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Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Johra, H. (2019). *Thermal properties of common building materials*. Department of Civil Engineering, Aalborg University. DCE Technical Reports No. 216

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ISSN 1901-726X
DCE Technical Report No 216

DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

Aalborg University
Department of Civil Engineering
Architectural Engineering

DCE Technical Report No. 216

Thermal properties of common building materials

by

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January 2019

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Published 2019 by
Aalborg University
Department of Civil Engineering
Thomas Manns Vej 23
DK-9220 Aalborg Ø, Denmark

Printed in Aalborg at Aalborg University

ISSN 1901-726X
DCE Technical Report No. 216

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1. Introduction

The aim of this technical report is to provide a large collection of the main thermos-physical properties of various common construction materials and materials composing the elements inside the indoor environment of residential and office buildings. The Excel file enclosed with this document can be easily used to find thermal properties of materials for building energy and indoor environment simulation or to analyze experimental data.

The main thermo-physical properties which are needed for thermodynamics calculations, and compiled in this database are the mass density [kg/m³], the thermal conductivity [W/m.K] and the specific heat capacity [J/kg.K]. From these properties are calculated the volumetric heat capacity [kJ/m³.K] and the thermal diffusivity [mm²/s]. These material thermo-physical properties are stated for normal conditions of pressure (atmospheric pressure) and ambient temperature between 10 °C and 40 °C.

The thermo-physical properties of these construction materials are compiled from various sources [1] listed in the references section, but also measurements carried out in the Laboratory of Building Energy and Indoor Environment in the Department of Civil Engineering at Aalborg University (Denmark). In addition, suggestions are made for the thermos-physical properties of the materials composing the indoor content and furniture elements present in the built environment [35][36]. Some materials may have multiple entries with variations in the estimates of the thermo-physical properties. These variations between the different sources emphasize the difficulty to accurately determine the thermo-physical properties of building materials. In addition, these thermo-physical properties can vary significantly with temperature and humidity. For some material entries, only a part of the thermo-physical properties are indicated in the source and therefore compiled in this database.

The materials of this database are classified into 13 categories:

- Insulation
- Cellular glass / mineral
- Textile
- Paper / cardboard
- Polymer foam
- Wood
- Plastic / polymer
- Plaster
- Ceramic
- Structure material
- Natural stone
- Metal
- Carbon structure

In each category, the material entries are ordered alphabetically by name.

2. Data overview

One can see in the following figures an overview of the different thermo-physical properties of the different material categories. As illustrated in *Figure 1 - 4*, there is a clear correlation between material density and thermal conductivity. Apart from metals and ceramics, most of the building materials have a certain degree of porosity. Consequently, their thermal conductivity is mainly determined by the air and water content of these pores, which is directly correlated to their porosity and, therefore, to their density. Higher porosity (lower density) with air-filled cavities can lead to a higher amount of air. The latter having a very low thermal conductivity, it drives the entire thermal conductivity of the porous material down. On the other hand, the specific heat capacity of the material is more difficult to assess. It can be noted that the same value of specific heat capacity is often given for a whole category of material in the same source. In addition, one can see in *Figure 5* that there is no clear correlation between the density and the specific heat capacity of common construction materials [35].

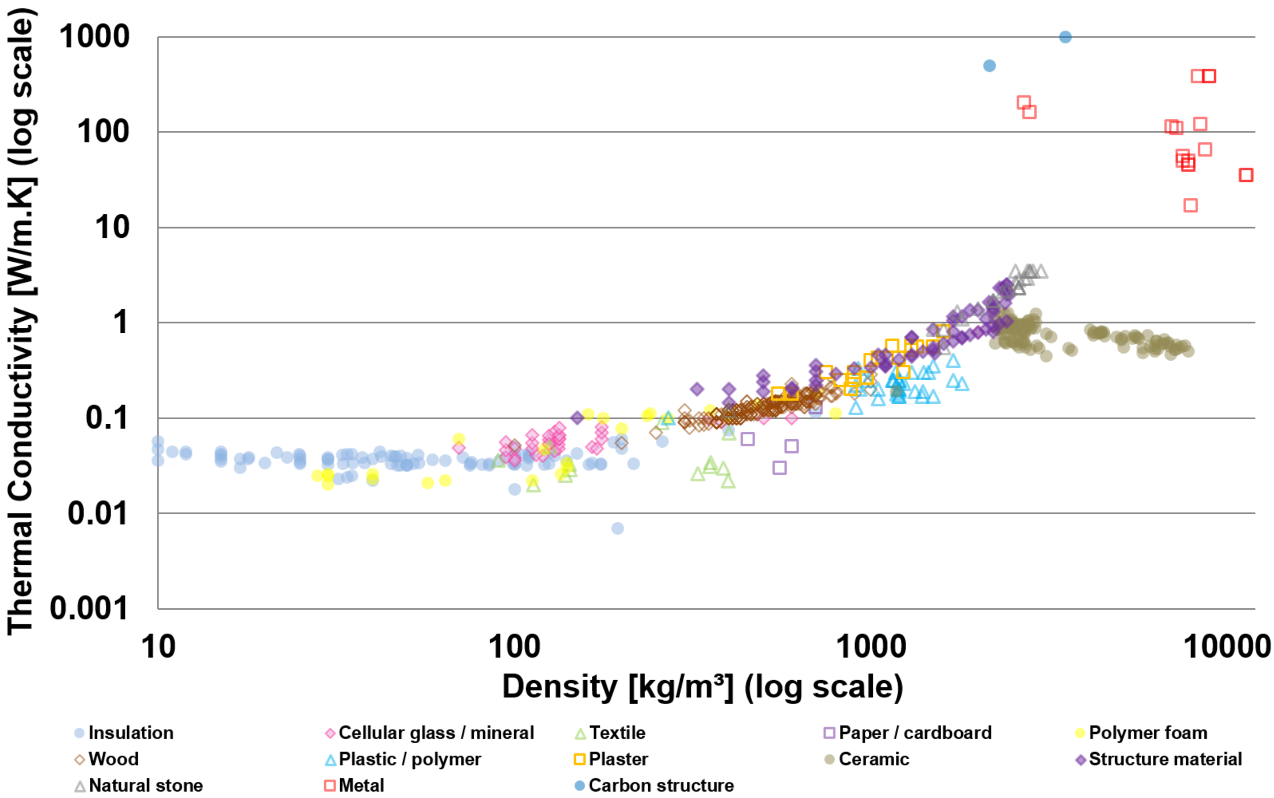

Figure 1: Overview of the material thermal conductivity as function of density.

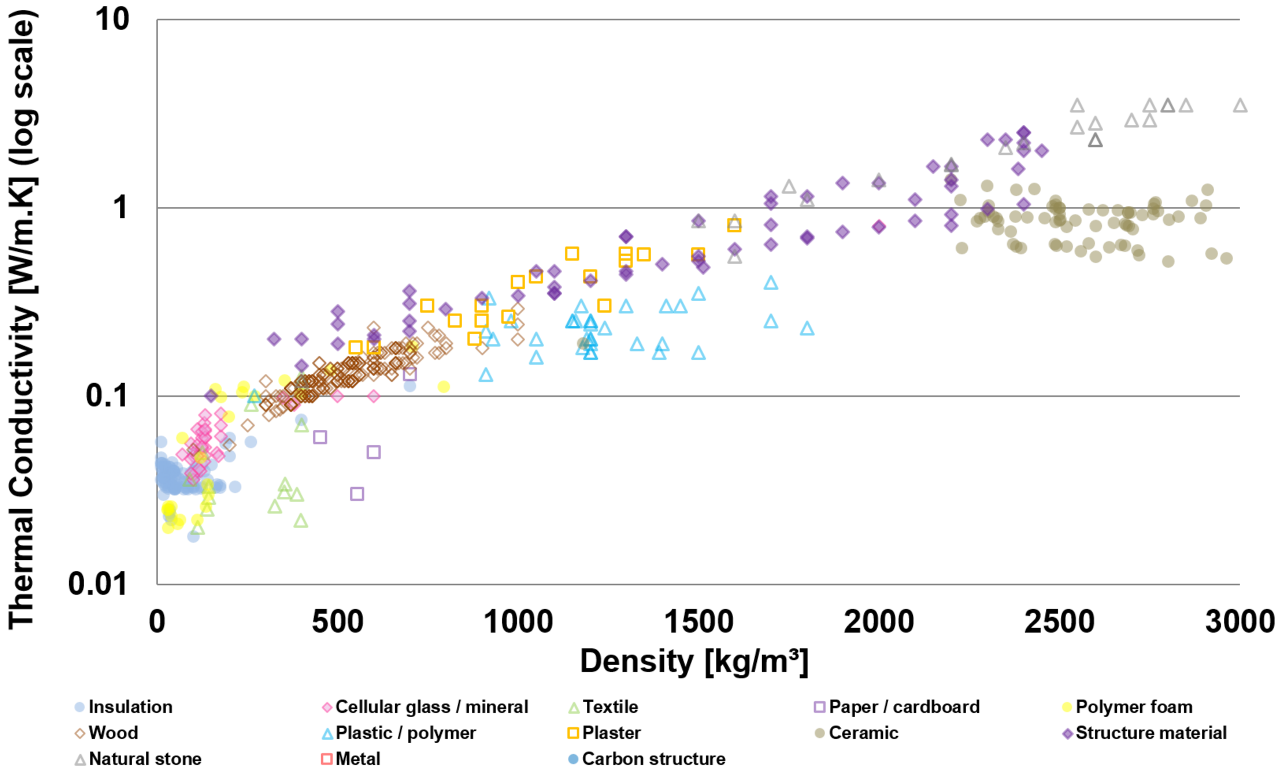

Figure 2: Overview of the material thermal conductivity as function of density.

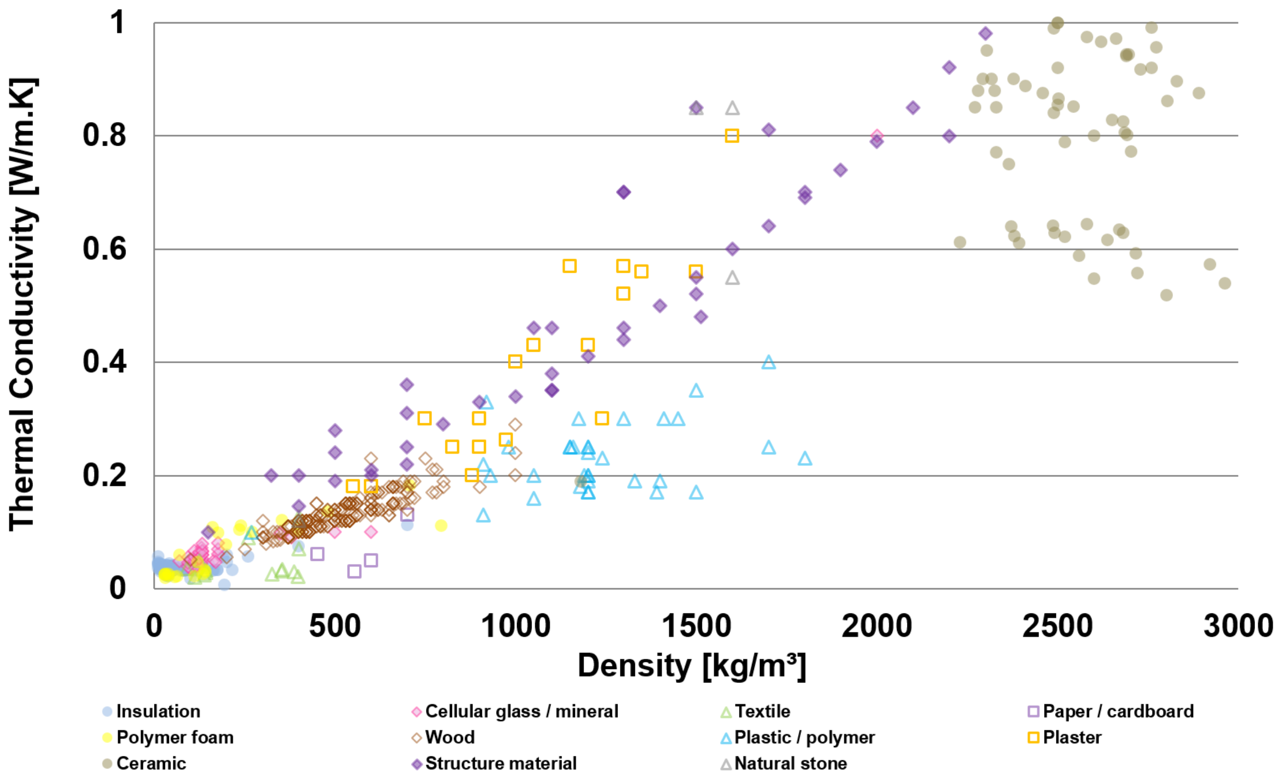

Figure 3: Overview of the material thermal conductivity as function of density.

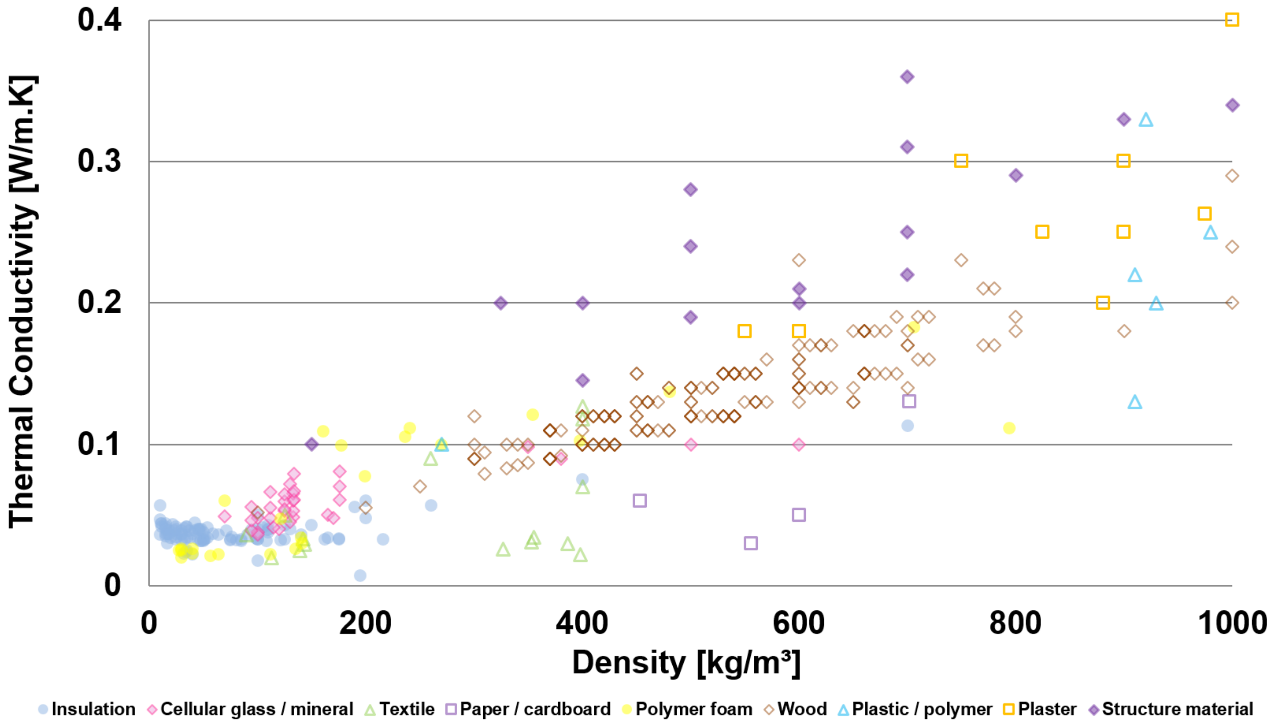

Figure 4: Overview of the material thermal conductivity as function of density.

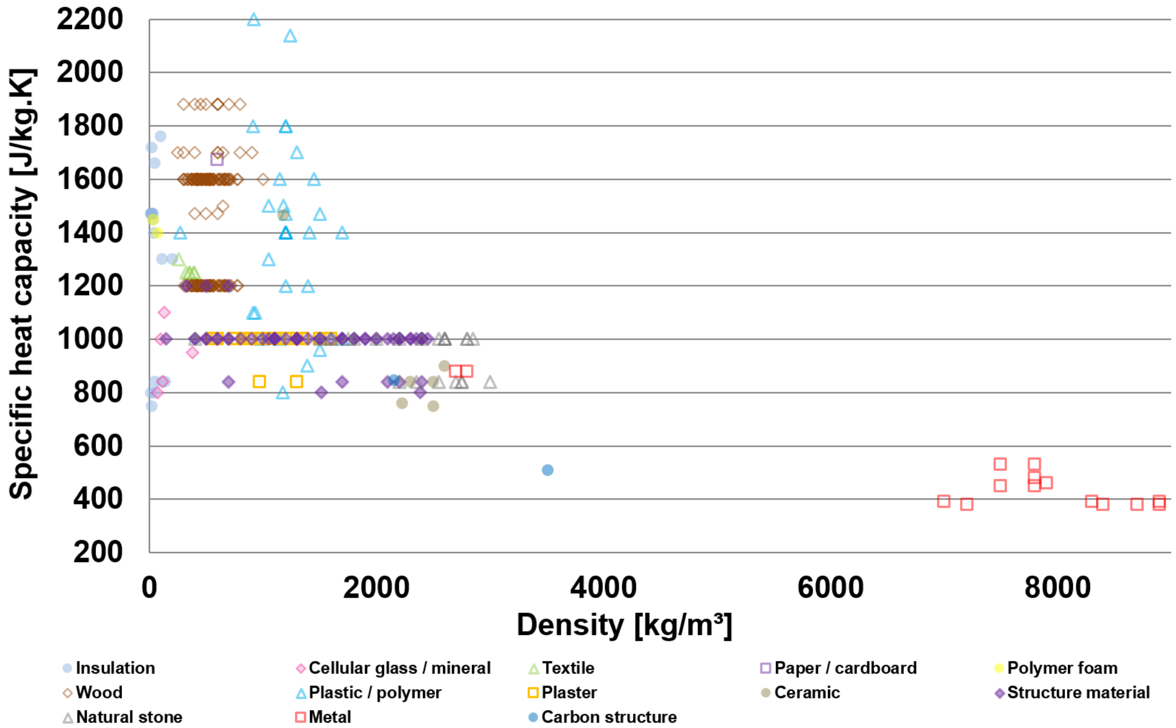

Figure 5: Overview of the material specific heat capacity as function of density.

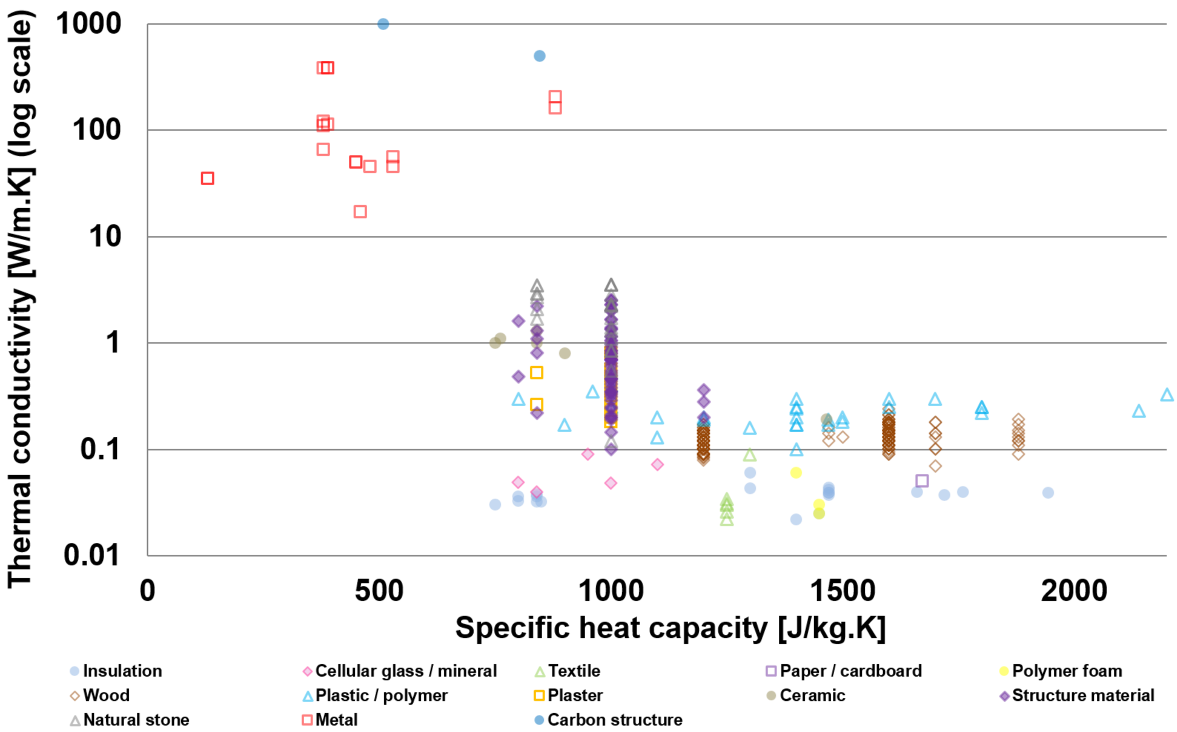

Figure 6: Overview of the material thermal conductivity as function of specific heat capacity.

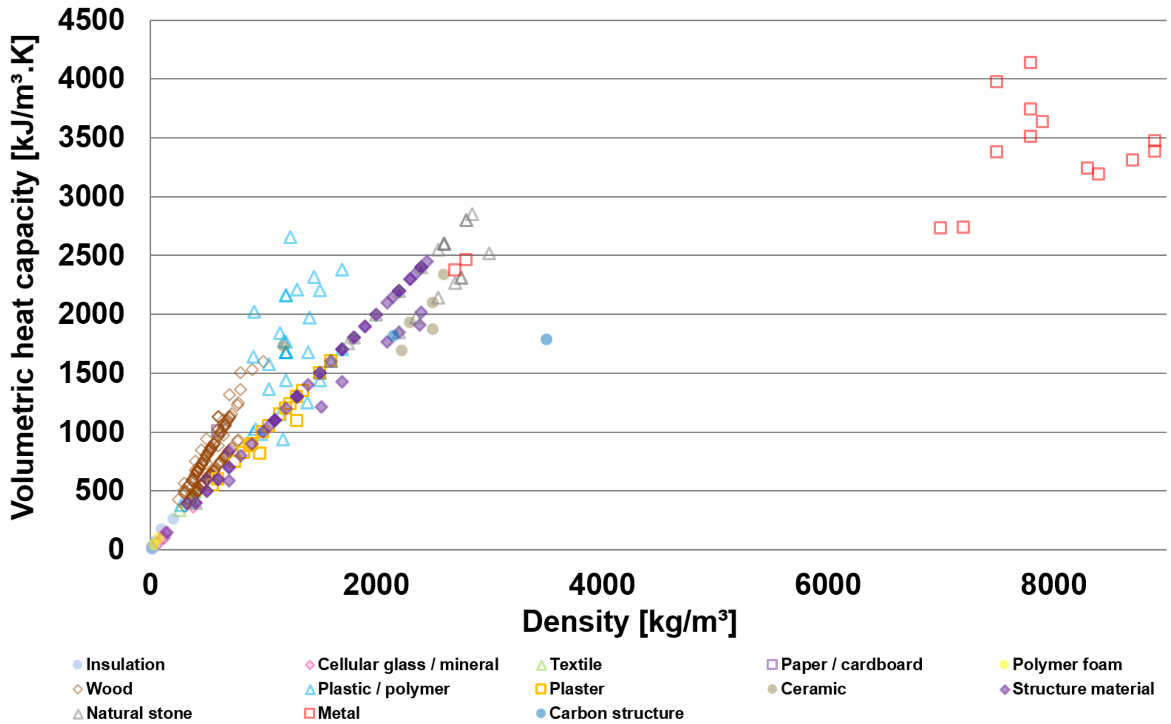

Figure 7: Overview of the material volumetric heat capacity as function of density.

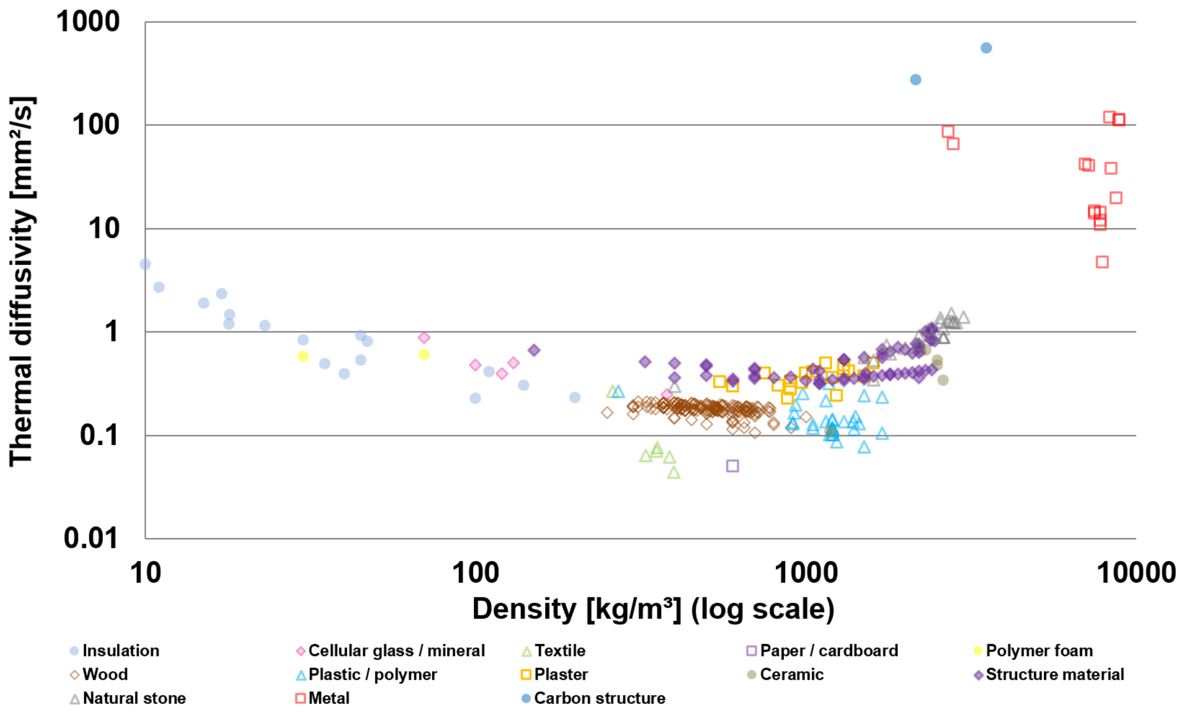

Figure 8: Overview of the material thermal diffusivity as function of density.

3. Thermo-physical material properties of the indoor content and furniture elements

The indoor content and furnishing elements present inside the built environment often have complex geometries with various types of material. One can find in *Table 1* recommendations for the thermo-physical properties of these indoor content elements. It is considered that the materials composing the indoor content elements can be classified into 4 main categories: light material, wood / plastic material, concrete / glass material, metal material. In addition, the properties of an equivalent indoor content material (which would therefore account for the equivalent thermo-physical properties of the overall indoor content elements) is given. For all categories, indications on the dimensions, effective thermal inertia and amount in buildings (mass relative to floor surface area) are given. These recommendations are valid for both residential and office buildings [35][36].

Table 1: Thermo-physical properties of the representative indoor content material categories [36].

Material category	Room mass content (kg/m² floor area)	Surface area (m²/m² floor area)	Material density (kg/m³)	Material thermal conductivity (W/m.K)	Material specific heat capacity (J/kg.K)	Planar element thickness (cm)	Daily effective thermal inertia (kJ/K.m² floor area)
Light material	7 (0.5–14)	0.3 (0.1–0.6)	80 (20–140)	0.03	1400	10 (0.5–24)	3 (0.2–7)
Wood / plastic material	30 (8–80)	1.4 (0.5–2)	800 (400–1200)	0.2 (0.1–0.3)	1400	1.8 (1–5)	26 (9–45)
Concrete / glass material	1 (0.5–2)	0.03 (0.01–0.04)	2000 (1500–2500)	1.25 (0.5–2)	950	1 (0.2–2)	0.1 (0.05–0.2)
Metal material	2 (1–5)	0.02 (0.01–0.03)	8000	60	450	0.2 (0.1–0.3)	0.1 (0.05–0.4)
Equivalent indoor content material	40 (10–100)	1.8 (0.8–2.8)	600 (150–1500)	0.3 (0.1–0.5)	1400	4 (1–10)	30 (10–50)

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