COMPASS

COMposite super-structures for large PASsenger Ships
Partners

DBI - Danish Institute of Fire and Security Technology (lead)

Support: (non-complete list of 9 companies)

Scandlines

MAERSK

DTU Mechanical Engineering
Department of Mechanical Engineering

DTU Civil Engineering
Department of Civil Engineering

- Lightweight Structures group (Mech)
- Fire Engineering group (Civil)
- Maritime group (Mech)
Funding (2014 and 2015)

+ co-funding from DTU and DBI
Challenges

- Complicated and time demanding analysis of fire safety according to SOLAS II-2, Rule 17
- Barrier for further development and use of FRP in larger civilian vessels
- Large potential for retrofit and new-builds of ships using composites
Aims

• KOMPAS aims at making the path easier for design and retrofit of composite superstructures for larger passenger ships for
  – yards / design consultants
  – sub-suppliers
  – ship owners
  – authorities

• Adopt a standalized approach through guidelines combined with (pre-) fire proven FRP structural standard components
Work packages

WP 1: Dissimination and distribution of knowledge

WP 2: Structural design, analysis and testing

WP 3: Fire testing and analysis

WP 4: Development of Rule 17 guidelines for analysis- and testing procedures
Demonstration Ship: Princess Benedikte

<table>
<thead>
<tr>
<th>Route</th>
<th>Puttgarden-Rødby</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>RoPax</td>
</tr>
<tr>
<td>Construction year</td>
<td>1997/2003</td>
</tr>
<tr>
<td>Gross tonnage</td>
<td>14,822</td>
</tr>
<tr>
<td>Shipbuilder</td>
<td>Ørskov Staalskibs, Denmark</td>
</tr>
<tr>
<td>Flag</td>
<td>Danish</td>
</tr>
<tr>
<td>Engines</td>
<td>4 pc Mak, type 8M32 / 1 pc MAN type 6L32 / 44CR</td>
</tr>
<tr>
<td>KW</td>
<td>17,440</td>
</tr>
<tr>
<td>Length, oa</td>
<td>142 m</td>
</tr>
<tr>
<td>Breadth incl. fender</td>
<td>25.4 m</td>
</tr>
<tr>
<td>Service speed</td>
<td>18.5 kn</td>
</tr>
<tr>
<td>Length, oa</td>
<td>1 track, 118 m</td>
</tr>
<tr>
<td>Lanemeter, lorries</td>
<td>580</td>
</tr>
<tr>
<td>Lanemeter, cars</td>
<td>1,747</td>
</tr>
<tr>
<td>Car capacity</td>
<td>364</td>
</tr>
<tr>
<td>Passenger capacity</td>
<td>1,140</td>
</tr>
</tbody>
</table>
Superstructure

Retrofitting is focused on the passenger Decks
-17700 mm above the Baseline
Comparison between designs

Steel Superstructure
- Structural Analysis

Composite Superstructure
- Design
- Structural Analysis
- Effects
Superstructure retrofitting design

Geometry

**COMPASS project:**
Superstructure geometry to remain **unchanged**
Composite Superstructure Design Phase

Skin material: Epoxy resin / Glass fibers
Core material: Divinycell foam (PVC)

Composite Materials

Design Loads

Scantling Calculations

Rules for ships

High Speed Light Craft Rules
Composite Superstructure Design Phase

3D CAD Model of the Superstructure

Interior / Composite stiffeners
Structural Analysis

3D CAD Model ➔ Global Finite Element Model for both designs under development
Effects on the ship

Composite Superstructure weight: 136 tons

The effects on the stability of the ship will be calculated
Structural Analysis

Structural loads

+ 

Detailed finite element simulations

Thermal loads

Experimental testing
Testing is separated in three phases:

- Material Characterisation
- Mid-scale Testing
- Large scale testing

The tests’ specifications for the first two phases have been defined. The experimental setup is being assembled at the moment.
### Standard fire resistance tests

<table>
<thead>
<tr>
<th>Scale</th>
<th>Apparatus</th>
<th>Data obtained</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matter Scale</td>
<td>TG Analyzer, ...</td>
<td>Chemical</td>
<td></td>
</tr>
<tr>
<td>Material Scale</td>
<td>Cone Calorimeter, ...</td>
<td>Ignitability, heat release rate, smoke production</td>
<td>Not truly fire resistance test</td>
</tr>
<tr>
<td>Products Scale</td>
<td>ISO 21367, ...</td>
<td>Heat release rate, ignitability, surface spread of a flame, falling droplets/particles and smoke production</td>
<td></td>
</tr>
<tr>
<td>Large Scale</td>
<td>Furnace</td>
<td>Fire resistance (with time-temperature curve ISO 834 and mechanical loads)</td>
<td>Time, High cost, Repeatability</td>
</tr>
</tbody>
</table>

Could be replace by by avoiding H-TRIS
H-TRIS: Heat Transfer Rate Inducing System

Thermal loading
How to replicate the thermal conditions of the furnace test?
With a mobile array of gas-fired high performance radiant heaters, along with a mechanical linear motion system and/or a high precision controller for the heat flux.

Mechanical loading
How to replicate mechanical stresses experienced by structural elements or assemblies?
With a custom designed mechanical loading frame.

Results (from C. Maluk et al., Dec. 2012, SFPE Hong Kong.)

Comparison of concrete specimens’ internal temperatures recorded in a furnace as compared against H-TRIS test results.

Finally:
H-TRIS can replicate the thermal conditions of the furnace test and the mechanical stresses With as benefits:
• Low cost, easy and quickly to conduct
• Greater repeatability
Aim of the burner calibration:

- To verify the homogeneity of the flux at the target panel
- To know the position/heat flux of the burner in order to have the required flux at the target panel
- To know the time of stabilization during a change of intensity of the burner heat flux or during the change of position of the burner

Experimental device for the calibration of the burner
Calibration of the burner

Verification of the homogeneity of the flux at the target panel -
Position of heat flux gauges

Calibration panel

Position of the burner

Heat flux gauge

Heat flux gauge of reference (0,0)
Calibration of the burner

the position/ heat flux of the burner in order to have the required flux at the target panel – Results (50% of max burner intensity)

Calibration of the burner
the position/ heat flux of the burner in order to have the required flux at the target panel – Results (50% of max burner intensity)
**Philosophy A:** Staying as close as possible to the prescriptive regulations by making conservative equivalences in terms of passive protection compared to an equivalent prescriptive design (Eco-Island ferry).
- **Pros:** Fairly straightforward, also testing-wise
- **Cons:** Faces the “non-combustibility” challenge (i.e. direct comparison with steel)

**Philosophy B:** Adapting the protection to the level of risk in a given compartment, combining both active and passive protection (MP08 project).
- **Pros:** Freedom of design
- **Cons:** Requires more engineering to begin with
APPLICATION OF REGULATION 17 OF CH. II-2 OF THE SOLAS CONVENTION

**Qualitative Analysis**
- Description of the Prescriptive Design
- Description of the Alternative Design
- Composition of the Design Team
- Fire hazard identification
- Selection of fire scenarios

**Main Difference between philosophy A and B**

**Quantitative Analysis**
- Estimation of fire Risk on Prescriptive Design ($R_{PD}$)
- Estimation of fire Risk on Alternative Design ($R_{AD}$)
- Comparison of Risks

IF $R_{AD} > R_{PD}$
Immediate actions

• Test relevant composite materials
  – Does anybody want to partner with us?
• Increased interaction between FEM results and Fire test results
• Continued work on method for application of Rule 17
We invite any interested companies and partners to make contact with the group throughout the project to share input and results.