Development of lightweight structures in BESST

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Development of Steel-Composite solutions

Three Application cases

Application case No 1
“Deck structure above of Deck 11 of Norwegian GEM”. (MW)

Application case No 2
“Emergency generator housing on a RO-Pax Ferry “(FSG)

Application case No 3
“Integration of Composite Superstructure Module in Steel Shipyard Environment” (DSNS)
Development of joint system between Steel and FRP sandwich structure

Web connection with fixed ends

Web connection with sniped ends
Development of joint system between Steel and FRP sandwich structure

- Temperature impact at welding of a steel/composite joint
- Development of bonding system between steel-composite
- FEM analysis of interface between steel and composite performed
- Ageing testing of the sill system
- Fatigue testing of the sill system
“Adhesively bonded steel/composite joint”

Combined spacer and mechanical locking device

Composite panel
Fatigue testing of the steel/composite joint

Fatigue failure in the steel after 1.8 million load cycles at 100kN
No damages in the steel/composite interface
When a single frequency is input to the material, the same frequency is measured when the material is undamaged. When the material is damaged higher harmonics are created and can be measured.
Ageing tests in high humidity

Mechanical testing of adhesive joints

- Test conditions
  - 160 kN hydraulic press
  - Force and displacement from press continuously recorded 5 times/second
  - Load applied at 1100/885 mm distance from support (885 mm for Syl3 specimens)
  - Load is applied at a rate of 10 mm/minute
  - Load is applied as a pushing force onto the edge of the sample
  - Conditioning at high humidity, 50°C for 120 hours, circulating water

Conditioned samples are placed on a net in a box with circulating water underneath the net. A lid is placed on top to increase humidity.
Application Case No 1 “Mock-up of a balcony structure of a cruising vessel”

Deck demonstrator will be used for load bearing fire test

Exterior flame spread tested with a separate panel
Fire tests, outside fire, Application case No 1

Drencher and external flame spread test

Ignition

Activation (~5 min)

Controlled (~7 min)
Fire tests, outside fire, Application case No 1

Water application system

<table>
<thead>
<tr>
<th>Test</th>
<th>Design discharge density (mm/min)</th>
<th>Design flow rate (L/min)*</th>
<th>Total water flow rate (L/min)**</th>
<th>Collected flow rate (L/min)</th>
<th>Actual measured discharge density (mm/min)***</th>
<th>Percentage of water reaching the vertical surface (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>48</td>
<td>60</td>
<td>31.8</td>
<td>1.32</td>
<td>66%</td>
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<tr>
<td>1</td>
<td>3</td>
<td>72</td>
<td>90</td>
<td>34.7</td>
<td>1.45</td>
<td>48%</td>
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<tr>
<td>5</td>
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<td>72</td>
<td>90</td>
<td>42.5</td>
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<tr>
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<td>96</td>
<td>120</td>
<td>57.3</td>
<td>2.39</td>
<td>60%</td>
</tr>
</tbody>
</table>
Fasade tests

Results – Comparison 3 mm/min of water vs. non-combustible

![Graph showing comparison of HRR against time for free burning and 3 mm materials.](image)
Fasade tests
Results – Comparison pre-activated drencher vs. non-combustible
Fire tests, outside fire, new treatment of fibre and resin systems

LEO – No drencher activation

Fully developed

Fuel pan burn-out

Self-extinguished
Outside fire-Fasad tests

Results – Comparison LEO vs. non-combustible

~500 kW
Outside Fire, New Structural concept

Fire test of two types of triple sandwich for outside fire (FRD 60)

- Triple sandwich with Balsa core (passed)
- Triple sandwich with PVC core, Glass core (failed)

- Centre Foam Glass 280°C
- 130°C Centre balsa
- None exposed side 40°C
- 60 minutes
Several ideas and solution for outfitting and penetrations were realised and tested.

Successful fire test on developed solutions
Fire test Application case No 2

Fire test on metal sandwich structure from building industry equipped with pipe penetrations and an approved A-60 door. The A60 approved door may have failed due to ignition of the rubber seal caused by the low heat transfer of the sandwich structure.
Steel / composite joint that can be used in traditional steel shipyards conditions in full scale production.
Lessons Learned from BESST and Ro-pax project

- Realistic fire tests which have been performed must convince Administrations with low or none experience of light weight structures if they are well informed in advance of a project (Administrations must be on the train from start of a new project!)

- Continues work to establish Classification Rules is a kea-factor for success

- Ship owners that can see the benefits of lower fuel costs, greening profile and lower life cycle costs with lightweight structures must put pressure on IMO to establish Classification Rules

- Methodology of Risk based Analysis when combustible materials according to Rule 17 shall be used must be harmonized and known by the Administrations!!