MULTISCALE APPROACH FOR THE ANALYSIS OF COMPOSITE CONNECTIONS AND STIFFENERS IN MARINE SHELL STRUCTURES

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COMPOSITES AND **A**DVANCED **M**ATERIALS FOR **M**ULTIFUNCTIONAL **S**TRUCTURES (CAMMS)

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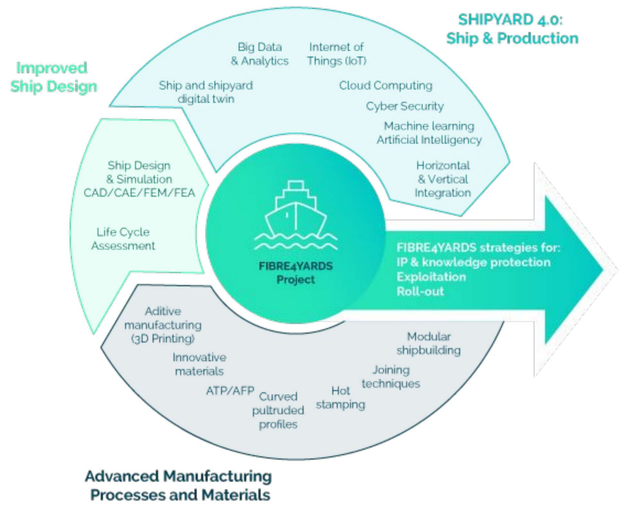
INTRODUCTION – FIBRE4YARDS

Fibre Composite Manufacturing Technologies for the Automation and Modular Construction in Shipyards

PROJECT OBJECTIVES

- Develop new production technologies to increase the automatization and modular construction in shipbuilding,
- Digitalize the shipyard to improve the quality, its efficiency and maintenance
- Incorporate all these improvements, as well as sustainability aspects in the boat design.

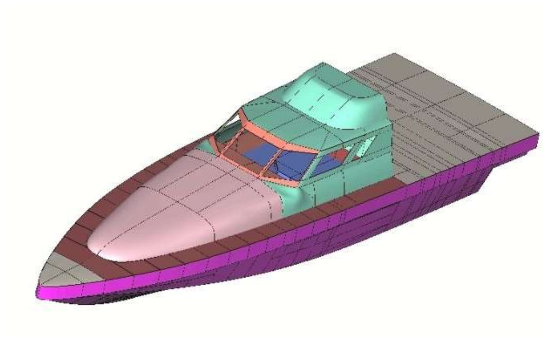


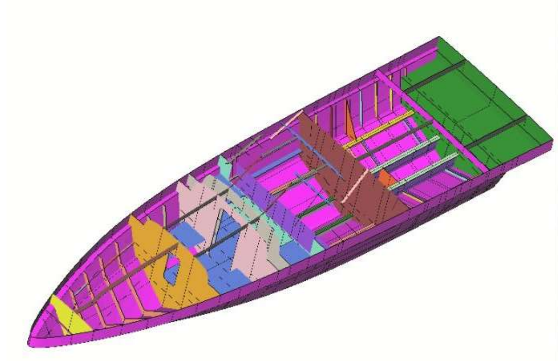
INTRODUCTION

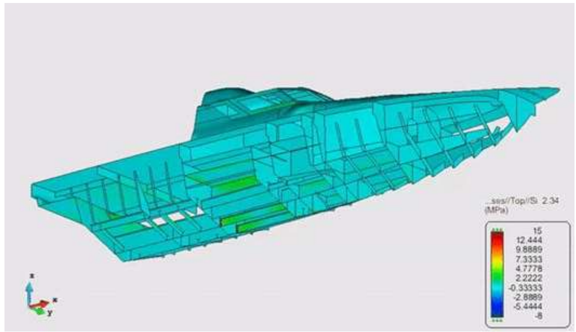
One of the improvements in SHIP DESIGN is the development of new formulations for the analysis of shell structures, as FEM have become essential for ship design.

An accurate simulation must account for the effect of stiffeners and other shell irregularities as these:

- Define the stiffness and strength of the panel (and structure)
- Are responsible of stress concentrations (which can lead to fatigue failure)







INTRODUCTION – SHIP DESIGN

Stiffeners are usually characterized as:

- Beam elements attached to the shell element
- Shell elements

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These two problems can be solved using

- Detailed solid models

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- Computationally too expensive

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Current work proposes an homogenized shell element aimed to provide "solid model" accuracy with an affordable computational cost

Multiscale Homogenization

PROPOSED APPROACH

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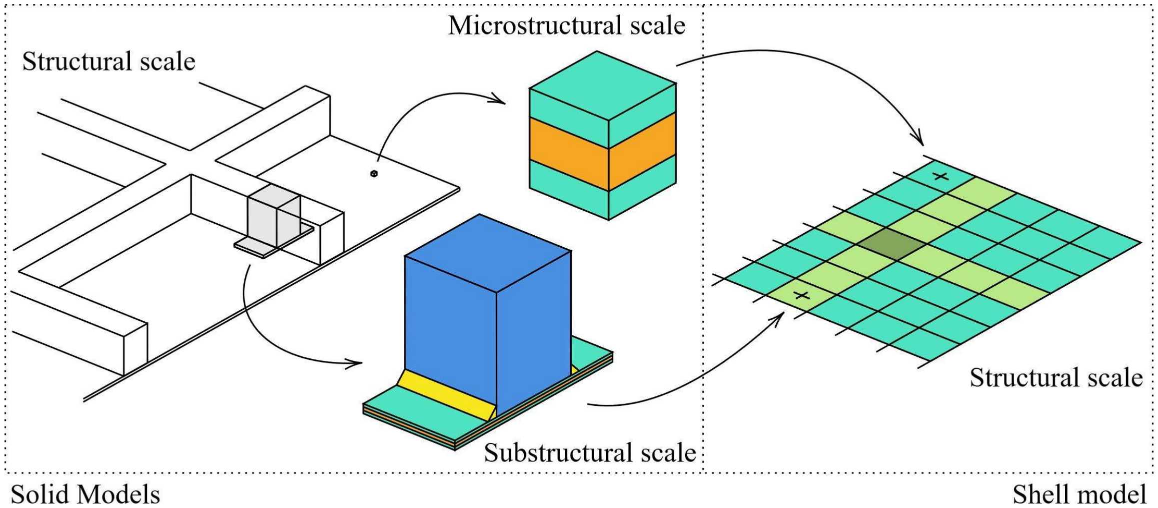
The procedure consists on using multiscale procedures, such the ones defined in homogenization processes, to obtain the stiffness matrix of the shell element from a numerical model of the stiffener or discontinuity



MULTISCALE HOMOGENIZATION

The shell element is defined by its ABD matrix

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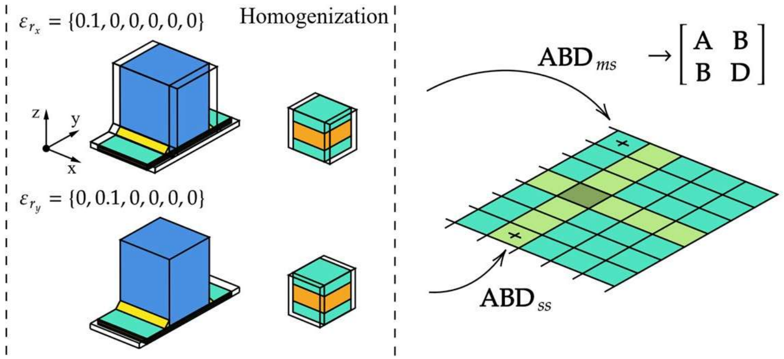
[illegible]

The ABD matrix is obtained with a process equivalent to the one used in a numerical derivation:

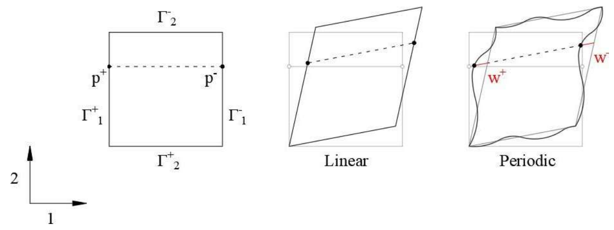
A unit deformation is applied to the microstructure or substructure RVE

The equivalent stress field provided by these deformations correspond to a given column of the ABD matrix.



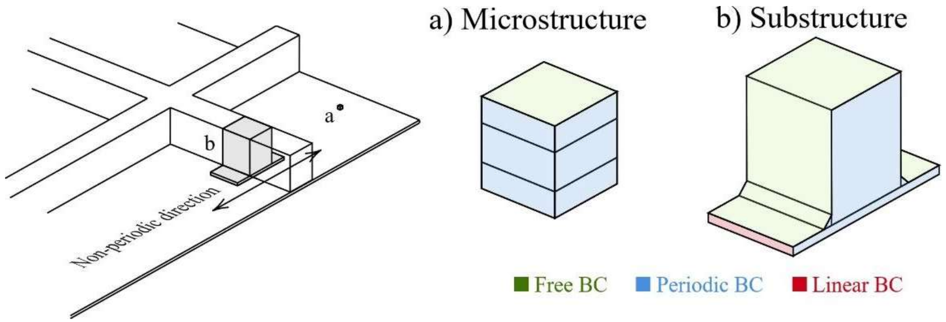
MULTISCALE HOMOGENIZATION

In order to apply the unity displacements, it is necessary to define a set of boundary conditions.



With current approach it is necessary to define MIXED BOUNDARY CONDITIONS.

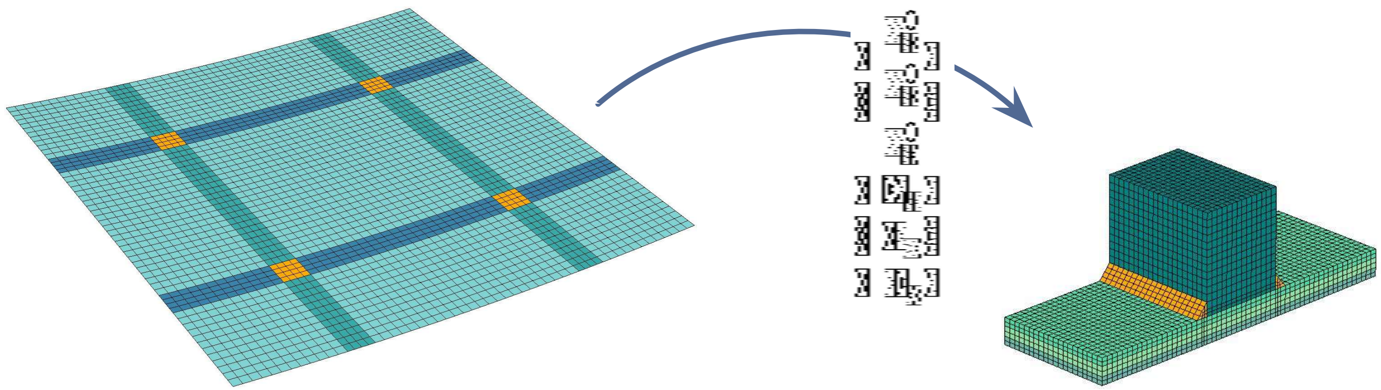
These differ from the microstructure and the substructure:



MULTISCALE HOMOGENIZATION

The proposed procedure not only allows obtaining the ABD matrix of the shell element taking into account the specific stiffness of the stiffener or connection.

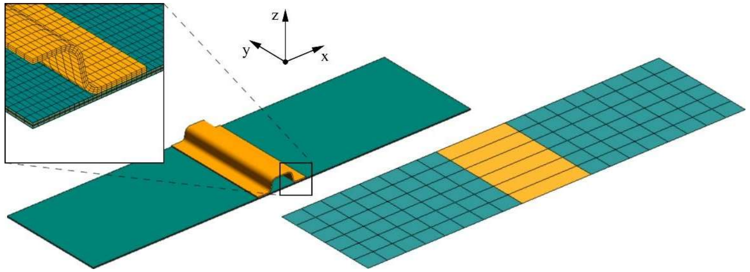
It also allows obtaining the stress pattern in the structure model, for a given strain state.



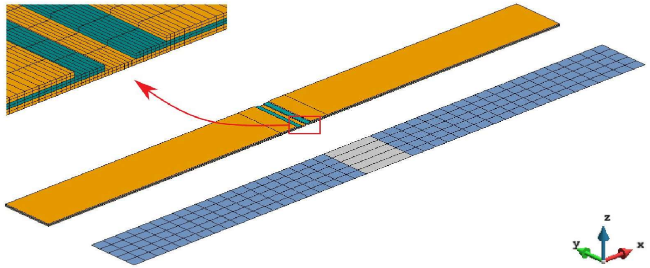
MULTISCALE HOMOGENIZATION

The developed approach can be applied to any type of shell irregularities

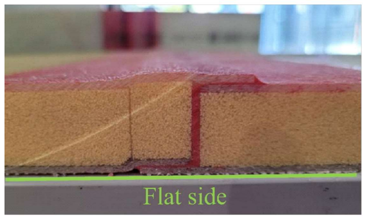
STIFFENERS



CHANGE OF THICKNESS



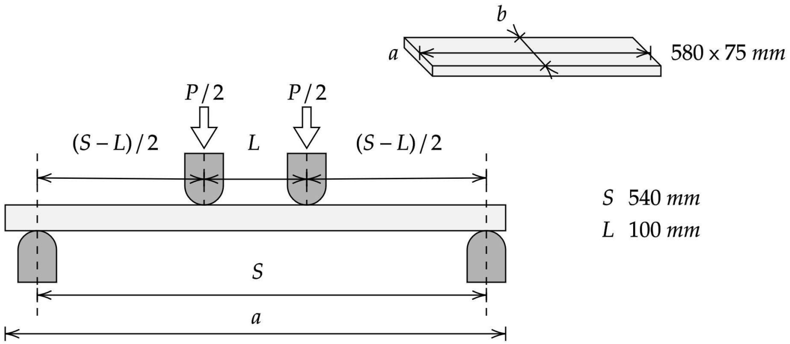
CONNECTIONS



Analysis of a Composite Connection

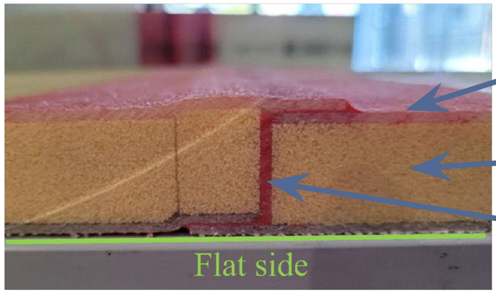
NUMERICAL EXAMPLE

Composite Connection – TESTED SPECIMEN



S 540 mm
L 100 mm

Property	ETXL 400 layer	Unie300	Foam Core
E_1 [MPa]	35264	33184	334
E_2 [MPa]	9091	11306	334
G_{12} [MPa]	3408	3408	98
ν_{12} [-]	0.288	0.23	0.3

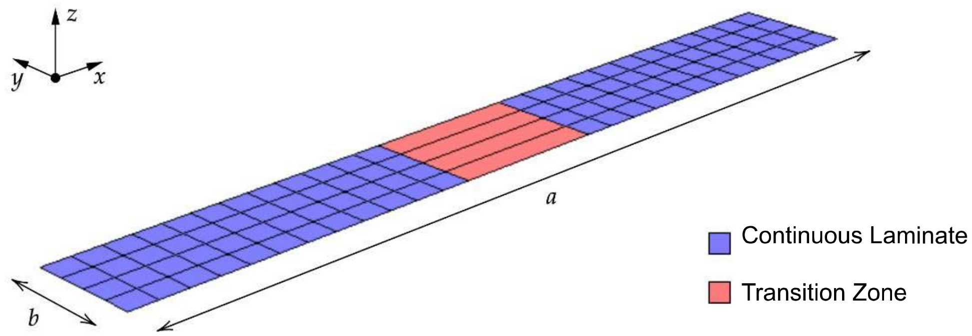


[+45/-45/0/0]s
3 layers of EXTEL400 + 1 layer of Unie300

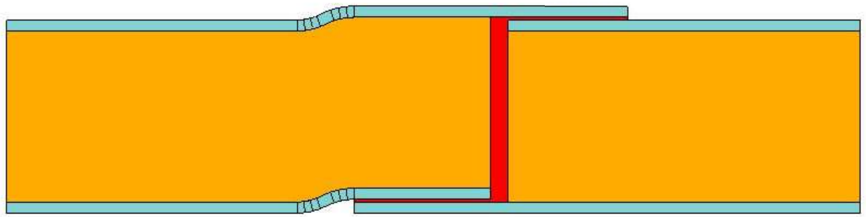
Foam Core, 20mm

Epoxy adhesive

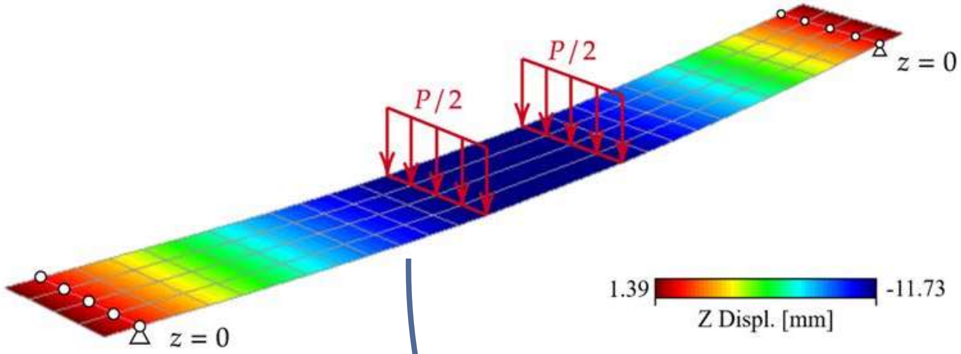
Composite Connection – NUMERICAL MODEL



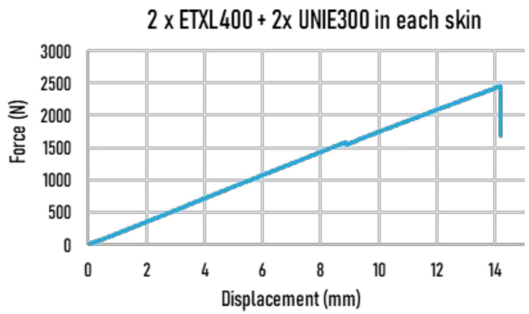
Property	Skin	Epoxy	Core
E_1 [MPa]	27097	3260	334
E_2 [MPa]	11644	3260	334
E_3 [MPa]	10287	3260	334
G_{12} [MPa]	5436	1253	98
G_{13} [MPa]	3408	1253	98
G_{23} [MPa]	3408	1253	98
ν_{12} [-]	0.378163	0.3	0.3
ν_{13} [-]	0.208751	0.3	0.3
ν_{23} [-]	0.279164	0.3	0.3



Composite Connection - RESULTS

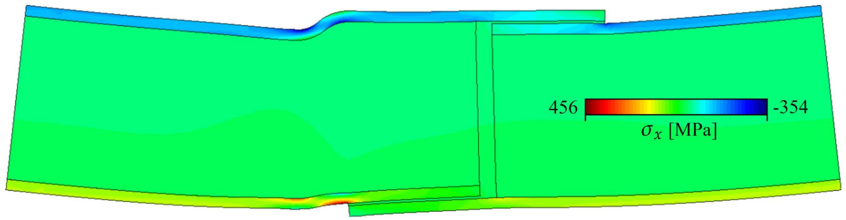


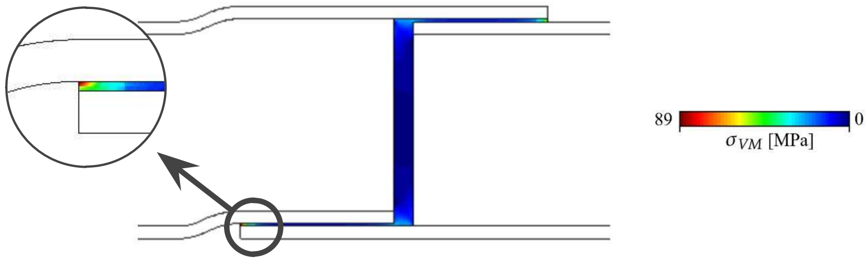
The displacement obtained in this figure corresponds to the maximum load obtained with the experimental test before rupture: 2.45 kN

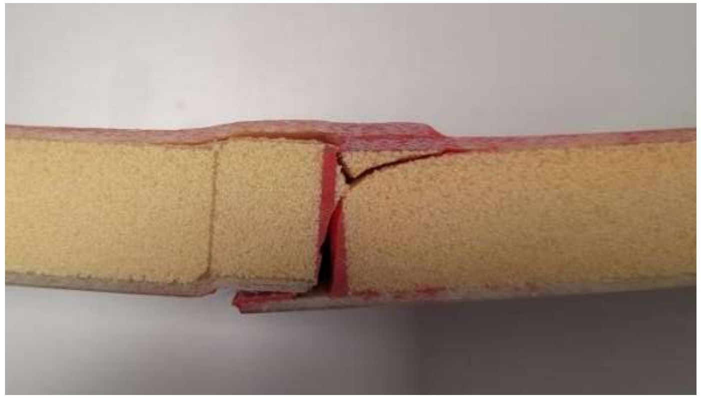


The strain field obtained from the shell model can be applied to the 3D solid model to obtain the connection stress field

Composite Connection - RESULTS

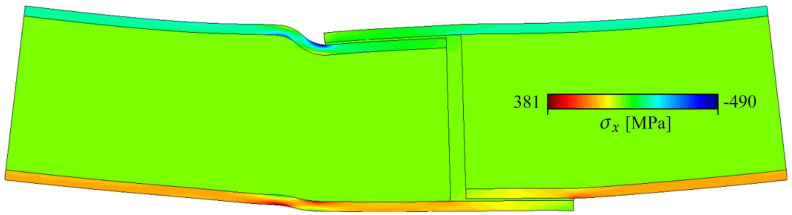


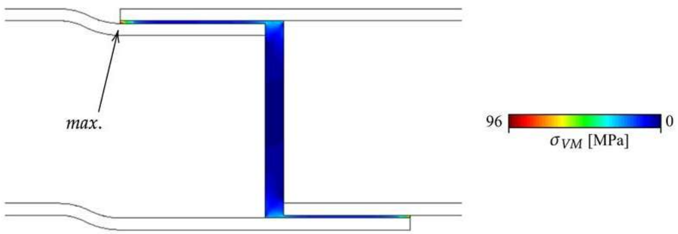




The failure mode is equivalent to the one obtained with the experimental campaign.
Both specimens break at the bottom adhesive

Composite Connection - RESULTS





Changing the connection configuration, also produces a change in the failure region in both specimens (experimental and numerical)

CONCLUSIONS

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- The new homogenization procedure allows improving the accuracy of F.E. shell models containing irregularities such as stiffeners, connections, etc.
- The results obtained from the shell analysis can be used to verify the irregularity, capturing possible failures, or to conduct a more precise fatigue analysis.
- Stress patterns in the irregularities will be better determined because the stiffness considered in the shell model is characterized better.
- All these advantages are obtained with a minimal computational cost.

Acknowledgements

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CIMNE EXCELENCIA SEVERO OCHOA

FIBRE4YARDS SHIPYARD FOR THE FUTURE

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