FIRE RESISTANCE
OF GALVANISED MEMBERS

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Contents of the presentation

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Motivation

- Surfacing of the Steel Structures is not accounted in the calculation of Fire Resistance

- Advantages of Galvanizing compared to Intumescent Coating
  - Price availability
  - Reduction of labour consumption
  - Acceleration of construction
  - Aesthetic properties
  - New possibility of using zinc coated members
Heat Transfer in Fire Technology

**Conduction** – molecular process of heat transfer

Fourier’s Law
\[
\frac{\partial}{\partial x} \left( k \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( k \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( k \frac{\partial T}{\partial z} \right) = c_p \frac{\partial T}{\partial t}
\]

Heat flux to boundary depends on surrounding and surface temperature:
\[
\dot{q}_{tot} = \dot{q}_{rad} + \dot{q}_{con}
\]

**Radiation** - heat flux of electromagnetic waves

\[
\dot{q}_{rad} = \varepsilon \sigma (T_r^4 - T_s^4)
\]

**Convection** – fluid passing by the surface

\[
\dot{q}_{con} = h_c (T_g - T_s)
\]
Fire Test 2010

- Pavus a.s., Veselí nad Lužnicí, 20. 10. 2010
- Horizontal Furnace with System of Oil-burners
- Standard Fire Curve
Fire Test 2010

Specimens:
- Hollow Cross Sections – TR 114,3 x 4 – 1000 mm
- Opened Cross Sections – IPE 200 – 1000 mm

Galvanized Surface:
- Average Thickness 119 μm
- Temperature of Galvanizing 460°C
- 1 Specimen – Admixure Al in Galvanizing Bath
Motivation

Heat transfer in fire technology

**Fire test 2010**

Fire test 2011 – Real structure

Fire test 2011 - Furnace

Further research

**Fire Test 2010**
Motivation

Heat transfer in fire technology

Fire Test 2010

• Specimens after Fire Test
Fire Test 2010

Surfacing after fire test
Fire Test 2010

Measured Values

Motivation

Heat transfer in fire technology

Fire test 2010

Fire test 2011 – Real structure

Fire test 2011 - Furnace

Further research
Results - Analytical Approach

Heat Transfer – „black“ specimen:

\[ h_{\text{net}} = h_{\text{net},c} + h_{\text{net},r} \]

\[ \Delta \Theta_a(t) = k_{sh} \cdot \frac{A_m}{V} \cdot \frac{1}{c_a(t) \cdot \rho_a} \cdot h_{\text{net}}(t) \cdot \Delta t \]

\[ h_{\text{net},c}(t) = \alpha_c \cdot \left[ \Theta_g(t) - \Theta_a(t) \right] \]

\[ h_{\text{net},r}(t) = \phi \cdot \varepsilon_m \cdot \varepsilon_f \cdot \sigma \cdot \left[ (\Theta_g(t) + 273)^4 - (\Theta_a(t) + 273)^4 \right] \]
Heat Transfer – galvanised specimen:

\[ h_{net} = h_{net,c} + h_{net,r} \]

\[ \Delta \Theta_a(t) = k_{sh} \cdot \frac{A_m}{c_a(t) \cdot \rho_a} \cdot h_{net}(t) \cdot \Delta t \]

\[ h_{net,c}(t) = \alpha_c \cdot \left[ \Theta_g(t) - \Theta_a(t) \right] \]

\[ h_{net,r}(t) = \phi \cdot \varepsilon_m \cdot \varepsilon_f \cdot \sigma \cdot \left[ \left( \Theta_g(t) + 273 \right)^4 - \left( \Theta_a + 273 \right)^4 \right] \]
Results - Analytical Approach

- **Surface Emissivity**
  - Aluminum \( \varepsilon_m = 0.3 \)
  - Galvanized Steel \( \varepsilon_m = 0.32 \)
  - Stainless Steel \( \varepsilon_m = 0.4 \)
  - Steel without surfacing \( \varepsilon_m = 0.7 \)
Results - Analytical Approach

\[ \varepsilon_m = 0.32 \]
Fire Test 2011 – Real structure

Pavus a.s., Veselí nad Lužnicí, 15. 09. 2011

Full scale test on real structure, dimensions 10.4 x 13.4 m

$q_{f,d} = 525 \text{ MJ/m}^2$, opening 5 x 2 m
Fire Test 2011 – Real structure

Motivation

Heat transfer in fire technology

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Fire test 2011 - Furnace

Further research
Fire Test 2011 – Real structure

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Fire test 2011 - Furnace

Further research

Graph showing steel temperature over time for TZ5 and TZ6.
Motivation

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Fire test 2011 – Real structure

Fire test 2011 - Furnace

Further research

**Fire Test 2011 – Furnace**

Pavus a.s., Veselí nad Lužnicí, 11. 10. 2011
Department of Steel and Timber Structures

Training School Malta

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**Fire test 2011 - Furnace**

Further research

**Fire Test 2011 – Furnace**

![Graph showing temperature over time during fire test.](image)

- **Temperature [°C]**
- **Time [min]**

- Red line: O-block 22
- Yellow line: O-block 23
- Purple line: O-Zn 50
- Blue line: O-Zn 51
- Green line: PEC u profilů L 25
- Turquoise line: PEC u profilů P 57

Further research
Further research

- Aging of zinc coated members
- Influence of thickness of zinc coating surfacing
- Composition of galvanizing bath
- Numerical model

Goal of the work

- Specify emissivity of galvanised surface
- Calibrated numerical model
- Schedule of temperatures for zinc coated steel members in standard temperature curve
Thank you for attention

URL: www.ocel-drevo.fsv.cvut.cz

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