



Co-Patch project logo

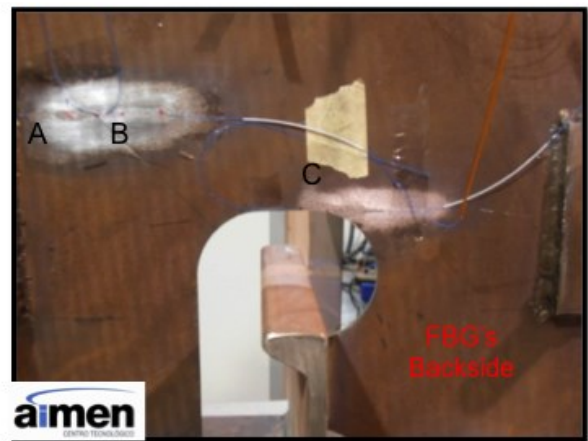
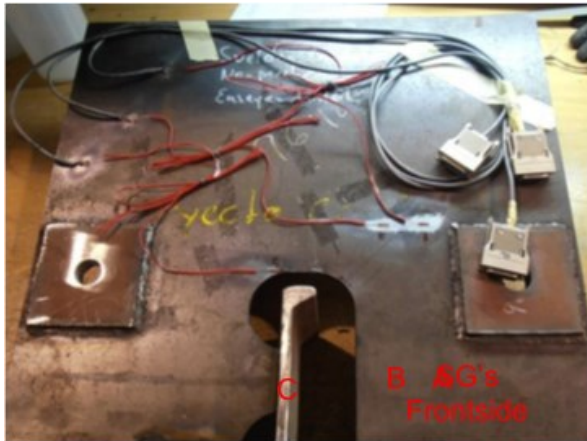
The Co-Patch list of participants and their contact details is as follows:

| Participant Number | Participant organization name                                       | Business activity                                                                  | Contact person                                                                                  |
|--------------------|---------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| 1<br>(Coordinator) | NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA), Greece              | University – Teaching and research                                                 | N. Tsouvalis<br><a href="mailto:tsouv@mail.ntua.gr">tsouv@mail.ntua.gr</a>                      |
| 2                  | ASOCIACIÓN DE INVESTIGACIÓN METALÚRGICA DEL NOROESTE (AIMEN), Spain | R&D and consultancy – Welding, materials, manufact. processes, NDE                 | E. Rodríguez<br><a href="mailto:erodriguez@aimen.es">erodriguez@aimen.es</a>                    |
| 3                  | FRANCISCO CARDAMA S.A. (CARDAMA), Spain                             | Industry – Shipbuilding, construction & repair, <u>SME</u>                         | M.B. Cardama<br><a href="mailto:bca@astilleroscardama.com">bca@astilleroscardama.com</a>        |
| 4                  | CETENA S.p.A. (CETENA), Italy                                       | R&D and consultancy – All naval fields                                             | G. Risso<br><a href="mailto:giovanni.risso@cetena.it">giovanni.risso@cetena.it</a>              |
| 5                  | ESTALEIROS NAVAIS DE PENISCHE S.A. (ENP), Portugal                  | Industry – Shipbuilding, construction & repair in steel and composites, <u>SME</u> | F. Manuel<br><a href="mailto:f.manuel@enp.pt">f.manuel@enp.pt</a>                               |
| 6                  | HELLENIC REGISTER OF SHIPPING S.A. (HRS), Greece                    | R&D and consultancy – Classification society, <u>SME</u>                           | A. Theodoulides<br><a href="mailto:theo@hrs.gr">theo@hrs.gr</a>                                 |
| 7                  | INSTITUTO DE SOLDADURA E QUALIDADE (ISQ), Portugal                  | R&D and consultancy – Materials and joining, design and fabrication, NDE           | G.F. Pimenta<br><a href="mailto:GFPimenta@isq.pt">GFPimenta@isq.pt</a>                          |
| 8                  | METTLE SARL (METTLE), France                                        | R&D and consultancy – All naval fields, <u>SME</u>                                 | M. Labrosse<br><a href="mailto:m.labrosse@mettle.org">m.labrosse@mettle.org</a>                 |
| 9                  | NORGES TEKNISK - NATURVITENSKAPELIGE UNIVERSITET (NTNU), Norway     | University – Teaching and research                                                 | A. Echtermeyer<br><a href="mailto:Andreas.Echtermeyer@ntnu.no">Andreas.Echtermeyer@ntnu.no</a>  |
| 10                 | SHIPBUILDERS AND SHIPREPERAIRS ASSOCIATION (SSA), UK                | Industry – UK trade association of shipyards, <u>SME</u>                           | M. Lightfoot<br><a href="mailto:martyn@ssa.org.uk">martyn@ssa.org.uk</a>                        |
| 11                 | TWI Ltd. (THE WELDING INSTITUTE) (TWI), UK                          | R&D, consultancy and training – Materials joining technology                       | E. Kellar<br><a href="mailto:ewen.kellar@twi.co.uk">ewen.kellar@twi.co.uk</a>                   |
| 12                 | ALVEUS d.o.o. (AS2CON), Croatia                                     | R&D and consultancy – All naval fields, <u>SME</u>                                 | A. Klanac<br><a href="mailto:alan.klanac@as2con.com">alan.klanac@as2con.com</a>                 |
| 13                 | THE UNIVERSITY OF SURREY (UNIS), UK                                 | University – Teaching and research                                                 | M. Chryssanthopoulos<br><a href="mailto:mkchry@surrey.ac.uk">mkchry@surrey.ac.uk</a>            |
| 14                 | UMOE MANDAL AS (UM), Norway                                         | Industry – All composite shipbuilding, repair in steel and composites              | T. Salvesen<br><a href="mailto:tormod.salvesen@um.no">tormod.salvesen@um.no</a>                 |
| 15                 | BUREAU VERITAS (BV), France                                         | R&D and consultancy – Classification society                                       | A. Larsen<br><a href="mailto:Allan.Larsen@bureauveritas.com">Allan.Larsen@bureauveritas.com</a> |

Table of Co-Patch Stakeholders Forum members

| #  | Company                                                            | Business field                                                                       | Country        |
|----|--------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------|
| 1  | ABS                                                                | Classification society                                                               | USA            |
| 2  | AMBER COMPOSITES                                                   | Composite materials manufacturer                                                     | UK             |
| 3  | ANEK Lines                                                         | Ship owner                                                                           | Greece         |
| 4  | AVIN International S.A.                                            | Tanker Operator                                                                      | Greece         |
| 5  | ATLANTIC BULK CARRIERS MANAGEMENT Ltd                              | Bulk carriers operators                                                              | Greece         |
| 6  | BABCOCK MARINE DIVISION                                            | Composite technology                                                                 | UK             |
| 7  | Basque Maritime Forum                                              | Association - Maritime cluster                                                       | Spain          |
| 8  | CARNIVAL SHIP BUILDING                                             | Cruise ship operator                                                                 | UK / Italy     |
| 9  | CIRIA                                                              | Construction Industry Research and Information Association,                          | UK             |
| 10 | CRS                                                                | Classification society                                                               | Croatia        |
| 11 | DCNS                                                               | DCNS Research - Centre d' Expertise des Structures et Matériaux Navals               | France         |
| 12 | DEPARTMENT OF DEFENCE, DEFENCE SCIENCE and TECHNOLOGY ORGANISATION | Defence                                                                              | Australia      |
| 13 | DEVOLD AMT                                                         | Fibers manufacturer                                                                  | Norway         |
| 14 | ERS Equipment Rental & Services (SAIPEM)                           | Offshore oil and gas                                                                 | Italy / France |
| 15 | ESR Technology Ltd                                                 | Repair and strengthening of metallic bridges                                         | UK             |
| 16 | FINCANTIERI                                                        | Shipbuilding                                                                         | Italy          |
| 17 | FURMANITE                                                          | Plants and pipelines maintenance                                                     | UK             |
| 18 | GRIMALDI GROUP                                                     | Ship owner: Car Carriers, Multipurpose, Full Containers, General Cargo and Car Ferry | Italy          |
| 19 | GURIT                                                              | Development and manufacture of advanced composite materials                          | UK             |
|    | GURIT Italy SpA                                                    |                                                                                      | Italy          |
| 20 | HAVEL COMPOSITES                                                   | Composite materials supplier                                                         | Czech republic |
| 21 | HIGHWAYS AGENCY                                                    | Executive Agency of the UK Department for Transport – Public Sector                  | UK             |
| 22 | ICC                                                                | CFRP & GFRP repairs, mining industry                                                 | Australia      |
| 23 | LONDON UNDERGROUND                                                 | London underground network management                                                | UK             |
| 24 | Marine Technical Limits                                            | Repair consultancy                                                                   | UK             |
| 25 | Neptune Research Inc.                                              | Composite repair solutions - pipelines                                               | USA            |
| 26 | NETWORK RAIL                                                       | Railways operator                                                                    | UK             |
| 27 | NOOR & Partners                                                    | Consulting in materials                                                              | Italy          |
| 28 | ONR - Office of Naval Research                                     | Office of Naval Research - executive branch agency within the Department of Defence  | USA            |
| 29 | Pauger Carbon Ltd                                                  | Shipbuilder (race ships) in carbon composites                                        | Hungary        |
| 30 | PETROBRAS                                                          | Oil and gas                                                                          | Brasil         |
| 31 | Port of Lisbon Administration                                      | Port authority                                                                       | Portugal       |
| 32 | REICHOLD AS                                                        | Resin manufacturer                                                                   | Norway         |
| 33 | SolarTech International Ltd.                                       | Repairs, oil and gas                                                                 | UK             |
| 34 | TANKERSKA                                                          | Ship owner                                                                           | Croatia        |
| 35 | Walker Technical Resources Ltd.                                    | Composite repairs, pipes                                                             | UK             |

## MONITORING METHODS AND PROCEDURES

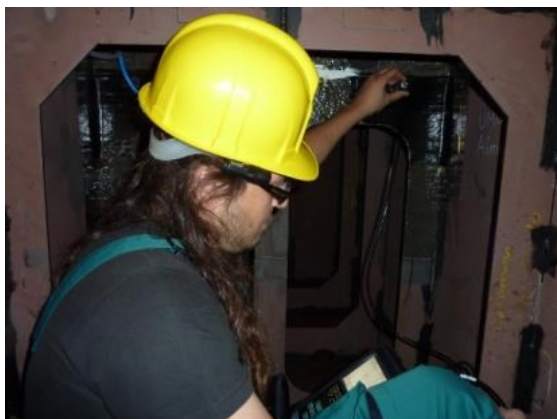


Typical steel structural detail with crack, instrumented with optical FBG gauges and electrical strain gauges



**OPTICAL BACKSCATTER REFLECTOMETER™**  
(Model OBR 4600)

Patched plate test specimens with Optical Backscatter Reflectometry fibres and measurement unit



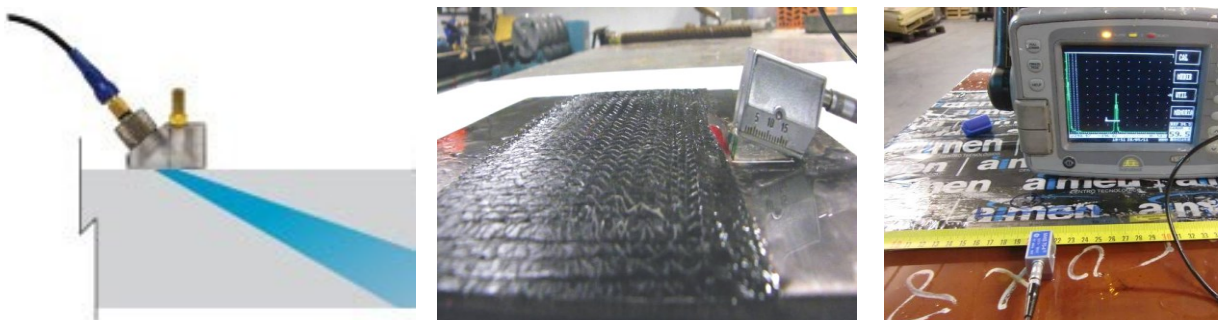
BondMaster acousto-ultrasonic NDE device applied to the Co-Patch full-scale catamaran application



Findings in patched plate specimens after inspection with BONDMASTER device prior to testing



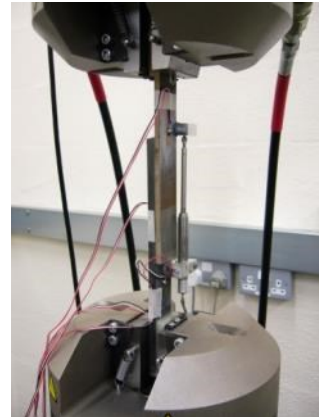
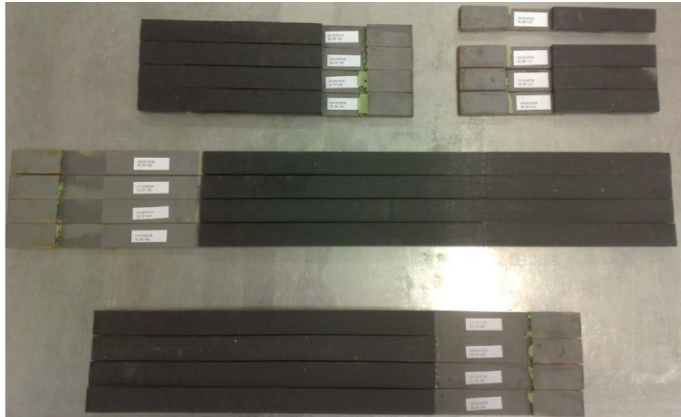
FBG attached to the steel (left), OBR applied to the CFRP composite patch (centre), embedded monitoring systems (right).



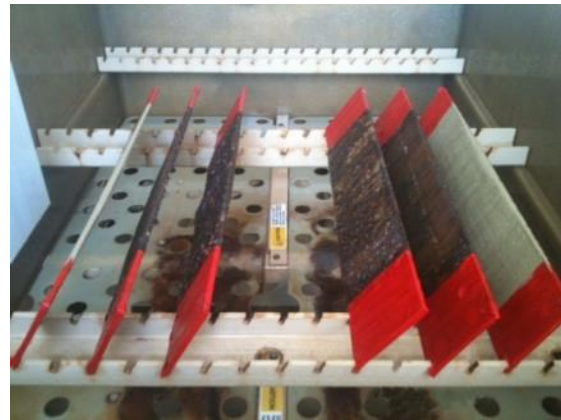
Application of the ultrasonics Pulse-Echo technique on the patched plate



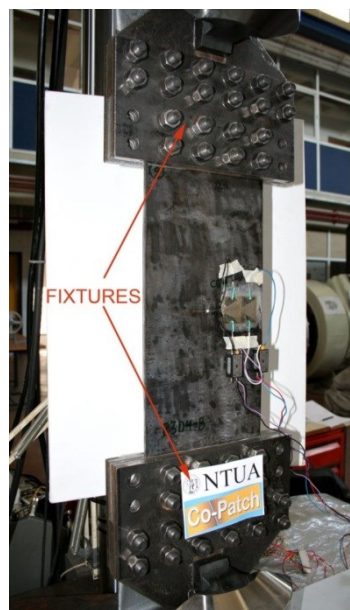
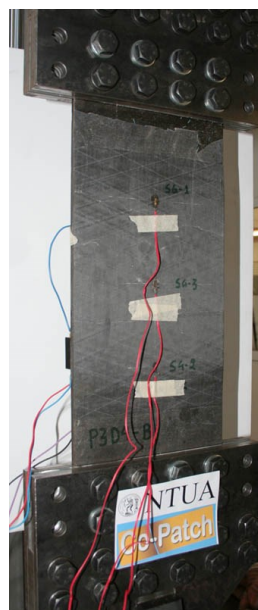
## LABORATORY TESTS



A batch of Single Lap Shear test specimens (left) and typical test arrangement (right)



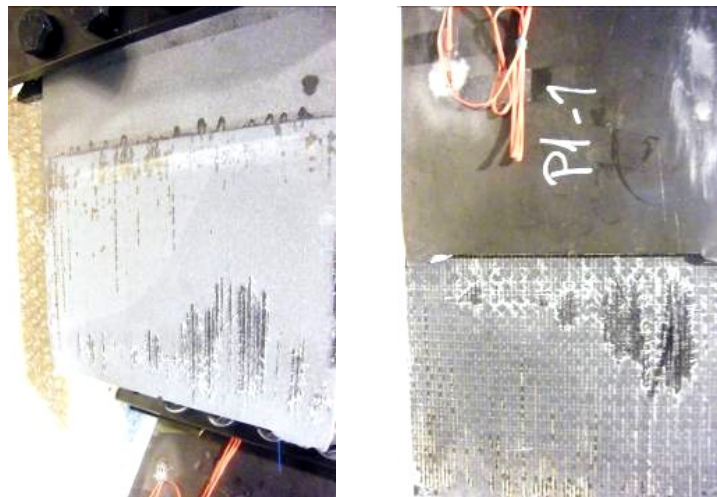
Manufacturing (left) and artificial aging (right) of P2 plate specimens



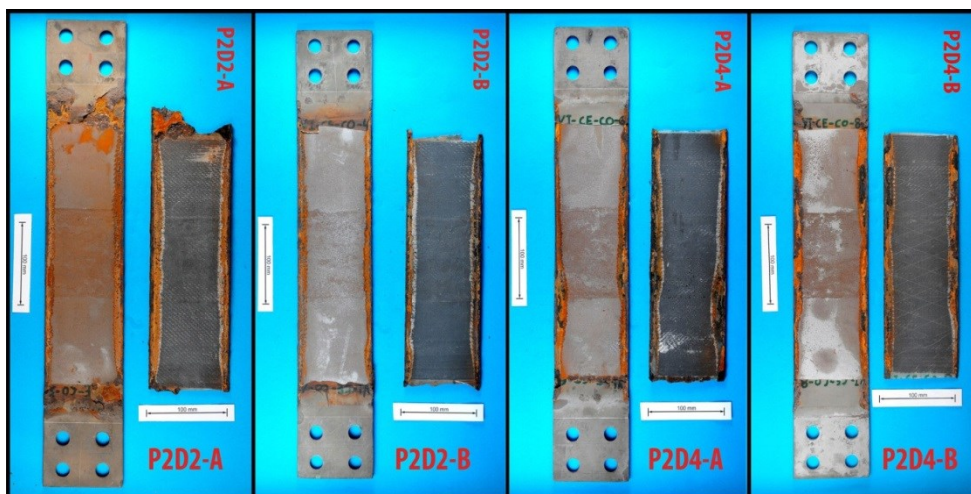
Patched plate specimens tested in fatigue (patched side-left, unpatched side-right)



Back side (left) and patched side (middle) of a plate tensile test;  
patch debonding on a plate specimen (right)



Indicative patch debonding of grit blasted plate specimen after failure

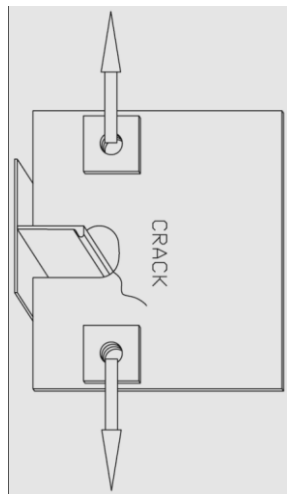


Reduction of the effective bonding area due to corrosion infiltration  
in unpainted, aged corroded specimens (after testing)

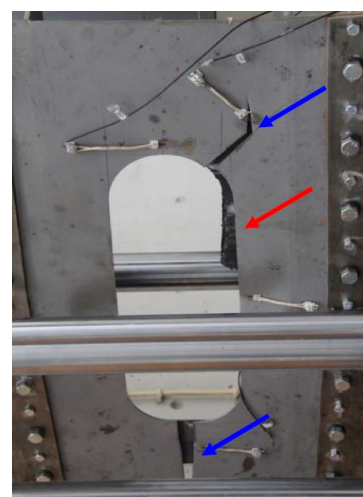
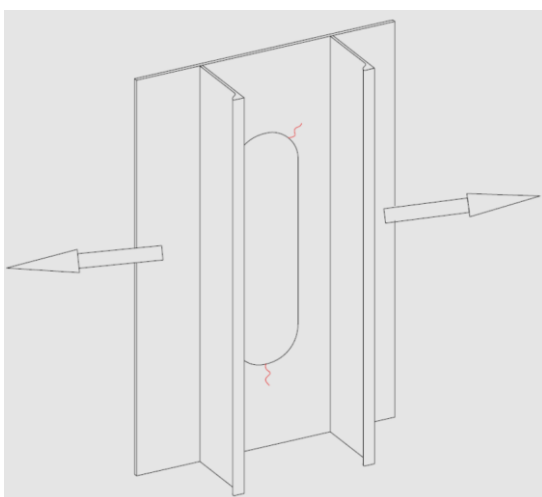




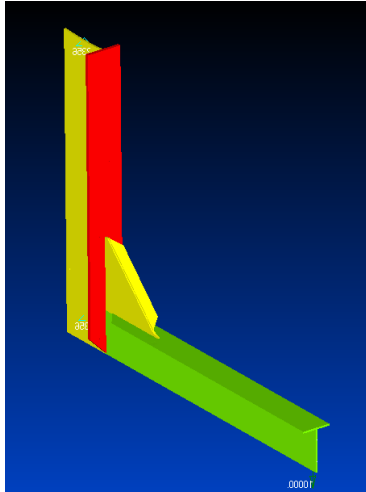
4-point bending test arrangement of patched beam specimens (left) and patch debonding (right)



Test of large-scale marine case 1



Test of large-scale marine case 2



Test of large-scale marine case 3



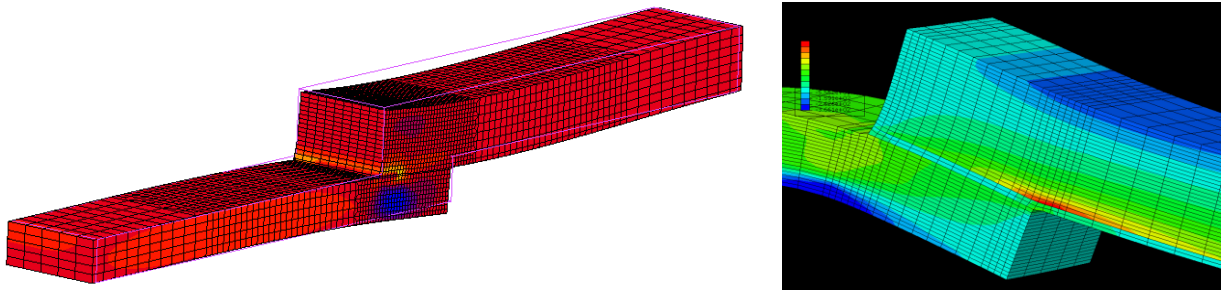
Patch lamination at the bottom flange of a civil engineering application girder



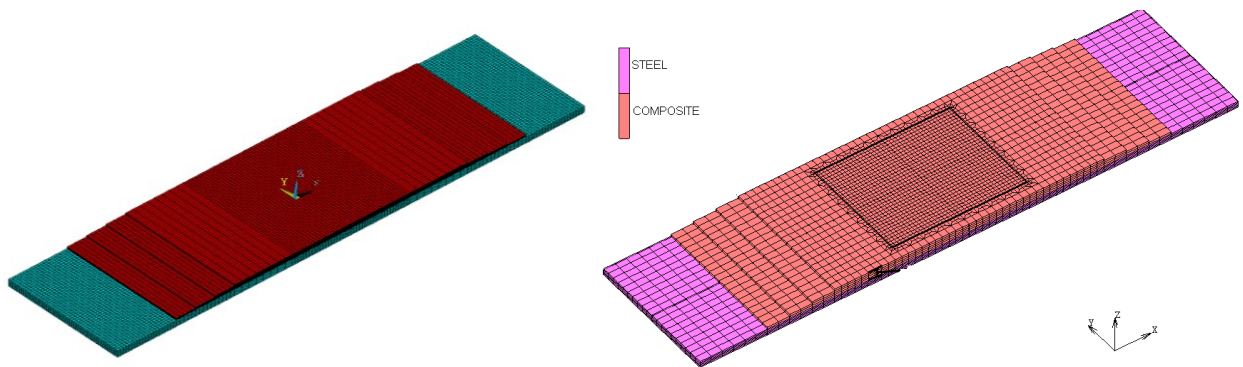
4-point bending test arrangement (left) and bonded composite beams against web breathing (right) in civil engineering applications steel girders



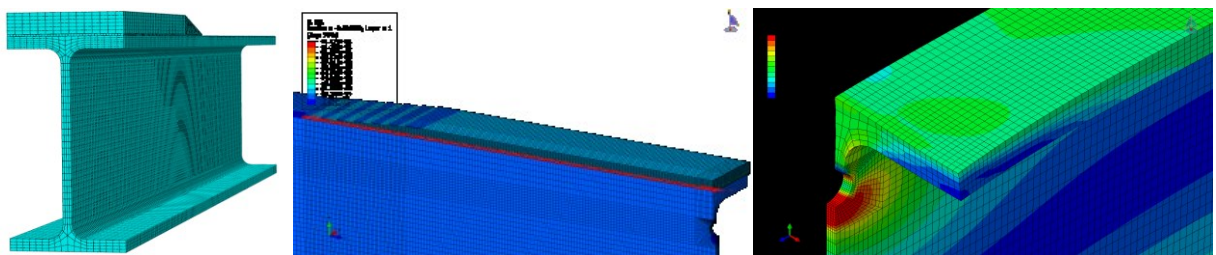
## NUMERICAL SIMULATIONS



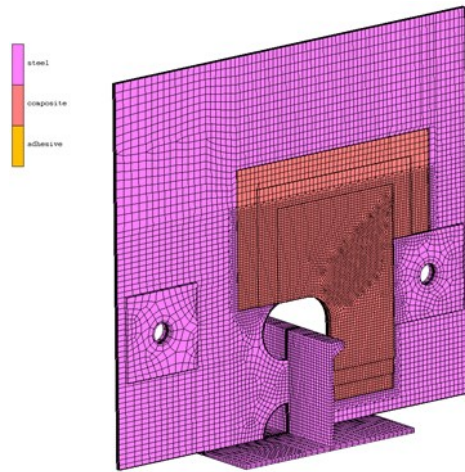
Numerical models of Single Lap Shear test specimens



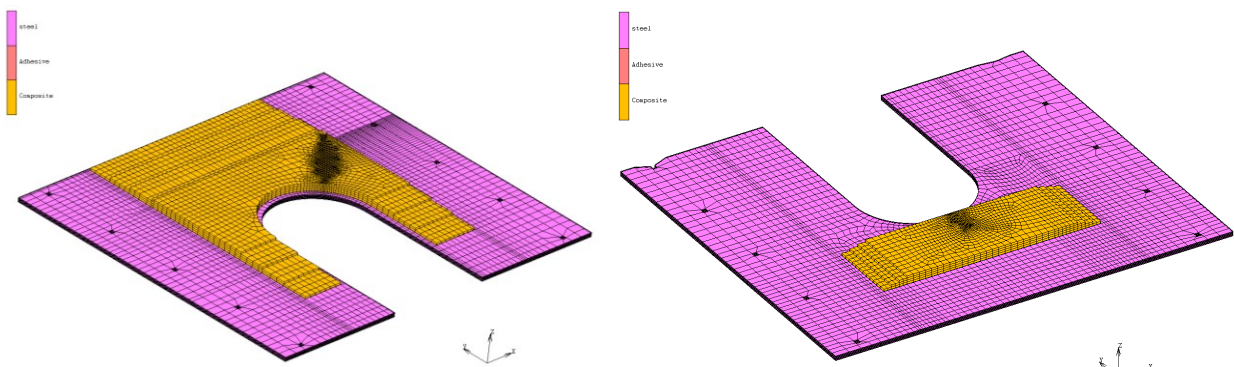
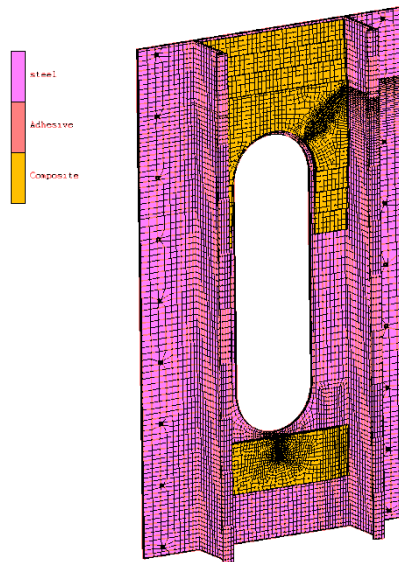
Numerical models of patched plate specimens



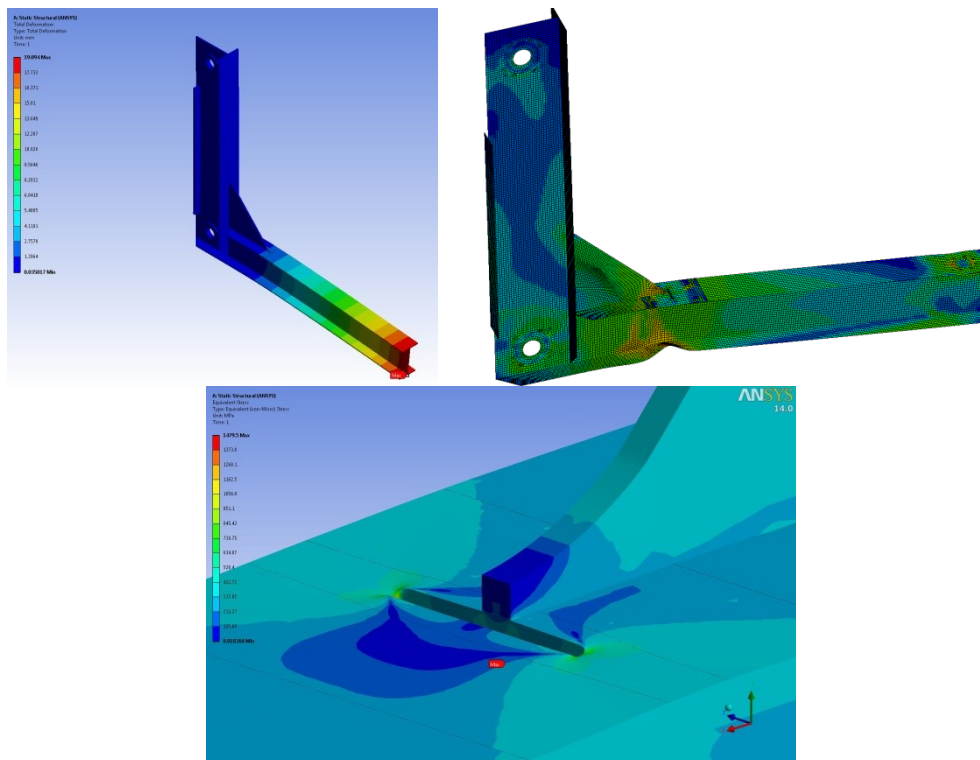
Numerical models of mid-scale patched beam specimens



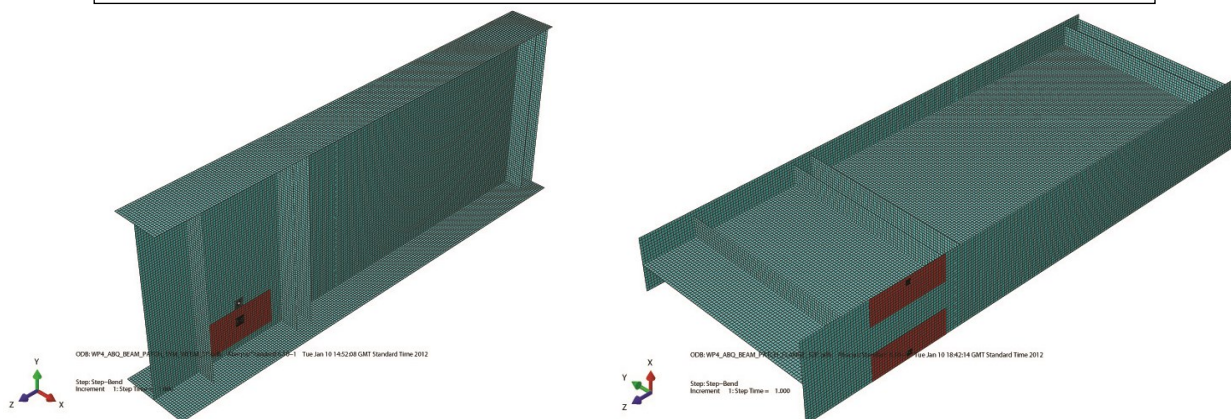
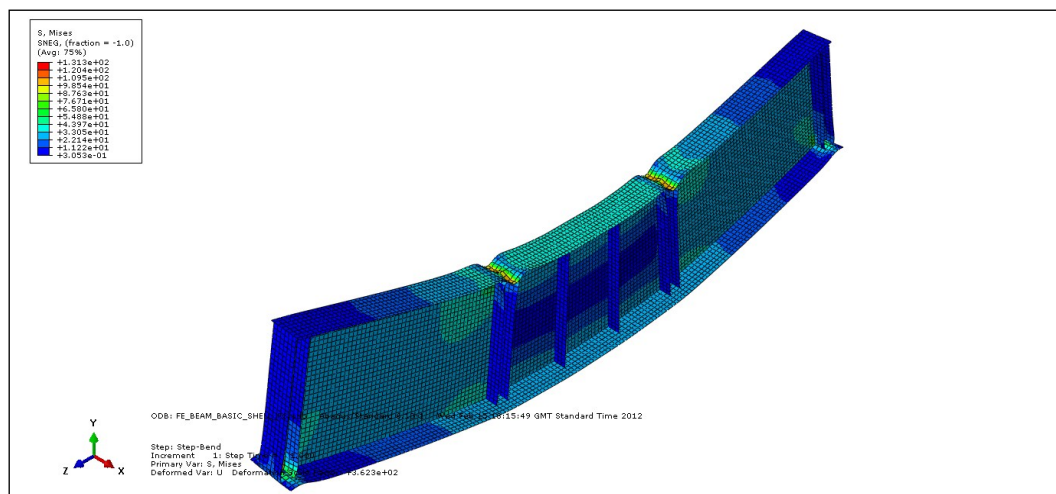
Numerical model of large-scale marine case 1



Numerical model of large-scale marine case 2

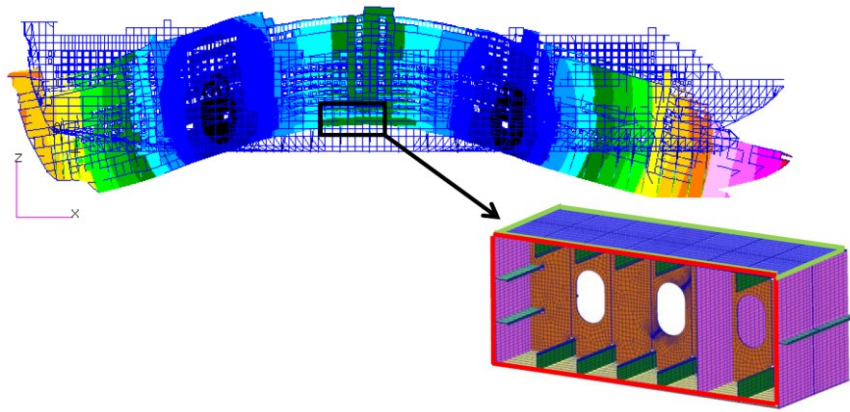


Numerical model of large-scale marine case 3

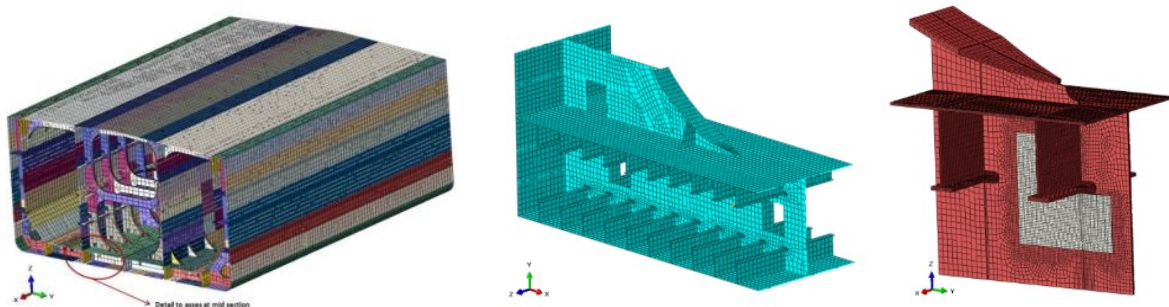


Configurations of civil details in FE modelling

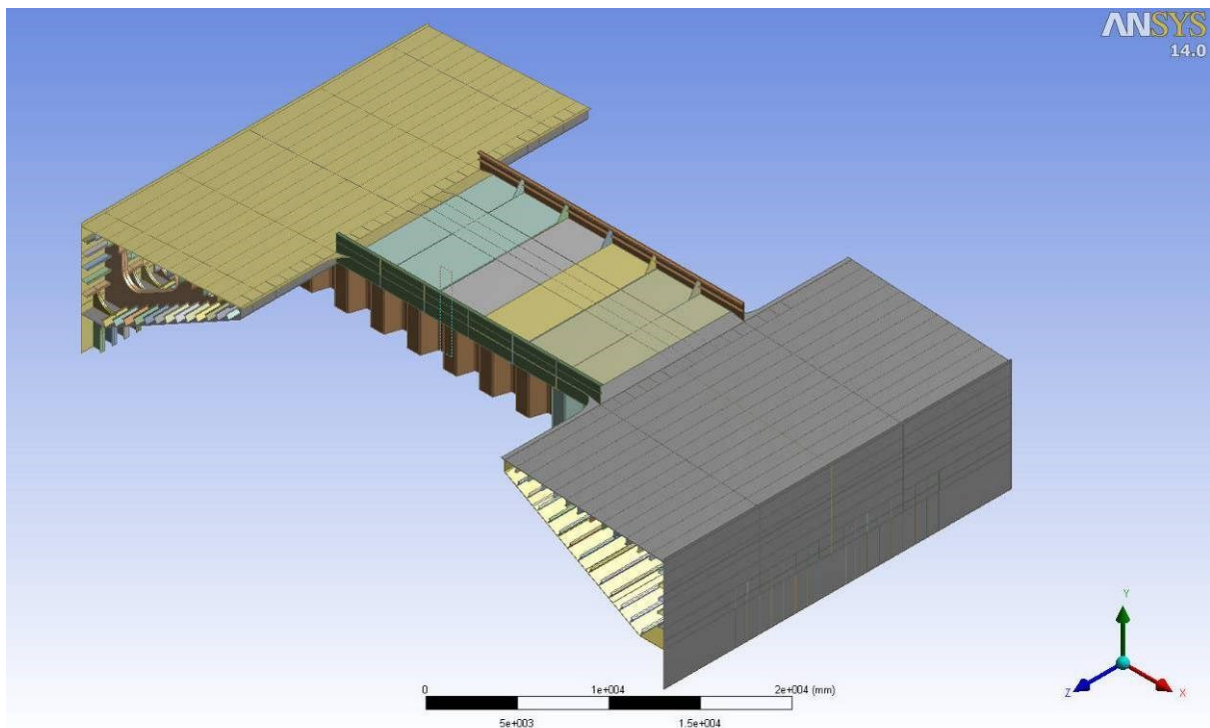




Global / local modelling guidelines for a ship structure



Different FE models from global to local (one of the typical patch repair cases)

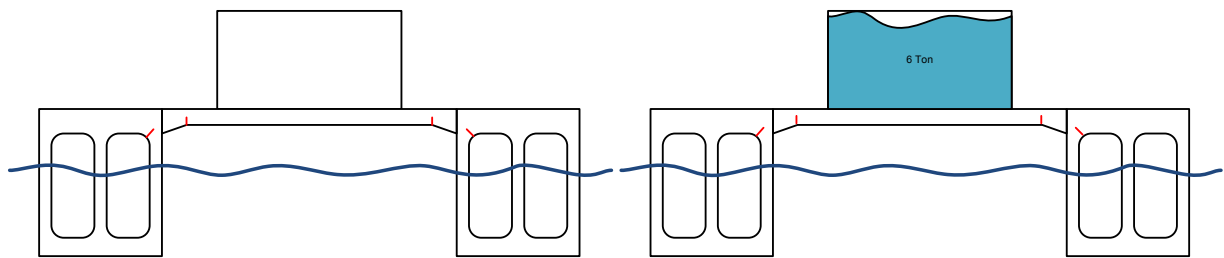


FE model of the typical repair case of strengthening the cross deck of a bulk carrier against buckling

## FULL-SCALE TESTS



Patch installed on deck of M/V FRANKOPAN – unpatched plate (left), patched plate (right)



Section view of the specially built Catamaran. Upper tank is sequentially loaded and unloaded.

Matrix of different types of defects on Catamaran

| <i>Crack 1</i> | <i>Crack 2</i> | <i>Crack 3</i> | <i>Corroded bulkhead</i> |
|----------------|----------------|----------------|--------------------------|
|                |                |                |                          |



The Catamaran structure platform for full-scale tests



Different types of cracks on the transverse beams of the Catamaran



Sensors' wiring at the defects area for monitoring structural response





Vacuum infusion of patch repair inside the Catamaran (left) and finished patch (right)



Ro-PAX garage floor repairs – before repair (left), after patch repair (right)