# RAMSSES - Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships

ELASS meeting
June 12th, 2019
O Porriño – Pontevedra (Spain)

## Steel and repair in RAMSSES

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CETENA

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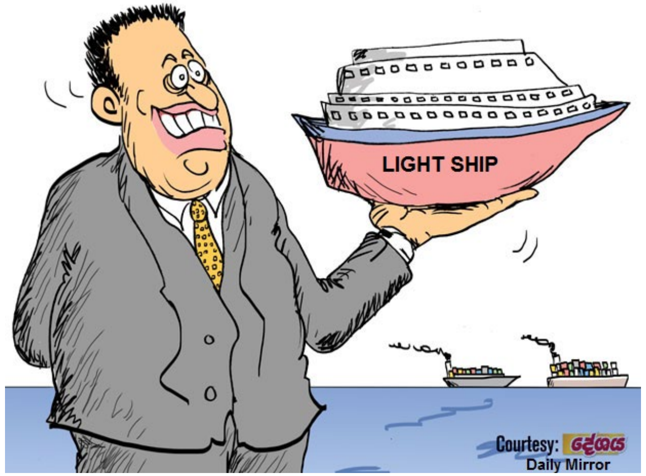
# Part I

## Introduction: how RAMSSES faces the problem of the ship weight reduction

# Why ship weight reduction

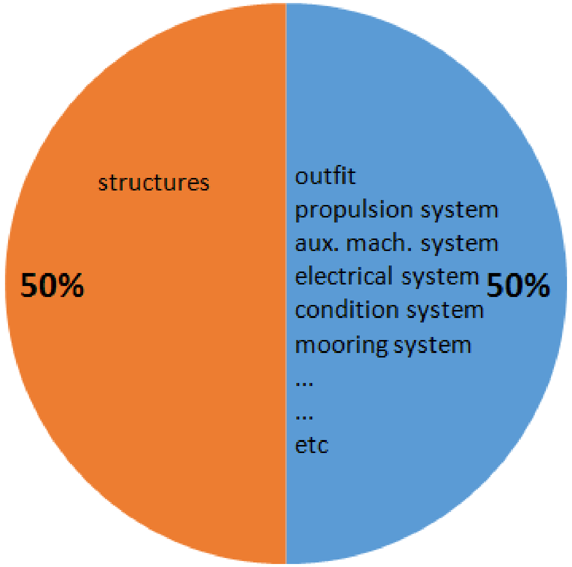
- The ship weight reduction is the one of the most challenging topic of the research in marine industry

- Ship weight reduction means:
  - More payload
  - Less fuel consumption
  - Less pollution
  - Less hot work (e.g. Welding)




- Among the objectives of the RAMSSES project there is the reduction of the ship ship structures weight through the introduction of innovative materials in the field of the marine industry

**Tipical distribution of ship weight (e.g. cruise ships, cargo ships)**




The contribution of the structure to the total ship weight **is greater than 50%**

**To reduce the weight of the structures** appears to be the most effective way to reduce the ship weight

# How to reduce the weight of the structure


**Reduce the weight of the ship structures**

1. **To use more performing material**
2. **To use lighter material**

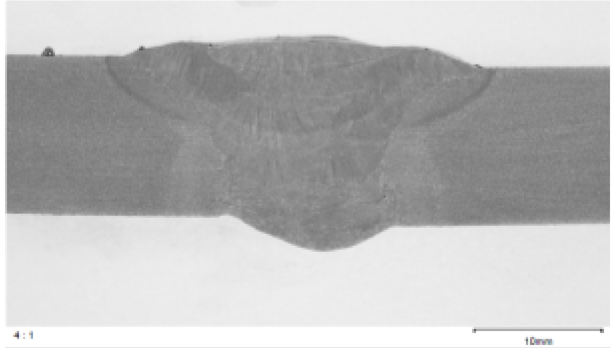
| | |
|---|---|
| **More performing material** → | **High strenth steels** |
| **Lighter material** → | **Composite** |

**RAMSSES is facing the topic of the structures weight reduction in the “Steel and repair cluster”**

STEEL AND REPAIR CLUSTER

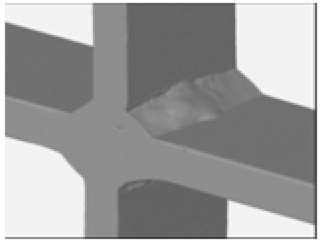
WP19 – Highly loaded structural details from high tensile steel in passenger and research vessels

FINCANTIERI



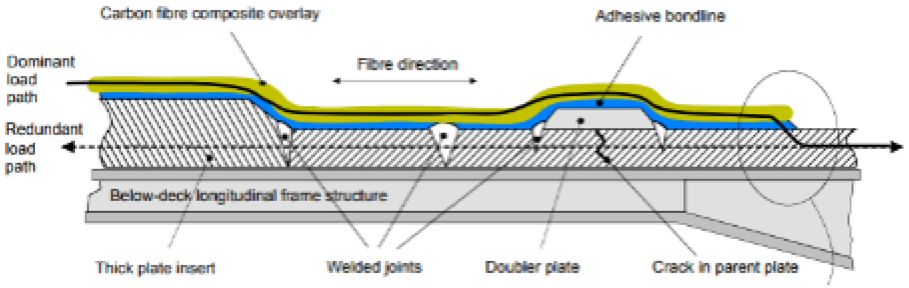
WP20 – Lightweight Deck using High Tensile Steel in cruise ships

MEYER TURKU



WP21 – Composite Overlay to repair and improve metallic and non-metallic structure

Cardama Astilleros/Shipyard



# Part II

# High strength steel

- **Steel is incombustible**

- Structural scantling led by 3 main constraints:
  - Strength (stress)
  - Stiffness (deformation/buckling)
  - Long time performance (fatigue and corrosion)

- **Minimum thickness and overthickness for corrosion** imposed by Classification Societies

- Deformations depend on **Young modulus of the material** (and on structural geometry): the Young modulus is almost constant for all the steel types

- There is a significant variability of the admissible stresses of the steel (both yielding and fatigue) theref the use of non-conventional steels could help to reduce thickness and weight of the ship structures

**Use of High strength steel (HSS)**

# Pro/cons high strength steels

- Advantages HSS(respect conventional steel):
  - Greater admissible stress values (static and fatigue)
  - Less insert plates (less welding, less plates in warehouse)
  - Lower thicknesses

- Disadvantages HSS:
  - Greater cost of the HSS
  - The designing criteria could change significantly (es. **buckling influence**)
  - Welded joints quality and performances
  - Performance of the welded
  - Logistic
  - Deformability

- Main obstacle to the use of high strength steels in marine sector: the Classification Societies do not contemplate the use HSS in their Rules

# Economical considerations

- Cost of the HSLA: it is true that HSS steels are more expensive than conventional steel (e.g. grade S355)

- The average extra cost of the HSS steel is about **30%** with respect the conventional steel

- However **the steel is not the most expensive component of the ship** (e.g. for a cruise ship 20÷30%, for a military vessel 7÷15%) so the impact of extra cost of the steel is negligible over the whole ship cost

- The HSS could become an economical issue when **their use requires non-standard process** as new welding tecniques, welding in protected environment, pre- and/or post-heat operations

- One of the objective of RAMSSES is to demonstrate that the **HSS can be welded in shipyard condition without pre- and post-heat operations**

# Rule framework (1)

- There is currently a lack of the rules about the steels with yield strength greater than 390 N/mm$^2$

e.g. LLoyd's Register
(Rules and Regulations for the Classification of Ships, 2018)

| Specified minimum yield stress in N/mm$^2$ | $k_L$ |
|---|---|
| 235 | 1,0 |
| 265 | 0,92 |
| 315 | 0,78 |
| 355 | 0,72 |
| 390 | 0,68 (0,66 *see* Note 3) |
| 460 *see* Note 4 | 0,62 *see* Note 4 |

Note 1. Intermediate values by linear interpolation.

Note 2. For the purpose of calculating hull moment of inertia as specified in *Pt 3, Ch 4, 5.8 Hull moment of inertia 5.8.1*, $k_L$ = 1,0.

Note 3. A $k_L$ factor of 0,66 may be applied to all ship types provided that a fatigue assessment is carried out as required by *Pt 3, Ch 2, 1.2 Steel 1.2.4*.

Note 4. Grade only applies to thickness above 50 mm for upper deck, hatch coamings, shear strake, uppermost strake of longitudinal bulkhead and other longitudinal strength members in way of the above structures of container ships. The requirements specified in *Ch 3, 3 Higher strength steels for ship and other structural applications* of the Rules for Materials apply, *see Pt 3, Ch 2, 1.2 Steel 1.2.4* and *Pt 3, Ch 2, 1.2 Steel 1.2.5*.

... and the other registers

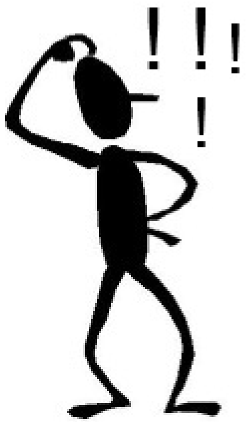
| ReH (N/mm$^2$) | RINAMIL 2011 | RINAMIL 2017 | RINA 2016 | RINA 2019 | BV 2011 | BV 2018 | DNV-GL 2018 | LL 2018 | ABS 2018 |
|---|---|---|---|---|---|---|---|---|---|
| 390 | 0.70 | 0.68 | 0.66 | 0.68 | 0.68 | 0.68 | 0.66 | 0.68 | 0.68 |
| 460 | -- | -- | 0.62 | 0.62 | -- | -- | 0.62 | 0.62 | -- |

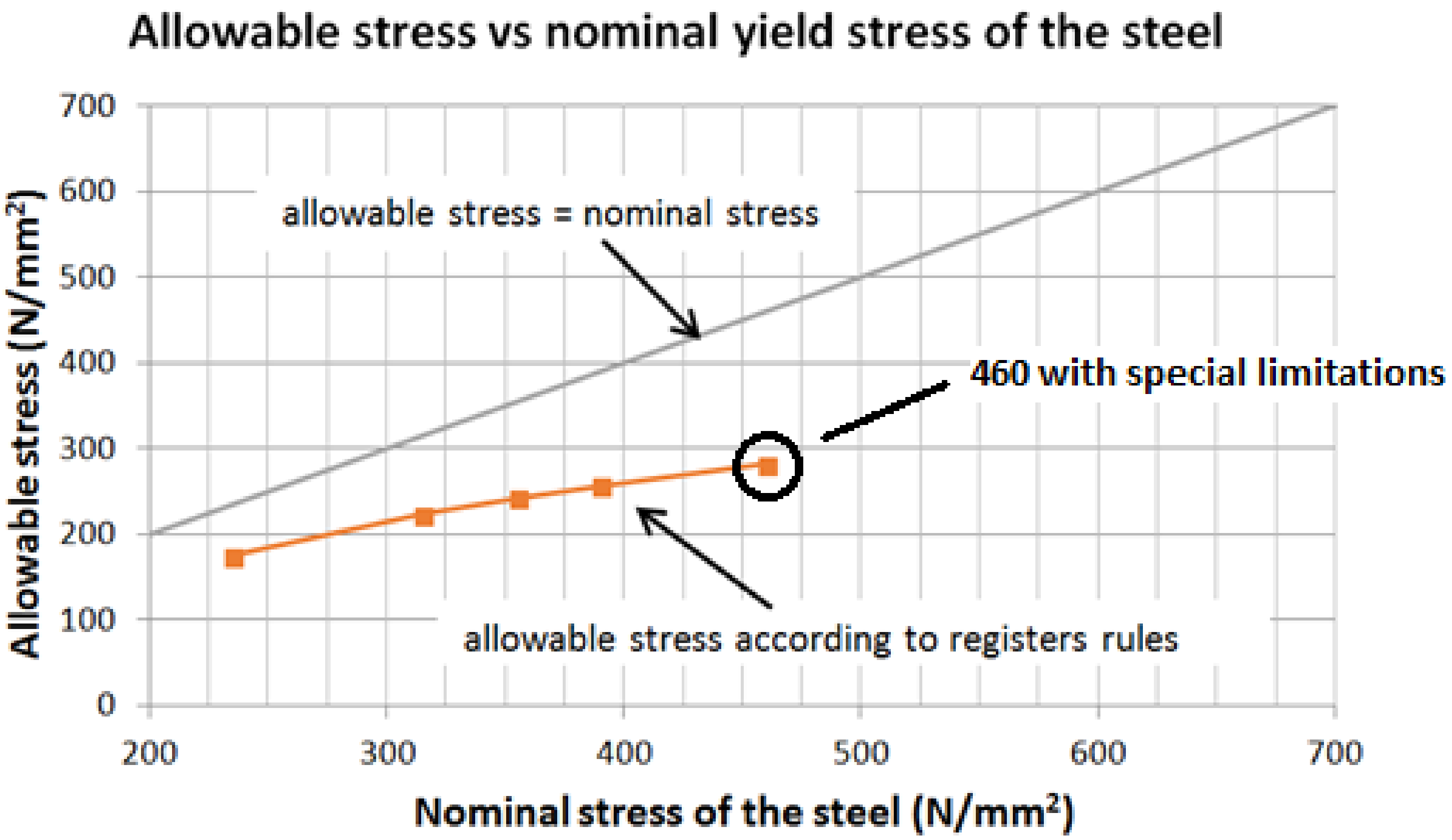
# Rule framework (2)

- The use of high strength steel is not encouraged by the rules because materials with higher yield receive proportionally greater safety coefficient

e.g. allowable stress for the global strenght check

- And above 390 N/mm$^2$?



- Numerical calculations
- Test campaign

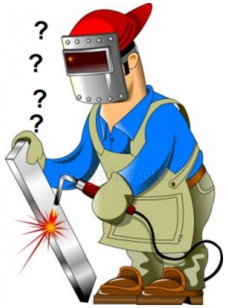
- Numerical calculations
- Test campaign

Obtain from the Classification Society the approval for the use of the HSS

# Technical considerations

- The HSS considered as bulk material are not an issue since it is well known that their mechanical properties are better than conventional steels

- The same can not be stated for the welded HSS taking into account the shipyard constraints (**no pre- and post-heat operations** )



- The HSS welded without special pre/post operations could be subject to mechanical properties downgrade

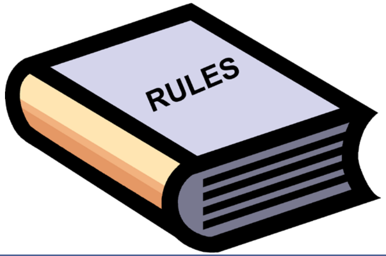
- Furthermore, the integration of the HSS with the conventional steel (e.g. S235 and S355) must be specially considered and studied

Answers from **TEST CAMPAIGN OF RAMSSES**

# Test campaign of RAMSSES

- Cluster steel of RAMSSES is performing an extensive test campaign to evaluate the performance of the welded joint of HSS
- Qualification test to demonstrate the weldability of the HSS in shipyard conditions (issues of the Welding procedure Specification)
- Long term test to demonstrate the better fatigue behaviour of the HSS steels
- Corrosion test

**The objective is to get at the end of the test campaign the approval for the use of the HSS from Classification Societies**



# Test campaign of RAMSSES: which grades of HSS are tested

- We identified 2 main applications for the use of the HSS:

1. Building of large portions of the ship and potentially the whole ship (extensive use).
   In this case it is useless consider a HSS with very high yielding (greater than 690 MPa) stress because the thickness of the plates can not below the limits imposed by the buckling and corrosion phenomena.
   The optimum steel grades for this application could be **S460** (yielding = 460 MPa).
   Steel grade **S690** (yielding = 690 MPa)is considered for the building of cruise ship superstructures with very thin plates

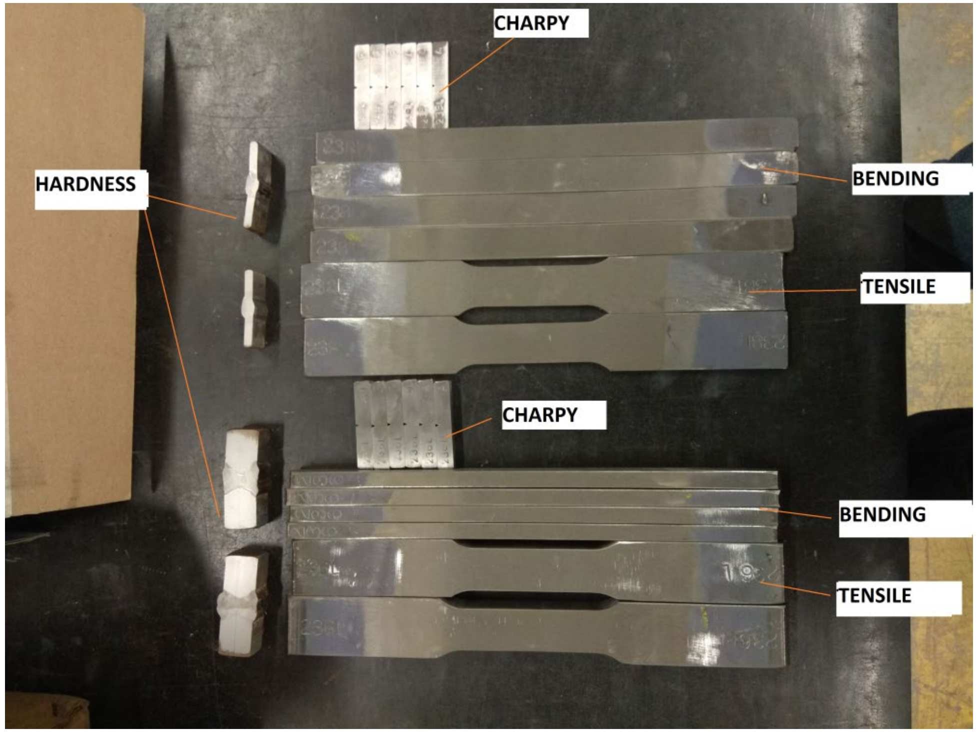
2. Local use to mitigate the effect of the stress concentrations (e. g. insert plate).
   In the second case very high yielding stress and high fatigue resistance are required.
   A HSS of grade S690 (yielding = 690 MPa) could be right choice.

- On the basis of these considerations we decided to study the following HSS grade in RAMSSES
  - **S460 (or X65)**
  - **S690**

- The conventional steel **AH36** was considered too as reference case for comparison purpose

# Test campaign of RAMSSES: some details

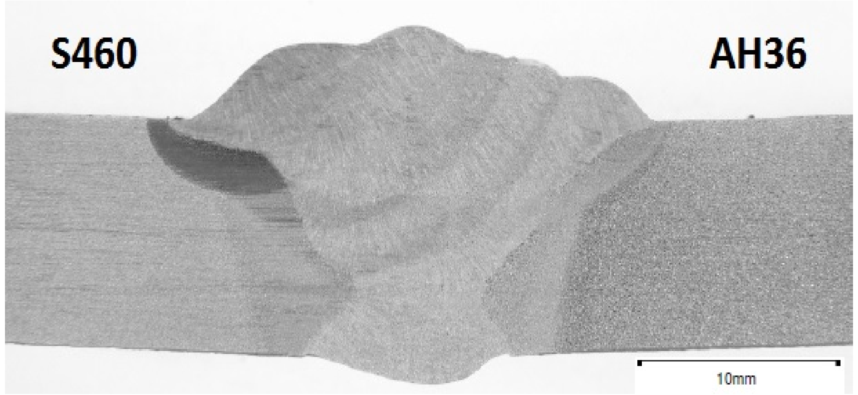
- Welding technique: FCAW (Flux Cored Arc Welding)
- Material combinations:
  - AH36-S460
  - S460-S460
  - AH36-S690
  - AH36-AH36 (reference case)
- Qualification test
  - Hardness
  - Tensile
  - Bending
  - Charpy
  - Macro and NDT
- Corrosion
  - Open Circuit Potential measurements
  - DC polarization measurements to obtain
  - AC polarization measurements : Electrochemical Impedance Spectroscopy
- Fracture test (FCGR and CTOD)
- Fatigue

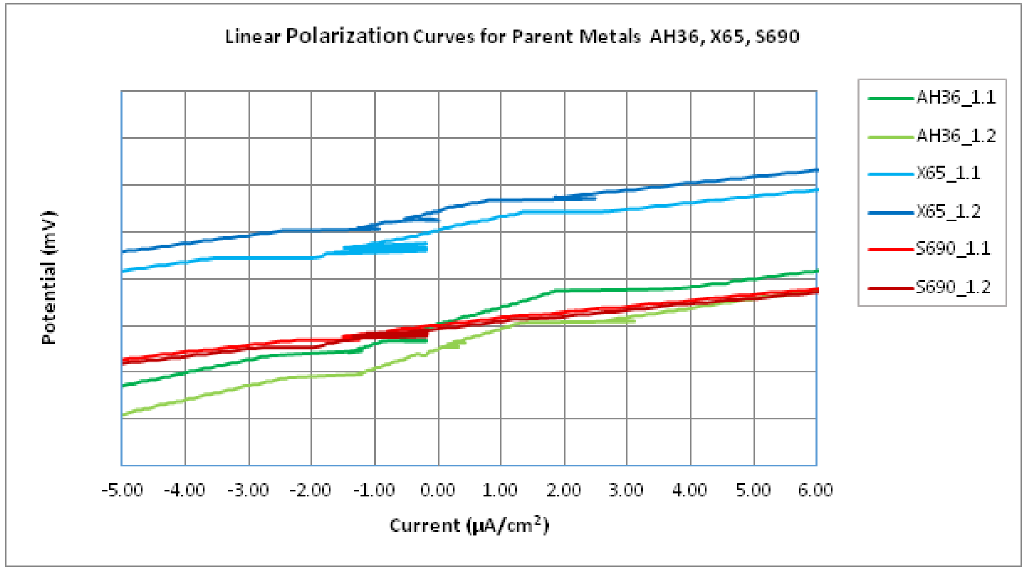



# Test campaign of RAMSSES: results preview and next activities

- The Qualification tests are almost completed: all tested configurations gave positive response

- Corosion test are in progress




- Next activities: fracture and fatigue tests

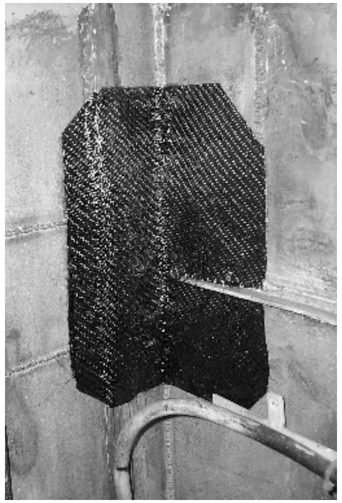
# RAMSSES conclusions and beyond RAMSSES

- Main expected conclusion of RAMSSES:
    - At the end of the test campaign will be possible (in case of positive results) to demonstrate through the qualification test that **the high strength steel can be welded without extra cost** with respect the conventional steels
    - The tests will contribute to the **update of the rules framework** and push the Classification Societies towards **the approval of the ships built in high strength steel**
    - The **weight saving** due to the extensive use on board of high strength steel is expected to be equal to **2÷5 %** (weight of the whole ship)
- Work to be done (in next research projects):
    - To study the implications of the high strength steels in the **design criteria** (e. g. buckling )

# Part III

# Composite patch

- The composite patch are **an effective repair and/or reinforcement method** for large steel structures with defects



- Objectives of the patch:
  - Repair fatigue damage
  - Repair corrosion damage
  - Improve the strength and/or the stiffness of the structures

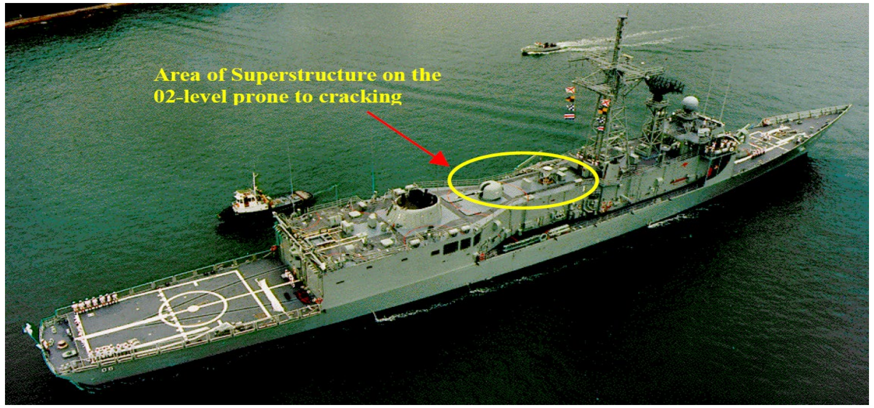
- Patch advantages
  - Patch application **doesn't need any hot work**
  - **Low cost and time of application**
  - **Application "in situ"**

- Critical aspect: uncertainty about the **long term performance**

# Composite patch: state of the art

- Composite patch over-lamination was successfully tested in several projects, and has been applied e.g. for repair of aluminium shipbuilding structures as well as thick steel sections in offshore and pipelines

- Validation and approval of these solutions by classification societies is done on a case by case basis in large vessels.




RAN (The Royal Australian Navy) Adelaide Class Frigate

Repair of the main deck

FPSO (Floating Production Storage and Offloading) - Norway

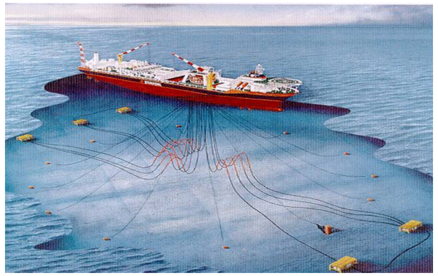
Repair of the cargo tank bulkhead

Type 21 Frigate (Amazon class)

Repair of the main deck

# Composite patch: some case histories

- In the 1980s composite patches were used to repair the aluminium alloy superstructure of some Royal Navy frigates. The patches (carbon-fibre epoxy) were 2.4 m x 1 m x 5 mm. All the patches were operating effectively after ten years and the ship are currently still in service
- RAN Adelaide missile frigates: unidirectional carbon fibre with epoxy vinyl resin. Reparation on main deck
- Since 1997 carbon fibre reinforced patches have been applied to secondary structures (food lifts) of Royal Navy Destroyers
- In 2002 the carbon fibre-epoxy patches were applied to the bulkheads surface of a FPSO unit (Floating Production Storage & Offloading) using pre-impregnated material. The patches operate in an environment of crude oil and water at 50° C. The composite repairs were still in operation after 18 months

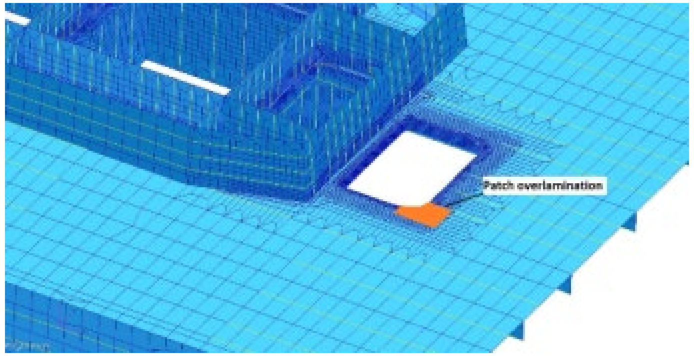



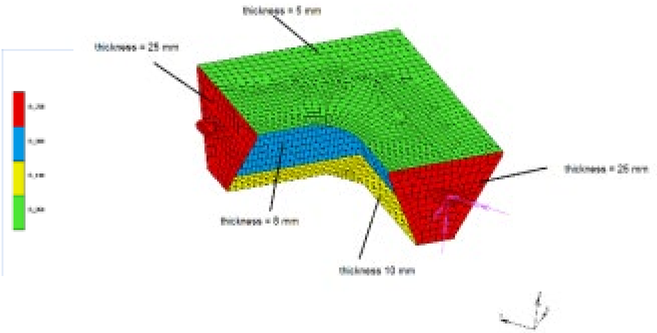
# Composite patch: the RAMSSES way

In RAMSSES PROJECT we want to demonstrate that composite over-laminating is suitable both as a **repair** technology for damaged structures in a marine environment, as well as for **improving the pristine properties of welded joints**

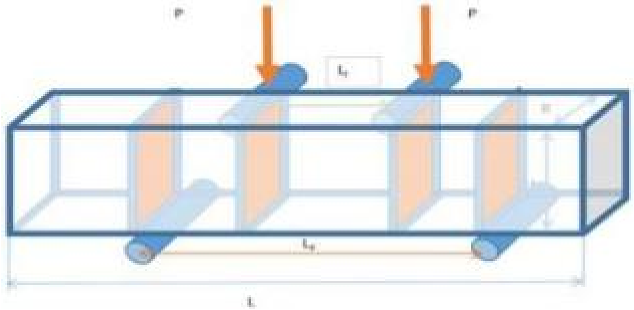
# Application cases studied in RAMSSES

**COMPOSITE OVERLAMINATION SOLUTION AS CRACK ARRESTORS IN STEEEL.**
DC21.1. STRUCTURAL DETAIL ON A DECK OPENING OF A CRUISE SHIP

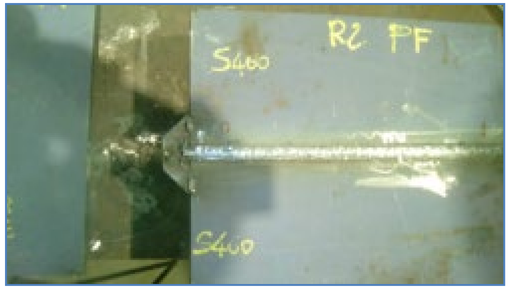


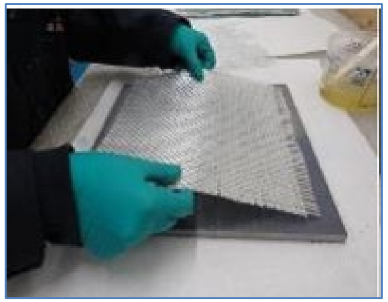



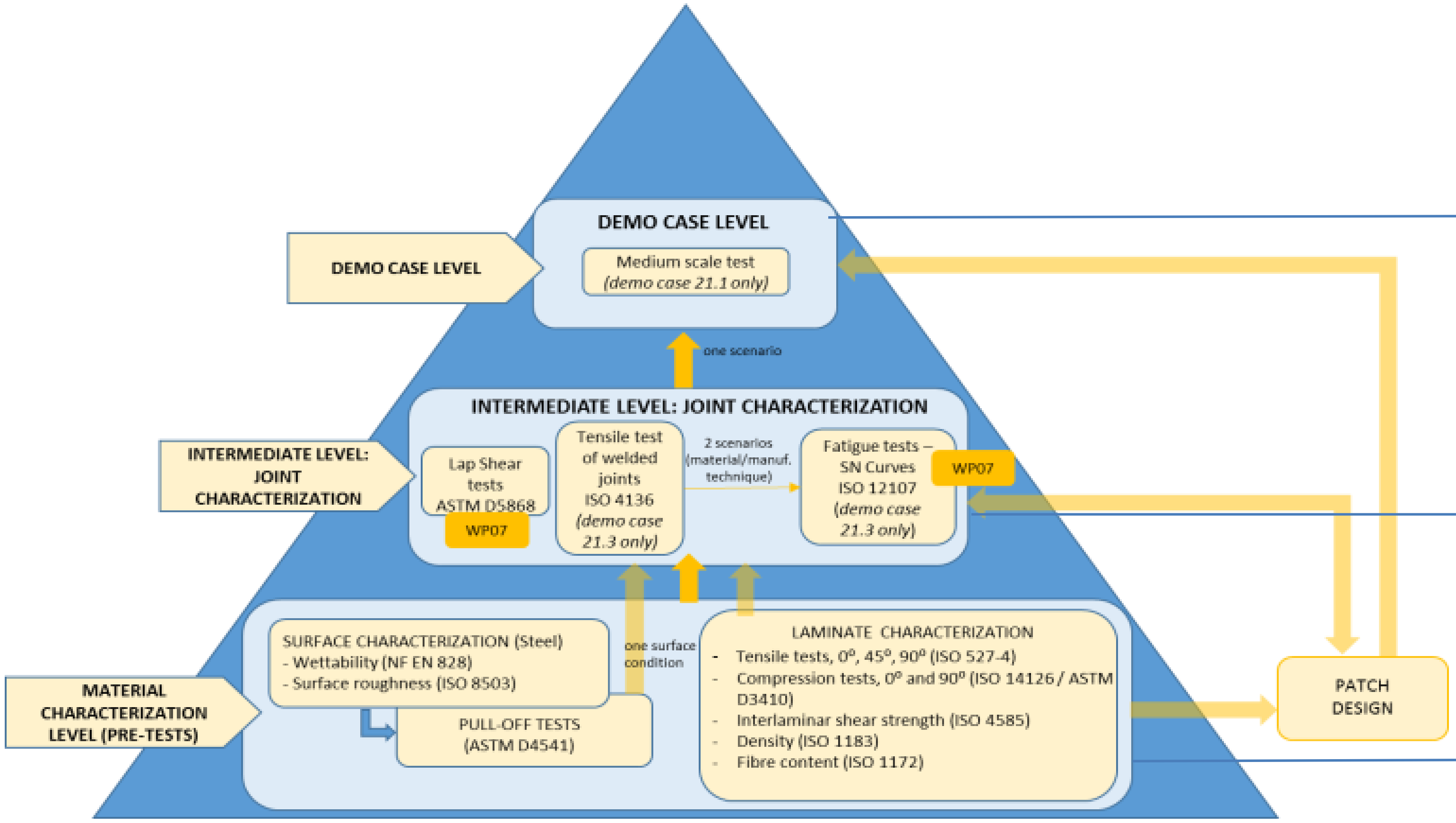
**JOINT REPAIR BY COMPOSITE OVERLAMINATION SOLUTIONS**
DC21.2 COMPOSITE JOINT REPAIR BY COMPOSITE OVERLAMINATION SOLUTIONS. **WP17'S TEST BOX**

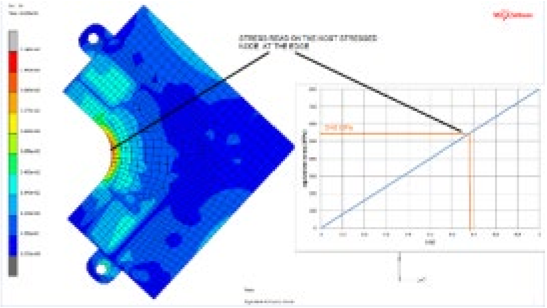


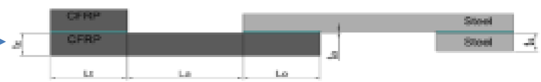
**EFFECTS OF COMPOSITE OVERLAMINATION TO IMPROVE FATIGUE LIFE OF WELDED JOINTS**
DC21.3. REINFORCEMENT IN WAY OF STRUCTURAL DETAILS WITH EXTERNAL EXPOSURES. **LINKED TO WP19**

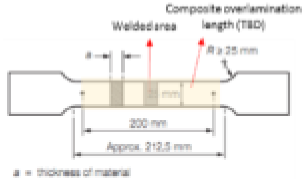


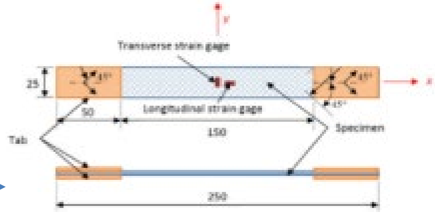



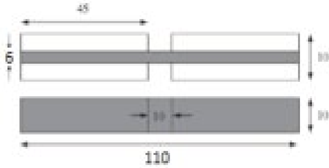

DEMO CASE LEVEL
DEMO CASE LEVEL
Medium scale test
(demo case 21.1 only)
one scenario
INTERMEDIATE LEVEL: JOINT CHARACTERIZATION
INTERMEDIATE LEVEL: JOINT CHARACTERIZATION
Lap Shear tests ASTM D5868
WP07
Tensile test of welded joints ISO 4136 (demo case 21.3 only)
2 scenarios (material/manuf. technique)
Fatigue tests – SN Curves ISO 12107 (demo case 21.3 only)
WP07
MATERIAL CHARACTERIZATION LEVEL (PRE-TESTS)
SURFACE CHARACTERIZATION (Steel)
- Wettability (NF EN 828)
- Surface roughness (ISO 8503)
one surface condition
PULL-OFF TESTS (ASTM D4541)
LAMINATE CHARACTERIZATION
- Tensile tests, 0º, 45º, 90º (ISO 527-4)
- Compression tests, 0º and 90º (ISO 14126 / ASTM D3410)
- Interlaminar shear strength (ISO 4585)
- Density (ISO 1183)
- Fibre content (ISO 1172)
PATCH DESIGN



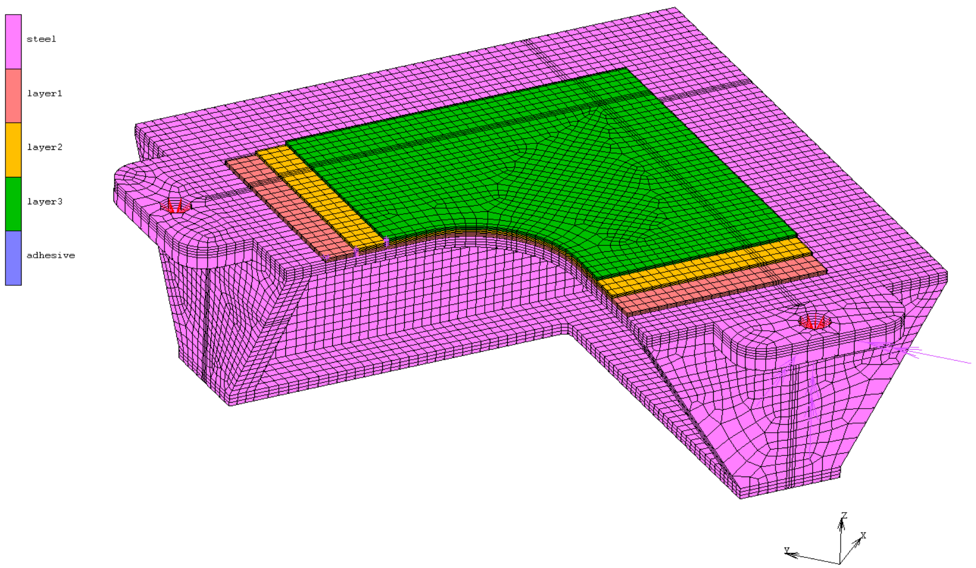

CFRP
CFRP
Steel
Steel


Composite overlamination length (TBD)
Welded area
200 mm
Approx. 212,5 mm


Transverse strain gage
Longitudinal strain gage
Specimen
Tab
25
50
150
250


45
110

- The laminate characterization has been completed :
  - Carbon – vinylester vaccum bag
  - Carbo-epoxy vaccum bag
- Joint characterization is in progress
- Patch design of the large scale demonstrator




- Next activities
  - Building of the large scale demonstrator
  - Test of the large scale demonstrator

# RAMSSES conclusions and beyond RAMSSES

- Test results and analyses results of RAMSSES will:
  - Identify new patch applications (overlamination of welded joints to increase the fatigue resistance)
  - Increase the knowledge about patch behaviour
  - Increase the capability of simulate numerically the behaviour of the patches (set up of numerical model)
  - Help the process of update of the rules framework

- Topic to be further studied in next research projects:
  - Fire issues
  - Continue to study and monitor the long time performances of the patch in marine environment

# THANK YOU
# FOR
# YOUR ATTENTION