Composite testing for marine applications

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Presentation

- **Introduction, IFREMER**
- **Marine applications of composites**
- **The marine environment**
- **Floating structures**
  - Small boats
  - Racing yachts
  - Offshore
- **Underwater structures**
  - Oceanography
  - Offshore
- **Assemblies**
- **Conclusions & Perspectives**

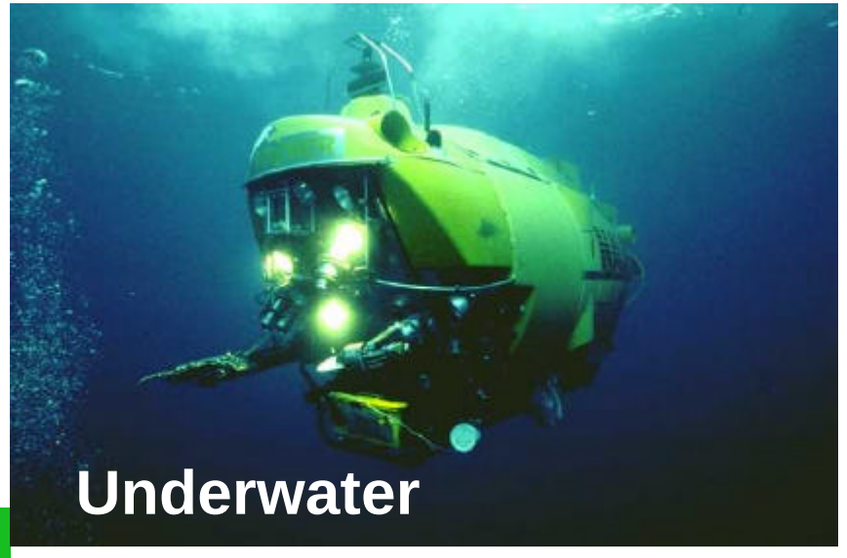
IFREMER
The French Ocean Research Institute

Ifremer

Deep sea exploration

CompTest 2004

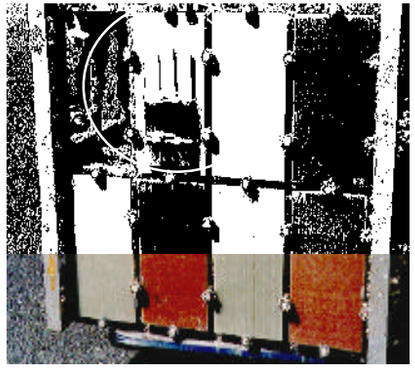
Marine Applications of composites

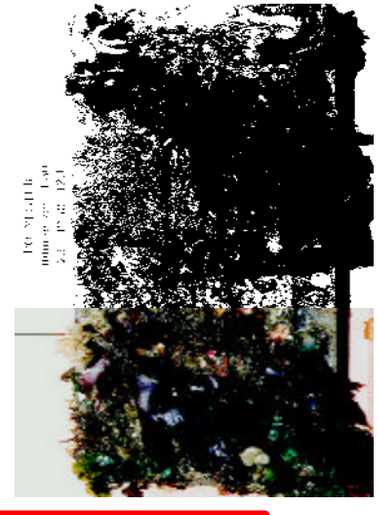


The Marine Environment

- **Physico-chemical** — ***Seawater (pH, salinity…)***
  Temperature (-15 to 60°C)
  Sunlight, UV

- **Biological**





- **Mechanical** — ***Hydrodynamic***
  Aerodynamic
  Hydrostatic pressure

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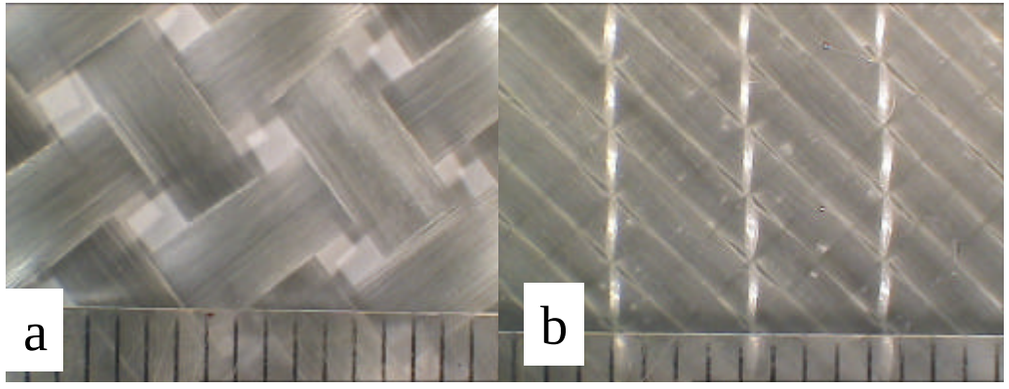
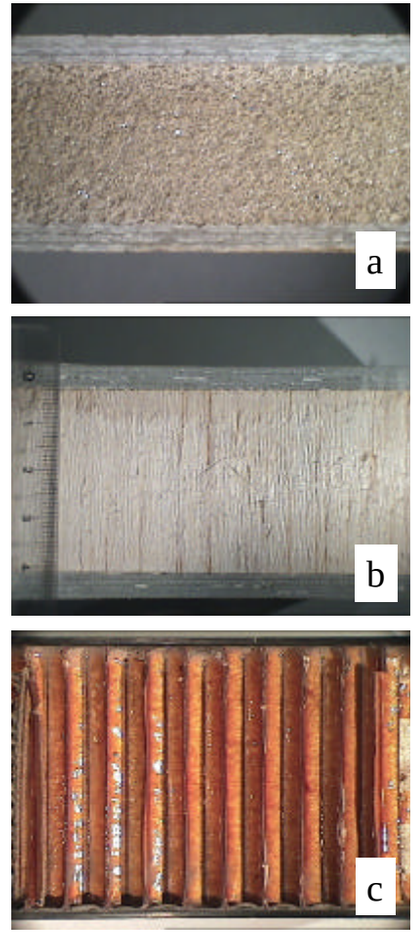
Floating structures:
Marine Materials

Traditional laminates: woven, “rovimat”
Resin: polyester





Sandwich

PVC foams, balsa, (nida)

Small composite boats

composites for > 40 ans

A rapidly-evolving industry:

- **VOC legislation**
- **Infusion methods**
- **Carbon……**

Design of small boats (<24m)

Draft standard ISO/DIS 12215 :

"Hull construction - Scantlings -
Part 5: Design presures for monohulls"

based on expérience, ABS, DNV, BV, Lloyds...

Aim: achieve a level of structural resistance which guarantees the integrity of the vessel

Rapporteur: G. Dolto, FIN
(Fédération des Industries Nautiques)

1 Plating – Scantling equations

1.1 FRP single skin plating

The minimum required thickness of the plating t is the greater of t_1 and t_2 defined below

$$t_1 = b \cdot f_k \cdot \sqrt{\frac{P \cdot k_2}{1000 \cdot s_d}} \quad \text{(mm)}$$

$$t_2 = b \cdot f_k \cdot \sqrt[3]{\frac{P \cdot k_3}{1000 \cdot k_1 \cdot E_f}} \quad \text{(mm)}$$

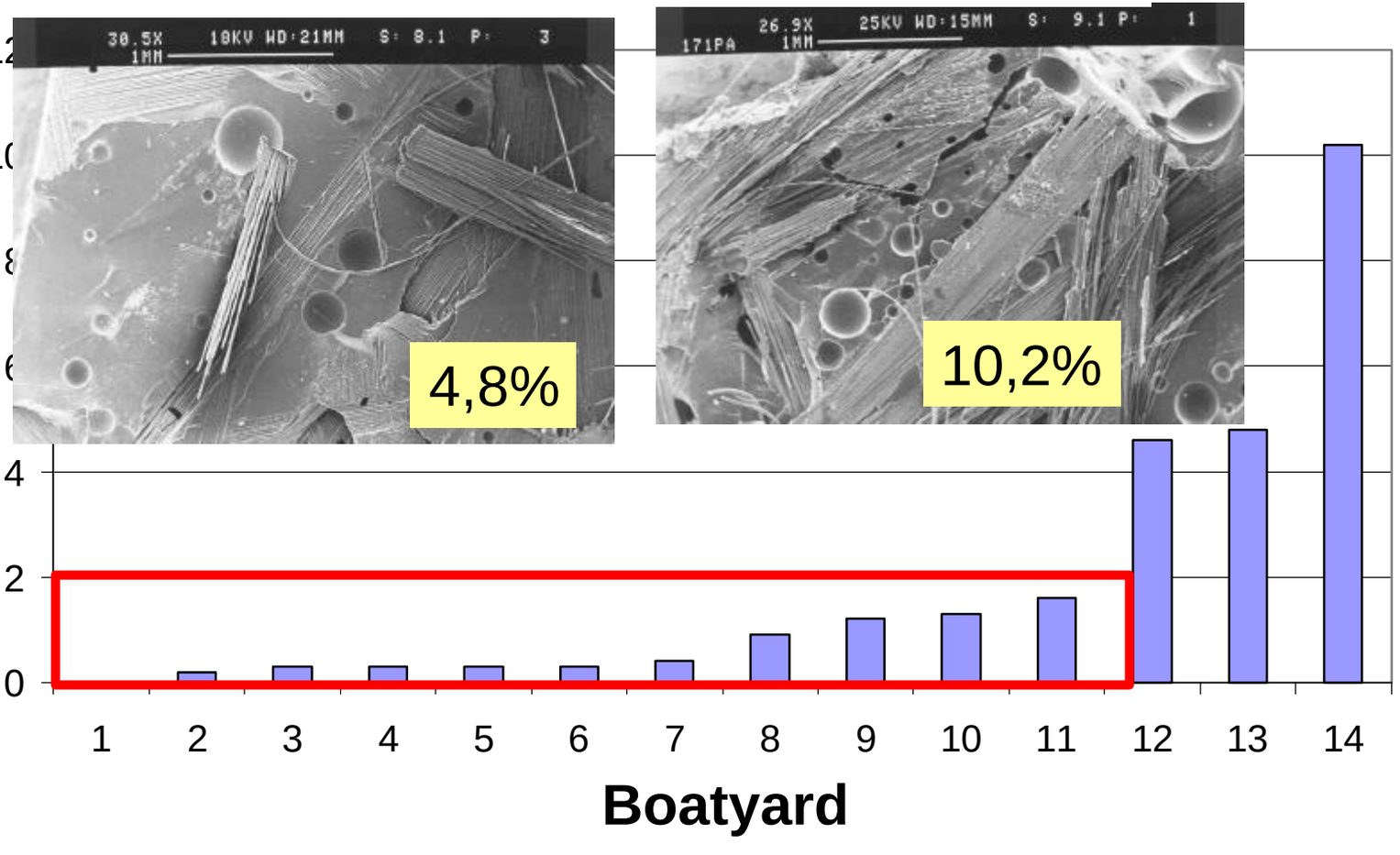
Table 1 — Design stresses for FRP single skin plating

Material	Structural element	design stress σ_d N/mm^2
FRP single skin	Hull bottom and side	$0{,}5 \cdot \sigma_{uf}$
	Decks and superstructures	$0{,}5 \sigma_{uf}$
	Structural and tank bulkheads	$0{,}5 \cdot \sigma_{uf}$
	Watertight bulkheads	$0{,}625 \cdot \sigma_{uf}$

where σ_{uf} is the minimum ultimate flexural strength

Material variability

Void content (image analysis, SEM)

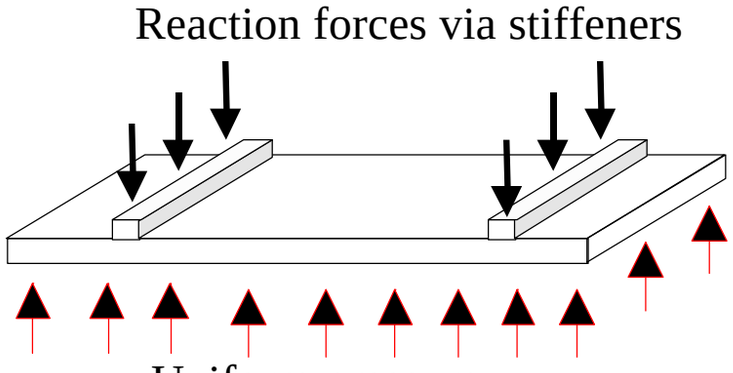


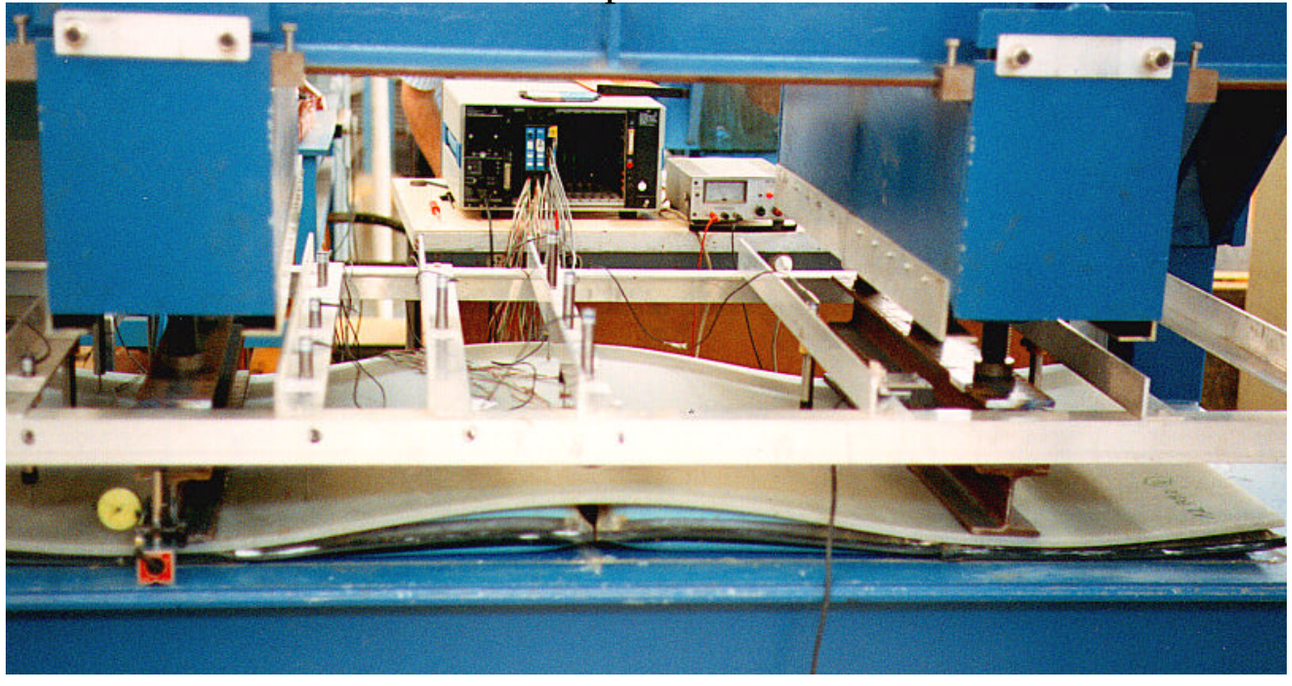
700 tests: Coefficients of Variation 10-15%

ISO: $s_f\,(MPa) = 502 * M_f^2 + 106{,}8$

Component testing

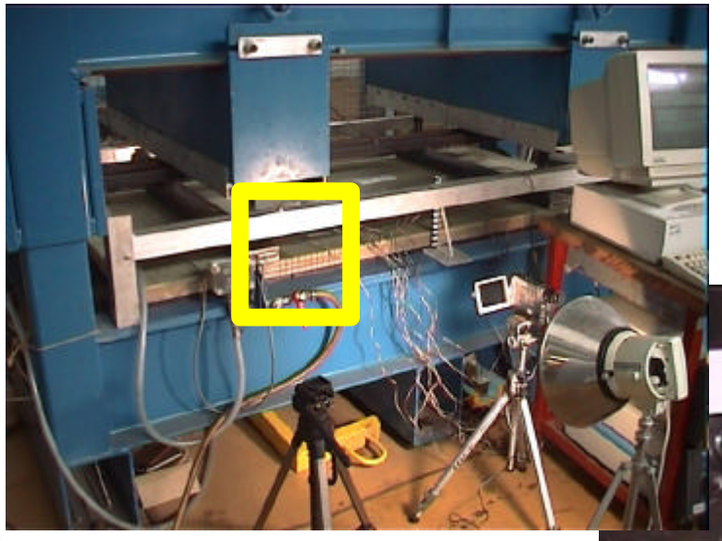
Development of pressure loading test for composite and sandwich panels

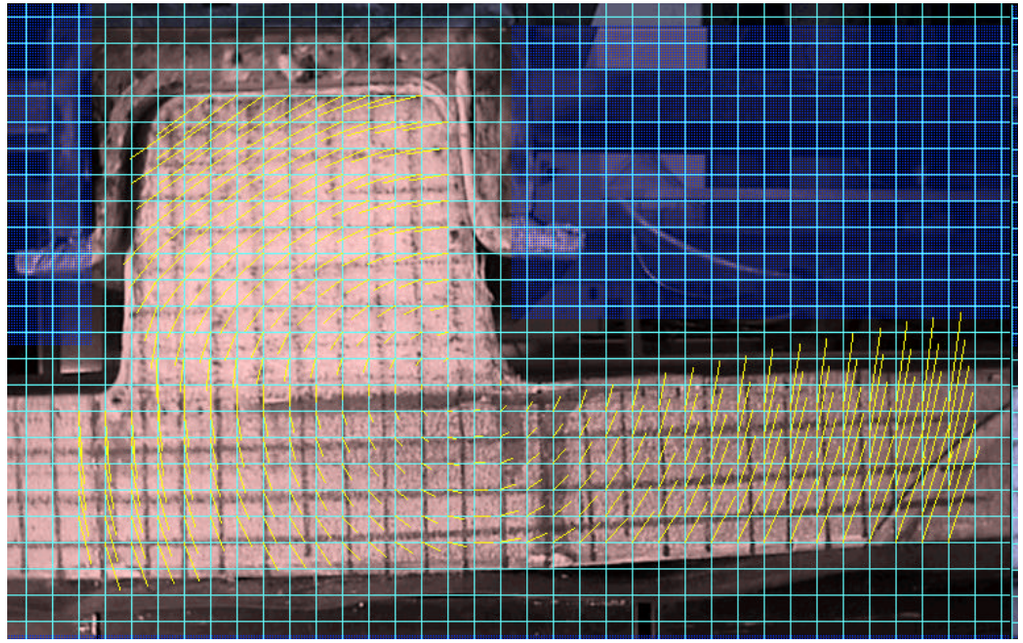


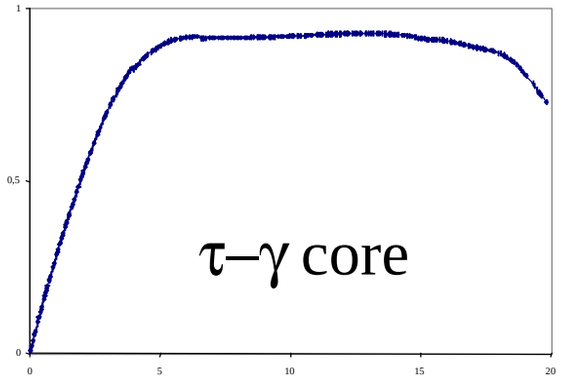


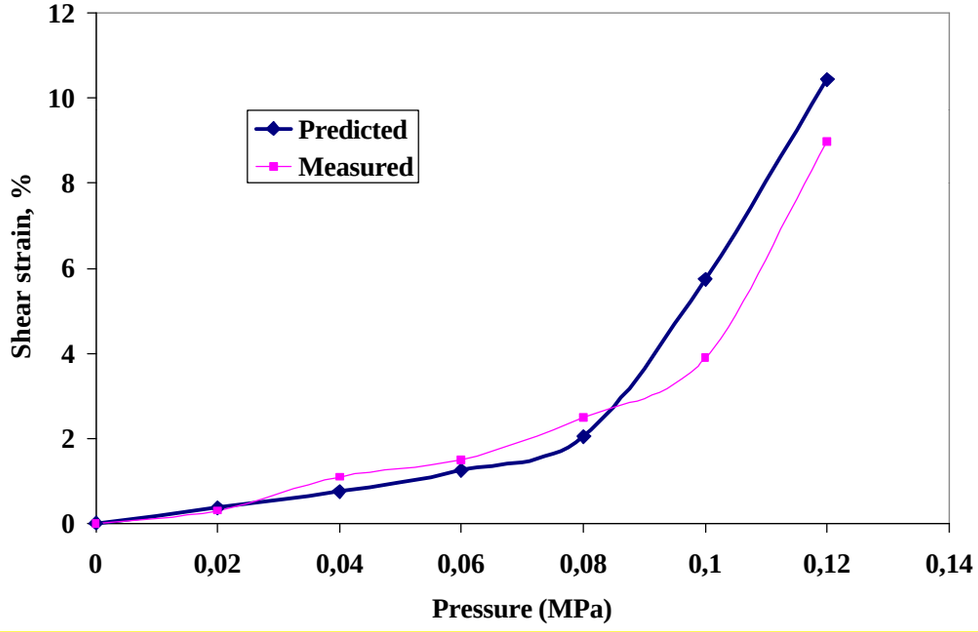
Component testing

Study of core behaviour in sandwich panels





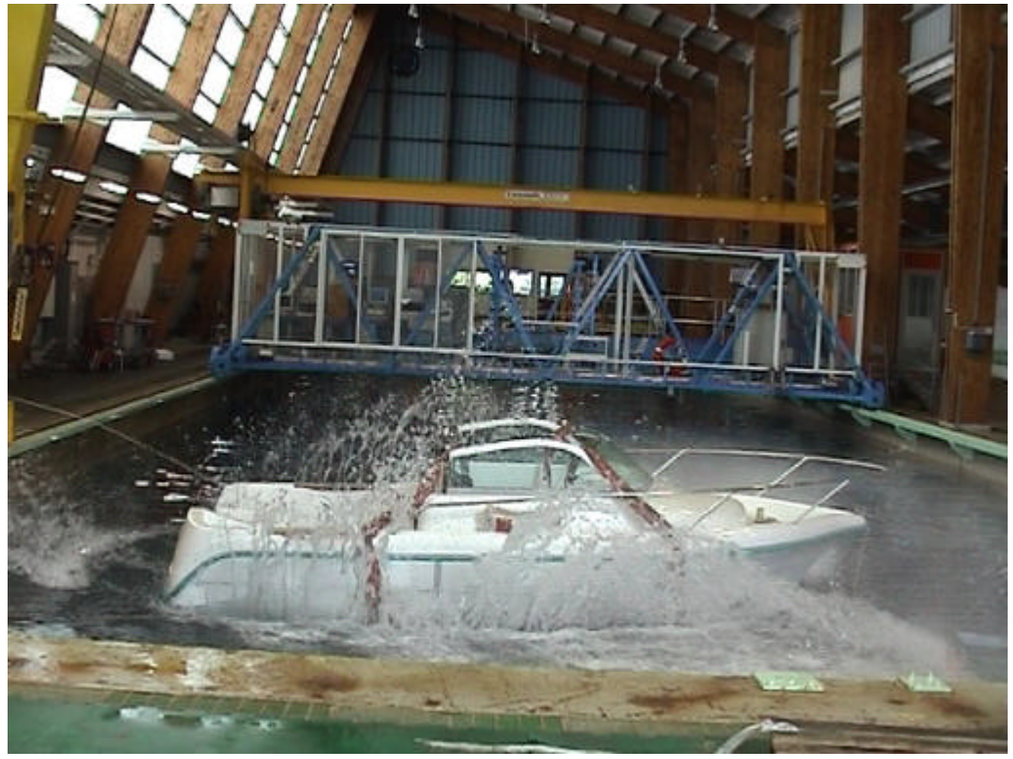

τ–γ core


Predicted
Measured
Shear strain, %
Pressure (MPa)
0
2
4
6
8
10
12
0
0,02
0,04
0,06
0,08
0,1
0,12
0,14

Ex. Motor boat design

ISO/DIS 12215: Annex B.Validation: Drop tests

Drop height = $f(V/L^{1/2})$



Racing yachts

Test platform for new technology

Groupama 2

Mast:
high modulus carbon

Platform:
carbon sandwich

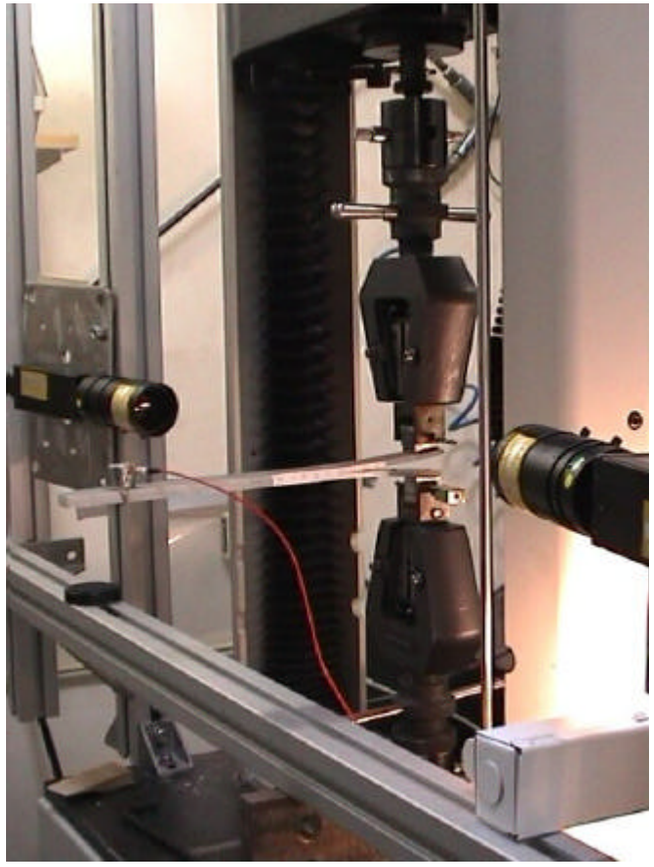
Sails:
aramid, carbon….

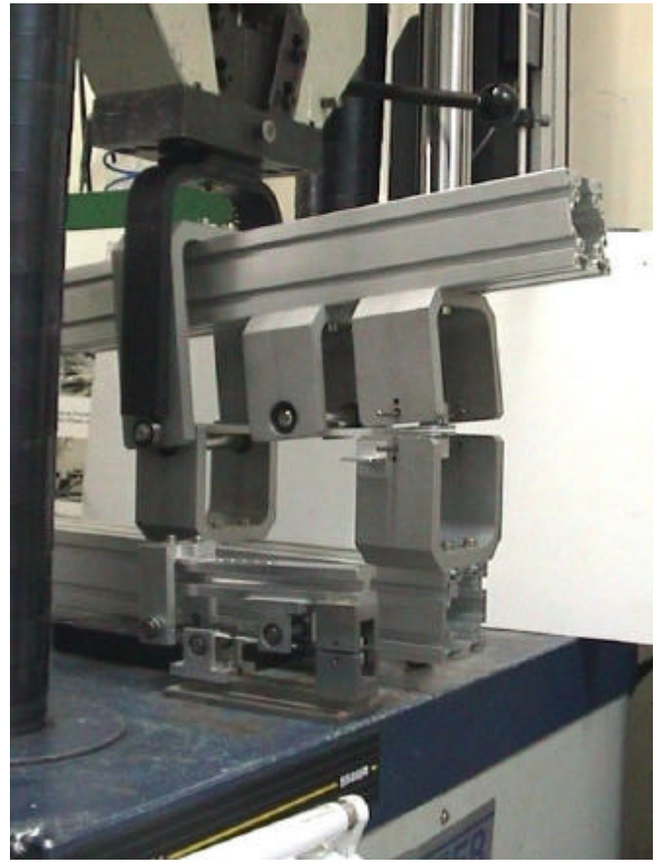
Rigging:
PBO, aramid

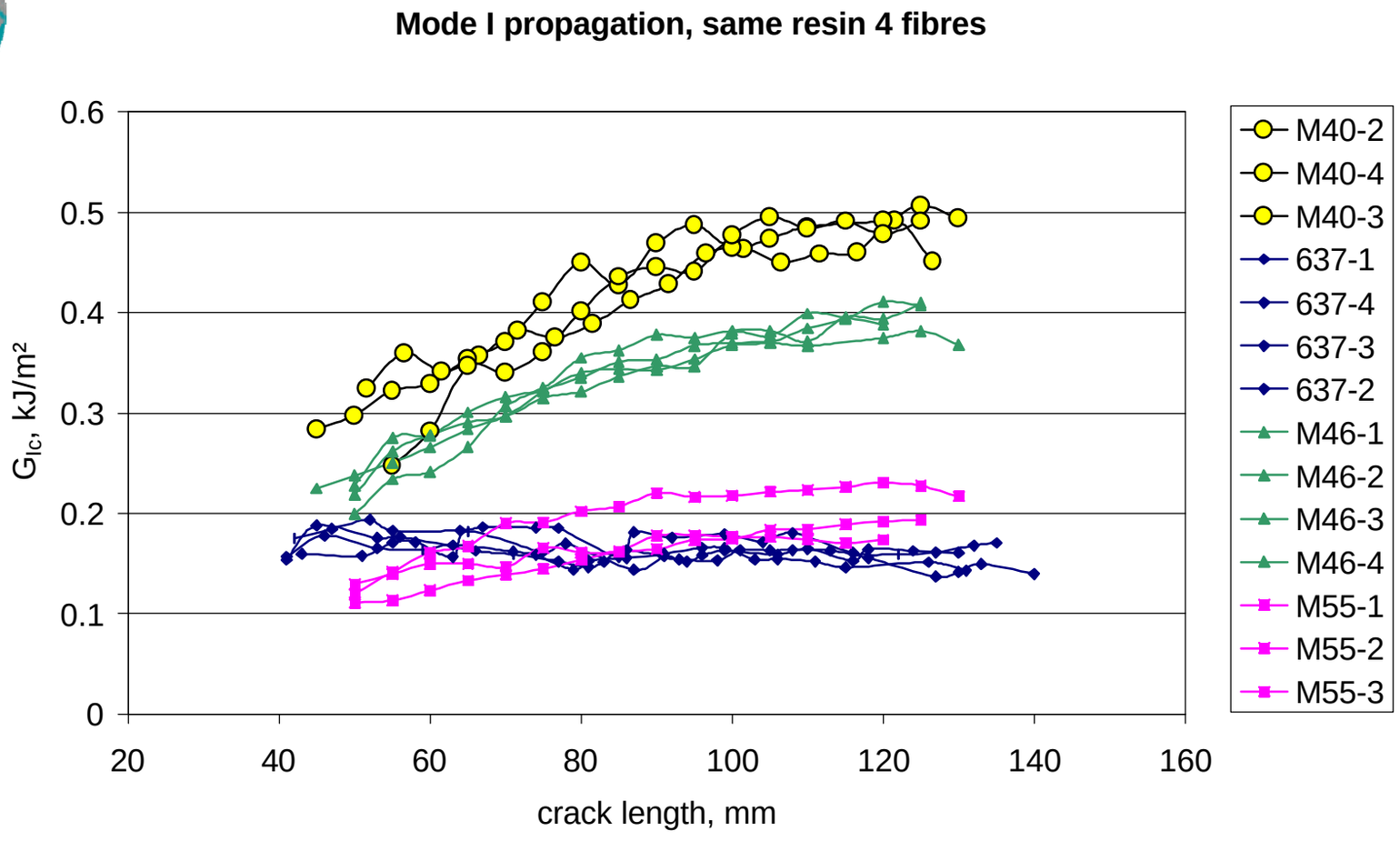
Material tests
Component tests

Material tests:

Fracture of high modulus fibre composites

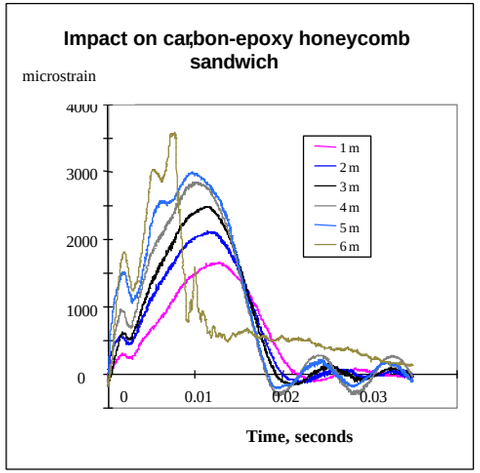


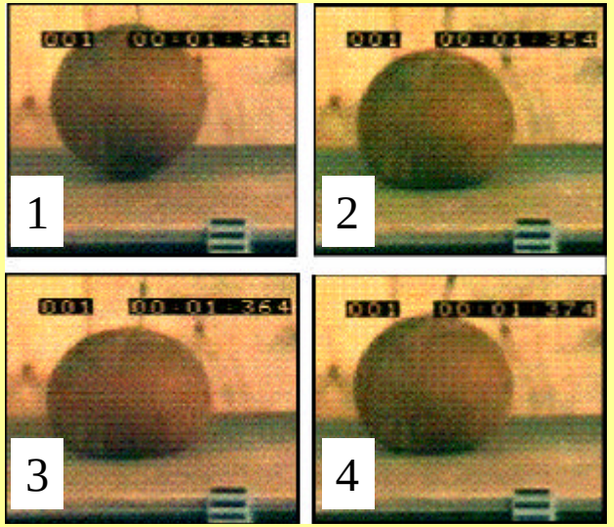


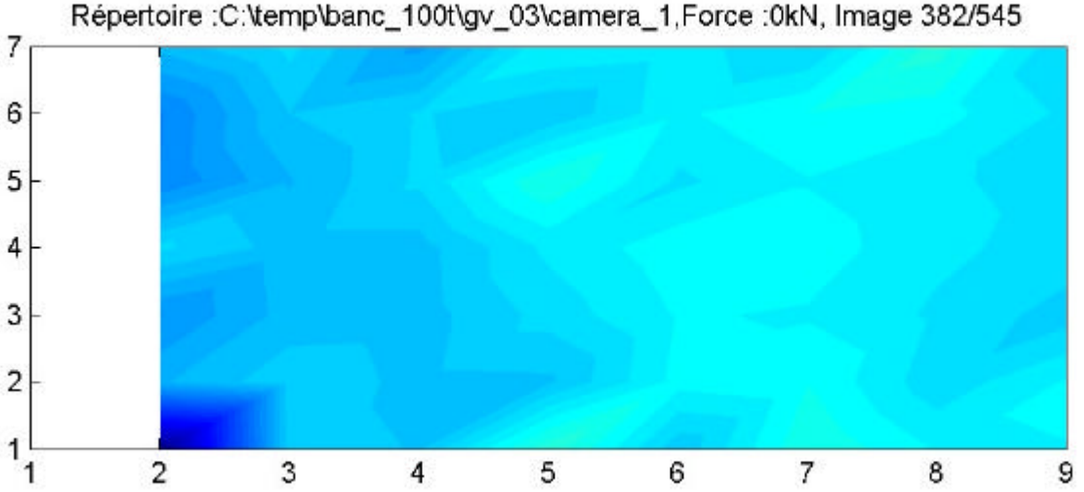


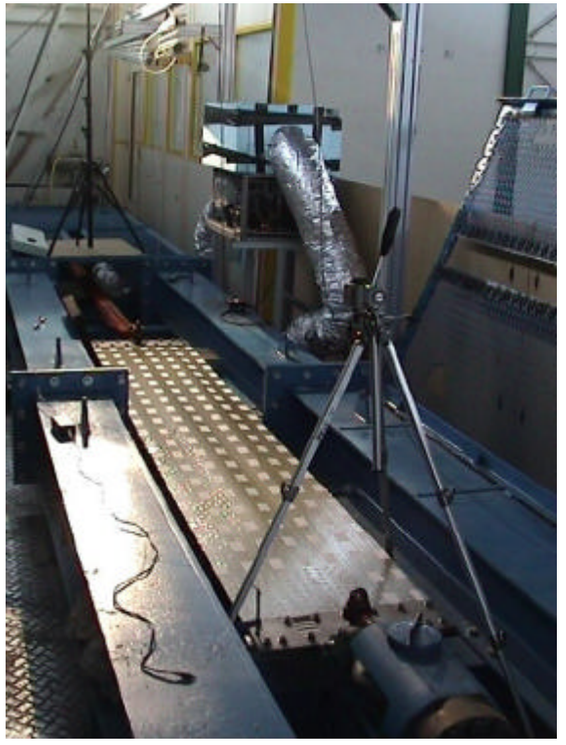
Influence of Z-pinning

Test to simulate slamming impact









Sailcloth testing:

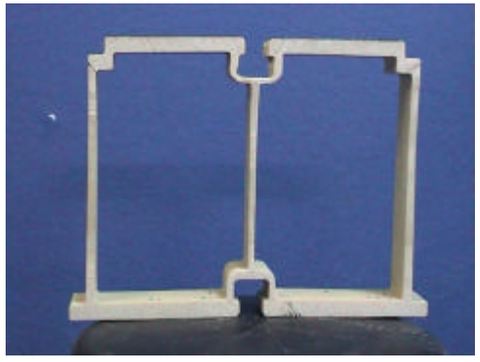
- Size effects
- High rate

Composites offshore

Impact testing

4 tons dropped from 3 metres

- **Steel**
- **Composite**



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Testing for underwater applications

Pressure vessels, often cylindrical

Manufacture: filament winding, tape laying

Materials:

glass/epoxy
carbon/epoxy
(thermoplastic)

Loading well-defined:

$P(bar)=0,101*H + 0,5*10^{-6}*H^2$ *(H depth in m)*

Testing of curved, thick specimens under pressure

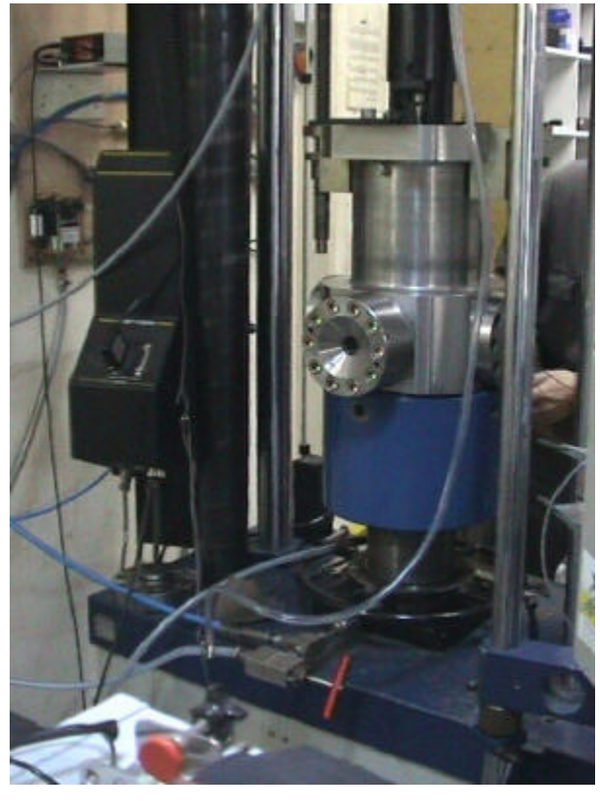
Development of dedicated test facility

- **Pressure up to 1000 bars (10 km depth)**

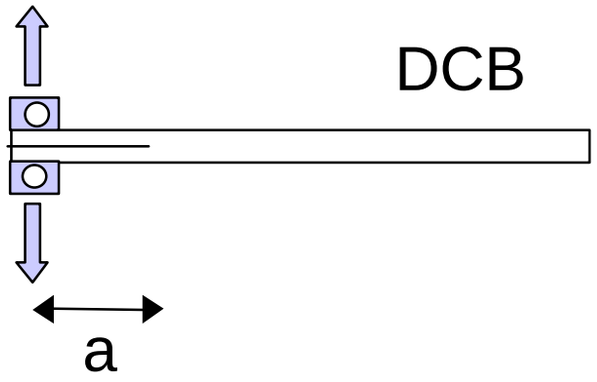
- **Dimensions to test all standard specimens**
  Tension, Compression, Flexure
  plus Fracture tests

- **Direct observation of tests in-situ**

Pressure vessel adapted to standard 20 ton capacity test machine



i) Mode I fracture testing of composites



ISO 15024-2001

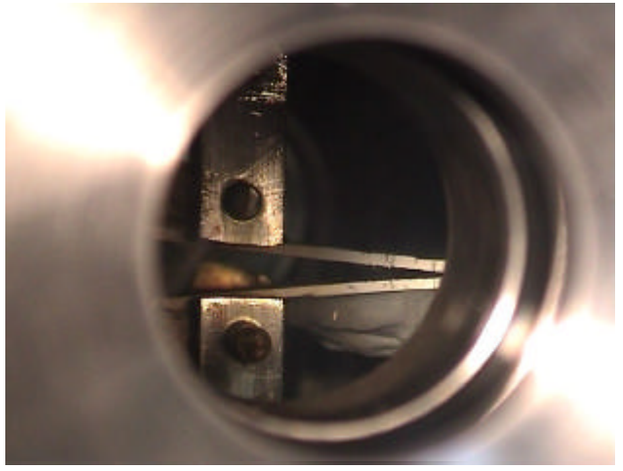
IM7/977-2
UD Carbon/Epoxy

Mode I testing of composites
Procedure

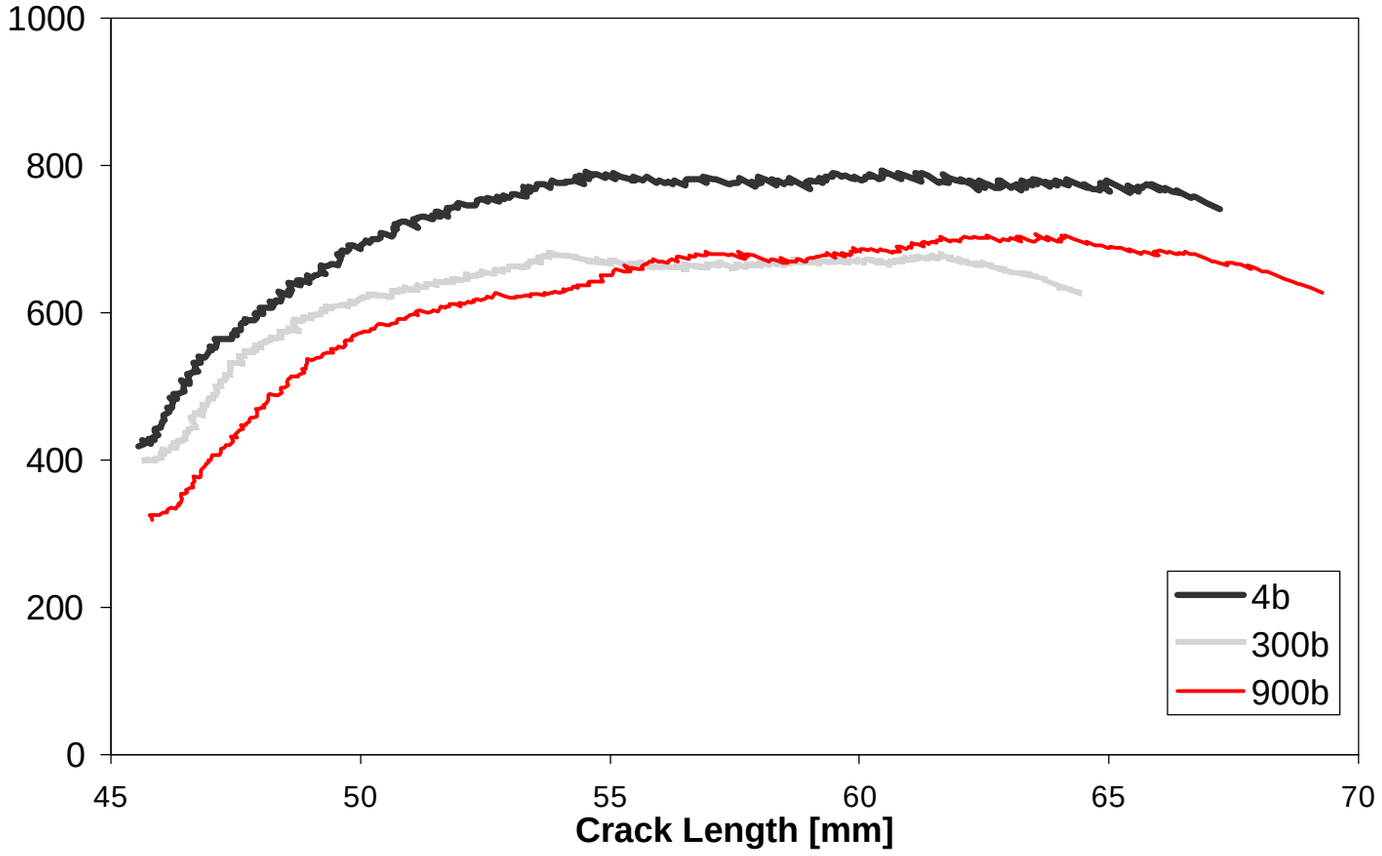
Instrumentation, P, d, strain gage

To check Displacement

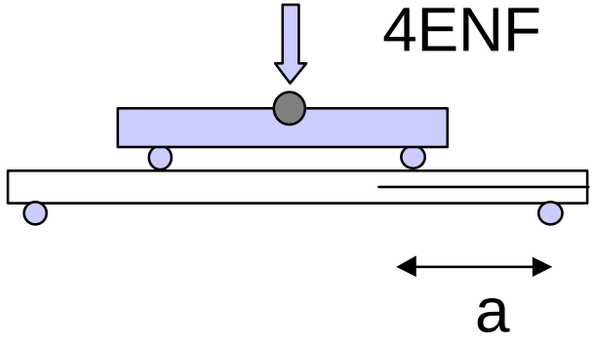
Image analysis through viewglass



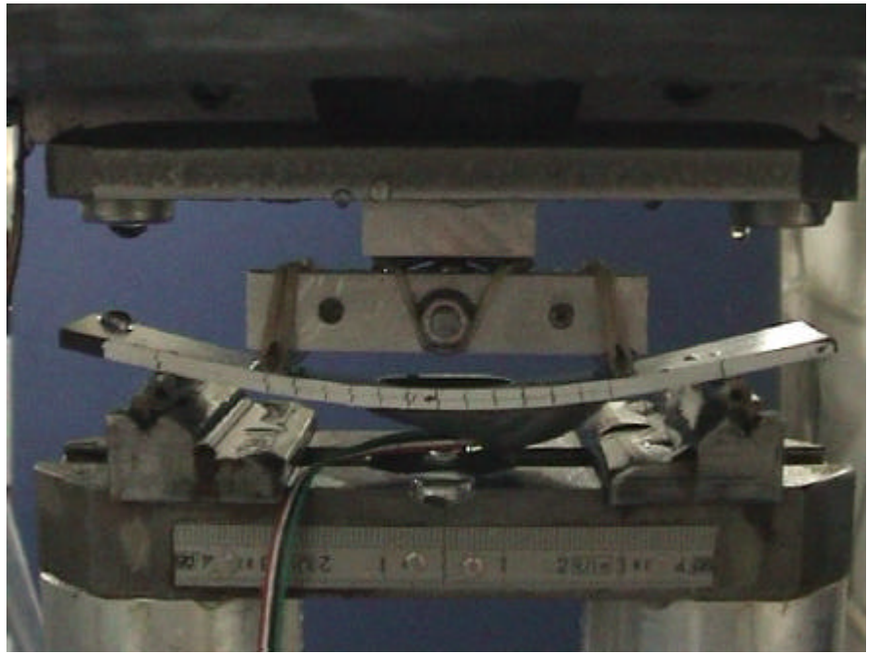
Mode I testing of composites
Examples of results



ii) Mode II (in-plane shear) fracture testing of composites

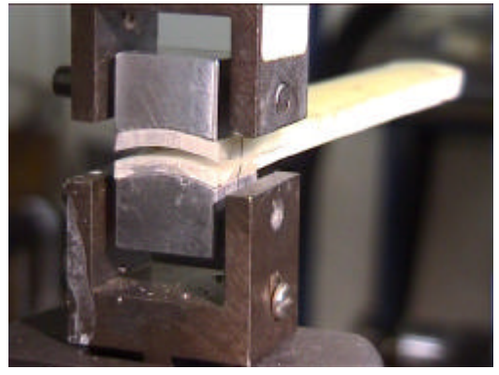


Four point Edge Notched Flexure specimen



Influence of curvature

Filament wound specimens cut from tubes (+/-q)

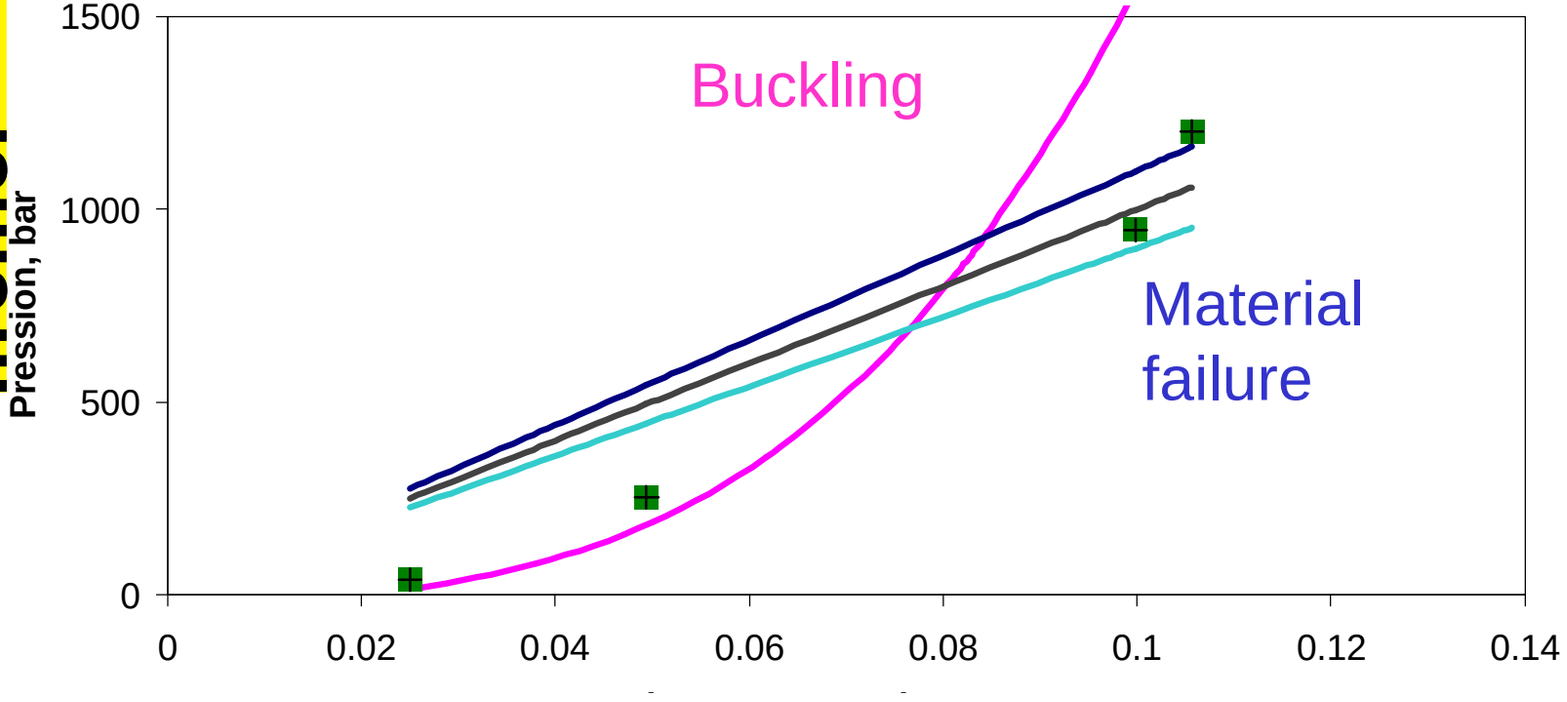


Underwater Applications

Component testing

Two failure modes, depending on t/R ratio :

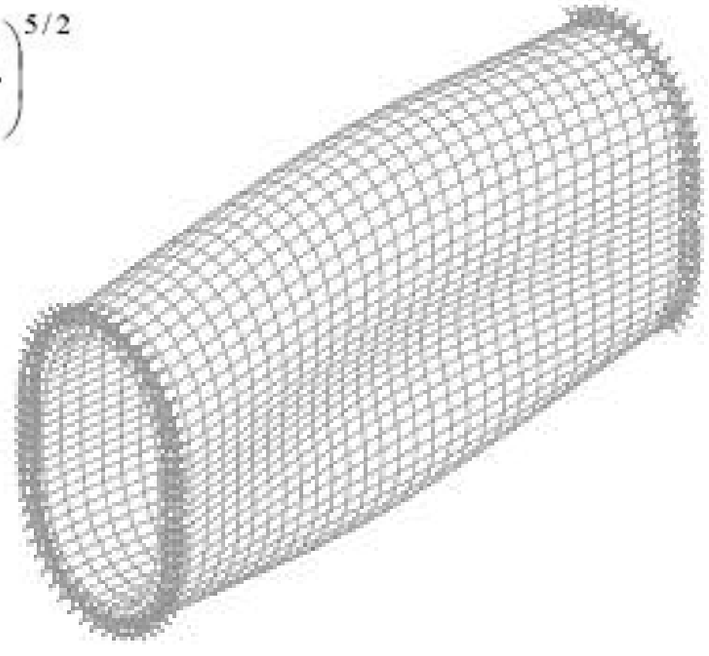
Implosion pressure, glass/epoxy ±55°



Buckling studies

Analytical expressions :

$$P_{cr} = \frac{0.807\, E_\theta}{(1 - \nu_{\theta z}\nu_{z\theta})^{3/4}} \left(\frac{r}{h}\right)\left(\frac{t}{r}\right)^{5/2}$$



FE analyses:

Imperfections:
"knock-down factors"

European Projects,
BRITE "DEVILS", EUCLID RTP3.8
MAST "AUV", "Composite Housings"

Material failure

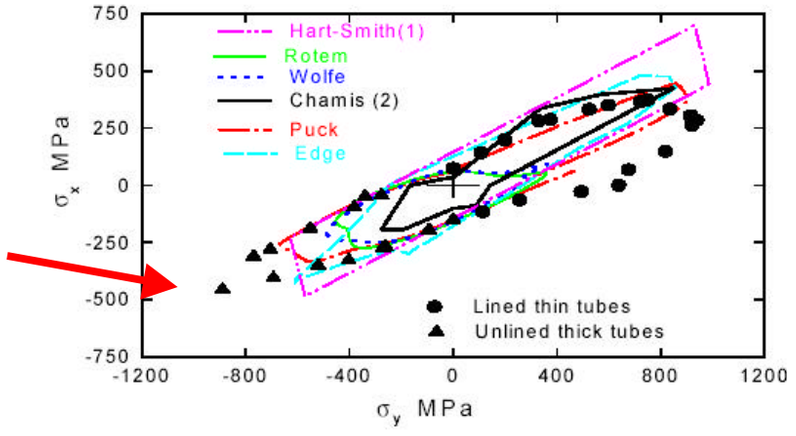


Figure 2(a) Biaxial Final Failure Envelope for ±55° GRP angle ply lay-up

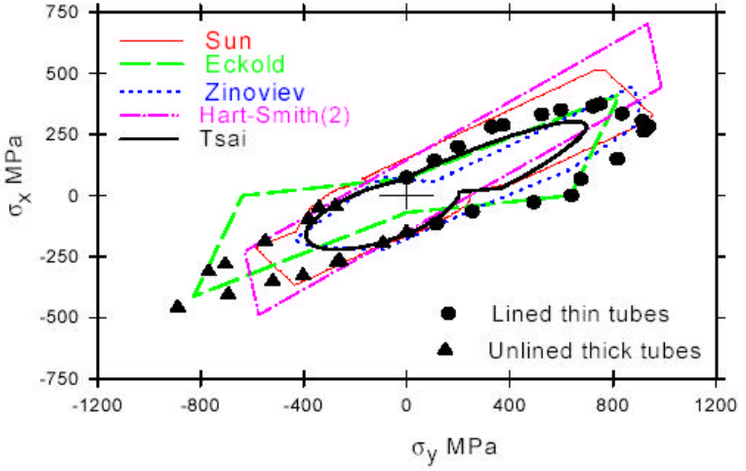


Figure 2(b) Biaxial Final Failure Envelope for ±55° GRP angle ply lay-up

Biaxial Compression WWFE

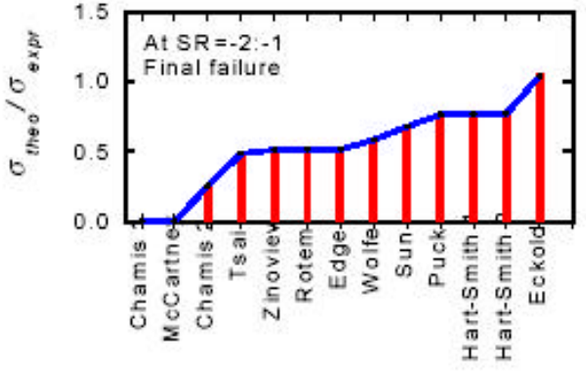


Fig 5. Bar charts showing the ratio of theoretical/experimental failure stresses for ± 55° GRP laminate under SR = -2/-1

Input data: s_{1c}, s_{2c} ?

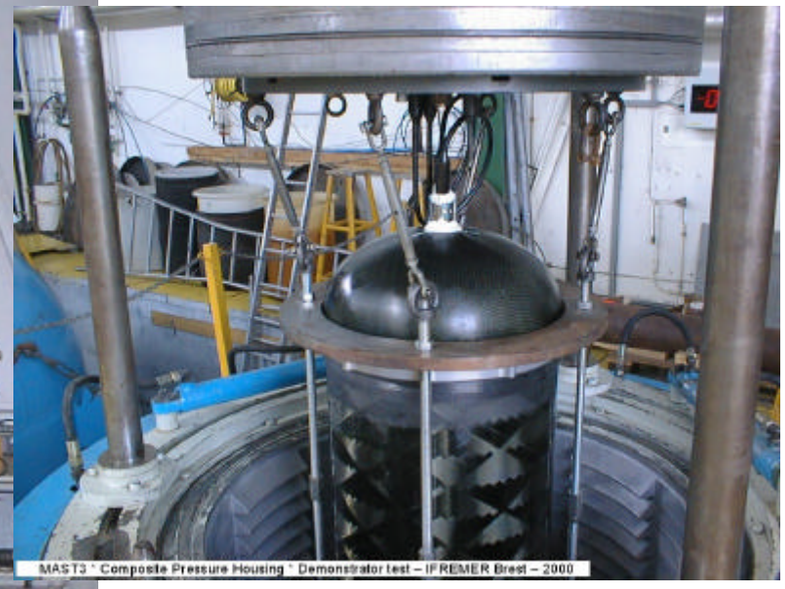
Material failure

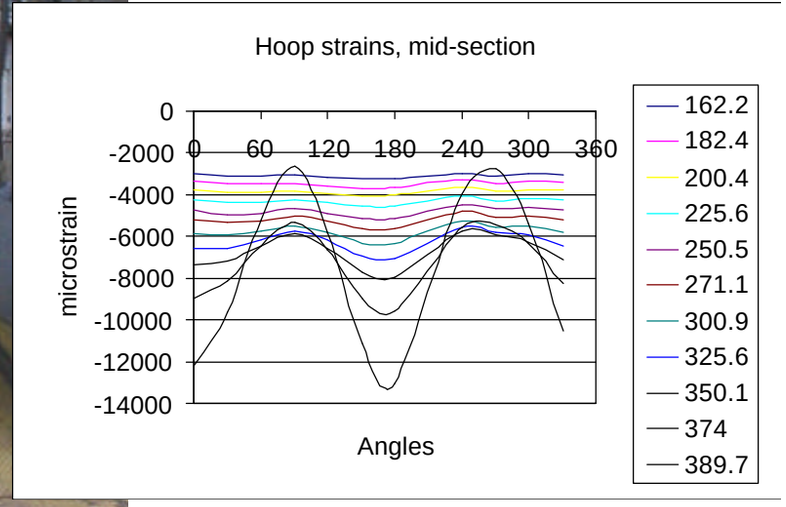
Uniaxial compression on specimens

Biaxial compression on tubes

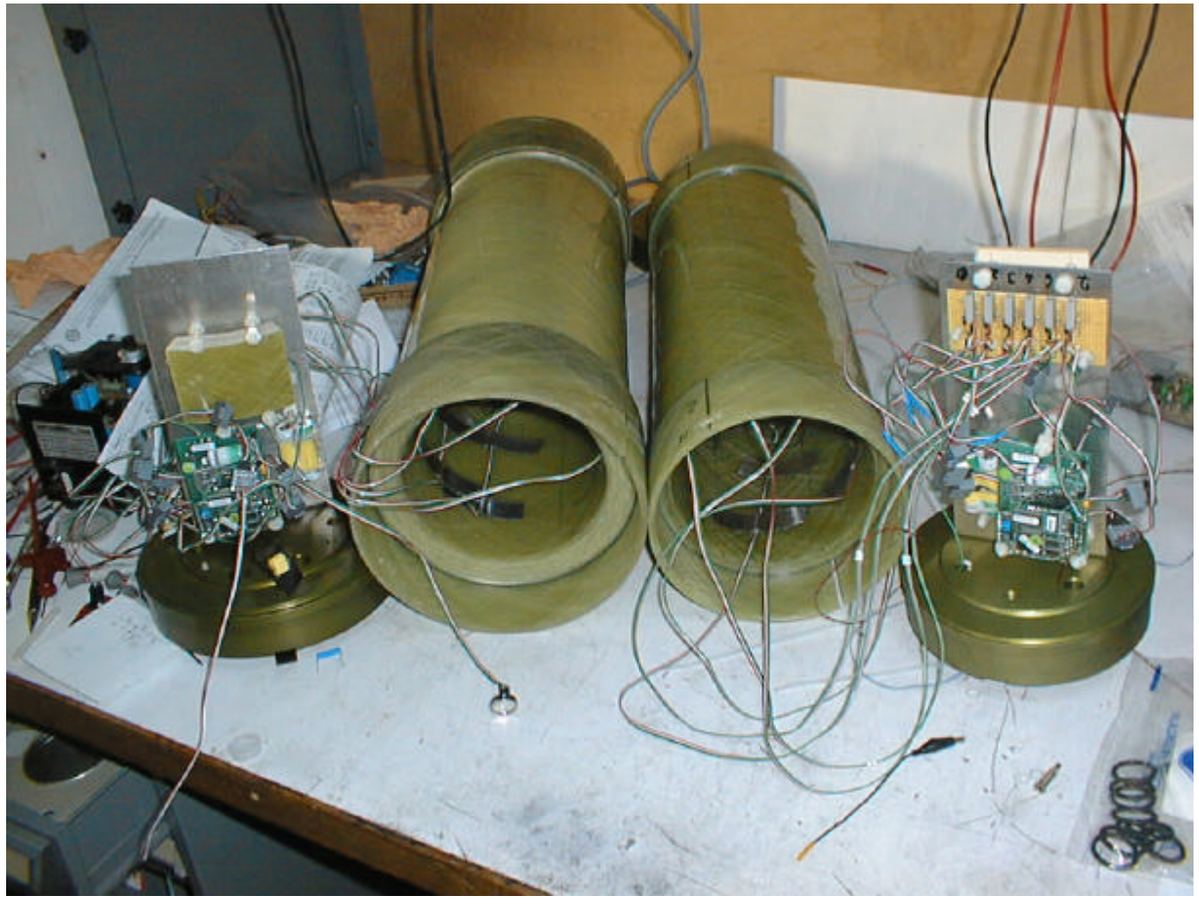
Implosion tests

MAST3 ' Composite Pressure Housing ' Demonstrator test – IFREMER Brest – 2000


MAST3 ' Composite Pressure Housing ' Demonstrator test – IFREMER Brest – 2000

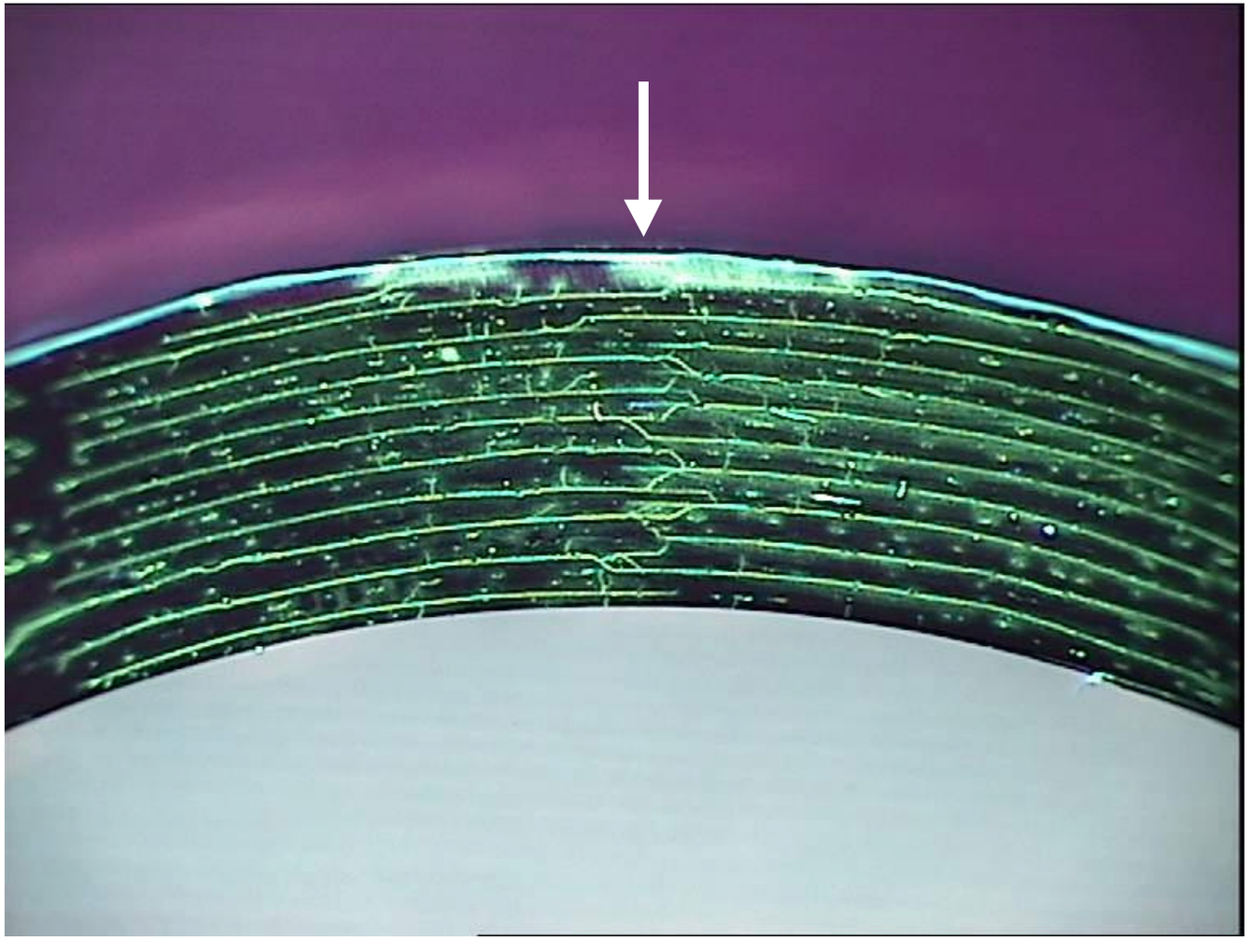


Long term behaviour: tests at sea



Biaxial compression creep tests
2500m, Mediterranean
to validate laboratory qualification

Damage tolerance



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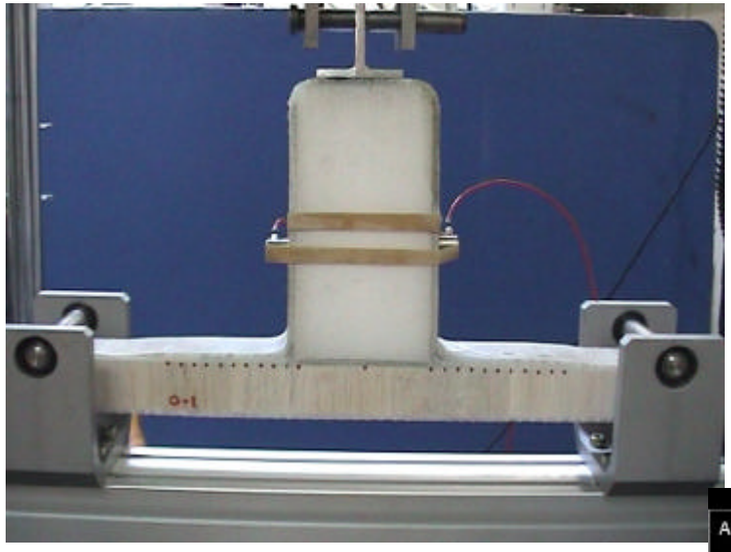
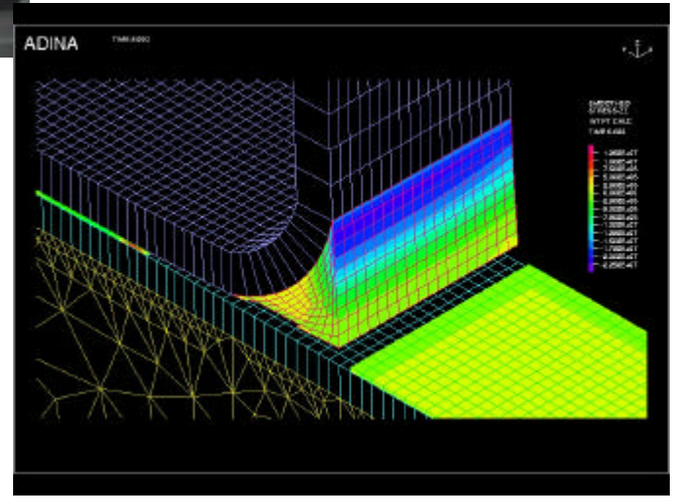
Assemblies

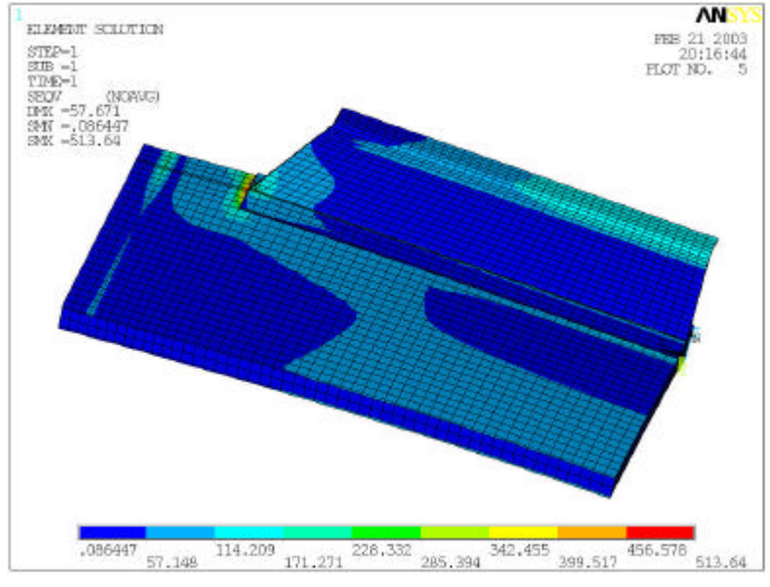
Recent experimental studies: 2-D pull-off

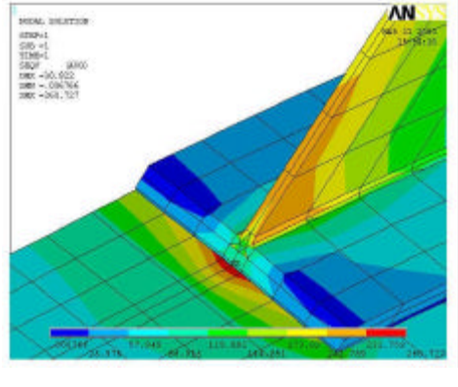




Assemblies

Recent experimental studies: 3-D





High rate testing of adhesive joints

Acknowledgements

Small boats:

FIN, Université Bretagne Sud

BV (Groupement National Composites Navals)

A. Roy CRITT Rochefort/ENSMA

P. Casari (Univ. Nantes)

Racing yachts:

Groupama, HDS, Incidences, Cranfield...

Offshore:

Projets CEP&M IFP, DCN, Total...

Underwater:

European projects (BRITE DEVILS, MAST AUV, Composite Housings) DERA, Univ Athènes, SOC...

Assemblies

EUCLID RTP 3.21 (DNV leader, DCN GERBAM, ….)

Adhesive bonding (ENSIETA, ENS, UBO, Multiplast, HDS)

and IFREMER colleagues Dominique Choqueuse, Benoit Bigourdan