FP7-SST-2008-RTD-1 Sustainable Surface Transport

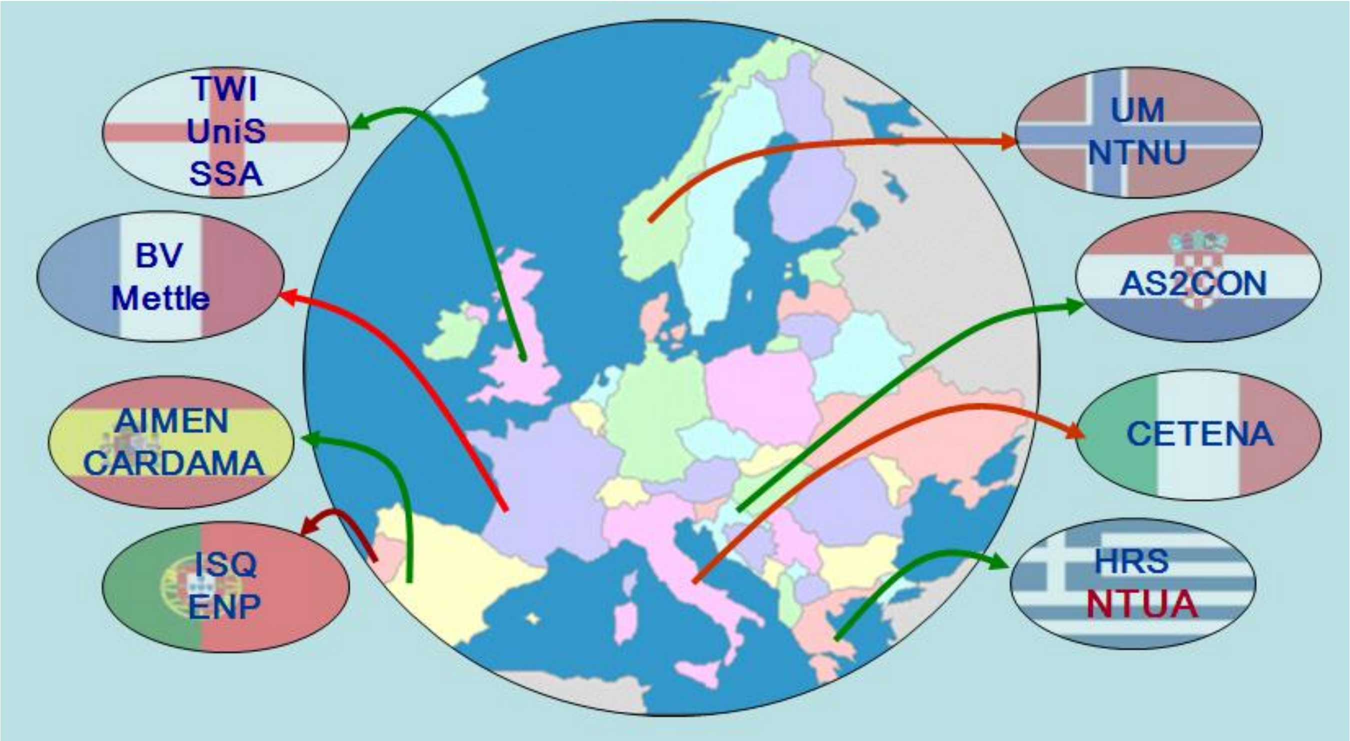
Co-Patch

Composite Patch Repair
for Marine and Civil Engineering Infrastructure Applications

General Overview of the Project

E-LASS Kick-off + E-LASS & MESA workshop, Borås, Sweden, 8-9 October 2013

Co-Patch Consortium



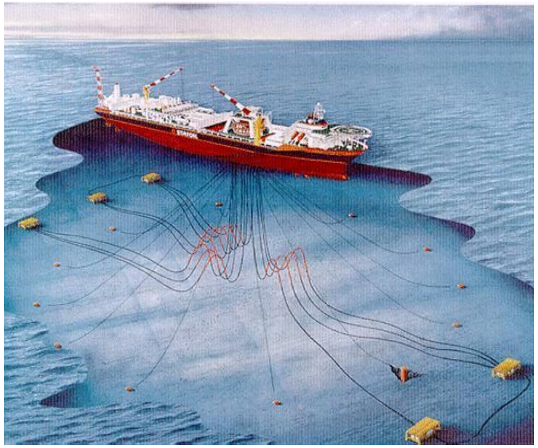
3 partners from UK, 2 partners from France, Greece, Norway, Portugal and Spain, 1 from Croatia and Italy

PROJECT COORDINATOR: National Technical University of Athens, Shipbuilding Technology Laboratory

January 2010 – April 2013 (40 months)

Total budget 5,285,000 Euro

Composite patches have been applied successfully on naval ships, offshore platforms and civil constructions



FPSO (Floating Production Storage and Offloading) (Norway)

Repair of the corroded deck floor and of the cargo tank bulkhead - DNV

Bridge

Pottawattamie County, USA

Type 21 Frigate (Amazon class)

Repair of the main deck

RAN Adelaide Class Frigate

Repair of the main deck

Main objective of the project:

Definition of a new effective repair/reinforcement method for large steel structures with defects and demonstrate that composite patch repairs or reinforcements can be environmentally stable and that they can be used as permanent repair measures

Field of application:

- Marine (vessels, platforms, ...)
- Civil (bridges, cranes, ...)

Repair of damages caused by:

- Fatigue
- Corrosion

Advantages with respect to conventional repair/reinforcement technologies:

- No hot work
- Application 'in situ'
- No stress concentrations
- Low added weight

Upgrade of existent structures for:

- Sustain new loads
- Mitigating initial structural deficiencies

Critical aspect of composite patches:

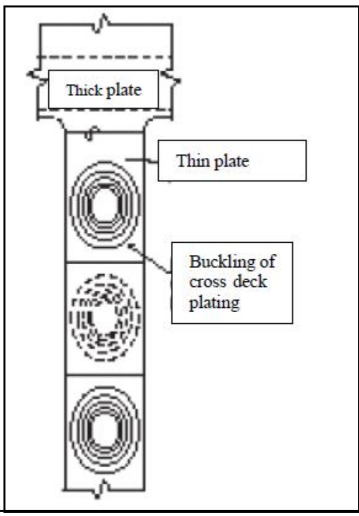
- Long term performance ???

Specification of application cases BV

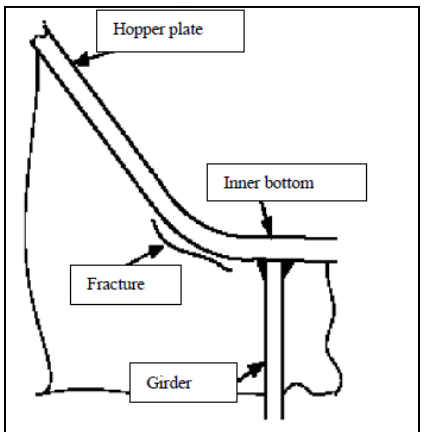
Various repair application cases were specified

A stakeholder forum was established to discuss and agree the business and regulatory implications of introducing composite patch repair (more than 30 members)

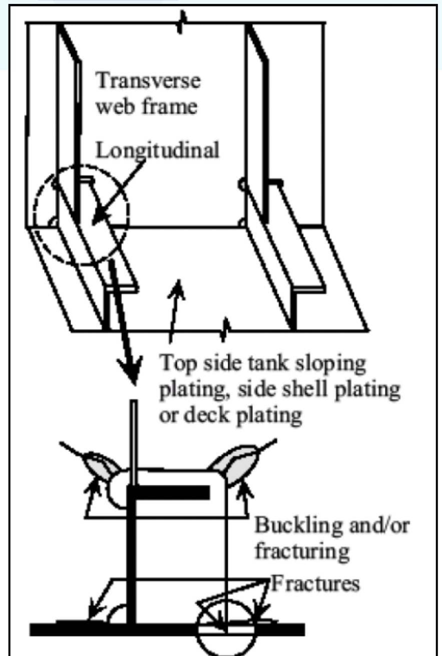
Highways Agency www.highways.gov.uk
Gurit gurit.com
Fincantieri www.fincantieri.com
Amber Composites www.ambercomposites.com
Marine Technical Limits www.technical-limits.com
Saipem www.saipem.com
Australian DOD - DSTO www.dsto.defence.gov.au
Construction Industry Research and Information Association (CIRIA) www.ciria.org
Atlantic Bulk Carriers Management Ltd www.abcml.com
Carnival Corporation & PLC www.carnivalcorp.com
Devold AMT amt.no
Babcock babcock.co.uk
ESR Technology www.esrtechnology.com
PETROBRAS
Network Rail www.networkrail.co.uk
Reichhold reichhold.com
DCNS



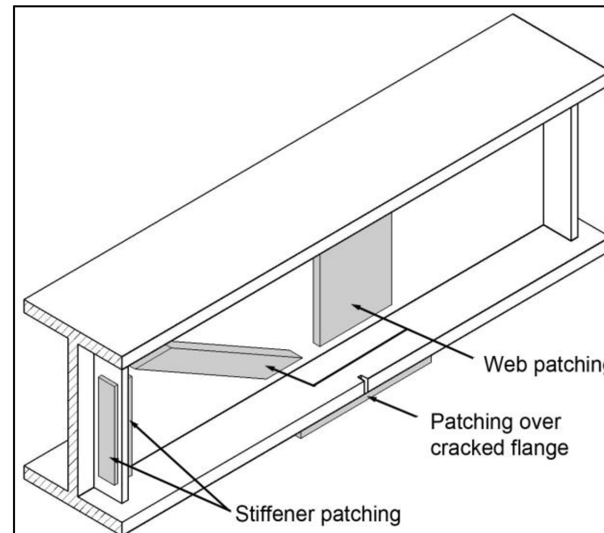
Reinforcement of cross deck plating in container ships



Defects at bilge hopper plates



Reinforcement in way of structural details for passage of stiffeners



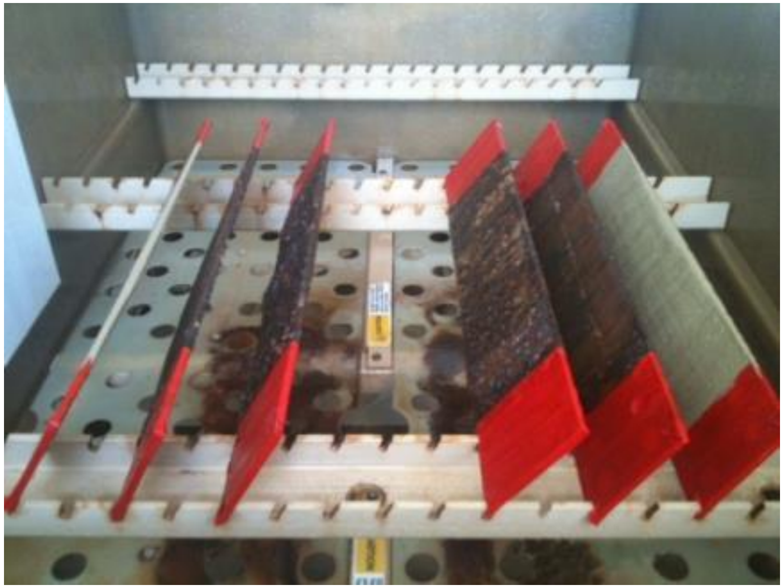
Civil applications cases

Co-Patch

Laboratory testing NTUA

Composite materials characterization
Single Lap Shear tests

Various composite configurations: **HLU-C/V**, **VI-C/V** & **VI-C/E**
Two surface preparation methods: Grit Blasting (**GB**) & Needle-Gun (**NG**)
Two aging scenarios: Non-aged & 300 cycles (100 days) aging



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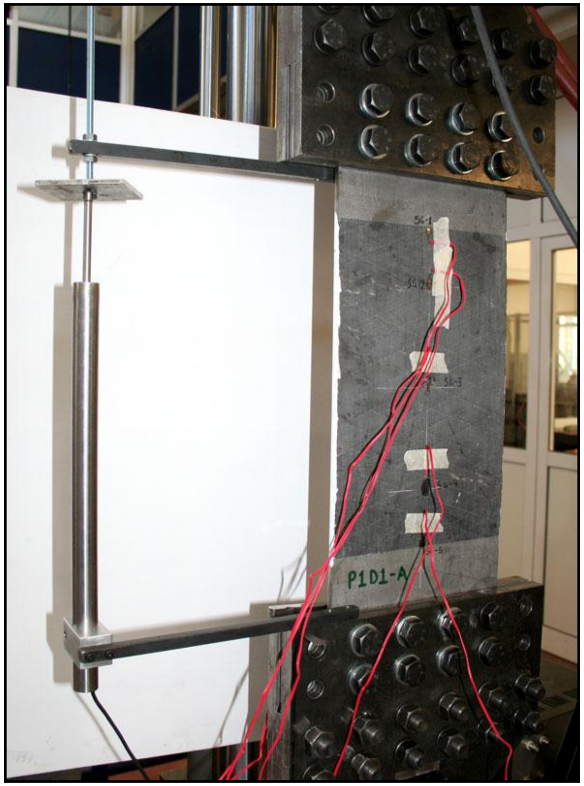
<u>Small scale tests</u>

Patched cracked plates in static tension



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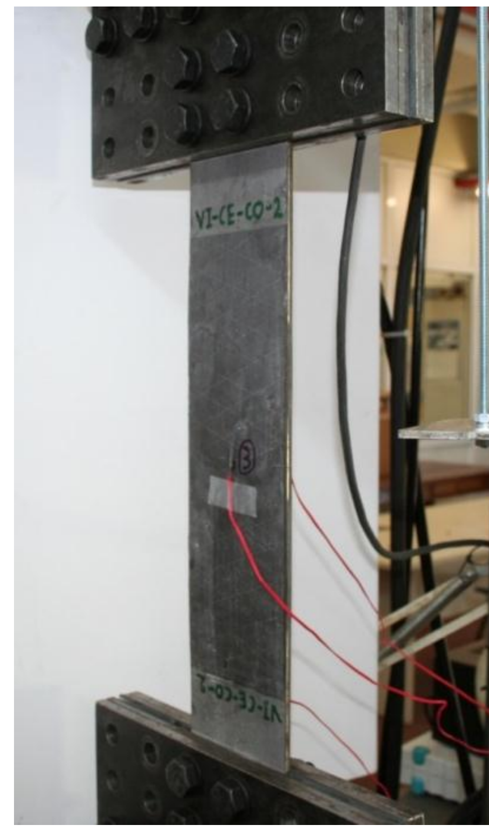
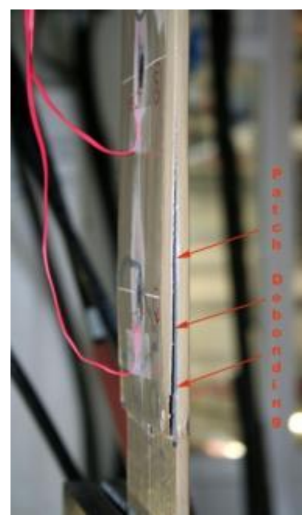


<u>Small scale tests</u>

Patched cracked plates in static tension

Patched corroded plates in static tension



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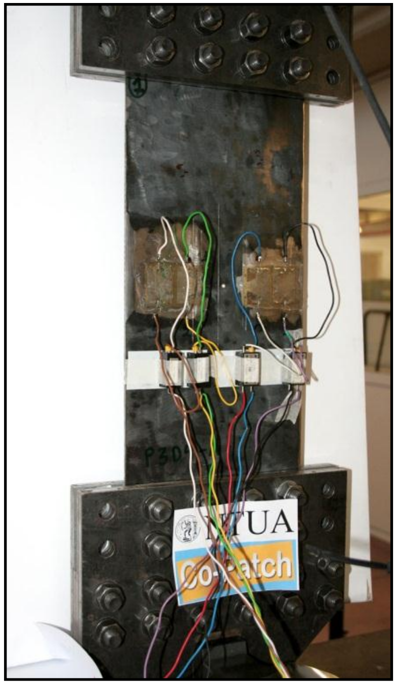
<u>Small scale tests</u>

- Patched cracked plates in static tension
- Patched corroded plates in static tension
- Patched cracked plates in fatigue (±100 MPa, f = 2 Hz)

Patch side

Back side



Laboratory testing NTUA

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Single Lap Shear tests

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Two surface preparation methods: Grit Blasting (**GB**) & Needle-Gun (**NG**)
Two aging scenarios: Non-aged & 300 cycles (100 days) aging

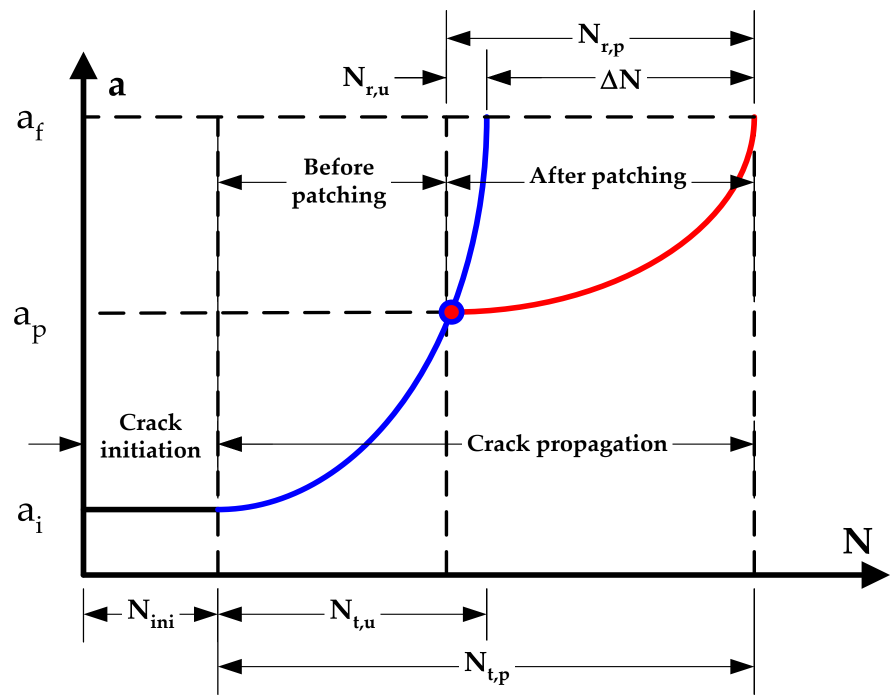
<u>Small scale tests</u>

- Patched cracked plates in static tension
- Patched corroded plates in static tension
- Patched cracked plates in fatigue (±100 MPa, f = 2 Hz)
- 4-point bending beam tests

Laboratory testing NTUA

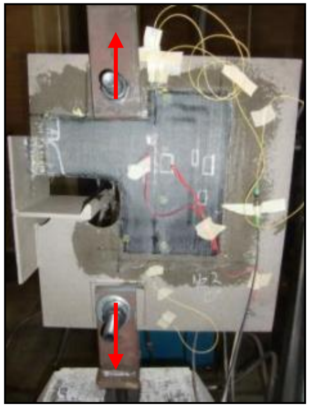
Small scale tests - Major conclusions

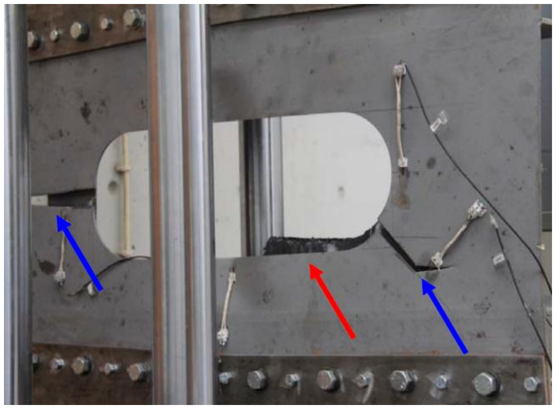
- Needle gun surface treatment proved completely ineffective
- Aging decreases the static strength of unpainted patched specimens. Properly painted specimens were not influenced by aging.
- Yield initiation load increased by a factor of 2
- A non-aged or a properly painted aged patch fully reinstates the strength of a corroded plate
- Fatigue life increased by a factor of up to 5
- The sooner the patch is applied, the better improvement of the fatigue life is accomplished



Laboratory testing NTUA

Large scale tests





Major conclusions

- Double patch case strength exceeds that of intact plate
- Single patch cases strength approx. 80% of the intact strength and 165% of the defected unpatched case (130% for case 2)

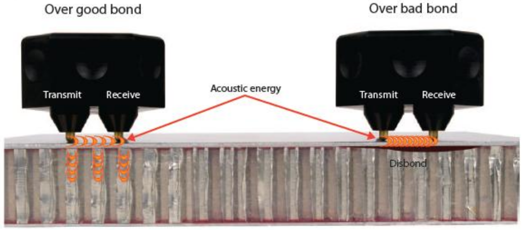
Monitoring methods and procedures NTNU

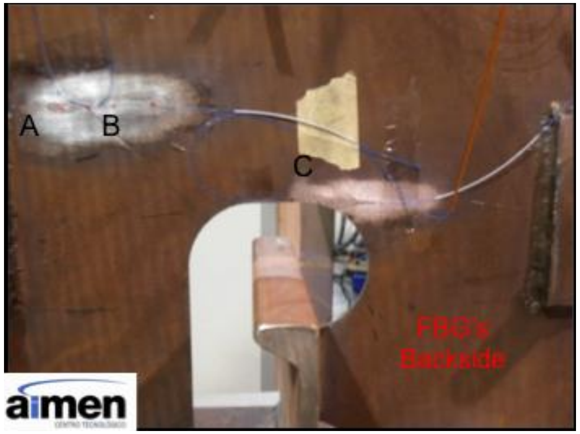
An inspection procedure was developed, tailored to the application of patch repairs. A pertinent checklist was provided to guide the inspector.

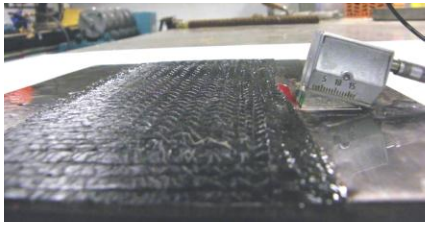
Four methods were identified as being most appropriate:

BondMaster (acousto-ultrasound technique), electrical strain gauges, fibre optical Bragg gratings and optical back scattering reflectometer

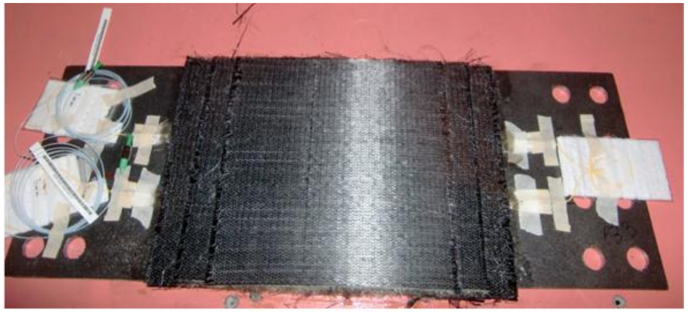
OLYMPUS
BondMaster 1000e+





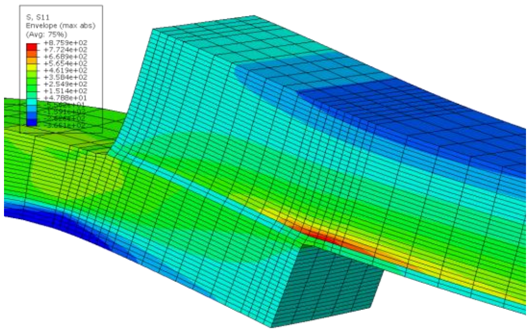


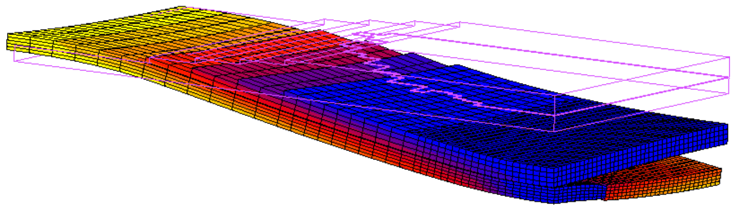
OPTICAL BACKSCATTER REFLECTOMETER™
(Model OBR 4600)

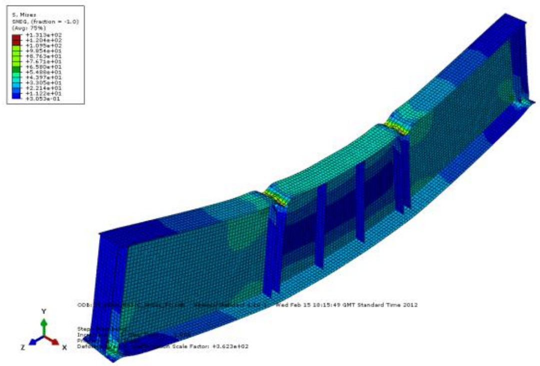


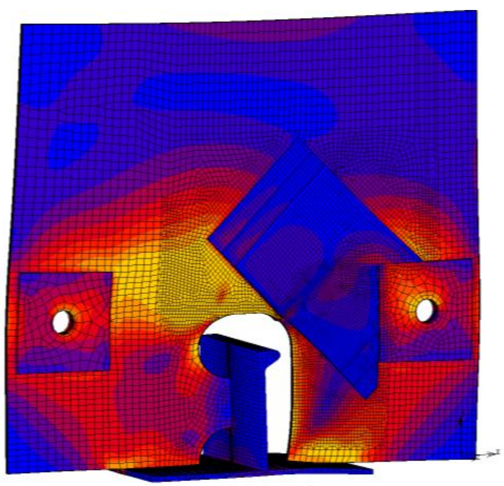
Numerical simulation procedures CETENA

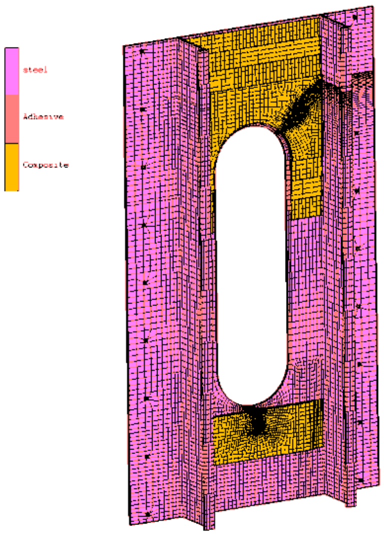
Development and validation of various numerical models (comparison with experimental results)

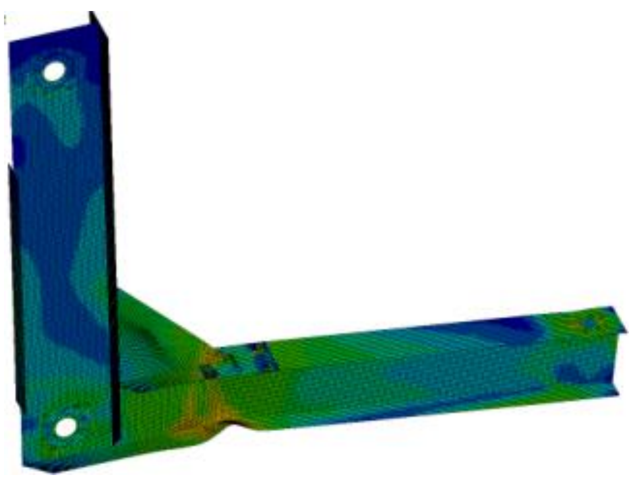










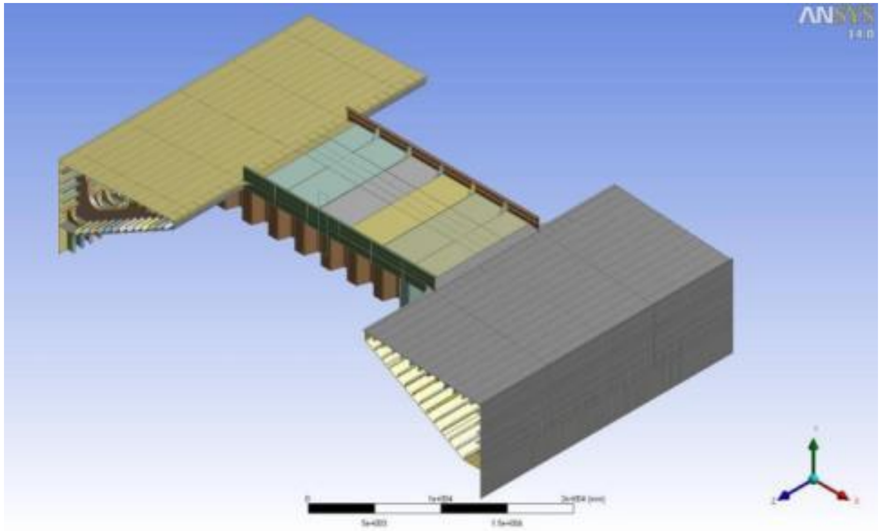


Extensive parametric study (key factors: stress intensity factor, load carrying capacity, J-integral values, cost minimization)

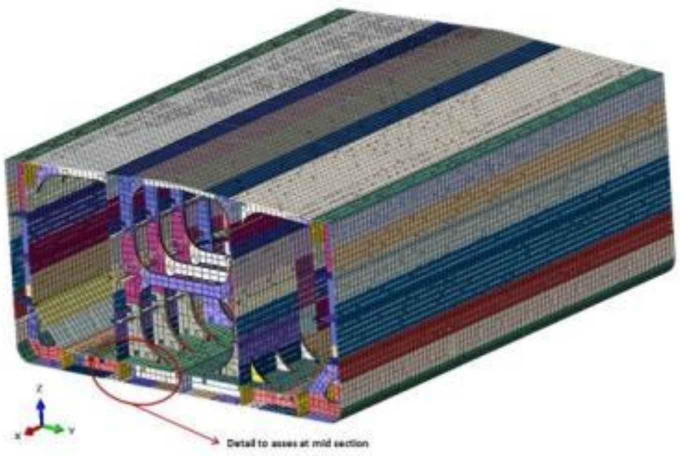
Numerical simulation procedures CETENA

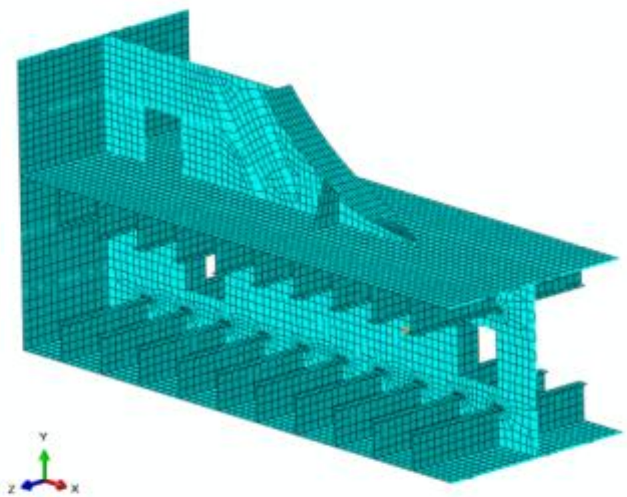
Development of numerical modeling guidelines

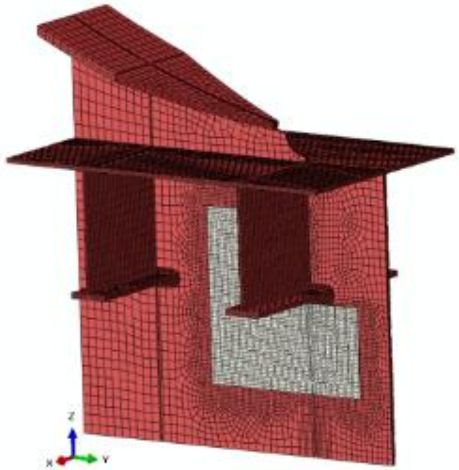
- Type of analysis
- Selection of the finite element type
- Mesh topology
- Boundary conditions / Loading
- Material modelling
- Solution parameters
- Post-processing / Results evaluation



Modeling of standard cases







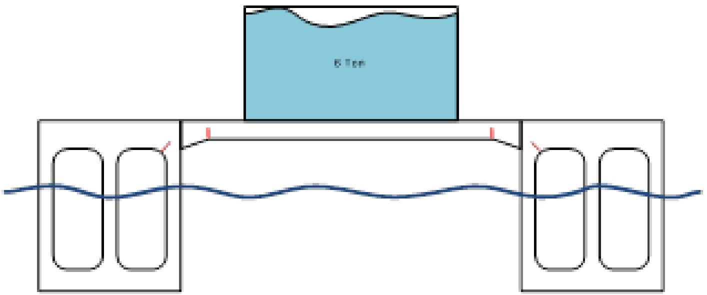
Full scale on site tests BV

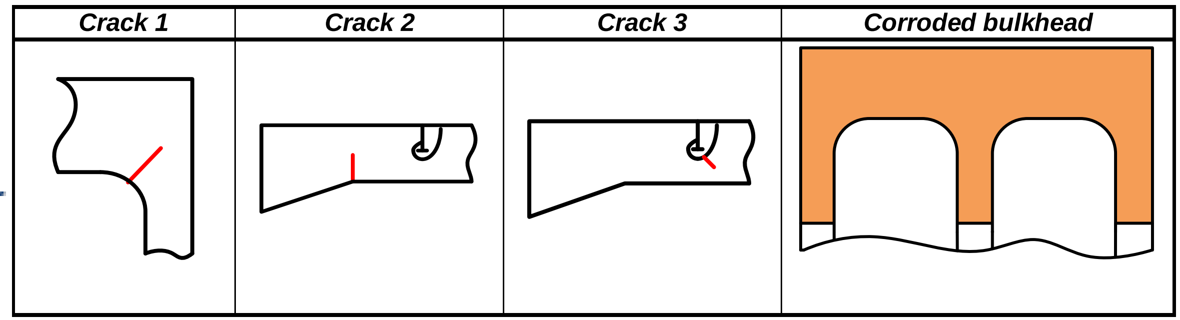
Test pieces fitted on deck of a seagoing tanker early in the project

failure of bond-line after 16 months due to poor surface preparation and lack of protection

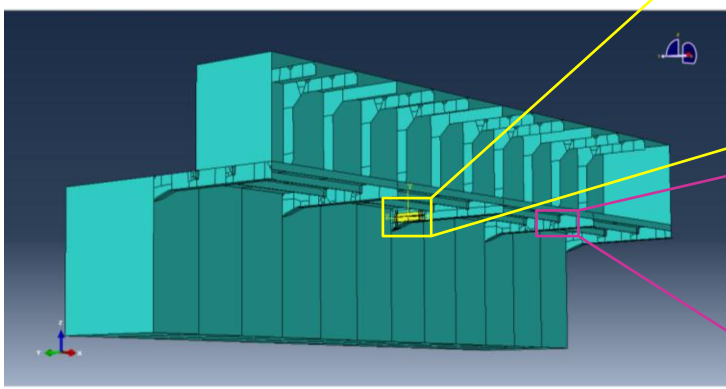
Full scale on site tests BV

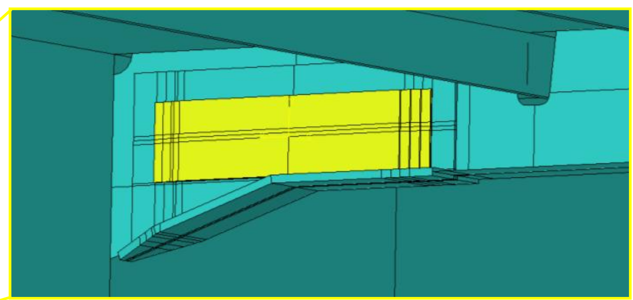
A catamaran like structure with various defects was specially built (L=6m, B=4.4m, LS=5.15 tons)

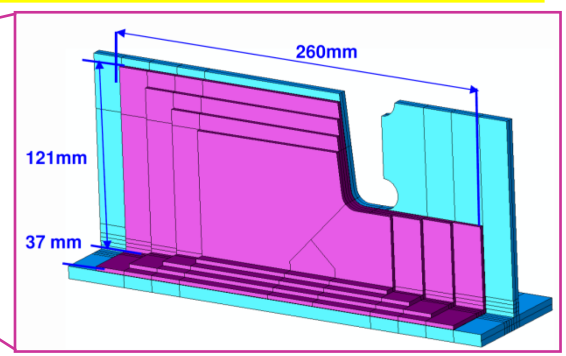


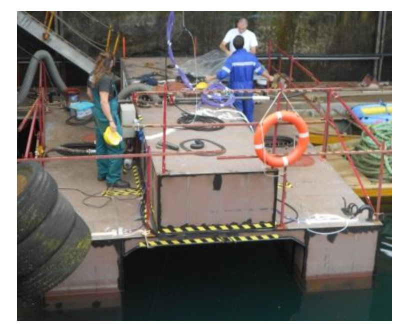


Numerical design of patches









Full scale on site tests BV

Six hand lay-up and vacuum infused patches (some defects left unpatched)
Test run for 10 months (more than 20000 cycles)
Continuous monitoring with conventional strain gages, FBG and OBR optic strain sensors
All patches remained intact (no degradation, no debonding)
No crack propagation, lower strains on the patched side

Guidelines and design procedures AIMEN

Best practice patch repair/reinforcement design and application procedures were developed

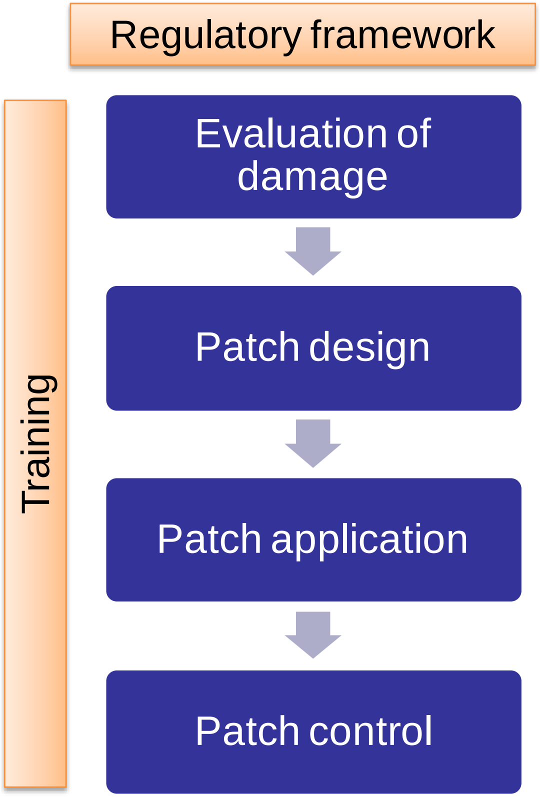
Regulatory framework
- remarks on survey procedure (conditions, preparations, performance)
- a repair and survey time-line for composite repairs is developed by BV
- guidelines for design and installation reporting and in-service inspection program

Damage evaluation – check list for inspection
- type, location, dimensions, free area, load, environment, accessibility, NDE, mapping

Patch design
- materials selection (fibers, fabric, resin, SR)
- dimensions (thickness, shape, configuration, tapering)
- manufacturing method (HLU, VI, pre-pregs, direct lamination)
- failure modes

Patch application
- surface preparation, primers, process, production control

Patch control
- steel and patch defects monitoring guidelines



Training programme for personnel TWI

- Training materials and assessment to support skills development within marine and construction sectors
- Application for CSWIP (Certification Scheme for Welding and Inspection Personnel) certification for course approval is submitted
- CSWIP scope includes
  - Surface preparation
  - Preparation for installation of composite patch
  - Application of composite reinforcement
  - Curing the composite system
  - Quality control checks
  - Installer theoretical and practical examinations
  - Supervisor theoretical examinations

CERTIFICATION SCHEME FOR PERSONNEL CSWIP

CERTIFICATION SCHEME FOR PERSONNEL

DOCUMENT No. CSWIP- CPRMCS – 23-12

Requirements for the Certification of Installers and Supervisors of Composite Patch Repair for Marine and Civil Structures (CPRMCS)

Future research needs for steel-to-composite joints

- Experimental studies to assess the effect of aging
- Experimental studies to define adhesive joints cohesive properties (for FE modelling)
- Definition of testing protocols in accordance with industry needs
- High strain rate tests
- Large-scale fatigue tests
- Fire tests
- Standardization of regulatory framework