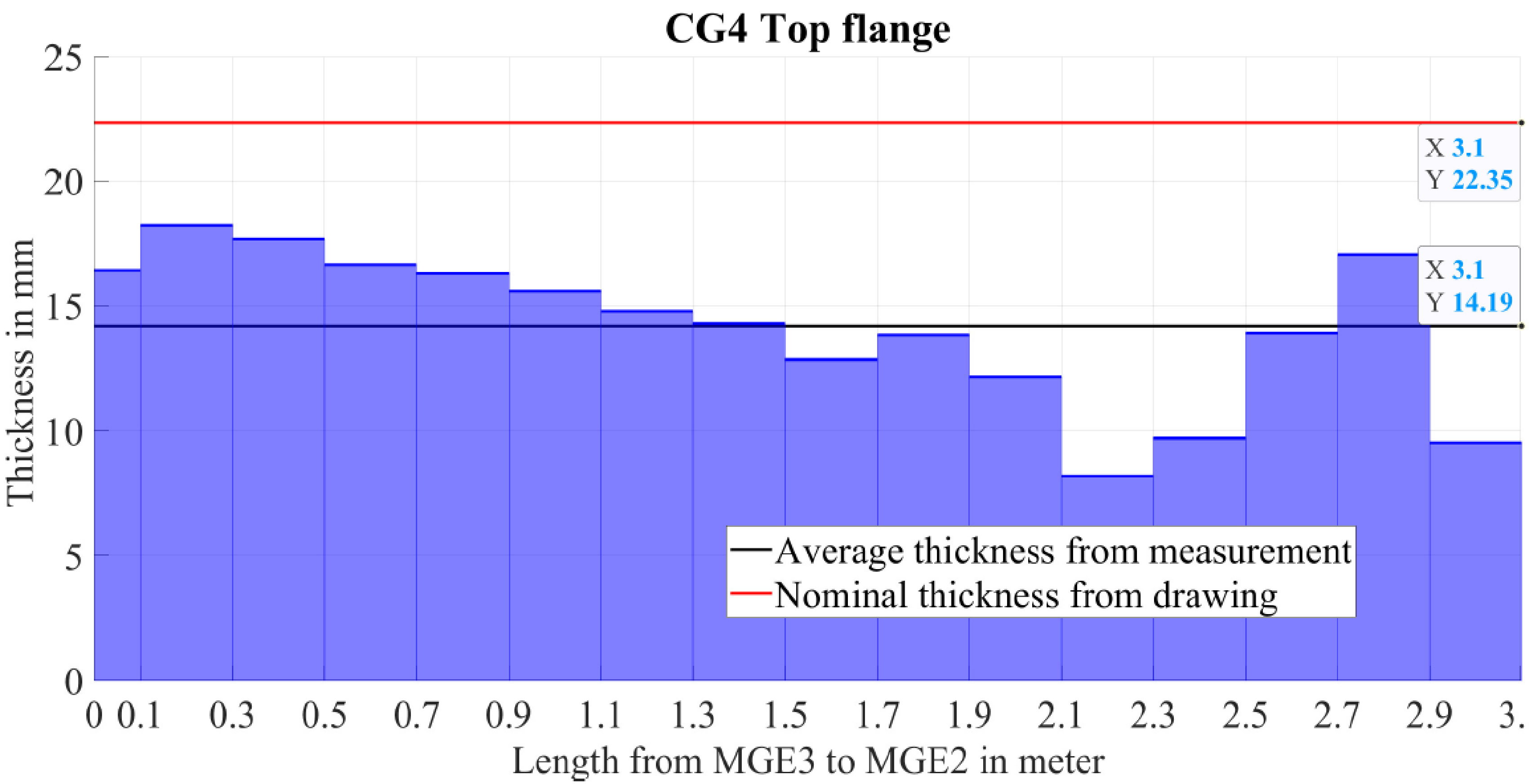
Bridge Blasting

- Thickness measurements



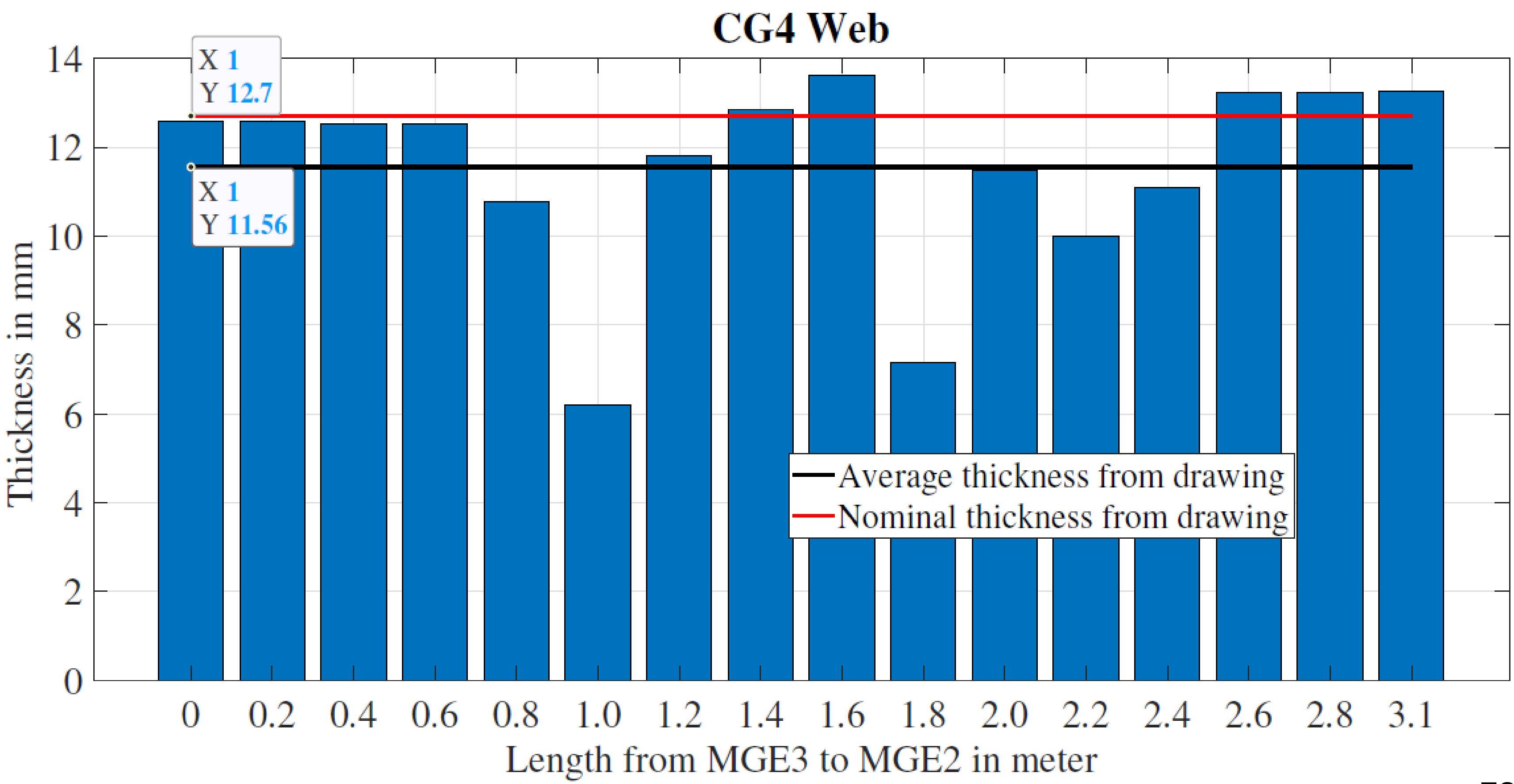
Bridge Blasting

- Thickness measurements



Bridge Blasting

- Thickness measurements



Modal Testing

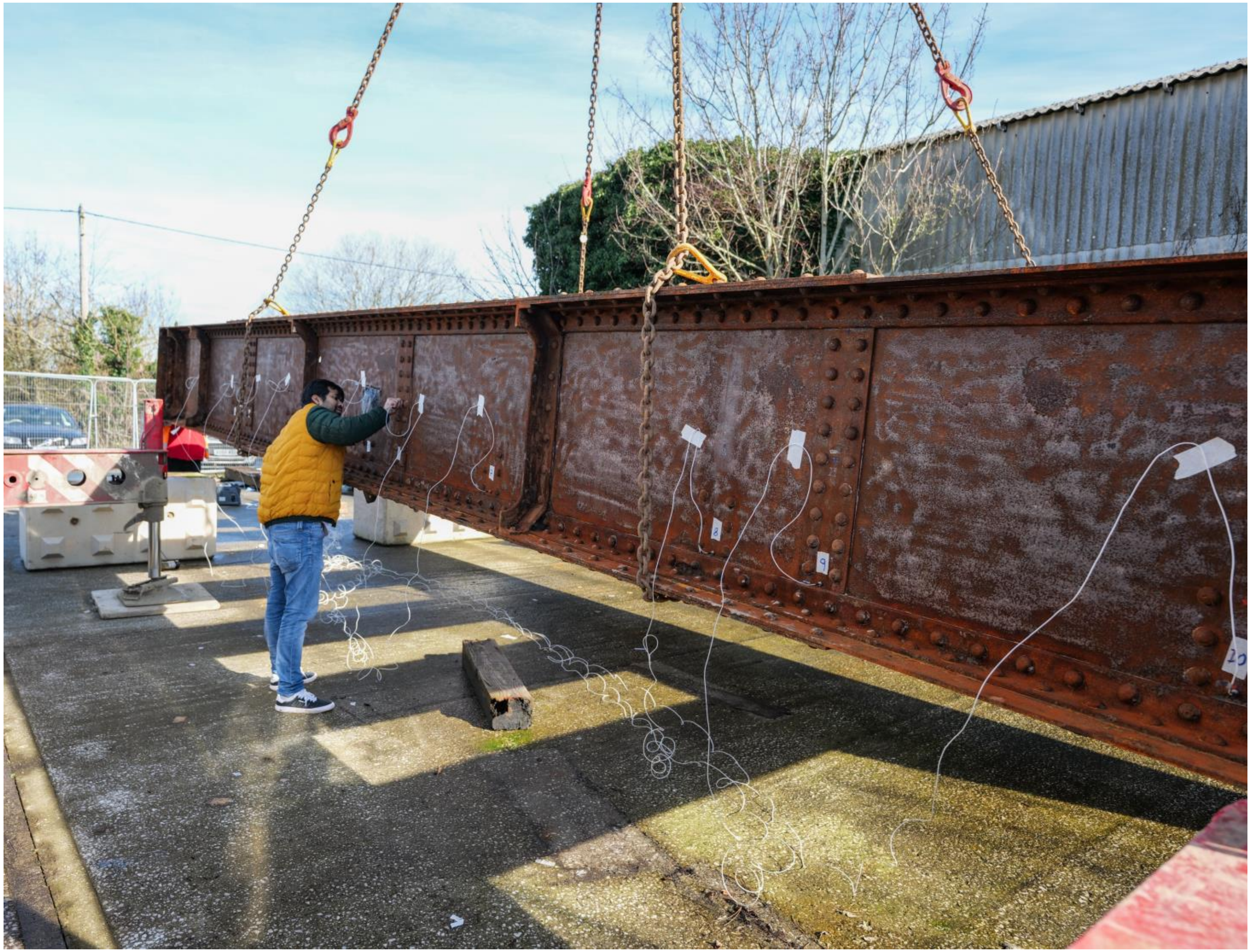
- Modal testing under in-situ and free-free support conditions

Modal Testing

- Modal testing under in-situ and free-free support conditions

Modal Testing

- Modal testing under in-situ and free-free support conditions



Modal Testing

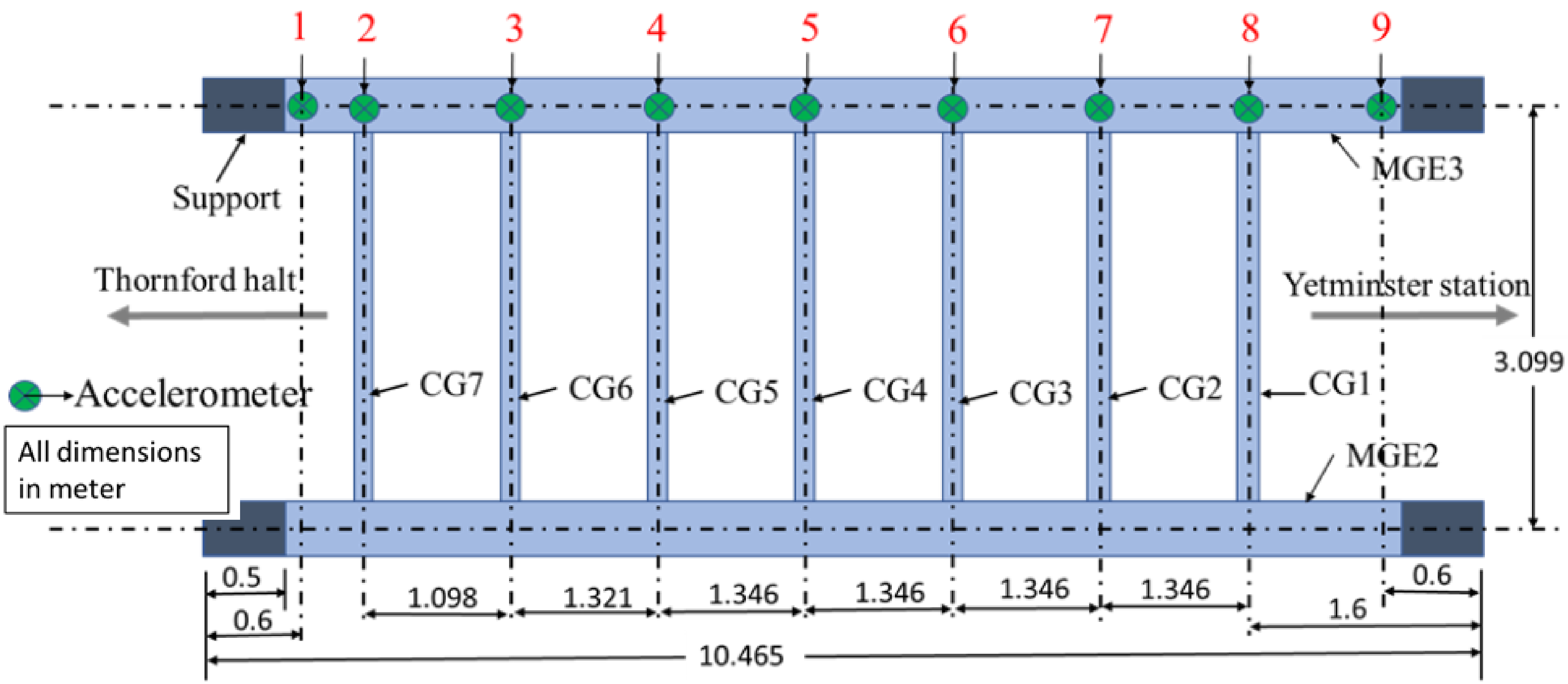
- Modal testing under in-situ and free-free support conditions

Modal Testing

- Modal testing under in-situ and free-free support conditions

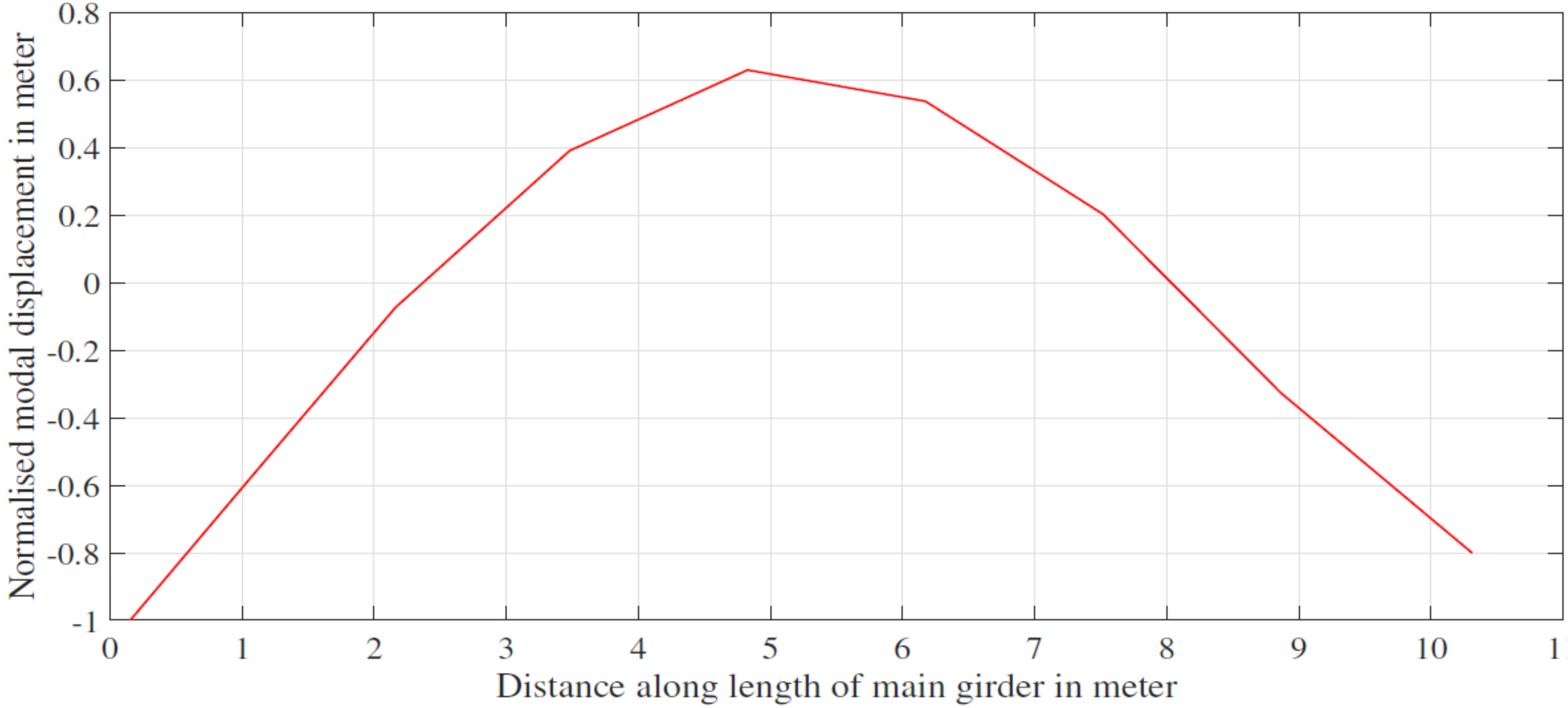
Modal Testing

- Modal testing under in-situ and free-free support conditions



Modal Testing

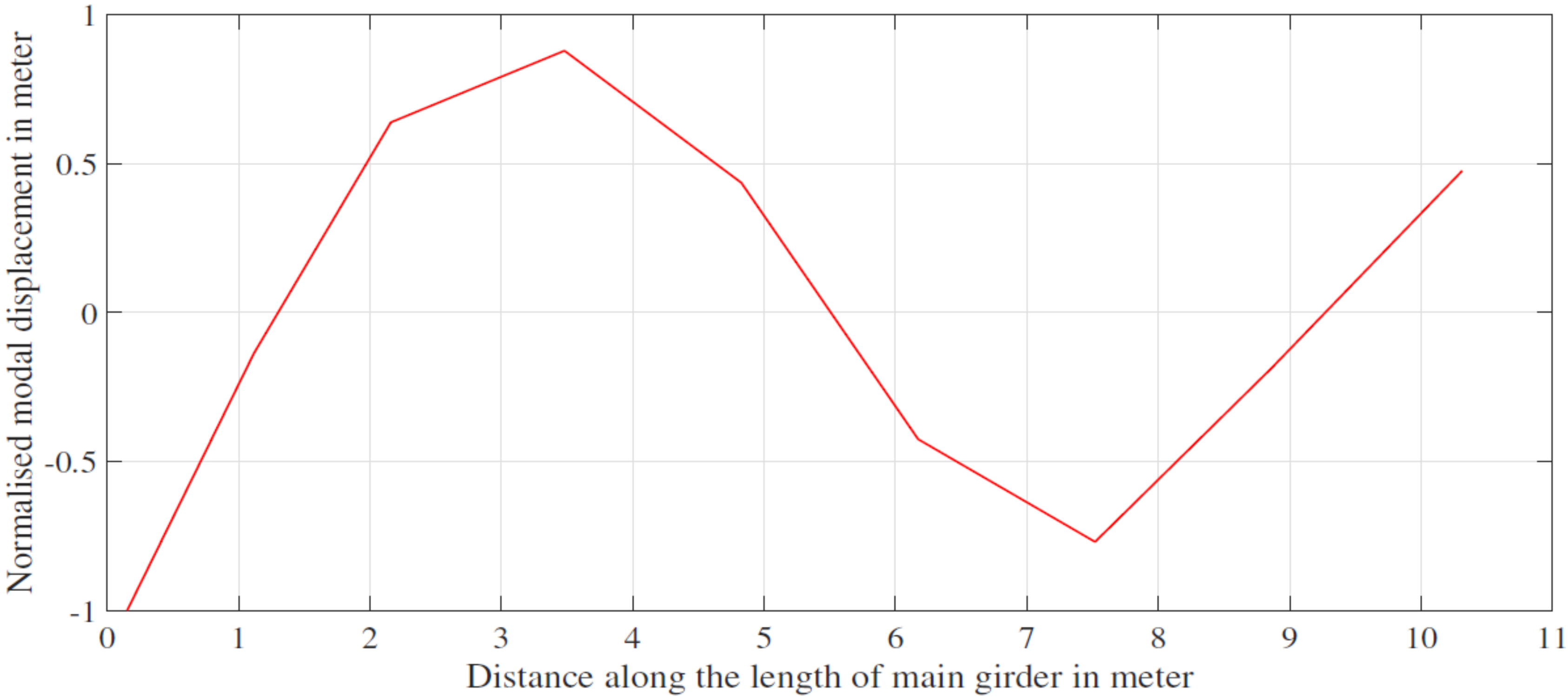
- 1st mode shape



1^{st} bending mode of main girder from modal testing at **51Hz**.

Modal Testing

- 2^{nd} mode shape



2^{nd} bending mode of main girder from modal testing at **122Hz**.

Small-scale Coupons

<u>Material property characterisation</u>

- Young's modulus (wrought-iron & mild steel)
- Yield strength
- Ultimate tensile strength

Bridge Cutting

- Cutting into full-scale components

Bridge Cutting

- Static & cyclic fatigue laboratory tests

The Danish Bridge Testing project 2016-21

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DENMARK

Jacob Wittrup Schmidt
Associate professor

Danish Faculty of Engineering and Science
Section of Civil Engineering | Department of Built environment

Vejdirektoratet DTU AALBORG UNIVERSITY DENMARK COWI

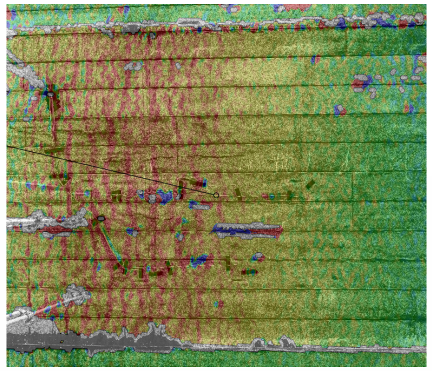
The Danish Bridge Testing project 2016-21

<u>General aims and deliveries of the bridge testing project version (V1):</u>

- Description and design of test set-ups for loading tests, including related structural elements
- Planning and perform bridge test on six bridges at the Holstebro – Herning main road stretch in 2016.
- A simple methodology (using advanced back ground knowledge) where measurements and inspections are optimized for in-situ testing.
- Calculation models should produce results which conform with the results of the load-carrying capacity tests.
- Thus calculation models shall reflect the actual fracture mechanics and load-carrying capacity of the bridge in question.
- Guideline with specific instructions for the completion of bridge proof loading

Background, Interplay of project activities

- Research areas

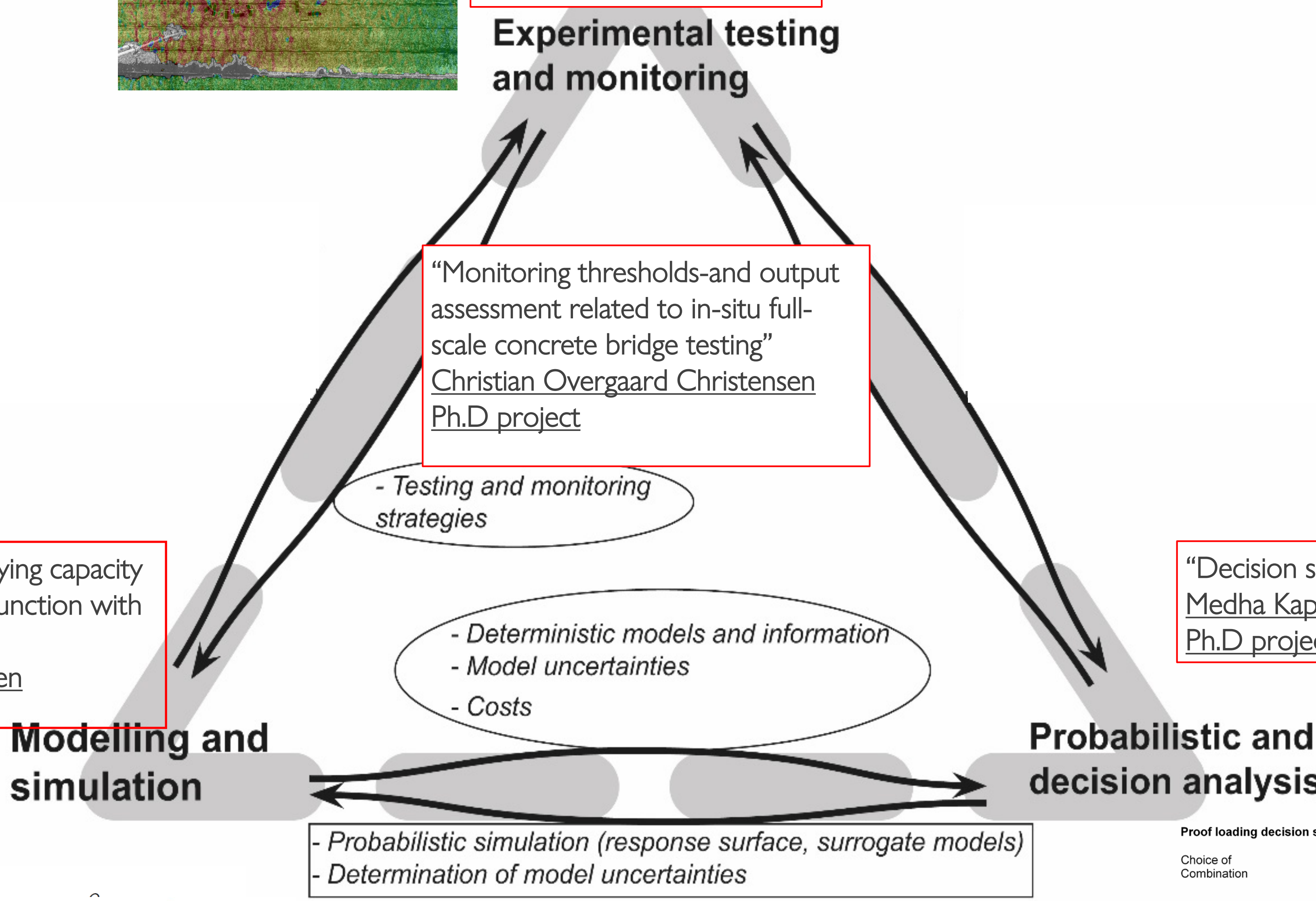


"Monitoring and full-scale test of existing bridges"
Philip Skov halding"
Post Doc

"Monitoring thresholds-and output assessment related to in-situ full-scale concrete bridge testing"
Christian Overgaard Christensen
Ph.D project

"Modelling of the load carrying capacity of concrete bridges in conjunction with in-situ monitoring"
Thomas Westergaard Jensen
Ph.D project

"Decision support for reclassification of bridges"
Medha Kapoor
Ph.D project



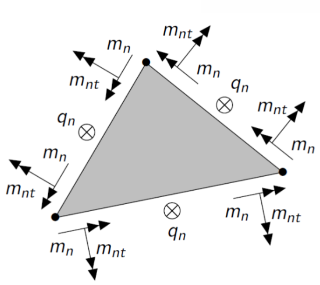


Figure: Boundary equilibrium. a) Full continuity element b) Kirchhoff element

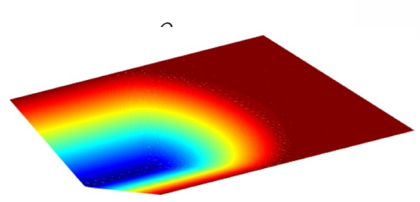
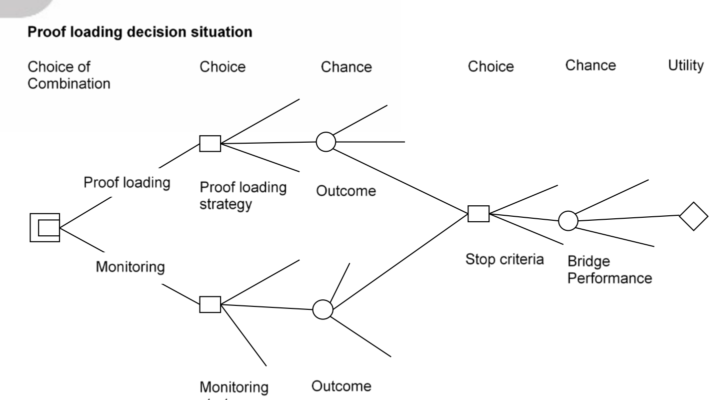


Figure: Yield mechanism of OT-bridge



Background, Danish classification system

- Administration and control of heavy vehicles in Denmark
- Handled through a unique bridge classification system,
- based on different sizes of "standard vehicles" with a defined load configuration.
- A heavy vehicle can pass the bridge if the bridge class is higher than the vehicle class.
- the weight shall be reduced or re-arranged (to reach a lower class), otherwise an alternate route must be found.
- Strategic road map based on this system, where heavy vehicles can drive safely.
- However, the number of heavy vehicles has increased significantly during the last decades

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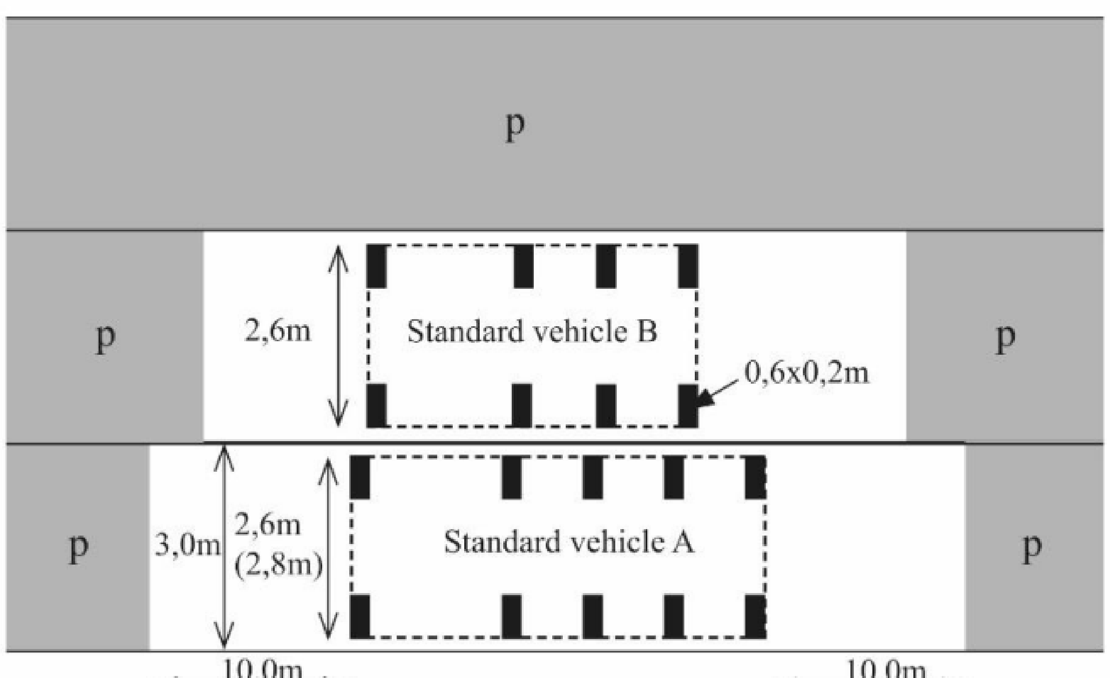
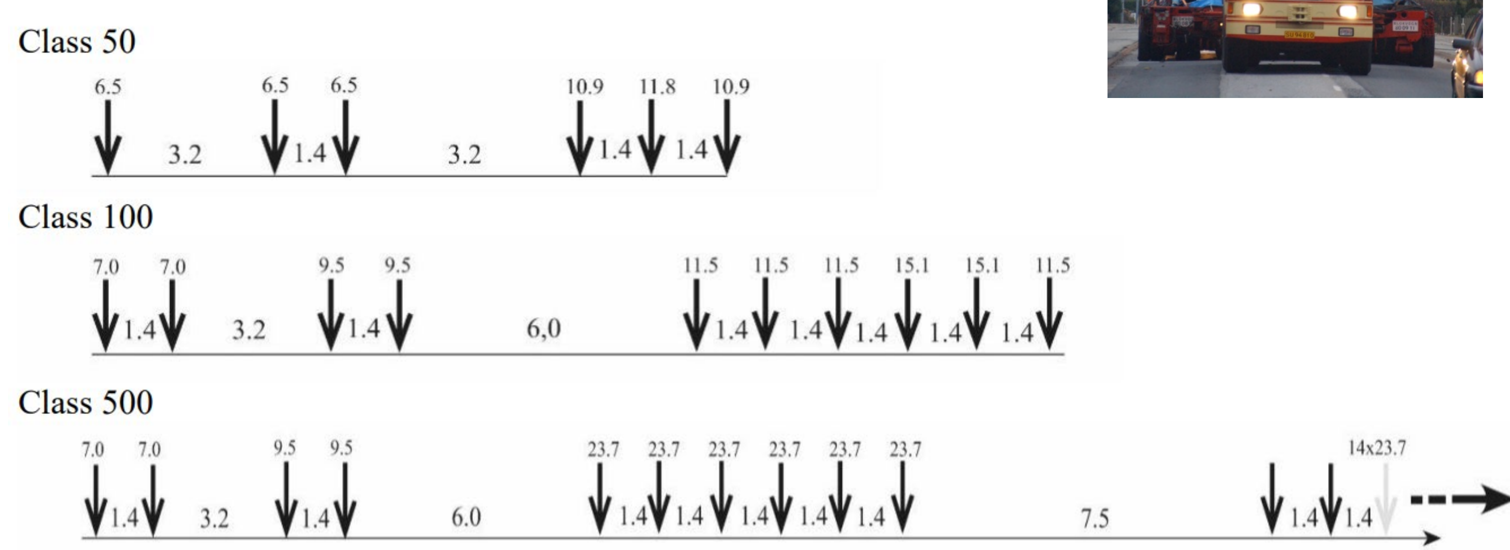
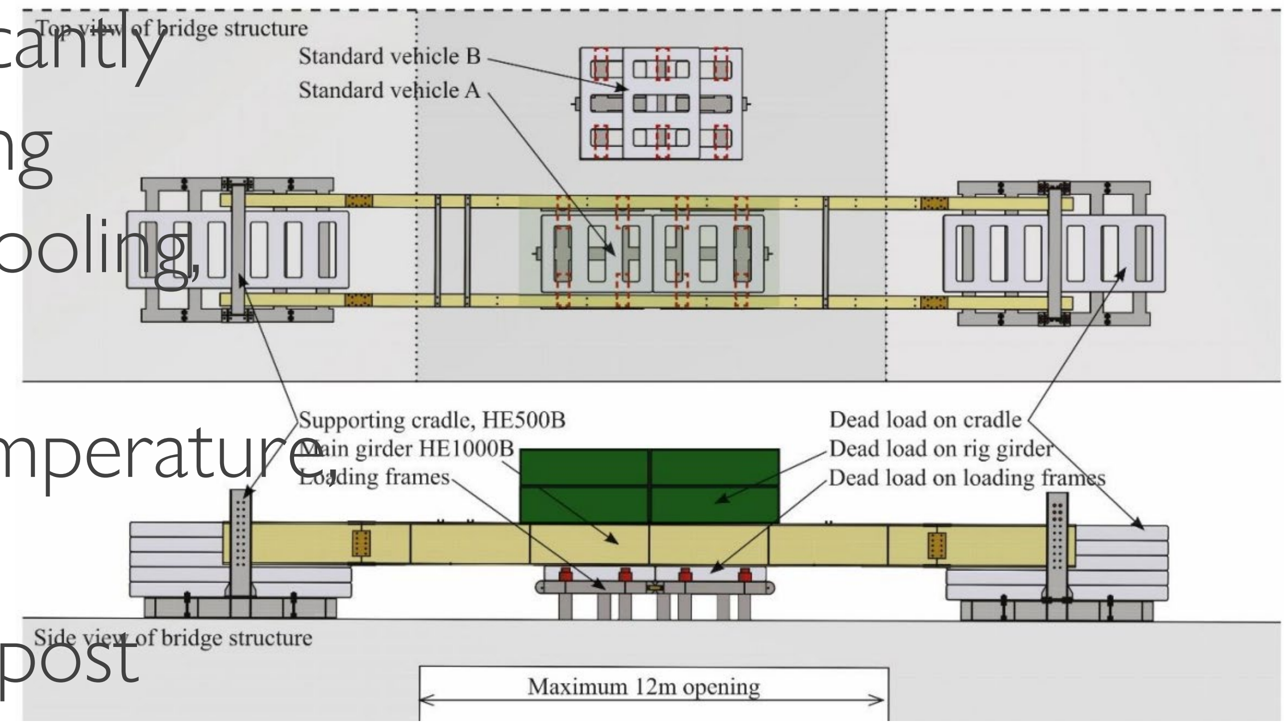
Pictures: heavy transports, Torben Rafn & Cp A/S, vognmand

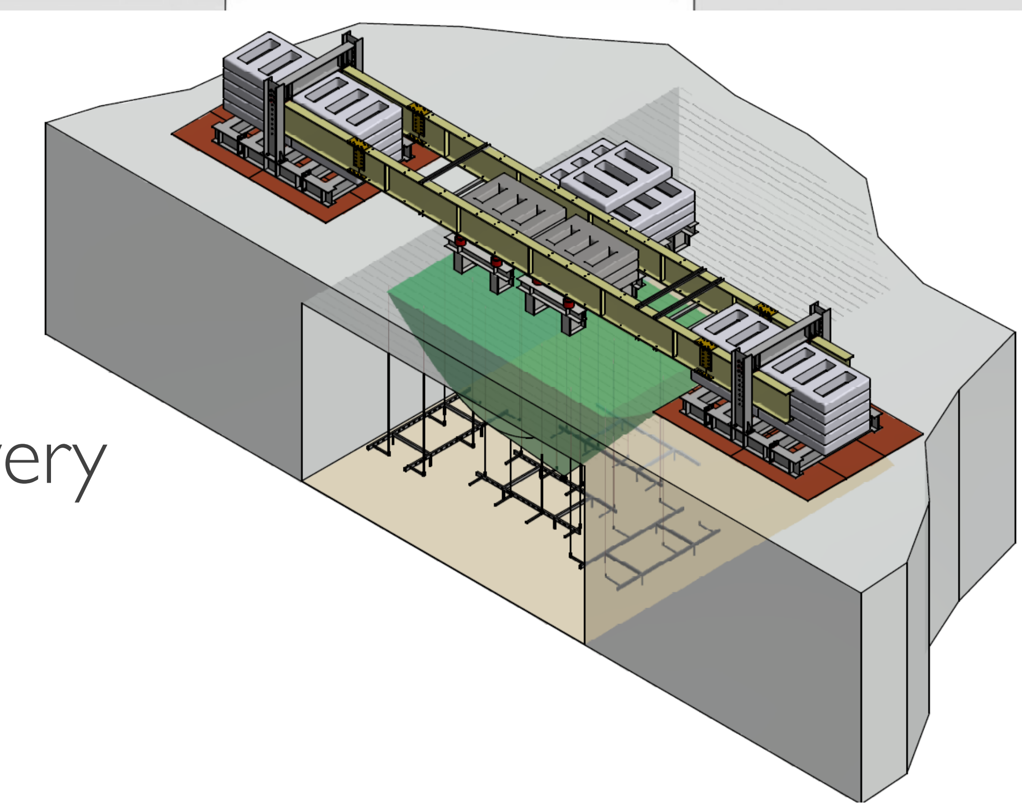




Background, In-situ challenges and experience

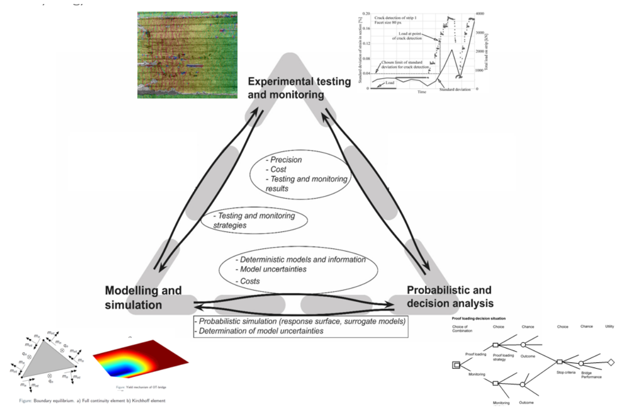
- Planning with short testing time and high safety measures
- Loading rig, imitating classification vehicle
- In-situ monitoring- and testing is significantly more demanding than laboratory testing
- Practical challenges (electrical outlets, tooling, etc.)
- Weather conditions(light, moisture, temperature etc.)
- Limited time detailed adjustments and post processing
- Large structure - Working above and below bridge
- Difficult access
- Several unknown parameters compared to very controlled laboratory testing



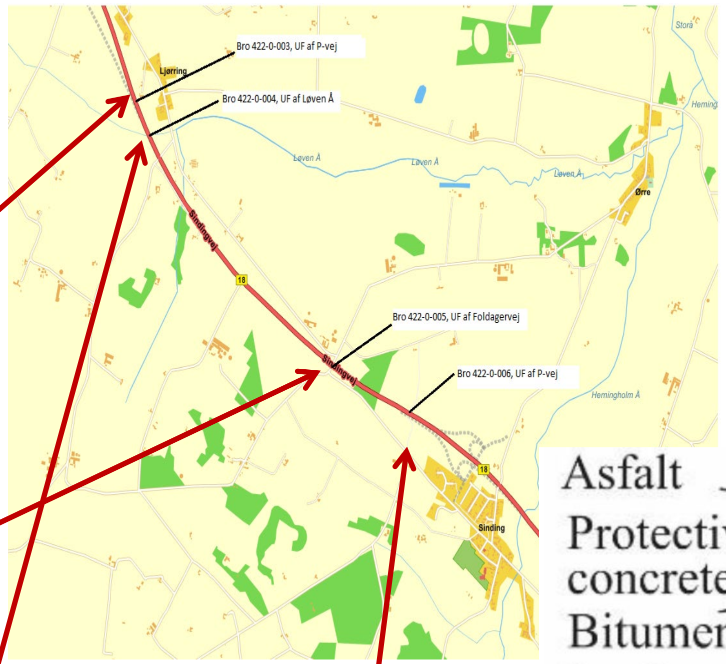


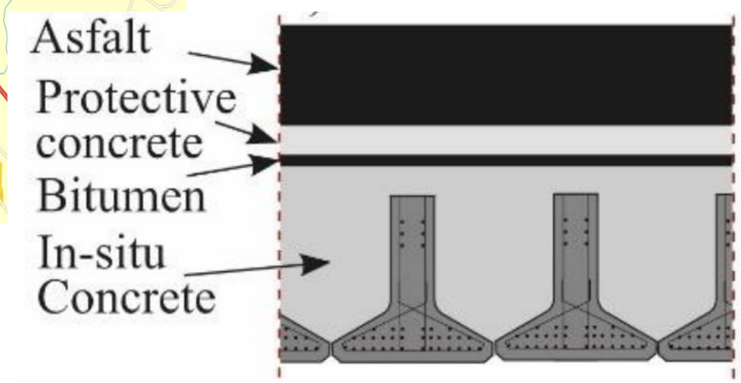
Initial in-situ testing in 2016

- Example of bridges on the Herning - Holstebro stretch
- Experience with load testing, response and possible failure mechanism
- Testing
- Monitoring
- Theory



- OT bridges were of highest interest
- Large span
- Low capacity
- Excellent basis for project framing





Med donkraftsystem

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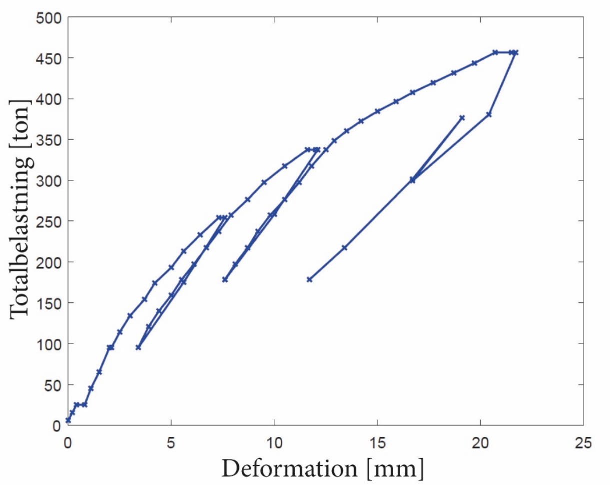
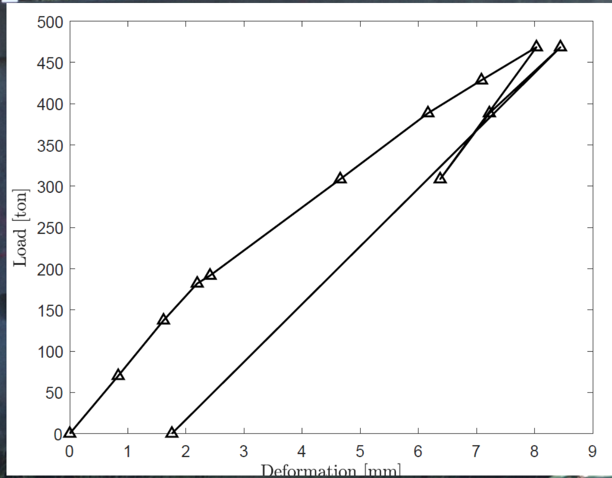
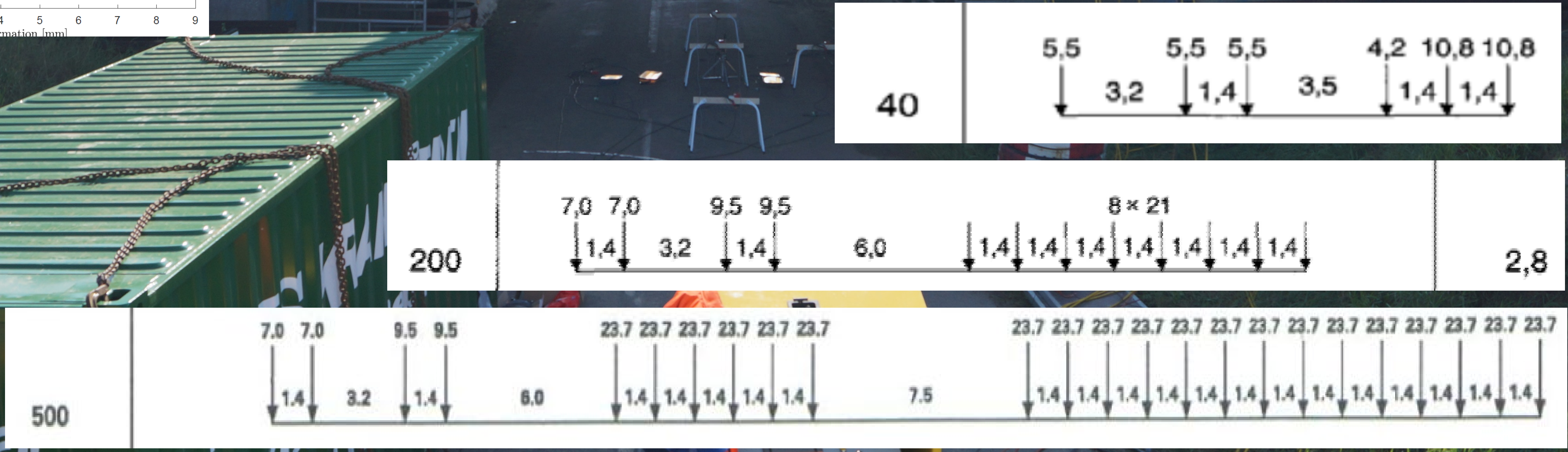
- Almost 100 tone axel load

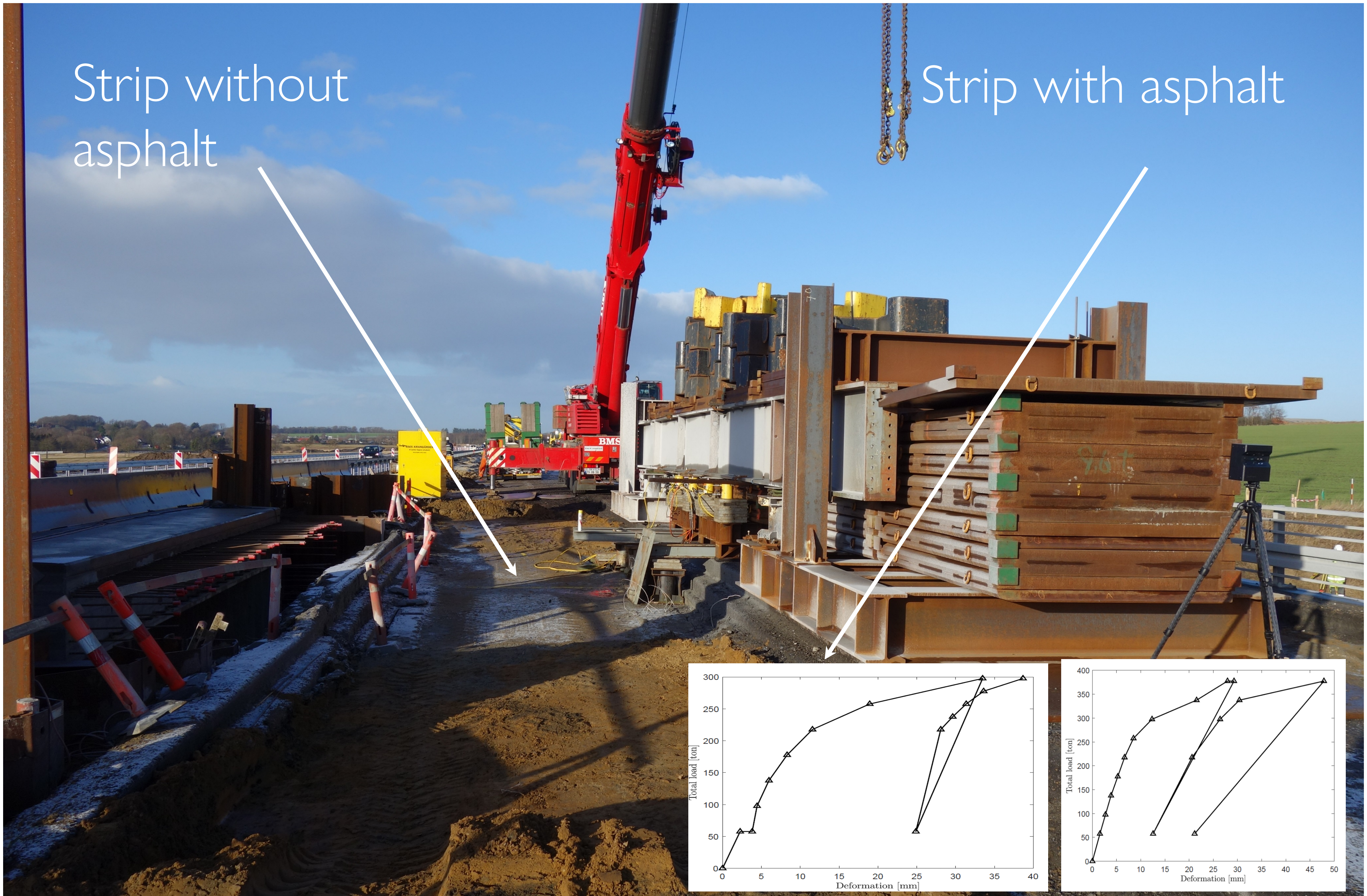






Forsøg i januar

- 11 beam strip with and without asphalt



Strip testing

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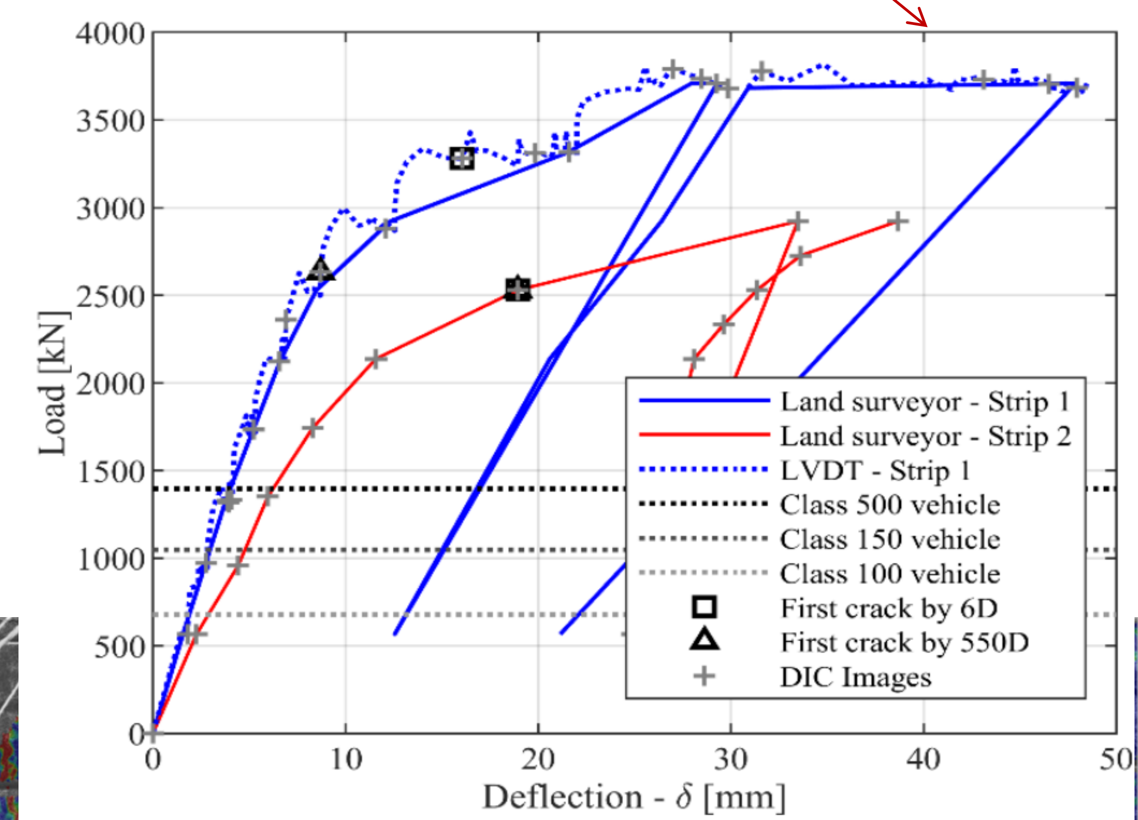
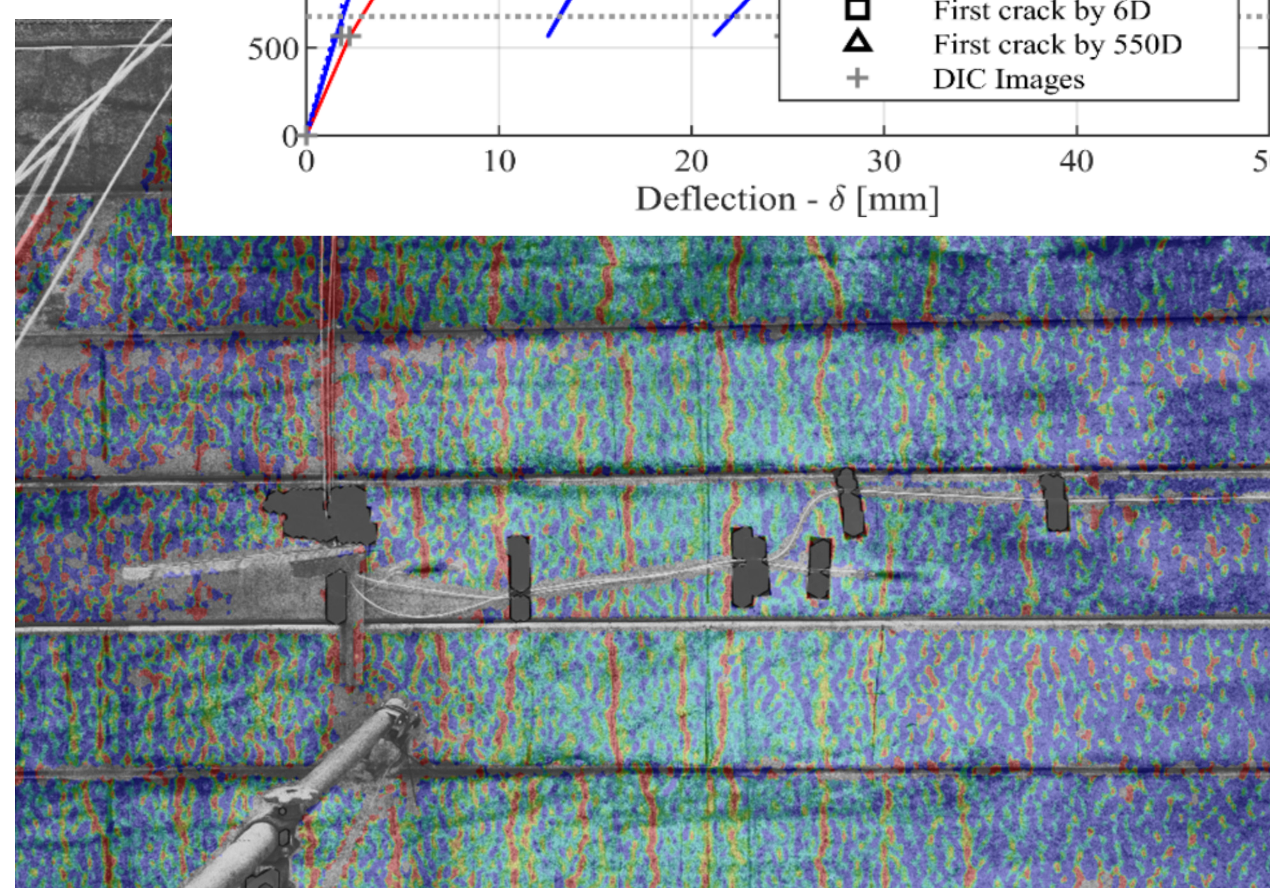
- In-situ DIC measurements (wide angle)
- Full-scale strip tests (1 strip = 11 beams cut from bridge)
  - No surface pattern applied
  - Challenging lighting conditions
  - Areas blocked by instrumentation



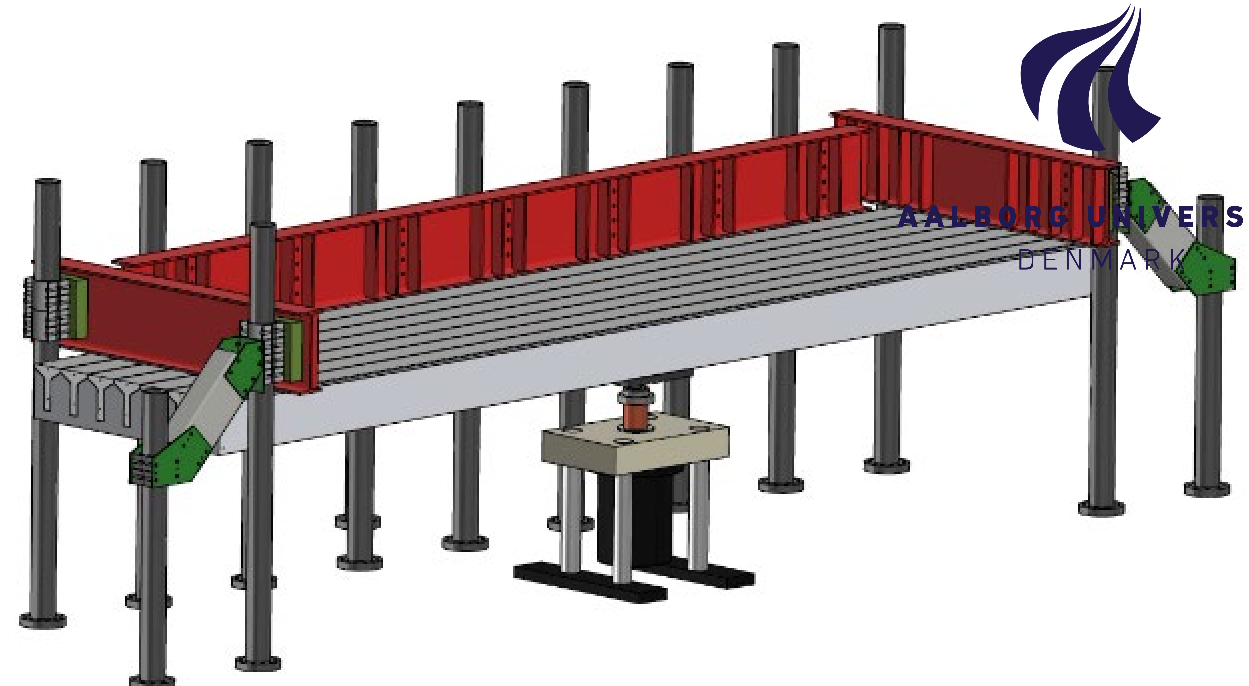
- Results
  - Camera distance of 3.8 m and 2.6 m
  - Crack detection at the end of the elastic regime
  - Crack widths at crack detection (0.104 mm to 0.332 mm)

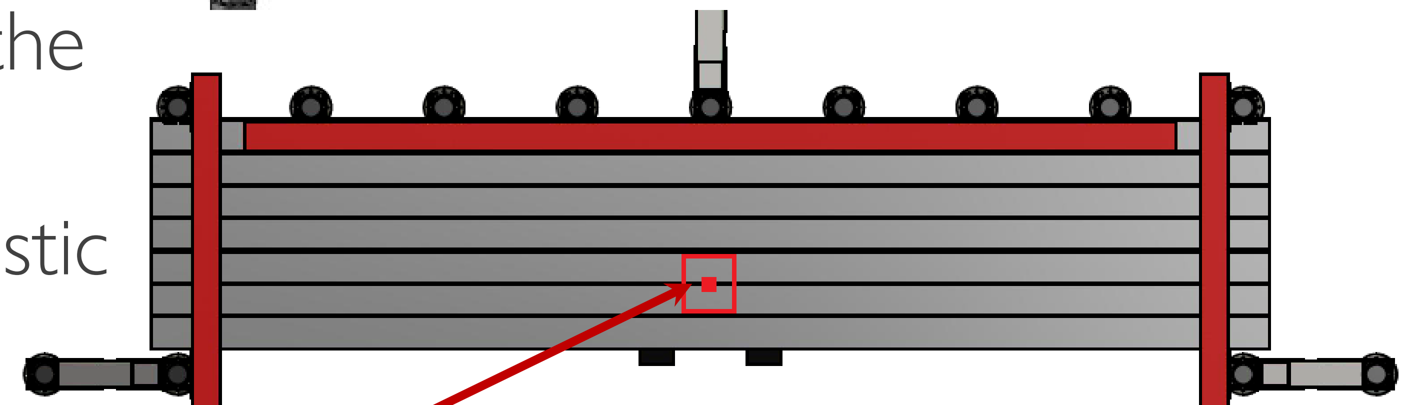


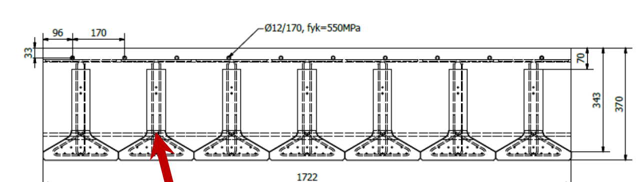
Christensen, C.O.; Schmidt, J.W.; Halding, P.S.; Kapoor, M.; Goltermann, P. Digital Image Correlation for Evaluation of Cracks in Reinforced Concrete Bridge Slabs. Infrastructures 2021, 6, 99.

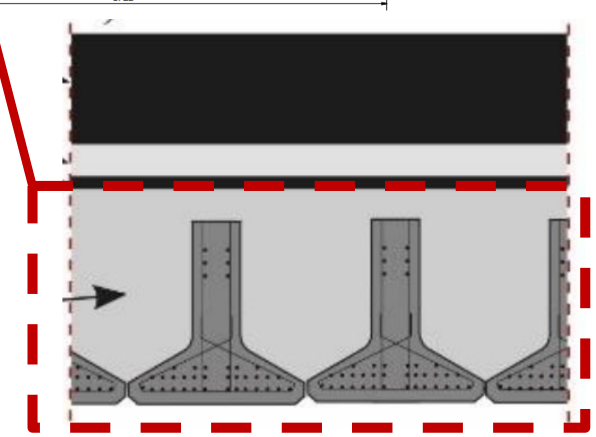
OT laboratorie tests

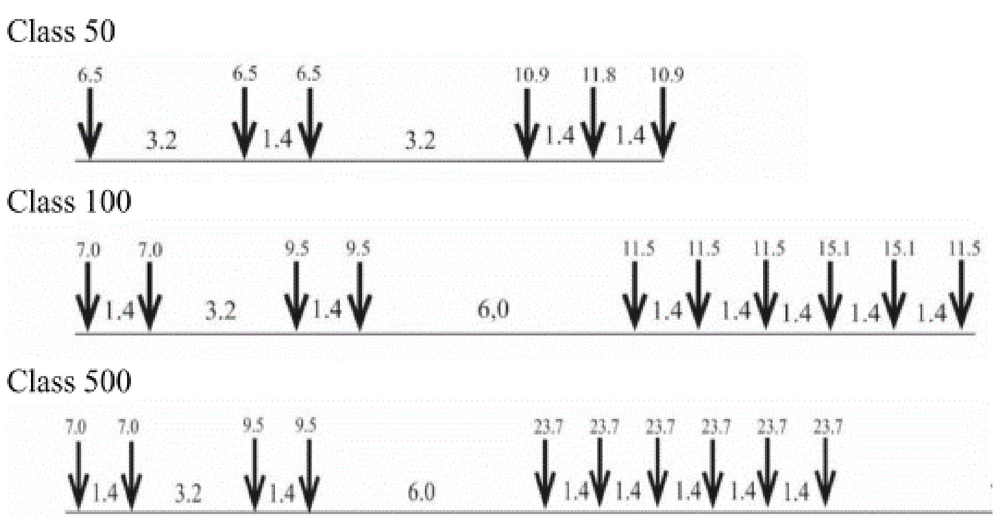
- Down scaled element
- Reinforcement ratio same and cross section height 2/3
- To provide further knowledge in regards to the interaction between the elements
- Monitoring as input for the probabilistic analysis
- Stop criterion investigations!
- Real time evaluations











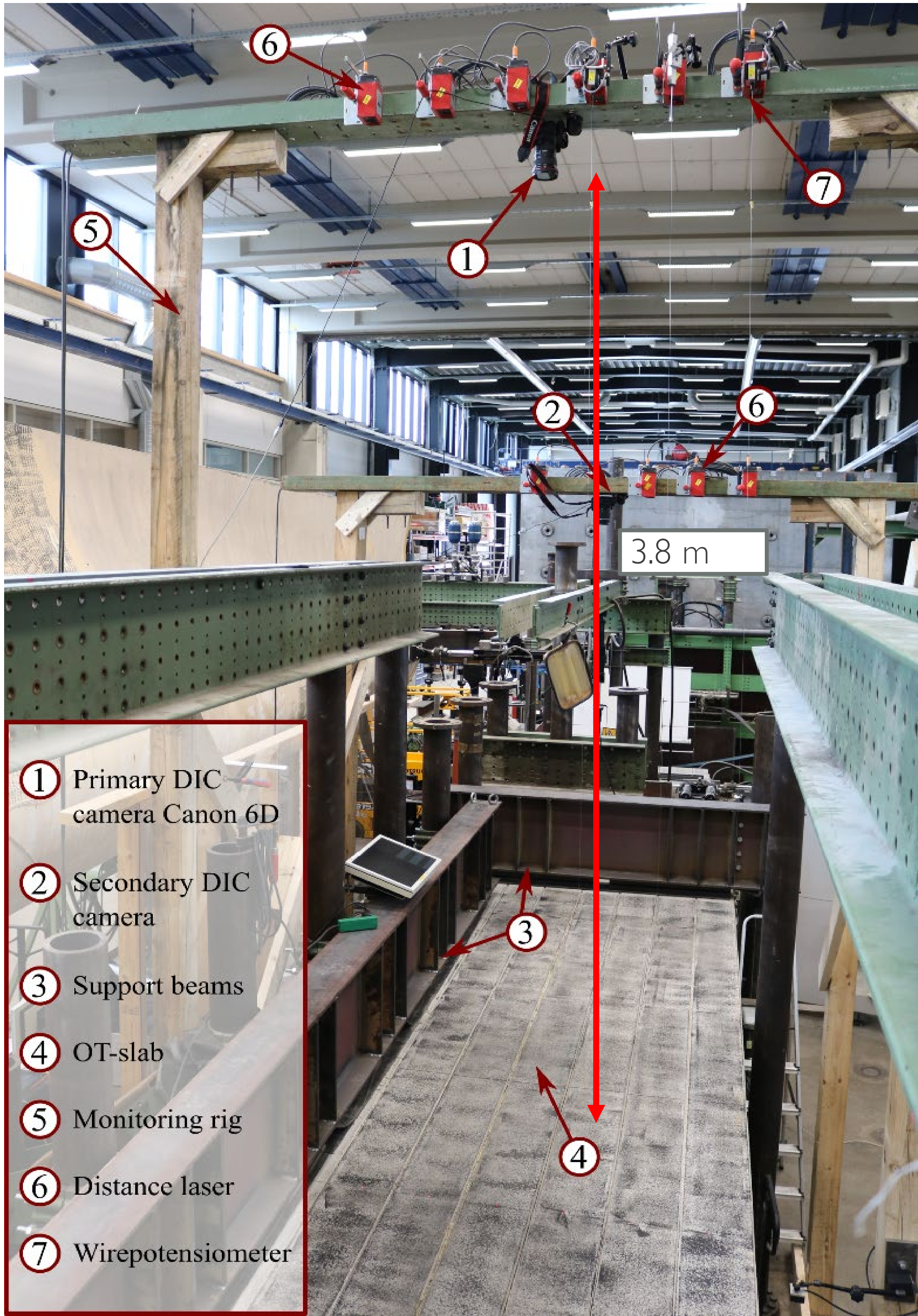
- Christensen, C.O.; Schmidt, J.W.; Halding, P.S.; Kapoor, M.; Goltermann, P. Digital Image Correlation for Evaluation of Cracks in Reinforced Concrete Bridge Slabs. Infrastructures 2021, 6, 99.
- Christensen, C.O.; Zhang, F.; Garnica, G.Z.; Lantsoght, E.O.L.; Goltermann, P.; Schmidt, J.W. Identification of Stop Criteria for Large-Scale Laboratory Slab Tests Using Digital Image Correlation and Acoustic Emission. Infrastructures 2022, 7, 36

OT laboratory tests

The monitoring included:

- Regular contact measurements
  - LVDT's
  - Wire potentiometers
  - Inclinometers
  - Strain gauges

- Non-contact and other measurements
  - Distance lasers
  - 2-D digital image correlation with camera distance similar to bridge tests (3.8 m), and a wide-angle lens for full-field coverage of the entire span
  - Acoustic emission in OT test 2



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OT laboratory tests

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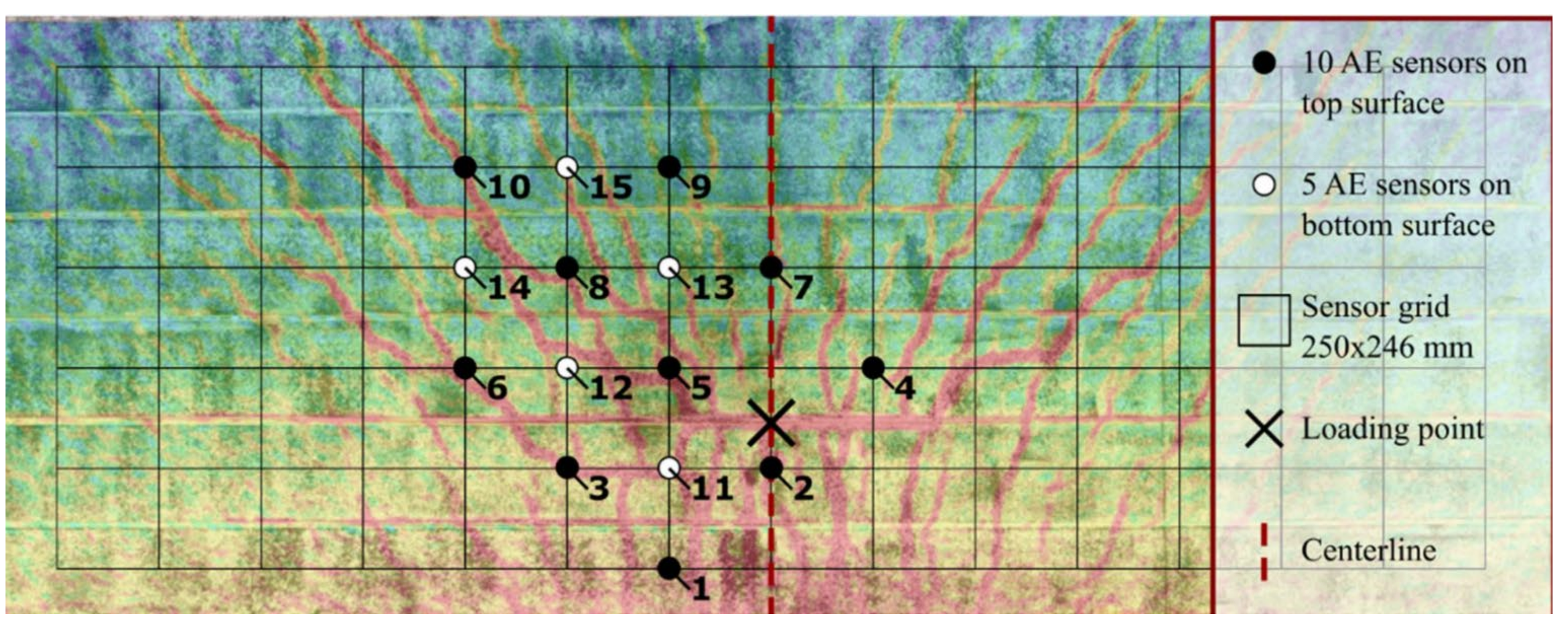
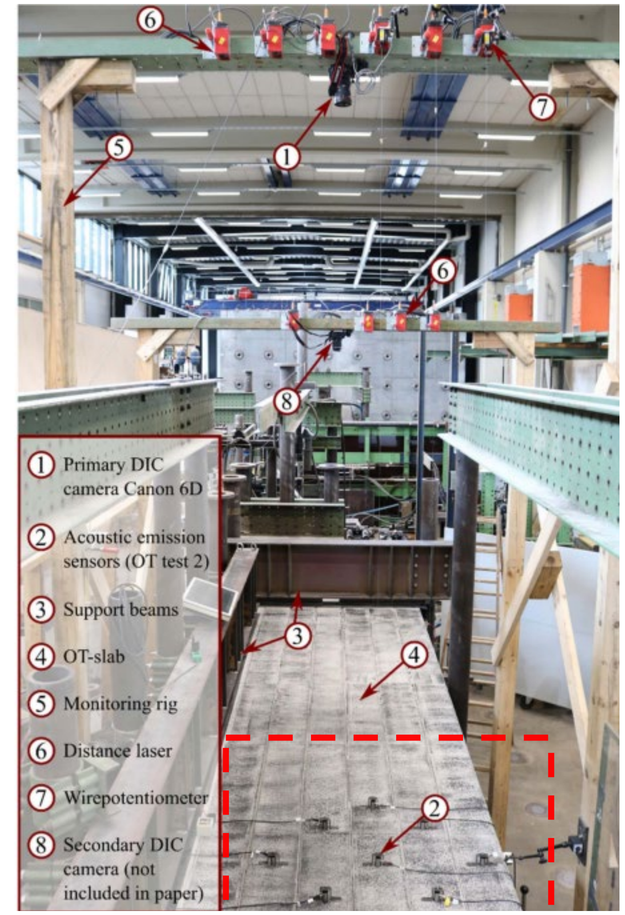
- Collaboration with TU Delft
- Acoustic emission (AE) in combination with crack measurements
- Surface and interior evaluation
- Sensors are placed in a grid setup
- Is it possible to measure activity in the most critical areas?
- Does the AE and DIC measurements support each other?





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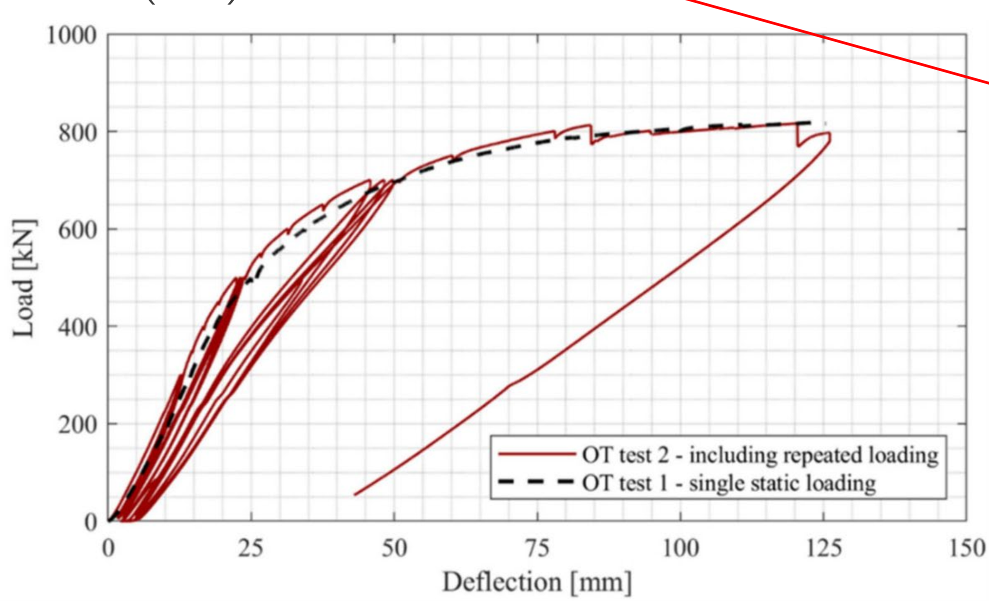
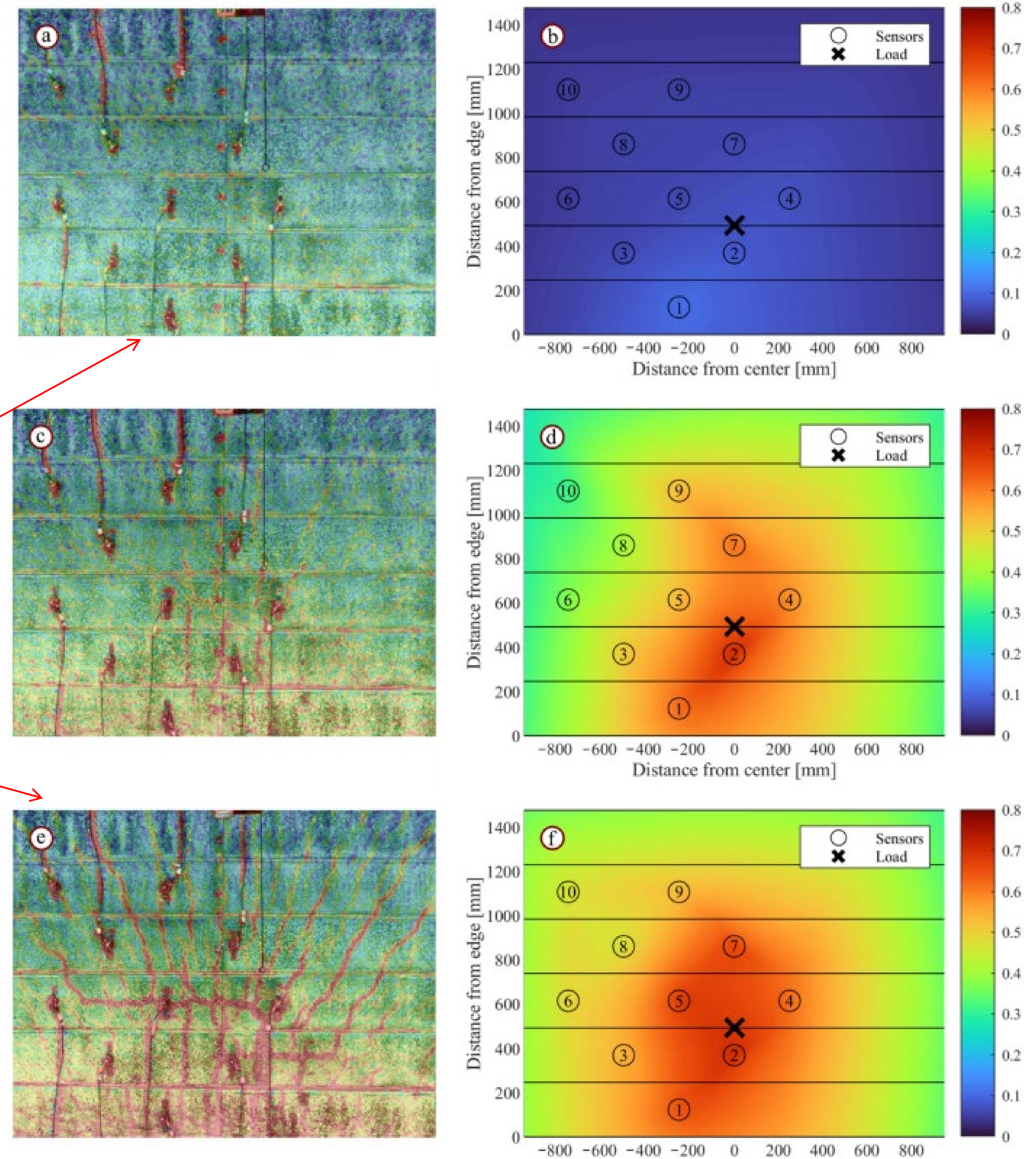
OT laboratory tests

- Only top sensors are included.
- showed values of 0.080 mm to 0.132 mm in the laboratory tests. (0.104 mm to 0.332 mm initially)
- Crack pattern compared with surface plot of calm ratio at the third cycle of:
- (a,b) 300 kN,
- (c,d) 500 kN
- (e,f) 700 kN.





Monitoring and response verification

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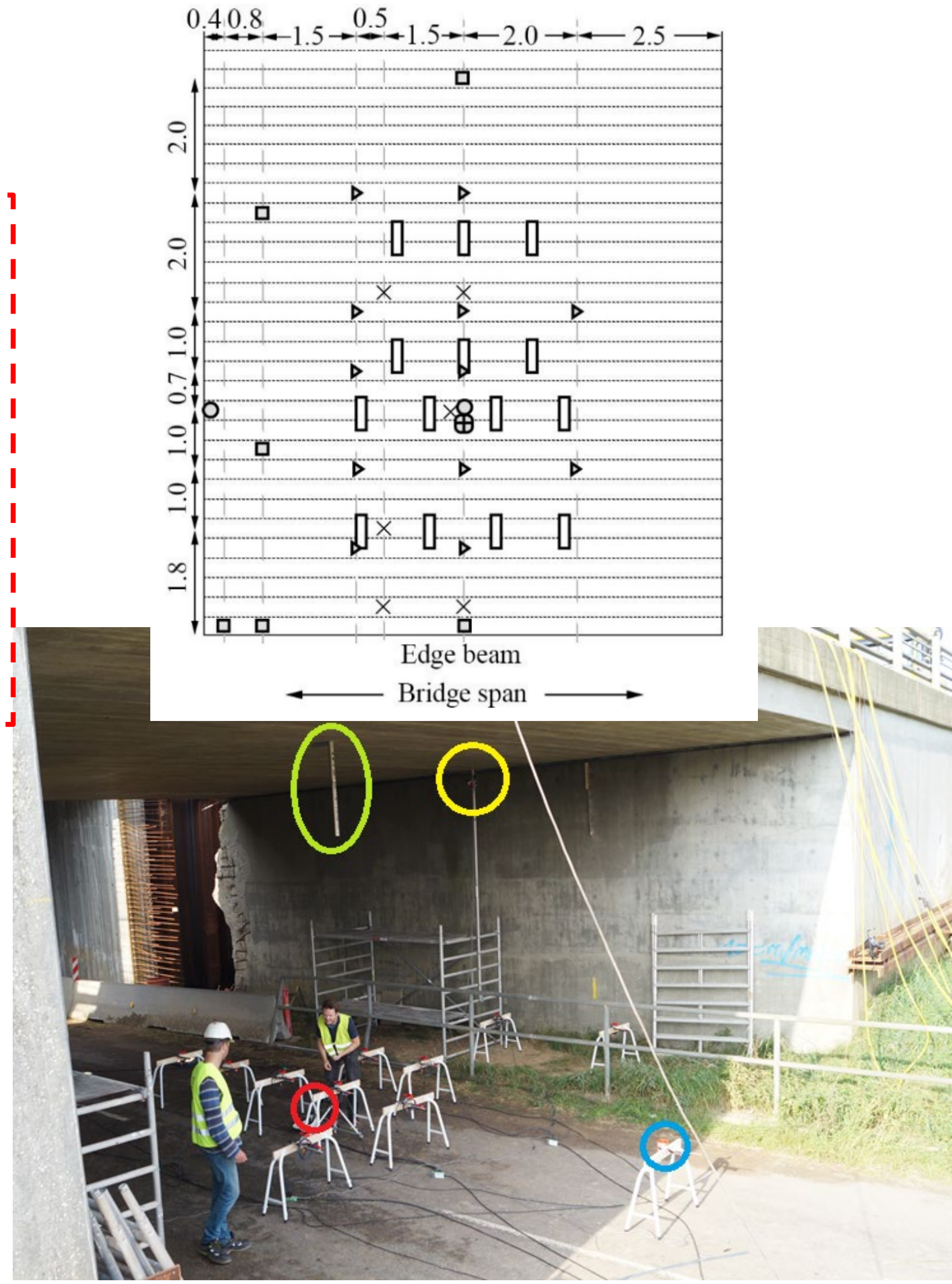
- Example of used monitoring in the project
- Combination of independent monitoring equipment a main scope
- Surface- and interior measurements?
- Verification of loading method and basis for future loading methods
- Response verification

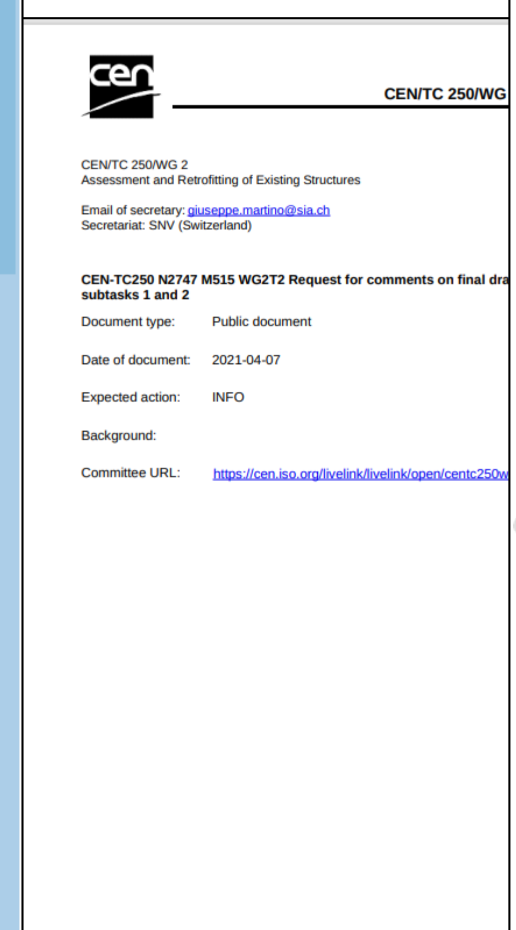
- *Standard point measurements:* LVDT's, strain gauges, distance lasers, extensometers, Land surveyor, Inclinometers, Wire potentiometers etc.
- *2D DIC:* Used for full-field evaluation, with one or multiple cameras for crack detection and crack width monitoring. Wide angle- and conventional camera
- *Acoustic Emission:* Used for internal crack detection and localization, as well as identification of irreversible damage.
- *"Hydra" and IBIS, IDS GeoRadar:* Interferometric radar system designed for early warning and real-time measurements of sub-millimetric displacements
- *Not prioritized: (Fiber Optic Sensing (FOS):* Used for distributed strain measurements in sections of interest.)



Danish guideline and Eurocode input

- Work concerning a Danish guideline " VEJLEDNING FOR PRØVEBELASTNING AF BROER" was initiated – will be finallized in 2021
- Basis in the Danish classification system
- CEN/TC 250/WG 2 Assessment and Retrofitting of Existing Structures - Svend Engelund, John Dalsgaard Sørensen


HÅNDBOG
VEJLEDNING FOR PRØVEBELASTNING AF BROER
ANLÆG OG PLANLÆGNING
APRIL 2021
Foreløbig udgave
Fortrolig Draft
VEJREGLER

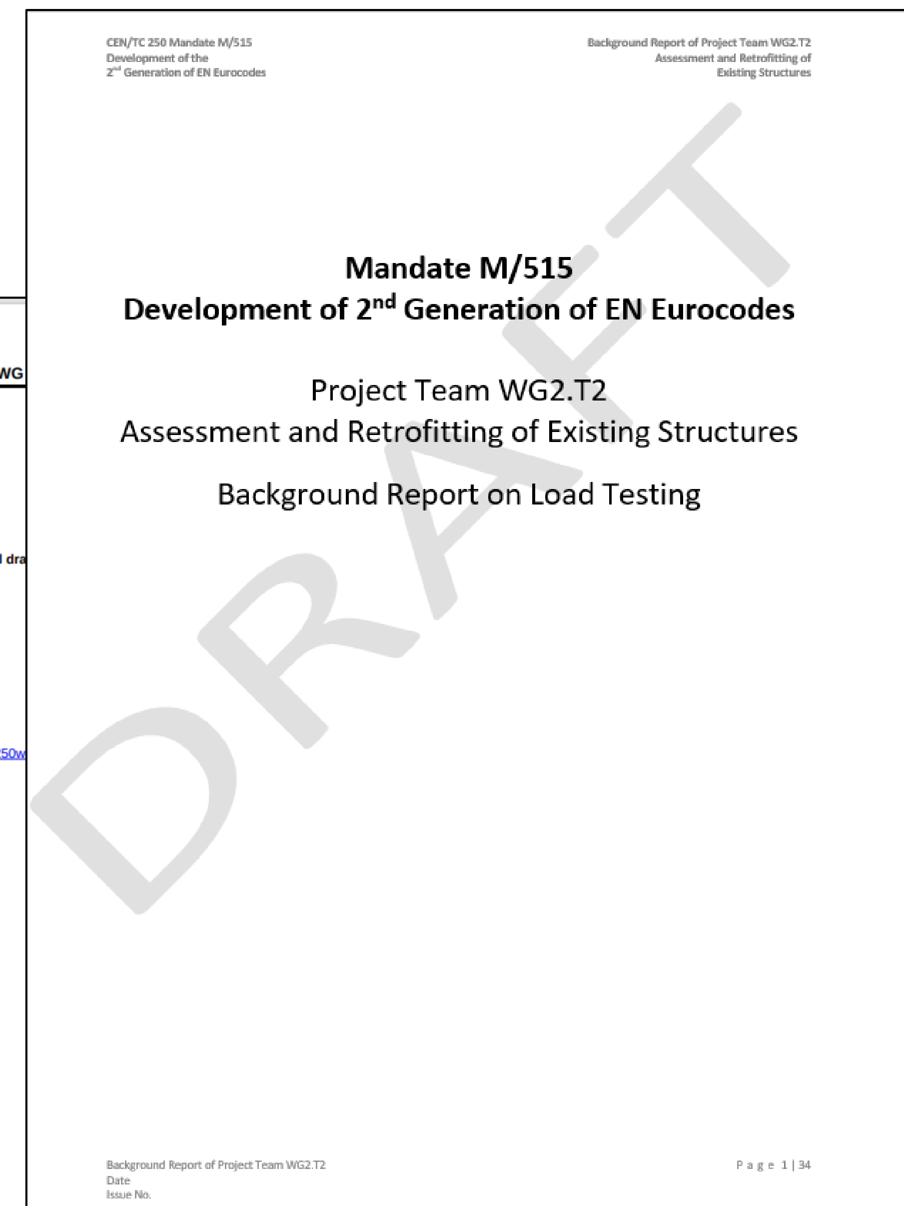

CEN/TC 250/WG

CEN/TC 250/WG 2
Assessment and Retrofitting of Existing Structures

Email of secretary: giuseppe.martino@sia.ch
Secretariat: SNV (Switzerland)

CEN-TC250 N2747 M515 WG2T2 Request for comments on final dra
subtasks 1 and 2

Document type:	Public document
Date of document:	2021-04-07
Expected action:	INFO
Background:	
Committee URL:	https://cen.iso.org/livelink/livelink/open/centc250w


CEN/TC 250 Mandate M/515
Development of the
2nd Generation of EN Eurocodes

Background Report of Project Team WG2.T2
Assessment and Retrofitting of
Existing Structures

Mandate M/515
Development of 2nd Generation of EN Eurocodes

Project Team WG2.T2
Assessment and Retrofitting of Existing Structures

Background Report on Load Testing

DRAFT

Background Report of Project Team WG2.T2
Date
Issue No.
Page 1 | 34

The Danish Bridge Testing project 2016-21

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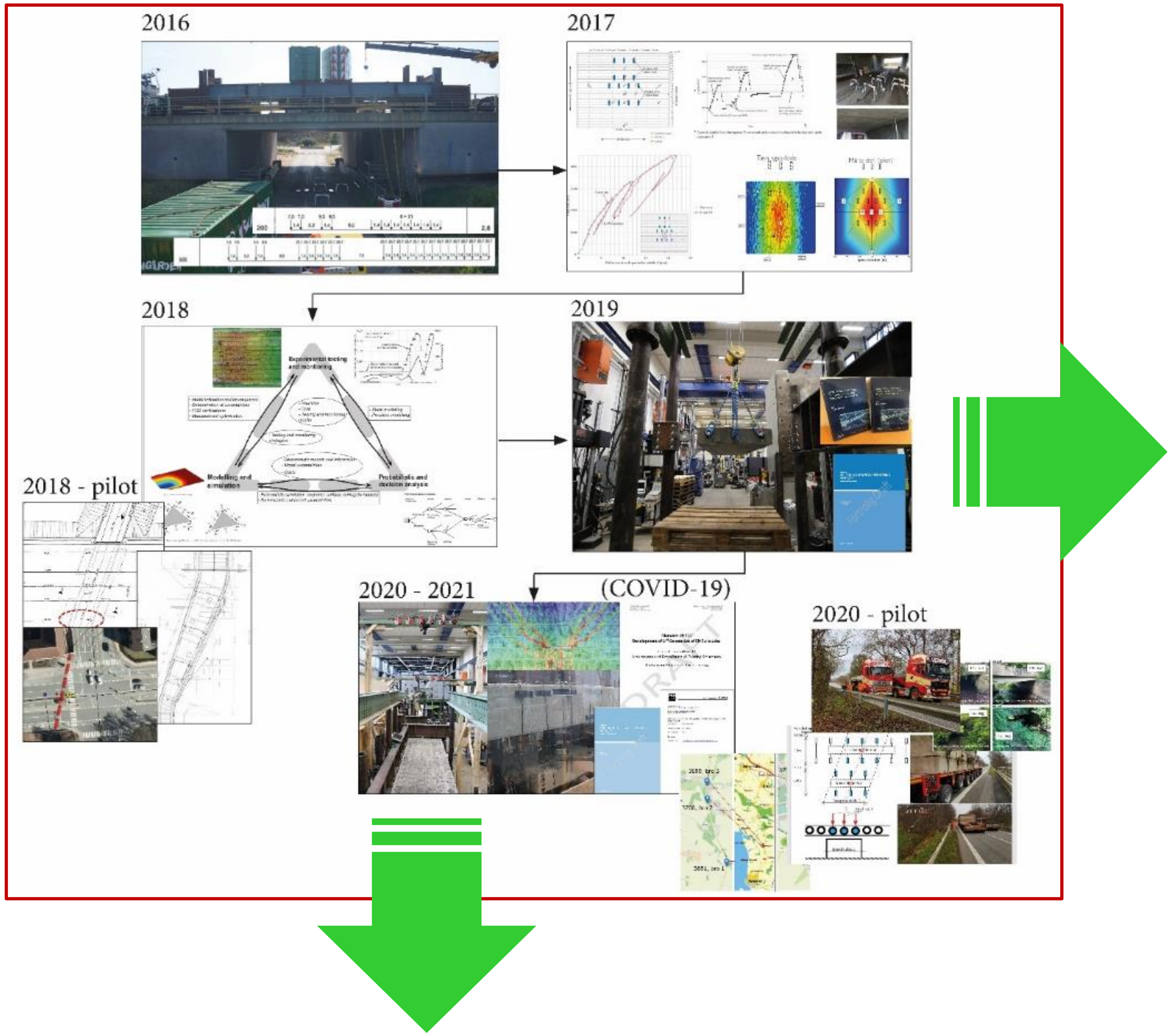
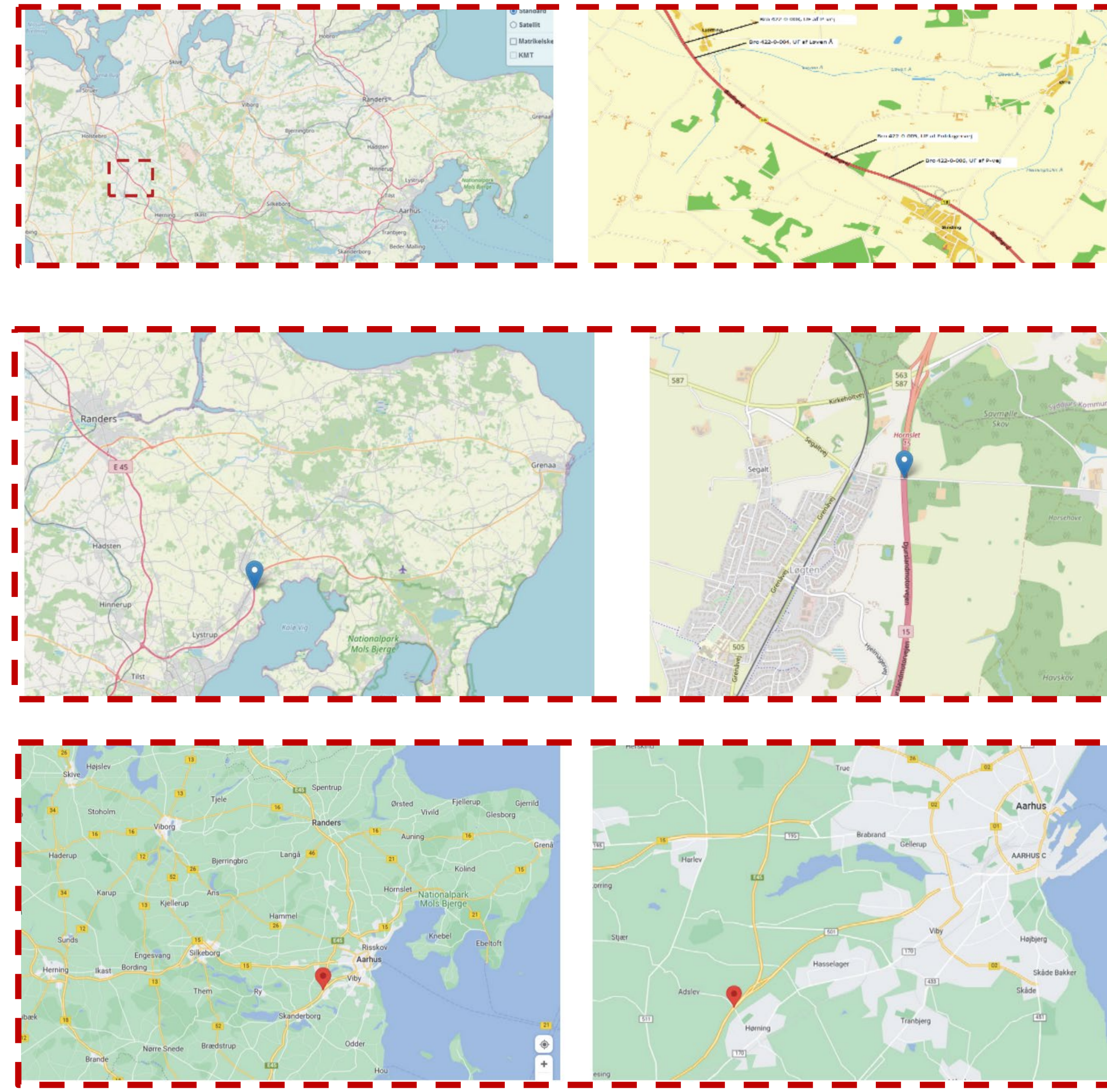
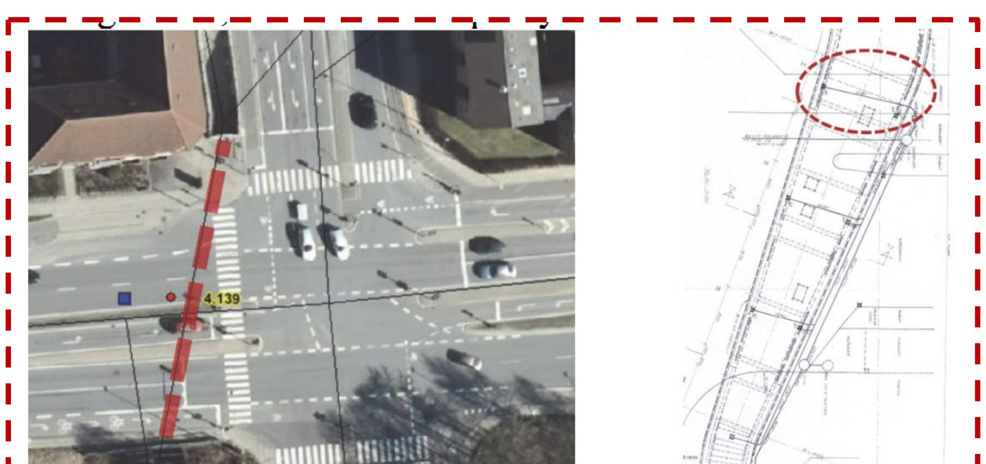
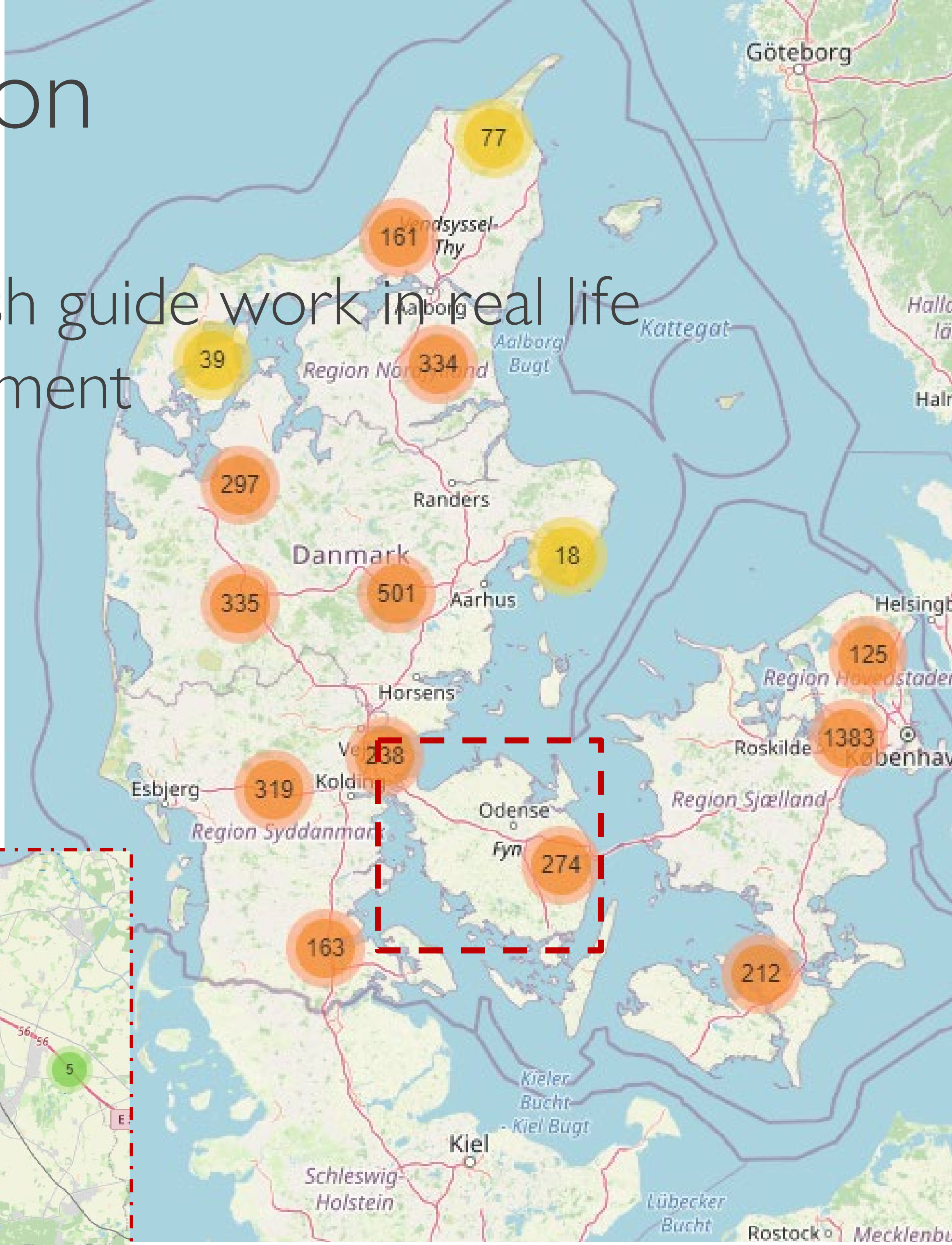


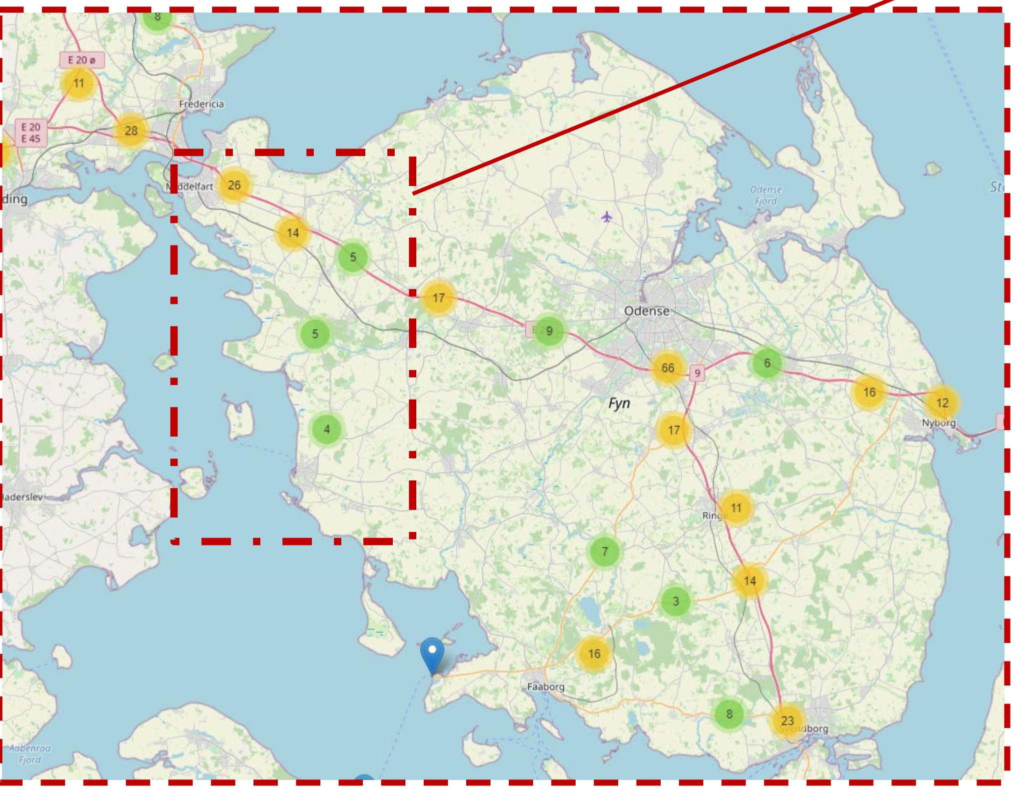


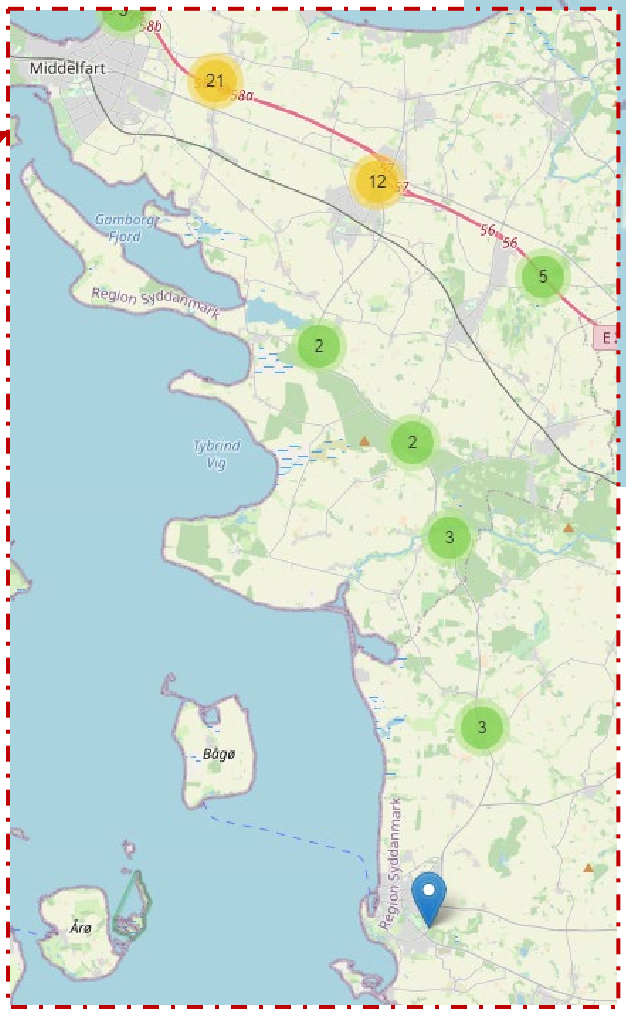


Guideline procedure verification

- Does the information included in the Danish guide work in real life
- Mythologies have to comply with the document
- Is there a road stretch fit for this purpose
- Registered structures in DanBroWeb

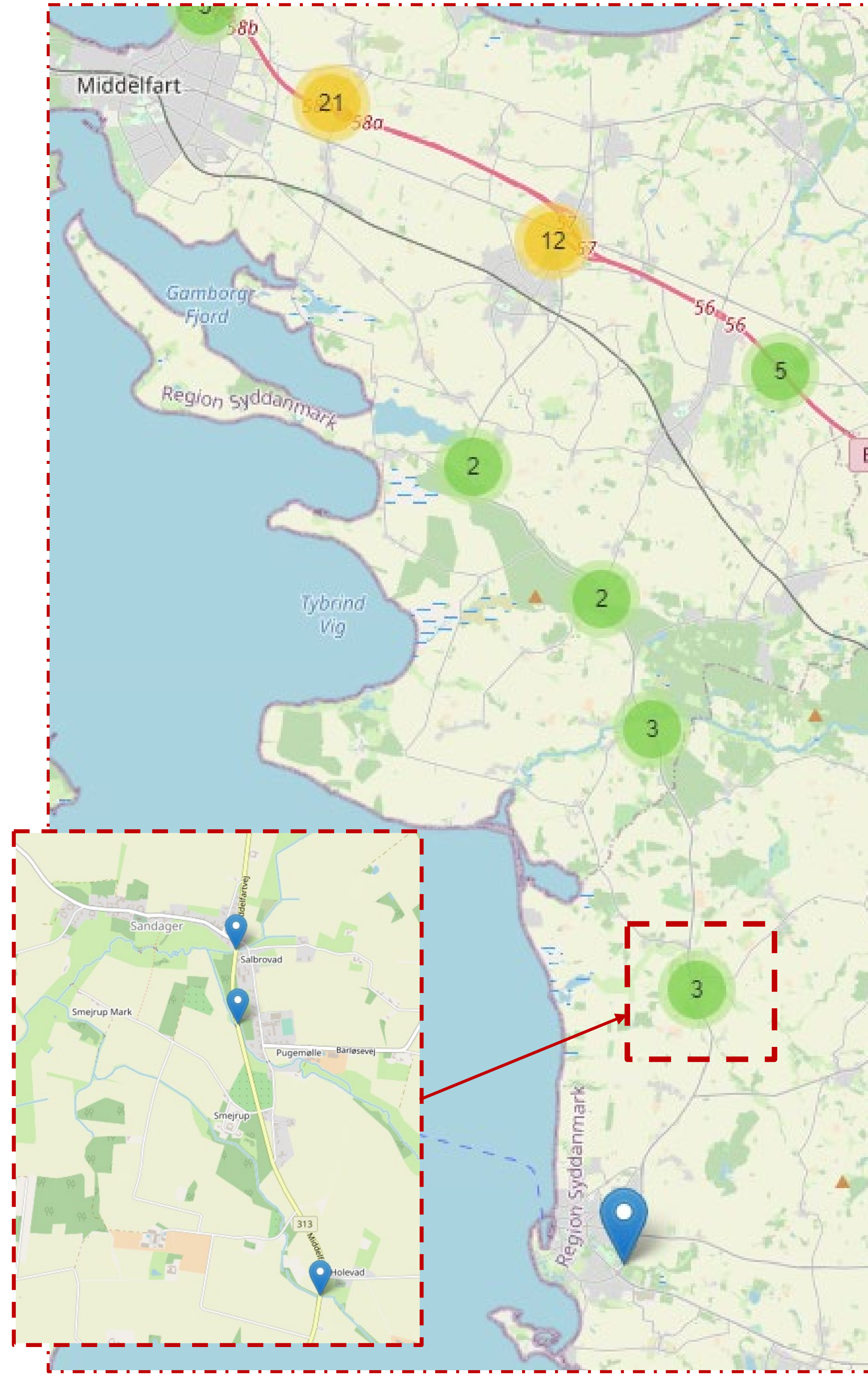






Guideline procedure verification

- Class 80 road stretch
- Aim to upgrade to class 100
- Location of the tested road stretch
- Proof loading of 4 bridges
- Testing performed in three days



Guideline procedure verification

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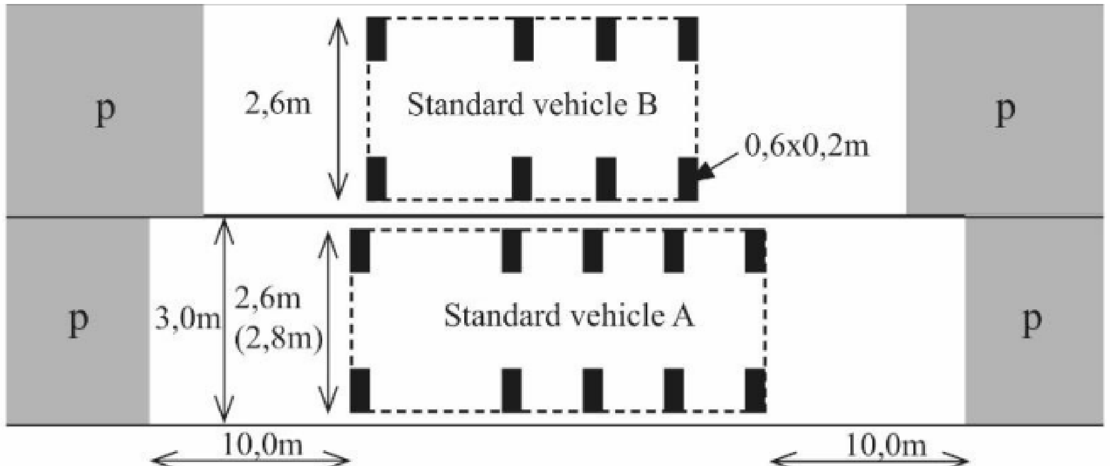
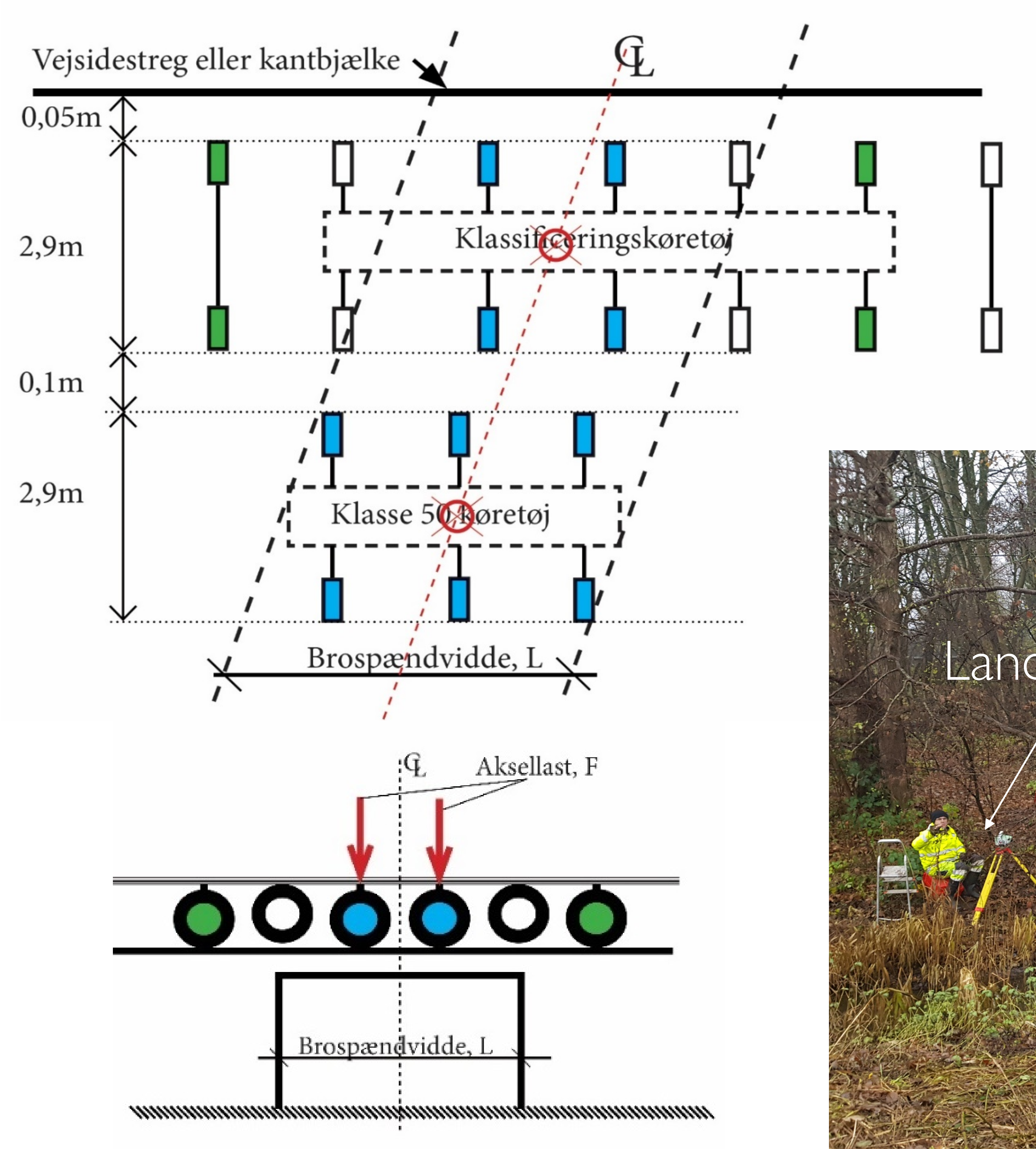
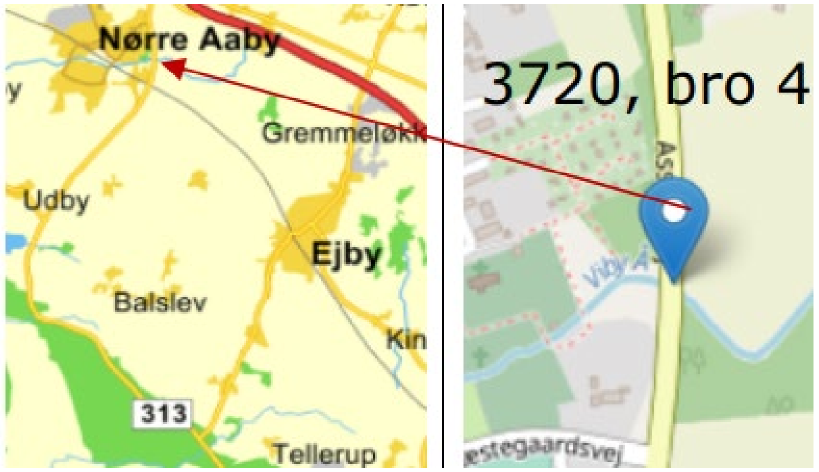


Guideline procedure verification

Guideline procedure verification

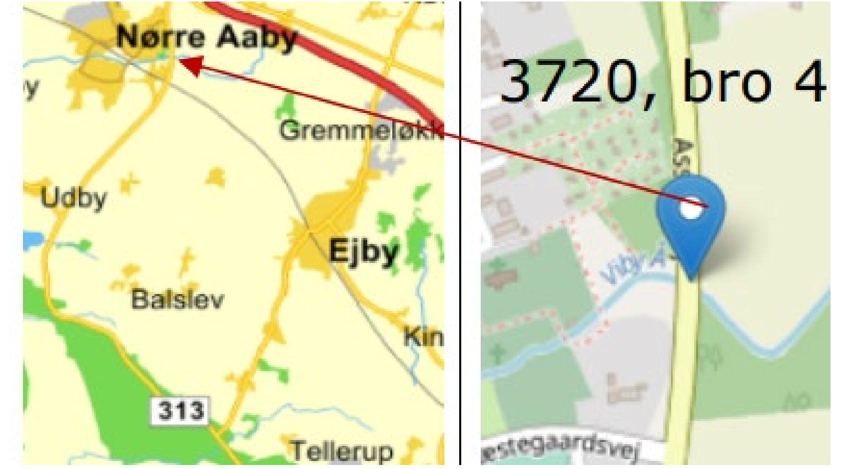
- Testbridge 4, span: 4,0m, F=36,4tone

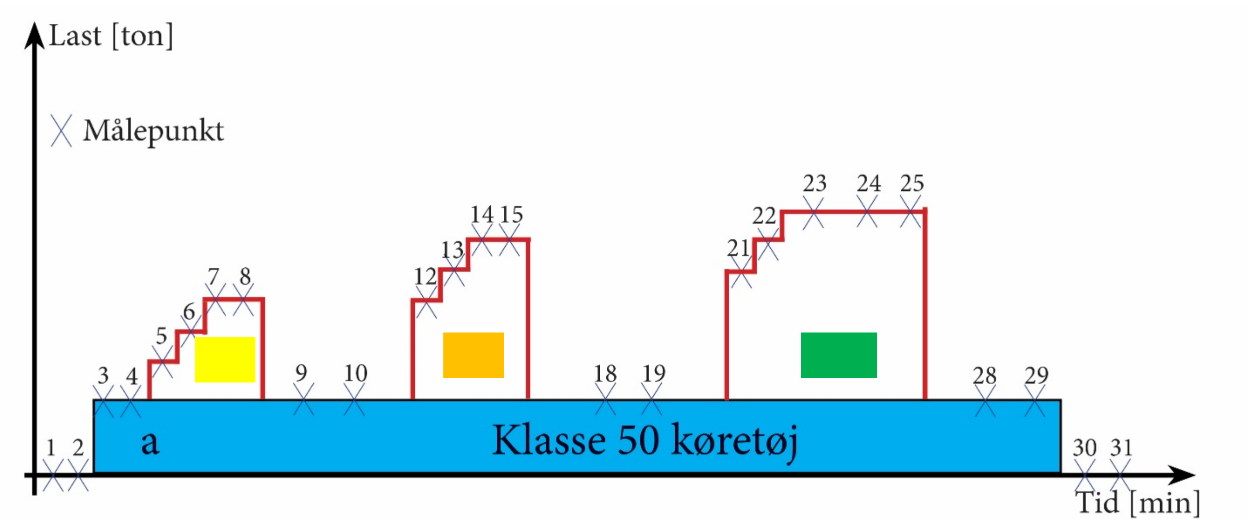


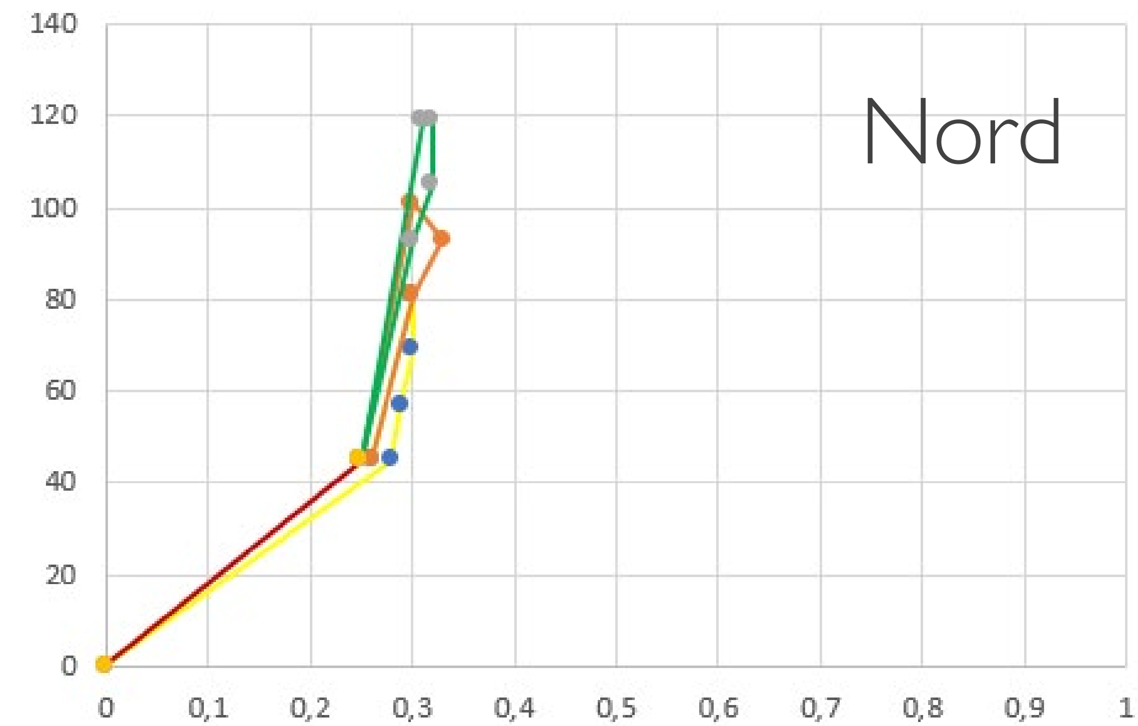


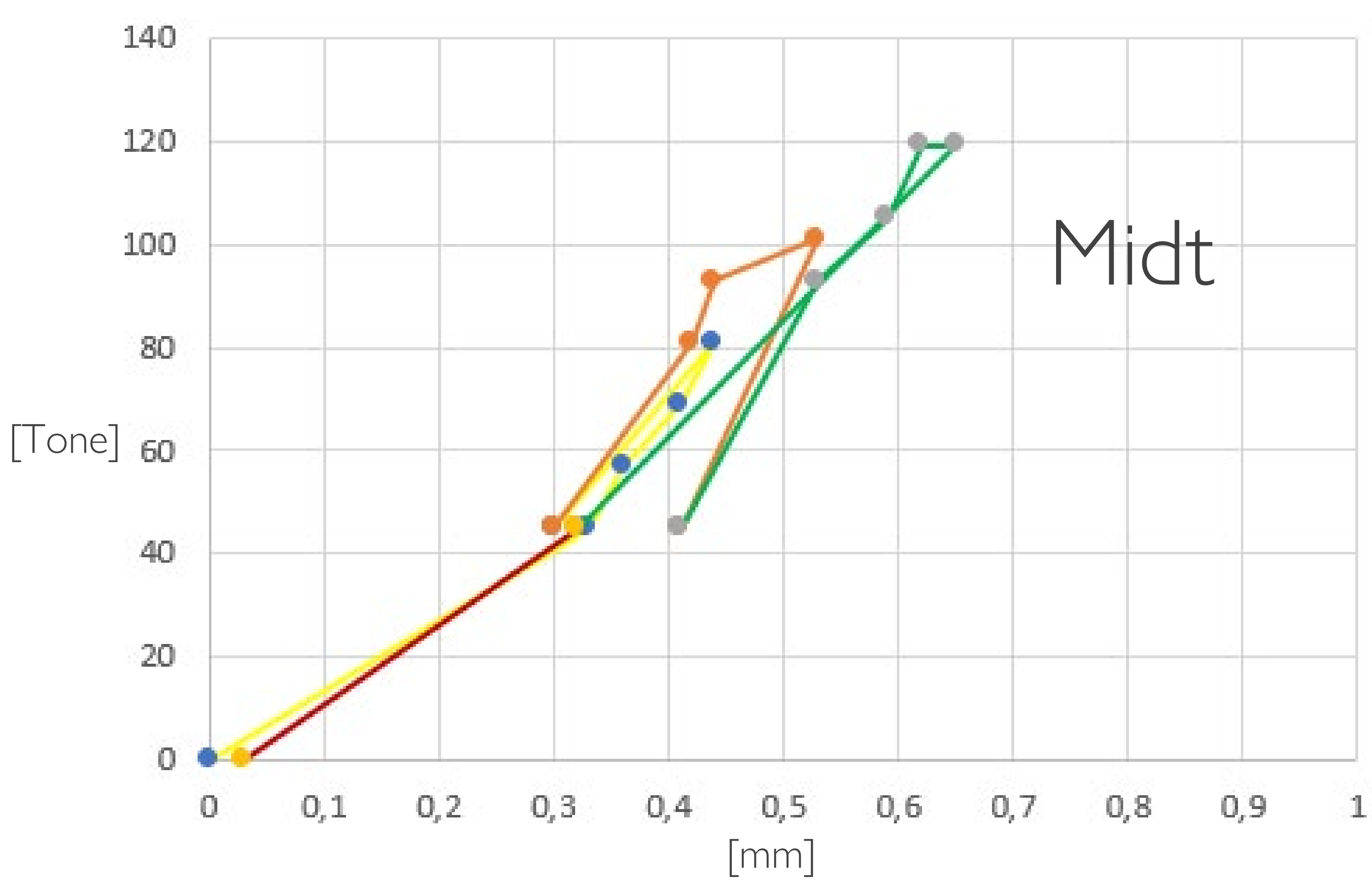
Guideline procedure verification

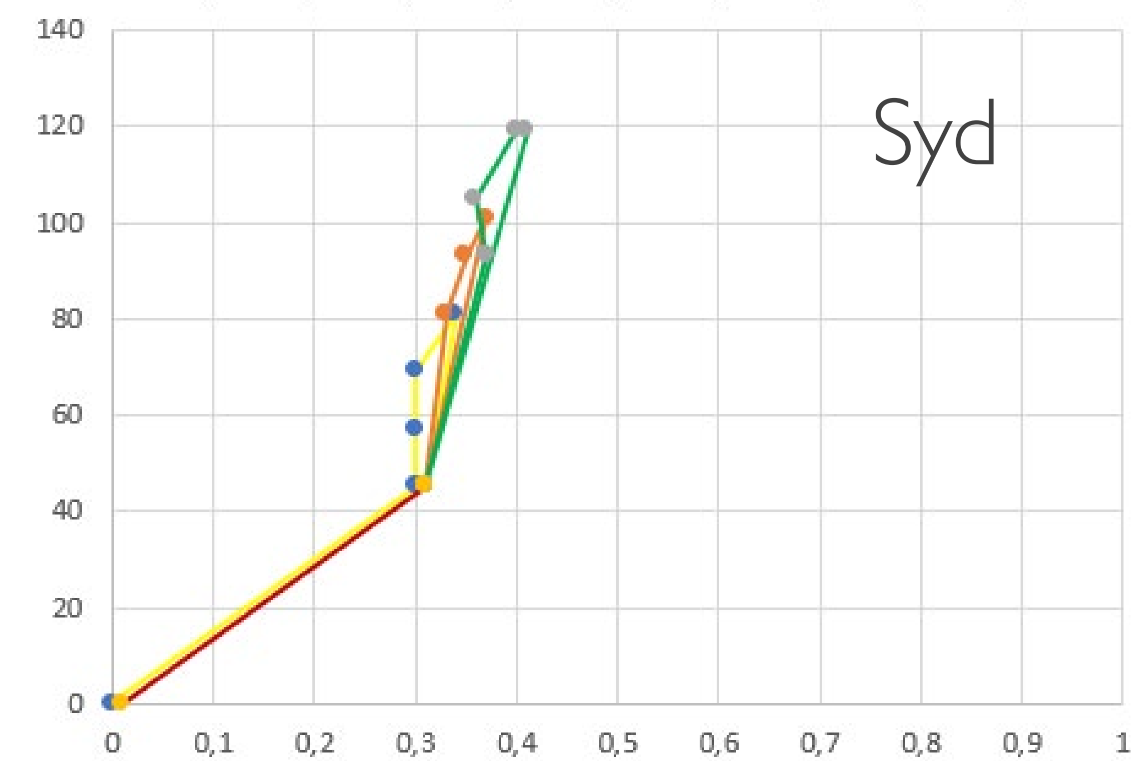
- Testbridge 4, span: 4,0m, F=36,4tone











Some initial discussions - V2.0 bridge testing project

- Proof loading procedures for 2- and 3 span bridges and in-situ sub-components
- Further stop criterion identification (input from different sources, brittle failure mechanism etc.)

- Optimization and extend load configuration mythology, monitoring methods, synergy effects, etc.
- Value optimization method (CO2 and economical savings)

- Updating of the Danish guideline
- Ensure result- and experience input generation for the upcoming Eurocode provision on "Assessment and retrofitting of existing structures "

- Collaboration synergy to ensure optimal mutual gain

Vejdirektoratet DTU AALBORG UNIVERSITY DENMARK COWI