2.24 Temperature dependent thermal properties of fire protection materials (short version)

Wang Y., United Kingdom

MANCHESTER 1824 — The University of Manchester

Temperature Dependent Thermal Properties of Fire Protection Materials

Yong Wang

University of Manchester, UK

5 July 2010 COST TU0904

1

MANCHESTER 1824 — The University of Manchester

Contents

- Importance of using appropriate data
- Specific heat
- Thermal conductivity of porous material
- Some results
  - Rock fibre
  - Mineral fibre
  - Calcium silicate
  - Vermiculite
- Intumescent coating

5 July 2010 COST TU0904

2

MANCHESTER 1824 — The University of Manchester

Typical data from manufacturers

Colour and finish	Off-white with a monolithic spray texture
Minimum practical thickness	8mm when unreinforced, 15mm when reinforced
Theoretical coverage	172m²/tonne at 15mm thickness
Number of coats	One or more as required
Cure	By hydraulic set
Initial set	2 to 6 hours at 20°C and 50% RH
Density	390kg/m³ ± 15% (when dry and in place)
Bond impact	No cracks or delamination
Air erosion resistance	No erosion to ASTM E859
Deflection effect	No cracks or delaminations within normal code limits
Compressive strength	563kPa (81.6lb/in²) to ASTM E761
Combustibility	Non-combustible to BS476: Part 4
Flame spread	Class 0 as defined by the Building Regulations
Smoke generation	Does not contribute to smoke generation
Thermal conductivity	0.095W/mK at 20°C

5 July 2010 COST TU0904

3

MANCHESTER 1824 — The University of Manchester

Sensitivity of Steel Temperature to Thermal Conductivity/specific heat

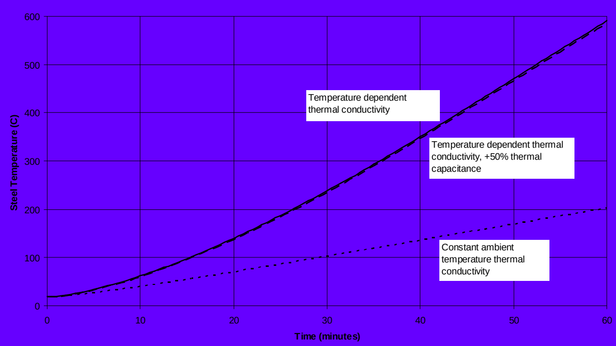
- Hp/A = 150m^{-1}
- Specific heat of steel = 650 J/kg.K
- Standard fire exposure time = 60 minutes
- Rock fibre: thickness = 10mm,density=160 kg/m^3, specific heat value = 900 J/kg.K, thermal conductivity = 0.0257 W/(m.K) or temperature dependent (relationship given later)
- Vermiculite: thickness = 15mm, density = 600 kg/m^3, specific heat = 900 J/kg.K, thermal conductivity = 0.1638 W/(m.K) or temperature dependent (relationship given later)

5 July 2010 COST TU0904

4

MANCHESTER 1824 — The University of Manchester

Results for Rock Fibre

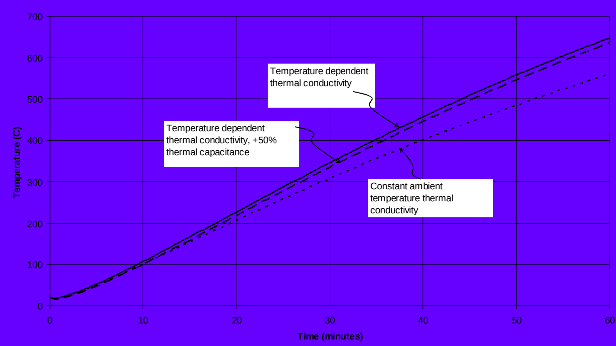


5 July 2010 COST TU0904

5

MANCHESTER 1824 — The University of Manchester

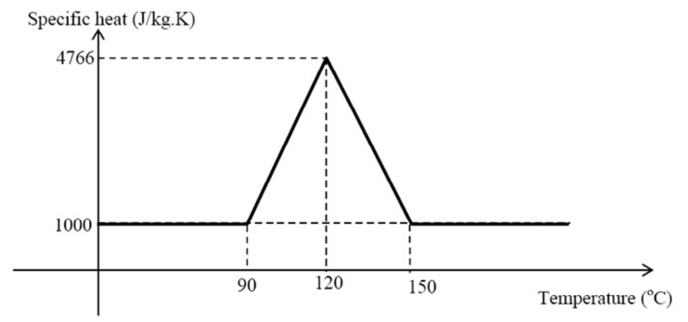
Results for Vermiculite



5 July 2010 COST TU0904

6

Specific Heat: Effects of moisture



5 July 2010 COST TU0904

Thermal Conductivity of Porous Material

$$\lambda^* = \lambda_s \frac{\lambda_g \varepsilon^{\frac{2}{3}} + (1-\varepsilon^{\frac{2}{3}})\lambda_s}{\lambda_g(\varepsilon^{\frac{2}{3}}-\varepsilon) + (1-\varepsilon^{\frac{2}{3}}+\varepsilon)\lambda_s} = \lambda_s \frac{\beta\varepsilon^{\frac{2}{3}} + (1-\varepsilon^{\frac{2}{3}})}{\beta(\varepsilon^{\frac{2}{3}}-\varepsilon) + (1-\varepsilon^{\frac{2}{3}}+\varepsilon)}$$

$$\lambda_g = \lambda_{g,cond} + \lambda_{g,rad}$$

$$\lambda^* = C_1 + C_2\lambda_g$$

$$\lambda_{g,rad} = 4GdE\sigma T^3$$

$$\lambda^* = \lambda_0^* + CT^3$$

5 July 2010 COST TU0904

Summary

Material	Density ρ (kg/m³)	Base value of specific heat (J/kg.K)	Thermal conductivity (W/m.K)
Rock fibre	155-180	900	$\lambda_{rock\ \ fibre} = 0.022 + 0.1475\left(\frac{T}{1000}\right)^3$
Mineral wool	165	840	$\lambda_{mineral\ \ wool} = 0.03 + 0.2438\left(\frac{T}{1000}\right)^3$
Calcium Silicate	various	900	$\lambda^* = \lambda_0^* + CT^3$ $\lambda_0^* = 0.23\frac{\rho}{1000}$ $C = 0.08 \times \frac{(2540-\rho)}{2540}$
Vermiculite	various	900	$\lambda^* = \lambda_0^* + CT^3$ $\lambda_0^* = 0.27\frac{\rho}{1000}$ $C = 0.18 \times \frac{(1000-\rho)}{1000}$

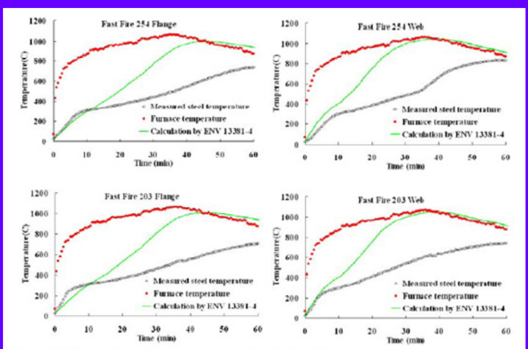
5 July 2010 COST TU0904

Intumescent Coating

- Thermal conductivity not only temperature dependent, but also fire exposure dependent
- Thermal conductivity obtained from standard fire resistance test cannot be used in performance based design using parametric fire curves

5 July 2010 COST TU0904

Steel Temperature Comparison



5 July 2010 COST TU0904

Conclusions

- Important to include effects of temperature on thermal conductivity
- Thermal radiation in pores can significantly increase thermal conductivity of porous material
- Temperature dependent thermal properties given for a number of common fire protection materials
- Intumescent coating requires further study

5 July 2010 COST TU0904