VOI related to composite patch reparations

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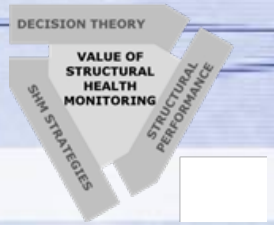

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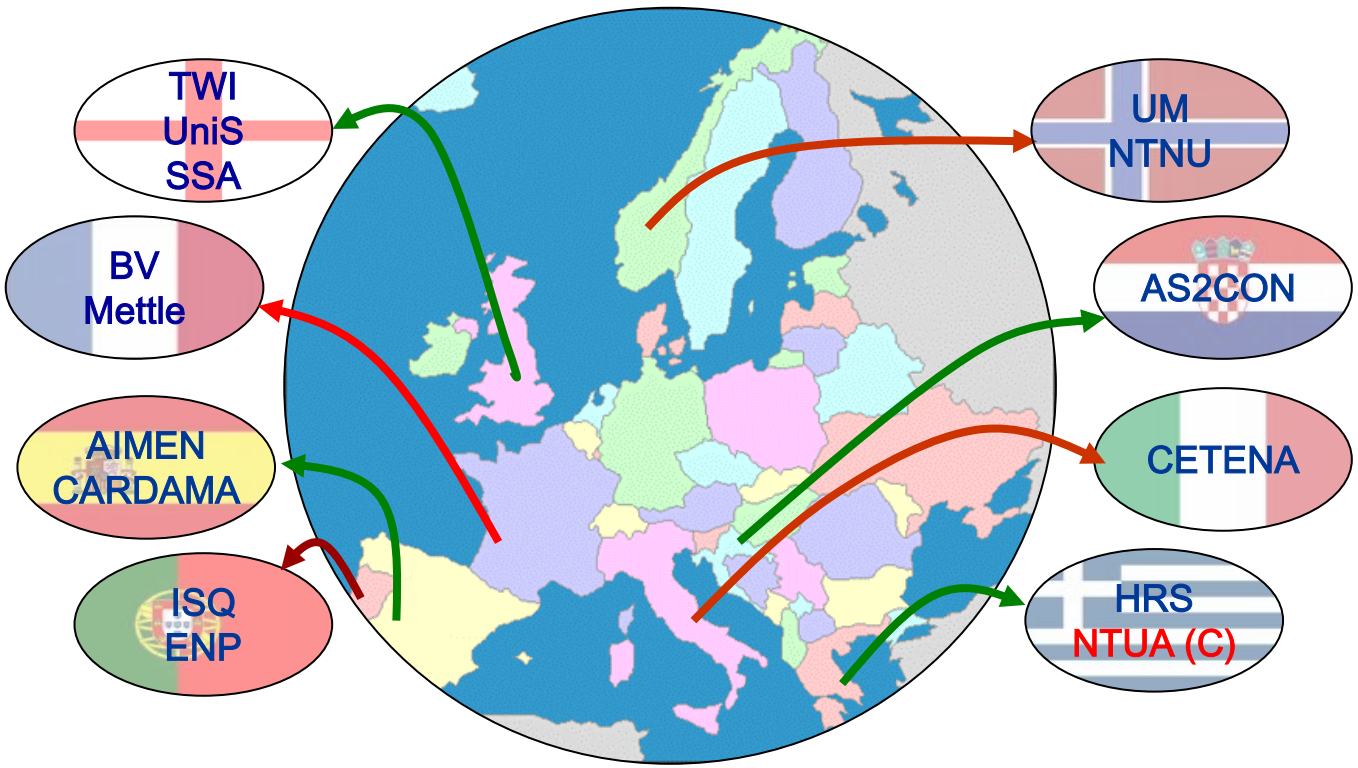
24 | 25 August, 2016. 5th COST TU1402 workshop

COMPOSITE PATCH REPAIR OF METALLIC MARINE STRUCTURES (www.co-patch.com)

Collaborative Project. *Call ID FP7-SST-2008-RTD-1– Proposal N° 233969. Duration: 40 Months (2010 – 2013)*

PROJECT PARTICIPANTS



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- EXPERIMENTAL RESULTS
- VALUE OF INFORMATION (VOI)

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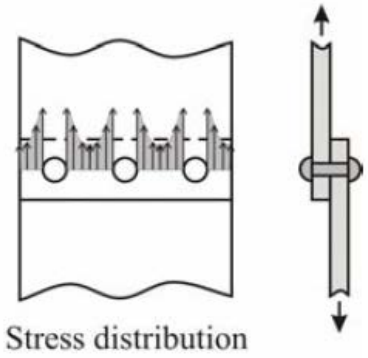
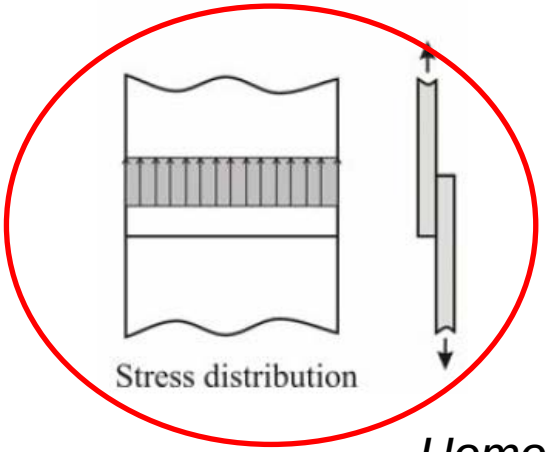
COPATCH CONCEPT

Repairing the damaged structure by a bonded composite patch

Damage: crack or corrosion



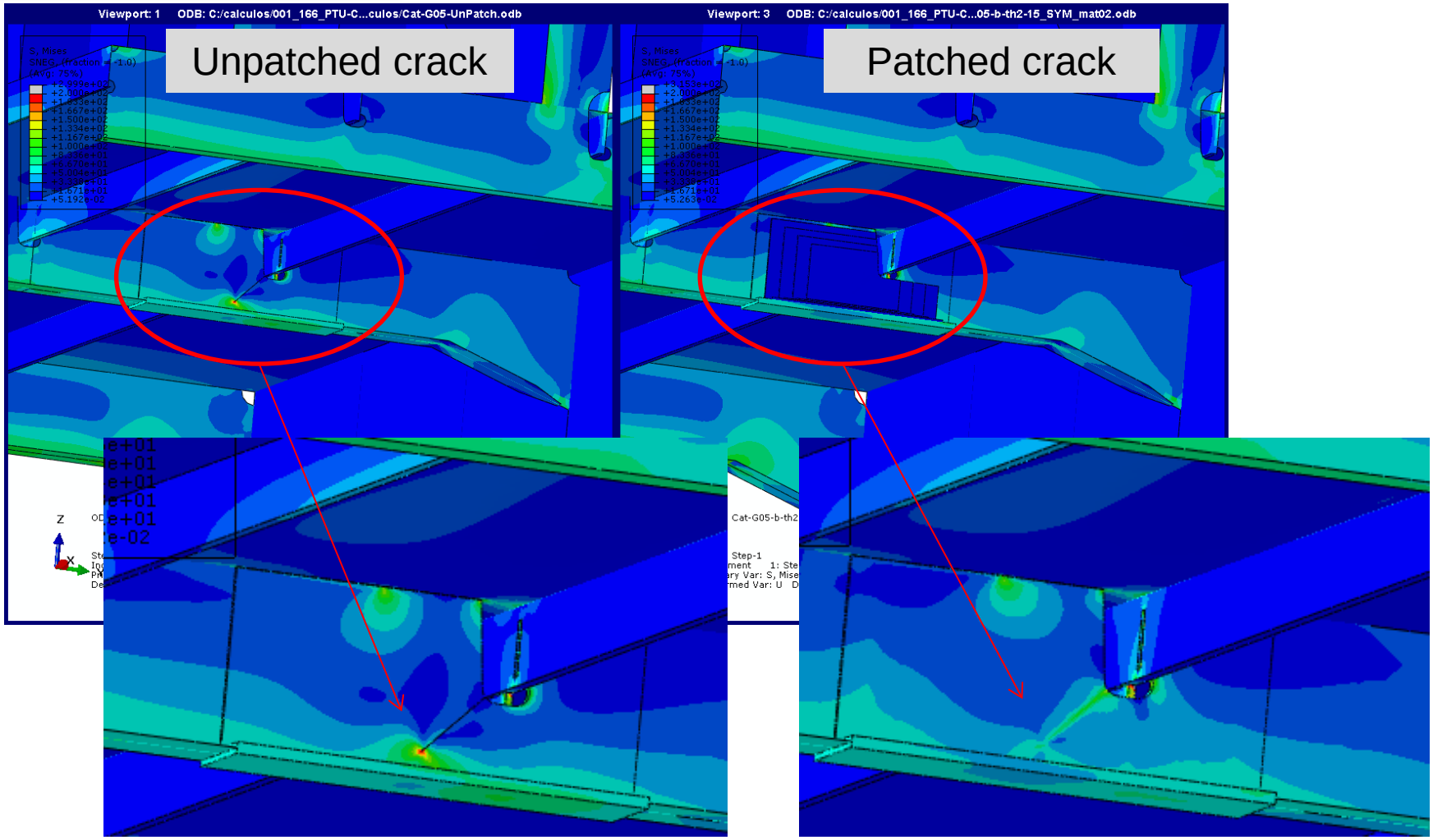


COPATCH solution works **transferring the stress** from the damaged steel to the composite patch **through the adhesive layer.**

It allows **to recover** the integrity of the damaged steel to **its original state**.

Homogeneous load transfer

COPATCH CONCEPT



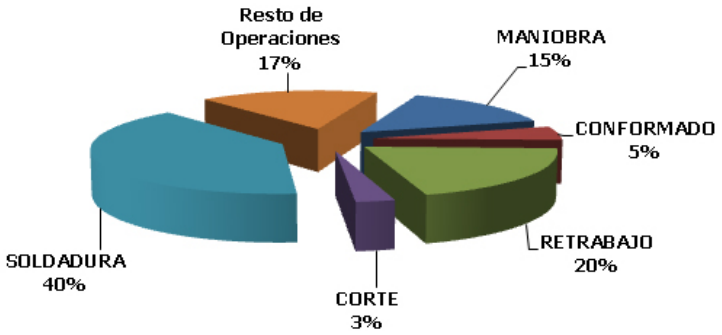
ADVANTAGES OF THE COMPOSITE PATCH REPAIR

Conventional solution in shipbuilding: replacement of the damaged steel sheet (cutting and welding) or double sheet welding.

Disadvantages of the conventional solution:

- ✓ **Temperature:** thermal treatment distortions
- ✓ Residual stress
- ✓ Weight increase
- ✓ Harmful environment work (particles, fumes, smokes)
- ✓ Necessity of grounding
- ✓ At explosive environments: Need of emptying and cleaning of tanks
- ✓ Large working hours and high labor costs

www.distorsioncero.es

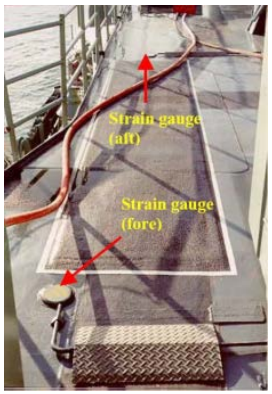


ADVANTAGES OF THE COMPOSITE PATCH REPAIR

Conventional solution in shipbuilding: replacement of the damaged steel sheet (cutting and welding) or double sheet welding.

Main advantages of COPATCH solution:

- ✓ Low (almost environment) temperatures
- ✓ “In situ” application
- ✓ Low added weight – low weight materials – cranes are not necessary to move the material
- ✓ No stress concentrations – good fatigue behavior
- ✓ Good durability – less corrosion
- ✓ Easy to perform



BACKGROUND – COMPOSITE PATCH REPAIR

Composite patches have been applied successfully on civil constructions, on naval ships (military), aircraft, pipe works and offshore platforms :

www.compclass.org.uk

West Gate Bridge, Melbourne, 2012

The Royal Australian Navy. Adelaide Class Frigate

Repair of the main deck

FPSO (Floating Production Storage and Offloading) - Norway

Repair of the cargo tank bulkhead

ISO/TS 24817:2006: Petroleum, petrochemical and natural gas industries -- Composite repairs for pipework -- Qualification and design, installation, testing and inspection

BACKGROUND – COMPOSITE PATCH REPAIR

COPATCH CHALLENGE

SPECIAL FEATURES OF COMPOSITE REPAIR IN SHIPBUILDING

- Material: conventional steel (grade A)
- Thickness: 6 - 20 mm
- Classification Society Approval

Control of patch repairs
FBGs Monitoring

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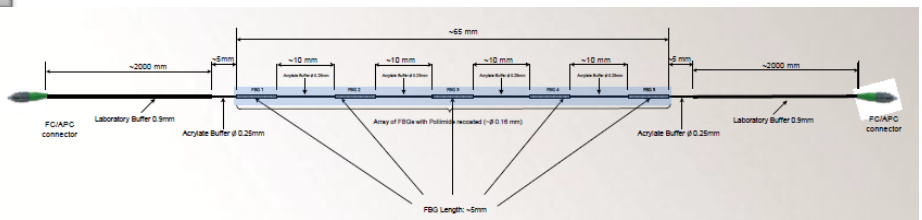
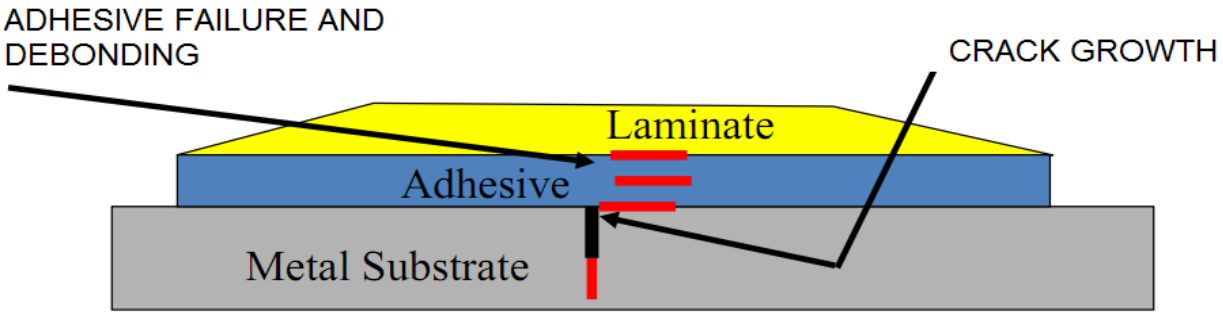
Advantages of FBG Strain Sensors



- ✓ Small **size** and weight
- ✓ **Multiplexing** and **multifunctionality**
- ✓ Highly **sensitive** and precise
- ✓ Excellent performance in **harsh environments** with long term stability
- ✓modular equipment
- ✓ **Absolute measurements** without referencing
- ✓ Suitable for **hard-to-reach locations**
- ✓ **Immunity** to electromagnetic and radio frequency interferences
- ✓ Packaging suitable for various applications (laboratory, outdoor, concrete...) and large scale sensing networks.
- ✓ Ideal for remote **monitoring**

FBG Strain Sensors to monitor bonded composite patch repairs

Failure modes of a composite patch repair:

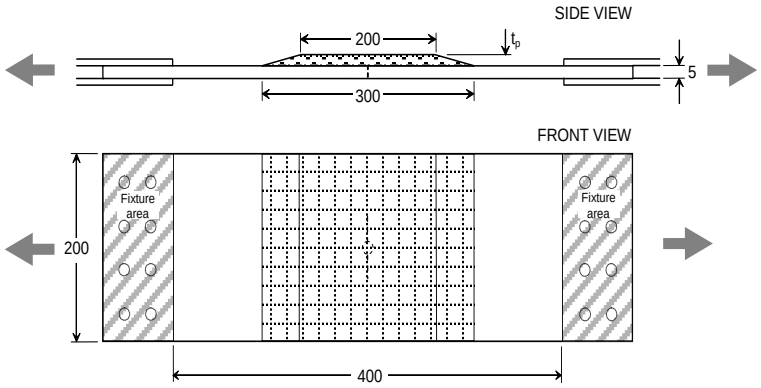


FBGs can monitor:

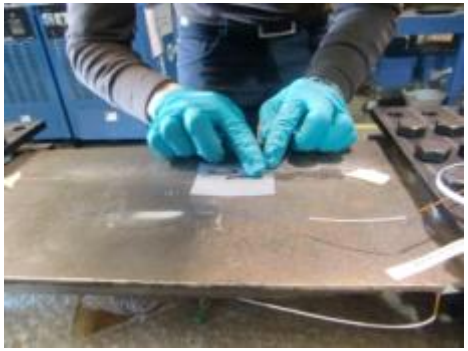
1. Steel crack growth (patch side or back side)
2. Composite debonding (adhesive layer)
3. Internal composite failure

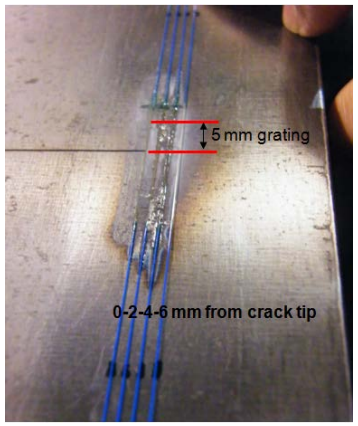
FBG Strain Sensors to monitor bonded composite patch repairs

Mid-scale tests specimen

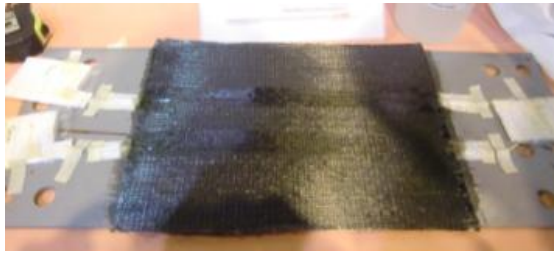


Back side steel monitoring





Composite laminate monitoring (Embedded FBGs)

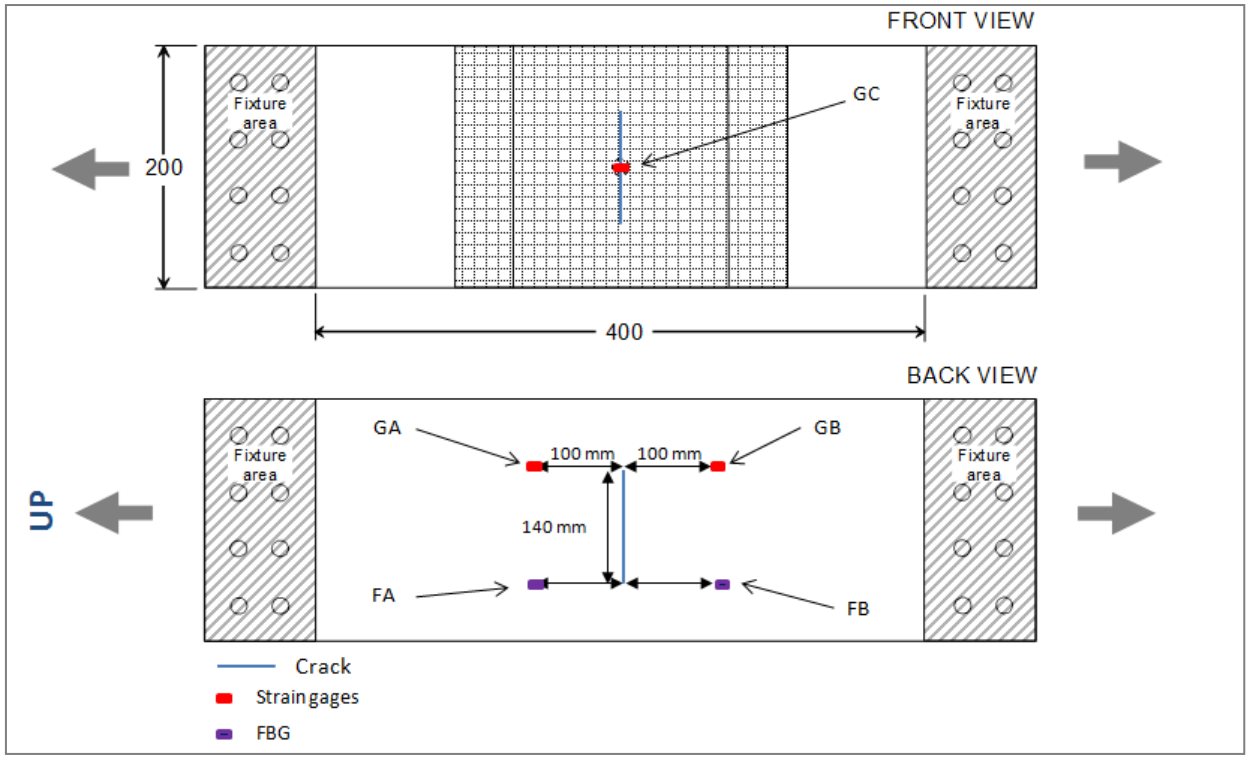


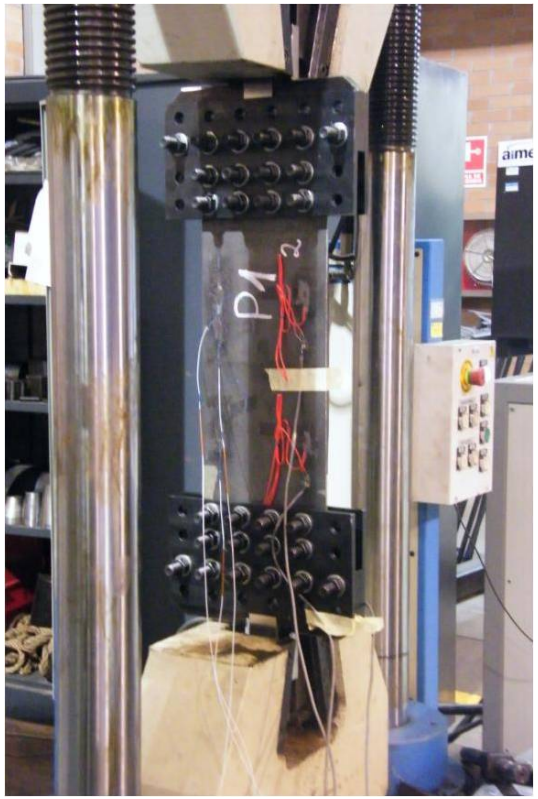
Adhesive layer monitoring

Mid-scale specimen - Static Tensile tests

Comparative study: Conventional strain gages *vs* FBGs measurements

FBGs (FA, FB) *and strain* ***gages (GA,GB)*** *bonded in steel and one strain gage bonded in the top of the patch* ***(GC)***





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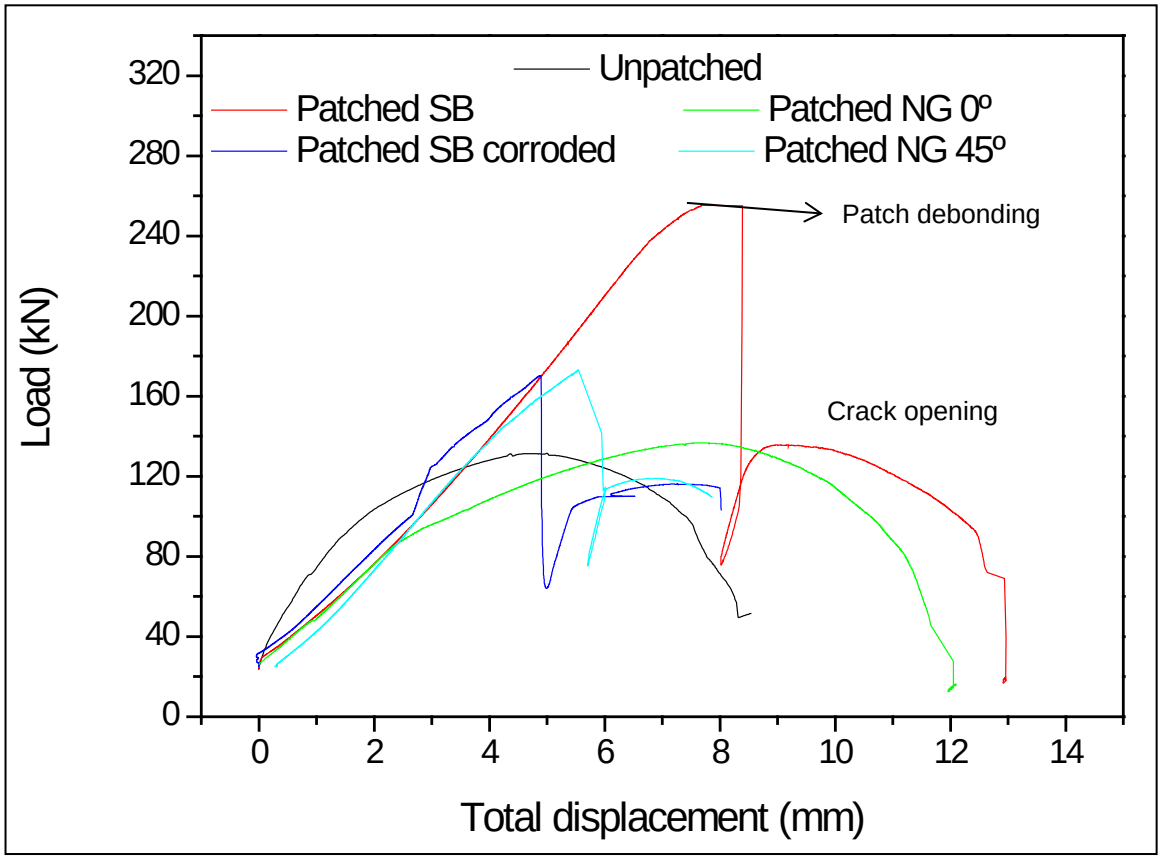
Mid-scale specimen - Static Tensile tests

Preliminary tests to select patch materials and steel surface treatment

Global Load vs Displacement curve. FAILURE: patch debonding.



Patch effectiveness: greatly increase the stiffness of the structure and the maximum load

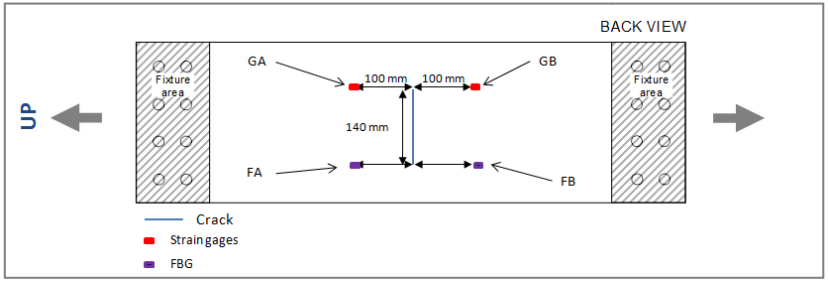
	Max load
Unpatched	125 kN
Patched	260 kN

Best results:

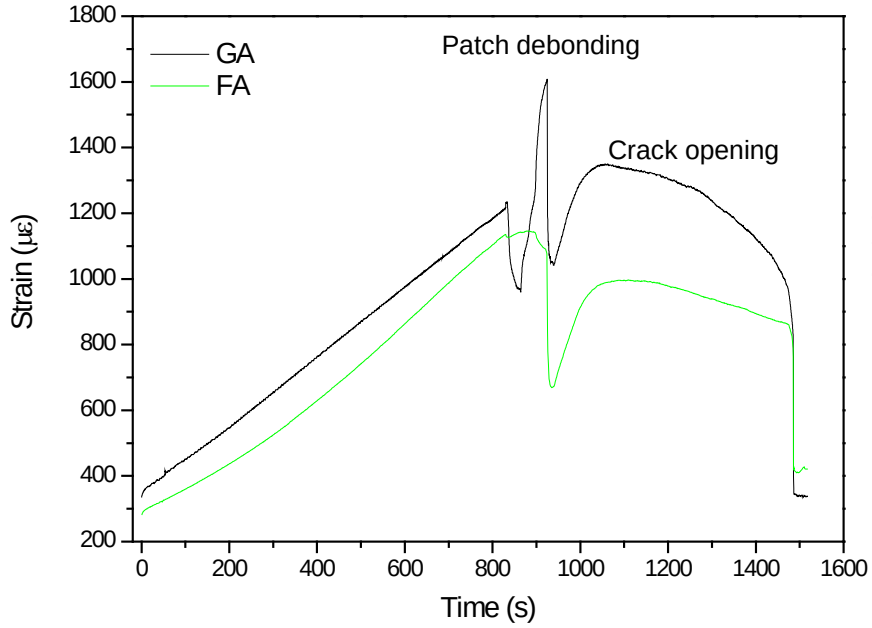
- ✓ Grit blasting surface treatment
- ✓ Hand lay-up manufacturing
- ✓ Vinyl ester
- ✓ Carbon fiber, unidirectional

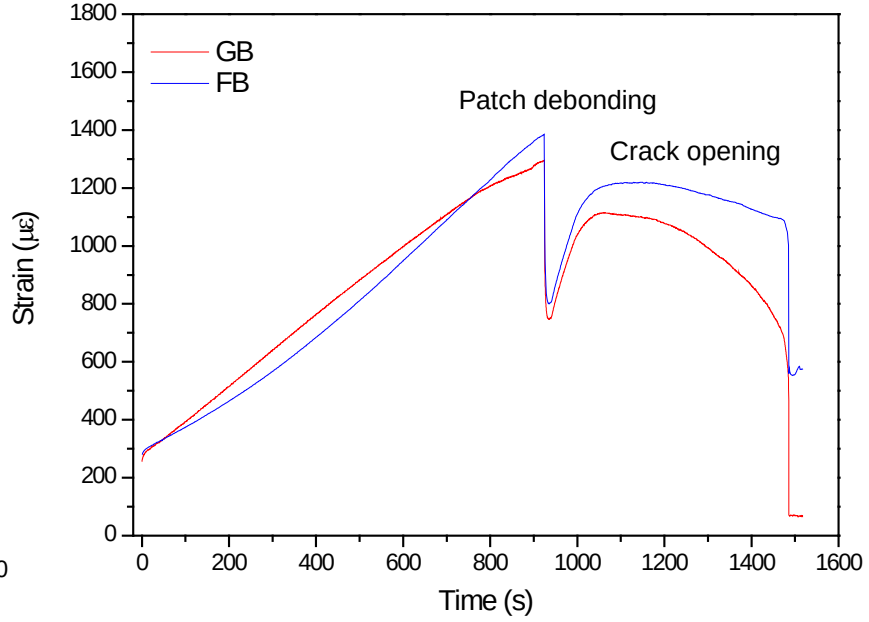
Mid-scale specimen - Static Tensile tests

Comparative study: Conventional strain gages *vs* FBGs measurements



FBGs same behavior than conventional gages

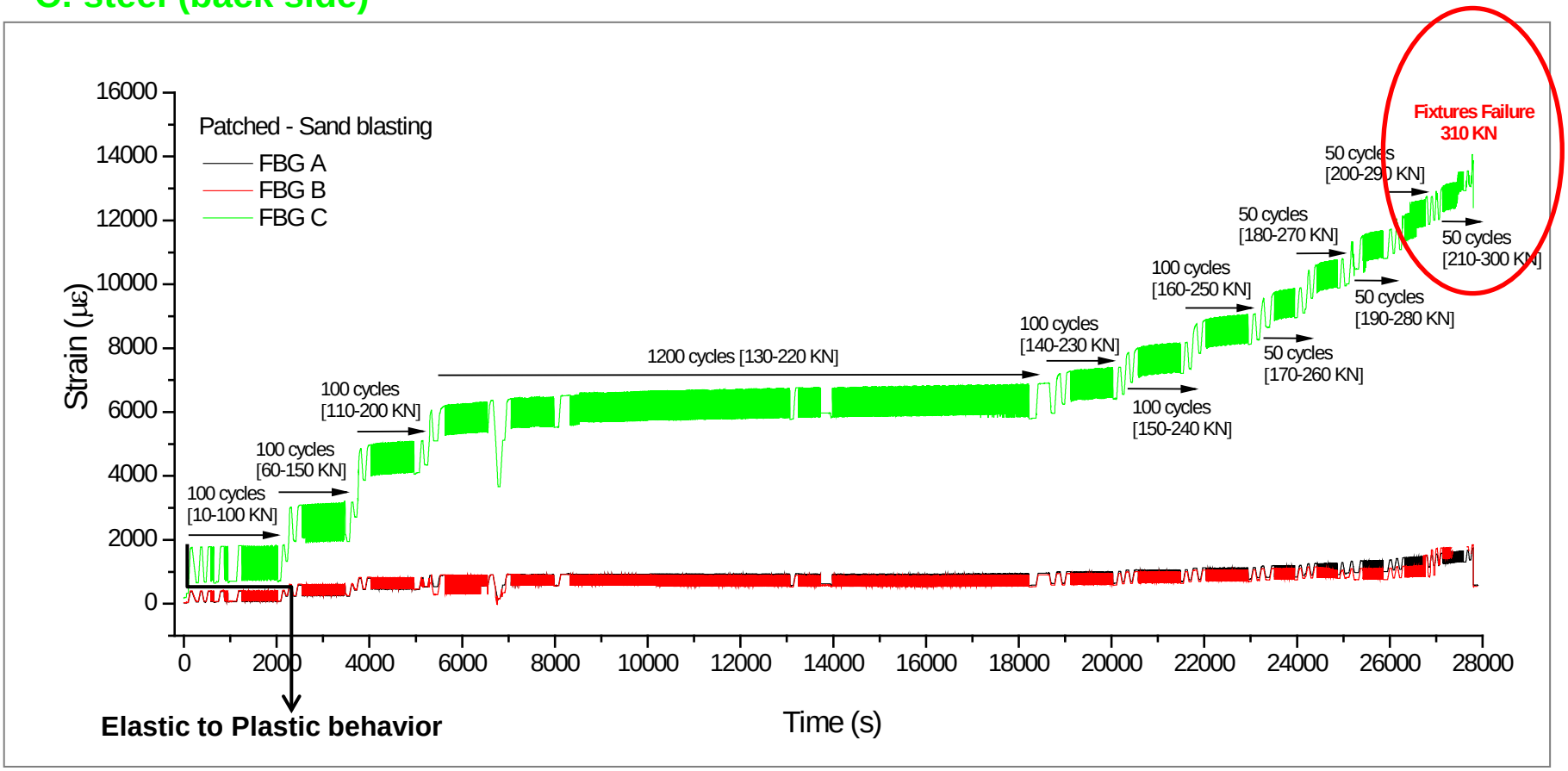




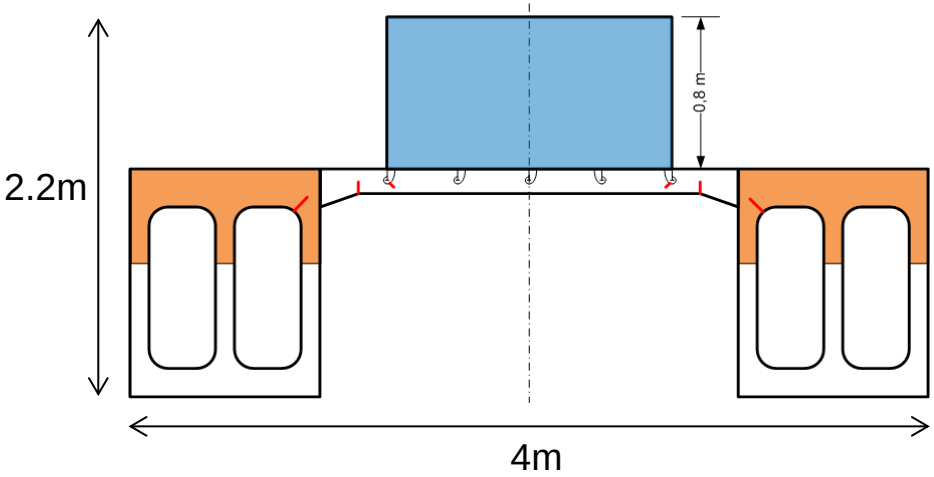
Mid-scale specimen - Cycled Tensile tests

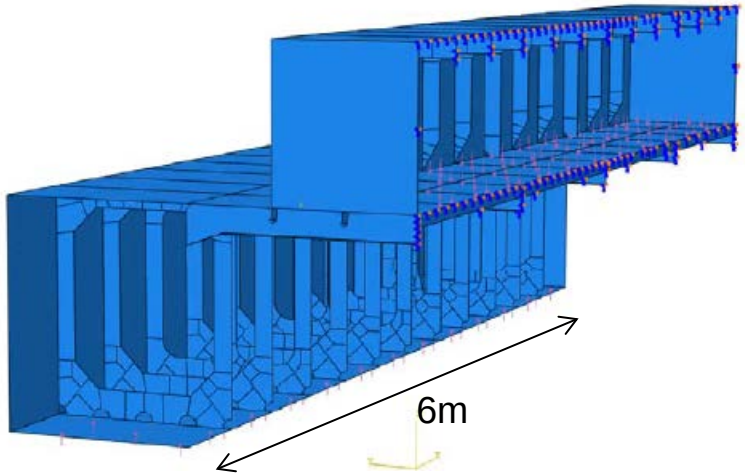
A, **B**: adhesive layer
C: steel (back side)

Good patch adhesion



Full-scale test - CATAMARAN steel structure monitoring



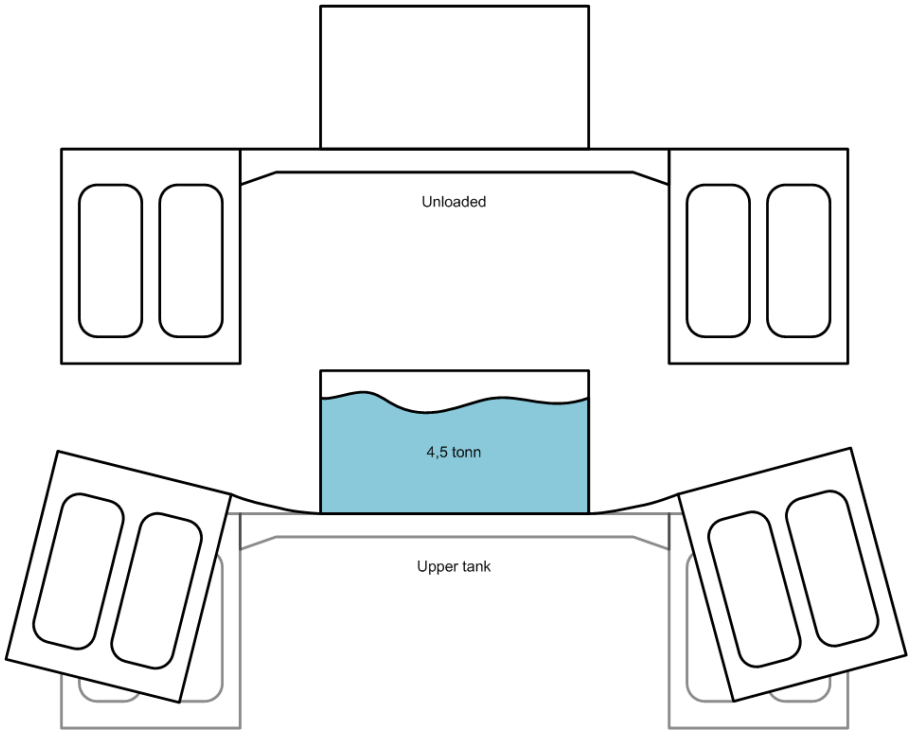


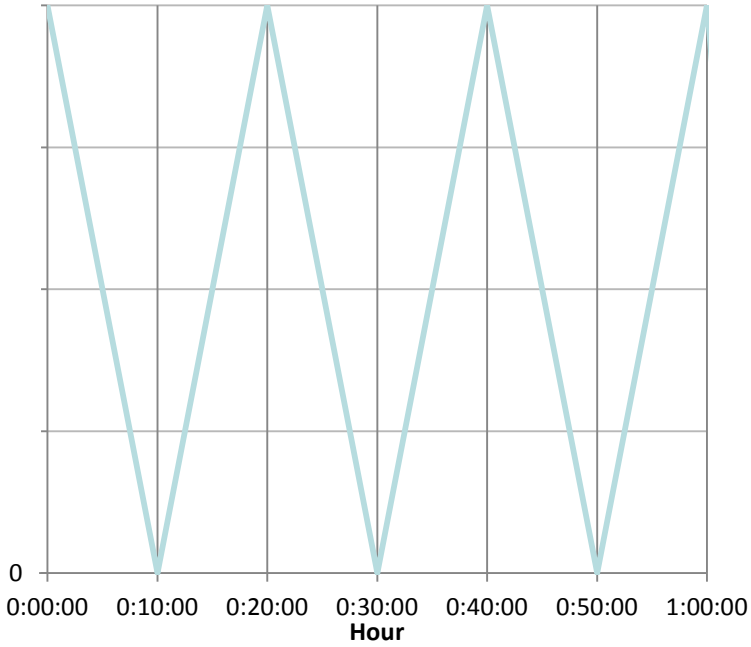
Vigo sea inlet

Shipbuilder
CARDAMA

Full-scale test - CATAMARAN steel structure monitoring

Fatigue cycle (bending): filling up/emptying the upper tank

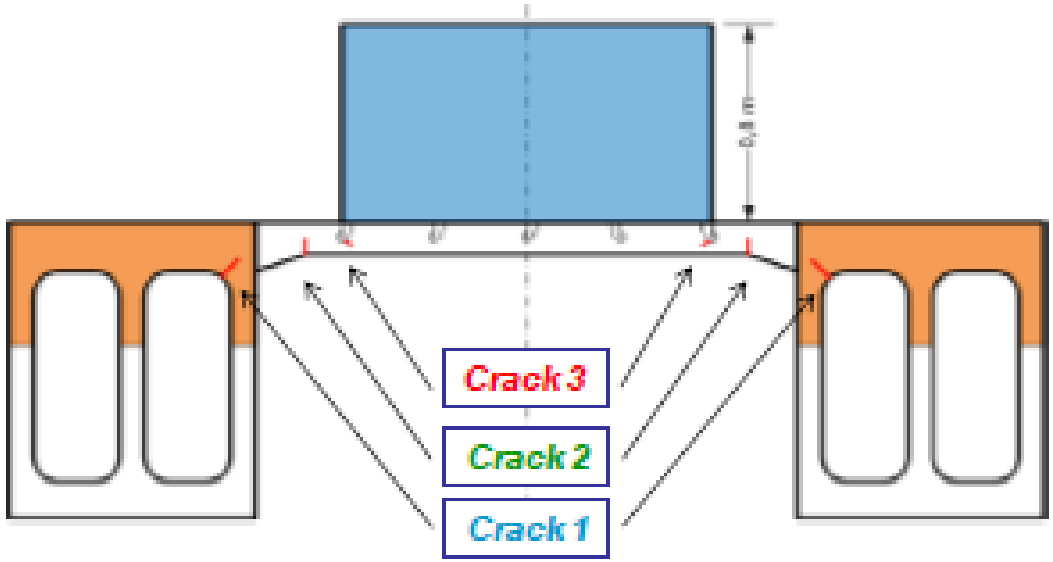




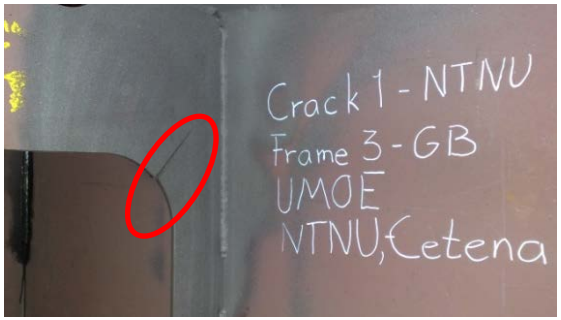
Full-scale test - CATAMARAN steel structure monitoring

FBG Monitoring of:

- ✓ 3 types of cracks
- ✓ In different frames
- ✓ Patched and unpatched



1. 45º, length=100mm

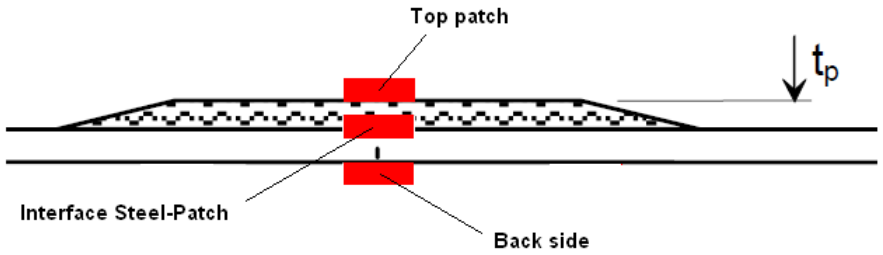


2. Vertical, length= 40mm

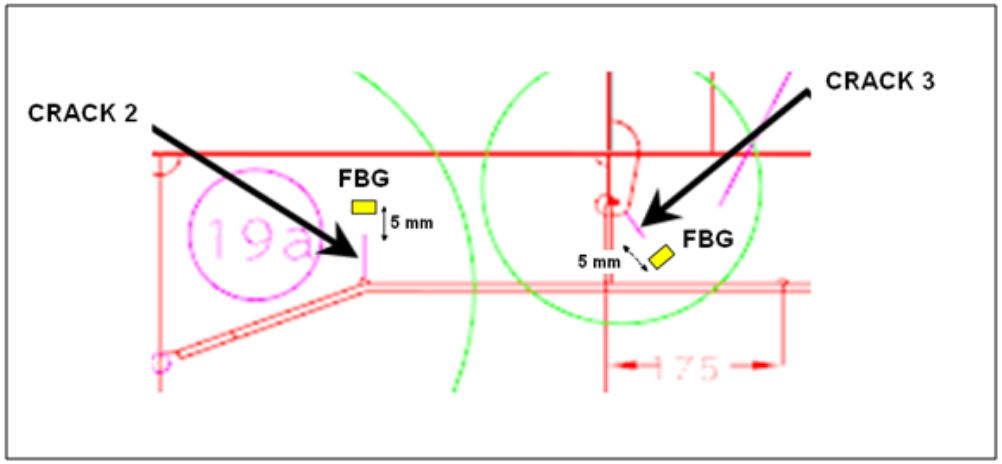
3. 45º, length=60mm

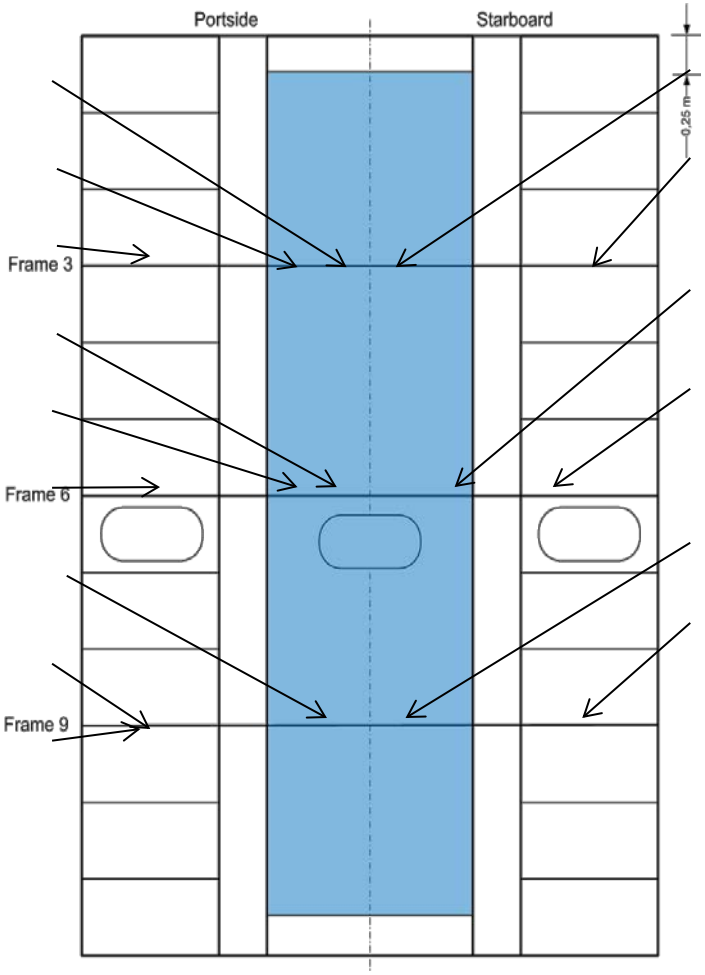
Full-scale test - CATAMARAN steel structure monitoring

Patched: 3 FBGs



Unpatched: 1 FBGs





Full-scale test - CATAMARAN steel structure monitoring

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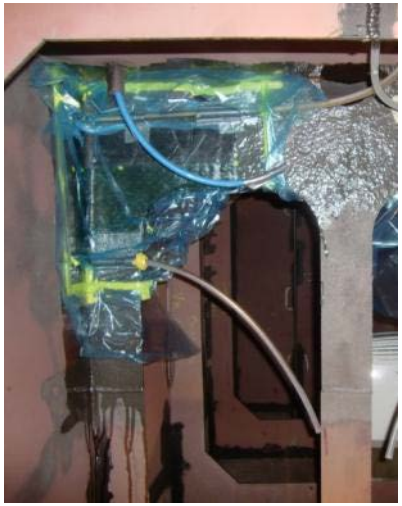

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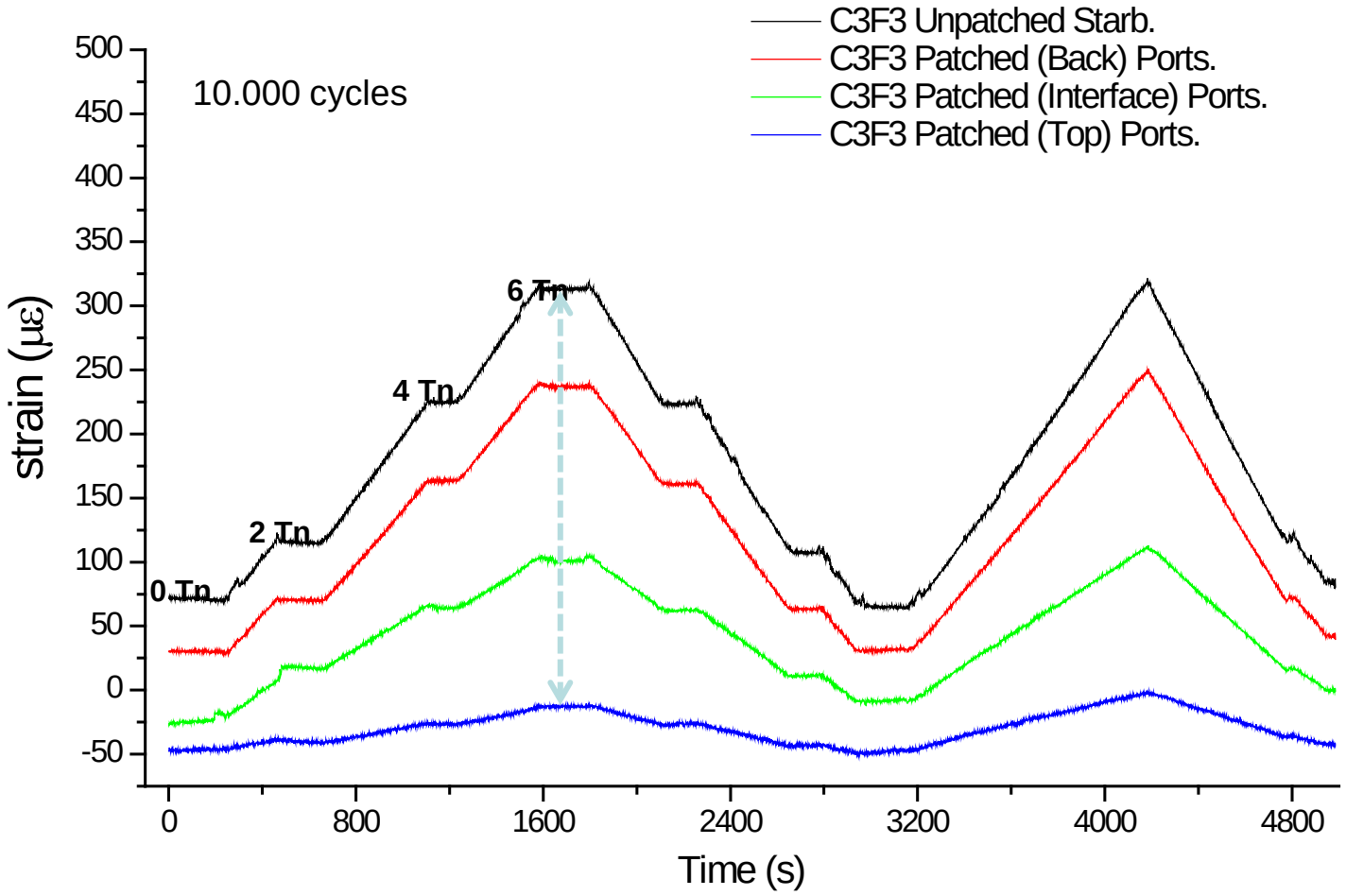

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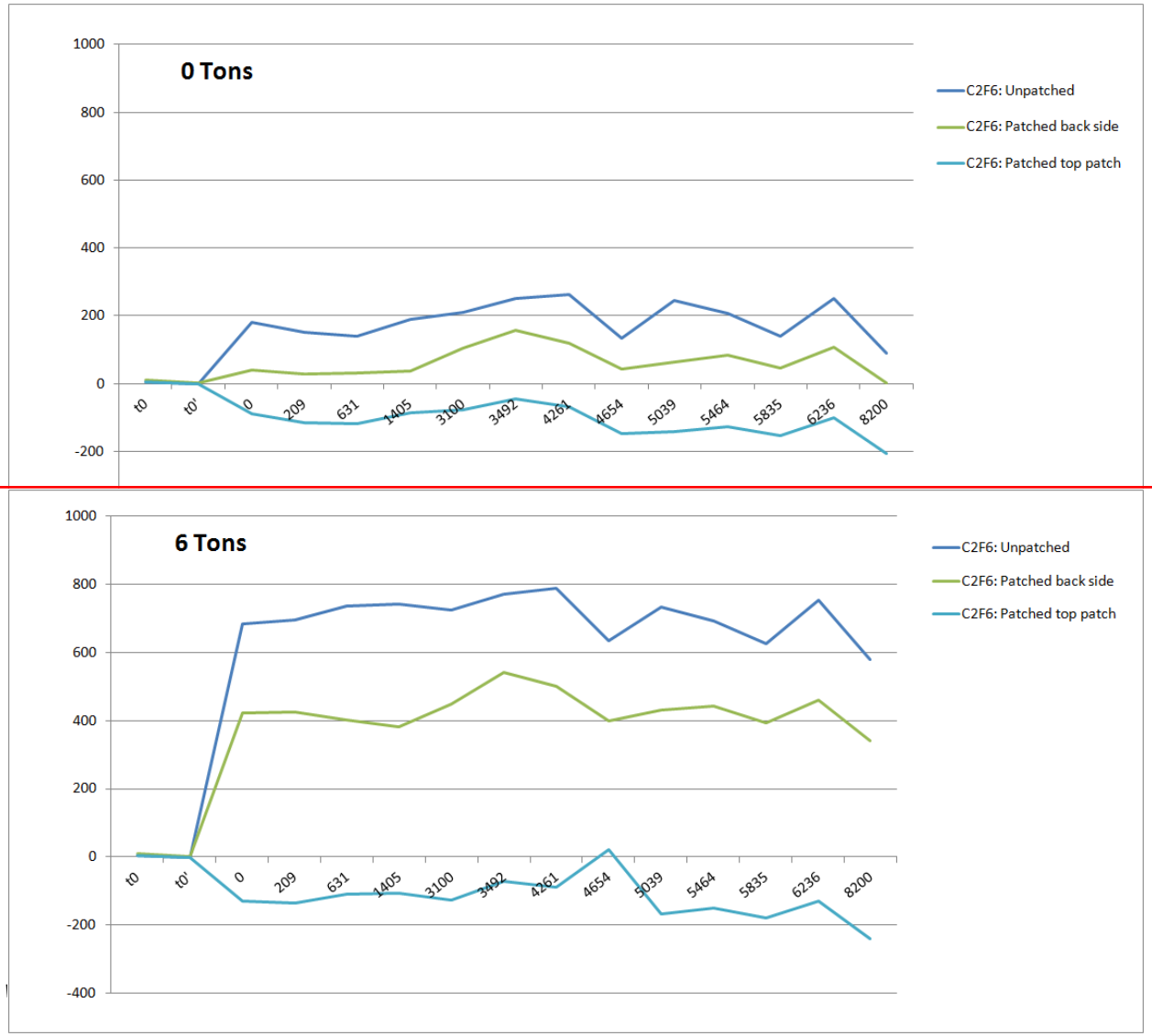
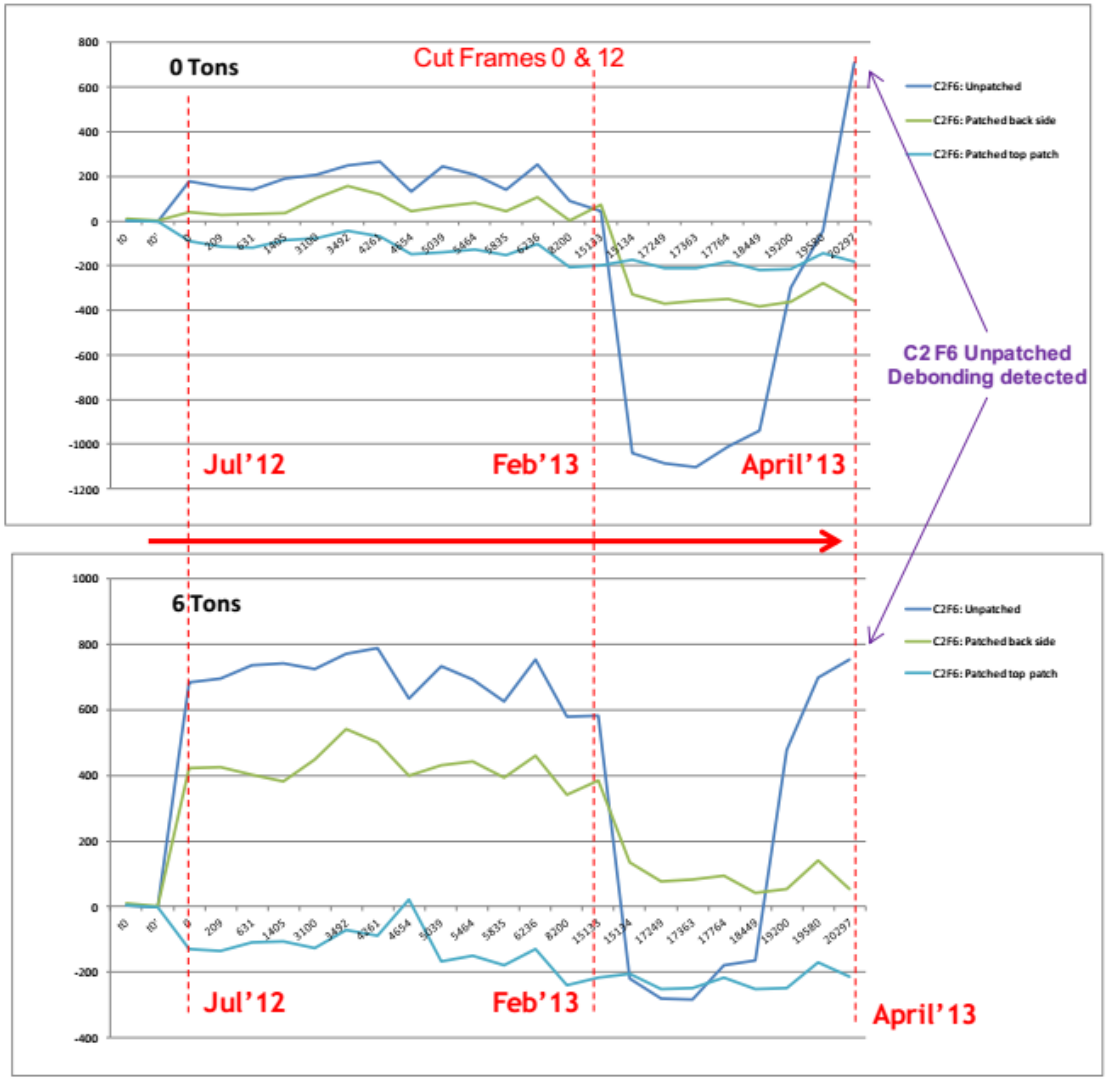


July´12 → May´13

After 20.000 cycles neither patch debonding nor crack growth have been observed

- Premature FBG's debonding was detected because of the action of the corrosion.
- Protective paint should be applied in whole area where the FBGs are bonded to avoid corrosive processes that damage the fiber.



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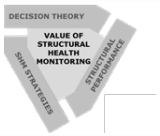

Value of information

- FBG monitoring gives information of the reparation and **defects can be detected**: debonding and crack growth

- Patch material and application **techniques have been optimized during co-patch project and failure reduced**: no defects in 20.000 cycles of fatigue in a full scale demonstrator catamaran

- **Codes, Flag administrations and Classification society do not include composite patch reparations**

- Additional inspections and approvals (plan reviews) are needed to compile for approvals by Classification Society – they are expensive
  - Monitoring with FBGs could accelerate inclusion of patch reparations in codes – we have the **adequate tool to evaluate and feed models with experimental data**

- VOI will be related **tradeoff between ship downtime, reparation costs (+plan review?), maintenance cost of reparation and failure/defect probability**

Thank you!

Acknowledgments

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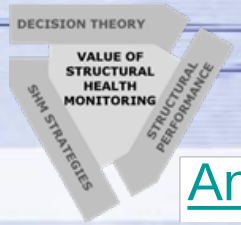
Astilleros Cardama and *Estaleiros Navais de Peniche* in the specimens manufacturing and full-scale tests.



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