Fire-Resist
Marine application case

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Contents

- Who, Where and What we do;
- Fire-Resist EU project summary;
- Fire-Resist marine application fire test results.

Who and Where

- **NewRail** www.newrail.org:
  - Based in Newcastle University
  - Rail Vehicle group
  - Rail Freight and Logistic group
  - Rail Infrastructure
  - Rail Systems
  - Rail Education
  - Rail Strategy Group

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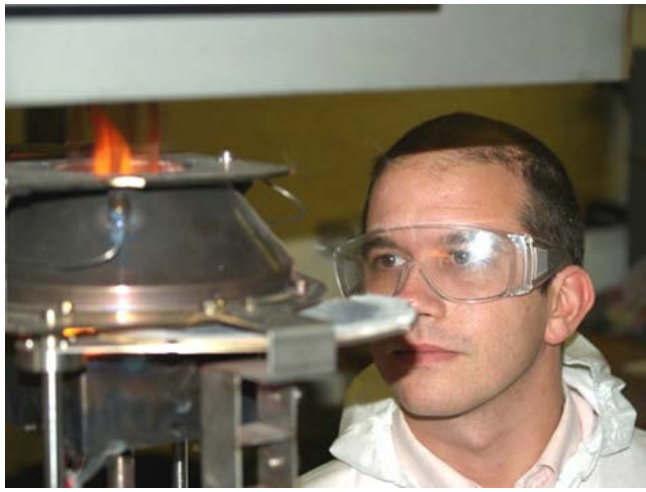
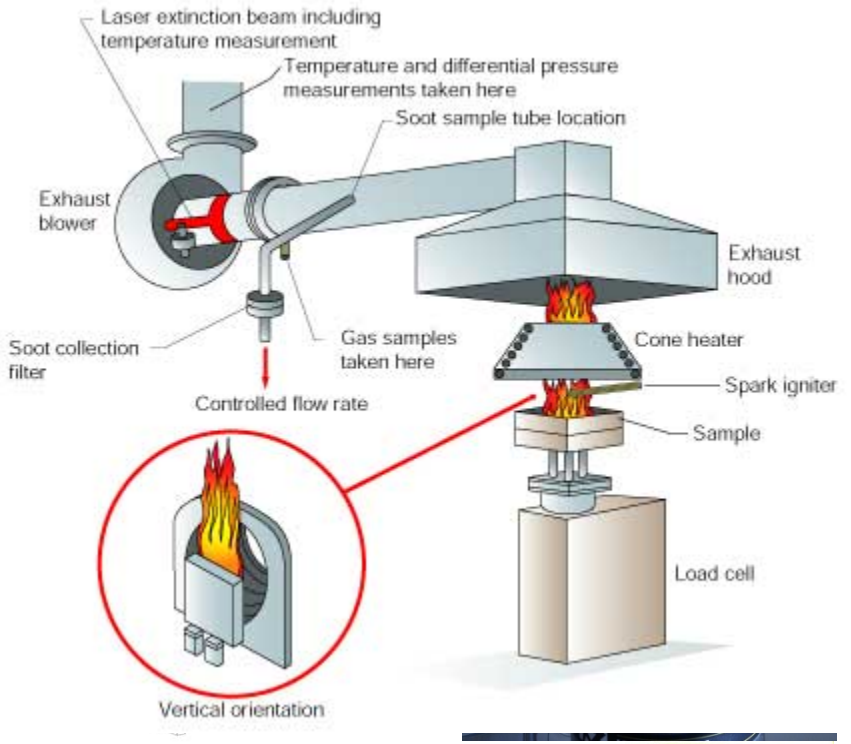
Testing capabilities

- **NEWRAIL**
  - **Fire-reaction**





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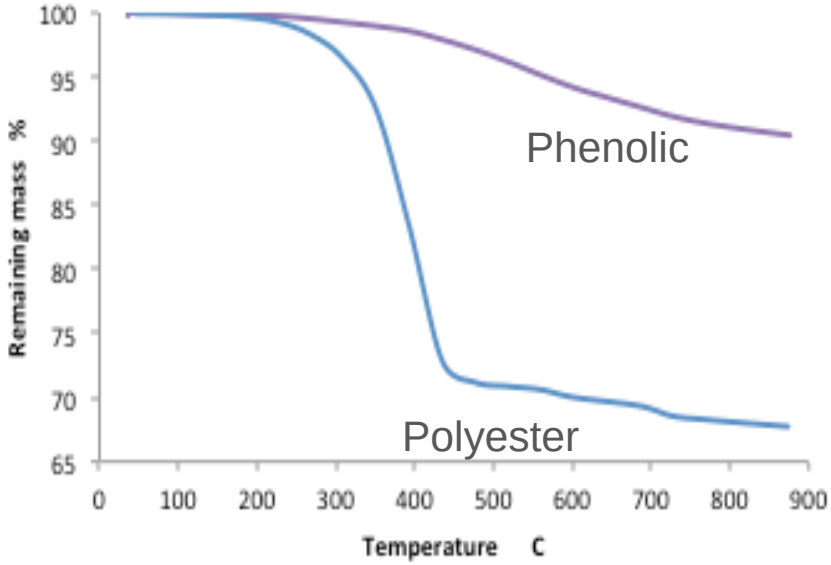
Testing capabilities

- **NEWRAIL**
  - **Fire-reaction**
  - **Thermal-degradation**



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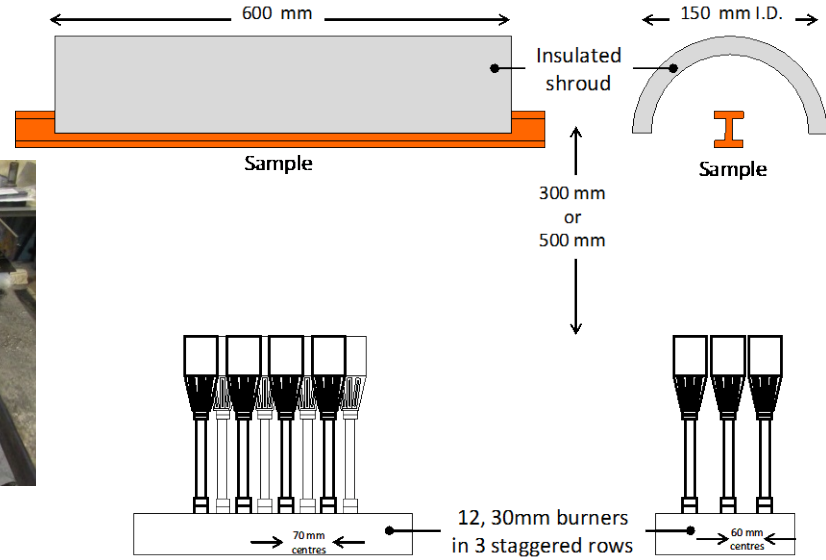
Testing capabilities

- **NEWRAIL**
  - Fire-reaction
  - Thermal-degradation
  - Fire-resistance (Fire tests under load)



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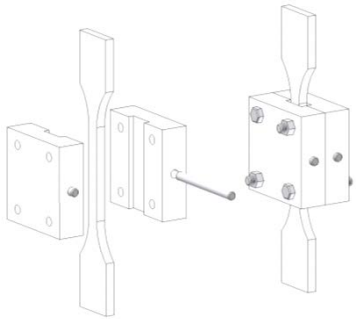
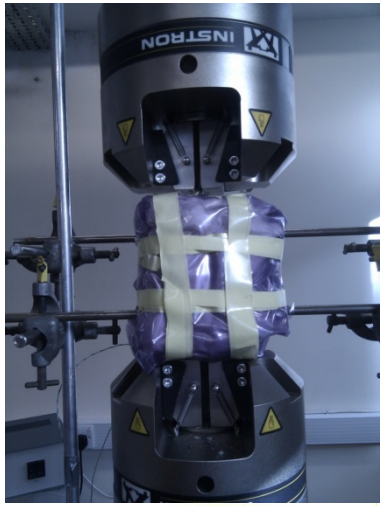
Testing capabilities

- **NEWRAIL**
  - Fire-reaction
  - Thermal-degradation
  - Fire-resistance (Fire tests under load)
  - Mechanical tests
  - Mechanical tests at high temperatures
  - Thermal properties measurements





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FIRE-RESIST

Fire-Resist
A collaborative approach

- The rationale behind the FIRE-RESIST project was to bring together:
  - Vehicle/vessel manufacturers from the rail, aerospace and maritime industries.
  - Industry certification bodies.
  - Suppliers of fire-resistant composite materials.
  - Producers of composite mouldings.
  - Developers of new composite materials and processes.
  - Specialists in fire testing.
  - Specialists in fire simulation.
  - Specialists in managing the risk of new product development and introduction.

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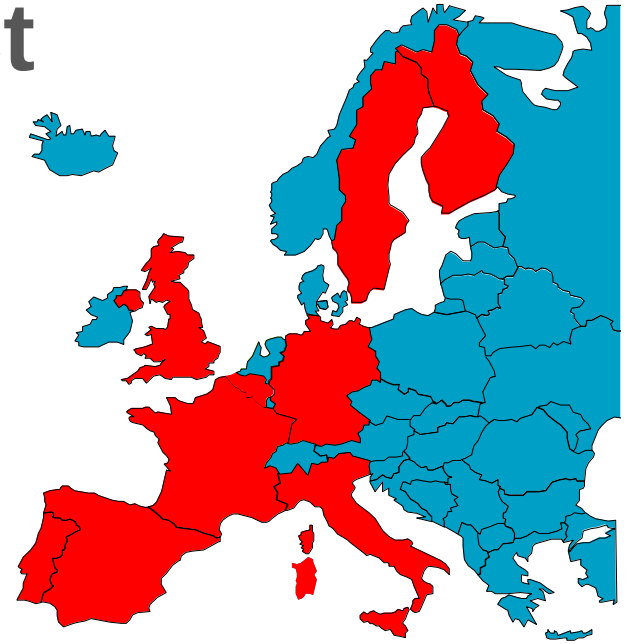
FIRE-RESIST

The FIRE-RESIST project

- 4 year project commenced February 2011- January 2015.
- 18 partners from 9 European countries.
- Remit:
  - To develop new concepts for composite materials that are both lightweight and fire-resisting.
  - To develop multi-scale approaches to simulating the fire behaviour of composite materials.
  - To validate the performance of the FIRE-RESIST materials through the design, manufacturing and testing of industrial case study components.



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FLENSBURGER SCHIFFBAU-GESELLSCHAFT
AP&M
APC Composite
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proplast PLASTICS INNOVATION POLE
GAIKER
INSA LYON
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FIRE-RESIST
swerea SICOMP
SEVENTH FRAMEWORK PROGRAMME
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VTT
CYTEC
tfc
AMORIM
Amorim Cork Composites
BIOMASS BASED CHEMICALS
BALance Technology Consulting
Steinbeis Advanced Risk Technologies
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FIRE-RESIST

The approach

Fundamental Materials Development

- Structural Surface Laminates
- High Char-forming Composites
- High char-forming bio-composites
- Particle-doped Commingled Composites

Formulate – Characterise – Model – Scale-up – Cost

Modelling

- Advanced Multi-scale Simulation

•Materials under normal operating conditions.
•Material decomposition due to fire.
•Degradation of mechanical properties due to fire.
•Evolution of smoke and toxic products.

Apply and Evaluate Materials Technologies

- Aeronautic Application(s)
- Rail Application(s)
- Maritime Application(s)

Innovation Risk Management and Life Cycle Studies

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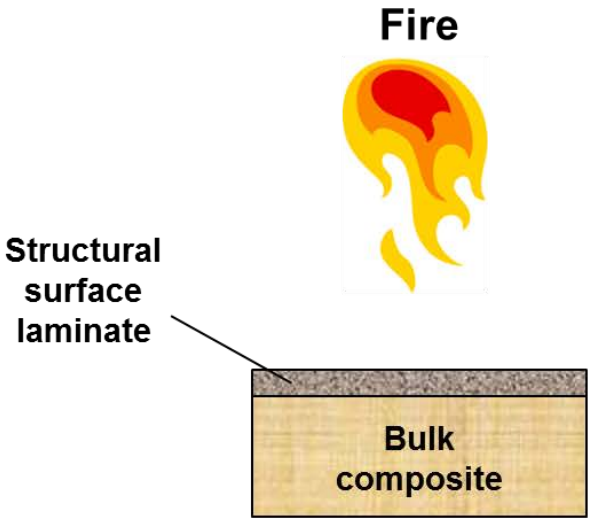
New material developments 1: structural surface laminates



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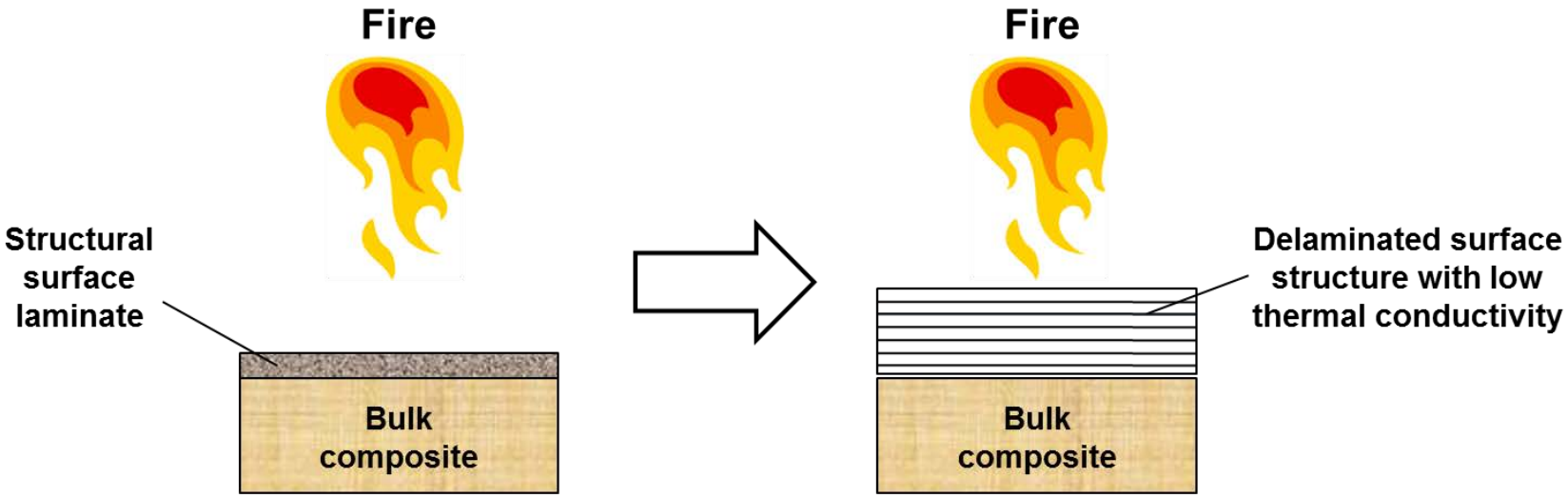
New material developments 1: structural surface laminates



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New material developments 2/3: high char-forming composites

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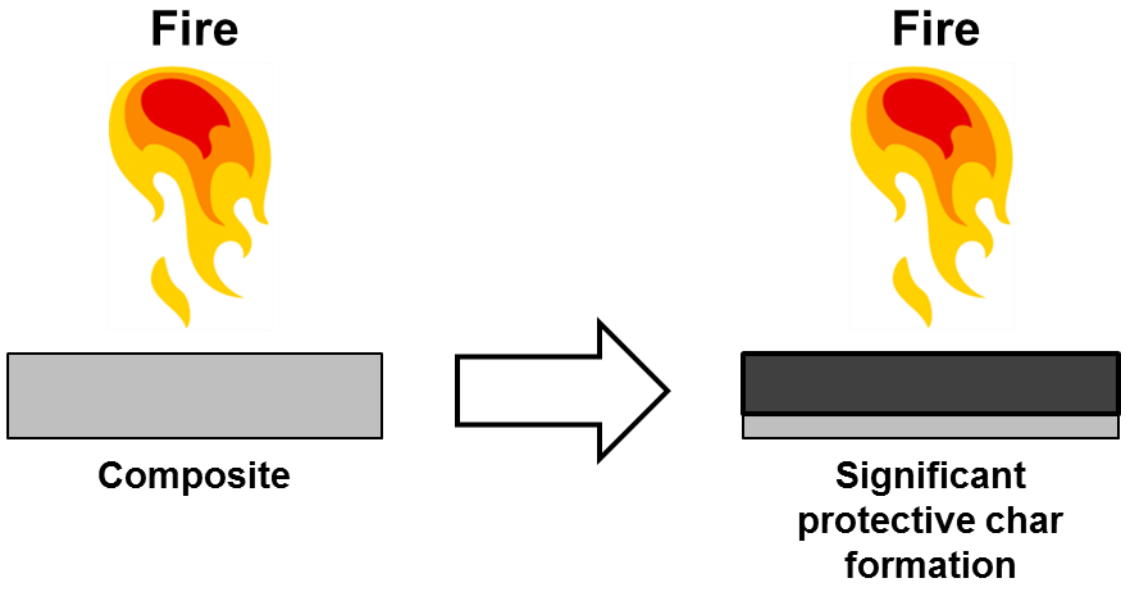
FIRE-RESIST

New material developments 2/3: high char-forming composites



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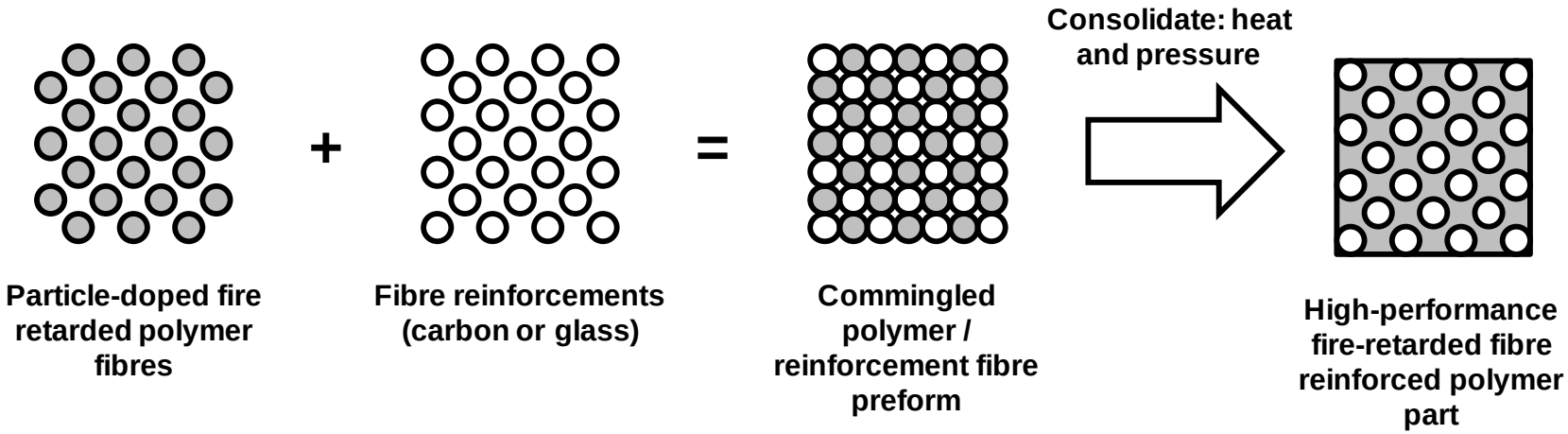
New material developments 4: particle-doped commingled composites



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Multi-scale fire simulation

Detailed Material Level Modelling

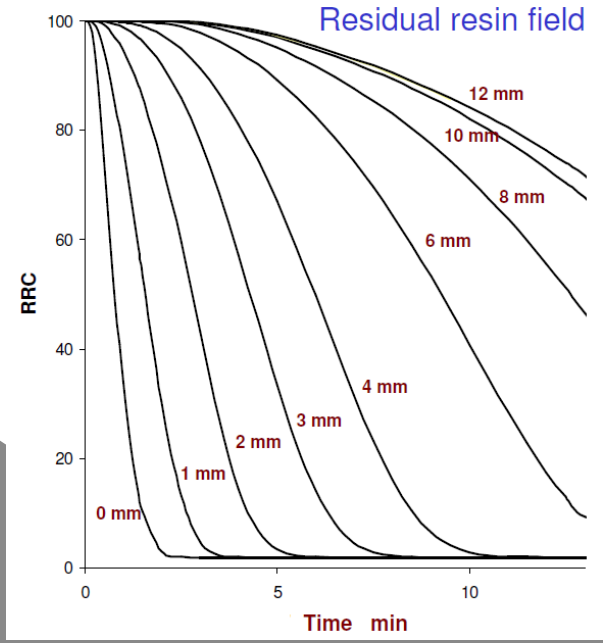
- *Temperature vs. Time.*
- *Residual resin content.*
- *Degradation of mechanical properties.*

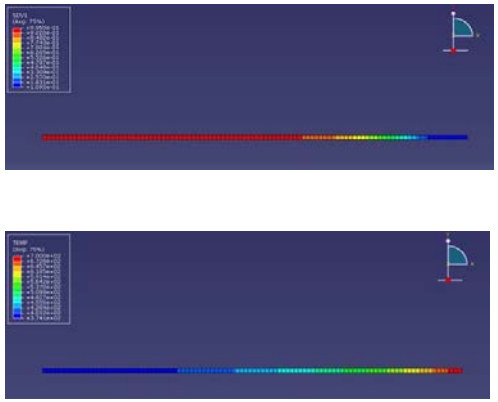
Structural Finite Element Analysis

- *Structural response:*
  - *Deformation under load.*
  - *Structural failure prediction.*

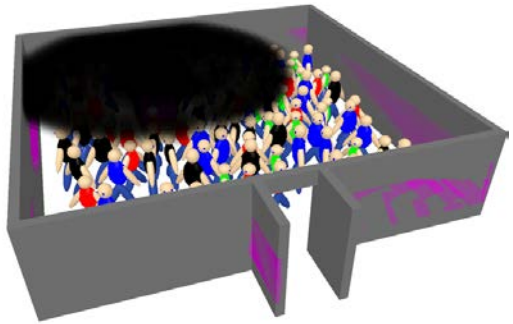
Computational Fluid Dynamics

- *Fire dynamics:*
  - *Heat release.*
  - *Flame spread.*
  - *Smoke / toxic gases.*





Courtesy of Swerea SICOMP



Courtesy of VTT

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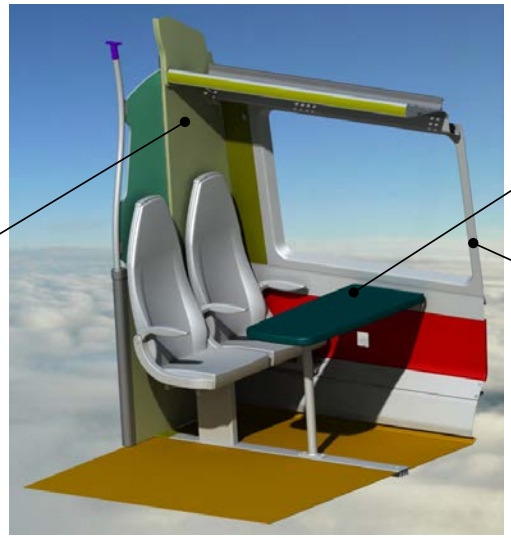
Validation through case studies

Sandwich material samples



Rail vehicle interior protype CAD model.

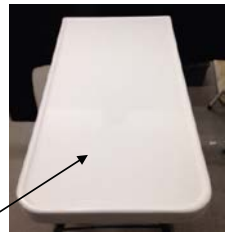


Table top

Draft screen

Window pan

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Maritime demonstrator

FIRE-RESIST

Composite Ropax superstructure

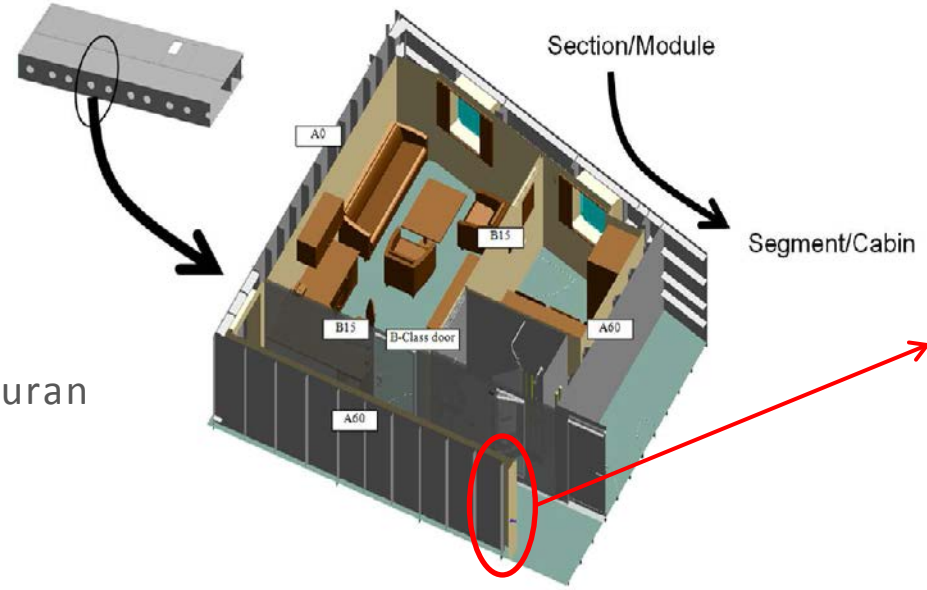
Replacing A60 bulkhead with FRP design.

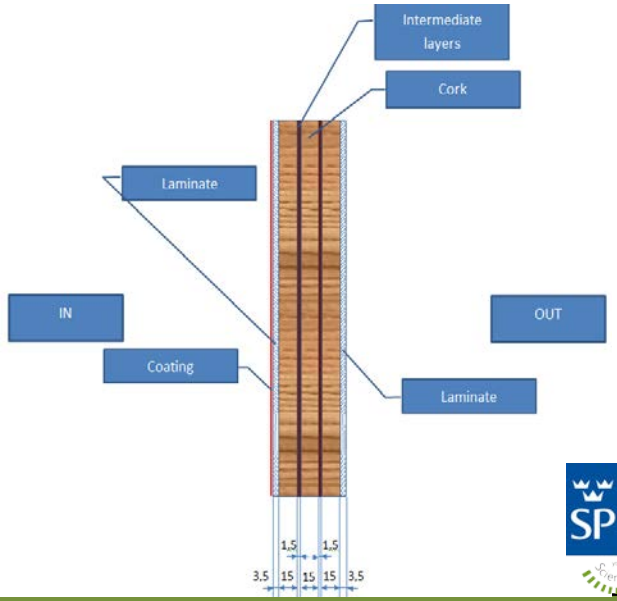
Candidate bulkhead:

- Triple cork core sandwich with furan laminates
- Intumescent coating on internal surface

Ambition: Equivalent safety compared to A60 steel design.

Requirements/performance indicators determined on FMEA-workshop led by DNV-GL at a workshop in Alessandria in September 2014.



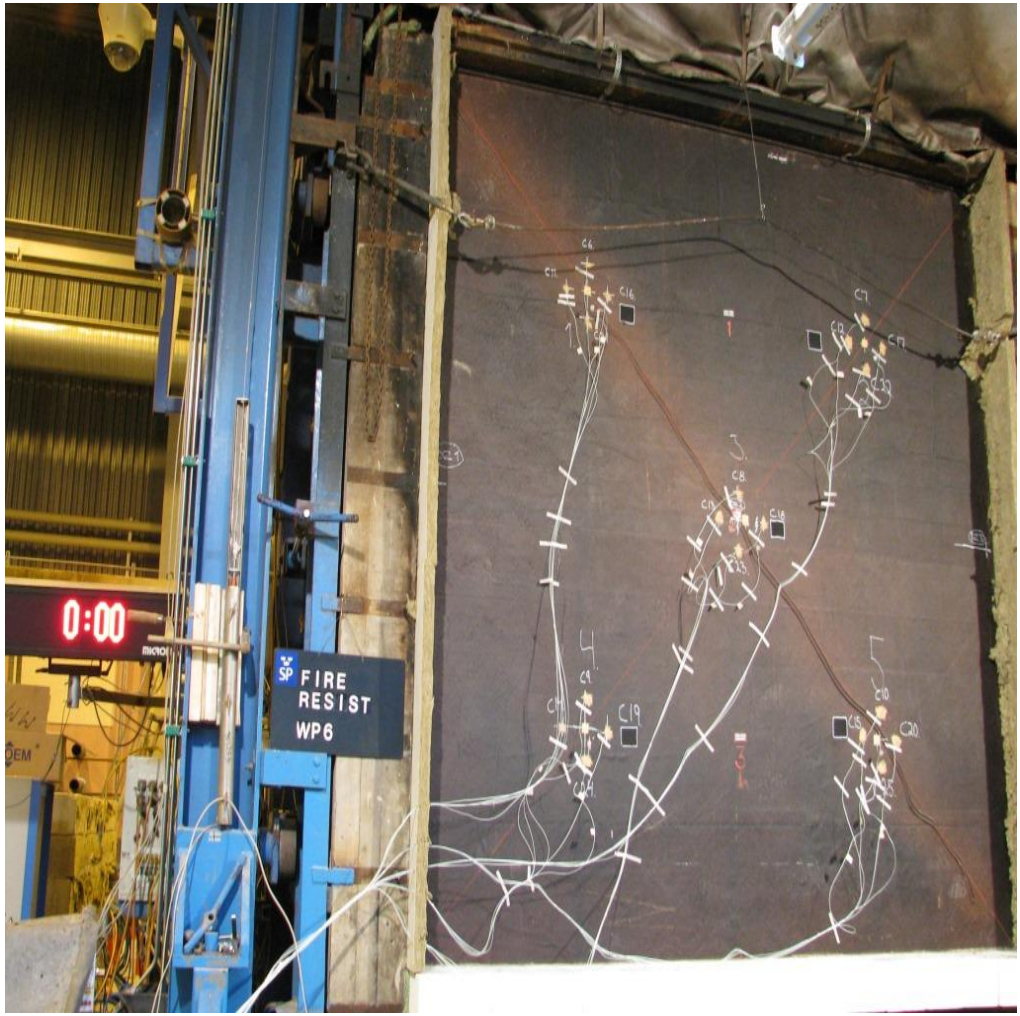


Maritime demonstrator – Fire resistance, large scale

Requirements

FRD60 according to Part 11 in the FTP-code:

- Load bearing capacity; 7 kN/m vertical load for 60 minutes
- Insulation, after 60 minutes;
  - Average temperature rise on unexposed surface < 140 ° C
  - Individual temperature rise on unexposed surface < 180 ° C
- Integrity, for 60 minutes;
  - No flaming on the unexposed face
  - No ignition of the cotton-wool pad
  - It shall not be possible to enter the gap gauges into any opening in the specimen



Maritime demonstrator – Fire resistance, large scale

FIRE-RESIST

Results

FRD60 according to Part 11 in the FTP-code:

- Load bearing capacity; 7 kN/m vertical load for 77 minutes (60 minutes requirement)
- Insulation, after 60 minutes;
  - Average temperature rise on unexposed surface 5 ° C (< 140 ° C requirement)
  - Individual temperature rise on unexposed surface 6 ° C (< 180 ° C requirement)
- Integrity, was maintained until the load bearing capacity was lost after 77 minutes

Maritime demonstrator – Fire resistance, reduced scale

FIRE-RESIST

Correlations full vs reduced scale

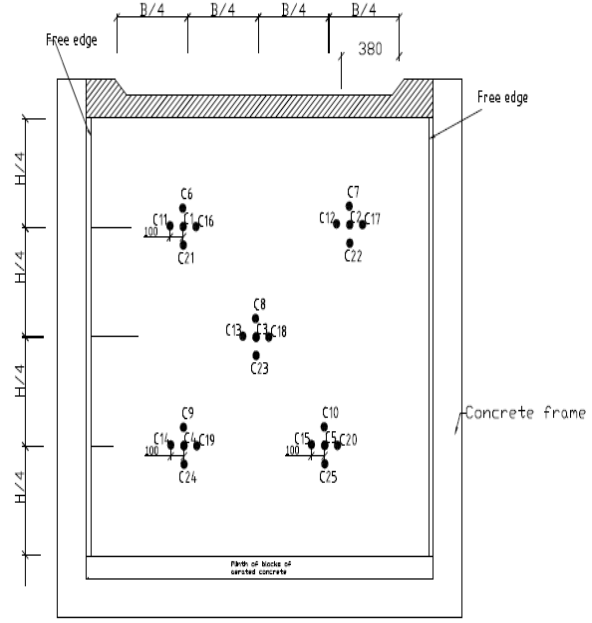
Full scale specimen: 3000x3000 mm

Reduced scale specimen: 600x500 mm

Full scale vertically mounted

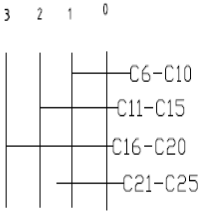
Reduced scale horizontally mounted

Temperature measured on unexposed side of each laminate in multiple positions, average temperature on each laminate compared.

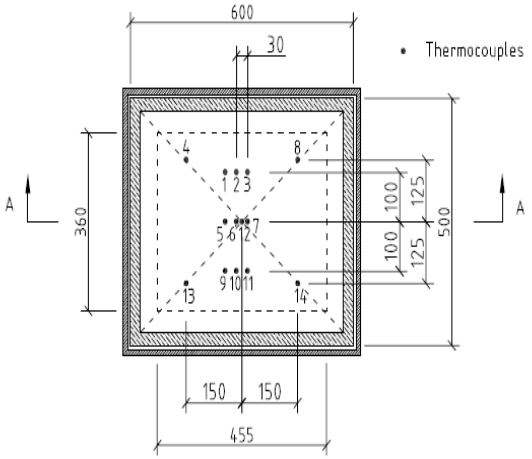


Internal thermocouples

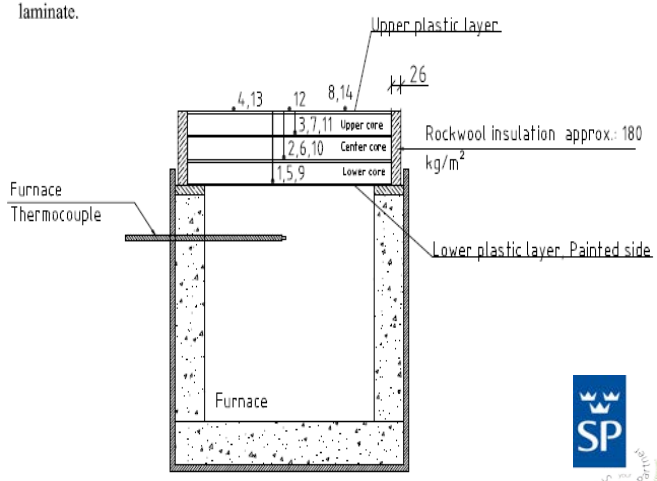
- C6–C10 Placed inside the stuctural core, close to the laminate in the first layer of the structural core
- C11–C15 Placed inside the stuctural core, close to the laminate in the second layer of the structural core
- C16–C20 Placed inside the stuctural core, close to the laminate in the third layer of the structural core
- C21–C25 Placed inside the stuctural core, in the middle of the second layer of cork.



Full scale test



TC 1, 5, 9 are drilled down to measure above the lower plastic laminate.
TC 2, 6, 10 are drilled down to measure above the second plastic laminate.
TC 3, 7, 11 are drilled down to measure above the third plastic laminate.
TC 4, 8, 12, 13 and 14 are standard surface temperature thermocouples on the upper plastic laminate.



Reduced scale test

Maritime demonstrator – Fire resistance, reduced scale

FIRE-RESIST

Correlations full vs reduced scale

Full scale specimen: 3000x3000 mm

Reduced scale specimen: 600x500 mm

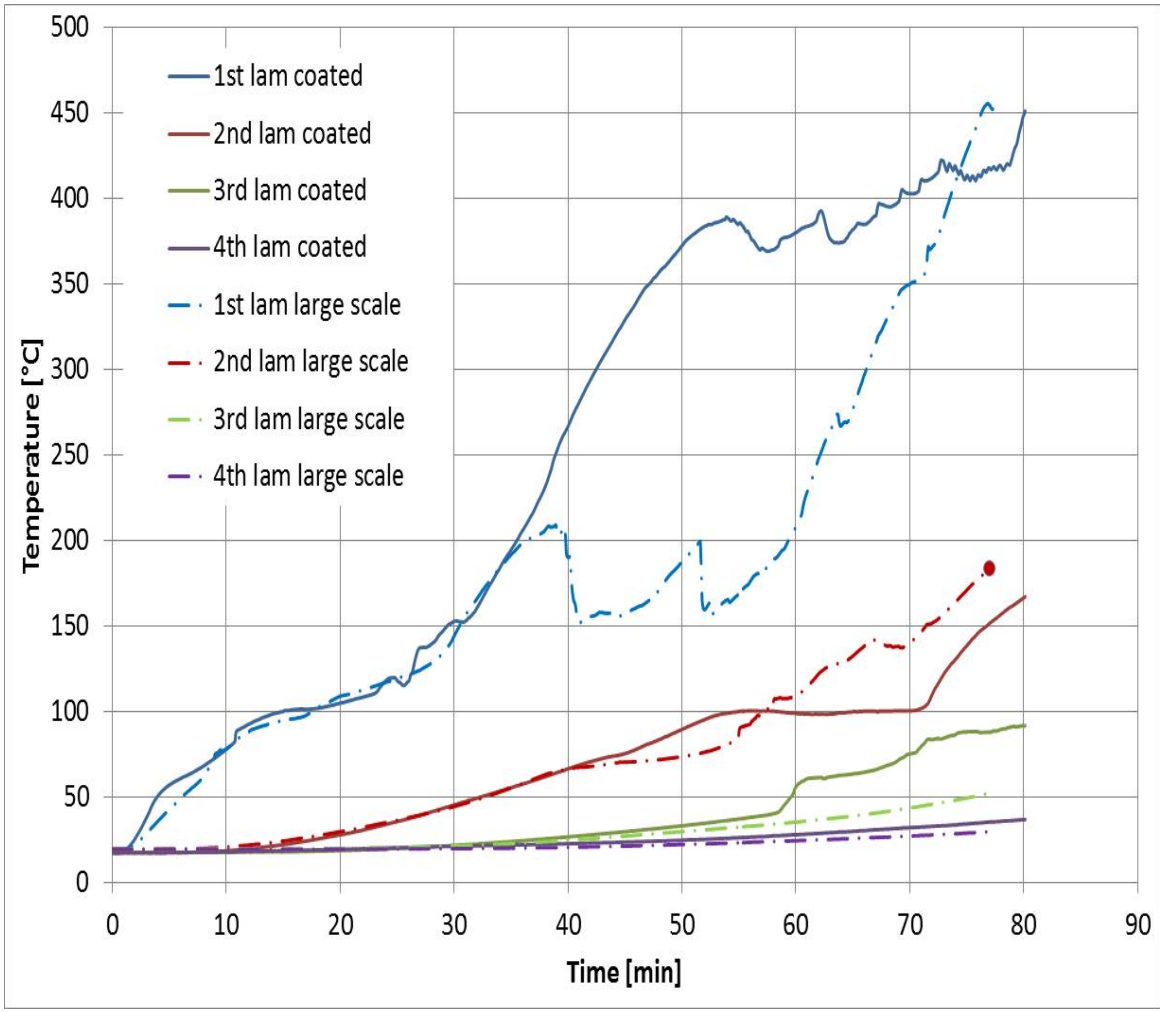
Full scale vertically mounted

Reduced scale horizontally mounted

Temperature measured on unexposed side of each laminate in multiple positions, average temperature on each laminate compared.

In general quite good correlation!

Collapse occurs when the second laminate reached approximately 175 °C. This correlates quite well with previous experience where traditional sandwiches with two polyester laminates collapses at about 150 °C.



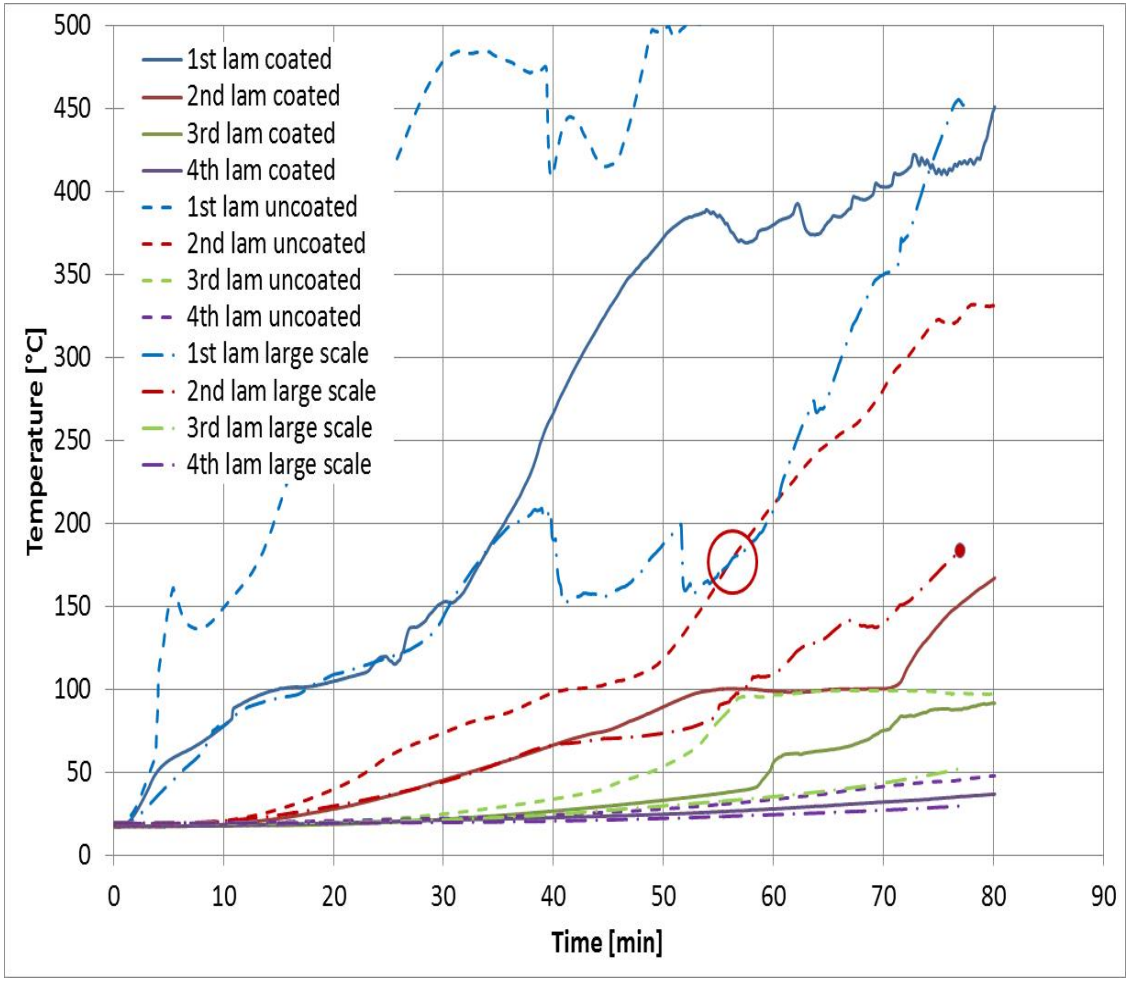
Maritime demonstrator – Fire resistance, reduced scale

FIRE-RESIST

Comparison with and without intumescent paint

An additional small scale test without intumescent paint was performed.

If the assumption is correct that the load carrying capacity is lost when the second laminate reaches 170-180 °C approximately 50 – 60 minutes of fire resistance can be expected from a non-coated sandwich.



Maritime demonstrator – Reaction to fire

Requirements

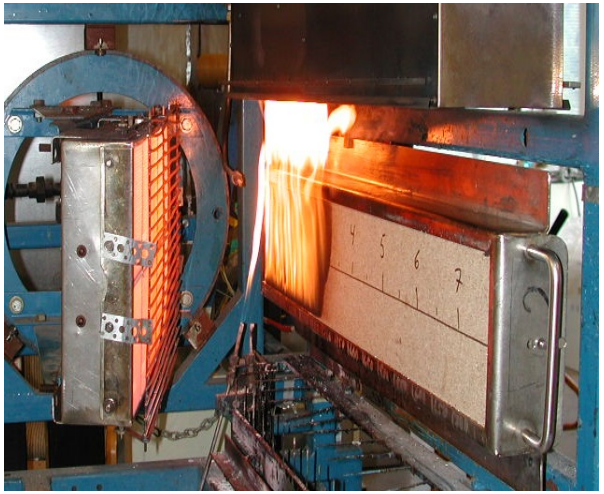
Low flame spread characteristics according to Part 2 and Part 5 in the FTP-code.

Part 5 criteria:

- CFE, critical flux at extinguishment: ≥ 20.0 kW/m²
- Qsb, average heat for sustained burning: ≥ 1.5 MJ/m²
- Qt, total heat release: ≤ 0.7 (0.2*) MJ
- Qp, peak heat release rate: ≤ 4.0 (1.0*) kW

*If values within brackets are reached the product is considered to comply with Part 2 without further testing.

The demonstrator with coating reaches low flame spread characteristics without further testing.



With coating Test no	1	2	3	Average	Surface flammability criteria
Heat for ignition, MJ/m²	-*	-*	-*	-*	—
Q_{sb}, MJ/m²	-**	-**	-**	-**	≥ 1.5
CFE, kW/m²	48.4	48.4	48.4	48.4	≥ 20.0
Q_t, MJ	< 0.1	< 0.1	< 0.1	< 0.1	≤ 0.7
Q_p, kW	< 0.1	< 0.1	< 0.1	< 0.1	≤ 4.0

* Not calculated (extent of burn < 150 mm).
** Not calculated (extent of burn < 175 mm).

Maritime demonstrator – Reaction to fire

Requirements

Low flame spread characteristics according to Part 2 and Part 5 in the FTP-code.

Part 5 criteria:

- CFE, critical flux at extinguishment: ≥ 20.0 kW/m^2
- Qsb, average heat for sustained burning: ≥ 1.5 MJ/m^2
- Qt, total heat release: ≤ 0.7 (0.2*) MJ
- Qp, peak heat release rate: ≤ 4.0 (1.0*) kW

*If values within brackets are reached the product is considered to comply with Part 2 without further testing.

The demonstrator without coating does not reach the criteria for low flame spread characteristics.

Without coating Test no	1	2	3	Average*	Surface flammability criteria
Heat for ignition, MJ/m^2	4.40	3.50	-	4.0	—
Q_{sb}, MJ/m^2	4.40	3.70	-	4.1	≥ 1.5
CFE, kW/m^2	12.4	16.5	-	14.5	≥ 20.0
Q_t, MJ	0.70	0.70	-	0.7	≤ 0.7
Q_p, kW	6.3	3.9	-	5.1	≤ 4.0

* Average based on two measured value.

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Maritime demonstrator – Reaction to fire

FIRE-RESIST

Requirements

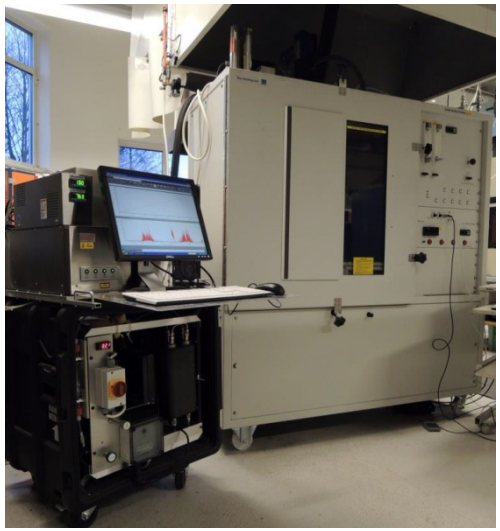
Part 2 criteria:

The samples were tested under each of the following conditions:

- Irradiance of 25 kW/m^2 in the presence of pilot flame.
- Irradiance of 25 kW/m^2 in the absence of pilot flame.
- Irradiance of 50 kW/m^2 in the absence of pilot flame.

At all of these conditions the following criteria must be met:

- Dm, average maximum specific optical density, ≤ 200
- Gas concentration limits:
  - CO 1 450 ppm
  - HCl 600 ppm
  - HF 600 ppm
  - NO_X 350 ppm
  - HBr 600 ppm
  - HCN 140 ppm
  - SO_2 120 ppm



With coating	Limit	25 kW/m^2 with pilot flame	25 kW/m^2 without pilot flame	50 kW/m^2 with pilot flame
Dm	200	81	97	134
CO conc.	1 450 ppm	260	132	692
HF conc.	600 ppm	<5	<5	<5
HCl conc.	600 ppm	16	15	15
HBr conc.	600 ppm	<10	<10	<10
HCN conc.	140 ppm	39	27	123
NO_X conc.	350 ppm	43	<20	26
SO_2 conc.	120 ppm	<10	<10	<10

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Conclusion

- Composite materials can be improved in terms of fire resistance without loosing in mechanical performance
- Composites, if formulated ad hoc, can perform as good as steel or even better.
- Structural composite applications in transport industry can be achieved and become a reality.

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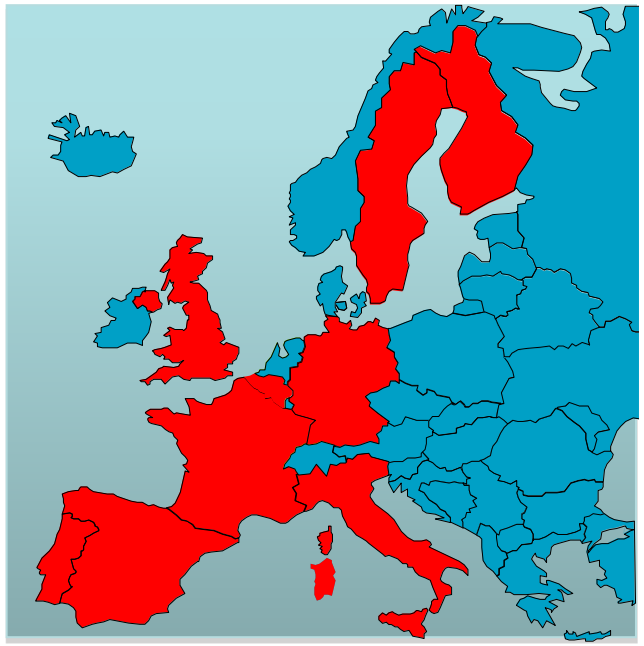
Acknowledgement

EU FIRE-RESIST PARTNERSHIP

To develop new concepts for composite materials that are both lightweight and fire-resisting.



SEVENTH FRAMEWORK PROGRAMME

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Thanks for your attention.

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