BRE Publication

BEPAC Research Report

**The Harmonisation of Thermal Properties of Building Materials**

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**SUMMARY**

This report presents a thorough review of existing data-sets of thermo-physical properties of building materials, devises and applies a suitable merging method for these data-sets, and proposes a summary specification for an electronic database for the containment and context dependent extraction of the data. The report also discusses the need for a standard test procedure, and identifies areas for further attention to and improvement of existing data.

In total, 14 data sets were obtained. Examination revealed the following key points:

-1 The range of properties for which values are quoted is often limited to only thermal conductivity, density and vapour resistivity as required for simple steady state heat loss and condensation calculations.

-2 The sources of much of the data are not identified, and little information is given on the underlying experimental conditions or procedure, which may be with non-standard apparatus or from a date which precedes modern standards. As a consequence it is often impossible to check compatibility between different values.

-3 Much of the agreement that does exist between different data-sets may be attributable to historical ‘borrowing’ one from the other. This may lead, erroneously, to an optimistic assessment of the inherent uncertainty.

-4 No guidance is given on the variation in properties such as density and internal structure inherent in the production of many building materials, and there is no agreement on the procedure for determining the thermal conductivity of materials as the moisture content varies. Such variations can lead to very large differences in reported material properties.

The report distinguished between two contexts in which the data might be used. The first is in comparative studies, where the aim might be to compare different buildings made of ostensibly the same materials. In such cases, the absolute accuracy of data is not paramount and, although not attempted in this study, the selection of ‘reference’ data is easier (such selection is being undertaken by, for example, CEN, in the context of a European standard building assessment procedure).

The second is in the calculation of real building performance. In such cases, the importance of, for example, variations of properties with moisture content, and the inherent uncertainties in the manufacture and use of building materials, are of key importance. In this context, the report examines current testing procedures, and makes recommendations as to how these should be improved or standardised.

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# Table of Contents

# Section One: Introduction

## 1.1 Introduction

At the present time several modelling systems exist which are capable of predicting the environmental states and energy demands of a building on the basis of inputs which define its form, fabric and operation. These systems have reached a stage in their evolution where a growing number of users are attempting to apply them in a real design context. Three current organisations are cited as evidence of an accelerating rate of uptake: the Building Environmental Performance Analysis Club operating in the UK [1,2], the International Building Performance Simulation Association recently established in North America [3] and the Royal Incorporation of Architect in Scotland's Energy Design Advisory Service [4] now in its third year of operation in Scotland.

In support of this uptake, the BEPAC task group on standardisation (Task Group 4) has identified several desirable developments, including the need for a common set of material thermo-physical properties from which the different programs could draw. To meet this requirement a project was set up, having the following objectives:

1. To determine the requirements of those who use building environmental prediction methods for material thermo-physical properties.
2. To review the existing data-sets in terms of data source, underlying test procedures and degree of consensus.
3. To comment on the need for a standard test procedure.
4. To suggest areas for further attention and improvement to the data.
5. To consolidate the currently available data-sets and deliver the result in a form compatible with future transformation to an electronic database.
6. To prepare an outline specification for the structure of such a database.

## 1.2 Thermophysical Properties of Interest

The following material properties were addressed within the project

conductivity ( $W/mK$ )
density ( $kg/m^3$ )
specific heat ( $J/kgK$ )
surface emissivity (-)
surface shortwave absorptivity (-)
vapour resistivity and resistance ( $MNs/gm$ or $MNs/g$ ).

In particular an attempt was made to obtain data which described the variation of these properties as a function of temperature and/or moisture content.

Some materials, particularly those such as insulation, in which there are large numbers of air pockets, transfer heat by a combination of conduction, convection and longwave exchange within the material. However, these processes are usually aggregated, and the resulting overall heat transfer coefficient is called the 'conductivity'. In this report, such conductivities are referred to as apparent conductivities, to distinguish them from materials which transfer heat solely by conduction.

## 1.3 The Process

The project was carried out in four stages as follows.

*Stage One:* The starting point was to contact a representative sample of program users/developers and material testing groups to obtain information on the data-sets in current use and to develop an understanding of the underlying test procedures. A wide range of organisations was polled including:

| |
|---|
| Professional bodies such as CIBSE and ASHRAE. |
| Architectural and Engineering design practices. |
| Government laboratories. |
| Academic groups. |
| Software vendors. |
| Material manufacturers. |
| Research organisations. |
| Testing laboratories. |
| All BEPAC and IBPSA members. |

Two questionnaires were devised for this purpose. In total some 400 questionnaires were despatched and 100 replies received. Section Two shows the form of the two questionnaires and gives a summary of the information contained in the replies.

*Stage Two:* A selective follow-up was then initiated to obtain the data-sets identified on the questionnaire returns and to document these in terms of their source, size and associated test procedures. This stage is reported in Section Three.

*Stage Three:* A mechanism for merging the collected data-sets was then devised. Section Four reports on the outcome and lists the merged data-sets.

*Stage Four:* This gives recommendations for future data-set refinement and presents a summary specification for an electronic database.

**1.4 Deliverables**

The deliverables from the project include:

1. The information from the questionnaire returns.
2. The 14 data-sets as collected and a description of each in terms of data source and underlying test procedure.
3. A description of the mechanism used to merge and categorise the data.
4. The merged collection.
5. A set of recommendations for future test procedures.
6. An outline specification for an electronic database to manipulate the collated data and provide context dependent values.

**1.5 Acknowledgements**

We are indebted to the the many individuals/organisations who responded to our questionnaires and were so willing to give us advice and their data-sets. We are also grateful to Dr V V Verma, a visiting British Council Scholar from the Central Building Research Institute at Roorkee, India, who assisted in the compilation and review of the project databases.

This work is part of the research programme of the Building Research Establishment, and is published with the permission of the Director.

**1.6 References**

1. Irving, S. 1989 ‘BEPAC, Building Environmental Performance Analysis Club’ Proc. of Building Simulation ’89, Vancouver, Canada, June 23-24, pp 1-4.
2. Pinney, A.A. 1988 ‘The Need for Standards in Environmental Modelling’ Paper to the BEPAC meeting, Polytechnic of Central London, June 14. Available from the Building Research Establishment, Watford.
3. ‘IBPSA Bylaws and Charter Statement’ Available from: Sowell, E., Department of Computer Science, Cal State Fullerton, Fullerton, California.
4. Emslie S V 1988 ‘The Energy Design Advisory Service in Scotland: Technology Transfer in Advanced Building Energy Simulation’ *Proc. 2rd European Simulation Congress* Ostend, Belgium.

# Section Two: Summary of Questionnaire Returns

## 2.1 Questionnaire to Model Users/ Developers

The following questionnaire (here compressed) was devised and despatched to some 257 addresses.

************************************************************************************************************************

**Questionnaire:**
**Thermophysical Properties of Building Materials**

**General**

We start by requesting a few general facts about your organisation.

| | |
|---|---|
| Name | |
| Organisation | |
| Nature of business | |
| Address | |
| Telephone | |
| Telex | |
| e_mail | |

**Existing Data-sets**

Principally we are interested in the *inherent* thermophysical properties of opaque and transparent materials as used in the building construction industry. The following table gives examples of these properties, please enter any others you might work with.

| Property | Please Tick if Existing |
|---|---|
| Conductivity ( $W/mK$ )<br>Density ( $kg/m^3$ )<br>Specific heat capacity ( $J/kgK$ )<br>Longwave emissivity<br>Shortwave absorptivity<br>Shortwave reflectivity<br>Shortwave transmissivity<br>Vapour resistivity ( $Ns/kgs$ )<br>Other(s) | |
| For approximately how many different materials. | |
| Are you a user or a producer of these data. | |
| For what purpose do you use or produce these data. | |

**Quality and Availability**

It is important that we be able to assess the quality and availability of your data-set before seeking your permission to include it in our project.

| | |
|---|---|
| Would you characterise your data-set as extensive or limited, of general value or specialist. | |
| Is your data-set held in electronic or paper form. | |
| Do you have data on the variation of any of the above properties as a function of temperature and/or moisture variations. | |
| Is your data-set generally available for use by others. | |
| What is the source of your data. | |

**Miscellaneous**

| | |
|---|---|
| Can you suggest anyone else we might contact on this subject. | |
| Free Comment. | |

Many thanks for taking the time to complete this questionnaire. Please now return it to:

************************************************************************************************************************

### 2.1.1 Analysis of Returns

The following table summarises the information contained in the returned questionnaires.

| | |
|---|---|
| Number of returns | 66 (25.7%) |
| of which | Users: 40<br>Producers: 6<br>User & producer: 9<br>Null response: 12 |
| Sector | Consulting Engineers: 5<br>Academic: 22<br>Government Research Lab: 22<br>Software Vendor: 15<br>Trade associations: 3 |
| Returns contained all, half or none of the properties of interest | All: 27<br>Half: 30<br>None: 10 |
| Scope of data-set used | Extensive: 17<br>Moderate: 24<br>Limited: 15<br>Null response: 14 |
| Returns contained data temp./moisture dependency | Yes: 22<br>No : 32<br>Null response: 12 |
| Data Sources | ASHRAE Guide: 18<br>Thermal programs: 16<br>CIBSE Guide: 13<br>National laboratories: 11<br>Technical Publications: 11<br>Test laboratories: 10<br>Manufacturer's Data: 7<br>Building regs: 1<br>Null response: 22 |

On analysing the returns (see section 3), it became clear that many of the data-sets in current use are simply derivatives of another, more authoritative data-set. In essence some 14 useful data-sets were identified (data from Leeds University were obtained separately, not via the questionnaire) as listed below.

| Data-Set | Code# |
|---|---|
| ASHRAE, USA | A |
| Univ. Leuven, Belgium | B |
| BRE, UK | - |
| BS5250, UK | BS |
| CIBSE, UK | C |
| CSTC, Belgium | T |
| DOE-2 Program, USA | D |
| ESP Program, UK | E |
| France | F |
| Germany | G |
| The Netherlands | S |
| Italy | Y |
| India | I |
| Leeds Univ. UK | L |

# Referred to in tables of Sections 4.3, 4.4, 4.5 and 4.6

## 2.2 Questionnaire to Material Testing Organisations

The following questionnaire (here compressed) was devised and despatched to some 39 addresses.

*************************************************************************************************************************

**Questionnaire:**
**Thermophysical Properties of Building Materials**

We are interested in the inherent thermophysical properties of opaque and transparent materials as used in the building construction industry and the test procedures used in their determination. The following table lists such properties. Please enter the appropriate test procedure reference(s) against any property measured by your organisation.

| Property | Test procedure reference(s) |
|---|---|
| Conductivity ( $W/mK$ )<br>Density ( $kg/m^3$ )<br>Specific heat capacity ( $J/kgK$ )<br>Longwave emissivity<br>Shortwave absorptivity<br>Shortwave reflectivity<br>Shortwave transmissivity<br>Vapour resistivity ( $Ns/kgs$ ) | |

Thank you for taking the time to complete this questionnaire. Please now return it to:

*************************************************************************************************************************

### 2.2.1 Analysis of Returns

The following table summarises the information contained in the questionnaire returns.

| | |
|---|---|
| Number of returns | 20 (51%) |
| of which | Useful: 18<br>Null response: 2 |
| Organisations measuring | Thermal Conductivity: 18<br>Density#: 12<br>Specific Heat Capacity: 6<br>Longwave emissivity: 6<br>Shortwave properties*: 5<br>Vapour Resistivity: 11 |
| # As distinct from density tests incorporated within standards for the measurement of thermal conductivity.<br>* Any one or more of absorptivity, reflectivity or transmissivity. | |

It appears that there is most concentration amongst these organisations in determining the thermal conductivity of building materials for steady-state type calculations. The decision by ASHRAE in 1985 to quote only recommended U-values for building assemblies typical of past, present and future constructions determined by hot box tests is consistent with this conclusion. This suggests that testing procedures are becoming less helpful to the requirements of dynamic simulation.

Vapour resistivity is determined by somewhat under two thirds of these organisations. The test standards quoted lead at most to only two results at different conditions, which are not sufficient to generate a differential permeability curve of the kind required to define the behaviour of hygroscopic materials.

Few organisations seem to be interested in measuring longwave emissivity, and even fewer in measuring shortwave properties. In the case of glazing and glazing systems, this is because manufacturers are relied on to provide specific product values. It seems that in other cases, such measurements are likely to be subcontracted out to research institutions on an ad hoc basis if and when required, or reliance placed on published results from various sources.

Thermal conductivity apart, the evidence suggests that many organisations concerned with both the use of, and advising on the use of, thermo-physical property values do not generate the information first hand. This raises the question of the quality control of such data.

The fact that a standard exists does not, of course, guarantee that it is actually in use. Standards tend to vary by material and there are, for example, hundreds of standards in the USA alone. Any one organisation is likely to test only a limited subset of what is possible. A listing by thermophysical property of standards which have been quoted in the questionnaire returns is given in the following table.

| | |
|---|---|
| Thermal Conductivity: | |
| UK | BS 874, BS 1142, BS 3837, BS 3927, BS 4370, BS 4840, BS 5608, BS 5617 |
| USA | ASTM C-158, ASTM C-177, ASTM C 236, ASTM C 335, ASTM C 518, ASTM C 687, ASTM C 691 |
| West Germany | DIN 52612 |
| Belgium | NBN B62-200, NBN B62-201, NBN B62-203 |
| Density: | |
| UK | BS 874, BS 2972, BS 4370, BS 5669 |
| USA | ASTM C-158, ASTM C-177, ASTM C-209, ASTM C-302, ASTM C-303, ASTM C-519, ASTM C-520, ASTM C-1622 |
| Belgium | STSO8.82.41, STSO8.82.5 |
| Specific Heat Capacity: | |
| UK | Yarsley: in-house |
| USA | ASTM C-351 |
| East Germany | TGL 20475 |
| Longwave Emissivity: | |
| UK | Draft BS 87/12988 |
| USA | ASTM E-408, Manville: in-house |
| Australia | CSIRO: in-house |
| Shortwave Properties: | |
| UK | Draft BS 87/12988 |
| USA | ASHRAE 74-73 |
| East Germany | Sonntag's Pyranometer |
| Vapour Resistivity: | |
| UK | BS 2782, BS 2972, BS 3177, BS 4370: 1973, Part 2, DD 146 |
| USA | ASTM C755, ASTM E96 |
| West Germany | DIN 52615 |
| Austria | ONORM B 6016 |

An examination of the BSI and ASTM yearbooks shows that standards change perhaps as often as every 3 to 5 years. Current standards will not affect data already in use for some time to come. For example, much of the CIBSE thermal properties data-set predates 1970 and several amendments of BS 874. An historical perspective may be of some value in assessing data-sets.

Particular national standards may not cover certain areas and, in any case, a catalogue of standards would fail to reveal the use of in-house testing procedures. Some such in-house procedures have, in fact, been identified.

# Section Three: Review of Existing Data-Sets

## 3.1 ASHRAE

### 3.1.1 General Observations

The tabulated values of thermal properties in the 1985 ASHRAE Handbook [1] for individual materials as opposed to multi-layered constructions are, for the most part, the same as in the 1981 edition. Table 3A of Chapter 23, entitled ‘Thermal Properties of Typical Building and Insulating Materials - Design Values’, gives information on conductivity or conductance and specific heat. The table has been slightly reordered and revised since the 1981 edition. A new section ‘Field Applied’ has been inserted which replaces and revises the information on the properties of insulation materials applied in-situ which were previously given in Table 3C in Chapter 23 of the 1981 handbook. The information on the thermal properties of woods has been refined in detail.

The logic and consequences of the difference between thermal conductivity as a defined property of a thermally homogeneous material and as an apparent property of materials which support other modes of heat transmission is made explicit. In particular, the behaviour of thermal insulation materials is discussed in Chapter 20. The logic follows through into testing procedures and the presentation of thermal data. This leads to a conclusion that for non-homogeneous materials (for example tiles and blocks with voids and insulation materials) the basic quantum of thermal data is the conductance of the manufactured unit. It is noticeable that most of the values given in Table 3A are of the thermal conductance of specimens of stated thickness rather than of thermal conductivity. This is markedly different to, for example, the CIBSE philosophy where the conductance of such items is estimated by combining the individual thermal conductivities of the solid parts and the thermal resistances of the voids.

Further values of the (apparent) thermal conductivities of insulating materials that can be found in existing buildings but which are no longer commercially available are listed separately in Table 3B. Design values for industrial insulation are listed in Table 6 for cryogenic through to elevated temperatures. Values for soils, in the context of buried lines, are given in Table 9.

Water vapour transmission is dealt with in Chapter 21: vapour permeance and permeability values of materials being listed in Table 2 of that chapter. Again, the values are given for design guidance only. Longwave emissivities are quoted for some surfaces in Table 2A of Chapter 23: the context is the thermal resistance of plane air spaces. The solar absorptance of opaque surfaces appears implicitly in Chapter 26 within the context of the computation of sol-air temperature. Solar reflectances for some opaque surfaces appear in Table 12 of Chapter 27 within the context of solar heat gains through fenestration, where the associated properties of glass and fenestration are considered.

The tables of values are accompanied by numerous informative footnotes offering useful interpretations of and guidance about the data.

It is important to understand the meaning of the term ‘design values’ as used in this database. They are NOT representative of values to be found in practice where, for example, moisture content may be important. Design values are explicitly stated to be different to specification values that are representative of materials in normal use. In the latter case, the user is referred to values supplied by the manufacturer or obtained from unbiased tests. This is different to the approach adopted in the CIBSE database where values are deliberately derived and quoted that are representative of actual use.

One obvious difference between the 1981 and 1985 versions of Chapter 23 is the removal of Tables 4A through to 4K from the later edition. The significance of this to test methodology and future database material is discussed later. A list of the physical properties of materials is given in Chapter 39 with sources referenced. However, the Handbook explicitly identifies Chapter 23 as the source for building materials.

The footnotes to Tables 3A and 6 of Chapter 23 offer guidance on the effect of ageing on the thermal properties of polyurethane and polyisocyanurate boards. Reference is also made to the effects of ageing on reflective surfaces, for example through oxidation and dust accumulation in reducing thermal resistance in the context of air spaces. No numerical information is provided, but the user is advised to make direct measurement of surface emittance values using, for example, ASTM C-445 or of thermal conductances using ASTM hot box tests on the appropriate construction.

### 3.1.2 Classifications

The entries in the first three tables noted in 3.1.1 are arranged by a mixture of generic building material type (for example building board), method of installation (for example loose fill) and by construction type (for example roofing). Otherwise, classification is by broad building material type. The headings do not follow in simple alphabetical order.

As noted above, insulants are distinguished according to whether they are for industrial use or not, and whether they are in current use.

Thermal conductivity/conductance values correspond to dry materials, except for wood which is conditioned to 12% moisture content by weight in all cases. Hence, no attempt is made to classify materials by degree of exposure. For water vapour permeance/permeability, some values are quoted for both wet- and dry-cup measurements giving some idea of behaviour under different conditions. This is far from universal and is not applied to wood, for instance, which has a permeability very sensitive to vapour pressure.

With respect to radiative heat transfer, materials are divided into three classes of emissivity for the purposes of calculating surface conductances. In the case of solar absorptance, opaque surfaces are classified as either dark or light coloured for the purpose of calculating fabric solar heat gain. For solar reflectance, a subgroup of materials is identified as ‘foreground surfaces’ for the purposes of calculating solar heat gains through glass.

### 3.1.3 Sources of Data

The selection of the design values for the thermal conductivity/conductance of typical building and insulating materials, and for industrial insulation appearing in Chapter 23, Tables 3A and 6 respectively, is attributed to ASHRAE Technical Committee 4.4. Only the sources for wood are specifically referenced [2 - 6]. The test conditions are reasonably well documented. The behaviour of the apparent thermal conductivity of low density thermal insulation materials as a function of density, mean temperature and, for fibrous insulations, fibre diameter is shown in figures 1 through 4 in Chapter 20. The non-linear behaviour with thickness is also mentioned [7]. The source of the values for the obsolete insulating materials appearing in Table 3B of Chapter 23 is referenced [8]. The mean test temperatures are recorded.

The source of the values of specific heat appearing in Table 3A of Chapter 23 is not referenced other than to selection by ASHRAE Technical Committee 4.4.

The sources of permeance/permeability values quoted in Chapter 21, Table 2, are extensively referenced [9 - 24]. All quoted thermal properties are for dry materials other than for wood at 12% moisture content [2 - 6]. No attempt is made to relate thermal conductivity or conductance to degree of moisture content.

For the purposes of calculating surface conductances, materials are given either a high emissivity of 0.9, a low emissivity of 0.2 or a very low emissivity of 0.05. Explicit mention is made of the significance of an error in the estimated value of surface conductance to the overall error in calculating the thermal transmittance. The reflectivity and emissivity values of various surfaces are given in Table 2B of Chapter 23. No source is referenced.

For opaque surfaces, no explicit value of solar absorptance is given in Chapter 26. However, it can be deduced that the value for a light or dark coloured surface is about the same as that quoted in the CIBSE Guide. No reference is given for these values. A limited number of reflectances appear in Table 12 of Chapter 27 for foreground surfaces. They are given as a function of the angle of incidence. The source is acknowledged [25].

For transparent surfaces some information on the solar optical properties of glass and of plastic sheeting is given in Figures 11, 12 and 34 of Chapter 27. The values in Table 34 are referenced [26,27].

### 3.1.4 Test Methods

For thermal conductivity/conductance values as listed in Chapter 23, Tables 3A and 3B, the data are explicitly attributed to measurements using the test procedures of ASTM C-518 or ASTM C-177. The former refers to the guarded hot plate method which is also the method referred to in section A3 of the CIBSE Guide (in the context of BS 874). The latter refers to the heat flow meter method which is not referred to by the CIBSE Guide but is described in BS 874. There is no specific reference to any test method in relation to the values of thermal conductivity of industrial insulation quoted in Table 6.

Direct measurement on representative sections of building construction using the guarded hot box method (ASTM C-236) or the calibrated hot box method (ASTM C-976) is positively recommended. In fact, Chapter 23 states

> “The most exact method of determining the heat transmission coefficient for a given combination of building materials as a building section is to test a representative sample in a guarded hot box or calibrated hot box.”

Interestingly, only in the absence of such measurements are calculation techniques based on the properties of the individual components of construction recommended. The reason for the removal of Tables 4A through to 4K from the 1985 edition of the ASHRAE Handbook which was referred to above, is directly related to this approach. The intention is that a ‘Manual of Heat Transmittance Coefficients for Building Components’ based on measurements using the hot box methodology will act as a source of design values of thermal transmittances for typical past, present and future building constructions.

The values of water vapour permeance and permeability given in Chapter 21 are identified with test methods. For the most part these are wet- and/or dry-cup tests after ASTM E 96 and ASTM C 355.

With respect to longwave emissivity, reference is made to ASTM C-445. The use of ASHRAE 74-73 can be inferred in relation to solar absorptance/reflectance data in the context of fenestration.

With respect to specific heat and moisture content, no test methods are identified.

### 3.1.5 Use of Data

The material thermal properties listed in Chapter 23 are intended to be used in the computation of the steady state thermal transmittances of assembled building constructions. In the case of heat-bridged constructions, a calculation method is put forward to enable an estimate of the thermal transmittance to be obtained from the properties of the components. Nevertheless, it is only to be used where direct measurement by a hot box test cannot be carried out. The vapour permeances and permeabilities listed in Chapter 21 are intended to be used in simple steady state vapour transmission calculations in direct analogy with the thermal calculations. They assume conditions of no condensation. The results so calculated are for design guidance and therefore are not representative of actual service conditions. This is primarily because there is no allowance or correction for moisture content.

### 3.1.6 References

2. American Soc. of Heating, Refrogeration and Air-conditioning Engineers, Inc. **US ASHRAE Handbook, 1985 Applications.**
2. Forest Products Laboratory **US Department of Agriculture Handbook No.72** (Tables 3-7 and 4-2 and Figures 3-4 and 3-5) 1974.
3. Adams L ‘Supporting cryogenic equipment with wood’ **Chemical Engineering** 17 May 1971.
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7. Pelanne C M ‘Thermal insulation heat flow measurements: requirements for implementation’ **ASHRAE Journal V21(3)** p51 March 1979.
8. **Heating, Ventilating and Air-Conditioning Guide**, pp95-8 1939.
9. US Housing and Home Finance Agency ‘Condensation control in dwelling construction’ June 1950.
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12. ‘Water vapor transmission testing’ **Materials research & Standards V1(2)** p117 February 1961.
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15. Teesdale L V ‘Remedial Measures for Building Construction’ **US Forest Products Laboratory Report R1710** US Dept. of Agriculture 1947.

16. Rowley F B, Algren A B and Lund C E ‘Methods of Moisture Control and Their Application to Building Construction’ **Bulletin No.17** University of Minnesota, Engineering Experiment Station.

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19. Wray R I and Van Vorst A R ‘Permeability of paint films to moisture’ **Industrial and Engineering Chemistry V25** p.842 1933.

20. Britton R R and Reichel R C ‘Water Vapor Transmission of Building Materials Using Four Different Testing Methods’ **Technical Bulletin No.12** US Housing and Home Finance Agency, January 1950.

21. Bell E R, Seidl M G and Kruger N. T ‘Water-vapor permeability of building papers and other sheet materials’ **ASHVE Transactions V57** p287 1951.

22. ‘How to estimate the amount of water vapor transmitted through building walls’ **Heating and Ventilating** September 1942.

23. Edwards J D and Strohm D B ‘Measuring permeability’ **Modern Packaging** October 1945.

24. Lotz W A ‘Vapor barrier design, neglected key to freezer insulation effectiveness’ **Quick Frozen Foods** November 1964.

25. Bliss R W ‘Atmospheric radiation near the surface of the ground’ **Solar Energy V5(3)** p103 1961.

26. Burkhardt W C ‘Acrylic plastic glazing: properties, characteristics and engineering data’ **ASHRAE Trans. V82** Part 1 p683 1986.

26. Burkhardt W C ‘Solar optical properties of gray and brown solar control series transparent acrylic sheet’ **ASHRAE Technical Symposium** Atlantic City January 1975.

## 3.2 University of Leuven, Belgium

### 3.2.1 General Observations

This database contains values of bulk density and thermal conductivity or thermal resistance for building and insulating materials for both indoor and outdoor conditions. It refers to a relatively limited set of materials. As such it only applies to materials at normal environmental temperatures. The temperature limits for use of the listed values are -10°C to 30°C [1].

### 3.2.2 Classifications

The entries in this database are by broad generic building material type. Within each entry, values are listed against the various forms in which the material appears. There is a subdivision of values into those for use under indoor conditions and those for use under outdoor conditions. Materials which are not recommended for exposure to external conditions are specifically identified as such. Values for metals are listed under outdoor conditions. There is a separate section for non-homogeneous materials. The thermal resistance and associated thickness of the manufactured unit are given. Examination of the database shows that materials for which the thermal conductivity is an apparent property are included. However, there is no reference to apparent thermal conductivity as such.

### 3.2.3 Sources of Data

Thermal conductivity/resistance values are attributed to a single Belgian Standard [2].

Moisture content values for indoor use are attributed to any material layer which cannot be wetted by rain or which will come to hygroscopic equilibrium with the environment. The values for outdoor use are to be attributed to any material wetted by rain.

### 3.2.4 Test Methods

No test methods are identified for thermal conductivity or moisture content, the only two properties given.

### 3.2.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances.

### 3.2.6 References

1. IEA Annex XIV, Condensation and Energy: 1. Material Properties, Laboratorium voor Bouwfysica, Katholieke Universiteit Leuven.
2. Belgium Standard NBN B62-002, Thermische geleidbaarheid van de bouwmaterialen, Conductivities thermiques des materiaux de construction, Brussel, 1980.

## 3.3 UK BRE

### 3.3.1 General Observations

Although the listing of this database is now no longer available, it is known that it was structured to store up to seven material properties. These were density, thermal conductivity, vapour resistivity, specific heat, linear expansion, porosity and strength (either tensile or crushing). Values for at least the first four properties had to be given for any material to be stored in the database. An interesting feature of this database was the fact that each item of data was associated with a 4-character code which identified the reference source for the data. Unfortunately the sources, and any index to them, are also no longer available. Another interesting feature was the facility to list materials conforming to a desired value of one of the material properties. Some documentation which describes the structure and operation of the database is still available [1, 2, 3 & 4]. Examination of a hardcopy of the database structure shows that it was divided into a first part consisting of a listing of approximate properties of materials for general calculation purposes, followed by a more detailed listing of properties. It is noteworthy that only a single figure for vapour resistivity was stored, irrespective of whether the material was hygroscopic or not. Taken together with the listing of approximate values, this suggests the expected accuracy of calculations was not high. Some recent values developed by the BRE on vapour resistance and on solar absorptivity and longwave emissivity have been passed to ESRU. The latter two properties were not included in the original database.

### 3.3.2 Classifications

All entries were by broad generic building material type. Each entry was then subdivided into the various forms in which the material appears, and arranged in alphabetic order. The actual group headings were Asbestos, Asphalt, Brick, Concrete, Felt, General, Glass, Plaster, Plastic, Timber and Wool. The more recent data follow the same logic but with different group headings and materials.

### 3.3.3 Sources of Data

The source of the thermal conductivity and specific heat data is unknown, but for water vapour transmission there are two sources [5 & 6]. Concerning moisture content there is evidence in the documentation that the thermal conductivities for wet masonry were stored, and correspond to the values given in the CIBSE Guide. These would have been derived by using the Jakob corrections, and cannot be considered reliable. All longwave emissivity and shortwave absorptance data come from a single source [7].

### 3.3.4 Test Methods

The test methods for thermal conductivity, specific heat, moisture content and longwave emissivity are unknown. Water vapour transmission is based on a wet cup modification of BS 3177 [6]. With shortwave absorptance no specific test method is identified, although one source [8] does reference the instrumentation employed.

### 3.3.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances, admittances and dewpoint profiles [4].

### 3.3.6 References

1. Filmer R N **Technical Bulletin T69** Building Research Establishment, January 1977.
2. Wordsworth L M and Filmer R N **Technical Bulletin T70** Building Research Establishment, January 1977.
3. Filmer R N **Technical Bulletin T76** Building Research Establishment, January 1978.
4. Filmer R N **Technical Bulletin T77** Building Research Establishment, January 1978.
5. McIntyre I S ‘Timber Housing Performance’ Private Communication, Building Research Establishment, 1989.
6. Covington S A and McIntyre R S ‘Timber Frame Wall Materials: Measurement of Vapour Resistance’ **Timber in Building** pp207-10.

7. Penwarden A ‘Solar absorptivity and longwave emissivity values for a wide range of materials’ Unpublished paper, Building Research Establishment, January 1989.

8. Beckett H E ‘The Exclusion of Solar Heat’ **JIHVE V3(25)**, pp84-8, 1935.

## 3.4 BS 5250

### 3.4.1 General Observations

Following the withdrawal of the original BS 5250, a much revised version was published in 1989. The revision concerns both the method of condensation risk calculation and the data to be used. As such, the Standard contains tables of thermal and vapour resistivities. In particular, the vapour resistivities have been heavily revised and represent a considerable accumulation of practical experience. Much of that experience is contained internally within organisations and not generally published. It should be noted that the values quoted do not allow for the effects of installation.

### 3.4.2 Classifications

The database entries are by building material type, listed alphabetically. A single value of thermal conductivity is associated with each material entry. In the case of the vapour resistivity, both a typical value and upper and lower bounds of the range of values found for a particular material are quoted. A separate table is given for the vapour resistances of vapour barriers. A further table is devoted to the thermal resistance of airspaces. Examination of the database shows that materials for which the thermal conductivity is an apparent property are included. However, there is no reference to apparent thermal conductivity as such.

### 3.4.3 Sources of Data

Although there is no direct reference to the source of thermal resistivity/resistance values in the Standard, enquiry has revealed that the values are derived from the CIBSE Guide [1].

The vapour resistivities and resistance values are derived from a large number of sources, with selection based on practical experience. Fortunately, a note of these sources has been kept and obtained from one of the committee members who worked on the Standard [2,3,4,5,6,7,8,9,10,11,12,13,14,15,16].

While there is no specific reference to moisture content in the tabulated data, examination of the thermal conductivity values shows that most are equivalent to the CIBSE values for exposed conditions. Further enquiry has confirmed this, and revealed that the reason for so doing lies in the belief that the CIBSE values significantly underestimate the true moisture content of materials found in practice [17].

### 3.4.4 Test Methods

Concerning thermal resistivity/resistance, no test method is identified (as the historic CIBSE source data set contains no reference). Similarly for water vapour transmission no test method is identified. However, many of the source references quote wet and dry cup test methodology.

### 3.4.5 Use of Data

The data are intended for use in the steady state calculation of condensation risk based on the method given by Glaser [18].

### 3.4.6 References

1. **CIBSE Guide** Section A3, 1980.
2. National House Building Council, internal data.
3. Department of the Environment Northern Ireland, internal data.
4. Timber Research and Development Association, internal data.
5. Pilkington Bros Ltd, internal data.
6. Princes Risborough Laboratory, internal data.
7. Building Research Establishment, internal data.
8. ‘Condensation’ **BRE Digest 110** Building Research Establishment, Watford, 1972.
9. **BS 5250** ‘Code of basic data for the design of buildings: the control of condensation in dwellings’, 1975.
10. **BS 6229** ‘Flat roofs with continuously supported coverings’.

11. **CIBSE Guide** Section A10 1986.
12. Prangnell R D 'The water vapour resistivity of building materials - a literature survey' **Materiaux et Constructions 4(24)** November 1971.
13. **ASHRAE Handbook** Fundamentals Volume 1985 .
14. 'Condensation, Part 1: The risks' and 'Part 2: The remedies' **AJ** 9 and 16 April 1986.
15. **AJ** <book of about 3 years ago>.
16. Sieffert K 'Damp diffusion and buildings: prevention of damp diffusion damage in buildings' Elsevier 1970.
17. Cornish P C *Personal communication* BRE Scottish Laboratory.
18. Derricott R and Chissick S S (Eds) **Energy Conservation and Thermal Insulation** Chapter 21 John Wiley & Sons Ltd 1981.

## 3.5 CIBSE

### 3.5.1 General Observations

The source of these data is the CIBSE Guide [1]. The tabulated thermal properties of materials appear mainly in Section A3 (1980), and are largely based on the values previously given in section A3 of the 1970 edition of the Guide. In particular, the bulk densities, thermal conductivities and resistivities of miscellaneous materials, as given in Table A3.22 of the 1980 edition, are identical to those given in Table A3.23 of the 1970 edition. The thermal conductivities of homogeneous masonry, as given in Table A3.1 of the 1980 edition, differ from Table A3.3 of the 1970 edition in that the values for concrete with foamed slag aggregate are now quoted separately from other forms of concrete. Otherwise, the values for concrete and brickwork remain unchanged from the 1970 edition. As stated in the introduction to the 1980 edition of Section A3, values were 'selected impartially' against a policy to use only 'traditionally accepted' values as given in the 1970 edition wherever possible. The descriptors 'impartial' and 'traditional' appear to mean historical consensus rather than recently validated test results. Indeed, the 1980 edition states

> "The thermal conductivities and other properties of materials contained in this section are drawn mainly from historical data".

A noteworthy feature of the 1980 edition is the considerable extension of precalculated thermal properties for composite constructions now including both thermal transmittance and admittance. The latter did not appear in the 1970 edition of section A3. The values of density, thermal conductivity, specific heat capacity and surface resistance used to calculate transmittance and admittance are given in Table A3.15. These values form a subset of representative or typical values on which to base computations of the thermal properties of composite building constructions.

Vapour resistivities for materials and resistances for films are given in Section A10 (1986). This Section has been much revised and extended. It bears little resemblance to the 1970 version, and now reflects a much greater interest in condensation. Table A10.4 contains both vapour resistivities and thermal conductivities as an aid to condensation calculations.

Longwave emissivities are quoted in Section C3. Values of solar absorptance and reflectance for opaque surfaces appear in Section A2 (1982) (originally in Section A6 which has now been discontinued). The absorptance values for clean surfaces has been dropped. Solar reflectance continues to receive the same cursory treatment as before. In the context of solar gains, the properties of glazing are treated separately in section A5.

The effect of ageing on the properties of polyurethane is given in Table A3.22.

### 3.5.2 Classifications

The miscellaneous materials for which thermal properties are given in Table A3.22 are listed by generic building material type in simple alphabetic order. Under each entry, values are attributed to the various forms in which the material may appear.

Because of their temperature dependence, the thermal conductivities of common insulating materials for use at elevated temperatures are given separately in Section C3 in the context of pipe insulation. Soil thermal conductivities are also quoted in Section C3 in the context of underground services.

The thermal conductivity of any porous building material is affected by the moisture content of the pores. This is the reason why the thermal conductivities of homogeneous concrete and brickwork are listed separately in Table A3.1. Such materials may contain amounts of moisture significantly above that due to thermal equilibrium with the ambient air, either because they are hygroscopic or because of exposure to rain. This requires a further classification of thermal conductivities for masonry materials according to the degree of exposure. The basic hypothesis, as expressed in Table A3.2, is that a standard moisture content can be attributed to brickwork and concrete according to whether the material is in a protected or exposed condition. The Guide gives the following definitions of these conditions:

> 'Protected' covers internal partitions, inner leaves separated from outer leaves by a continuous airspace, masonry protected by tile hanging, sheet cladding or other such protection, separated by continuous airspace.

> 'Exposed' covers masonry directly exposed to rain, unrendered or rendered. The standard moisture contents are to be used throughout the UK without further corrections for macro- or micro-climatic

corrections.

The vapour resistivities in Table A10.4 are classed under minimum or typical. According to the Guide:

> (‘minimum values’) are the smallest values found in the relevant literature and should not be used for general calculations. ‘Typical values’ are taken from the middle range of values for each material and may be used for calculation in the absence of more specific data.

The meaning of this classification becomes unclear when the accompanying thermal conductivities are examined. The values for brick and concrete clearly relate to the standard moisture content for exposed conditions (Table A3.1). The conductivities for other materials are in agreement with those in Table A3.22 for dry or air-dry conditions. The interpretation of ‘typical vapour resistivity’ is therefore not obviously related to moisture content or degree of exposure or, importantly, the degree of condensation risk.

With respect to radiative heat transfer from building surfaces, only two classes of materials are distinguished for the purposes of attributing emissivity values. These are common building materials, generally deemed to be of high emissivity, and polished metal finishes of low emissivity. With respect to solar absorptance for opaque materials, two classes of surfaces are distinguished: dark or light coloured. The representative values given in Table A3.15 used in deriving the thermal transmittances and admittances of the constructions quoted in Tables A3.16 to A3.21 are classified by construction element type (Walls, Surface Finishes, Roofs and Floors) except in the one case where the classification is by the generic material type (Insulation).

### 3.5.3 Sources of Data

The majority of thermal conductivities for masonry materials are derived from an empirical relationship between density and thermal conductivity. The source of this relationship is not referenced in the text of section A3. As noted above, the thermal conductivities and other properties of materials contained in section A3 are drawn mainly from historical data. Examination of Table A3.22 shows that the test conditions under which the thermal properties were measured are unknown or incomplete in most cases. There are also many instances of values being identified as representative and for use in the absence of precise information. Further information on the thermal conductivities of commonly used insulating materials at higher temperatures is given in Table C3.2. The values are otained from section A3 and BS 3958 [2]. The soil conductivities listed in Table C3.21 are from reference [3].

Specific heat values are quoted in Table A3.15. There is no mention of the source of these values. The water vapour resistances appearing in Table A10.4 are attributed to two sources [4 & 5]. The film vapour resistances appearing in Table A10.6 are not referenced. Equilibrium moisture contents for some materials are quoted in Table A10.1, and the source is cited [6]. The standard moisture contents for masonry materials are based on the empirical work of Arnold [7]. Where the thermal conductivity is measured at other than the standard moisture content, it is to be corrected to the latter value by use of the empirical correction factors in Table A3.23 as proposed by Jakob [8].

Longwave emissivity values, normal to the surface, are given in Table C3.7. Correction factors for hemispherical emissivities are also quoted. The contents of the Table are unreferenced. For the purposes of calculating building heat losses, materials are either given a high emissivity of 0.9 or a low emissivity of 0.05. No particular reference for this choice of values is given, but the implication is that a higher degree of accuracy is not required in calculating the thermal performance of building constructions.

Opaque surface solar absorptance enters into the precalculated values of sol-air temperature given in Table A2.33. In calculating these temperatures, the values of solar absorptance are taken as 0.9 for dark surfaces and 0.5 for light surfaces. No reference is given for these values but examination of the 1970 Guide shows that the values are taken from Table A6.14 for building surfaces when dirty. These represent ‘in-use’ surfaces and not laboratory clean specimens. The value of 0.8 for medium dirty surfaces has been dropped. Solar reflectance appears in the context of ground reflected solar radiation in Section A2 where it is given in a very simplified form. Ground reflection factors are quoted in Table A2.31 with one of two values, either 0.5 for arid tropical localities or 0.2 elsewhere. There is no allowance for angle of incidence. The source of these values is not referenced but they are identical to those quoted in the 1970 Guide.

For glass, solar transmittance, absorptance and reflectance near normal incidence is given in Table A5.2. No source is quoted, but manufacturers are recommended as the source of more detailed data.

### 3.5.4 Test Methods

With respect to conductivity, the data in section A3 are historical or based on empirical relations with an incomplete record of, or reference to, the test conditions and methodology. For this reason it is difficult to comment on the underlying test method. However, it is stated that any future values to be incorporated in section A3 will have to be determined using the guarded or unguarded hot plate apparatus in accordance with BS 874 [9]. This Standard also covers methods suitable for measurements on high temperature insulations and on soils in situ. Section A3 recommends the acceptance of measurements only when carried out by a laboratory accredited by the British Calibration Service now under NAMAS [10]. This seems not to distinguish between calibration and testing as accredited by NATLAS [11]. A caveat is also given on quality assurance, in that the test sample should be representative of the actual product which will be supplied. On the basis of the work of Jespersen [12], it is recommended that the thermal conductivities of masonry materials should be derived from measurements made in the moisture content range of 1-5% by volume. This is to ensure that the Jakob correction will not lead to an erroneous result particularly where the measurements are carried out on test specimens in the dry state. Finally, reference is made to the thermal conductance testing of complete or almost complete constructions. The absence of a precise UK standard is given as the reason for expressing doubt over thermal properties determined in this way. It is also noted that the Jakob correction cannot be applied to thermal conductance test measurements. A set of measurements at the minimum of three moisture contents spanning the standard moisture content is recommended.

For specific heat there is no reference to any test method, and BS 874 offers only the broadest of guidance. With water vapour transmission, examination of the source literature shows that some of the data were derived using dry- and/or wet-cup techniques but under a variety of conditions [4]. No method is mentioned in the other reference [5]. With moisture content, the weight of a sample of wet material is compared with the dry weight.

No test method is identified for longwave emittance or shortwave absorptance.

### 3.5.5 Use of Data

The general context of all thermal properties is steady state heat transfer calculation. As noted above, Section A3 gives values of bulk density and thermal conductivity for a broad range of materials in Table A3.22, and values modified for standard moisture content for masonry materials in Table A3.1. It is, however, the representative subset in Table A3.15 that is intended to be used in the calculation of U- and Y-values. The computation of the thermal resistance of non-homogeneous and heat-bridged constructions from the properties of the individual material components is recognised as being complicated. Nevertheless, the 1980 edition of Section A3 is the first edition to incorporate a simple calculation method for dealing with thermal bridges. It is, therefore, still proposed that the thermal performance of building constructions be computed from the individual properties of their component material parts, albeit from a modified subset.

The vapour resistivities and resistances are intended to be used for simple steady state (non-condensing) calculations of moisture transmission through building structures.

### 3.5.6 References


1. CIBSE Guides A2, A3, A5, A10 & C3, Chartered Institution of Building Services Engineers, London, 1980, 1982 and 1986.
2. BS 3958, ‘Thermal insulating materials’ (6 parts).
3. Mochlinski K and Gosland L ‘Field Evidence on Soil Properties Affecting Cable Ratings’, ERA 70-88, Electrical Research Station, 1970.
4. Prangnell R D ‘The water vapour resistivity of building materials: a literature survey’ **Materiaux et Constructions** V4(24), November 1971.
5. ‘Condensation’, **Digest 110** Building Research Establishment, 1972.
6. Johansson C H ‘Moisture transmission and moisture distribution in building materials’ **Technical Translation TT 189** National Research Council, Canada.
7. Arnold P J ‘Thermal Conductivity of Masonry Materials’ **Current Paper CP 1/70** Building Research Establishment, 1970.

8. Jakob M **Heat Transfer, Part 1** Chapman Hall, London, 1949.

9. BS 874 'Methods for determining thermal insulating properties with definitions of thermal insulating terms' Nov. 1973 with amendment 3006, Aug. 1979.

10. **NAMAS document M1** 'Introducing NAMAS National Physical Laboratory, Middlesex, 1985.

11 **NATLAS document N1** 'NATLAS Accreditation Standard' National Physical Laboratory, Middlesex, 1986.

12. Jespersen H B 'Thermal Conductivity of Moist Materials and its Measurement' **JIHVE** V21, pp157-74, August 1953.

## 3.6 CSTC, Belgium

### 3.6.1 General Observations

This database has been derived to provide a common, verified set of values for use in calculations carried out in accordance with the requirements of the Thermal Regulation for new dwellings adopted on 29 February 1984 by the Executive of the Flemish speaking region of Belgium. This regulation, which concerns thermal insulation, requires U-values to be calculated and submitted along with the application for a building permit. Although only two thermal calculation procedures are allowed, it was recognised that the wide variation in available values for thermal properties being used in calculations made the assessment of submissions difficult. Hence, there was a need to produce a set of agreed values to be used with the specified calculation procedures.

The values for both thermal and water vapour transmission calculations are listed together. The properties for any building material listed can be read off in a single line. Although not included in the material provided, the accompanying documentation refers to the fact that tables of precalculated U-values for different types of partitions are also available to designers. Preference is given to values appearing in Belgian Standard NBN B62-002 [1]. Only three other sources are recognised for the purposes of providing additional values, chiefly, but not exclusively, for moisture transmission properties [2, 3 & 4]. A useful feature of this database is that the source of the values for each material is quoted, although only four sources are involved.

### 3.6.2 Classifications

The database is divided into a series of sections, each identified with a particular building material type. Within each section, values are listed against the various forms in which the material may appear. A subclassification of thermal properties according to whether they apply to inside or outside use is enforced, whether appropriate or not to the use of the particular material. Where a material is not suitable for outside use, it is positively identified as being unsuitable - but only if a value for the dry state is quoted. Inside use is appropriate to any layer which cannot be wetted by rain or which may dry to hygroscopic equilibrium after an initially high moisture content. Outside use applies to any layer that can be wetted by rain.

Non-homogeneous materials, for which thermal conductivity is not a defined property, are listed in a separate section. Here, the values of thermal resistance and the associated thickness of the manufactured unit are recorded instead. Examination of this section reveals that it refers to products containing voids or composed of different material layers. Nevertheless, a material such as cellular concrete appears in the homogeneous material section where it is associated with both thermal conductivity and thermal resistance values for a known thickness. Materials which support modes of heat transfer other than conduction are generally included with those which do not. Hence, the values of conductivity shown include values of apparent conductivity. In addition to wet- and dry-cup values for the dimensionless water vapour diffusion resistance factor $\mu$ or, for materials without a conveniently defined thickness d (m), of the product $\mu \times d$, there is an additional subclass of values of $\mu \times d$ which take account of joints and leakages for the purposes of practical calculations.

### 3.6.3 Sources of Data

Three sources are acknowledged for thermal conductivity and specific heat [1, 2 & 3]. The moisture transmission and content data are attributed to NBN B62-002 and three other sources [2, 3 & 4]. In the case of longwave emissivity and shortwave absorptivity no source is given.

### 3.6.4 Test Methods

No test methods are identified for thermal conductivity. However, direct communication with CSTC has established that this parameter is based on NBN B62-200, NBN B62-201 and B62-203. Allied density measurements are carried out according to Belgium Technical specifications STS 08.82.41 and STS 08.82.5. No test method is identified for specific heat, moisture content or water vapour transmission. For the latter, direct communication with CSTC revealed that diffusion resistance factor measurements are carried out according to DIN 52615.

**3.6.5 Use of Data**

As noted earlier, the purpose of this database is specifically related to the need to provide explicit calculations of heat losses and condensation risk for new dwellings when applying for a building permit. As such, the data set provides a common, verified set of values for use in calculation in accordance with the requirements of the Thermal Regulation adopted by the Executive of the Flemish speaking region of Belgium on 29 February 1984. The Regulation further stipulates the methods of calculation, and only two methods are recognised, namely K 70 and Be 500.

**3.6.6 References**


1. Belgium Standard NBN B62-002, Thermische geleidbaarheid van de bouwmaterialen/Conductivities thermiques des materiaux de construction, Brussel 1980.
2. van Hees R ‘Eigenschappen van bouwen isolatiematerialen’, No.9, 3eme edition, Publie par le Stichting Bouwresearch.
3. Hens H ‘Catalogue des properties hygothermiques des materiaux de construction et d’isolation’, Publie par les Services de Programmation de la Politique Scientifique, 1984.
4. Uyttenbroek J and Carpentier G ‘Coefficient de conduction de la vapeur d’eau Delta et facteur de resistance a la diffusion Mu des materiaux de construction’, Cours - conferences No.35 du CSTC, 1983.

## 3.7 DOE-2, USA

### 3.7.1 General Observations

This database, obtained from the Lawrence Berkeley Laboratory, contains values of thickness, bulk density, specific heat, thermal conductivity and thermal resistance for building and insulating materials. Each entry for a given material is associated with a single value for each property. Not all the entries are complete. Direct enquiry to the Lawrence Berkeley Laboratory has established that the materials properties were compiled by a student 11 years ago (his whereabouts is now unknown). It is known that, for the most part, the data are based on information developed by ASHRAE but, unfortunately, there is now no documentary evidence of the exact references for the data. The numerical values are quoted in Imperial units. Conversion to SI units is therefore required to bring them into line with other databases.

### 3.7.2 Classifications

The database is divided into listings for building materials and for insulating materials. A third listing, for air films and spaces, also exists. The entries for building materials are listed basically by product form in alphabetic order. Those for insulation materials are listed by generic material type but not in alphabetic order. In each listing, values are listed against the various forms and thicknesses in which the product appears. The separate listing of insulation materials does not appear to be a recognition of the concept of apparent thermal conductivity. The values quoted show no variation with thickness, and there is no information on other non-linear behaviour such as, for instance, variation with density or temperature. There is also no separate section for non-homogeneous materials. Examination of the database shows that building products such as blocks with voids or insulation fillings appear alongside homogeneous products, with both a thermal conductivity and a thermal resistance quoted. Clearly, in the case of non-homogeneous products, the thermal conductivity quoted is peculiar to the product form as, indeed, is the thermal resistance.

### 3.7.3 Sources of Data

With conductivity and specific heat, the listings are extracted from a single document [1]. However, as noted earlier, no record can be found of the source references for the values in this document or elsewhere. There are no data for vapour transmission, moisture content, longwave emissivity and shortwave absorptivity.

### 3.7.4 Test Methods

No test methods are specified.

### 3.7.5 Use of Data

If based on the work of ASHRAE 11 years ago, it can be inferred that the data are intended for use in manual thermal calculations.

### 3.7.6 References

1. **DOE-2 Reference Manual** Lawrence Berkeley Laboratory, Report No.LBL-8706, Rev.4, May 1984.

## 3.8 ESP, UK

### 3.8.1 General Observations

This database, obtained from the Energy Simulation Research Unit of the University of Strathclyde, contains values of thermal conductivity, bulk density, specific heat capacity, longwave emissivity, shortwave absorptivity and vapour diffusivity for a range of building and insulating materials. Each entry for a given homogeneous material is associated with a single value for each property. The data-set was compiled in 1976 by reviewing the (then) IHVE guide, various technical publications and manufacturers' catalogues. Only those materials for which the various sources were in agreement were included in the final data-set. Unfortunately the process documentation has been lost and so the original source of the entries are unknown.

### 3.8.2 Classifications

The database is divided into 14 classifications as follows:

Asbestos
Asphalt and Bitumen
Brick
Carpet
Concrete
Earth
Glass
Insulation
Metal
Plaster
Screeds and Renders
Stone
Tiles
Wood

with some 108 materials arranged in alphabetical order. No information is given on the variation of properties with temperature or moisture content.

### 3.8.3 Sources of Data

All data were extracted from a single document [1]. However, as noted earlier, no record can be found of the source references for the values in this document or elsewhere.

### 3.8.4 Test Methods

No test methods are specified.

### 3.8.5 Use of Data

The data are intended for use with the ESP system, and to this end a database management program exists which allows the materials to be combined into multi-layered constructions for use at building definition time.

### 3.8.6 References

1. **ESP Reference Manual** Energy Simulation Research Unit, University of Strathclyde, September 1989.

## 3.9 France

### 3.9.1 General Observations

This database, obtained from the CSTB, contains values of bulk density and thermal conductivity for building and insulating materials. Each material is associated with a single value of thermal conductivity. The temperature limits for use of the listed values are -20°C to 30°C [1]. Explanatory notes are included in the listings. Standards relevant to material specifications are noted. The text accompanying this database draws attention to further extensive listings of the thermal resistances of masonry walls, hollow concrete floors, etc. In other words, extensive pre-calculated thermal resistances for building constructions are available.

### 3.9.2 Classifications

The entries in this database are by broad generic building material type. Within each entry, values are listed against the various forms in which the material appears. There is no separate section for non-homogeneous materials. Examination of the database shows that materials for which the thermal conductivity is an apparent property are included. This is made clear in the one particular case of stonework including joints.

### 3.9.3 Sources of Data

Thermal conductivity values are attributed to a single French Standard [2]. The other properties are not referenced.

### 3.9.4 Test Methods

No test methods are identified.

### 3.9.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances.

### 3.9.6 References

1. IEA Annex XIV, ‘Condensation and Energy: 1. Material Properties’, Laboratorium voor Bouwfysica, Katholieke Universiteit Leuven.

2. DTU, Regles Th-K77, Cahiers du CSTB, Cahier 1478, Nov.1977.

## 3.10 Germany

### 3.10.1 General Observations

This database contains values of bulk density, thermal conductivity and vapour diffusion resistance for building and insulating materials. Each material is associated with a single value of thermal conductivity. In general, the vapour diffusion resistance is represented by both a lower and upper value. The temperature limits for use of the listed values are -20°C to 30°C [1]. Standards relevant to particular material specifications are comprehensively noted in the listing. A series of explanatory notes is appended which are referred to in the listing.

### 3.10.2 Classifications

The entries in this database are classed by constructional element type in some cases, and by generic building material type in others. Within each class, values are listed against the various forms in which the relevant material appears. There is no separate section for non-homogeneous materials. Materials for which the thermal conductivity is an apparent property are included without comment.

### 3.10.3 Sources of Data

Thermal conductivity and vapour diffusion resistance values are attributed to a single German Standard [2].

### 3.10.4 Test Methods

No test methods are identified.

### 3.10.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances.

### 3.10.6 References

1. IEA Annex XIV, ‘Condensation and Energy: 1. Material Properties’, Laboratorium voor Bouwfysica, Katholieke Universiteit Leuven.
2. DIN 4108, Warmeschutz im Hochbau, Warme und feuteschutztechnische Kenwerte, August 1981.

## 3.11 The Netherlands

### 3.11.1 General Observations

This database contains a wide number of properties. In addition to the more commonly quoted properties associated with the transmission of heat and water vapour through building and insulating materials, it also lists values for the thermal coefficient of linear expansion, the equilibrium moisture content as a function of humidity, irreversible shrinkage due to drying and modulus of elasticity. The listed values apply to materials at normal environmental temperatures. Emissivities are quoted for 0°C to 200°C; otherwise the temperature limits for use of the listed values are -10°C to 30°C [1].

The change in thermal conductivity of insulating plastic foams as the Freon gas disappears over time is specifically noted.

### 3.11.2 Classifications

The database is divided into three main sections identified respectively with thermal properties, hygrometric properties and the properties of thermal expansion, elastic modulus and irreversible shrinkage. Additional smaller tabulations list longwave emissivities for surfaces, thermal conductivities of gases and hygrometric properties for vapour barriers.

The entries in each of the three main sections are listed identically by broad generic building material type. Within each entry, values are listed against the various forms in which the material appears, although some of the forms may not appear in all lists. In each case, the listing of materials and their densities is repeated. In the case of thermal conductivity, there is a subdivision of values into those for use in indoor conditions and those for use in outdoor conditions. Examination of the database also shows that materials for which the thermal conductivity is an apparent property are included. However, there is no reference to apparent thermal conductivity as such. There is no separate section for non-homogeneous materials.

The listings are accompanied by a few explanatory footnotes. One of those to the hygrometric properties listing is of interest as it draws attention specifically to the strong rise in permeability of certain timber products above a relative humidity of 60%.

### 3.11.3 Sources of Data

Thermal conductivity, specific heat, vapour transmission and long-wave emissivity values appear in a single report [2]. Moisture content values for indoor use are attributed to any material layer which cannot be wetted by rain or which will come to hygroscopic equilibrium with the environment. The values for outdoor use are to be attributed to any material wetted by rain [3]. There is no reference to shortwave absorptivity.

### 3.11.4 Test Methods

No test method is identified for any parameter.

### 3.11.5 Use of Data

The data are usable for both steady state and dynamic calculations.

### 3.11.6 References

1. IEA Annex XIV, 'Condensation and Energy: 1.Material Properties' Laboratorium voor Bouwfysica, Katholieke Universiteit Leuven.
2. 'Eigenschappen van bouwen isolatiematerialen' Report no.17, Stichting Bowresearch.
3. Belgium Standard NBN B62-002, Thermische geleidbaarheid van de bouwmaterialen - Conductivities thermiques des materiaux de construction, 1980.

## 3.12 Italy

### 3.12.1 General Observations

This database contains values of bulk density and thermal conductivity for building and insulating materials and thermal conductances for some non-homogeneous products. It is the only current database examined (apart from DOE-2) which is not quoted in SI units. The introductory heading to the listing states that the values are to be taken as representing conditions of normal humidity and not exposed to bad weather unless otherwise stated. The temperature limits for use of the listed values are -10°C to 30°C [1].

### 3.12.2 Classifications

The entries in this database are by building material type simply listed alphabetically. While there is no general subdivision of values into those for use in indoor conditions and those for use in outdoor conditions, some materials are identified with both an internal and an external value of thermal conductivity. There is a separate section for non-homogeneous materials for hollow brick and blockwork. The dimensions and geometry of each manufactured unit are shown associated with a value of thermal conductance. Examination of the database shows that materials for which the thermal conductivity is an apparent property are included. However, there is no reference to apparent thermal conductivity as such.

### 3.12.3 Sources of Data

Thermal conductivity values appear in a single Italian Standard [2]. Contrary to what has been stated elsewhere [1], the listing does distinguish between internal and external climatic conditions with respect to humidity and, hence, moisture content.

### 3.12.4 Test Methods

No test methods are identified.

### 3.12.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances.

### 3.12.6 References

1. IEA Annex XIV, ‘Condensation and Energy: 1. Material Properties’, Laboratorium voor Bouwfysica, Katholieke Universiteit Leuven.

2. Italian Standard **UNI 7357**.

## 3.13 India

### 3.13.1 General Observations

The context of this database differs from most of the others examined in that the main problem of thermal design is to minimise solar heat gain rather than to prevent heat loss. Hence the thermal properties quoted are for a mean temperature of 50°C which is appropriate to the tropical Indian climate.

This database contains values of bulk density, thermal conductivity and specific heat capacity for building and insulating materials. It refers to a relatively limited set of materials that are appropriate to the types of construction found in India. A single value for each property is attributed to each material. Listings also exist for the thermal performance of walls and roofs, both flat and sloping. These include U-values and other factors useful in the calculation of fabric solar gain [1].

### 3.13.2 Classifications

Entries are listed either under building materials or insulating materials. Each entry is numbered separately, both for different materials and variants of the same material. The entries do not follow alphabetically. Examination of the database shows that materials for which the thermal conductivity is an apparent property are included. However, there is no reference to apparent thermal conductivity as such, nor any reference to non-homogeneous materials.

### 3.13.3 Sources of Data

Thermal conductivity and specific heat values are attributed to a single Indian Standard [2]

### 3.13.4 Test Methods

No test methods are referenced although the test methods for determining thermal conductivity are for materials in the dry state.

### 3.13.5 Use of Data

The data are intended for use in the calculation of steady state thermal transmittances and in pseudo steady state heat transfer calculations for solar gain.

### 3.13.6 References

1. Building Digest 138, ‘Thermal Performance of Wall and Roof Sections’, Central Building Research Institute, Roorkee, India, February 1980.
2. **IS:3792-1978**, ‘Revised guide for heat insulation of non industrial buildings’, Indian Standards Institution, New Delhi, India.
3. **IS:3346-1980**, ‘Guarded Hot Plate Apparatus’, Indian Standards Institution, New Delhi, India.
4. **IASTM C177-1966**, ‘Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by means of a Guarded Hot Plate Apparatus’, American Society for Testing Materials, Philadelpia, USA.

## 3.14 Leeds University

### 3.14.1 General Observations

Although not a database in the same sense as the others mentioned above (data are not collected together in a single document or computer database), many measurements have been carried out by staff at Leeds University, particularly on concrete and mortar [1,2,3]. Results give conductivity for a range of densities and moisture content of each material. Where data are expressed at the ‘standard’ 3% moisture content, corrections were made using the Jakob correction factors.

### 3.14.2 Classifications

Results are often presented in graphical format, with measured values of conductivity given against different density values. Some tabular values are given, with each entry being listed by mortar grade, mix proportions (cement:sand), density, moisture content and resulting conductivity.

### 3.14.3 Sources of Data

All data are obtained directly from measurement.

### 3.14.4 Test Methods

All measurements are made to BS 874, in a plain hot plate apparatus. Apparatus calibration was regularly monitored by duplicate testing of selected samples at a BCS laboratory.

### 3.14.5 Use of Data

The data are not intended for any specific purpose. The lack of any surface properties makes their widespread use limited.

### 3.14.6 References

1. PhD Thesis. Aspects of mix proportioning and moisture content on the thermal conductivity of lightweight aggregate concretes. J.A. Tinker, University of Salford, 1984.
2. Tinker, J.A. & O’Rouke, A. Development of a low thermal conductivity building mortar. Second Europ. Conf. on Architecture, Paris, 4th - 8th Dec., 1989.
3. Tinker, J.A. 1989 Personnel communication.

# Section Four: The Merging Process and the Final Data-sets

## 4.1 Computational Context

A distinction can be made between the context of design calculations and that of calculations intended to simulate reality. Design calculations are carried out to ensure compliance with set target values for conditions as specified in building regulations and codes. They only make sense, of course, if they are referred to a single database of material properties. As a result, standard lists of values have been generated in many countries to support design calculations.

The context of such calculations is not to simulate any particular real behaviour, but to minimise the risk of failure such as excessive heat loss or the occurrence of condensation. In practice, the choice of calculation procedures, target conditions and associated standard lists of material property values reflect the need for robust methods of risk assessment that implicitly accept the inherently uncertain nature of building material property values. The disadvantage of such procedures is that they are not capable of providing much insight into the detailed hygrothermal behaviour of buildings, particularly where new materials, systems or situations may be involved. Nevertheless, the inherent uncertainty of present building material property values has to be recognised as also placing a limit on the accuracy with which any real situation can be modelled, irrespective of the degree of accuracy of the computational model.

The recognition that all predictive methods concerning the behaviour of buildings and their components operate within a probabilistic context has been, and continues to be, a source of considerable interest and concern. A useful overview of the problem has been presented by Keeble [1]. Computational techniques also influence the choice of data. Given that design calculations have evolved within the context of simplified, steady state models, the range of properties required to be listed has been restrictive, and has influenced the range and kind of test procedures currently in use. One aspect of this has been the move towards the steady state testing of whole building assemblies, first in North America and latterly in Europe, as a preferred option to computing behaviour from individual material constituents.

The 1985 edition of the ASHRAE Handbook of Fundamentals departed from previous practice by removing tables of calculated U-values for building assemblies in favour of placing reliance on U-values determined by calibrated or guarded hot box tests. The justification was based on the difficulty of calculating the thermal performance of heat bridged assemblies. Irrespective of the merits of the argument, current hot box test methods provide only steady state values of overall heat conductance for particular assemblies, not materials. This suggests that testing procedures may be becoming less helpful in providing data to meet the needs of dynamic computer modelling.

## 4.2 The Merging Process

From consideration of the use context of the materials, and the reliability/scope of their underlying test procedures, the following mechanism was adopted for material grouping:

1. Materials with real conductivities which are not affected by moisture.
2. Materials with apparent conductivities which are not affected by moisture.
3. Materials with real conductivities which are strongly affected by moisture but whose vapour permeabilities are not affected by moisture.
4. Materials with real conductivities which are not affected by moisture but whose vapour permeabilities are strongly affected by moisture.

Such a mechanism is strongly related to the reliability of the test procedures, with the certainty decreasing from 1 to 4. For example the vapour permeability of type 4 materials is underestimated in current data bases for materials at high humidities. This mechanism gives rise to the following four material categories:

*Category 1: Impermeables*

Materials which act as a barrier to water in the vapour and/or liquid states and do not alter their hygrothermal properties by absorbing or being wetted by water.

*Category 2: Non-Hygroscopic*

Lightweight insulations, such as mineral wools and foamed plastics, which display water vapour permeability, zero hygroscopic water content and an apparent thermal conductivity, and which operate under conditions of air-dry equilibrium normally protected from wetting by rain.

*Category 3: Inorganic-Porous*

Masonry and related materials which are inorganic, porous and may contain significant amounts of water due to hygroscopic absorption from the air or wetting by rain, which affects their hygrothermal properties and their thermal conductivity in particular.

*Category 4: Organic-Hygroscopic*

Organic materials such as wood and wood based products which are porous and strongly hygroscopic and which display a highly non-linear water vapour permeability characteristic.

It is important to note that the data presented in the tables which follow have not been subject to any verification procedure. They are merely the original data reorganised and reclassified.

Within each table, the ‘Source’ column refers to the original data-set from which the material entry was extracted. The key letters are defined in Section 2.1. Owing to the large number of data points for similar materials, but of different densities, from Leeds University, only a representative sample of their data is presented.

## 4.3 Impermeables

This category contains all materials which act as a barrier to water in the vapour and/or liquid states and do not alter their hygrothermal properties by absorbing water.

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | **$C_p$** ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Asphalt ***** | | | | | |
| Asphalt | | C | 0.50 | 1700. | 1000. |
| Asphalt | | E | 1.20 | 2300. | 1700. |
| Asphalt flooring with foamed slag | Dry | C | 0.22 | 1200. | - |
| Asphalt, laid | | BS | 0.5 | - | - |
| Asphalt roofing | Dry | C | 0.43 | 1600. | - |
| Asphalt roofing | | C | 0.50 | 1700. | - |
| Asphalt roofing | | C | 0.58 | 1925. | - |
| Asphalt mastic roofing | | E | 1.15 | 2325. | 837. |
| Asphalt reflective coat | | E | 1.20 | 2300. | 1700. |
| Asphalt roofing, inert mineral | Dry | C | 0.43 | 1600. | - |
| Asphalt roofing, inert mineral | Dry | C | 0.58 | 1925. | - |
| Heavy mastic asphalt roofing, 20% grit | Dry | C | 1.15 | 2325. | - |
| Mastic asphalt | | G | 0.70 | 2000. | - |
| Mastic asphalt flooring with limestone | Dry | C | 1.22 | 2250. | - |
| Mastic asphalt roofing, heavy, 20% grit | Dry | C | 1.15 | 2325. | - |
| Mastics for joints and water-proofing | $\rho$ 1000-1650 | F | 0.40 | 1325. | - |
| Poured asphalt | NBN B46-101, Low exp. | B | 1.20 | 2100. | - |
| Poured asphalt | NBN B46-101, Std exp. | B | 1.20 | 2100. | - |
| Poured asphalt | NBN | T | 1.20 | 2100. | 920. |
| Waterproofing materials, pure asphalt | | F | 0.70 | 2100. | - |
| Waterproofing materials, sanded asphalt | | F | 1.15 | - | - |
| ***** Bitumen ***** | | | | | |
| Bitumen | | G | 0.17 | 1100. | - |
| Bitumen composit, flooring | | E | 0.85 | 2400. | 1000. |
| Bitumen containing mineral matter | Dry | C | 1.20 | 2250. | - |
| Bitumen emulsion flooring, cement & aggr. | | C | 0.60 | 2000. | - |
| Bitumen emulsion flooring, cement & aggr. | Dry | C | 0.55 | 1600. | - |
| Bitumen flooring, inert mineral matter | Dry | C | 0.75 | 1700. | - |
| Bitumen, pure | Dry | C | 0.16 | 1055. | - |
| Bitumen, sand or slate filled | Dry | C | 0.26 | 1300. | - |
| Bitumen, sand or slate filled | Dry | C | 0.35 | 1450. | - |
| Bitumen, sand or slate filled | Dry | C | 0.50 | 1600. | - |
| Bituminous insulation, all types | SPPS | T | 0.20 | 1000. | 1700. |
| Bituminised roofing sheets | | G | 0.17 | 1200. | - |
| Non-insulated bituminised roofing sheets | | G | 0.17 | 1200. | - |
| ***** Ceramics (Glazed) ***** | | | | | |
| Ceramic and glazed mosaic | | G | 1.20 | 2000. | - |
| Ceramic tiles | CSTC | T | - | 2000. | - |
| Glazed ceramic | SPPS | T | 1.40 | 2500. | 840. |
| ***** Floor Tiles ***** | | | | | |
| Epoxy silica flour | Dry, 33% Wht. | C | 0.34 | 1400. | - |
| Pitch flooring with inert mastic mineral matter | Dry | C | 0.68 | 1850. | - |
| Pitch mastic flooring | Dry | C | 1.10 | 2250. | - |
| ***** Glass ***** | | | | | |
| Cellular glass | SPPS, $\rho$ 115-129 | T | 0.047 | 122. | - |
| Cellular glass | SPPS, $\rho$ 130-144 | T | - | 137. | - |
| Cellular glass | $\rho$ 120-130 | F | 0.05 | 125. | - |
| Cellular glass | $\rho$ 130-140 | F | 0.055 | 135. | - |
| Cellular glass | $\rho$ 140-180 | F | 0.063 | 160. | - |
| Cellular glass board | | A | 0.051 | 136. | 754. |
| Cellular glass in sheets | NBN, $\rho$ 120-130 | T | 0.045 | 125. | 840. |
| Cellular glass in sheets | NBN, $\rho$ 130-140 | T | 0.048 | 135. | 840. |
| Cellular glass in sheets | NBN, $\rho$ 140-180 | T | 0.053 | 160. | 840. |
| Cellular glass slab | | C | 0.063 | 175. | - |
| Cellular glass, calcium silicate | At 10°C | A | 0.04759 | 136. | - |
| Cellular glass, calcium silicate | At 148°C | A | 0.07066 | 136. | - |
| Cellular glass, calcium silicate | At 23.8°C | A | 0.05047 | 136. | - |
| Cellular glass, calcium silicate | At 260°C | A | 0.10094 | 136. | - |
| Cellular glass, calcium silicate | At 37.7°C | A | 0.05191 | 136. | - |
| Cellular glass, calcium silicate | At 371°C | A | 0.14853 | 136. | - |
| Cellular glass, calcium silicate | At 93.3°C | A | 0.06056 | 136. | - |
| Cellular glass, in granules | Low exp., $\rho$ 150-200 | B | 0.07 | 175. | - |
| Cellular glass, in sheets | Low exp., $\rho$ 120-130 | B | 0.045 | 125. | - |
| Cellular glass, in sheets | Low exp., $\rho$ 130-140 | B | 0.048 | 135. | - |
| Cellular glass, in sheets | Low exp., $\rho$ 140-180 | B | 0.053 | 160. | - |
| Foam glass | $\rho$ 100-150 | G | 0.045 | 125. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Foam glass | $\rho$ 100-150 | G | 0.05 | 125. | - |
| Foam glass | $\rho$ 100-150 | G | 0.05 | 125. | - |
| Foam glass | $\rho$ 100-150 | G | 0.06 | 125. | - |
| Foam glass | Low exp., $\rho$ 120-150 | S | 0.052 | 135. | 840. |
| Foam glass | At 50°C | I | 0.055 | 160. | 750. |
| Foam glass | At 50°C | I | 0.056 | 127. | 750. |
| Glass | | F | 1.15 | 2700. | - |
| Glass | | G | - | 2500. | - |
| Glass | | I | 1. | 2350. | 880. |
| Glass | NBN | T | 1. | 2500. | 840. |
| Glass | SPPS | T | - | 2700. | - |
| Glass | Low exp. | B | 1. | 2500. | - |
| Glass | Std exp. | B | 1. | 2500. | - |
| Glass 4mm clear float | | E | 1.05 | 2500. | 750. |
| Glass 6mm Antisun | | E | 1.05 | 2500. | 750. |
| Glass block | | E | 0.7 | 3500. | 837. |
| Glass cloth, woven | | C | 0.06 | 480. | - |
| Glass cloth, woven | | C | 0.09 | 800. | - |
| Glass, expanded or foamed | | BS | .063 | - | - |
| Glass plate | | E | 0.76 | 2710. | 837. |
| Glass sheet | | BS | 1. | - | - |
| Glass sheet, flint | | C | 0.7 | 3500. | - |
| Glass sheet, heat resisting | | C | 1.1 | 2250. | - |
| Glass sheet, window | | C | 1.05 | 2500. | - |
| Glass bricks | SBR | T | 1.4 | 2500. | 840. |
| Glass, mirror and float | Low exp. | S | - | 2500. | 840. |
| Glass, mirror and float | Std exp. | S | 2.8 | 2500. | 840. |
| Hollow glass block wall | | C | 0.68 | - | - |
| Ceramic glass | | S | 1.4 | 2500. | 840. |
| ***** Linoleum ***** | | | | | |
| Cork linoleum | | G | 0.081 | 700. | - |
| Linoleum | | G | 0.17 | 1000. | - |
| Linoleum | NBN | T | 0.19 | 1200. | 1470. |
| Linoleum | SPPS | T | - | 1200. | - |
| Linoleum | Low exp. | S | 0.17 | 1200. | 1470. |
| Linoleum compound coating | | G | 0.12 | 100. | |
| Linoleum tile | | D | - | 1730. | 1256. |
| Linoleum, in-laid | | C | 0.22 | 1150. | - |
| Linoleum, PVC tiles | Low exp. | B | 0.19 | 1200. | - |
| P.V.C. linoleum | | C | 0.22 | 1600. | - |
| Plastic linoleum | | C | 0.35 | 1750. | - |
| ***** Metal ***** | | | | | |
| Aluminium | | S | 200. | 2800. | 880. |
| Aluminium | SBR | T | 200. | 2800. | - |
| Aluminium | | E | 210. | 2700. | 880. |
| Aluminium | | F | 230. | 2700. | - |
| Aluminium | NBN | T | 203. | 2700. | 880. |
| Aluminium | SPPS | T | 230. | 2700. | 880. |
| Aluminium (99%) | | B | 203. | 2700. | - |
| Aluminium | | G | 200. | - | - |
| Aluminium alloy | | C | 160. | 2800. | - |
| Aluminium or steel siding | | D | 45. | 7680. | 418. |
| Brass | | C | 130. | 8400. | - |
| Brass | | F | 110. | 8400. | - |
| Brass | SPPS | T | 110. | 8500. | 390. |
| Bronze | SPPS, $\rho$ 7400-8900 | T | 64. | 8150. | - |
| Copper | | S | 370. | 9000. | 390. |
| Copper | SBR | T | 370. | 9000. | - |
| Copper | SPPS | T | 380. | 8930. | 390. |
| Copper | | F | 380. | 8930. | - |
| Copper | | E | 200. | 8900. | 418. |
| Copper, commercial | | C | 200. | 8900. | - |
| Copper | NBN, $\rho$ 8300-8900 | T | 384. | 8600. | 390. |
| Copper | $\rho$ 8300-8900 | B | 384. | 8600. | - |
| Copper | | G | 380. | - | - |
| Duraluminium | | F | 160. | 2800. | - |
| Duraluminium | SPPS | T | 160. | 2800. | 580. |
| Iron | | S | 72. | 7900. | 530. |
| Iron | SBR | T | 72. | 7900. | 530. |
| Iron | | F | 72. | 7870. | - |
| Iron, cast | | C | 40. | 7000. | - |
| Iron, cast | | B | 56. | 7500. | - |
| Iron, cast | | F | 56. | 7500. | - |
| Iron, cast | NBN | T | 56. | 7500. | 530. |
| Iron, cast | SPPS | T | 56. | 7500. | 530. |
| Iron, corrugated | SPPS, dry | T | - | - | 1010. |
| Iron, corrugated | SPPS, moist | T | - | - | 1200. |
| Lead | | S | 35. | 12250. | 130. |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Lead | SBR | T | 35. | 12250. | - |
| Lead | | B | 35. | 11340. | - |
| Lead | | F | 35. | 11340. | - |
| Lead | NBN | T | 35. | 11340. | 130. |
| Steel | | B | 45. | 7800. | - |
| Steel | | E | 50. | 7800. | 502. |
| Steel | | S | 46. | 7800. | 505. |
| Steel | NBN | T | 45. | 7800. | 480. |
| Steel | SPPS | T | 41. | 7800. | 480. |
| Steel | SPPS | T | 52. | 7800. | 530. |
| Steel | | F | 52. | 7780. | - |
| Steel | | G | 60. | - | - |
| Stainless steel, 20% Ni | SPPS | T | 16. | 8000. | 480. |
| Stainless steel, 5% Ni | SPPS | T | 29. | 7850. | 480. |
| Steel, carbon | | C | 50. | 7800. | - |
| Steel, high alloy | | C | 15. | 8000. | - |
| Tin | SPPS | T | 65. | 7300. | 235. |
| Zinc | | S | 110. | 7200. | 390. |
| Zinc | SBR | T | 110. | 7200. | - |
| Zinc | | F | 112. | 7130. | - |
| Zinc | SPPS | T | 110. | 7130. | 390. |
| Zinc | | B | 113. | 7000. | - |
| Zinc | NBN | T | 113. | 7000. | 390. |
| Metal tray, floor | | C | 50. | 7800. | 480. |
| Metal or metal cladding | | BS | 50. | - | - |
| ***** Miscellaneous ***** | | | | | |
| Acrylic resin | Dry | C | 0.20 | 1440. | - |
| Alumina, activated gel | Dry, h.f. 100°C, c.f. 10°C | C | 0.13 | 700. | - |
| Artificial stone | | C | 1.30 | 1750. | - |
| Beeswax | Dry | C | 0.26 | 1000. | - |
| Butyl | SPPS | T | 0.20 | - | 1480. |
| EPS | | E | 0.03 | 25. | 1000. |
| Epoxy casting | Dry | C | 0.20 | 1200. | - |
| Epoxy glass cloth laminate | Dry | C | 0.38 | 1750. | - |
| Epoxy glass fibre | Dry | C | 0.23 | 1500. | - |
| Gasket material, graphited | | C | 0.40 | 1750. | - |
| Gasket material, metallic | | C | 0.40 | 1900. | - |
| Hard vulcanized sheet | | C | 0.30 | 1200. | - |
| Lubricating grease | | C | 0.14 | 950. | - |
| Melamine glass cloth | Dry | C | 0.55 | 2000. | - |
| Mica flakes bonded with shellac | | C | 0.31 | - | - |
| Muscorite sheet, mica | | C | 0.69 | 2900. | - |
| Porcelain Electrical grade | Dry | C | 1.44 | 2400. | - |
| Phlogonite sheet, mica | | C | 0.62 | 2900. | - |
| Pitch | Dry | C | 0.14 | 1000. | - |
| Plasticine | | C | 0.65 | 1760. | - |
| Putty | | C | 0.33 | 1350. | - |
| Resin bonded board | Dry | C | 0.30 | 1280. | - |
| Sealing compound, flexible | | C | 0.40 | 1350. | - |
| Solid alumina, electrical insulator | At 600°C | C | 9.00 | 3600. | - |
| Solid alumina, electrical insulator | Dry, at 100°C | C | 17.00 | 3600. | - |
| ***** Paint/Varnish ***** | | | | | |
| Aluminium paint | | C | 0.46 | - | - |
| Anti-condensation paint | | C | 0.16 | 800. | - |
| Zinc-filled paint | | C | 2.16 | 4645. | - |
| Thermo-setting varnish | | C | 0.19 | 1075. | - |
| Varnish | | C | 0.32 | - | - |
| ***** Polys (Man-Made) ***** | | | | | |
| Methyl polymethacrilates (plexiglass) | $\rho$ 1200-1300 | F | 0.20 | 1250. | - |
| Polyamides (nylon, rilsan) | $\rho$ 1000-1150 | F | 0.40 | 1075. | - |
| Polycarbonate | Dry | C | 0.23 | 1150. | - |
| Polyester, glass mat | Dry | C | 0.23 | 1450. | - |
| Polyesters | $\rho$ 1400-1700 | F | 0.40 | 1550. | - |
| Polyether, flexible sheet | Dry, h.f. 20°C, c.f. 0°C | C | 0.039 | 30. | - |
| Polyether, flexible sheet | Dry, h.f. 45°C, c.f. 20°C | C | 0.045 | 30. | - |
| Polyether, flexible sheet | Dry, h.f. 80°C, c.f. 20°C | C | 0.05 | 30. | - |
| Polyethylene, high density | Dry | C | 0.50 | 960. | - |
| Polyethylene, low density | Dry | C | 0.35 | 920. | - |
| Polyethylenes | $\rho$ 900-1000 | F | 0.40 | 950. | - |
| ***** PVC ***** | | | | | |
| PVC floor covering | Dry | C | 0.40 | - | - |
| PVC, rigid | Dry | C | 0.16 | 1350. | - |
| PVC | SPPS | T | 0.20 | - | 1480. |
| PVC sheet or tile | | BS | .83 | - | - |
| PVC tiles | NBN | T | 0.19 | 1200. | 1470. |
| Plastic coating | | G | 0.23 | 1500. | - |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ **(** $W/mK$ **)** | $\rho$ **(** $kg/m^3$ **)** | $\mathbf{C_p}$ **(** $J/kgK$ **)** |
|---|---|---|---|---|---|
| PVC | | E | 0.16 | 1379. | 1004. |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Roof covering ***** | | | | | |
| Roofing felt | | E | 0.19 | 960. | 837. |
| Roofing felt | Dry | C | 0.19 | 960. | - |
| Roofing felt | Dry | C | 0.20 | 1120. | - |
| ***** Rubber ***** | | | | | |
| Ebonite, cellular insultn. brd | Dry, h.f. 15°C, c.f. -70°C | C | 0.026 | 64. | - |
| Ebonite, cellular insultn. brd | Dry, h.f. 20°C, c.f. 0°C | C | 0.03 | 64. | - |
| Ebonite, cellular insultn. brd | Dry, h.f. 40°C, c.f. 20°C | C | 0.033 | 64. | - |
| Ebonite, solid sheet | Dry, at 20°C | C | 0.155 | 1200. | - |
| Ebonite, solid sheet | Dry, at 30°C | C | 0.160 | 1200. | - |
| Rubber sheet, 40% vul., mineral fill | | C | 0.29 | 1500. | - |
| Rubber sheet, 50% vul., mineral fill | | C | 0.20 | 1380. | - |
| Rubber, expanded board, rigid | | G | 0.03172 | 72. | 1675. |
| Rubber, hard | | E | 0.15 | 1200. | 1000. |
| Rubber, natural sheet | Dry | C | 0.16 | 930. | - |
| Rubber | CSTC, $\rho$ 1200-1500 | T | - | 1350. | - |
| Rubber | NBN | T | 0.17 | 1500. | 1470. |
| Rubber | SPPS, $\rho$ 1300-1500 | T | - | 1400. | - |
| Rubber, compacted | | G | 0.20 | 1000. | - |
| Rubber | Low exp., $\rho$ 1200-1500 | S | 0.23 | 1350. | 1470. |
| Rubber | Low exp. | B | 0.17 | 1500. | - |
| Rubber | Std exp. | B | 0.17 | 1500. | - |
| Rubber, floor covering sheet | | C | 0.40 | - | - |
| Rubber linoleum | | C | 0.31 | 1600. | - |
| Rubber tiles | | E | 0.30 | 1600. | 2000. |
| Rubber tiles | | C | 0.30 | 1600. | - |
| Rubber tiles | | C | 0.50 | 1800. | - |
| Rubber, cellular slab | | C | 0.04 | 80. | - |
| Rubber, cellular slab | | C | 0.043 | 160. | - |
| Rubber, cellular slab | | C | 0.055 | 240. | - |
| Rubber, cellular slab | | C | 0.085 | 400. | - |
| Silicon rubber sheet | At 20°C | C | 0.25 | 1200. | - |
| Silicon rubber sheet | At 100°C | C | 0.23 | 1200. | - |
| Synthetic rubber | $\rho$ 1300-1500 | F | 0.40 | 1400. | - |
| Synthetic rubber sheet | | C | 0.16 | 960. | - |
| Synthetic rubber sheet, mineral filled | | C | 0.27 | 1500. | - |

## 4.4 Non-Hygroscopic

This category includes lightweight insulations, such as mineral wools and foamed plastics, which display water vapour permeability, zero hygroscopic water content and an apparent thermal conductivity, and which operate under conditions of air-dry equilibrium normally protected from wetting by rain.

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Carpet/Underlay ***** | | | | | |
| Carpet, cellular rubber underlay | | E | 0.1 | 400. | 1360. |
| Carpet, synthetic | | E | 0.06 | 160. | 2500. |
| Carpeting, cellular rubber underlay | | C | 0.065 | 270. | - |
| Carpeting, cellular rubber underlay | | C | 0.1 | 400. | - |
| Carpeting, Wilton | | C | 0.058 | - | - |
| Wool felt underlay | | C | 0.045 | 160. | - |
| ***** Foams ***** | | | | | |
| Extruded polystyrene foam | $\rho$ >25 | G | - | 25. | - |
| Foamed slag, loose granules | | C | 0.1 | 480. | - |
| Foamed slag, loose granules | | C | 0.13 | 640. | - |
| Formo-phenol foam | $\rho$ 30-100 | F | 0.044 | 65. | - |
| Formo-phenol foam | $\rho$ 30-35 | F | 0.037 | 32. | - |
| Formo-phenol foam | $\rho$ 35-45 | F | 0.037 | 40. | - |
| Formo-phenol foam | $\rho$ 55-65 | F | 0.04 | 60. | - |
| Formo-phenol foam | $\rho$ 65-85 | F | 0.042 | 75. | - |
| PVC foam | SBR, $\rho$ 25-50 | T | 0.035 | 38. | - |
| PVC foam | SPPS, $\rho$ 25-50 | T | - | 38. | - |
| Phenol foam | NBN | T | 0.04 | - | 1470. |
| Phenol formaldehyde foam | CSTC, $\rho$ 25-200 | T | - | 112. | - |
| Phenol resin-rigid foam | $\rho$ >30 | G | 0.03 | 30. | - |
| Phenol resin-rigid foam | $\rho$ >30 | G | 0.035 | 30. | - |
| Phenol resin-rigid foam | $\rho$ >30 | G | 0.04 | 30. | - |
| Phenol resin-rigid foam | $\rho$ >30 | G | 0.045 | 30. | - |
| Phenolic foam | | C | 0.04 | 30. | 1400. |
| Phenolic foam, rigid | Low exp., $\rho$ 25-200 | S | 0.035 | 112. | 1470. |
| Polyethylene foam | SPPS | T | - | 45. | - |
| Polyisocyanate foam | Low exp., $\rho$ 30-60 | S | 0.03 | 45. | 1470. |
| Polyisocyanurate foam | SBR, $\rho$ 30-60 | T | 0.026 | 45. | - |
| Polystyrene rigid foam | | G | 0.025 | - | - |
| Polystyrene rigid foam | | G | 0.03 | - | - |
| Polystyrene rigid foam | | G | 0.035 | - | - |
| Polystyrene rigid foam | | G | 0.04 | - | - |
| Polyurethane foam | | A | 0.025 | 32. | - |
| Polyurethane foam | NBN, $\rho$ >30 | T | 0.028 | 30 | 1470. |
| Polyurethane foam | $\rho$ >37 | G | 0.03 | 37. | - |
| Polyurethane foam board | | E | 0.03 | 30. | 837. |
| Polyurethane foam, cavity wall insulation | Low exp., $\rho$ 10-15 | S | 0.045 | 12. | - |
| Polyurethane foam, gas freon filled | Low exp., $\rho$ 30-60 | S | 0.03 | 45. | 1470. |
| Polyurethane, untreated freon bubbles | SPPS, $\rho$ 20-40 | T | - | 30. | - |
| Polyvinal chloride, rigid foam, small pore | Dry, h.f. 20°C, c.f. 0°C | C | 0.034 | 50. | - |
| Polyvinal chloride, rigid foam, small pore | Dry, h.f. 20°C, c.f. 0°C | C | 0.035 | 25. | - |
| Polyvinal chloride, rigid foam, small pore | Dry, h.f. 20°C, c.f. 0°C | C | 0.035 | 80. | - |
| Polyvinal chloride, rigid foam, small pore | Dry, h.f. 45°C, c.f. 20°C | C | 0.04 | 50. | - |
| Polyvinal chloride, rigid foam, small pore | Dry, h.f. 45°C, c.f. 20°C | C | 0.041 | 25. | - |
| Polyvinyl chloride foam | Low exp., $\rho$ 25-50 | S | 0.035 | 37. | 1470. |
| Rigid polyurethane foam | $\rho$ >30 | G | 0.02 | 30. | - |
| Rigid polyurethane foam | $\rho$ >30 | G | 0.025 | 30. | - |
| Rigid polyurethane foam | $\rho$ >30 | G | 0.03 | 30. | - |
| Rigid polyurethane foam | $\rho$ >30 | G | 0.035 | 30. | - |
| Rigid polyurethane or polyisocyanurate non expanding foam panels | $\rho$ 40-60 | F | 0.033 | 50. | - |
| Rigid polyurethane or polyisocyanurate non expanding foam panels | $\rho$ 30-40 | F | 0.03 | 35. | - |
| Synthetic foam | Low exp., $\rho$ <100 | B | 0.04 | 100. | - |
| Synthetic foam, polyurethane | Low exp., $\rho$ >30 | B | 0.028 | 30. | - |
| Synthetic foams, extruded polystyrene | Low exp., $\rho$ >25 | B | 0.035 | 25. | - |
| Synthetic foams, general | NBN, $\rho$ <100 | T | 0.04 | 100. | 1470. |
| Urea formaldehyde | | E | 0.03 | 30. | 1764. |
| Urea formaldehyde foam | | C | 0.04 | 10. | 1400. |
| Urea formaldehyde foam, cavity insulation | Low exp. | S | 0.05 | 10. | - |
| Urea resin foam | Low exp., $\rho$ 8-20 | S | 0.054 | 14. | 1470. |
| Urea formaldehyde resin foam | $\rho$ >10 | G | 0.041 | 10. | - |
| Ureaformaldehyde foam | | A | 0.036 | 18.4 | - |
| Urethane foam | SBR, $\rho$ 8-20 | T | 0.054 | 14. | - |
| Urethane formaldehyde foam | NBN | T | 0.04 | - | 1470. |
| Urethane formaldehyde foam | SPPS, $\rho$ 6-12 | T | 0.05 | 9.87 | |
| Urethane formaldehyde foam | SPPS, $\rho$ 8-20 | T | - | 14. | - |
| Rubber, foam | | Y | 0.026 | 72. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Gases ***** | | | | | |
| Air | | C | 0.026 | 1.17 | - |
| Carbon dioxide | | C | 0.017 | 1.84 | - |
| Hydrogen | | C | 0.18 | 0.082 | - |
| ***** Glass Fibre/Wool ***** | | | | | |
| Glass fibre | | BS | .04 | - | - |
| Glass fibre quilt | | E | 0.04 | 12. | 840. |
| Glass fibre, lightwt mats & quilts | Conditioned, 40%rh | C | 0.032 | 65. | - |
| Glass fibre, lightwt mats & quilts | Dry at 10°C | C | 0.04 | 12. | - |
| Glass fibre, lightwt mats & quilts | Dry, h.f. 15°C, c.f. 0°C | C | 0.033 | 50. | - |
| Glass fibre, lightwt mats & quilts | Dry, h.f. 40dg, c.f. 10°C | C | 0.036 | 50. | - |
| Glass fibre, lightwt mats & quilts | Dry, h.f. 40dg, c.f. 10°C | C | 0.042 | 12. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 200°C, c.f. 40°C | C | 0.053 | 130. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 300°C, c.f. 40°C | C | 0.062 | 130. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 400°C, c.f. 40°C | C | 0.075 | 130. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 40°C, c.f. 10°C | C | 0.035 | 80. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 90°C, c.f. 40°C | C | 0.039 | 80. | - |
| Glass fibre, loose mats & quilts | Dry, h.f. 90°C, c.f. 40°C | C | 0.045 | 130. | - |
| Glass fibre, loose wool blanket | Dry, h.f. 100°C, c.f. 25°C | C | 0.046 | 145. | - |
| Glass fibre, loose wool blanket | Dry, h.f. 200°C, c.f. 25°C | C | 0.053 | 145. | - |
| Glass fibre, loose wool blanket | Dry, h.f. 300°C, c.f. 25°C | C | 0.062 | 145. | - |
| Glass fibre, loose wool blanket | Dry, h.f. 40°C, c.f. 25°C | C | 0.042 | 145. | - |
| Glass fibre, rigid pipe sections | Dry, h.f. 100°C, c.f. 25°C | C | 0.042 | 160. | - |
| Glass fibre, rigid pipe sections | Dry, h.f. 150°C, c.f. 25°C | C | 0.046 | 160. | - |
| Glass fibre, rigid pipe sections | Dry, h.f. 200°C, c.f. 25°C | C | 0.052 | 160. | - |
| Glass fibre, rigid pipe sections | Dry, h.f. 250°C, c.f. 25°C | C | 0.058 | 160. | - |
| Glass fibre quilt | | C | 0.04 | 12. | 840. |
| Glass fibre slab | | C | 0.035 | 25. | 1000. |
| Glass wool | SPPS, $\rho$ 10-14 | T | - | 12. | - |
| Glass wool | SPPS, $\rho$ 20-150 | T | - | 85. | - |
| Glass wool, unbonded | | I | 0.043 | 69. | 920. |
| Glass wool, unbonded | | I | 0.04 | 189. | 920. |
| Glasswool | | E | 0.04 | 250. | 840. |
| Glass fibre, strawboard like | Low exp., $\rho$ 250-350 | S | 0.085 | 300. | 2100. |
| Resin bonded glass wool | At 50°C | I | 0.04 | 16. | 1000. |
| Resin bonded glass wool | At 50°C | I | 0.036 | 24. | 1000. |
| Semi-rigid panels and supple fibre matting in rock wool or glass wool | | F | 0.041 | - | - |
| Fibreglass | $\rho$ 15-110 | Y | 0.03 | 60. | - |
| Mineral fibre, blanket, org. bonded | At -31°C | A | 0.02740 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At -31°C | A | 0.03028 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At -31°C | A | 0.03461 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At -17.7°C | A | 0.02884 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At -17.7°C | A | 0.03605 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At-17.7°C | A | 0.03172 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At -3.8°C | A | 0.03020 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At -3.8°C | A | 0.03317 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At -3.8°C | A | 0.03893 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At 10°C | A | 0.03172 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At 10°C | A | 0.03605 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At 10°C | A | 0.04182 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At 23.8°C | A | 0.03316 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At 23.8°C | A | 0.03893 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At 23.8°C | A | 0.04614 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At 37.7°C | A | 0.03461 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At 37.7°C | A | 0.04038 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At 37.7°C | A | 0.04903 | 12. | 712. |
| Mineral fibre, blanket, org. bonded | At 93.3°C | A | 0.04470 | 48. | 712. |
| Mineral fibre, blanket, org. bonded | At 93.3°C | A | 0.05335 | 24. | 712. |
| Mineral fibre, blanket, org. bonded | At 93.3°C | A | 0.06922 | 12. | 712. |
| Min. fibre, textile, org. bonded | At -17.7°C | A | 0.04038 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At -3.8°C | A | 0.04182 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At -31°C | A | 0.03893 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At 10°C | A | 0.04326 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At 148.8°C | A | 0.03542 | 24. | - |
| Min. fibre, textile, org. bonded | At 148.8°C | A | 0.05912 | 48. | 712. |
| Min. fibre, textile, org. bonded | At 148.8°C | A | 0.08652 | 16. | 712. |
| Min. fibre, textile, org. bonded | At 148.8°C | A | 0.09517 | 12. | 712. |
| Min. fibre, textile, org. bonded | At 148.8°C | A | 0.09806 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At 23.8°C | A | 0.03461 | 48. | 712. |
| Min. fibre, textile, org. bonded | At 23.8°C | A | 0.03890 | 24. | - |
| Min. fibre, textile, org. bonded | At 23.8°C | A | 0.04182 | 16. | 712. |
| Min. fibre, textile, org. bonded | At 23.8°C | A | 0.04470 | 12. | 712. |
| Min. fibre, textile, org. bonded | At 23.8°C | A | 0.04470 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At 37.7°C | A | 0.04614 | 10.4 | 712. |
| Min. fibre, textile, org. bonded | At 37.7°C | A | 0.04614 | 12. | 712. |
| Min. fibre, textile, org. bonded | At 37.9°C | A | 0.03605 | 48. | 712. |
| Min. fibre, textile, org. bonded | At 37.9°C | A | 0.04180 | 24. | - |
| Min. fibre, textile, org. bonded | At 37.9°C | A | 0.04470 | 16. | 712. |

| Material<br>Description | Condition/<br>Test | Source | $\lambda$<br>( $W/mK$ ) | $\rho$<br>( $kg/m^3$ ) | $C_p$<br>( $J/kgK$ ) |
|---|---|---|---|---|---|
| Min. fibre, textile, org. bonded | At 93.3°C | A | 0.04614 | 48. | 712. |
| Min. fibre, textile, org. bonded | At 93.3°C | A | 0.05620 | 24. | - |
| Min. fibre, textile, org. bonded | At 93.3°C | A | 0.06489 | 16. | 712. |
| Min. fibre, textile, org. bonded | At 93.3°C | A | 0.06920 | 12. | 712. |
| Min. fibre, textile, org. bonded | At 93.3°C | A | 0.07210 | 10.4 | 712. |
| ***** Insulating Boards/Lagging ***** | | | | | |
| Boiler lagging, heavy | Dry, h.f. 70°C, c.f. 25°C | C | 0.17 | 720. | - |
| Boiler lagging, heavy | Dry, h.f. 100°C, c.f. 25°C | C | 0.19 | 880. | - |
| Boiler lagging, light | Dry, h.f. 100°C, c.f. 25°C | C | 0.063 | 255. | - |
| Boiler lagging, light | Dry, h.f. 100°C, c.f. 25°C | C | 0.115 | 400. | - |
| Cavity insulation, bonded polystyrene granules | Low exp. | S | 0.045 | 16. | - |
| Calcium silicate insulating composition | Dry, h.f. 300°C, c.f. 25°C | C | 0.068 | 200. | - |
| Calcium silicate insulating composition | Dry, h.f. 400°C, c.f. 25°C | C | 0.075 | 200. | - |
| Calcium silicate insulating composition | Dry, h.f. 500°C, c.f. 25°C | C | 0.082 | 200. | - |
| Calcium silicate insulating composition | Dry, h.f. 600°C, c.f. 25°C | C | 0.090 | 200. | - |
| Calcium silicate insulating composition | Dry, h.f. 700°C, c.f. 25°C | C | 0.100 | 200. | - |
| Calcium silicate insulating slab | High density | C | 0.095 | 430. | - |
| Calcium silicate insulating | Dry, h.f. -10°C, c.f. -190°C | C | 0.034 | 160. | - |
| Calcium silicate insulating | Dry, h.f. 10°C, c.f. -10°C | C | 0.046 | 160. | - |
| Fibre insulating board | Conditioned | C | 0.053 | 240. | - |
| Fibre insulating board | Dry, h.f. 45°C, c.f. 20°C | C | 0.059 | 290. | - |
| Fibre insulating board | Dry | C | 0.052 | 265. | - |
| Fibre insulating board | Conditioned | C | 0.056 | 290. | - |
| Fibre insulating board | Damp | C | 0.065 | 320. | - |
| Fibre insulating board | Wet | C | 0.08 | 345. | - |
| Fibre insulating board | Conditioned | C | 0.056 | 280. | - |
| Fibre insulating board | Conditioned | C | 0.057 | 300. | - |
| Fibre insulating board | Conditioned | C | 0.059 | 320. | - |
| Fibre insulating board | Conditioned | C | 0.062 | 360. | - |
| Fibre insulating board | Conditioned | C | 0.065 | 400. | - |
| Fibre insulating board | Hot face 10°C, c.f. -40°C | C | 0.049 | 290. | - |
| Fibre insulating board | Hot face 10°C, c.f. -10°C | C | 0.052 | 290. | - |
| Fibre insulating board | Dry, h.f. 30°C, c.f. 10°C | C | 0.056 | 290. | - |
| Fibre insulating blanket | Dry, h.f. 650°C, c.f. 40°C | C | 0.085 | 95. | - |
| Fibre insulating blanket | Dry, h.f. 650°C, c.f. 40°C | C | 0.110 | - | |
| Fibre insulating blanket | Dry, h.f. 950°C, c.f. 40°C | C | 0.14 | 95. | - |
| Fibre insulating blanket | Dry, h.f. 950°C, c.f. 40°C | C | 0.200 | - | |
| Fibreboard | | C | 0.06 | 300. | 1000. |
| Fibreboard | | E | 0.06 | 300. | 1000. |
| Fibreboard, corrugated | | Y | 0.055 | - | - |
| Insulating render, polystyrene bubbles | SBR, dry | T | 0.08 | - | 840. |
| Insulating render, polystyrene bubbles | SBR, moist | T | 0.11 | - | 840. |
| Mineral fibre slag, pipe insulation | At 23.8°C | A | 0.03605 | 104. | 712. |
| Mineral fibre slag, pipe insulation | At 23.8°C | A | 0.04759 | 200. | 712. |
| Mineral fibre slag, pipe insulation | At 37.7°C | A | 0.03749 | 104. | 712. |
| Mineral fibre slag, pipe insulation | At 37.7°C | A | 0.05480 | 200. | 712. |
| Mineral fibre slag, pipe insulation | At 93.3°C | A | 0.04759 | 104. | 712. |
| Mineral fibre slag, pipe insulation | At 93.3°C | A | 0.06489 | 200. | 712. |
| Mineral fibre slag, pipe insulation | At 148.8°C | A | 0.05768 | 104. | 712. |
| Mineral fibre slag, pipe insulation | At 148.8°C | A | 0.07931 | 200. | 712. |
| Mineral fibre, rock slag or glass, loose fill | | A | - | 20.8 | 712. |
| Mineral fibreboard, wet felted | | A | 0.05047 | 288. | 796. |
| Mineral fibreboard, wet moulded | | A | 0.06056 | 368. | 586. |
| Mineral fibreboard, with resin binder | | A | 0.04182 | 240. | 712. |
| Perlite silica impregnated cavity insulation | Low exp. | S | 0.045 | 80. | - |
| Roof insulation board | | E | 0.19 | 960. | 950. |
| ***** Liquid ***** | | | | | |
| Cylinder oil | | C | 0.15 | 890. | - |
| Glycerol | | C | 0.29 | 1200. | - |
| Paraffin | | C | 0.12 | 810. | - |
| Quenching oil | | C | 0.13 | 895. | - |
| Sea water | At 20°C | C | 0.58 | 1025. | - |
| Transformer oil | | C | 0.12 | 880. | - |
| Water | At 20°C | C | 0.60 | 1000. | - |
| Water | At 40°C | C | 0.63 | 990. | - |
| Water | At 80°C | C | 0.67 | 970. | - |
| Water | At 20°C | C | 0.60 | 1000. | - |
| Water | At 40°C | C | 0.63 | 990. | - |
| Water | At 80°C | C | 0.67 | 970. | - |
| ***** Loose Fill/Powders ***** | | | | | |
| Charcoal, loose | Dry | C | 0.055 | 190. | - |
| Cellulosic insulation, loose fill | | A | 0.04182 | 43.2 | 1382. |
| Charcoal | | Y | 0.07640 | - | - |
| Exfoliated vermiculite, loose | At 50°C | I | 0.069 | 264. | 880. |
| Vermiculite | | BS | .067 | - | - |
| Vermiculite, loose granules | | C | 0.065 | 100. | - |
| Vermiculite, granules, 5-10 mm dia. | Dry, h.f. 100°C, c.f. 20°C | C | 0.075 | 100. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Vermiculite, granules, 5-10 mm dia. | Dry, h.f. 250°C, c.f. 20°C | C | 0.09 | 100. | - |
| Vermiculite, granules, 5-19 mm dia. | Dry, h.f. 500°C, c.f. 20°C | C | 0.135 | 100. | - |
| Aluminium powder | | C | 0.2 | - | - |
| Ash, pulverized fuel powder | | C | 0.1 | 720. | - |
| Carborundum powder | | C | 0.19 | 1350. | - |
| Copper powder | | C | 0.45 | 5100. | - |
| Diatomaceous powder | | C | 0.06 | 210. | - |
| Diatomaceous insulating powder | Dry, h.f. 300°C, c.f. 40°C | C | 0.067 | 220. | - |
| Diatomaceous insulating powder | Dry, h.f. 300°C, c.f. 40°C | C | 0.09 | 360. | - |
| Diatomaceous insulating powder | H.f. 500°C, c.f. 40°C | C | 0.08 | 220. | - |
| Diatomaceous insulating powder | H.f. 500°C, c.f. 40°C | C | 0.105 | 360. | - |
| Diatomaceous insulating powder | H.f. 700°C, c.f. 40°C | C | 0.095 | 220. | - |
| Diatomaceous insulating powder | H.f. 700°C, c.f. 40°C | C | 0.115 | 360. | - |
| Graphite powder | | C | 0.1 | 320. | - |
| Graphite powder | | C | 0.21 | 460. | - |
| Silica aerogel powder | Dry | C | 0.024 | 130. | - |
| Silica aerogel insulating powder | Dry, at -20°C | C | 0.02 | 90. | - |
| Silica aerogel insulating powder | Dry, at 0°C | C | 0.021 | 90. | - |
| Silica aerogel insulating powder | Dry, at 10°C | C | 0.022 | 90. | - |
| Silica aerogel insulating powder | Dry, at 20°C | C | 0.024 | 130. | - |
| Talcum powder | | Y | 0.25 | 1080. | - |
| Crushed Brighton chalk | Dry | C | 0.25 | - | - |
| Crushed Brighton chalk | 10%d.w. | C | 0.5 | - | - |
| Crushed Brighton chalk | 20%d.w. | C | 0.8 | - | - |
| Fine silver sand | Dry, at 20°C | C | 0.32 | 1600. | - |
| Fine silver sand | Dry, at 150°C | C | 0.35 | 1600. | - |
| Fine silver sand | Dry, at 250°C | C | 0.37 | 1600. | - |
| Fossil flour mortar loose | | Y | 0.058 | 280. | - |
| Gravel | | E | 0.36 | 1840. | 840. |
| Gravel | Dry | Y | 0.80 | 1900. | - |
| Gravel Ham river, loose | Grading 10 to 19mm, dry | C | 0.30 | 1250. | - |
| Loose filling, blast-furnace slag | $\rho$ <400 | G | 0.16 | 400. | - |
| Loose filling, expanded clay or slate | $\rho$ <1000 | G | 0.19 | 1000. | - |
| Loose filling, expanded mica | $\rho$ <200 | G | 0.05 | 200. | - |
| Loose filling, expanded perlite | $\rho$ <100 | G | 0.07 | 100. | - |
| Loose filling, gravel shale | $\rho$ <1200 | G | 0.22 | 1200. | - |
| Loose filling, lava | $\rho$ <1500 | G | 0.27 | 1500. | - |
| Loose filling, polystyrene foam particles | | G | 0.045 | 15. | - |
| Loose filling, porous materials | $\rho$ <100 | G | 0.06 | 100. | - |
| Loose filling, sand, gravel or stone chips | Dry | G | 0.70 | 1800. | - |
| Stone chippings | | E | 0.96 | 1800. | 1000. |
| Stone chippings for roofs | | C | 0.96 | 1800. | 1000. |
| Perlite expanded, loose fill | | A | 0.05047 | 104. | 1089. |
| Perlite, loose expanded granules | Dry, h.f. 400°C, c.f. 40°C | C | 0.085 | 65. | - |
| Perlite, loose expanded granules | | C | 0.042 | 65. | - |
| Perlite, loose expanded granules | Dry, h.f. 200°C, c.f. 40°C | C | 0.06 | 65. | - |
| Perlite, loose expanded granules | Dry, h.f. 100°C, c.f. 40°C | C | 0.046 | 65. | - |
| Perlite, loose expanded granules | Dry, h.f. 300°C, c.f. 40°C | C | 0.07 | 65. | - |
| Pumice, loose 19 mm granules | | C | 0.09 | 480. | - |
| Pumice | Loose granules | C | 0.07 | 350. | - |
| Roof gravel or slag | | D | 1.444 | 880. | 1675. |
| Roof gravel or slag | | D | 1.444 | 880. | 1675. |
| Salt, loose grains | | C | 0.24 | 1450. | - |
| Sand | | I | 1.74 | 2240. | 840. |
| Sand, dry for filling | | Y | 0.50 | 1500. | - |
| Sand, 0 to 100 mesh | Dry | C | 0.42 | 1750. | - |
| Sand to 6mm pebbles | Dry | C | 0.42 | 1540. | - |
| Sand, building | Dry | C | 0.30 | 1500. | - |
| Sand, mixture 0% of 20 to 100 mesh and 70% of 3 to 9mm | Dry | C | 0.8 | 2000. | - |
| Sand, with epoxy resin blocks | Dry | C | 1.1 | 2000. | - |
| Sand, fine silver | Dry | C | 0.30 | 1600. | - |
| Sand, gravel | | G | 1.4 | - | - |
| Slag | | Y | 0.16 | 600. | - |
| Granular cellular glass | NBN, $\rho$ 150-200 | T | 0.07 | 175. | 840. |
| White dry render | | E | 0.50 | 1300. | 1000. |
| Vermiculite, exfoliated, loose fill | | A | 0.07 | 122. | - |
| Phosphate rock fertiliser | Damp, 90% rh | C | 0.40 | 1760. | - |
| Phosphate rock fertiliser | Dry | C | 0.23 | 1600. | - |
| Screed for floors | | C | 0.41 | 1200. | 840. |
| Screed for roofs | | C | 0.41 | 1200. | 840. |
| Diatomaceous brick, crushed | | C | 0.15 | 510. | - |
| ***** Mineral Wools ***** | | | | | |
| Aluminium wool | Dry, at 40°C | C | 0.09 | 30. | - |
| Aluminium wool | Dry, at 40°C, h.f. 200°C, c.f. 25°C | C | 0.17 | 40. | - |
| Carpeting, simulated sheepswool | | C | 0.055 | - | - |
| Mineral wool | CSTC, $\rho$ 35-250 | T | - | 145. | - |
| Mineral wool | NBN | T | 0.04 | - | 840. |
| Mineral wool | Low exp., $\rho$ 35-250 | S | 0.038 | 142. | 840. |

| **Material Description** | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Mineral wool | Low exp. | B | 0.04 | - | - |
| Mineral wool, unbonded | | I | 0.03 | 73.5 | 920. |
| Mineral wool, cavity insulation | Low exp., $\rho$ 40-120 | S | 0.045 | 80. | - |
| Mineral wool, felted | | C | 0.04 | 16. | - |
| Mineral wool, felted | Dry, h.f. 40°C, c.f. 10°C | C | 0.038 | 80. | - |
| Mineral wool, felted | Dry, h.f. 40°C, c.f. 10°C | C | 0.039 | 50. | - |
| Mineral wool, felted | Dry, h.f. 100°C, c.f. 40°C | C | 0.045 | 80. | - |
| Mineral wool, felted | H.f. 20°C, c.f. 0°C | C | 0.035 | 80. | - |
| Mineral wool, felted | H.f. 20°C, c.f. 0°C | C | 0.036 | 50. | - |
| Mineral wool, rigid slab | Dry, h.f. 150°C, c.f. 40°C | C | 0.05 | 155. | - |
| Mineral wool, rigid slab | Dry, h.f. 300°C, c.f. 40°C | C | 0.06 | 155. | - |
| Mineral wool, rigid slab | Dry, h.f. 400°C, c.f. 40°C | C | 0.071 | 155. | - |
| Mineral wool, rigid slab | Dry, h.f. 500°C, c.f. 40°C | C | 0.082 | 155. | - |
| Mineral wool, rigid slab | Dry, h.f. 600°C, c.f. 40°C | C | 0.095 | 155. | - |
| Mineral wool, high density slab | Hot face 10°C, c.f. -70°C | C | 0.03 | 290. | - |
| Mineral wool, high density slab | Hot face 10°C, c.f. -150°C | C | 0.025 | 290. | - |
| Mineral wool, high density slab | Hot face 10°C, c.f. -20°C | C | 0.035 | 290. | - |
| Mineral wool, loose felted slab | Dry, h.f. 100°C, c.f. 40°C | C | 0.048 | 180. | - |
| Mineral wool, loose felted slab | Dry, h.f. 200°C, c.f. 40°C | C | 0.059 | 180. | - |
| Mineral wool, loose felted slab | Dry, h.f. 300°C, c.f. 40°C | C | 0.071 | 180. | - |
| Mineral wool, loose felted slab | Dry, h.f. 400°C, c.f. 40°C | C | 0.084 | 180. | - |
| Mineral wool, loose felted slab | Dry, h.f. 40°C, c.f. 10°C | C | 0.042 | 180. | - |
| Mineral wool, semi-rigid felted mat | Dry, h.f. 100°C, c.f. 40°C | C | 0.044 | 130. | - |
| Mineral wool, semi-rigid felted mat | Dry, h.f. 200°C, c.f. 40°C | C | 0.056 | 130. | - |
| Mineral wool, semi-rigid felted mat | Dry, h.f. 300°C, c.f. 40°C | C | 0.07 | 130. | - |
| Mineral wool, semi-rigid felted mat | Dry, h.f. 40°C, c.f. 10°C | C | 0.036 | 130. | - |
| Mineral wool/fibre | | D | 0.04328 | 96. | 837. |
| Mineral wool/fibre | | D | 0.04675 | 96. | 837. |
| Mineral wool/fibre | | D | 0.04675 | 100.8 | 837. |
| Resin bonded mineral wool | | I | 0.0428 | 1000. | |
| Resin bonded mineral wool | | I | 0.0384 | 1000. | |
| Resin bonded mineral wool | | I | 0.036 | 99. | 1000. |
| Rock fibre | | BS | 0.04 | - | - |
| Rock wool | SPPS, $\rho$ 100-175 | T | - | 138. | - |
| Rock wool | SPPS, $\rho$ 20-44 | T | - | 32. | - |
| Rock wool | SPPS, $\rho$ 45-99 | T | - | 32. | - |
| Rock wool, unbonded | | I | 0.047 | 92. | 840. |
| Rock wool, unbonded | | I | 0.043 | 150. | 840. |
| ***** Miscellaneous ***** | | | | | |
| Acoustic tile | | D | 0.05713 | 288. | 1340. |
| Anhydrite coating | | G | 1.2 | 2100. | - |
| Coal, chunks | | Y | 0.16 | 600. | - |
| Cratherm board | | E | 0.05 | 176. | 837. |
| Extruded PS without surface skin | SPPS, $\rho$ 25-27.5 | T | - | 26. | - |
| Felt sheathing | | E | 0.19 | 960. | 950. |
| Hard panels of expanded perlite | NBN | T | 0.055 | 170. | 840. |
| Hard panels of expanded perlite | SPPS, $\rho$ 160-220 | T | - | 190. | - |
| Hard panels, expanded perlite base | Low exp. | B | 0.055 | 170. | - |
| Hollowed plastic | $\rho$ 10-60 | F | 0.046 | 35. | - |
| Interior finish plank or tile | | A | 0.05047 | 240. | 1340. |
| Magnesium coating, founds and substrata, double layered | DIN 272 | G | 0.47 | 1400. | - |
| Magnesium coating, floor founds | DIN 272 | G | 0.7 | 2300. | - |
| Mineral fibre | | E | 0.04 | 105. | 1800. |
| Mineral fibre slab | | C | 0.035 | 30. | 1000. |
| Mineral fibre, blanket, metal reinforced | At 148.8°C | A | 0.05624 | 144. | 712. |
| Mineral fibre, blanket, metal reinforced | At 260.0°C | A | 0.07787 | 144. | 712. |
| Mineral fibre, blanket, metal reinforced | At 37.7°C | A | 0.03749 | 144. | 712. |
| Mineral fibre, blanket, metal reinforced | At 93.3°C | A | 0.04614 | 144. | 712. |
| Mineral fibre, resin binder | At -45°C | A | 0.03317 | 240. | 712. |
| Mineral fibre, resin binder | At -31°C | A | 0.03461 | 240. | 712. |
| Mineral fibre, resin binder | At -17.7°C | A | 0.03690 | 240. | 712. |
| Mineral fibre, resin binder | At -3.8°C | A | 0.03749 | 240. | 712. |
| Mineral fibre, resin binder | At 10.0°C | A | 0.04038 | 240. | 712. |
| Mineral fibre, resin binder | At 23.8°C | A | 0.04182 | 240. | 712. |
| Mineral filling material for concrete | Low exp., $\rho$ 50-800 | S | 0.13 | 425. | 840. |
| PUR-COR bubbles | SPPS, $\rho$ 20-40 | T | - | 30. | - |
| Panels of expanded perlite, bitumen bonded | $\rho$ 170-190 | F | 0.058 | 180. | - |
| Panels of expanded vermiculite | NBN | T | 0.082 | 350. | 840. |
| Panels of expanded vermiculite | Low exp. | B | 0.082 | 350. | - |
| Preformed mineral board | | D | 0.04155 | 240. | 756. |
| Perlite, bitumen bonded | Low exp. | S | 0.061 | 240. | 840. |
| Polystyrene, rigid, moulded bead | At -73°C | A | 0.0245 | 16. | 1214. |
| Polystyrene, rigid, moulded bead | At -45°C | A | 0.0288 | 16. | 1214. |
| Polystyrene, rigid, moulded bead | At -17.7°C | A | 0.0317 | 16. | 1214. |
| Polystyrene, rigid, moulded bead | At 10°C | A | 0.0361 | 16. | 1214. |
| Polystyrene, rigid, moulded bead | At 37.7°C | A | 0.0404 | 16. | 1214. |
| Polyurethane board | | C | 0.025 | 1400. | |
| Pulpboard paper | | C | 0.07 | - | |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Pure expanded perlite | NBN, $\rho$ 50-80 | T | 0.046 | 65. | 840. |
| Pure expanded perlite | Low exp., $\rho$ 50-80 | B | 0.046 | 65. | - |
| Pure expanded vermiculite | NBN, $\rho$ <100 | T | 0.058 | 350. | 840. |
| Pure expanded vermiculite | Low exp., $\rho$ <100 | B | 0.058 | 100. | - |
| Rope, one layer 5mm diameter | H.f. 270°C, c.f. 120°C | C | 0.15 | - | - |
| Silicon | | E | 0.18 | 700. | 1004. |
| Silicon-bonded vermiculite panels | $\rho$ 200-300 | F | 0.1 | 250. | - |
| Silicon-bonded vermiculite panels | $\rho$ 300-400 | F | 0.14 | 350. | - |
| Silicon-bonded vermiculite panels | $\rho$ 400-500 | F | 0.19 | 450. | - |
| Snow, 20-40cm layer | | Y | 0.6 | 500. | - |
| Snow, 3-7cm layer | | Y | 0.1 | 200. | - |
| Snow, 3cm layer | | Y | 0.05 | 100. | - |
| Snow, 7-20cm layer | | Y | 0.2 | 300. | - |
| Snow, compacted | | C | 0.43 | 400. | - |
| Snow, freshly fallen | | C | 0.17 | 190. | - |
| Spray cellulosic fibre base | | A | 0.039 | 64. | - |
| Tarfelt | | I | 0.479 | - | 880. |
| Mineral tiles, ceiling | | E | 0.03 | 290. | - |
| Wall and ceiling boards, diatomaceous | Conditioned | C | 0.23 | 1200. | - |
| Wall and ceiling boards, diatomaceous | Conditioned 40% | C | 0.14 | 830. | - |
| Wall and ceiling boards, diatomaceous | Wet | C | 0.32 | 1355. | - |
| ***** Polys (Man-Made) ***** | | | | | |
| Polyisobuthelyne | SPPS | T | 0.2 | - | 1480. |
| Polyisocyanurate board | | A | 0.02019 | 32. | 921.14 |
| Polypropylene | Dry | C | 0.24 | 915. | - |
| Polyurethane foam, aged | Dry | C | 0.026 | 30. | - |
| Polystyrene | SPPS, $\rho$ 13-17.4 | T | - | 15. | - |
| Polystyrene | Dry | C | 0.17 | 1050. | - |
| Polystyrene | SPPS, $\rho$ 17.5-22.4 | T | - | 20. | - |
| Polystyrene | SPPS, $\rho$ 27.5-32.5 | T | - | 30. | - |
| Rigid polyisocyandrate, cellular, foilfaced, glass fibre reinforced | At -3.8°C | A | 0.0173 | 32. | 921. |
| Rigid polyisocyandrate, cellular, foilfaced, glass fibre reinforced | At 23.8°C | A | 0.0202 | 32. | 921. |
| Rigid polyisocyandrate, cellular, foilfaced, glass fibre reinforced | At 37.7°C | A | 0.0216 | 32. | 921. |
| Rigid polyisocyandrate, cellular, foilfaced, glass fibre reinforced | At 10°C | A | 0.0188 | 32. | 921. |
| Rigid foam with vinyl polychloric base, class 1 | $\rho$ 25-35 | F | 0.031 | 30. | - |
| Rigid foam with vinyl polychloric base, class 2 | $\rho$ 35-48 | F | 0.034 | 41. | - |
| Vinyl polychloric | $\rho$ 1300-1400 | F | 0.20 | 1350. | - |
| Fired pyrophylite, high-temperature refractory | | C | 1.9 | 2500. | - |
| P.T.F.E | Dry | C | 0.24 | 2200. | - |
| P.T.F.E. glass cloth | Dry | C | 0.30 | 2250. | - |
| Nylon | Dry | C | 0.30 | 1100. | - |
| Plastic tiles | | E | 0.50 | 1050. | 837. |
| Plastic tiles | | C | 0.50 | 1050. | - |
| Silicone, glass fabric | Dry | C | 0.34 | 1800. | - |
| Urea formaldehyde | Dry | C | 0.031 | 10. | - |
| Urea formaldehyde | Dry | C | 0.032 | 15. | - |
| Urea formaldehyde | Dry | C | 0.032 | 30. | - |
| Urea formaldehyde | | BS | 0.04 | - | - |
| Phenolic foam, close cell | | BS | 50. | - | - |
| Phenolic foam board | Dry | C | 0.038 | 30. | - |
| Phenolic foam board | Dry | C | 0.036 | 30. | - |
| Phenolic, cotton fabric | Dry | C | 0.34 | 1350. | - |
| Phenolic, paper | Dry | C | 0.27 | 1370. | - |
| Formo-phenol | $\rho$ 1000-1500 | F | 0.40 | 1250. | - |
| ***** Polystyrene (Expanded) ***** | | | | | |
| Expanded PVC | | E | 0.04 | 100. | 750. |
| Expanded plastic panels | $\rho$ >15 | G | 0.04 | 15. | - |
| Expanded polystyrene | CSTC, $\rho$ >30 | T | - | 30. | - |
| Expanded polystyrene | CSTC, $\rho$ 15-30 | T | - | 22. | - |
| Expanded polystyrene | CSTC, $\rho$ 20-30 | T | - | 25. | - |
| Expanded polystyrene | | I | 0.038 | 16. | 1340. |
| Expanded polystyrene (EPS) slab | | C | 0.035 | 25. | 1400. |
| Expanded polystyrene | Low exp., $\rho$ 15-30 | S | 0.035 | 22.5 | 1470. |
| Expanded polystyrene | | I | 0.035 | 34. | 1340. |
| Expanded polystyrene bead | | BS | 0.03 | - | - |
| Expanded polystyrene board, extruded cut cell surface | | A | 0.0361 | 28.8 | 1214. |
| Expanded polystyrene board, smooth skin surface | | A | 0.02884 | 41.6 | 1214. |
| Expanded extruded polystyrene | | BS | 0.025 | - | - |
| Expanded polystyrene extruded panels, with surface skin | $\rho$ 30-35 | F | 0.029 | 33. | - |
| Expanded polystyrene extruded panels, with surface skin | $\rho$ 35-40 | F | 0.029 | 38. | - |
| Expanded polystyrene extruded panels, without surface skin | $\rho$ 28-32 | F | 0.035 | 30. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Expanded polystyrene milled under constant humidity & dried | $\rho$ 25-35 | F | 0.036 | 30. | - |
| Expanded polystyrene milled under constant humidity & dried | $\rho$ 11-16 | F | 0.042 | 14. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Expanded polystyrene milled under constant humidity & dried | $\rho$ 16-20 | F | 0.038 | 18. | - |
| Expanded polystyrene, milled, grade 1 | $\rho$ 9-13 | F | 0.044 | 11. | - |
| Expanded polystyrene, milled, grade 2 | $\rho$ 13-16 | F | 0.042 | 14. | - |
| Expanded polystyrene, milled, grade 3 | $\rho$ 16-20 | F | 0.039 | 18. | - |
| Expanded polystyrene, milled, grade 4 | $\rho$ 20-25 | F | 0.039 | 22. | - |
| Expanded polystyrene, milled, grade 5 | $\rho$ 25-35 | F | 0.037 | 30. | - |
| Expanded polystyrene thermo-compressed at constant humidity | $\rho$ 12-15 | F | 0.041 | 14. | - |
| Expanded polystyrene thermo-compressed at constant humidity | $\rho$ 15-20 | F | 0.038 | 17. | - |
| Expanded polystyrene thermo-compressed in constant humidity | $\rho$ 20-25 | F | 0.036 | 23. | - |
| Expanded polystyrene thermo-compressed in constant humidity | $\rho$ 25-35 | F | 0.036 | 30. | - |
| Expanded polystyrene | | I | 0.035 | 24. | 1340. |
| Extruded polystyrene with surface skin | SPPS, $\rho$ 30-35 | T | 0.034 | 32. | - |
| Extruded polystyrene with surface skin | SPPS, $\rho$ 40-45 | T | 0.032 | 42. | - |
| Extruded polyethylene | NBN | T | 0.04 | - | 1470. |
| Extruded polystyrene | NBN, $\rho$ >25 | T | 0.035 | 25. | 1470. |
| Extruded polystyrene | Low exp., $\rho$ 30-40 | S | 0.027 | 35. | 1470. |
| Polystyrene, expanded | | D | 0.03463 | 28.8 | 1214. |
| Polystyrene, expanded board | Dry | C | 0.037 | 15. | - |
| Polystyrene, expanded board | Dry, h.f. 10°C, c.f. -10°C | C | 0.033 | 15. | - |
| Polystyrene, expanded board | Dry, h.f. 20°C, c.f. 0°C | C | 0.035 | 15. | - |
| Polystyrene, expanded board | Dry, h.f. 45°C, c.f. 20°C | C | 0.039 | 15. | - |
| Polystyrene, expanded board | Dry | C | 0.0345 | - | - |
| Polystyrene, expanded board | Dry, h.f. 10°C, c.f. -10°C | C | 0.031 | 25. | - |
| Polystyrene, expanded board | Dry, h.f. 20°C, c.f. 0°C | C | 0.033 | 25. | - |
| Polystyrene, expanded board | Dry, h.f. 45°C, c.f. 20°C | C | 0.037 | 25. | - |
| Polystyrene, expanded board | Dry, h.f. 20°C, c.f. 0°C | C | 0.03 | 30. | - |
| ***** Polyurethane ***** | | | | | |
| Cellular polyurethane board | | A | 0.02307 | 24. | 1591. |
| Polyurethane expanded | | D | 0.02303 | 24. | 1591. |
| Polyurethane expanded in situ | CSTC, $\rho$ >37 | T | - | 37. | - |
| Polyurethane foam, closed cell | | BS | 0.029 | - | - |
| Polyurethane, gas filled, rigid, new | Dry, h.f. 20°C, c.f. 0°C | C | 0.021 | 30. | - |
| Polyurethane, gas filled, rigid, new | Dry, h.f. 45°C, c.f. 20°C | C | 0.024 | 30. | - |
| Polyurethane, gas filled, rigid, new | Dry, h.f. 10°C, c.f. -10°C | C | 0.02 | 30. | - |
| Polyurethane, gas filled, rigid, 1.5yrs | Dry, h.f. 10°C, c.f. -10°C | C | 0.023 | 30. | - |
| Polyurethane, gas filled, rigid, 1.5yrs | Dry, h.f. 20°C, c.f. 0°C | C | 0.025 | 30. | - |
| Polyurethane, gas filled, rigid, 1.5yrs | Dry, h.f. 45°C, c.f. 20°C | C | 0.027 | 30. | - |
| Rigid polyurethane or polyisocyanurate expanded foam panels | $\rho$ 30-40) | F | 0.029 | 35. | - |
| Unfaced polyurethene | At -73°C | G | 0.0231 | 32. | 1591. |
| Unfaced polyurethene | At -59°C | G | 0.0245 | 32. | 1591. |
| Unfaced polyurethene | At -45°C | G | 0.026 | 32. | 1591. |
| Unfaced polyurethene | At -31°C | G | 0.026 | 32. | 1591. |
| Unfaced polyurethene | At -17.7°C | G | 0.026 | 32. | 1591. |
| Unfaced polyurethene | At -3.8°C | G | 0.0245 | 32. | 1591. |
| Unfaced polyurethene | At 10°C | G | 0.0231 | 32. | 1591. |
| Unfaced polyurethene | At 23.8°C | G | 0.0231 | 32. | 1591. |
| Unfaced polyurethene | At 37.7°C | G | 0.0245 | 32. | 1591. |

## 4.5 Inorganic-Porous

This category included masonry and related materials which are inorganic, porous and may contain significant amounts of water due to hygroscopic absorption from the air or wetting by rain, which affects their hygrothermal properties and their thermal conductivity in particular.

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Asbestos-Related ***** | | | | | |
| Asbestos, 85% Magnesia | Dry, h.f. 100°C, c.f. 25°C | C | 0.06 | 190. | - |
| Asbestos, 85% Magnesia | h.f. 200°C, c.f. 25°C | C | 0.065 | 190. | - |
| Asbestos, 85% Magnesia | h.f. 300°C, c.f. 25°C | C | 0.072 | 190. | - |
| Asbestos, 85% Magnesia | h.f. 400°C, c.f. 25°C | C | 0.08 | 190. | - |
| Asbestos, 85% Magnesia | h.f. 150°C, c.f. 25°C | C | 0.065 | 235. | - |
| Asbestos, 85% Magnesia | Dry, h.f. 200°C, c.f. 25°C | C | 0.067 | 235. | - |
| Asbestos, 85% Magnesia | Dry, h.f. 300°C, c.f. 25°C | C | 0.074 | 235. | - |
| Asbestos, 85% Magnesia | h.f. 400°C, c.f. 25°C | C | 0.083 | 235. | - |
| Asbestos, 85% Magnesia | h.f. 500°C, c.f. 25°C | C | 0.09 | 235. | - |
| Asbestos, lightweight slab | | C | 0.05 | 70. | - |
| Asbestos, lightweight slab | | C | 0.053 | 95. | - |
| Asbestos, slab | Soaked | C | 0.2 | 135. | - |
| Asbestos, slab | Wet | C | 0.15 | 135. | - |
| Asbestos | Sprayed | C | 0.043 | 80. | - |
| Asbestos | Sprayed | C | 0.046 | 130. | - |
| Asbestos | Sprayed | C | 0.061 | 160. | - |
| Asbestos | Sprayed | C | 0.075 | 240. | - |
| Asbestos, slab | Dry | C | 0.05 | 135. | - |
| Asbestos and asphalt tiles | Conditioned | C | 0.55 | 1900. | - |
| Asbestos P.V.C. tiles | | C | 0.85 | 2000. | - |
| Asbestos/phenolic cloth | Dry | C | 0.3 | 1300. | - |
| Asbestos/phenolic cloth | | C | 0.50 | 1700. | - |
| Asbestos/phenolic flock | Dry | C | 0.38 | 1600. | - |
| Asbestos/plastic insulation | h.f. 100°C, c.f. 40°C | C | 0.12 | 400. | - |
| Asbestos/plastic insulation | h.f. 100°C, c.f. 40°C | C | 0.075 | 275. | - |
| Asbestos/plastic insulation | h.f. 200°C, c.f. 40°C | C | 0.08 | 275. | - |
| Asbestos/plastic insulation | h.f. 300°C, c.f. 40°C | C | 0.13 | 400. | - |
| Asbestos/plastic insulation | h.f. 400°C, c.f. 40°C | C | 0.095 | 275. | - |
| Asbestos/plastic insulation | h.f. 400°C, c.f. 40°C) | C | 0.135 | 400. | - |
| Asbestos/plastic insulation | h.f. 200°C, c.f. 40°C) | C | 0.125 | 400. | - |
| Asbestos/plastic insulation | h.f. 300°C, c.f. 40°C) | C | 0.085 | 275. | - |
| Asbestos/plastic insulation | h.f. 500°C, c.f. 40°C) | C | 0.105 | 275. | - |
| Asbestos/silicone mat | Dry | C | 0.34 | 1600. | - |
| Asbestos, slab with high amosite content | h.f. 500°C, c.f. 40°C | C | 0.11 | 320. | - |
| Asbestos, slab with high amosite content | h.f. 400°C, c.f. 40°C | C | 0.075 | 145. | - |
| Asbestos, slab with high amosite content | h.f. 500°C, c.f. 40°C | C | 0.083 | 145. | - |
| Asbestos, slab with high amosite content | h.f. 100°C, c.f. 40°C | C | 0.08 | 320. | - |
| Asbestos, slab with high amosite content | h.f. 200°C, c.f. 40°C | C | 0.085 | 320. | - |
| Asbestos, slab with high amosite content | h.f. 300°C, c.f. 40°C | C | 0.09 | 320. | - |
| Asbestos, slab with high amosite content | h.f. 400°C, c.f. 40°C | C | 0.097 | 320. | - |
| Asbestos, slab with high amosite content | h.f. 100°C, c.f. 40°C | C | 0.055 | 145. | - |
| Asbestos, slab with high amosite content | h.f. 200°C, c.f. 40°C | C | 0.06 | 145. | - |
| Asbestos, slab with high amosite content | h.f. 300°C, c.f. 40°C | C | 0.068 | 145. | - |
| Asbestos laminated paper | At 148.8°C | A | 0.0721 | 480. | - |
| Asbestos laminated paper | At 260°C | A | 0.08652 | 480. | - |
| Asbestos laminated paper | At 37.7°C | A | 0.05768 | 480. | - |
| Asbestos laminated paper | At 93.3°C | A | 0.06489 | 480. | - |
| Asbestos, millboard | | C | 0.11 | 720. | - |
| Asbestos, millboard | | C | 0.19 | 1050. | - |
| Asbestos, paper, corrugated and aluminium foil bonded | Dry | C | 0.065 | 145. | - |
| Asbestos, paper, corrugated and plain bonded | Dry | C | 0.087 | 190. | - |
| Asbestos, paper, thin sheet | Dry | C | 0.15 | 950. | - |
| Asbestos cement | | Y | 0.50 | 1700. | - |
| Asbestos cement | CSTC | T | - | 800. | - |
| Asbestos cement | CSTC | T | - | 1750. | - |
| Asbestos cement | $\rho$ 1400-1800 | F | 0.65 | 1600. | - |
| Asbestos cement | $\rho$ 1800-2200 | F | 0.95 | 2000. | - |
| Asbestos cement | Low exp., $\rho$ 1600-1900 | S | 0.53 | 1750. | 840. |
| Asbestos cement | Std exp., $\rho$ 1600-1900 | S | 1.02 | 1750. | 840. |
| Asbestos cement, compressed slab | | Y | 0.80 | 1900. | - |
| Asbestos cement building board | | A | 0.5768 | 1920. | 1005. |
| Asbestos cement building board | | D | 0.59732 | 1920. | 837. |
| Asbestos cement decking | | C | 0.36 | 1500. | 1050. |
| Asbestos cement panels | DIN 274 | G | 0.58 | 2000. | - |
| Asbestos cement sheet | | C | 0.36 | 700. | 1050. |
| Asbestos sheet | | E | 0.16 | 2500. | 1050. |
| Asbestos cement sheet | | E | 0.36 | 700. | 1050. |
| Asbestos cement sheet | Conditioned | C | 0.37 | 1520. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Asbestos cement sheet | | C | 0.25 | 1360. | - |
| Asbestos cement sheet | | C | 0.40 | 1600. | - |
| Asbestos cement sheet | | C | 0.55 | 2000. | - |
| Asbestos cement sheet & substitutes | | BS | 0.4 | - | - |
| Asbestos insulation | | E | 0.16 | 577. | 840. |
| Cellulose asbestos cement | $\rho$ 1000-1400 | F | 0.35 | 1200. | - |
| Cellulose asbestos cement | $\rho$ 1400-1800 | F | 0.46 | 1600. | - |
| Asbestos cement | | E | 0.36 | 1500. | 1000. |
| Asbestos fibre | At 50°C | I | 0.06 | 640. | 840. |
| Asbestos mill board | At 50°C | I | 0.249 | 1397. | 840. |
| Asbestos cloth | Dry | C | 0.11 | 450. | - |
| Asbestos cloth | Dry | C | 0.17 | 560. | - |
| Asbestos felt | Dry | C | 0.078 | 144. | - |
| Asbestos insulating board | Conditioned | C | 0.11 | 720. | - |
| Asbestos insulating board | Conditioned | C | 0.12 | 750. | - |
| Asbestos insulating board | Conditioned | C | 0.14 | 800. | - |
| Asbestos insulating board | Conditioned | C | 0.16 | 900. | - |
| Asbestos insulating board | Wet | C | 0.21 | 845. | - |
| Asbestos vermiculite slabs | | C | 0.095 | 320. | - |
| Asbestos vermiculite slabs | | C | 0.115 | 400. | - |
| Asbestos vermiculite slabs | Dry | C | 0.13 | 400. | - |
| Asbestos wallboard | Conditioned | C | 0.16 | 900. | - |
| Asbestos wallboard | | C | 0.25 | 1200. | - |
| Asbestos, hard setting composition | Dry, h.f. 70°C, c.f. 25°C | C | 0.25 | 1200. | - |
| Asbestos Vermiculite slabs | | C | 0.08 | 260. | - |
| ***** Brick ***** | | | | | |
| Brick, aerated | | S | 0.30 | 1000. | 840. |
| Brick, aerated | | S | 0.43 | 1350. | 840. |
| Brick, alumina, insulating | Dry, h.f. 500°C, c.f. 40°C | C | 0.29 | 720. | - |
| Brick, alumina, insulating | h.f. 750°C, c.f. 40°C | C | 0.31 | 720. | - |
| Brick, alumina, insulating | h.f. 1000°C, c.f. 40°C | C | 0.34 | 720. | - |
| Brick, external | | Y | 0.75 | 1800. | - |
| Brick, external | | Y | 0.80 | 2000. | - |
| Brick, facing | | Y | 1.12 | 2100. | - |
| Brick, internal | | Y | 0.60 | 1800. | - |
| Brick, internal | | Y | 0.70 | 2000. | - |
| Brick tile | At 50°C | I | 0.798 | 1892. | 880. |
| Brick | | A | 0.721 | 1920. | 796. |
| Brick | | D | 0.72145 | 1920. | 837. |
| Brick | | A | 1.2978 | 2080. | - |
| Brick | | D | 1.31167 | 2080. | 921. |
| Brick, breeze block | | E | 0.44 | 1500. | 650. |
| Brick, diatomaceous | Dry, h.f. 500°C, c.f. 40°C | C | 0.125 | 480. | - |
| Brick, diatomaceous | Dry, h.f. 750°C, c.f. 40°C | C | 0.13 | 480. | - |
| Brick, diatomaceous | Dry, h.f. 900°C, c.f. 40°C | C | 0.135 | 480. | - |
| Brick, diatomaceous | Dry, h.f. 500°C, c.f. 40°C | C | 0.14 | 560. | - |
| Brick, diatomaceous | Dry, h.f. 750°C, c.f. 40°C | C | 0.145 | 560. | - |
| Brick, diatomaceous | Dry, h.f. 900°C, c.f. 40°C | C | 0.15 | 560. | - |
| Brick, diatomaceous | Dry, h.f. 500°C, c.f. 40°C | C | 0.18 | 720. | - |
| Brick, diatomaceous | Dry, h.f. 750°C, c.f. 40°C | C | 0.20 | 720. | - |
| Brick, diatomaceous | Dry, h.f. 900°C, c.f. 40°C | C | 0.21 | 720. | - |
| Brick, inner leaf | | E | 0.62 | 1800. | 840. |
| Brick, outer leaf | | E | 0.96 | 2000. | 650. |
| Brick, paviour | | E | 0.96 | 2000. | 840. |
| Brick, silica, 95% SiO2 | Dry, at 1000°C | C | 1.40 | 1900. | - |
| Brick, silica, 95% SiO2 | Dry, at 500°C | C | 1.30 | 1900. | - |
| Brick, vermiculite insulating | | E | 0.27 | 700. | 840. |
| Brick, vermiculite insulating | Dry, h.f. 500°C, c.f. 40°C | C | 0.26 | 700. | - |
| Brick, vermiculite insulating | Dry, h.f. 750°C, c.f. 40°C | C | 0.28 | 700. | - |
| Brick, vermiculite insulating | Dry, h.f. 1000°C, c.f. 40°C | C | 0.29 | 700. | - |
| Brickwork, common or facing | | BS | 0.67 | 1500. | - |
| Brickwork, engineering | | BS | 1.25 | 2000. | - |
| Brickwork, sandlime | | BS | .67 | 1500. | - |
| Brickwork, inner leaf | | C | 0.62 | 1700. | 800. |
| Brickwork, outer leaf | | C | 0.84 | 1700. | 800. |
| Brickwork, outer leaf | Low exp. | S | 0.80 | 2100. | 840. |
| Brickwork, outer leaf | Std exp. | S | 1.30 | 2100. | 840. |
| Brick, burnt | At 50°C | I | 0.811 | 1820. | 880. |
| Fire brick | Dry at 1000°C | C | 1.30 | 2000. | - |
| Fire brick | Dry at 500°C | C | 1.00 | 2000. | - |
| Brick, fossil flour | | Y | 0.09 | 400. | - |
| Brick, fossil flour | | Y | 0.18 | 800. | - |
| Brick, light perforated | DIN 105 | G | 0.36 | 700. | - |
| Brick, light perforated | DIN 105 | G | 0.39 | 800. | - |
| Brick, light perforated | DIN 105 | G | 0.42 | 900. | - |
| Brick, light perforated | DIN 105 | G | 0.45 | 1000. | - |
| Brick, light perforated | DIN 105, Type W1 | G | 0.30 | 700. | - |
| Brick, light perforated | DIN 105, Type W1 | G | 0.33 | 800. | - |
| Brick, light perforated | DIN 105, Type W1 | G | 0.36 | 900. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Brick, light perforated | DIN 105, Type W1 | G | 0.39 | 1000. | - |
| Brick, mud | At 50°C | I | 0.75 | 1731. | 880. |
| Brick, burned | Low exp. | S | 0.65 | 1700. | 840. |
| Brick, burned | Low exp. | S | 0.55 | 1500. | 840. |
| Brick, burned | Low exp. | S | 0.45 | 1300. | 840. |
| Brick, burned | Std exp. | S | 1.00 | 1700. | 840. |
| Brick, burned | Std exp. | S | 0.85 | 1500. | 840. |
| Brick, burned | Std exp. | S | 0.75 | 1300. | 840. |
| Brick, refractory, alumina | Dry, h.f. 500°C, c.f. 40°C | C | 0.29 | 720. | - |
| Brick, refractory, alumina | Dry, h.f. 750°C, c.f. 40°C | C | 0.31 | 720. | - |
| Brick, refractory, alumina | Dry, h.f. 1000°C, c.f. 40°C | C | 0.34 | 720. | - |
| Brick, reinforced | At 50°C | I | 1.10 | 1920. | 840. |
| Brick, solid or perforated lightwt | Low exp., $\rho$ 1100-1199 | B | 0.37 | 1150. | - |
| Brick, solid or perforated lightwt | Low exp., $\rho$ 1200-1299 | B | 0.42 | 1250. | - |
| Brick, solid or perforated lightwt | Low exp., $\rho$ 700-799 | B | 0.22 | 750. | - |
| Brick, solid or perforated lightwt | Low exp., $\rho$ 800-899 | B | 0.24 | 850. | - |
| Brick, solid or perforated lightwt | Low exp., $\rho$ 900-999 | B | 0.27 | 950. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 1000-1099 | B | 0.37 | 1050. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 1000-1099 | B | 0.47 | 1050. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 1100-1199 | B | 0.52 | 1150. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 1200-1299 | B | 0.58 | 1250. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 700-799 | B | 0.34 | 750. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 800-899 | B | 0.36 | 850. | - |
| Brick, solid or perforated lightwt | Std exp., $\rho$ 900-999 | B | 0.41 | 950. | - |
| Brick, solid or perforated mediumwt | Low exp., $\rho$ 1300-1399 | B | 0.45 | 1350. | - |
| Brick, solid or perforated mediumwt | Low exp., $\rho$ 1400-1499 | B | 0.49 | 1450. | - |
| Brick, solid or perforated mediumwt | Low exp., $\rho$ 1500-1599 | B | 0.54 | 1550. | - |
| Brick, solid or perforated mediumwt | Std exp., $\rho$ 1300-1399 | B | 0.63 | 1350. | - |
| Brick, solid or perforated mediumwt | Std exp., $\rho$ 1400-1499 | B | 0.69 | 1450. | - |
| Brick, solid or perforated mediumwt | Std exp., $\rho$ 1500-1599 | B | 0.75 | 1550. | - |
| Brick, well burned | Low exp. | S | 0.68 | 1800. | 840. |
| Brick, well burned | Std exp. | S | 1.10 | 1800. | 840. |
| ***** Cement, Plaster & Mortar ***** | | | | | |
| Cement and lime plastering | Low exp. | S | 0.70 | 1600. | 840. |
| Cement and lime plastering | Std exp. | S | 0.80 | 1600. | 840. |
| Cement plaster | | S | 0.721 | 1762. | 840. |
| Cement plaster | Low exp. | S | 0.93 | 1900. | 840. |
| Cement plaster | Std exp. | S | 1.50 | 1900. | 840. |
| Gypsum | | E | 0.42 | 1200. | 837. |
| Gypsum or plaster board | | D | 0.16032 | 800. | 837. |
| Gypsum or plaster board | | D | 0.16032 | 800. | 837. |
| Gypsum plaster | | S | 0.512 | 1120. | 960. |
| Gypsum plaster | | C | 0.38 | 1120. | - |
| Gypsum plaster | | C | 0.46 | 1280. | - |
| Gypsum plaster board | | A | 0.16727 | 800. | 1088. |
| Gypsum plaster board | | C | 0.16 | 950. | - |
| Gypsum plaster board | | E | 0.19 | 950. | 840. |
| Gypsum plaster board | Low exp., $\rho$ 800-1400 | S | 0.35 | 1100. | 840. |
| Gypsum plaster board | Std exp., $\rho$ 800-1400 | S | 0.65 | 1100. | 840. |
| Gypsum plastering | Low exp. | S | 0.52 | 1300. | 840. |
| Gypsum plastering | Std exp. | S | 0.80 | 1300. | 840. |
| Gypsum powder | | C | 0.065 | 320. | - |
| Gypsum foamed plaster | | C | 0.25 | 880. | - |
| Gypsum plasterboard | | C | 0.16 | 950. | - |
| Gypsum plastering | | C | 0.38 | 1100. | - |
| Gypsum plastering | | C | 0.46 | 1300. | - |
| Insulating plaster | | G | 0.20 | 600. | - |
| Insulating plaster, PS-granules as filling | Low exp. | S | 0.095 | - | 840. |
| Lightweight aggregate plaster | | D | 0.23027 | 720. | 837.36 |
| Limestone mortar | NBN | T | 0.70 | 1600. | 840. |
| Limestone mortar | NBN, moist | T | 1.20 | 1600. | 840. |
| Limestone mortar and limestone cement mortar | | G | 0.87 | 1800. | - |
| Limestone plaster, anhydrite mortar, anhydrite limestone mortar | | G | 0.70 | 1400. | - |
| Non-granular plaster for interior render | $\rho$ 750-1000 | F | 0.35 | 875. | - |
| Non-granular plaster, hardened and ultra hard | $\rho$ 1100-1300) | F | 0.50 | 1200. | - |
| Perlite plaster | | E | 0.08 | 400. | 837. |
| Perlite cement, sprayed on | Dry | C | 0.08 | 350. | - |
| Perlite cement, sprayed on | Wet | C | 0.11 | 420. | - |
| Perlite plaster | | C | 0.079 | 400. | - |
| Perlite plaster | | C | 0.08 | 400. | - |
| Perlite plaster | | C | 0.19 | 600. | - |
| Perlite plaster | | C | 0.19 | 610. | - |
| Perlite plaster board | | C | 0.18 | 800. | - |
| Perlite plaster board | | E | 0.18 | 800. | 837. |
| Perlite plaster board | Conditioned, 2% m.c. | C | 0.18 | 800. | - |
| Perlite plaster board | Conditioned | C | 0.18 | 800. | - |
| Plaster | | BS | 0.5 | - | - |
| Plasterboard | | BS | 0.17 | - | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Plaster | NBN | T | 0.52 | 1300. | 840. |
| Plaster | SPPS | T | - | 980. | - |
| Plaster, dense | | C | 0.50 | 1300. | 1000. |
| Plaster, lightweight | | C | 0.16 | 600. | 1000. |
| Plaster | Low exp. | B | 0.52 | 1300. | - |
| Plaster, cellular | | Y | 0.055 | 200. | - |
| Plaster, mortar | | Y | 0.37 | 1240. | - |
| Plaster with cement and sand | | Y | 1.20 | 2200. | - |
| Plaster, lightweight mineral fibres | $\rho$ 800-1000 | F | 0.35 | 900. | - |
| Plaster, lightweight mineral fibres & perlite | $\rho$ 500-700 | F | 0.25 | 600. | - |
| Plaster, lightweight mineral fibres & perlite | $\rho$ 700-900 | F | 0.30 | 800. | - |
| Plaster, with lime and sand, external | | Y | 0.75 | 1800. | - |
| Plaster, with lime and sand, internal | | Y | 0.60 | 1800. | - |
| Plaster, with mortar, internal | | Y | 0.45 | 1200. | - |
| Plaster, with mortar and sand | | Y | 0.70 | 1670. | - |
| Plaster, with or without light granules | Low exp., $\rho$ 800-1099 | B | 0.35 | 950. | - |
| Plaster, with or without light granules | Low exp., $\rho$ <800 | B | 0.22 | 800. | - |
| Plaster, with or without light granules | Low exp., $\rho$ >1100 | B | 0.52 | 1100. | - |
| Plaster, with or without light granules | NBN, $\rho$ 800-1099 | T | 0.35 | 949. | 840. |
| Plaster, with or without light granules | NBN, $\rho$ <800 | T | 0.22 | 800. | 840. |
| Plaster, with or without light granules | NBN, $\rho$ >1100 | T | 0.52 | 1100. | 840. |
| Plaster, with sawdust | | Y | 0.17 | 920. | - |
| Plaster, with vermiculite and perlite | | Y | 0.20 | 720. | - |
| Plaster, with wood fibre | | Y | 0.26 | 820. | - |
| Plaster, without admixtures | | G | 0.35 | 1200. | - |
| Plaster, dense | | E | 0.50 | 1300. | 1000. |
| Plaster, foamed | | C | 0.10 | 400. | - |
| Plaster, foamed | | C | 0.16 | 640. | - |
| Plaster, foamed | | C | 0.25 | 880. | - |
| Plaster, light | | E | 0.16 | 600. | 1000. |
| Plaster, ceiling tiles | | E | 0.38 | 1120. | 840. |
| Plaster board | | C | 0.16 | 950. | 840. |
| Plaster board panels | | G | 0.21 | 900. | - |
| Sand aggregate plaster | | D | 0.81997 | 1680. | 837. |
| Sand cement plaster | Conditioned | C | 0.53 | 1570. | - |
| Sand cement and lime plaster | Conditioned | C | 0.48 | 1440. | - |
| Sand gypsum plaster, 3:1 | Conditioned | C | 0.65 | 1555. | - |
| Screed, aerated | | BS | 0.4 | - | - |
| Screed, cast | | BS | 1.25 | - | - |
| Synthetic resin plaster | | G | 0.70 | 1100. | - |
| Vermiculite plaster | | E | 0.20 | 720. | 837. |
| Vermiculite plaster | | C | 0.14 | 480. | - |
| Vermiculite plaster | | C | 0.20 | 640. | - |
| Vermiculite plaster | | C | 0.26 | 800. | - |
| Vermiculite plaster | | C | 0.30 | 960. | - |
| Vermiculite plastering | | C | 0.144 | 480. | - |
| Vermiculite plastering | | C | 0.20 | 640. | - |
| Vermiculite plastering | | C | 0.26 | 800. | - |
| Vermiculite plastering | | C | 0.303 | 960. | - |
| Plaster wall panel, pores hollows aggr. | | G | 0.29 | 600. | - |
| Plaster wall panel, pores hollows aggr. | | G | 0.35 | 750. | - |
| Plaster wall panel, pores hollows aggr. | | G | 0.41 | 900. | - |
| Plaster wall panel, pores hollows aggr. | | G | 0.47 | 1000. | - |
| Plaster wall panel, pores hollows aggr. | | G | 0.58 | 1200. | - |
| Gypsum plaster board | | C | 0.16 | 950. | - |
| Cement coating | | G | 1.40 | 2000. | - |
| Cement fibreboard, magnesium oxysulphide binder | | A | 0.08219 | 352. | 1298. |
| Cement mortar | | G | 1.40 | 2000. | - |
| Cement mortar | | S | 0.719 | 1648. | 920. |
| Cement mortar | NBN, dry | T | 0.93 | 1900. | 840. |
| Cement mortar | NBN, moist | T | 1.50 | 1900. | 840. |
| Cement mortar | Low exp. | B | 0.93 | 1900. | - |
| Cement mortar | Std exp. | B | 1.50 | 1900. | - |
| Masonry cement:sand mortar | 1:2 mix, 3.4% MC by vol. | L | 1.01 | 1928. | - |
| Masonry cement:sand mortar | 1:4 mix, 2.3% MC by vol. | L | 0.89 | 1878. | - |
| Masonry cement:sand mortar | 1:5 mix, 2.4% MC by vol. | L | 0.85 | 1858. | - |
| Masonry cement:sand mortar | 1:6 mix, 2.1% MC by vol. | L | 0.80 | 1810. | - |
| Masonry cement:sand mortar | 1:7 mix, 1.7% MC by vol. | L | 0.77 | 1776. | - |
| Cement:sand mortar | 1:2 mix, 3.3% MC by vol. | L | 1.08 | 2041. | - |
| Cement:sand mortar | 1:3 mix, 2.4% MC by vol. | L | 0.99 | 1998. | - |
| Cement:sand mortar | 1:4 mix, 2.8% MC by vol. | L | 1.03 | 1949. | - |
| Cement:sand mortar | 1:6 mix, 2.3% MC by vol. | L | 0.97 | 1893. | - |
| Cement:sand mortar | 1:7 mix, 1.6% MC by vol. | L | 0.88 | 1844. | - |
| Cement:sand mortar | 1:8 mix, 1.3% MC by vol. | L | 0.79 | 1852. | - |
| Cement screed | | E | 1.40 | 2100. | 650. |
| Decorative render (synthetic resin), exterior insulation | SPPS | T | 0.70 | 1100. | 900. |
| External rendering | | C | 0.50 | 1300. | 1000. |
| Lime mortar | Low exp. | B | 0.70 | 1600. | - |
| Lime mortar | Std exp. | B | 1.20 | 1600. | - |
| Render made from synthetic resin | SBR | T | - | 1500. | - |

| **Material Description** | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Rendering | 1% m.c. | E | 1.13 | 1431. | 1000. |
| Rendering | 8% m.c. | E | 0.79 | 1329. | 1000. |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Cement | | D | 0.72145 | 1856. | 837. |
| Cement panels, natural & mineral fibre reinforced | NBN, moist, $\rho$ 1400-1900 | T | 0.50 | 1650. | - |
| Cement panels, natural & mineral fibre reinforced | NBN, dry, $\rho$ 1400-1900 | T | 0.35 | 1650. | 840. |
| Cement, acid resisting, phenolic binder | | C | 0.80 | 1700. | - |
| Cement, plaster, sand aggregate | | A | 0.721 | 1856. | 837.4 |
| Cement, heat conducting, graphite filled | Dry, at 100°C | C | 17.00 | 1600. | - |
| Cement, heat conducting, graphite filled | At 300°C | C | 15.00 | 1600. | - |
| Cement based panels of wood fibres | SBR, $\rho$ 350-750 | T | - | 550. | - |
| Cement based panels of wood fibres | SPPS, dry, $\rho$ 300-400 | T | 0.08 | 350. | 1890. |
| Cement based panels of wood fibres | SPPS, moist, $\rho$ 300-400 | T | 0.12 | 350. | 3040. |
| Cement/ashes conglomerate | | Y | 0.62 | - | - |
| Cement/magnesia conglomerate | | Y | 0.15 | 700. | - |
| Cement/rice husks | | Y | 0.07 | 380. | - |
| Cement/sand in blocks, external | | Y | 0.90 | 2200. | - |
| Cement/sand in blocks, internal | | Y | 0.80 | 2200. | - |
| Masonry, cellular cemented blocks | SPPS | T | 0.33 | 524. | 2040. |
| Panels, wood fibres bonded to cement | CSTC, $\rho$ 350-700 | T | - | 525. | - |
| Panels, wood fibres bonded to cement | NBN | T | 0.12 | 400. | 1470. |
| Panels, cement reinforced with natural fibre | Low exp., $\rho$ 1400-1900 | B | 0.35 | 1650. | - |
| Panels, cement reinforced with natural fibre | Std exp., $\rho$ 1400-1900 | B | 0.50 | 1650. | - |
| Perlite/cement conglomerate | | Y | 0.195 | 650. | - |
| Perlite/cement conglomerate | | Y | 0.079 | 415. | - |
| Perlite/cement conglomerate | | Y | 0.092 | 500. | - |
| Perlite/cement conglomerate | $\rho$ 120-150 | Y | 0.038 | 135. | - |
| Pumice stone/cement conglomerate, ext. | | Y | 0.45 | 1000. | - |
| Pumice stone/cement conglomerate, ext. | | Y | 0.55 | 1200. | - |
| Pumice stone/cement conglomerate, ext. | | Y | 0.35 | 800. | - |
| Pumice stone/cement conglomerate, int. | | Y | 0.32 | 1000. | - |
| Pumice stone/cement conglomerate, int. | | Y | 0.40 | 1200. | - |
| Pumice stone/cement conglomerate, int. | | Y | 0.25 | 800. | - |
| Pumice stone/cement conglomerate, cellular | | Y | 0.15 | 650. | - |
| Refractory aggregate aluminous cement, 4:1 by vol. | h.f. 400°C, c.f. 40°C | C | 0.45 | 1350. | - |
| Refractory aggregate aluminous cement, 4:1 by vol. | h.f. 600°C, c.f. 40°C | C | 0.47 | 1350. | - |
| Refractory aggregate aluminous cement, 4:1 by vol. | h.f. 800°C, c.f. 40°C | C | 0.49 | 1350. | - |
| Wood fibre and cement blocks | Conditioned | C | 0.32 | 1550. | - |
| ***** Ceramics ***** | | | | | |
| Ceramic tiles | CSTC, dry | T | 1.20 | 2000. | 850. |
| Ceramic tiles | CSTC, moist | T | 1.30 | 2000. | - |
| Floor tiles | SPPS, dry | T | 0.80 | 1700. | 850. |
| Hard floor tiles | SPPS, moist | T | 1.10 | 1700. | - |
| ***** Clay Tiles & Blocks ***** | | | | | |
| Burnt clay tiles | Conditioned | C | 0.85 | 1900. | - |
| Clay soil | | Y | 0.80 | 1780. | - |
| Clay tile, hollow | .00762m, 1 cell | D | 0.54105 | 1120. | 837. |
| Clay tile, hollow | .01016m, 1 cell | D | 0.51923 | 1120. | 837. |
| Clay tile, hollow | 01524m, 2 cells | D | 0.57134 | 1120. | 837. |
| Clay tile, hollow | 02032m, 2 cells | D | 0.62329 | 1120. | 837. |
| Clay tile, hollow | 02540m, 2 cells | D | 0.64908 | 1120. | - |
| Clay tile, hollow | 03248m, 3 cells | D | 0.69254 | 1120. | 837. |
| Clay tile paver | | D | 1.80337 | 1920. | 837. |
| Solid blocks, from expanded clay | | G | 0.22 | 500. | - |
| Solid blocks, from expanded clay | | G | 0.24 | 600. | - |
| Solid blocks, from expanded clay | | G | 0.27 | 700. | - |
| Solid blocks, from expanded clay | | G | 0.31 | 800. | - |
| Tiles, clay | | E | 0.85 | 1900. | 837. |
| Well burnt clay tiles | Low exp. | S | 1.20 | 2000. | 840. |
| Well burnt clay tiles | Std exp. | S | 1.30 | 2000. | 840. |
| ***** Concrete ***** | | | | | |
| Conc., aerated | Low exp., $\rho$ 1000-1400 | S | 0.42 | 1200. | 840. |
| Conc., aerated | Low exp., $\rho$ 700-1000 | S | 0.29 | 850. | 840. |
| Conc., aerated roofing slab | | C | 0.16 | 500. | 840. |
| Conc., aerated, cellular | Low exp. | S | 0.50 | 1300. | 840. |
| Conc., aerated, cellular | Low exp. | S | 0.35 | 1000. | 840. |
| Conc., aerated, cellular | Low exp. | S | 0.23 | 700. | 840. |
| Conc., aerated, cellular | Low exp. | S | 0.15 | 400. | 840. |
| Conc., aerated, cellular | Std exp. | S | 1.20 | 1300. | 840. |
| Conc., aerated, cellular | Std exp. | S | 0.70 | 1000. | 840. |
| Conc., calcareous compound | $\rho$ 1650-1900 | F | 1.15 | 1775. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., cast | | E | 1.28 | 2100. | 1007. |
| Conc., cast, dense | | C | 1.40 | 2100. | 840. |
| Conc., cast, lightweight | | C | 0.38 | 1200. | 1000. |
| Conc., cast, dense, compacted, not reinforced | Low exp. | S | 1.70 | 2400. | 840. |
| Conc., cast, dense, compacted, not reinforced | Std exp. | S | 2.20 | 2400. | 840. |
| Conc., cast, dense, compacted, reinforced | Low exp. | S | 1.90 | 2500. | 840. |
| Conc., cast, dense, compacted, reinforced | Std exp. | S | 2.30 | 2500. | 840. |
| Conc., cast, dense, not compacted, not reinforced | Low exp. | S | 1.30 | 2200. | 840. |
| Conc., cast, dense, not compacted, not reinforced | Std exp. | S | 1.70 | 2200. | 840. |
| Conc., cast, dense, not compacted, reinforced | Low exp. | S | 1.40 | 2300. | 840. |
| Conc., cast, dense, not compacted, reinforced | Std exp. | S | 1.90 | 2300. | 840. |
| Conc., cast, floor | | C | 1.13 | 2000. | 1000. |
| Conc., cellular | CSTC | T | - | 400. | - |
| Conc., cellular | SBR | T | - | 1000. | - |
| Conc., cellular | SBR | T | - | 1300. | - |
| Conc., cellular | SPPS | T | 0.28 | 480. | 2150. |
| Conc., cellular | SPPS | T | - | 600. | - |
| Conc., cellular | SPPS, $\rho$ 450-494 | T | 0.16 | 474. | 840. |
| Conc., cellular | At 50°C | I | 0.188 | 704. | 1050. |
| Conc., cellular, pipe insulation | Dry, h.f. 40°C, c.f. 10°C | C | 0.095 | 400. | - |
| Conc., cellular pipe insulation | Dry, h.f. 100°C, c.f. 10°C | C | 0.10 | 400. | - |
| Conc., cellular, autoclave treated | $\rho$ 375-425 | F | 0.16 | 400. | - |
| Conc., cellular, autoclave treated | $\rho$ 425-475 | F | 0.17 | 450. | - |
| Conc., cellular, autoclave treated | $\rho$ 475-525 | F | 0.18 | 500. | - |
| Conc., cellular, autoclave treated | $\rho$ 525-575 | F | 0.20 | 550. | - |
| Conc., cellular, autoclave treated | $\rho$ 575-625 | F | 0.22 | 600. | - |
| Conc., cellular, autoclave treated | $\rho$ 625-675 | F | 0.24 | 650. | - |
| Conc., cellular, autoclave treated | $\rho$ 675-725 | F | 0.27 | 700. | - |
| Conc., cellular, autoclave treated | $\rho$ 725-775 | F | 0.29 | 750. | - |
| Conc., cellular, autoclave treated | $\rho$ 775-825) | F | 0.33 | 800. | - |
| Conc., cellular, cement or limestone base | SBR, $\rho$ 400-750 | T | - | 575. | - |
| Conc., cement or lime based, aerated | Low exp., $\rho$ 400-750 | S | 0.21 | 575. | 840. |
| Conc., cinder | At 50°C | I | 0.686 | 1406. | 840. |
| Conc., close textured, light, using porous textured aggregate | | G | 0.47 | 1000. | - |
| Conc., close textured, light, using porous textured aggregate | | G | 0.59 | 1200. | - |
| Conc., close textured, light, using porous textured aggregate | | G | 0.72 | 1400. | - |
| Conc., close textured, light, using porous textured aggregate | | G | 0.87 | 1600. | - |
| Conc., close textured, light, using porous textured aggregate | | G | 0.99 | 1800. | - |
| Conc., close textured, light, using porous textured aggregate | | G | 1.20 | 2000. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.30 | 800. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.35 | 900. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.38 | 1000. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.44 | 1100. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.50 | 1200. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.56 | 1300. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.62 | 1400. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.67 | 1500. | - |
| Conc., close textured, light, using expanded clay or slate | | G | 0.73 | 1600. | - |
| Conc., cellular | | Y | 0.12 | 400. | - |
| Conc., cellular | | Y | 0.20 | 600. | - |
| Conc., cellular | | Y | 0.25 | 800. | - |
| Conc., ordinary | | Y | 1.10 | 2200. | - |
| Conc., reinforced | | Y | 1.30 | 2400. | - |
| Conc., thin | | Y | 0.80 | 1800. | - |
| Conc., residuals of iron works | Low exp. | S | 0.70 | 1900. | 840. |
| Conc., residuals of iron works | Low exp. | S | 0.45 | 1600. | 840. |
| Conc., residuals of iron works | Low exp. | S | 0.30 | 1300. | 840. |
| Conc., residuals of iron works | Low exp. | S | 0.23 | 1000. | 840. |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., residuals of iron works | Std exp. | S | 1.00 | 1900. | 840. |
| Conc., residuals of iron works | Std exp. | S | 0.70 | 1600. | 840. |
| Conc., residuals of iron works | Std exp. | S | 0.45 | 1300. | 840. |
| Conc., residuals of iron works | Std exp. | S | 0.35 | 1000. | 840. |
| Conc., heavyweight block | | C | 1.63 | 2300. | 1000. |
| Conc., lightweight block | | C | 0.19 | 600. | 1000. |
| Conc., mediumweight block | | C | 0.51 | 1400. | 1000. |
| Conc. block | Lightweight | BS | .26 | 800. | - |
| Conc. block | Mediumweight | BS | .56 | 1400. | - |
| Conc. block | Dense | BS | 1.3 | 2000. | - |
| Conc. block | .015m mediumweight | D | 0.76924 | 1904. | 837. |
| Conc. block | .015m heavyweight | D | 1.31150 | 2240. | - |
| Conc. block | .015m lightweight | D | 0.66120 | 1760. | 837. |
| Conc. block | .01m heavyweight | D | 1.31150 | 2240. | - |
| Conc. block | .01m lightweight | D | 0.63973 | 1664. | 837. |
| Conc. block | .02m heavyweight | D | 1.31150 | 2240. | - |
| Conc. block | .02m lightweight | D | 0.75469 | 1840. | 837. |
| Conc. block | .02m mediumweight | D | 0.85823 | 1968. | 837. |
| Conc. block | .03m lightweight | D | 0.72613 | 1808. | 837. |
| Conc. block, conc. and perlite | .015m mediumweight | D | 0.39111 | 1344. | 837. |
| Conc. block, conc. and perlite | .015m heavyweight | D | 0.73375 | 1664. | - |
| Conc. block, conc. and perlite | .015m lightweight | D | 0.33398 | 1184. | 837. |
| Conc. block, conc. and perlite | .01m heavyweight | D | 0.82620 | 1840. | - |
| Conc. block, conc. and perlite | .01m lightweight | D | 0.35995 | 1264. | 837. |
| Conc. block, conc. and perlite | .02m heavyweight | D | 0.72024 | 1488. | - |
| Conc. block, conc. and perlite | .02m lightweight | D | 0.36272 | 1104. | 837. |
| Conc. block, conc. and perlite | .02m mediumweight | D | 0.41777 | 1232. | 837. |
| Conc. block, conc. and perlite | .01m medium weight | D | 0.43163 | 1440. | 837. |
| Conc. block, hollow | .02m lightweight | D | 0.57706 | 720. | 837. |
| Conc. block, hollow | .03m mediumweight | D | 0.85858 | 928. | 837. |
| Conc. block, hollow | .015 mediumweight | D | 0.61826 | 1040. | 837. |
| Conc. block, hollow | .015m heavyweight | D | 0.96176 | 1360. | - |
| Conc. block, hollow | .015m lightweight | D | 0.48080 | 880. | 837. |
| Conc. block, hollow | .01m heavyweight | D | 0.81269 | 1616. | - |
| Conc. block, hollow | .01m lightweight | D | 0.38471 | 1040. | 837. |
| Conc. block, hollow | .02m heavyweight | D | 1.04920 | 1104. | - |
| Conc. block, hollow | .02m mediumweight | D | 0.67107 | 848. | 837. |
| Conc. block, hollow | .03m heavyweight | D | 1.35270 | 1216. | 837. |
| Conc. block, hollow | .03m lightweight | D | 0.76266 | 784. | 837. |
| Conc. block, partially filled | .01m heavyweight | D | 1.01180 | 1824. | - |
| Conc. block, partially filled | .01m lightweight | D | 0.48616 | 1248. | 837. |
| Conc. block, partially filled | .02m lightweight | D | 0.66588 | 1088. | 837. |
| Conc. block, partially filled | .03m lightweight | D | 0.73998 | 1120. | 837. |
| Conc. block, partially filled with Conc. | .015m heavyweight | D | 1.05941 | 1664. | - |
| Conc. block, partially filled with Conc. | .03m mediumweight | D | 0.85165 | 1264. | 837. |
| Conc. block, partially filled | .015m lightweight | D | 0.55213 | 1168. | 837. |
| Conc. block, partially filled | .02m heavyweight | D | 1.16797 | 1488. | - |
| Conc. block, perlite filled | .01m lightweight | D | 0.22005 | 1072. | 837. |
| Conc. block, perlite filled | .015 mediumweight | D | 0.20188 | 1072. | 837. |
| Conc. block, perlite filled | .015m heavyweight | D | 0.38471 | 1408. | - |
| Conc. block, perlite filled | .015m lightweight | D | 0.17054 | 912. | 837. |
| Conc. block, perlite filled | .01m heavyweight | D | 0.51958 | 1648. | - |
| Conc. block, perlite filled | .02m heavyweight | D | 0.39336 | 1120. | - |
| Conc. block, perlite filled | .02m lightweight | D | 0.16673 | 768. | 837. |
| Conc. block, perlite filled | .01m medium weight | D | 0.26178 | 1248. | 837. |
| Conc. block, perlite filled | .02m mediumweight | D | 0.19755 | 896. | 837. |
| Conc. block | .01m medium weight | D | 0.77149 | 1840. | 837. |
| Conc. block | .03m heavyweight | D | 1.31150 | 2240. | 837. |
| Conc. block | .03m mediumweight | D | 0.83347 | 1936. | 837. |
| Conc. block, hollow | .01m medium weight | D | 0.51992 | 1216. | 837. |
| Conc. block, partially filled | .015 mediumweight | D | 0.63817 | 1328. | 837. |
| Conc. block, partially filled | .01m medium weight | D | 0.57238 | 1424. | 837. |
| Conc. block, partially filled | .02m mediumweight | D | 0.83936 | 1216. | 837. |
| Conc. block, partially filled | .03m heavyweight | D | 1.34578 | 1568. | 837. |
| Conc., cast | Lightweight | BS | 1. | 1800. | - |
| Conc., cast | Dense | BS | 1.25 | 2200. | - |
| Conc., cast, no-fines | | BS | 1. | 1800. | - |
| Conc. from blast furnace slag | CSTC | T | - | 1300. | - |
| Conc. from blast-furnace slag | CSTC | T | - | 1000. | - |
| Conc. from blast-furnace slag | CSTC | T | - | 1900. | - |
| Conc. from polystyrene foam granules | CSTC, $\rho$ 350-400 | T | - | 375. | - |
| Conc. from slag and Rhine sand | SPPS | T | - | 1500. | - |
| Conc. from slag and Rhine sand | SPPS | T | - | 1700. | - |
| Conc. from slag and Rhine sand | SPPS | T | - | 1900. | - |
| Conc. from expanded clay | CSTC | T | - | 775. | - |
| Conc. from fly ash, loose granules | $\rho$ 1000-1200 | F | 0.35 | 1100. | - |
| Conc. from wood cuttings | $\rho$ 450-650 | F | 0.16 | 550. | - |
| Conc. roof tiles | SPPS, dry | T | - | 2100. | 930. |
| Conc. roof tiles | SPPS, moist | T | - | 2100. | 1000. |
| Conc. tiles | Conditioned | C | 1.10 | 2100. | - |
| Conc. with expanded clay filling | Low exp., $\rho$ 550-1000 | S | 0.26 | 775. | 840. |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ **(** $W/mK$ **)** | $\rho$ **(** $kg/m^3$ **)** | $\mathbf{C_p}$ **(** $J/kgK$ **)** |
|---|---|---|---|---|---|
| Conc. with expanded clay filling | Low exp., $\rho$ 1000-1800 | S | 0.60 | 1400. | 840. |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | **$C_p$** ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., lightweight block | Low exp., $\rho$ 500-549 | B | 0.20 | 525. | - |
| Conc., expanded clay or shale, river & light sand | $\rho$ 1400-1600 | F | 0.85 | 1500. | - |
| Conc., expanded clay or shale, river sand | $\rho$ 1600-1800 | F | 1.05 | 1700. | - |
| Conc., natural pumice, loose granules | $\rho$ 950-1150 | F | 0.46 | 1050. | - |
| Conc., aerated | | E | 0.16 | 500. | 840. |
| Conc., aerated block | | E | 0.24 | 750. | 1000. |
| Conc., inner block | 3% m.c. | E | 0.51 | 1400. | 1000. |
| Conc., foamed inner block | 3% m.c. | E | 0.16 | 600. | 1000. |
| Conc., foamed outer block | 5% m.c. | E | 0.17 | 600. | 1000. |
| Conc., foamed slag | | E | 0.25 | 1040. | 960. |
| Conc., glass reinforced | | E | 0.90 | 1950. | 840. |
| Conc., heavy mix | | E | 1.40 | 2100. | 653. |
| Conc., lightweight | | D | 0.36064 | 1280. | 837. |
| Conc., lightweight | | D | 0.13002 | 480. | 837. |
| Conc., lightweight block | Low exp., $\rho$ 450-499 | B | 0.19 | 475. | - |
| Conc., lightweight block | Low exp., $\rho$ 550-599 | B | 0.22 | 575. | - |
| Conc., lightweight block | Low exp., $\rho$ 600-649 | B | 0.24 | 625. | - |
| Conc., lightweight block | Low exp., $\rho$ 650-699 | B | 0.25 | 675. | - |
| Conc., lightweight block | Low exp., $\rho$ 700-749 | B | 0.26 | 725. | - |
| Conc., lightweight block | Low exp., $\rho$ 750-799 | B | 0.28 | 775. | - |
| Conc., lightweight block | Low exp., $\rho$ 800-849 | B | 0.29 | 825. | - |
| Conc., lightweight block | Low exp., $\rho$ 850-899 | B | 0.30 | 875. | - |
| Conc., lightweight block | Std exp., $\rho$ 600-649 | B | 0.42 | 625. | - |
| Conc., lightweight block | Std exp., $\rho$ 650-699 | B | 0.43 | 675. | - |
| Conc., lightweight block | Std exp., $\rho$ 700-749 | B | 0.44 | 725. | - |
| Conc., lightweight block | Std exp., $\rho$ 750-799 | B | 0.46 | 775. | - |
| Conc., lightweight block | Std exp., $\rho$ 800-849 | B | 0.48 | 825. | - |
| Conc., lightweight block | Std exp., $\rho$ 850-899 | B | 0.50 | 875. | - |
| Conc., no fines | | E | 0.96 | 1800. | 840. |
| Conc., refractory insulating | | E | 0.25 | 10. | 837. |
| Conc., vermiculite aggregate | | E | 0.17 | 450. | 837. |
| Conc., panels, wood fibres or fibreglass | $\rho$ 250-350 | F | 0.10 | 300. | - |
| Conc., panels, wood fibres or fibreglass | $\rho$ 350-450 | F | 0.12 | 400. | - |
| Conc., panels, wood fibres or fibreglass | $\rho$ 450-550 | F | 0.15 | 500. | - |
| Conc., foam | At 50°C | I | 0.07 | 320. | 920. |
| Conc., foam | At 50°C | I | 0.084 | 400. | 920. |
| Conc., foam | At 50°C | I | 0.149 | 704. | 920. |
| Conc., foam panels, normal jointing thickness and mortar | | G | 0.22 | 500. | - |
| Conc., foam panels, normal jointing thickness and mortar | | G | 0.24 | 600. | - |
| Conc., foam panels, normal jointing thickness and mortar | | G | 0.27 | 700. | - |
| Conc., foam panels, normal jointing thickness and mortar | | G | 0.29 | 800. | - |
| Conc., foam panels, thin joints | | G | 0.19 | 500. | - |
| Conc., foam panels, thin joints | | G | 0.22 | 600. | - |
| Conc., foam panels, thin joints | | G | 0.24 | 700. | - |
| Conc., foam panels, thin joints | | G | 0.27 | 800. | - |
| Conc., foam slag | At 50°C | I | 0.285 | 1320. | 880. |
| Conc., heavy | NBN, dry, $\rho$ >1800 | T | 1.30 | 2000. | 840. |
| Conc., heavy | NBN, moist, $\rho$ >1800 | T | 1.70 | 2000. | 840. |
| Conc., heavy | SBR | T | - | 1900. | - |
| Conc., heavy, non-compacted, non-reinforced | CSTC | T | - | 2200. | - |
| Conc., heavy, non-compacted, reinforced | CSTC | T | - | 2300. | - |
| Conc., heavy, reinforced | NBN | T | - | 2400. | - |
| Conc., heavywt, non-reinforced | Std exp. | B | 1.70 | 2200. | - |
| Conc., heavywt, non-reinforced | Low exp. | B | 1.30 | 2200. | - |
| Conc., heavywt, reinforced | Low exp. | B | 1.70 | 2400. | - |
| Conc., heavywt, reinforced | Std exp. | B | 2.20 | 2400. | - |
| Conc., hollow blocks | $\rho$ <1800 | G | 0.92 | 1800. | - |
| Conc., hollow blocks | $\rho$ <1800 | G | 1.30 | 1800. | - |
| Conc., hollowed & semi-hollowed, light or river sand | $\rho$ <600 | F | 0.20 | 600. | - |
| Conc., hollowed & semi-hollowed, light or river sand | $\rho$ 600-800 | F | 0.25 | 700. | - |
| Conc., hollowed and semi-hollowed, light sand only | $\rho$ 800-1000 | F | 0.33 | 900. | - |
| Conc., hollowed | $\rho$ 1700-2100 | F | 1.40 | 1900. | - |
| Conc., hollowed, <10% river sand | $\rho$ 1600-2000 | F | 0.70 | 1800. | - |
| Conc., insulating & conductive, light & 10% river sand | $\rho$ 1200-1400 | F | 0.70 | 1300. | - |
| Conc., insulating and conductive, light sand only | $\rho$ 1000-1200 | F | 0.46 | 1100. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., insulating | SBR, $\rho$ 300-700 | T | - | 500. | - |
| Conc., light | CSTC | T | - | 700. | - |
| Conc., light | NBN, dry, $\rho$ 600-649 | T | 0.20 | 624. | 840. |
| Conc., light | NBN, dry, $\rho$ 600-899 | T | 0.25 | 749. | 840. |
| Conc., light | NBN, dry, $\rho$ 650-699 | T | 0.21 | 674. | 840. |
| Conc., light | NBN, dry, $\rho$ 700-749 | T | 0.22 | 724. | 840. |
| Conc., light | NBN, dry, $\rho$ 800-849 | T | 0.24 | 824. | 840. |
| Conc., light | NBN, dry, $\rho$ 850-899 | T | 0.25 | 874. | 840. |
| Conc., light | NBN, moist, $\rho$ 600-649 | T | 0.31 | 624. | - |
| Conc., light | NBN, moist, $\rho$ 600-899 | T | 0.43 | 749. | 840. |
| Conc., light | NBN, moist, $\rho$ 650-699 | T | 0.34 | 674. | - |
| Conc., light | NBN, moist, $\rho$ 700-749 | T | 0.36 | 724. | - |
| Conc., light | NBN, moist, $\rho$ 800-849 | T | 0.40 | 824. | 840. |
| Conc., light | NBN, moist, $\rho$ 850-899 | T | 0.43 | 874. | 840. |
| Conc., light, with expanded clay | | G | 0.18 | 500. | - |
| Conc., light, with expanded clay | | G | 0.20 | 600. | - |
| Conc., light, with expanded clay | | G | 0.23 | 700. | - |
| Conc., light, with expanded clay | | G | 0.26 | 800. | - |
| Conc., light, with expanded clay | | G | 0.30 | 900. | - |
| Conc., light, with expanded clay | | G | 0.35 | 1000. | - |
| Conc., light, with expanded clay | | G | 0.46 | 1200. | - |
| Conc., light, with natural pumice | | G | 0.15 | 500. | - |
| Conc., light, with natural pumice | | G | 0.18 | 600. | - |
| Conc., light, with natural pumice | | G | 0.20 | 700. | - |
| Conc., light, with natural pumice | | G | 0.24 | 800. | - |
| Conc., light, with natural pumice | | G | 0.27 | 900. | - |
| Conc., light, with natural pumice | | G | 0.32 | 1000. | - |
| Conc., light, with natural pumice | | G | 0.44 | 1200. | - |
| Conc., light, with non-porous aggr. | | G | 0.81 | 1600. | - |
| Conc., light, with non-porous aggr. | | G | 1.10 | 1800. | - |
| Conc., light, with non-porous aggr. | | G | 1.40 | 2000. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.22 | 600. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.26 | 700. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.28 | 800. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.36 | 1000. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.46 | 1200. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.57 | 1400. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 0.75 | 1600. | - |
| Conc., light, porous aggregate,s no quartz sand admixture | | G | 0.92 | 1800. | - |
| Conc., light, porous aggregate, no quartz sand admixtures | | G | 1.20 | 2000. | - |
| Conc., light | NBN, $\rho$ 750-799 | T | 0.38 | 774. | 840. |
| Conc., light | NBN, dry, $\rho$ 750-799 | T | 0.23 | 774. | 840. |
| Conc., lightweight | | E | 0.41 | 1200. | 840. |
| Conc., lightweight | Low exp., $\rho$ 600-649 | B | 0.20 | 625. | - |
| Conc., lightweight | Low exp., $\rho$ 650-699 | B | 0.21 | 675. | - |
| Conc., lightweight | Low exp., $\rho$ 750-799 | B | 0.23 | 775. | - |
| Conc., lightweight | Low exp., $\rho$ 800-849 | B | 0.24 | 825. | - |
| Conc., lightweight | Low exp., $\rho$ 850-899 | B | 0.25 | 875. | - |
| Conc., lightweight | Std exp., $\rho$ 650-699 | B | 0.34 | 675. | - |
| Conc., lightweight | Std exp., $\rho$ 750-799 | B | 0.38 | 775. | - |
| Conc., lightweight | Std exp., $\rho$ 800-849 | B | 0.40 | 825. | - |
| Conc., lightweight | Std exp., $\rho$ 850-899 | B | 0.43 | 875. | - |
| Conc., lightweight | Std exp., $\rho$ 1200-1400 | F | 0.44 | 1300. | - |
| Conc., lightweight | Low exp. | S | 0.95 | 1900. | 840. |
| Conc., lightweight | Low exp. | S | 0.17 | 500. | 840. |
| Conc., lightweight | Low exp. | S | 0.12 | 300. | 840. |
| Conc., lightweight | Low exp. | S | 0.08 | 200. | 840. |
| Conc., lightweight | Low exp. | S | 0.70 | 1600. | 840. |
| Conc., lightweight | Low exp. | S | 0.45 | 1300. | 840. |
| Conc., lightweight | Low exp. | S | 0.35 | 1000. | 840. |
| Conc., lightweight | Low exp. | S | 0.23 | 700. | 840. |
| Conc., lightweight | Std exp. | S | 1.40 | 1900. | 840. |
| Conc., lightweight | Std exp. | S | 1.20 | 1600. | 840. |
| Conc., lightweight | Std exp. | S | 0.80 | 1300. | 840. |
| Conc., lightweight | Std exp. | S | 0.50 | 1000. | 840. |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.301 | 1210. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.350 | 1150. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.373 | 1120. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.374 | 1300. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.379 | 1220. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.419 | 1400. | - |
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.431 | 1230. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., lightweight, Aglite. | 3% MC by vol. | L | 0.431 | 1370. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.261 | 1290. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.264 | 1220. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.277 | 1240. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.288 | 1290. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.299 | 1310. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.316 | 1360. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.318 | 1320. | - |
| Conc., lightweight, Pellite. | 3% MC by vol. | L | 0.323 | 1420. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.305 | 1120. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.310 | 1260. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.331 | 1350. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.360 | 1410. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.362 | 1330. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.384 | 1190. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.404 | 1380. | - |
| Conc., lightweight, Lytag. | 3% MC by vol. | L | 0.460 | 1350. | - |
| Conc., lightweight, no sand or other fine components | $\rho$ 1000-1200 | F | 0.35 | 1100. | - |
| Conc., lightweight granular | $\rho$ 1400-1600 | F | 0.52 | 1500. | - |
| Conc., lime | At 50°C | I | 0.73 | 1646. | 880. |
| Conc., medium lightweight | Low exp., $\rho$ 950-999 | B | 0.47 | 975. | - |
| Conc., medium lightweight | CSTC | T | - | 1300. | - |
| Conc., medium lightweight | NBN, dry, $\rho$ 1000-1099 | T | 0.32 | 1049. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 1100-1199 | T | 0.37 | 1149. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 1200-1499 | T | 0.59 | 1349. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 1500-1799 | T | 0.84 | 1649. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 900-1199 | T | 0.37 | 1049. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 900-949 | T | 0.27 | 924. | 840. |
| Conc., medium lightweight | NBN, dry, $\rho$ 950-999 | T | 0.29 | 975. | 840. |
| Conc., medium lightweight | NBN, moist, $\rho$ 1000-1099 | T | 0.52 | 1049. | - |
| Conc., medium lightweight | NBN, moist, $\rho$ 1100-1199 | T | 0.59 | 1149. | - |
| Conc., medium lightweight | NBN, moist, $\rho$ 1200-1499 | T | 0.87 | 1349. | - |
| Conc., medium lightweight | NBN, moist, $\rho$ 1500-1799 | T | 1.18 | 1649. | - |
| Conc., medium lightweight | NBN, moist, $\rho$ 900-1199 | T | 0.59 | 1049. | 840. |
| Conc., medium lightweight | NBN, moist, $\rho$ 900-949 | T | 0.45 | 924. | - |
| Conc., medium lightweight | NBN, moist, $\rho$ 950-999 | T | 0.47 | 975. | - |
| Conc., medium lightweight | SBR | T | - | 1000. | - |
| Conc., medium lightweight | SBR | T | - | 1600. | - |
| Conc., medium lightweight, made from bimers | CSTC | T | - | 1200. | - |
| Conc., medium lightweight, made from expanded clay | SBR | T | - | 1400. | - |
| Conc., medium lightweight, granular expanded clay base | SPPS | T | - | 950. | - |
| Conc., medium lightweight | Low exp., $\rho$ 1000-1099 | B | 0.32 | 1050. | - |
| Conc., medium lightweight | Low exp., $\rho$ 1100-1199 | B | 0.37 | 1150. | - |
| Conc., medium lightweight | Low exp., $\rho$ 900-949 | B | 0.27 | 924. | - |
| Conc., medium lightweight | Low exp., $\rho$ 950-999 | B | 0.29 | 975. | - |
| Conc., medium lightweight | Std exp., $\rho$ 1000-1099 | B | 0.52 | 1050. | - |
| Conc., medium lightweight | Std exp., $\rho$ 1100-1199 | B | 0.58 | 1150. | - |
| Conc., medium lightweight | Std exp., $\rho$ 900-949 | B | 0.45 | 924. | - |
| Conc., non-reinforced, heavy | NBN, dry | T | 1.30 | 2200. | 840. |
| Conc., non-reinforced, heavy | NBN, moist | T | 1.70 | 2200. | - |
| Conc., normal, close-textured gravel | DIN 1045 | G | 2.10 | 2400. | - |
| Conc., polystyrene | SBR | T | - | 220. | - |
| Conc., polystyrene | SPPS | T | - | 260. | - |
| Conc., polystyrene | SPPS | T | - | 400. | - |
| Conc., polystyrene | SPPS | T | - | 650. | - |
| Conc., polystyrene foam | Low exp. | S | 0.07 | 220. | - |
| Conc., polystyrene foam | Low exp. | S | 0.11 | 400. | - |
| Conc., polystyrene foam | Low exp. | S | 0.20 | 650. | - |
| Conc., slag/conc. conglomerate | | Y | 0.60 | 1250. | - |
| Conc., lightweight solid blocks | | G | 0.29 | 500. | - |
| Conc., lightweight solid blocks | | G | 0.87 | 1800. | - |
| Conc., lightweight solid blocks | | G | 0.99 | 2000. | - |
| Conc., lightweight solid blocks | | G | 0.32 | 600. | - |
| Conc., lightweight solid blocks | | G | 0.35 | 700. | - |
| Conc., lightweight solid blocks | | G | 0.39 | 800. | - |
| Conc., lightweight solid blocks | | G | 0.43 | 900. | - |
| Conc., lightweight solid blocks | | G | 0.46 | 1000. | - |
| Conc., lightweight solid blocks | | G | 0.54 | 1200. | - |
| Conc., lightweight solid blocks | | G | 0.63 | 1400. | - |
| Conc., lightweight solid blocks | | G | 0.74 | 1600. | - |
| Conc., solid | $\rho$ 2200-2400 | F | 1.75 | 2300. | - |
| Conc., solid with granular slag | $\rho$ 2100-2300 | F | 0.80 | 2200. | - |
| Conc., solid with river sand or quarry sand | $\rho$ 2200-2400 | F | 1.40 | 2300. | - |
| Conc., foam, steam hardened | | G | 0.14 | 400. | - |
| Conc., foam, steam hardened | | G | 0.16 | 500. | - |
| Conc., foam, steam hardened | | G | 0.19 | 600. | - |
| Conc., foam, steam hardened | | G | 0.21 | 700. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Conc., foam, steam hardened | | G | 0.23 | 800. | - |
| Conc. tiles | | E | 1.10 | 2100. | 837. |
| Conc., very light | CSTC | T | - | 200. | - |
| Conc., very light | CSTC | T | - | 500. | - |
| Conc., very light | CSTC | T | - | 300. | - |
| Conc., very light | NBN, $\rho$ 350-399 | T | 0.14 | 374. | 840. |
| Conc., very light | NBN, $\rho$ 400-449 | T | 0.15 | 424. | 840. |
| Conc., very light | NBN, $\rho$ 450-499 | T | 0.16 | 474. | 840. |
| Conc., very light | NBN, $\rho$ 500-549 | T | 0.17 | 524. | 840. |
| Conc., very light | NBN, $\rho$ 500-599 | T | 0.18 | 574. | 840. |
| Conc., very light | NBN, $\rho$ <350 | T | 0.12 | 350. | 840. |
| Conc., very light | NBN, $\rho$ <599 | T | 0.18 | 597. | 840. |
| Conc., very light | SBR | T | - | 200. | - |
| Conc., very light | Low exp., $\rho$ 350-399 | B | 0.14 | 375. | - |
| Conc., very light | Low exp., $\rho$ 400-449 | B | 0.15 | 425. | - |
| Conc., very light | Low exp., $\rho$ 450-499 | B | 0.16 | 475. | - |
| Conc., very light | Low exp., $\rho$ 500-549 | B | 0.17 | 525. | - |
| Conc., very light | Low exp., $\rho$ 550-599 | B | 0.18 | 575. | - |
| Conc., very light | Low exp., $\rho$ <350 | B | 0.12 | 350. | - |
| Conc. wall panels, light | | G | 0.29 | 800. | - |
| Conc. wall panels, light | | G | 0.32 | 900. | - |
| Conc. wall panels, light | | G | 0.37 | 1000. | - |
| Conc. wall panels, light | | G | 0.47 | 1200. | - |
| Conc. wall panels, light | | G | 0.58 | 1400. | - |
| Conc., lightweight | Low exp., $\rho$ 700-749 | B | 0.22 | 725. | - |
| Conc., lightweight | Std exp., $\rho$ 700-749 | B | 0.36 | 725. | - |
| Conc., light mix | | E | 0.38 | 1200. | 653. |
| Conc. conglomerate in granules | SPPS | T | - | 2100. | - |
| Conc., dense | At 50°C | I | 1.74 | 2410. | 880. |
| Conc., dense | 1.9% MC by vol. | L | 0.593 | 1551. | - |
| Conc., dense | 3.6% MC by vol. | L | 0.810 | 1818. | - |
| Conc., dense | 1.8% MC by vol. | L | 1.379 | 1899. | - |
| Conc., dense | 3.0% MC by vol. | L | 1.770 | 2207. | - |
| Conc., dense | 2.7% MC by vol. | L | 2.532 | 2236. | - |
| Conc., dense | 4.8% MC by vol. | L | 3.207 | 2341. | - |
| ***** Masonry ***** | | | | | |
| Masonry, blast furnace slag | | G | 0.47 | 1000. | - |
| Masonry, blast furnace slag | | G | 0.52 | 1200. | - |
| Masonry, blast furnace slag | | G | 0.58 | 1400. | - |
| Masonry, blast furnace slag | | G | 0.64 | 1600. | - |
| Masonry, blast furnace slag | | G | 0.70 | 1800. | - |
| Masonry, blast furnace slag | | G | 0.76 | 2000. | - |
| Masonry, calcareous sand stones | | G | 0.50 | 1000. | - |
| Masonry, calcareous sand stones | | G | 0.56 | 1200. | - |
| Masonry, calcareous sand stones | | G | 0.70 | 1400. | - |
| Masonry, calcareous sand stones | | G | 0.79 | 1600. | - |
| Masonry, calcareous sand stones | | G | 0.99 | 1800. | - |
| Masonry, calcareous sand stones | | G | 1.10 | 2000. | - |
| Masonry, calcareous sand stones | | G | 1.30 | 2200. | - |
| Masonry, cellular bonded conc. | SPPS, $\rho$ 500-549 | T | 0.30 | 524. | 2040. |
| Masonry, cellular bonded conc. | SPPS, $\rho$ 600-649 | T | - | 624. | 1850. |
| Masonry, cellular cemented conc. | SPPS, $\rho$ 650-699 | T | - | 674. | 1770. |
| Masonry, foam conc. blocks | | G | 0.22 | 500. | - |
| Masonry, foam conc. blocks | | G | 0.24 | 600. | - |
| Masonry, foam conc. blocks | | G | 0.27 | 700. | - |
| Masonry, foam conc. blocks | | G | 0.29 | 800. | - |
| Masonry, hollowed engineering brick | | G | 0.81 | 1800. | - |
| Masonry, light blocks | NBN, dry, $\rho$ 600-649 | T | 0.24 | 624. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 600-899 | T | 0.30 | 749. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 650-699 | T | 0.25 | 674. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 700-749 | T | 0.26 | 724. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 750-799 | T | 0.28 | 774. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 800-849 | T | 0.29 | 824. | 840. |
| Masonry, light blocks | NBN, dry, $\rho$ 850-899 | T | 0.30 | 874. | 840. |
| Masonry, light blocks | NBN, moist, $\rho$ 600-649 | T | 0.42 | 624. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 600-899 | T | 0.50 | 749. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 650-699 | T | 0.43 | 674. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 700-749 | T | 0.44 | 724. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 750-799 | T | 0.46 | 774. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 800-849 | T | 0.48 | 824. | - |
| Masonry, light blocks | NBN, moist, $\rho$ 850-899 | T | 0.50 | 874. | - |
| Masonry, light conc. air bricks | | G | 0.35 | 600. | - |
| Masonry, light conc. air bricks | | G | 0.40 | 700. | - |
| Masonry, light conc. air bricks | | G | 0.47 | 800. | - |
| Masonry, light conc. air bricks | | G | 0.56 | 900. | - |
| Masonry, light conc. air bricks | | G | 0.65 | 1000. | - |
| Masonry, light conc. air bricks | | G | 0.77 | 1200. | - |
| Masonry, light conc. air bricks | | G | 0.91 | 1400. | - |
| Masonry, light conc. air bricks | | G | 1.00 | 1600. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Masonry, light conc. hollow blocks | | G | 0.29 | 500. | - |
| Masonry, light conc. hollow blocks | | G | 0.29 | 500. | - |
| Masonry, light conc. hollow blocks | | G | 0.32 | 600. | - |
| Masonry, light conc. hollow blocks | | G | 0.34 | 600. | - |
| Masonry, light conc. hollow blocks | | G | 0.35 | 700. | - |
| Masonry, light conc. hollow blocks | | G | 0.39 | 700. | - |
| Masonry, light conc. hollow blocks | | G | 0.39 | 800. | - |
| Masonry, light conc. hollow blocks | | G | 0.46 | 800. | - |
| Masonry, light conc. hollow blocks | | G | 0.44 | 900. | - |
| Masonry, light conc. hollow blocks | | G | 0.55 | 900. | - |
| Masonry, light conc. hollow blocks | | G | 0.49 | 1000. | - |
| Masonry, light conc. hollow blocks | | G | 0.64 | 1000. | - |
| Masonry, light conc. hollow blocks | | G | 0.76 | 1200. | - |
| Masonry, light conc. hollow blocks | | G | 0.60 | 1200. | - |
| Masonry, light conc. hollow blocks | | G | 0.73 | 1400. | - |
| Masonry, light conc. hollow blocks | | G | 0.90 | 1400. | - |
| Masonry, mediumweight blocks | NBN, dry, $\rho$ 1000-1099 | T | 0.35 | 1049. | 840. |
| Masonry, mediumweight blocks | NBN, dry, $\rho$ 1100-1199 | T | 0.40 | 1149. | 840. |
| Masonry, mediumweight blocks | NBN, dry, $\rho$ 900-1199 | T | 0.40 | 1049. | 840. |
| Masonry, mediumweight blocks | NBN, dry, $\rho$ 900-949 | T | 0.31 | 924. | 840. |
| Masonry, mediumweight blocks | NBN, dry, $\rho$ 950-999 | T | 0.32 | 974. | 840. |
| Masonry, mediumweight blocks | NBN, moist, $\rho$ 1000-1099 | T | 0.58 | 1049. | - |
| Masonry, mediumweight blocks | NBN, moist, $\rho$ 1100-1199 | T | 0.62 | 1149. | - |
| Masonry, mediumweight blocks | NBN, moist, $\rho$ 90-1199 | T | 0.62 | 1049. | - |
| Masonry, mediumweight blocks | NBN, moist, $\rho$ 900-949 | T | 0.52 | 924. | - |
| Masonry, mediumweight blocks | NBN, moist, $\rho$ 950-999 | T | 0.55 | 974. | - |
| Masonry, plaster blocks | SPPS | T | 0.35 | - | 860. |
| Masonry, quarrystones, calcareous, semi-firm | NBN, dry | T | 1.40 | 2200. | 840. |
| Masonry, quarrystones, calcareous, semi-firm | NBN, moist | T | 1.69 | 2200. | - |
| Masonry, semi-heavy blocks | CSTC, $\rho$ >1401 | T | - | 1401. | - |
| Masonry, semi-heavy blocks | NBN | T | - | 1400. | - |
| Masonry, semi-heavy blocks | NBN, dry, $\rho$ 1200-1449 | T | 0.60 | 1349. | 840. |
| Masonry, semi-heavy blocks | NBN, dry, $\rho$ 1500-1799 | T | 0.85 | 1649. | 840. |
| Masonry, semi-heavy blocks | NBN, dry, $\rho$ >1800 | T | 1.30 | 1800. | 840. |
| Masonry, semi-heavy blocks | NBN, moist, $\rho$ 1200-1449 | T | 0.90 | 1349. | - |
| Masonry, semi-heavy blocks | NBN, moist, $\rho$ >1800 | T | 1.70 | 1800. | - |
| Masonry, semi-heavy blocks | moist, $\rho$ 1500-1799 | T | 1.20 | 1649. | - |
| Masonry, silico-chalk bricks | CSTC, $\rho$ <1400 | T | - | 1400. | - |
| Masonry, silico-chalk bricks | CSTC, $\rho$ >1400 | T | - | 1400. | - |
| Masonry, silico-chalk bricks | SBR, $\rho$ >1400 | T | - | 2000. | - |
| Masonry, solid engineering brick | | G | 0.96 | 2000. | - |
| Masonry, solid engineering & hollowed brick | | G | 0.50 | 1200. | - |
| Masonry, solid engineering & hollowed brick | | G | 0.58 | 1400. | - |
| Masonry, solid engineering & hollowed brick | | G | 0.68 | 1600. | - |
| Masonry, solid engineering & hollowed brick | | G | 0.81 | 1800. | - |
| Masonry, solid engineering & hollowed brick | | G | 0.96 | 2000. | - |
| Masonry, very light blocks | CSTC, $\rho$ 500-800 | T | - | 650. | - |
| Masonry, very light blocks | NBN, $\rho$ 450-499 | T | 0.19 | 474. | 840. |
| Masonry, very light blocks | NBN, $\rho$ 500-549 | T | 0.20 | 524. | 840. |
| Masonry, very light blocks | NBN, $\rho$ 550-599 | T | 0.22 | 574. | 840. |
| Masonry, very light blocks | NBN, $\rho$ <599 | T | 0.22 | 599. | 840. |
| Masonry, heavy | Low exp., $\rho$ 1900-1999 | B | 0.79 | 1950. | - |
| Masonry, heavy | Low exp., $\rho$ 2000-2099 | B | 0.90 | 2050. | - |
| Masonry, heavy | Std exp., $\rho$ 1700-1799 | B | 0.87 | 1750. | - |
| Masonry, heavy | Std exp., $\rho$ 1900-1999 | B | 1.00 | 1950. | - |
| Masonry, heavy | Std exp., $\rho$ 2000-2099 | B | 1.10 | 2050. | - |
| Masonry, heavy | Low exp., $\rho$ 1600-1699 | B | 0.60 | 1650. | - |
| Masonry, heavy | Low exp., $\rho$ 1700-1799 | B | 0.66 | 1750. | - |
| Masonry, heavy | Low exp., $\rho$ 1800-1899 | B | 0.73 | 1850. | - |
| Masonry, heavy | Std exp., $\rho$ 1600-1699 | B | 0.81 | 1650. | - |
| Masonry, heavy | Std exp., $\rho$ 1800-1899 | B | 0.94 | 1850. | - |
| Masonry, mediumweight blocks | Low exp., $\rho$ 1000-1099 | B | 0.35 | 1050. | - |
| Masonry, mediumweight blocks | Low exp., $\rho$ 1100-1199 | B | 0.40 | 1150. | - |
| Masonry, mediumweight blocks | Low exp., $\rho$ 950-999 | B | 0.32 | 975. | - |
| Masonry, mediumweight blocks | Low exp., $\rho$ 900-949 | B | 0.31 | 925. | - |
| Masonry, mediumweight blocks | Std exp., $\rho$ 1000-1099 | B | 0.58 | 1050. | - |
| Masonry, mediumweight blocks | Std exp., $\rho$ 1100-1199 | B | 0.62 | 1150. | - |
| Masonry, mediumweight blocks | Std exp., $\rho$ 900-949 | B | 0.52 | 925. | - |
| Masonry, mediumweight blocks | Std exp., $\rho$ 950-999 | B | 0.55 | 975. | - |
| Masonry, semi-heavy blocks | Low exp., $\rho$ >1200 | B | 1.30 | 1200. | - |
| Masonry, semi-heavy blocks | Std exp., $\rho$ >1200 | B | 1.70 | 1200. | - |
| Masonry, mediumweight | CSTC | T | - | 1300. | - |
| Masonry, mediumweight | CSTC | T | - | 1500. | - |
| Masonry, mediumweight | NBN, dry, $\rho$ 1000-1099 | T | 0.32 | 1049. | 840. |
| Masonry, mediumweight | NBN, dry, $\rho$ 1000-1599 | T | 0.54 | 1299. | 840. |
| Masonry, mediumweight | NBN, dry, $\rho$ 1100-1199 | T | 0.37 | 1149. | 840. |
| Masonry, mediumweight | NBN, dry, $\rho$ 1200-1299 | T | 0.42 | 1249. | 840. |
| Masonry, mediumweight | NBN, dry, $\rho$ 1300-1399 | T | 0.45 | 1349. | 840. |
| Masonry, mediumweight | NBN, dry, $\rho$ 1400-1499 | T | 0.49 | 1449. | 840. |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | **$C_p$** ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Masonry, mediumweight | NBN, dry, $\rho$ 1500-1599 | T | 0.54 | 1549. | 840. |
| Masonry, mediumweight | NBN, moist, $\rho$ 1000-1099 | T | 0.47 | 1049. | - |
| Masonry, mediumweight | NBN, moist, $\rho$ 1000-1599 | T | 0.75 | 1299. | - |
| Masonry, mediumweight | NBN, moist, $\rho$ 1100-1199 | T | 0.52 | 1149. | - |
| Masonry, mediumweight | NBN, moist, $\rho$ 1300-1399 | T | 0.63 | 1349. | - |
| Masonry, mediumweight | NBN, moist, $\rho$ 1400-1499 | T | 0.69 | 1449. | - |
| Masonry, mediumweight | NBN, moist, $\rho$ 1500-1599 | T | 0.75 | 1549. | - |
| Masonry, heavyweight | CSTC | T | - | 2100. | - |
| Masonry, heavyweight | NBN, $\rho$ 1700-1900 | T | - | 1800. | - |
| Masonry, heavyweight | NBN, dry, $\rho$ 1600-2099 | T | 0.90 | 1849. | 840. |
| Masonry, heavyweight | NBN, dry, $\rho$ 1600-1699 | T | 0.60 | 1649. | - |
| Masonry, heavyweight | NBN, dry, $\rho$ 1700-1799 | T | 0.66 | 1749. | - |
| Masonry, heavyweight | NBN, dry, $\rho$ 1800-1899 | T | 0.73 | 1849. | 840. |
| Masonry, heavyweight | NBN, dry, $\rho$ 1900-1999 | T | 0.79 | 1949. | 840. |
| Masonry, heavyweight | NBN, dry, $\rho$ 2000-2099 | T | 0.90 | 2049. | 840. |
| Masonry, heavyweight | NBN, moist, $\rho$ 1600-1699 | T | 0.81 | 1649. | 840. |
| Masonry, heavyweight | NBN, moist, $\rho$ 1600-2099 | T | 1.10 | 1849. | - |
| Masonry, heavyweight | NBN, moist, $\rho$ 1700-1799 | T | 0.87 | 1749. | - |
| Masonry, heavyweight | NBN, moist, $\rho$ 1800-1899 | T | 0.94 | 1849. | - |
| Masonry, heavyweight | NBN, moist, $\rho$ 1900-1999 | T | 1.00 | 1949. | - |
| Masonry, heavyweight | NBN, moist, $\rho$ 2000-2099 | T | 1.10 | 2049. | - |
| Masonry, heavyweight | SBR | T | - | 1700. | - |
| Masonry, lightweight | NBN, moist, $\rho$ 1200-1299 | T | 0.58 | 1249. | - |
| Masonry, lightweight | CSTC, $\rho$ 700-1000 | T | - | 850. | - |
| Masonry, lightweight | CSTC, moist, $\rho$ 700-1000 | T | 0.34 | 749. | - |
| Masonry, lightweight | NBN, dry, $\rho$ 700-799 | T | 0.22 | 749. | 840. |
| Masonry, lightweight | NBN, dry, $\rho$ 700-999 | T | 0.27 | 849. | 840. |
| Masonry, lightweight | NBN, dry, $\rho$ 800-899 | T | 0.24 | 849. | 840. |
| Masonry, lightweight | NBN, dry, $\rho$ 900-999 | T | 0.27 | 949. | 840. |
| Masonry, lightweight | NBN, moist, $\rho$ 700-999 | T | 0.41 | 849. | - |
| Masonry, lightweight | NBN, moist, $\rho$ 800-899 | T | 0.36 | 849. | - |
| Masonry, lightweight | NBN, moist, $\rho$ 900-999 | T | 0.41 | 949. | - |
| Masonry, lightweight | SPPS | T | 0.20 | 500. | - |
| Masonry, lightweight | SPPS | T | 0.22 | 600. | - |
| ***** Miscellaneous ***** | | | | | |
| Asbestos, fibre | | Y | 0.055 | 57. | - |
| Asbestos, millboard | | Y | 0.17 | 970. | - |
| Asbestos, sprayed | | Y | 0.032 | 160. | - |
| Calcium silicate brick | Low exp. | S | 1.00 | 2000. | 840. |
| Calcium silicate brick | Std exp. | S | 1.50 | 2000. | 840. |
| Coal, pulverized powder | Conditioned | C | 0.065 | 575. | - |
| Composition flooring | Conditioned | C | 0.44 | 1600. | - |
| Composition flooring | Soaked | C | 0.85 | 1890. | - |
| Composition flooring, hard | Dry | C | 0.65 | 2100. | - |
| Composition flooring, hard | Wet | C | 0.80 | 2200. | - |
| Composition flooring | Wet | C | 0.58 | 1730. | - |
| Diatomaceous refractory aggregate | Dry, h.f. 300°C, c.f. 40°C | C | 0.25 | 1050. | - |
| Diatomaceous refractory aggregate | Dry, h.f. 500°C, c.f. 40°C | C | 0.26 | 1050. | - |
| Diatomaceous refractory aggregate | Dry, h.f. 800°C, c.f. 40°C | C | 0.27 | 1050. | - |
| Dried aggregate | | D | 1.31167 | 2240. | 837.36 |
| Floor bricks, ceramic tiles | Low exp. | S | 0.80 | 1700. | 840. |
| Floor bricks, ceramic tiles | Std exp. | S | 1.10 | 1700. | 840. |
| Gatch, aerated and baked | | C | 0.22 | 650. | - |
| Granolithic | | E | 0.87 | 2085. | 837. |
| Granolithic, aerated and baked | | C | 0.865 | 2085. | - |
| Gypsum plaster, perlite aggregate | | A | 0.2163 | 720. | 1339.84 |
| Gypsum plaster, sand aggregate | | A | 0.80752 | 1680. | 837.4 |
| Lime stone | At 50°C | I | 1.80 | 2420. | 840. |
| Magnesia with 15% asbestos | | Y | 0.06 | 300. | - |
| Magnesia based panels | SPPS, dry, $\rho$ 400-500 | T | 0.10 | 450. | - |
| Magnesia based panels | SPPS, moist, $\rho$ 400-500 | T | 0.12 | 450. | - |
| Mosaic | | Y | 1.200 | - | - |
| Mud phuska | At 50°C | I | 0.51900 | 1622. | 880. |
| Paving stones | At 50°C | G | 1.00 | 2000. | - |
| Pumice stone, natural | | Y | 0.20 | 390. | - |
| Quarrystone, semi-firm, calcareous | Low exp. | B | 1.40 | - | - |
| R.C.C. | At 50°C | I | 1.58 | 2288. | 880. |
| Render and jointing mortars | | F | 1.15 | 1950. | - |
| Roof tiling or slating | | BS | 0.83 | - | - |
| Sand, gravel or stone aggregate, not dried | | A | 1.73040 | 2240. | - |
| Sand, gravel or stone aggregate, oven dried | | A | 1.29780 | 2240. | 921.140, |
| Sandstone components | Low exp. | B | 1.20 | 2000. | - |
| Sandstone components | Std exp. | B | 1.30 | 2000. | - |
| Siporex | | E | 0.12 | 550. | 1004. |
| Slate | At 50°C | I | 1.72 | 2750. | 840. |
| Terracotta | $\rho$ 1800-1900 | F | 1.15 | 2000. | - |
| Terracotta tiles | Low exp. | B | 0.81 | 1700. | - |
| Terracotta tiles | Std exp. | B | 1.00 | 1700. | - |
| Terrazo | Conditioned | C | 1.59 | 2435. | - |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Thermalite | | E | 0.19 | 753. | 837. |
| Tile and lay-in panel building board | | A | 0.05768 | 288. | 586.180, |
| Tile bedding | | E | 1.40 | 2100. | 650. |
| Tiles, hanging | | C | 0.84 | 1900. | 800. |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Tufa | | Y | 0.54 | 1550. | - |
| Tufa | | Y | 1.44 | 2270. | 99. |
| Undried aggregate | | D | 1.80355 | 2240. | 837.360, |
| ***** Pumice Related ***** | | | | | |
| Solid blocks, made from pumice | | G | 0.20 | 500. | - |
| Solid blocks, made from pumice | | G | 0.22 | 600. | - |
| Solid blocks, made from pumice | | G | 0.25 | 700. | - |
| Solid blocks, made from pumice | | G | 0.28 | 800. | - |
| ***** Roofing ***** | | | | | |
| Artificial slate | SPPS, dry | T | - | - | 1010. |
| Artificial slate | SPPS, moist | T | - | - | 1200. |
| Built up roofing | | D | 0.16257 | 1120. | 1465. |
| Roof tile | | C | 0.84 | 1900. | 800. |
| Roof tiles | SPPS, dry, $\rho$ 1800-2000 | T | - | 1900. | 850. |
| Roof tiles | SPPS, moist, $\rho$ 1800-2000 | T | - | 1900. | 1010. |
| Terracotta roof tiles | CSTC | T | - | 1600. | - |
| Terracotta tiles | NBN | T | 81. | 1700. | 840. |
| ***** Soil ***** | | | | | |
| Alluvial clay, 40% sands | | I | 1.211 | 1958. | 840. |
| Black cotton clay, Indore | | I | 0.606 | 1683. | 880. |
| Black cotton clay, Madras | | I | 0.735 | 1899. | 880. |
| Blocks of compacted earth | $\rho$ 1700-1900 | F | 1.05 | 1800. | - |
| Bonded soils | | G | 2.10 | - | - |
| Clay soil | | C | 1.50 | - | - |
| Clay soil, loaded 100kPa | 14% d.w. | C | 1.20 | 1550. | - |
| Clay soil, loaded 5kPa | 14% d.w. | C | 0.70 | 1280. | - |
| Clay soil, loosely packed | 14% d.w. | C | 0.38 | 1200. | - |
| Clay soil, depth 1.5m | 11% d.w. | C | 1.10 | - | - |
| Clay soil, depth 3 m | 11% d.w. | C | 1.10 | - | - |
| Clay soil, depth 6 m | 11% d.w. | C | 1.15 | - | - |
| Clay soil, depth 8 m | 11% d.w. | C | 1.25 | - | - |
| Diatomaceous Kieselguhr or infusorial earth | 9% m.c. | C | 0.09 | 480. | - |
| Earth, common | | E | 1.28 | 1460. | 879. |
| Earth, gravel based | | E | 0.52 | 2050. | 184. |
| Earth, infusorial | 9% m.c. | E | 0.09 | 480. | 180. |
| Loam | Wet | C | 1.20 | - | - |
| Loam over sand & gravel, 1m deep | | C | 1.27 | - | - |
| Mud | 10% d.w. | C | 0.72 | 1920. | - |
| Mud | 150% d.w. | C | 0.79 | 1315. | - |
| Mud | 20% d.w. | C | 1.44 | 2115. | - |
| Mud | 40% d.w. | C | 1.15 | 1920. | - |
| Mud | 5% d.w. | C | 0.43 | 1840. | - |
| Mud | 80% d.w. | C | 0.94 | 1570. | - |
| Sandy loam | 5% d.w. | C | 0.55 | - | - |
| Sandy loam | 10% d.w. | C | 0.85 | - | - |
| Sandy loam | 15% d.w. | C | 1.20 | - | - |
| Silt, firm | 40% d.w. | C | 1.15 | 1920. | - |
| Silt, hard | 10% d.w. | C | 0.72 | 1920. | - |
| Silt, soft | 80% d.w. | C | 0.94 | 1570. | - |
| Silt, stiff | 20% d.w. | C | 1.44 | 2115. | - |
| Silt, very hard | 5% d.w. | C | 0.43 | 1840. | - |
| Silt, very soft | 150% d.w. | C | 0.79 | 1315. | - |
| Soil, damp | | Y | 1.50 | - | - |
| Soil, sandy | | Y | 0.70 | - | - |
| Soil | Wet | Y | 2.00 | - | - |
| Soil, crushed Brighton chalk | Dry | C | 0.25 | - | - |
| Soil, crushed Brighton chalk | 10% d.w. | C | 0.50 | - | - |
| Soil, crushed Brighton chalk | 20% d.w. | C | 0.80 | - | - |
| Soil, Liverpool clay, very damp | 17% d.w. | C | 1.70 | 2100. | - |
| Soil, London clay | 25% d.w., Wet | C | 1.40 | 1900. | - |
| ***** Stone ***** | | | | | |
| Basalt | | S | 3.5 | 3000. | 840. |
| Basalt | SPPS, $\rho$ 2800-3000 | T | - | 2900. | 840. |
| Basalt | $\rho$ 2800-3000 | F | 3.5 | 2900. | - |
| Basalt | NBN, $\rho$ 2750-3000 | T | 3.49 | 2875. | 840. |
| Calcareous white marble | Low exp. | B | 2.91 | 2750. | - |
| Calcareous white marble | Std exp. | B | 3.49 | 2750. | - |
| Calcareous white, semi-firm | Std exp. | B | 1.69 | 2200. | - |
| Calcareous white, firm | Low exp. | B | 1.74 | 2350. | - |
| Calcareous white, firm | Std exp. | B | 2.09 | 2350. | - |
| Calcareous white, hard | Low exp. | B | 2.21 | 2550. | - |
| Calcareous white, hard | Std exp. | B | 2.68 | 2550. | - |
| Calcareous white, semi-firm | Low exp. | B | 1.40 | 2200. | - |
| Cold stone marble | $\rho$ >2590 | F | 2.90 | 2590. | - |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Crystalline metamorphic rock (Granite, Basalt, Marble) | | G | 3.50 | 2800. | - |
| Firm stone | $\rho$ 2160-2340 | F | 1.70 | 2250. | - |
| Flint | $\rho$ 2600-2800 | F | 3.50 | 2700. | - |
| Gneiss | NBN, $\rho$ 2750-3000 | T | 3.49 | 2875. | 840. |
| Granite | | S | 3.50 | 3000. | 840. |
| Granite | NBN, $\rho$ 2750-3000 | T | 3.49 | 2875. | 840. |
| Granite | SPPS, $\rho$ 2500-3000 | T | - | 2750. | 840. |
| Granite | $\rho$ 2500-3000 | F | 3.50 | 2750. | - |
| Granite | | C | 2.5 | - | - |
| Granite | | C | 2.9 | 2650. | - |
| Granite | At 25°C | C | 2.30 | 2600. | - |
| Granite | At -100°C | C | 2.4 | 2600. | - |
| Granite, bluestone | Std exp. | B | 3.49 | 2700. | - |
| Granite ,bluestone | Low exp. | B | 2.91 | 2700. | - |
| Graphite achreson, solid | Dry. at 50°C | C | 140.00 | 1600. | - |
| Graphite achreson, solid | At 25°C | C | 115.00 | 1600. | - |
| Graphite, reactor grade | Dry at 50°C | C | 70. | - | - |
| Graphite, reactor grade | At 250°C | C | 65. | - | - |
| Hard stone | NBN, $\rho$ 2750-3000 | T | 3.49 | 2875. | 840. |
| Hard stone | $\rho$ 2350-2580 | F | 2.2 | 2465. | - |
| Hard granite, gneiss, basalt, porphyry | $\rho$ 2750-3000 | B | 3.49 | 2875. | - |
| Hardstone | Low exp. | S | 2.30 | 2750. | 840. |
| Hardstone | Std exp. | S | 2.90 | 2750. | 840. |
| Lava | $\rho$ 2100-2400 | F | 2.90 | 2250. | - |
| Lime stone | Dry | C | 1.5 | 2180. | - |
| Limestone | | E | 1.5 | 2180. | 720. |
| Limestone | Low exp. | S | 2.30 | 2750. | 840. |
| Limestone | Std exp. | S | 2.90 | 2750. | 840. |
| Marble | Low exp. | S | 2.3 | 2750. | 840. |
| Marble | Std exp. | S | 2.9 | 2750. | 840. |
| Marble | Dry | C | 2.00 | 2500. | - |
| Marble | | C | 2.50 | 2700. | - |
| Petit granit (blue stone) | NBN, dry | T | 2.91 | 2700. | 840. |
| Petit granit (blue stone) | NBN, moist | T | 3.49 | 2700. | 840. |
| Petit granit (blue stone) | SPPS | T | - | 2750. | 840. |
| Porphyry | NBN, $\rho$ 2750-3000 | T | 3.49 | 2875. | 840. |
| Porphyry | SPPS, $\rho$ 2400-2600 | T | - | 2500. | 840. |
| Porphyry | $\rho$ 2400-2600 | F | 2.90 | 2500. | - |
| Quartz | Dry at 40°C | C | 1.4 | 2190. | - |
| Quartz | Dry at 250°C | C | 1.5 | 2190. | - |
| Red granite | | E | 2.9 | 2650. | 900. |
| Natural slate | SPPS | T | - | - | 840. |
| Sandstone | | C | 1.3 | 2000. | - |
| Sandstone | | E | 1.83 | 2200. | 712. |
| Sandstone | CSTC, $\rho$ 2000-3000 | T | - | 2500. | - |
| Sandstone | SBR, $\rho$ 2000-2300 | T | 3. | 2150. | 840. |
| Sandstone | SPPS, $\rho$ 2000-2300 | T | 1.3 | 2150. | 840. |
| Sandstone | Low exp., $\rho$ 2000-2300 | S | 3. | 2150. | 840. |
| Sandstone | Std exp., $\rho$ 2000-2300 | S | 5. | 2150. | 840. |
| Sandstone tiles | NBN, dry | T | 1.2 | 2000. | 840. |
| Sandstone tiles | NBN, moist | T | 1.3 | 2000. | - |
| Sedimentary rock (Sandstone, Shell, Limestone) | | G | 2.3 | 2600. | - |
| Semi-firm stone | $\rho$ 1840-2150 | F | 1.4 | 1495. | - |
| Slate | | D | 1.44394 | 1600. | 1465. |
| Slate | | E | 2. | 2700. | 753. |
| Slate | | E | 2. | 2700. | 753. |
| Slate | | F | 2.1 | 2700. | - |
| Slate shale | SPPS, $\rho$ <2700 | T | 2.1 | 2700. | 840. |
| Slate | | C | 1.9 | 2700. | - |
| Slate | | C | 2. | 2700. | - |
| Soft stone no.2 | $\rho$ 1470-1640 | F | 0.95 | 1555. | - |
| Soft stone no.3 | $\rho$ 1650-1840 | F | 1.05 | 1745. | - |
| Solid stone, made from light conc. | | G | 0.32 | 500. | - |
| Solid stone, made from light conc. | | G | 0.34 | 600. | - |
| Solid stone, made from light conc. | | G | 0.37 | 700. | - |
| Solid stone, made from light conc. | | G | 0.40 | 800. | - |
| Solid stone, made from light conc. | | G | 0.43 | 900. | - |
| Solid stone, made from light conc. | | G | 0.46 | 1000. | - |
| Solid stone, made from light conc. | | G | 0.54 | 1200. | - |
| Solid stone, made from light conc. | | G | 0.63 | 1400. | - |
| Solid stone, made from light conc. | | G | 0.74 | 1600. | - |
| Solid stone, made from light conc. | | G | 0.87 | 1800. | - |
| Solid stone, made from light conc. | | G | 0.99 | 2000. | - |
| Stone | | D | 1.80337 | 2240. | 837. |
| Stonework (Granite, Slate, Marble) | | BS | 2. | - | - |
| Stonework (Limestone, Sandstone) | | BS | 2. | - | - |
| White calcareous stone, firm | NBN, moist | T | 2.09 | 2350. | 840. |
| White calcareous stone, firm | SPPS, $\rho$ 2160-2349 | T | - | 2254. | - |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| White calcareous stone, firm | SPPS, dry | T | 1.74 | 2350. | 840. |
| White calcareous stone, hard | NBN, dry | T | 2.21 | 2550. | 840. |
| White calcareous stone, hard | NBN, moist | T | 2.68 | 2550. | 840. |
| White calcareous stone, marble | NBN, dry | T | 2.91 | 2750. | 840. |
| White calcareous stone, marble | NBN, moist | T | 3.49 | 2750. | 840. |
| White calcareous stone, marble | SPPS, $\rho$ <2600 | T | - | 2600. | 840. |
| White calcareous stone, semi-firm | NBN, dry | T | 1.4 | 2200. | 840. |
| White calcareous stone, semi-firm | NBN, moist | T | 1.69 | 2200. | 840. |
| White calcareous stone, soft | SPPS, $\rho$ 1650-1839 | T | 1.1 | 1744. | - |
| White calcareous stone, soft tufa | CSTC, $\rho$ 1000-1500 | T | - | 1300. | - |
| White calcareous stone, soft tufa | SBR, dry, $\rho$ 1100-1500 | T | 0.35 | 1300. | 840. |
| White calcareous stone, soft tufa | SBR, moist, $\rho$ 1100-1500 | T | 0.50 | 1300. | - |
| White calcareous stone, soft tufa | SPPS, $\rho$ 1100-1500 | T | 0.35 | 1300. | 860. |
| White calcareous stone, soft tufa | SPPS, moist, $\rho$ 1100-1500 | T | 0.50 | 1300. | 1260. |
| White marble | | E | 2. | 2500. | 880. |
| Valcanised porous natural stone | | G | 0.55 | 1600. | - |
| Stoneware | Conditioned | C | 1.4 | 2150. | - |

## 4.6 Organic-Hygroscopic

This category contains organic materials such as wood and wood based products which are porous and strongly hygroscopic, and which display a highly non-linear water vapour permeability characteristic.

| **Material Description** | **Condition/ Test** | **Source** | $\lambda$ $(W/mK)$ | $\rho$ $(kg/m^3)$ | $C_p$ $(J/kgK)$ |
|---|---|---|---|---|---|
| ***** Cardboard/Paper ***** | | | | | |
| Bitumen impregnated paper | | E | 0.06 | 1090. | 1000. |
| Bitumen, cardboard felt and impregnated screed | $\rho$ 1000-1100 | F | 0.23 | 1050. | - |
| Cardboard | $\rho$ 600-75 | Y | 0.10 | 765. | - |
| Cardboard macerated for filling | | Y | 0.035 | 56. | - |
| Cardboard, corrugated and plain sheets, bonded | | C | 0.047 | 105. | - |
| Cardboard, plain sheet | | C | 0.22 | - | - |
| Cardboard, plain sheet, waxed | | C | 0.12 | 710. | - |
| Honeycomb paper board, empty cores, 19mm across | | C | 0.18 | - | - |
| Honeycomb paper board, granulated cork-filled | | C | 0.08 | - | - |
| Honeycomb paper board, vermiculite filled | | C | 0.10 | - | - |
| Paper, Kraft building paper | | C | 0.140 | 1090. | - |
| Paper, Kraft building paper | | C | 0.060 | 1090. | - |
| Seaweed/Paper sandwich | | Y | 0.03 | 70. | - |
| Laminated paper | | A | 0.0721 | 480. | 1381.71 |
| ***** Cloth, Carpet, Felt ***** | | | | | |
| Bitumen felt | | E | 0.50 | 1700. | 1000. |
| Bitumen roofing felt | | C | 0.20 | 1100. | - |
| Bituminous felt | NBN B46-101, low exp. | B | 0.23 | 1100. | - |
| Bituminous felt | NBN B46-101, std exp. | B | 0.23 | 1100. | - |
| Felt/bitumen layers | | C | 0.50 | 1700. | 1000. |
| Car body lining felt | | C | 0.039 | 30. | - |
| Carpet, simulated sheep wool | | E | 0.06 | 198. | 1360. |
| Carpet, wilton | | E | 0.06 | 186. | 1360. |
| Carpeting, normal backing | | BS | 0.05 | - | - |
| Carpeting, foam backed | | BS | 0.1 | - | - |
| Cloth | | Y | 0.075 | - | - |
| Cloth, wool | | Y | 0.03 | 150. | - |
| Cloth, woven | Dry, at 40°C | C | 0.080 | 1000. | - |
| Cloth, woven | Dry, at 500°C | C | 0.100 | 1000. | - |
| Cotton | $\rho$ 125-32 | Y | 0.04 | 225. | - |
| Cotton in strands | | Y | 0.036 | 80. | - |
| Hair felt | | C | 0.039 | 80. | - |
| Felt | | Y | 0.04 | 270. | - |
| Felt | | Y | 0.032 | 100. | - |
| Felt | | Y | 0.038 | 200. | - |
| Felt, semi-rigid, organic bonded | At 37.7°C | A | 0.03461 | 48. | 712. |
| Felt, semi-rigid, organic bonded | At 37.7°C | A | 0.03893 | 88. | 712. |
| Felt, semi-rigid, organic bonded | At 93.3°C | A | 0.05047 | 48. | 712. |
| Felt, semi-rigid, organic bonded | At 93.3°C | A | 0.05047 | 88. | 712. |
| Felt, semi-rigid, organic bonded | At 148.8°C | A | 0.06345 | 88. | 712. |
| Felt, semi-rigid, organic bonded | At 148.8°C | A | 0.07931 | 48. | 712. |
| Jute | | Y | 0.055 | 94. | - |
| Jute felt | At 50°C | I | 0.042 | 291. | 880. |
| Jute fibre | At 50°C | I | 0.067 | 329. | 1090. |
| Jute, bonded fibre mat | | C | 0.036 | 50. | - |
| Jute, resin-bonded board | | C | 0.065 | 430. | - |
| Kapok | | Y | 0.057 | 96. | - |
| Kapok, strands | | Y | 0.03 | 16. | - |
| Kapok, insulating quilt | | C | 0.035 | 20. | - |
| Kapok, insulating quilt | Dry, h.f. 10°C, c.f. -10°C | C | 0.03 | 30. | - |
| Kapok, insulating quilt | h.f. 80°C, c.f. 25°C | C | 0.039 | 30. | - |
| Pure wool | | Y | 0.033 | 136. | - |
| Sheep wool | | C | 0.045 | 50. | - |
| Silk, braided | | Y | 0.043 | 100. | - |
| Silk, loose | | Y | 0.035 | 58. | - |
| Undercarpet felt | | C | 0.045 | 120. | - |
| Wool blanket, closely woven | | C | 0.043 | 65. | - |
| Wool felt | | C | 0.039 | 150. | - |
| Wool felt underlay | | E | 0.04 | 160. | 1360. |
| ***** Cork ***** | | | | | |
| Cork | | E | 0.04 | 105. | 1800. |
| Cork | NBN, $\rho$ <10 | T | 0.04 | 100. | 1760. |
| Cork | NBN, $\rho$ >10 | T | 0.045 | 100. | 1760. |
| Cork | $\rho$ 80-50 | G | 0.045 | 290. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Cork | Low exp., $\rho$ <10 | B | 0.04 | 100. | - |
| Cork | Low exp., $\rho$ >10 | B | 0.045 | 100. | - |
| Cork board | | E | 0.04 | 160. | 1888. |
| Cork gasket | | C | 0.06 | 480. | - |
| Cork linoleum | | C | 0.07 | 510. | - |
| Cork linoleum | | Y | 0.07 | 535. | - |
| Cork linoleum | SPPS | T | 0.08 | 700. | - |
| Cork slab | | I | 0.043 | 164. | 960. |
| Cork slab | | I | 0.044 | 192. | 960. |
| Cork slab | | I | 0.055 | 304. | 960. |
| Cork slab, baked | Dry | C | 0.04 | 130. | - |
| Cork slab, baked | High density | C | 0.046 | 200. | - |
| Cork slab, baked | High density | C | 0.05 | 265. | - |
| Cork slab, ice-logged | Saturated, h.f. -5°C, c.f. -70°C | C | 0.08 | 325. | - |
| Cork slab, raw | Damp | C | 0.05 | 160. | - |
| Cork slab, raw | Damp, high density | C | 0.08 | 465. | - |
| Cork slab, soaked in water | Saturated | C | 0.085 | 325. | - |
| Cork slab, soaked in water and drained | Wet | C | 0.054 | 195. | - |
| Cork tiles | | E | 0.08 | 530. | 1800. |
| Cork tiles | Conditioned | C | 0.085 | 530. | - |
| Compressed cork | | F | 0.1 | 500. | - |
| Cork | | G | 0.05 | - | - |
| Cork | | G | 0.055 | - | - |
| Cork, Floor tiles | Conditioned, 40% rh | C | 0.085 | 540. | - |
| Loose filling from expanded cork chips | $\rho$ <60 | G | 0.13 | 600. | - |
| Cork, loose baked granules | Damp | C | 0.039 | 100. | - |
| Cork, loose baked granules | Dry, h.f. 80°C, c.f. 25dg.C | C | 0.045 | 100. | - |
| Cork, loose raw granules | Damp | C | 0.046 | 115. | - |
| Cork, loose raw granules | Dry, h.f. 80°C, c.f. 25°C | C | 0.052 | 115. | - |
| Cork, with bitumen or asphalt binder | | C | 0.055 | 240. | - |
| Cork, with bitumen or asphalt binder | | C | 0.145 | 640. | - |
| Cork, with bitumen or asphalt binder | | C | 0.290 | 1040. | - |
| Cork, with cement binder | | C | 0.073 | 280. | - |
| Cork, with cement binder | | C | 0.10 | 400. | - |
| Cork, with resin binder | Conditioned, 40% rh | C | 0.05 | 250. | - |
| Cork, with rubber latex binder | | C | 0.062 | 320. | - |
| Cork, with rubber latex binder | | C | 0.08 | 480. | - |
| Cork/oak, expanded in layers | | Y | 0.03 | 100. | - |
| Cork/oak, expanded in layers | | Y | 0.05 | 150. | - |
| Cork/oak in granules | | Y | 0.03 | 130. | - |
| Cork/oak in sheets | | Y | 0.04 | 250. | - |
| Cork/oak in sheets | $\rho$ 104-13 | Y | 0.03 | 117. | - |
| Corkboard | Dry, h.f. 65°C, c.f. 15°C | C | 0.043 | 130. | - |
| Corkboard | Dry, h.f. 90°C, c.f. 15°C | C | 0.046 | 130. | - |
| Corkboard | h.f. 15°C, c.f. -20°C | C | 0.038 | 130. | - |
| Corkboard | h.f. 15°C, c.f. 0°C | C | 0.039 | 130. | - |
| Corkboard | h.f. 15°C, c.f. -70°C | C | 0.033 | 130. | - |
| Corkboard | | C | 0.039 | 110. | - |
| Corkboard | | C | 0.04 | 130. | - |
| Corkboard | | C | 0.042 | 145. | - |
| Corkboard | | C | 0.045 | 160. | - |
| Expanded and impregnated cork | Low exp., $\rho$ 100-20 | S | 0.043 | 150. | 1760. |
| Expanded cork | CSTC, $\rho$ 100-200 | T | - | 100. | - |
| Expanded cork | SBR, $\rho$ 100-200 | T | - | 150. | - |
| Expanded cork | Low exp., $\rho$ 100-200 | S | 0.044 | 150. | 1760. |
| Expanded cork bonded with pitch or synthetic resins | $\rho$ 100-150 | F | 0.043 | 125. | - |
| Expanded cork bonded with pitch or synthetic resins | $\rho$ 150-250 | F | 0.048 | 200. | - |
| Expanded cork, bituminous binding | SPPS, $\rho$ 100-20 | T | - | 150. | - |
| Pure expanded cork | $\rho$ 100-15 | F | 0.043 | 125. | - |
| ***** Grasses/Straws ***** | | | | | |
| Compressed straw | $\rho$ 300-40 | F | 0.12 | 350. | - |
| Eel grass, insulating blanket | | C | 0.043 | 145. | - |
| Eel grass, insulating blanket | | C | 0.049 | 215. | - |
| Eel grass, insulating blanket | | C | 0.039 | 80. | - |
| Papyrus, building board | | C | 0.085 | 480. | - |
| Papyrus, insulating board | | C | 0.055 | 255. | - |
| Reed made into slabs | | Y | 0.05 | 250. | - |
| Straw, compressed | | Y | 0.05 | 175. | - |
| Straw, loose fibres | | Y | 0.047 | 140. | - |
| Straw board | At 50°C | I | 0.057 | 310. | 1300. |
| Straw fibre board or straw slabs | Low exp., $\rho$ 200-40 | S | 0.10 | 300. | 2100. |
| Straw slabs, compressed | Conditioned | C | 0.085 | 260. | - |
| Straw slabs, compressed | | C | 0.098 | 330. | - |
| Straw slabs, compressed | | C | 0.11 | 350. | - |
| Straw thatch | | E | 0.07 | 240. | 180. |
| Thatch, reed | | C | 0.09 | 270. | - |
| Thatch, straw | | C | 0.07 | 240. | - |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| ***** Miscellaneous ***** | | | | | |
| Afzelia, minunga, meranti | SPPS, $\rho$ 700-100 | T | 0.29 | 850. | 2070. |
| Expanded ebonite | Low exp. | S | 0.035 | 100. | 1470. |
| Expanded perlite board, organic bonded | | A | 0.05191 | 16. | 1256. |
| Glass fibre board, organic bonded | | A | 0.03605 | 104. | 963. |
| Panels, wood fibres bonded to cement | NBN 638, low exp. | B | 0.12 | 400. | - |
| Panels, wood fibres bonded to cement | NBN 638, low exp. | B | 0.14 | 500. | - |
| Panels, wood fibres bonded to cement | NBN 638, low exp. | B | 0.16 | 600. | - |
| Peat, slab | | Y | 0.05 | 100. | - |
| Peat, compresses block | | Y | 0.10 | 450. | - |
| Peat, pulverised | | Y | 0.06 | 450. | - |
| Peat slab | | C | 0.043 | 160. | - |
| Peat slab | Conditioned, 10% m.c. | C | 0.058 | 240. | - |
| Peat slab | | C | 0.094 | 400. | - |
| Peat slab | | C | 0.101 | 481. | - |
| Rice husk bonded with cement | Dry | C | 0.15 | 720. | - |
| Rice husks bonded with cement | Conditioned | C | 0.29 | 800. | - |
| Thermalite turbo block | | E | 0.11 | 480. | 1050. |
| Weatherboard | | E | 0.14 | 650. | 2000. |
| ***** Organics and Derivatives ***** | | | | | |
| Coconut pith insulation board | At 50°C | I | 0.06 | 520. | 1090. |
| Coir board | At mean temp. of 50°C | I | 0.038 | 97. | 1000. |
| Coir, fibre mats | | C | 0.047 | 80. | - |
| Coir, fibre mats | | C | 0.05 | 210. | - |
| Flax fibre board, flexible | | Y | 0.034 | 80. | - |
| Flax fibre board, semi-flexible | | Y | 0.039 | 210. | - |
| Flax seed | Conditioned | C | 0.11 | 650. | - |
| Flax shive, cement-bonded board | Low exp., $\rho$ 330-70 | S | 0.10 | 515. | 1470. |
| Flax shive, loose | Conditioned | C | 0.044 | 240. | - |
| Flax shive, synthetic resin bonded board | Low exp., $\rho$ 300-70 | S | 0.12 | 500. | 1880. |
| Flax shive, resin-bonded board | | C | 0.11 | 670. | - |
| Flax shive, resin-bonded insulating board | | C | 0.07 | 300. | - |
| Ground nut shell board, resin bonded | Conditioned | C | 0.12 | 650. | - |
| Husks, Bonded with cement | Conditioned, 6% mc | C | 0.11 | 560. | - |
| Husks, Bonded with cement | | C | 0.15 | 720. | - |
| Mineral and vegetable fibre insulation | $\rho$ 8-50 | G | 0.035 | - | - |
| Mineral and vegetable fibre insulation | $\rho$ 8-50 | G | 0.04 | - | - |
| Mineral and vegetable fibre insulation | $\rho$ 8-50 | G | 0.045 | - | - |
| Mineral and vegetable fibre insulation | $\rho$ 8-50 | G | 0.05 | - | - |
| Panels made from flax particles | $\rho$ 230-32 | F | 0.073 | 275. | - |
| Panels made from flax particles | $\rho$ 320-41 | F | 0.085 | 365. | - |
| Panels made from flax particles | $\rho$ 410-50 | F | 0.10 | 455. | - |
| Panels made from flax particles | $\rho$ 500-60 | F | 0.12 | 550. | - |
| Rice husk | At 50°C | I | 0.051 | 120. | 1000. |
| Rice husks, loose | | Y | 0.045 | 135. | - |
| Sponge clippings | | C | 0.043 | 30. | - |
| Sponge clippings | | C | 0.035 | 80. | - |
| Sugar cane compressed in rigid board | | Y | 0.05 | 270. | - |
| Sugar, white, granulated | | C | 0.21 | 900. | - |
| Sugar, yellow, demarrara | | C | 0.19 | 770. | - |
| Vegetable fibre sheathing | Regular density | A | 0.0548 | 288. | 1298. |
| Wheat seed | Conditioned | C | 0.16 | 880. | - |
| Feather | | Y | 0.03 | 80. | - |
| Leather | | Y | 0.140 | 1000. | - |
| ***** Wood ***** | | | | | |
| Ash | 12% m.c. | A | 0.158 | 642. | - |
| Balsa wood, fluffy wood fibres | | C | 0.04 | 40. | - |
| Balsa, across grain | Conditioned | C | 0.048 | 100. | - |
| Balsa, across grain | | C | 0.055 | 150. | - |
| Balsa, across grain | | C | 0.06 | 200. | - |
| Balsa, across grain | | C | 0.065 | 250. | - |
| Beech | | C | 0.165 | 700. | - |
| Beech, oak | | G | 0.2 | 800. | - |
| Birch | 12% m.c. | A | 0.171 | 704. | - |
| California red wood | 12% m.c. | A | 0.111 | 420. | - |
| Deal, across grain | Conditioned | C | 0.125 | 610. | - |
| Deal, along grain | Conditioned | C | 0.215 | 610. | - |
| Douglas fir-larch | 12% m.c. | A | 0.141 | 558. | - |
| Fir | 20% m.c. | E | 0.14 | 419. | 2720. |
| Fir, Pine etc. | | A | 0.11536 | 512. | 1382. |
| Hard wood, balsa wood | SPPS | T | 0.05 | 90. | 2810. |
| Hard wood fibre panels | CSTC | T | - | 1000. | - |
| Hard wood | NBN, dry, $\rho$ 600-80 | T | 0.17 | 700. | 1880. |
| Hard wood | NBN, moist, $\rho$ 600-80 | T | 0.19 | 700. | - |
| Hard wood | | D | 0.15859 | 720. | 1256. |
| Hard wood, balsa wood | CSTC | T | - | 125. | - |
| Hard wood | Low exp. | S | 0.17 | 800. | 1880. |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Hard wood | Std exp. | S | 0.23 | 800. | 1880. |
| Hard wood, across grain | | C | 0.15 | - | - |
| Hard wood, oak, beech | Low exp. | B | 0.17 | - | - |
| Hard wood, oak, beech | Std exp. | B | 0.19 | - | - |
| Hem fir, spruce pine fir | 12% m.c. | A | 0.118 | 447. | - |
| Light hardwood (Linden, Birch, Maple, Ash, Oak, soft Beech) | $\rho$ 450-60 | F | 0.15 | 510. | - |
| Light resinous wood (Fir, Spruce or very light resinous wood) | $\rho$ 300-45 | F | 0.12 | 375. | - |
| Mahogany, across grain | Conditioned | C | 0.155 | 700. | - |
| Maple | 12% m.c. | A | 0.164 | 670. | - |
| Maple, Oak and similar hard woods | | A | 0.15862 | 720. | 1256. |
| Oak | 12% m.c. | A | 0.17 | 704. | - |
| Oak, radial | | E | 0.19 | 700. | 2390. |
| Oak beech, ash, walnut, meranti | SPPS, moist, $\rho$ 600-699 | T | 0.23 | 649. | 3050. |
| Oak, across grain | Conditioned | C | 0.16 | 770. | - |
| Oak, along grain | Conditioned | C | 0.29 | 770. | - |
| Oak, beech, ash, walnut, meranti | SPPS, dry, $\rho$ 600-699 | T | 0.17 | 649. | 2120. |
| Wood, Oak | | Y | 0.18 | 850. | - |
| Pine, fir | SPPS, $\rho$ 350-449 | T | 0.12 | 424. | 2400. |
| Pine, fir | SPPS, $\rho$ 350-449 | T | - | 424. | 3920. |
| Pitch pine, across grain | Conditioned | C | 0.14 | 660. | - |
| Pitchpine | SPPS, dry, $\rho$ 600-699 | T | 0.17 | 649. | 2120. |
| Pitchpine | SPPS, moist, $\rho$ 600-699 | T | 0.23 | 649. | 3050. |
| Red fir, Oregon Fir | SPPS, dry, $\rho$ 450-599 | T | 0.14 | 524. | 2280. |
| Red fir, Oregon Fir | SPPS, moist, $\rho$ 450-599 | T | 0.17 | 524. | 3440. |
| Resinous wood | NBN, dry, $\rho$ 450-60 | T | 0.12 | 525. | 1880. |
| Resinous wood | NBN, moist, $\rho$ 450-60 | T | 0.13 | 525. | - |
| Resinous woods, spruce, sylvester pine | Low exp. | B | 0.12 | - | - |
| Resinous woods, spruce, sylvester pine | Std exp. | B | 0.13 | - | - |
| Semi-hardwood (Oak, Beech, Ash, Fruit trees, resinous wood) | $\rho$ 600-700 | F | 0.23 | 675. | - |
| Semi-heavy resinous wood (Sylvester Pine, Marine Pine) | $\rho$ 450-55 | F | 0.15 | 500. | - |
| Softwood | | D | 0.11548 | 512. | 1382. |
| Softwood | | E | 0.13 | 630. | 2760. |
| Softwood | Low exp. | S | 0.14 | 550. | 1880. |
| Softwood | Std exp. | S | 0.17 | 550. | 1880. |
| Softwood, across grain | Conditioned | C | 0.13 | - | - |
| Southern cypress | 12% m.c. | A | 0.131 | 508. | - |
| Southern pine | 12% m.c. | A | 0.153 | 614. | - |
| Special natural wood (balsa) | $\rho$ 60-12 | F | 0.052 | 90. | - |
| Special natural wood, heavy | $\rho$ 800-100 | F | 0.29 | 900. | - |
| Spruce | CSTC | T | - | 410. | - |
| Spruce | SBR | T | - | 410. | - |
| Spruce, across grain | Conditioned | C | 0.105 | 415. | - |
| Spruce, pine, fir | | G | 0.13 | 600. | - |
| Teak | CSTC | T | - | 600. | - |
| Teak, across grain | Conditioned | C | 0.17 | 700. | - |
| Timber | | BS | 0.14 | - | - |
| Timber | At 50°C | I | 0.072 | 480. | 1680. |
| Timber flooring | | C | 0.14 | 650. | 1200. |
| Timber | At 50°C | I | 0.144 | 720. | 1680. |
| Very light hardwood (poplar, gaboon) | $\rho$ 300-45 | F | 0.12 | 375. | - |
| Walnut, across grain | Conditioned | C | 0.14 | 660. | - |
| West coast woods cedars | 12% m.c. | A | 0.114 | 424. | - |
| Willow, North Canadian gaboon | SPPS, $\rho$ 350-499 | T | 0.12 | 424. | 2400. |
| Willow, birch, soft beech | SPPS, $\rho$ 450-599, 1 | T | 0.14 | 524. | 2280. |
| Willow, birch, soft beech | SPPS, moist, $\rho$ 450-599 | T | 0.17 | 524. | 3440. |
| Wood, Balsa | | Y | 0.04 | 120. | - |
| Wood, Fir | | Y | 0.1 | 450. | - |
| Wood, Maple | | Y | 0.165 | 715. | - |
| Wood, Pine | | Y | 0.13 | 545. | - |
| ***** Wood Derivatives ***** | | | | | |
| Bitumen impregnated board | Conditioned | C | 0.051 | 305. | - |
| Cellulose Wadding | | C | 0.038 | 30. | - |
| Cellulosic insulation, loose fill | | A | 0.04182 | 43.2 | 1382. |
| Chip board, perforated | At 50°C | I | 0.066 | 352. | 1260. |
| Chip board | At 50°C | I | 0.067 | 432. | 1260. |
| Chipboard | | E | 0.15 | 800. | 2093. |
| Chipboard, bonded with synthetic resin | Conditioned | C | 0.07 | 350. | - |
| Chipboard, bonded with synthetic resin | Conditioned | C | 0.10 | 500. | - |
| Chipboard, bonded with synthetic resin | Conditioned | C | 0.12 | 600. | - |
| Chipboard, bonded with synthetic resin | Conditioned | C | 0.15 | 800. | - |
| Chipboard, bonded with synthetic resin | Conditioned | C | 0.18 | 950. | - |
| Chipboard, wood chips and rubber | | C | 0.210 | 1350. | - |
| Chipboard, bonded P.F. | SPPS, dry, $\rho$ 600-70 | T | 0.12 | 650. | 2340. |
| Chipboard, bonded P.F. | SPPS, moist, $\rho$ 600-70 | T | 0.25 | 650. | 5020. |
| Chipboard, bonded U.F. | CSTC, $\rho$ 570-69 | T | - | 630. | - |

| Material Description | Condition/ Test | Source | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Chipboard, bonded U.F. | SPPS, $\rho$ 550-7 moist | T | 0.25 | 625. | 5020. |
| Chipboard, bonded U.F. | SPPS, dry, $\rho$ 550-70 | T | 0.12 | 625. | 2260. |
| Chipboard, bonded melamine | CSTC, $\rho$ 550-69 | T | - | 630. | - |
| Chipboard, bonded melamine | SPPS, dry, $\rho$ 550-70 | T | 0.12 | 625. | 2260. |
| Chipboard, bonded melamine | SPPS, moist, $\rho$ 550-70 | T | 0.25 | 625. | 5020. |
| Chipboard, compressed panels | | G | 0.13 | 700. | - |
| Chipboard, extruded panels, solid board without planking | | G | 0.17 | 700. | - |
| Fibreboard, sheet or ceiling tile | | BS | 0.07 | - | - |
| Hardboard | | BS | 0.125 | - | - |
| Hardboard | At 50°C | I | 0.279 | 979. | 1420. |
| Hardboard, high density | Service temp. | A | 0.1182 | 880. | 1340. |
| Hardboard, high density | Std temp. | A | 0.1442 | 1008. | 1340. |
| Hardboard | Low exp. | S | 0.29 | 1000. | 1680. |
| Hardboard, medium density | | A | 0.1053 | 800. | 1298. |
| Hardboard, medium density | | E | 0.08 | 600. | 2000. |
| Hardboard, standard density | | E | 0.13 | 900. | 2000. |
| Hardboard, high density | Service temp. | D | 0.1442 | 1008. | 1382. |
| Hardboard, high density | Std temp. | D | 0.1183 | 880. | 1382. |
| Hardboard, medium density others | | D | 0.1053 | 800. | 1298. |
| Hardboard, medium density siding | | D | 0.0942 | 640. | 1172. |
| Hardboard, medium | | C | 0.079 | 560. | - |
| Hardboard, medium | | C | 0.08 | 600. | - |
| Hardboard, standard | | C | 0.094 | 750. | - |
| Hardboard, standard | | C | 0.123 | 880. | - |
| Hardboard, standard | | C | 0.13 | 900. | - |
| Hardboard, standard | | C | 0.144 | 1010. | - |
| Layers of wood shavings (single layered) | $\rho$ 360-46 | G | 0.093 | 410. | - |
| Layers of wood shavings (single layered) | $\rho$ 460-65 | G | 0.15 | 555. | - |
| Layers of wood shavings (single layered) | | G | - | 800. | - |
| Lightwt panels, wood shavings | 15mm thick | G | 0.15 | 570. | - |
| Lightwt panels, wood shavings | 25mm thick | G | 0.093 | 420. | - |
| Marine plywood | SBR | T | - | 1000. | - |
| Multiplex | CSTC | T | - | 800. | - |
| Multiplex, North Canadian Gaboon | SPPS, dry, $\rho$ 400-499 | T | 0.12 | 449. | 2300. |
| Multiplex, North Canadian gaboon wood | SPPS, moist, $\rho$ 400-499 | T | 0.21 | 449. | - |
| Multiplex, beech | SPPS, dry, $\rho$ 600-699 | T | 0.15 | 649. | 2300. |
| Multiplex, beech | SPPS, moist, $\rho$ 600-699 | T | 0.24 | 649. | - |
| Multiplex, red fir | SPPS, $\rho$ 500-599, dry | T | 0.13 | 549. | 2300. |
| Multiplex, red fir | SPPS, $\rho$ 500-599, moist | T | 0.21 | 549. | 2300. |
| Triplex, multiplex | Low exp. | B | 0.14 | 600. | - |
| Triplex, multiplex | Std exp. | B | 0.15 | 600. | - |
| Triplex, multiplex | SBR | T | - | 700. | - |
| Panels, hard wood particles | SPPS | T | 0.290 | 1000. | 1990. |
| Panels, soft wood particles | CSTC, $\rho$ <30 | T | - | 300. | - |
| Panels, wood particles | NBN | T | 0.14 | 700. | 1880. |
| Panels, wood particles | NBN | T | 0.09 | 300. | 1880. |
| Panels, from wood particles | NBN | T | 0.12 | 500. | 1880. |
| Panels, compressed wood fibres | $\rho$ 360-450 | F | 0.10 | 382. | - |
| Panels, compressed wood fibres | $\rho$ 450-550 | F | 0.12 | 495. | - |
| Panels, compressed wood fibres | $\rho$ 550-650 | F | 0.14 | 600. | - |
| Panels, compressed wood fibres | $\rho$ 650-750 | F | 0.17 | 700. | - |
| Panels, extruded wood | $\rho$ 550-65 | F | 0.16 | 600. | - |
| Panels, Gaboon or Poplar | $\rho$ 350-450 | F | 0.12 | 400. | - |
| Panels, Marine or Oregon Pine | $\rho$ 450-550 | F | 0.15 | 500. | - |
| Panels, soft wood particles | SPPS, $\rho$ 200-300 | T | 0.08 | 250. | 2520. |
| Panels, particles of wood or flax | NBN 661, low exp. | B | 0.09 | 300. | - |
| Panels, particles of wood or flax | NBN 661, low exp. | B | 0.12 | 500. | - |
| Panels, particles of wood or flax | NBN 661, low exp. | B | 0.14 | 700. | - |
| Particle board | | I | 0.098 | 750. | 1300. |
| Particle board, high density | | A | 0.17016 | 1000. | 1298. |
| Particle board, low density | | A | 0.07787 | 592. | 1298. |
| Particle board, medium density | | A | 0.13555 | 800. | 1298. |
| Particle board, high density | | D | 1.70243 | 1200. | 1298. |
| Particle board, low density | | D | 0.07791 | 1200. | 1298. |
| Particle board, medium density | | D | 1.35616 | 1200. | 1298. |
| Particle board, underlayment | | D | 0.31095 | 1200. | 1214. |
| Plywood | | A | 0.11536 | 544. | 1214.23 |
| Plywood | | D | 0.11548 | 544. | 1214.172 |
| Plywood | | E | 0.15 | 560. | 2500. |
| Plywood | | E | 0.15 | 700. | 1420. |
| Plywood | | G | 0.15 | 800. | - |
| Plywood | | I | 0.174 | 640. | 1760. |
| Plywood | | Y | 0.10 | 545. | - |
| Plywood | NBN, dry | T | 0.14 | 600. | 1880. |
| Plywood | NBN, dry | T | 0.15 | 600. | - |
| Plywood | Low exp. | S | 0.17 | 700. | 1880. |
| Plywood | Std exp. | S | 0.23 | 700. | 1880. |

| Material Description | **Condition/ Test** | **Source** | $\lambda$ ( $W/mK$ ) | $\rho$ ( $kg/m^3$ ) | $C_p$ ( $J/kgK$ ) |
|---|---|---|---|---|---|
| Plywood, across grain | Conditioned | C | 0.14 | 530. | - |
| Plywood, across grain, fireproofed | Conditioned | C | 0.15 | 560. | - |
| Plywood sheathing | | BS | 0.14 | - | - |
| Plywood decking | | BS | 0.14 | - | - |
| Sawdust | At 50°C | I | 0.051 | 188. | 1000. |
| Sawdust or shavings | | A | 0.06489 | 184. | 1381.71 |
| Sawdust, loose | Conditioned | C | 0.08 | 145. | - |
| Sawdust, slabs, bonded with glue | Conditioned | C | 0.10 | 550. | - |
| Sawdust, slabs, lightly bonded | Conditioned | C | 0.05 | 160. | - |
| Soft board | At 50°C | I | 0.047 | 249. | 1300. |
| Soft board | At 50°C | I | 0.066 | 320. | 1300. |
| Softboard | | E | 0.56 | 350. | 1000. |
| Softboard | Low exp. | S | 0.08 | 275. | 2100. |
| Wall board | At 50°C | I | 0.047 | 262. | 1260. |
| Wood, for filling | | Y | 0.05 | 190. | - |
| Wood blocks flooring | | C | 0.14 | 650. | 1200. |
| Wood chip board | Low exp. | S | 0.10 | 450. | 1880. |
| Wood chip board | Low exp. | S | 0.15 | 600. | 1880. |
| Wood chip board | Low exp. | S | 0.290 | 1000. | 1880. |
| Wood chip cement-bonded board | Low exp., $\rho$ 350-70 | S | 0.15 | 525. | 1470. |
| Wood chippings | | Y | 0.14 | 500. | - |
| Wood fibre, soft wood, loose fill | | A | 0.04326 | 44.8 | 1382. |
| Wood fibre | | Y | 0.175 | 1000. | - |
| Wood fibre panels, hard wood fibres | | G | 0.170 | 1000. | - |
| Wood fibre panels, porous wood fibres and bituminised wood | | G | 0.045 | 200. | - |
| Wood fibre panels made from porous wood fibres and bituminised wood | | G | 0.056 | 300. | - |
| Wood fibre, hard & ultra-hard panels | $\rho$ 850-100 | F | 0.20 | 925. | - |
| Wood fibre/cement conglomerate | | Y | 0.068 | 400. | - |
| Wood fibre, soft insulation panels | $\rho$ 200-25 | F | 0.058 | 225. | - |
| Wood fibre, soft asphalt covered | $\rho$ 250-30 | F | 0.065 | 275. | - |
| Wood fibres compressed | | Y | 0.055 | 320. | 99. |
| Wood shingle | | D | 0.11548 | 512. | 1256. |
| Wood waste board, bonded with bitumen & cement | | C | 0.09 | 500. | - |
| Wood wool board, bonded with cement | At 50°C | I | 0.081 | 398. | 1130. |
| Wood wool board, bonded with cement | At 50°C | I | 0.108 | 674. | 1130. |
| Wood wool building slabs | Wet | C | 0.13 | 480. | - |
| Wood wool building slabs | Wet | C | 0.2 | 860. | - |
| Wood wool building slabs | Conditioned | C | 0.08 | 400. | - |
| Wood wool building slabs | Conditioned | C | 0.10 | 500. | - |
| Wood wool building slabs | Conditioned | C | 0.11 | 600. | - |
| Wood wool building slabs | Conditioned | C | 0.12 | 700. | - |
| Wood wool building slabs | Conditioned | C | 0.13 | 750. | - |
| Wood wool building slabs | | C | 0.13 | 800. | - |
| Wood wool roof slab | | C | 0.10 | 500. | 1000. |
| Wood wool slab | | BS | 0.1 | - | - |
| Wood wool xylolite cement slab | Low exp., $\rho$ 400-50 | S | 0.11 | 450. | 1470. |
| Wood wool, fluffy | | C | 0.04 | 40. | - |
| Wood, block | | E | 0.16 | 800. | 2093. |
| Wood, flooring | | E | 0.14 | 600. | 1210. |
| Woodwool | | E | 0.1 | 500. | 1000. |

### 4.7 Absorptivity and Emissivity

These data are grouped into 4 categories (one null), namely:

#### 4.7.1 Category One: Impermeables

| Material | Absorptivity | Emissivity |
|---|---|---|
| Aluminium (polished) | 0.10-0.40 | 0.03-0.06 |
| Aluminium (dull, rough polish) | 0.40-0.65 | 0.18-0.30 |
| Aluminium (anodised) | - | 0.72 |
| Aluminium surfaced roofing | - | 0.216 |
| Asphalt (new) | 0.91-0.93 | - |
| Asphalt (block) | 0.85-0.98 | 0.90-0.98 |
| Asphalt (weathered) | 0.82-0.89 | - |
| Asphalt (pavement) | 0.852-0.928 | - |
| Bitumen felt/roofing sheets | 0.86-0.89 | 0.91 |
| Bitumen (parking lot) | 0.86-0.89 | 0.90-0.98 |
| Brass (polished) | 0.30-0.50 | 0.03-0.05 |
| Brass (dull) | 0.40-0.065 | 0.20-0.30 |
| Brass (anodised) | - | 0.59-0.61 |
| Bronze | 0.34 | - |
| Ceramics | | |
| Copper (polished) | 0.18-0.50 | 0.02-0.05 |
| Copper (dull) | 0.40-0.065 | 0.20-0.30 |
| Copper (anodised) | 0.64 | 0.60 |
| Duraluminium | - | - |
| Glass | see manufacturer’s data | 0.88-0.937 |
| Iron (unoxidised) | - | 0.05 |
| Iron (polished/bright) | 0.40-0.65 | 0.20-0.377 |
| Iron (oxidised) | - | 0.736-0.74 |
| Iron (red rusted) | - | 0.61-0.65 |
| Iron (heavily rusted) | 0.737 | 0.85-0.94 |
| Iron, cast (unoxidised/polished) | - | 0.21-0.24 |
| Iron, cast (oxidised) | - | 0.64-0.78 |
| Iron, cast (strongly oxidised) | - | 0.95 |
| Iron, galvanised (new) | 0.64-0.66 | 0.22-0.28 |
| Iron, galvanised (aged/very dirty) | 0.89-0.92 | 0.89 |
| Lead (unoxidised) | - | 0.05-0.075 |
| Lead (old/oxidised) | 0.77-0.79 | 0.28-0.281 |
| Rubber (hard/glossy) | - | 0.945 |
| Rubber (grey/rough) | - | 0.859 |
| Steel (unoxidised/polished/stainless) | 0.20 | 0.074-0.097 |
| Steel (oxidised) | 0.20 | 0.79-0.82 |
| Tin (highly polished/unoxidised) | 0.10-0.40 | 0.043-0.084 |
| Paint, Aluminium | 0.30-0.55 | 0.27-0.67 |
| Paint, Zinc | 0.30 | 0.95 |
| PVC | - | 0.90-0.92 |
| Tile (light) | 0.3-0.5 | 0.85-0.95 |
| Varnishes | - | 0.80-0.98 |
| Zinc (polished) | 0.55 | 0.045-0.053 |
| Zinc (oxidised) | 0.05 | 0.11-0.25 |

#### 4.7.2 Category Two: Non-Hygroscopic

[illegible] never used as surface finishes,

#### 4.7.3 Category Three: Inorganic-Porous

l c c.

| Material | Absorptivity | Emissivity |
|---|---|---|
| Asbestos board / paper | - | 0.93-0.94 / 0.96 |

| | | |
|---|---|---|
| Asbestos cloth | - | 0.90 |
| Asbestos cement (new) | 0.61 | 0.95-0.96 |
| Asbestos cement (very dirty) | 0.83 | 0.95-0.96 |
| Brick (glazed/light) | 0.25-0.36 | 0.85-0.95 |
| Brick (light) | 0.36-0.62 | 0.85-0.95 |
| Brick (dark) | 0.63-0.89 | 0.85-0.95 |
| Cement mortar, screed | 0.73 | 0.93 |
| Clay tiles (red/brown) | 0.60-0.69 | 0.85-0.95 |
| Clay tiles (purple, dark) | 0.81-0.82 | 0.85-0.95 |
| Concrete and plain concrete tile | 0.65-0.80 | 0.85-0.95 |
| Concrete block | 0.56-0.69 | 0.94 |
| Plaster | 0.30-0.50 | 0.91 |
| Stone, Granite (red) | 0.55 | 0.90-0.93 |
| Stone, Limestone | 0.33-0.53 | 0.90-0.93 |
| Stone, Marble | 0.44-0.592 | 0.90-0.93 |
| Stone, Sandstone | 0.54-0.76 | 0.90-0.93 |
| Stone, Slate | 0.79-0.93 | 0.85-0.98 |
| Stone, Quartz | - | 0.90 |

## 4.7.4 Category Four: Organic Hygroscopic

| Material | Absorptivity | Emissivity |
|---|---|---|
| Paper | - | 0.091-0.94 |
| Paper (white, bond) | 0.25-0.28 | - |
| Cloth, cotton, black | 0.67-0.98 | - |
| Cloth, cotton, deep blue | 0.82-0.83 | - |
| Cloth, cotton, red | 0.562 | - |
| Cloth, wool, black | 0.87-0.88 | - |
| Cloth, wool, black | 0.749 | - |
| Cloth, felt, black | 0.775-0.861 | - |
| Cloth, all fabrics | - | 0.89-0.92 |
| Wood, Beach | - | 0.94 |
| Wood, Oak | - | 0.89-0.90 |
| Wood, Spruce | - | 0.82 |
| Wood, Walnut | - | 0.83 |

### 4.8 Vapour Resistivity

Vapour resistivity is grouped into 4 categories as follows.

#### 4.8.1 Impermeables

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Asphalt (laid) | ∞ |
| Bitumen roofing sheets | 2,000-60,000 |
| Bituminous felt | 15,000 |
| Glass, cellular | ∞ |
| Glass, sheet/mirror/window | ∞ |
| Glass, expanded/foamed | ∞ |
| Glass brick | ∞ |
| Linoleum ($\rho$ = 1200kg/m$^3$) | 9,000 |
| Metals and metal cladding | ∞ |
| Paint, Gloss (vapour resistant) | 40-200 |
| Plastics, PVC sheets on tile | 800-1,300 |
| Plastics, hard | 45,000 |
| Rubber ($\rho$ = 1200-1500 kg/m$^3$) | 4500 |
| Rubber Tiles ($\rho$ = 1200-1500 kg/m$^3$) | ∞ |
| Tiles, Ceramic | 500-5,000 |
| Tiles, Glazed ceramic | ∞ |
| Plastics, PVC sheets on tile | 800-1,300 |
| Plastics, hard | 45,000 |

#### 4.8.2 Category Two: Non-Hygroscopic

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Mineral fibre, glass fibre/wool | 5-7 |
| Mineral fibre/wool | 5-9 |
| Mineral fibre, rock wool | 6.5-7.5 |
| Phenolic (closed cell) | 150-750 |
| Phenol formaldehyde | 19-20 |
| Polystyrene, expanded | 100-750 |
| Polystyrene, extruded | 600-1,500 |
| Polystyrene, extruded without skin | 350-400 |
| Polyethylene foam | 20,000 |
| Polyurethylene foam | 115-1,000 |
| PVC foam (rigid) | 40-1,300 |
| Urea formaldehyde foam | 5-20 |

#### 4.8.3 Category Three: Inorganic-Porous

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Asbestos cement (800kg/m$^3$) | 70 |
| Asbestos cement, sheeting, substitutes (1600-1900kg/m3) | 185-1000 |
| Brick, blast furnace slag (1000-2000kg/m$^3$) | 350-500 |
| Brick, calcium silicate (<1400)kg/m$^3$) | 25-50 |
| Brick, calcium silicate (>1400)kg/m$^3$) | 75-125 |
| Brick, dense (>2000kg/m$^3$) | 100-250 |
| Brick, heavyweight (>1700kg/m$^3$) | 45-70 |
| Brick, lightweight (<1000kg/m$^3$) | 25-50 |
| Brick, mediumweight (>1300kg/m$^3$) | 23-45 |

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Brick, sand lime (<1400kg/m$^3$) | 25-50 |
| Brick, sand lime (>1500kg/m$^3$) | 75-200 |
| Concrete, cellular (450-1300kg/m$^3$) | 9-50 |
| Concrete, cast (<1000kg/m$^3$) | 14-33 |
| Concrete, cast (>1000kg/m$^3$) | 30-80 |
| Concrete, cast (>1900kg/m$^3$) | 115-1,000 |
| Concrete, expanded clay (500-1,000kg/m$^3$) | 25-33 |
| Concrete, expanded clay (1,000-1,800kg/m$^3$) | 33-75 |
| Concrete, foamed steam hardened (400-800kg/m$^3$) | 25-50 |
| Concrete, natural pumice (500-1,400kg/m$^3$) | 25-75 |
| Concrete, no fines (1800kg/m$^3$) | 20 |
| Concrete, polystyrene foamed (400kg/m$^3$) | 80-100 |
| Concrete, porous aggregate (1,000-2,000kg/m$^3$) | 15-50 |
| Concrete, porous aggregate without quartz sand | 25-75 |
| Concrete, close textured | 350-750 |
| Concrete, slag and Rhine sand (1,500-1,700kg/m$^3$) | 50-200 |
| Concrete, insulating | 23-26 |
| Concrete blocks (very light) | 15-30 |
| Concrete blocks (very light) | 20-50 |
| Concrete blocks (very light) | 30-80 |
| Concrete blocks (very light) | 60-150 |
| Plaster/Mortar, cement based (1900-2000kg/m$^3$) | 75-205 |
| Plaster/Mortar, lime based (1600-1800kg/m$^3$) | 45-205 |
| Plaster/Mortar, gypsum, gypsum plasterboard | 30-60 |
| Stone, Basalt, porphory, bluestone | $\infty$ |
| Stone, Granite, marble | 150-$\infty$ |
| Stone, Slate | 150-450 |
| Stone, Slatey shale | >3,000 |
| Stone, Limestone, firm | 350-450 |
| Stone, Limestone, soft | 130-160 |
| Stone, Limestone, soft tufa | 25-50 |
| Stone, Sandstone | 75-450 |
| Stone, Clay | 75 |
| Tiles, clay tile, ceramic | 750-1,500 |
| Tiles, floor tile, ceramic | 115 |
| Tiles, terracotta roof tile | 180-220 |

### 4.8.4 Category Four: Organic-Hygroscopic

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Carpet, normal backing | 7-20 |
| Carpet, foam backed or foam underlay | 100-300 |
| Corkboard/slabs | 50-200 |
| Cork Insulation | 25-50 |
| Cork, expanded | 23-50 |
| Cork, expanded and impregnated 45-230 | |
| Cork, expanded with bitumous binding | 45-230 |
| Mineral and vegetable fibre insulation | 5 |
| Paper | 500 |
| Strawboard | 45-70 |
| Wood, Ash | 200-1850 |
| Wood, Balsa | 45-265 |
| Wood, Beech | 200-1850 |
| Wood, Beech, soft | 90-700 |
| Wood, Birch | 90-700 |
| Wood, Fir | 45-1850 |
| Wood, Gaboon, North Canadian | 45-1850 |
| Wood, Oak | 200-1850 |
| Wood, Pine | 45-1850 |
| Wood, Pine, Northern red; Oregon | 90-200 |
| Wood, Pitch pine | 200-1850 |

| Material | Vapour Resistivity ( $MNs/gm$ ) |
|---|---|
| Wood, Spruce | 45-1850 |
| Wood, Teak | 185-1850 |
| Wood, Walnut | 200-1850 |
| Wood, Willow | 45-1850 |
| Wood Products, Chipboard | 230-500 |
| Wood Products, Chipboard, bonded with cement | 19-50 |
| Wood Products, Chipboard, bonded with U.F. | 200-700 |
| Wood Products, Chipboard, bonded with melanine | 300-500 |
| Wood Products, Chipboard, bonded with P.F. | 250-750 |
| Wood Products, Hardboard | 230-1000 |
| Wood Products, Triplex - Multiplex (700kg/$m^3$) | 200-500 |
| Wood Products, Multiplex (800kg/$m^3$) | 200-2000 |
| Wood Products, Multiplex, light pine | 80 |
| Wood Products, Multiplex, North Canadian Gaboon | 80 |
| Wood Products, Multiplex, red pine | 875-250 |
| Wood Products, Particle board, soft wood | 25 |
| Wood Products, Plywood | 150-2000 |
| Wood Products, Plywood, decking | 1000-6000 |
| Wood Products, Plywood, marine | 230-375 |
| Wood Products, Plywood, sheathing | 144-1000 |
| Wood Products, Fibreboard | 150-375 |
| Wood Products, Fibreboard, hard wood fibres | 350 |
| Wood Products, Fibreboard, porous wood fibres | 25 |
| Wood Products, Fibreboard, bitumened | 25 |
| Wood Products, Fibreboard, cement based | 19-50 |
| Wood Products, Wood wool slabs | 15-40 |
| Wood Products, Wood wool/cement slabs | 15-50 |
| Wood Products, Wood wool/magnesia slabs | 19-50 |
| Wood Products, Wood lath | 4 |

## 4.9 References

1. Keeble E J ‘Performance Values, Safety Margins And Risks Of Failure: Do We Need A Uniform Basis For Determining Reliability ?’ **Proc. Performance Concepts in Building** Department of Architecture and Building Science, University of Strathclyde, January 1979.

# Section Five: Recommendations for the Future

## 5.1 Review of Data-sets

The following observations can be made on the structure and contents of the data-sets described in Section Three.

- At present there is no consensus on the manner in which materials are grouped for presentation of data to designers. What is needed is a common system such as the CIB Master list of materials [1] which integrates thermal properties within a broad material classification system.
- The range of properties for which values are quoted is generally restricted. Commonly, the properties are thermal conductivity, density and vapour resistivity as required for simple steady state heat loss and condensation calculations.
- The sources of much of the data are not identified, and little information is given on the underlying experimental conditions. As a consequence data merging is an uncertain process because it is often impossible to ensure compatibility between different entries.
- It is suspected that much of the agreement that does exist between the different data-sets can be attributed to a high degree of historical ‘borrowing’ one from the other. This in turn may lead, erroneously, to an optimistic assessment of the inherent uncertainty.
- Many values are quoted without any statement as to whether they correspond to single or multiple measurements. A random inspection of several referenced works would suggest that values are usually derived from the work of a single researcher on the basis of a small sample size.
- Many of the data values are derived from work carried out with non-standard apparatus and from a date which precedes modern standards of equipment and operation.
- No guidance is given on the variation in properties such as density and internal structure inherent in the production of many building materials.
- There is no agreement on the procedure for the determination of the thermal conductivity of materials in the moist state.
- There is tacit agreement that the uncertainty within the data is use-context dependent. The various calculation methods proposed are clearly expected to yield no more than ball-park estimates of real conditions (as opposed to meeting some abstract standard).

## 5.2 Review of Bulk Properties

For any material, density, moisture content and internal structure are the major determinants of its thermal and hygroscopic behaviour. In some cases, the effects of temperature and ageing can also be significant. This section considers how and where these properties and environmental conditions give rise to uncertainties. It then suggests a mechanism for the management of this uncertainty.

*Thermal Conductivity*

It is well known that thermal conductivity is correlated with material density. For example Jakob [2] has established a relationship between average thermal conductivity and density for completely dry building materials. This relationship was later confirmed by work undertaken at the UK Building Research Establishment [3].

With respect to accuracy, Jakob suggested that individual values might deviate by up to ±15%. He also suggested that the internal structure of a material affected the thermal conductivity, according to whether it was amorphous or crystalline. This relationship, between the thermal conductivity of dry materials (including insulating materials) and their density, was also examined by Billington [4]. Although the magnitude of the deviations is not explicitly discussed, it is implied that deviations of 50% or more not uncommon. Billington also draws attention to the influence of internal structure on thermal conductivity, particularly in the case of concretes, but concludes that the conductivity depended on whether the material was cellular or granular in structure rather than amorphous or crystalline. A deliberate application of control of internal structure has shown that, in the case of concrete, the thermal conductivity can differ by up to 30% for a given density [5].

For fibrous and cellular insulations, the apparent thermal conductivity is a function of density and fibre or cell size. In general, a specific combination produces minimum thermal conductivity.

Concrete and masonry present a particular problem in that the variable nature of the constituents has a strong influence on the thermal conductivity. Several reports give correlations of conductivity with density for concrete [6, 7, 8] and for masonry [9, 10, 11]. It can be concluded that the prediction of the thermal conductivity of these materials from these correlations is quite approximate, particularly in the case of masonry.

Quite apart from trying to produce predictive algorithms, the inherent scatter in the relationship between thermal conductivity and density has important consequences for the retrieval of values from a database. Once a material is located, density is invariably the key parameter in locating the correct value of thermal conductivity. The essential problem is that the location on the thermal conductivity curve of the test sample or samples that gave rise to the value held is generally unknown, as is that of the material to be used on site. In the worst scenario, the value held may be derived from material with a high positive deviation while the material to be used on site has a high negative deviation. In practice the density assumed for thermal conductivity database retrieval will commonly be a nominal one supplied by the manufacturer. An error will arise if this deviates significantly from the actual density of the product as supplied and installed. A study of the properties of lightweight concrete blocks carried out by BRE Scottish Laboratory found substantial deviations between the density quoted by manufacturers and the actual mean density of the block samples as measured [12]. Out of seven cases where comparisons could be made, four showed differences of around 20% between the actual mean density and the quoted density. In addition, the actual spread of densities about the mean was, in most cases, substantial. The remedy for these problems lie in quality control procedures which can guarantee the delivery of materials to within a known density tolerance. Until this is achieved, the error introduced will be an unknown quantity.

The thermal conductivity of a material is also strongly affected by the presence of moisture. Jakob proposed that the thermal conductivity of a mineral building material containing a known percent of moisture by volume could be obtained by multiplying the thermal conductivity in the dry state by a correction factor which depended only on the moisture content by volume. This method of correction has been widely used and applied to masonry materials [2]. Some time later, thermal conductivity measurements on moist materials, by Jespersen [13], showed that the behaviour of different materials was not well represented by a single characteristic. He found that both the magnitude of the initial rise at low moisture content and the moisture content at which the relationship between thermal conductivity and moisture content becomes linear are significantly different for different groups of materials. He also noted that, in general, there is an initial region, corresponding to the transition from dry to the point of hygroscopic equilibrium under normal internal environmental conditions, where the thermal conductivity is little affected by increasing moisture content. As a result, he concluded that the equilibrium hygroscopic moisture content under such conditions - literally defined as ‘laboratory dry’ - has little effect on the thermal conductivity of materials.

In considering the rates of change of thermal conductivity with moisture content, Jespersen found that he was able to distinguish three kinds of behaviour associated with different material types. These were timber products, inorganic lightweight insulating materials and masonry. At one extreme, the organic materials proved to be little affected by moisture content, the relationship between the thermal conductivity and moisture content being approximately linear throughout with no rapid increase in thermal conductivity observed at low moisture contents. Consequently, the use of a single value of conductivity for such materials (when determined at the in-use moisture content) should be of adequate accuracy. At the other extreme, the mineral fibre insulating materials showed a violent increase in thermal conductivity with only small increases in moisture content, and thereafter assumed a linear relationship. Fortunately, such materials contain very small amounts of hygroscopic moisture under normal ‘air dry’ conditions, so that the value of thermal conductivity determined for the dry state, or an appropriately conditioned one, should yield the same value. However, should it be suspected that such materials may be exposed to conditions which might involve, for example, condensation or wetting, then the use of such thermal conductivity values would be extremely inaccurate. The range of behaviour of masonry materials was found to lie in a rather broadly defined zone located between the two extremes. Since the types of masonry tested were not fully representative, especially of concretes, the extent and shape of the zone is conjectural. Given the underlying physical processes, it is probable that a subdivision into cellular and granular materials would be useful.

Since masonry materials are usually subject to conditions involving significant moisture content, it is not surprising that there have been numerous attempts to define their behaviour [2, 4, 8, 13, 14, 15, 16]. There is evidence that the relationship between thermal conductivity and moisture content can be represented by linear expressions in terms of moisture content by volume or by weight. In order to compare published results, it is useful to express them as the percentage change in thermal conductivity per one percent change in moisture content by volume or by weight. It is also useful to adopt the convention of moisture correction factors such that the thermal conductivity, $\lambda$, at some percentage moisture content, $m$, is related to that at a reference moisture content, $m_r$:

$$\lambda/\lambda_r = (1 + Cm)/(1 + Cm_r)$$

from which it follows that

$$\lambda - \lambda_r/\lambda_r(m - m_r) = C/(1 + Cm_r)$$

where $C$, a constant, is independent of $m$ for linear relationships. Thus the percentage change in $\lambda$ per 1% change in $m$ is determined not only by $C$ but also by the choice of $m_r$. Jespersen found significant linear behaviour for all masonry materials between 2% and 10% moisture content by volume [13]. Above a reference moisture content of 2%, the upper and lower bounds of his curves for the percent change in $\lambda$ with $m$ yield a rate of 6% to 7%.

For lightweight concrete, Jespersen's regression equation for $\lambda$ versus $m$ can be rearranged to yield $C$ by dividing his coefficient 'a' by a reference thermal conductivity consisting of the air-dry conductivity plus a diffusion conductivity. By using his quoted data and working in the units he used, a reasonable mean for the air-dry conductivity is 0.9 $BtU\ in/ft^2hF$ (0.13 $W/mK$). The value of 'a' does not vary much, and the mean value is 0.056. The mean value of the reference conductivity is close to unity so that an estimate of $C$ is 0.06. These results may be compared with the linear change in $\lambda$ per 1% change in $m$ by volume of about 6% given by the moisture correction factors in DIN 52612 [14]. By comparison, analysis of the non-linear Jakob correction factors for $m$ in the range 2.5% to 10% by volume yields mean interval rates of 10% falling to 7%.

This suggests that the Jakob corrections are atypical, particularly at low moisture contents. However, Arnold examined the validity of the correction proposed by Jakob [9]. A curve of the thermal conductivity of masonry materials corrected to 1% moisture content against dry density was produced from published results. The fit was concluded to be satisfactory. If the Jakob corrections were correct, the resulting curve should have reduced, after removing the dependence on moisture content, to the same form as the dry thermal conductivity versus density curve with the same associated scatter. While only passing reference was made to the scatter of the results, others have examined it in some detail [17]. Whereas a maximum deviation for this type of curve of ±15% could be expected [2], the average spread was 15%, with individual deviations of over 40%, and particularly poor agreement below 2% moisture content by volume [17]. This is in accord with present findings. A linear change in $\lambda$ per 1% change in moisture content by weight has been given as 4% for lightweight concrete [15] and 6% for bricks [4]. For the former material, relationships have been quoted giving $C$ as 0.06 [8] or about 0.05 [16]. The respective rates of change are 3%-6% and 4%-6% over the range of validity of the latter relationship in moisture content and density. Minimum moisture contents quoted for linear behaviour have been 1% by volume [16] and 1.5% by weight [15]. Dependence quoted in terms of moisture content by weight implies a dependence on density when quoted in terms of volume since, with increasing density, the same change in moisture content causes less change in thermal conductivity. This agrees with the finding of Jespersen that lightweight materials had the greatest overall sensitivity to changes in moisture content (by volume).

In general, the corrections proposed in DIN 52612 seem more appropriate than those proposed by Jakob, particularly if referenced to a moisture content of not less than 1% to 2% by volume. For relationships expressed in terms of moisture content by weight, there is considerable agreement that the factor $C$ lies in the range 0.04 to 0.06 when referenced to a minimum moisture content of 1.5% by weight or 1% by volume. The inherent scatter in results due to experimental error and, just as importantly, to differences in internal composition between samples which cannot be eliminated by density dependency, means any quest for further accuracy is questionable. The relationship for lightweight concrete given by Valore seems credible in current circumstances [8]. The question of which moisture contents actually exist in practice is a vexed one. The standard moisture contents quoted for design purposes in Section A3 of the CIBSE Guide cover the range 1% to 5% moisture content by volume [18]. By contrast, Jakob gives the range as 5% for inner walls and 10% for outer walls, and draws attention to the possibility of great deviations [2]. The choice of the standard moisture contents for the UK is admitted to be based on sparse evidence[9]. Even so, the data show considerable spread. It follows that the uncertainty in specifying the moisture content in a real situation could be a major source of error in predicting thermal conductivity. In fact, such errors could match or exceed the kind of errors noted in connection with the use of the Jakob corrections [16].

In general, the thermal conductivity of dry materials increases with temperature. The changes are small at normal temperatures and are usually neglected. Possible exceptions are the fibrous and porous insulation materials where the apparent conductivity may vary significantly in extreme environmental conditions [19]. The presence of moisture increases the effect of temperature on the thermal conductivity of inorganic materials. This is particularly acute for lightweight inorganic insulating materials, but for any material with a moisture corrected thermal conductivity of less than 0.5 $W/mK$, the effect of temperature will have doubled or more [13].

Thickness also has an effect on the apparent conductivity of low density fibrous and cellular insulations due to radiative heat transfer. The effect is relatively small over thicknesses of 25mm to 150mm [20]. Measurements at the Electricity Council Research Centre have found no evidence of a thickness effect in mineral fibre quilt of thickness 90mm to 360mm [21]. The evidence suggests little error will result in neglecting the effect of thickness. Finally, ageing can be identified as a significant cause of increase in thermal conductivity for foamed insulations blown with gas of a thermal conductivity below that of air. In time, the gas diffuses away and the thermal conductivity increases. Hence, only the value of the aged insulation should be used.

*Specific Heat Capacity*

The seemingly straightforward definition of specific heat capacity as the amount of heat energy required to be added or removed to change unit mass of a material by unit temperature belies the difficulty of measuring such a value. The difficulty of obtaining reliable values for different materials, and the absence of a predictive method, has been noted elsewhere [6]. One of the difficulties of measurement, particularly for materials of low conductivity, is that it is difficult to input or extract heat quickly, making the design of accurate practical experimental apparatus difficult. Perhaps partly because of such difficulties, very few laboratories which responded to the project questionnaire measured this quantity. Test techniques identified included a relatively conventional absolute calometric method [22] and an indirect dynamic test method based on Fourier’s equation and computer regression analysis of test results [23]. Both are in-house methods.

Because of the high specific heat capacity of water, the effect of moisture content on the specific heat of a material is significant and must be taken into account. In principle, the overall specific heat capacity of a material is simply the linear addition of that of the dry material to that due to the amount of water present in the material. In practice, this means a knowledge of the in-use moisture content. While calculations can be based on standard design values, their relevance to real site values are doubtful. The absence of a practical, non-destructive test method for determining on-site moisture contents means inherent uncertainty in calculating values of specific heat capacity for moisture containing materials. This uncertainty is compounded when it is realised that it is, in fact, the volumetric heat capacity (that is the product of density and specific heat capacity) which is important in determining thermal capacity. Hence, the uncertainty in density, as discussed above, is added to the uncertainty in specific heat capacity for volumetric heat capacity.

A further source of error may arise from the fact that, in practice, conditions are dynamic. In general, materials will be subject internally to both temperature and moisture gradients that do not correspond to equilibrium distributions. Hence, both the thermal resistivity and capacity will vary from point to point within the material. Finally, it is also the case that the specific heat capacity is a function of temperature. However, given the relatively small range of temperature involved in calculating the hygrothermal performance of buildings, the error associated with adopting a single figure value will be insignificant compared to the scale of error from other causes.

*Water Vapour Transmission*

The behaviour of a material where gaseous diffusion is the vapour transport mechanism is relatively simple. Where a material can absorb water, the diffusion process can be complemented by other forms of transport which are capable of causing a considerable increase in the permeability of the material [24]. Consequently there is a fundamental distinction to be made between hygroscopic and non-hygroscopic materials. Fortunately, there is an approach to measuring vapour permeability which can identify and evaluate these differences in behaviour [25]. This method has been applied to measurements of vapour permeability on ‘Gyproc’ plasterboard (non-hygroscopic) and plywood (strongly hygroscopic) [26]. The results obtained typify the differences in behaviour between hygroscopic and non-hygroscopic materials.

In the latter case, the vapour permeability is little affected by relative humidity, and is adequately represented by a single value. There is the possibility of a slight increase with increasing humidity. Where more than one value is quoted, a rational way to limit variation and represent real conditions would be to select the value obtained under the highest conditions of humidity where this can be identified.

The behaviour of hygroscopic materials falls into two distinct regions. At low humidities where gaseous diffusion dominates, the behaviour is like that of non-hygroscopic materials. However, above 60% RH the behaviour becomes non-linear, with vapour permeability showing rapid changes with small changes in humidity. In the tests referred to above, the permeability of plywood at 95% RH was found to have increased twenty-fold over the low humidity value. The behaviour at high humidities might be even more complicated. A high moisture content causes plywood to undergo dimensional changes and swell. Consequently the pore sizes can increase and reduce the hygroscopic effects [27]. A limiting effect on the increase in the permeability of wood based materials could operate at very high humidities. Current quoted data on water vapour transmission properties are based on measurements at one or, at most, two values of humidity. While this is reasonable for non-hygroscopic materials, it can be seen to be an entirely inadequate description of the behaviour of hygroscopic materials above the transition point. One result is that there is a wide variation in values quoted for hygroscopic materials, since they are extremely sensitive to relatively small changes in test conditions, as between different national standards for example. A survey of quoted values for plywood revealed the highest value to be some forty times the smallest [26].

The best that can be done at present is to represent the vapour transmission data for hygroscopic materials as a range, so that they at least convey some idea of the magnitude of the changes to be expected at humidities beyond 60% relative humidity. This is obviously important in the context of choosing values for condensation risk assessment. Clearly, the vapour permeability of non-hygroscopic materials can be defined with much greater certainty than for hygroscopic materials. It would therefore make sense to distinguish such materials from each other. Unfortunately, current data are not of a form to allow such a distinction to be made reliably for all the degrees of hygroscopic behaviour displayed by building materials.

It is, however, possible to attempt a breakdown of materials into groups according to the certainty with which their vapour permeability can be established. Clearly timber based products (organic and very hygroscopic) are the least certain. Equally clearly, there are materials such as metal and glass which are impermeable and have effectively zero permeability. Between these two extremes are the inorganic materials which are permeable. These can again be broken down into two groups. On the one hand there are non-hygroscopic inorganic materials such as mineral fibre insulations which behave in a simple manner. On the other hand there are masonry materials which are inorganic but display weak to strong hygroscopic behaviour.

It is interesting to find that, impermeables apart, these groupings correspond closely to those used by Jespersen to distinguish the behaviour of moist materials in terms of thermal conductivity. Masonry materials occupied a broad zone, timber displayed the least variation and lightweight non-hygroscopic inorganics the most.

With regard to the dependence of vapour permeability on temperature, it is only of significance in the case of the least permeable membranes [25]. Such membranes would naturally fall under the impermeable grouping adding further to its significance in terms of defining behaviour.

*Surface Properties: Opaque Materials*

Radiative heat transfer properties are conveniently considered together and, indeed, are now commonly tabulated together. Unlike the bulk properties considered above, such surface properties can be determined with considerable accuracy. The properties are wavelength and therefore source temperature dependent. For opaque bodies, although emissivity and absorptivity are equal to each other at the same wavelength, the difference in the spectra of radiation at normal environmental temperatures and solar temperatures results in significantly different values. It is usually considered sufficiently accurate to quote a single value for the relatively small range covered by normal environmental temperatures.

In practice, one possible source of inaccuracy is to use values of laboratory tested materials that compare to a pristine surface state as opposed to the in-use surface state after a material has been subject to ageing through such agencies as weathering, chemical attack, and dirt accumulation. Where possible, values appropriate to an in-use condition should be quoted.

Values of emissivity quoted are commonly for the total normal emissivity. The actual power emitted depends on the hemispherical emissivity, which may differ. For nonconductors, the hemispherical emissivity may be lower by up to 7%, and for highly polished metallic surfaces, it may be greater by up to 30% [28]. The hemispherical emissivities can be calculated by multiplying the total normal emissivities by 1.2 for bright metal surfaces, by 0.98 for nonconducting rough surfaces and 0.95 for non-conducting smooth surfaces [29]. It can be seen that the least error will occur with normal building surfaces. A casual inspection of the values quoted by various sources suggests excellent agreement. Closer inspection reveals the extent of the borrowing that underlies this commonality. As an example, a recent compilation of solar absorptivities and emissivities by Penwarden at BRE borrows extensively from an earlier review carried out at the CSIRO and published in 1951 [30]. In turn, many of the solar absorptivity values quoted in this earlier review can be traced back to the work carried out at BRE (BRS as it was then) and published in 1935 [31]. In a similar way, many emissivities can be found in a 1941 publication [32].

The listing by Penwarden includes additional new values and represents the most up to date amendment of the historical data on solar absorptivities and emissivities to hand [33]. It has therefore been adopted as the core data for present purposes.

*Surface Properties: Transparent Materials*

Transparent materials have the property of transmission in addition to those of reflection and absorption. As the sum of the three properties must equal unity, it is only necessary to measure two of them.

It is universal practice to refer to glazing manufacturers for data on the solar optical properties of the various forms of sheet glass used in window systems. Unlike many building materials, both the quality control of glass and the precision with which the manufacturers determine their product properties is high. The general way of treating the data is to provide values of the properties including, perhaps, total transmittance at normal incidence. The behaviour at other angles of incidence is supplied in a graphical form showing the fractional change in properties as a function of the angle of incidence. The value of any property at other than normal incidence can then be estimated with good accuracy by adjusting its value at normal incidence by the appropriate fractional change indicated by the graph. In the case of coated versions of glasses, the behaviour at oblique angles of incidence above 30 degrees is not so well approximated by the characteristics of the non-coated glass, although even then the error is only around ±3% [34]. If better accuracy is required, then separate graphical corrections will be needed for coated versions of glasses. Transparent plastic materials are used in a number of speciality glazing applications. Appropriate data on their properties are obtained from the manufacturers as for glass.

## 5.3 Review of Test Methods

This section provides an review of the test methods underlying thermal conductivity, water vapour transmission, longwave emissivity and solar optical properties.

*Thermal Conductivity*

Quoted data are derived from measurements carried out by either the hot-plate or heat flow meter techniques. Both are steady state methods and primarily designed for measurements in the dry state. As such, the design and behaviour of equipment has received considerable attention [35]. Tests using the hot-plate method make absolute measurements of the conductivity for 1-dimensional (longitudinal) heat flow. It is possible to achieve an accuracy of ±3%, although in practice this is very dependent on the operation of the apparatus and the skill of the operator. Recently, schemes such as that operated by NAMAS, have been introduced to remedy this, by rationalising operation and inspection of equipment [36]. Measurements made prior to such schemes may be subject to larger errors. Even so the assumption of an accuracy to within 5% for later measurements may be misplaced. Inspecting agencies have some discretion on uncertainty, and in particular cases the error for some materials may be around 20% rather than 5% [37].

The heat flow meter technique is a relative technique which requires the use of calibration samples measured by the hot plate method. As such, the error associated with measurements carried out using this technique are about twice that of the hot plate, that is the error in the hot plate calibration sample measurement plus the heat flow meter error. It is, however, simpler to use and less dependent on operator error. Success in use depends on the existence of a well defined set of calibration samples.

The behaviour of both sets of apparatus has received considerable analysis and improvement, including the development of standard samples for heat flow meter calibration [38]. Nevertheless, what is apparent by its omission is any reference to the measurement of moist samples. Indeed, the recent ISO draft standards on hot plate and heat flow metering simply refer to the matter as complex and consider only measurements in the dry state [39, 40]. In principle this is correct, because neither form of apparatus is suited to the measurement of moist materials. However, since such measurements for masonry materials are of particular practical importance, the problems are worth considering in detail.

The essence of the problem is that the application of a temperature difference to a moist specimen results in a moisture gradient, causing moisture to migrate from the higher temperature. This affects the spot conductivity through the specimen and hence the temperature distribution. It has been observed that the spot thermal conductivity decreases more rapidly in the warmer (drier) region than it increases in the colder (moister) region [41]. At constant applied temperature difference, the same sample will have different moisture gradients for different moisture contents while, at constant moisture content, the same sample will have different moisture gradients for different applied temperatures. In addition, as the moisture content increases, condensate will appear at the cold side of the specimen [17]. This suggests that the measured conductivity will increasingly fall below the conductivity for a linear moisture distribution, as the moisture content increases.

In the absence of a knowledge of the moisture gradient, quoting applied temperatures at constant moisture content does not uniquely define the measurement. As such, measurements become particular functions of:

temperature
moisture content
sample thickness
sample orientation: up- or down-ward heat flow
length of measurement period.

The present situation is unsatisfactory and is unlikely to be resolved in terms of current test methods which are specifically designed for measurement in the dry state. A method of measurement involving a much lower applied temperature difference than is required by either the hot-plate or heat flow meter methods would help reduce the problem of moisture migration. One possibility that deserves investigation is the thin-heater thermal conductivity apparatus. In describing recent developments with this apparatus, Hager has drawn specific attention to the potential of this method in minimising water vapour migration, because of the low temperature difference involved [42].

*Water Vapour Transmission*

There is a need to modify existing wet- and dry-cup techniques to determine at least five points on the vapour permeability versus relative humidity curve so that differential permeability curves can be generated. This is required not only for known hygroscopic materials, but to identify all the materials that are significantly hygroscopic. In the longer term, more realistic results would be obtained if tests could be carried out for simultaneous vapour pressure and temperature differences, rather than isothermally as at present.

*Moisture Content*

There is an urgent need to establish the true distribution of moisture content in building materials in different regions for statistically significant samples. The UK is a particular case in point. Destructive testing in the form of drilling out core samples and weighing them would not be acceptable to many building owners and would take a long time. A review of alternative methods was not very optimistic, except in promoting a capacitance measuring technique [36].

*Longwave Emissivity and Solar Optical Properties*

The techniques of pyrometry and photometry are well established and supported by well developed instrumentation (both total and spectral). However, there is a lack of Standards relating to the measurement of such properties, particularly in relation to in-use building surfaces.

## 5.4 Review of Classifications

There is little agreement between the data-sets in terms of the classification of the data. One interesting possibility for the future would be to adopt the approach recommended by Eldridge [1]. To quote the preface

> “This listing of the properties of building materials puts into effect the recommendations of the CIB that such properties should be presented in a systematic manner according to an internationally agreed standard method. The result is a uniquely practical volume dealing with the important materials in a clear, concise and easily understood manner.”

## 5.5 The Data-Sets Compared

In essence the CIBSE and ASHRAE data-sets define the extremities of a spectrum within which the other collections can be placed. For example the Belgian and French collections, like CIBSE, attempt to compensate for moisture, while the Indian collection, like ASHRAE, contains properties only for the dry state. It is interesting therefore to compare the CIBSE and ASHRAE collections.

| ASHRAE | CIBSE |
|---|---|
| Differentiates between homogeneous and non-homogeneous materials (conductance for stated thickness). | No differentiation, conductance determined from component part conductivities and air space resistances. |
| Quotes dry state values which are not representative of materials in use. | Compensates for moisture so that values are representative of materials in use. |
| Source of data well documented. | Source not well documented. |
| Known test procedures: ASTM C-518 (guarded hot plate) or ASTM C-177 (heat flow meter method). | Test procedures largely unknown (guess: pre-standard guarded hot plate). BS 874 for new entries. |
| For non-homogeneous materials ASTM C-236 (guarded hot box) or ASTM C-976 (calibrated hot box) recommended. | Calculation recommended. |
| Data intended for computation of steady state U-values. | Data more useful for dynamic modelling. |

**5.6 Summary Specification of an Electronic Database**

Given the complexity of the Section Four data-sets, and the fact that the use of the data is context-dependent, it is recommended that the data-sets be installed within a relational database and contained within an expert system framework. This will allow future management of the data and ensure that the material properties are used in the correct context. The following summary specification is offered.

- Logical records should relate to a given material and be comprised of any number of physical records corresponding to the different thermo-physical parameter sets associated with the different test conditions and use contexts. A physical record would comprise the material descriptor, the thermo-physical properties of interest, a source identifier and the context definition.
- The structure should facilitate future growth, both in the number of logical/physical records, and in the associated attribute data.
- The database should have efficient data access and retrieval mechanisms including the ability to report, graphically and textually, any sub-set selected by type, identifier, property range and so on. For example:

  list all metals and their properties
  list all inorganic materials with a density $x \leq \rho \leq y$
  identify all organic materials associated with CIBSE.

- The database should permit the later addition of other material attributes, such as cost, and/or be able to operate in conjunction with other databases holding such data.
- Multi-user access and networking capabilities should be in-built in order to facilitate future CABD integration.
- A rollback facility should be incorporated to prevent data loss or corruption.
- Data transfer options should be included, allowing, for example, import/export of information to/from ASCII and other formats.
- The database should have a user friendly interface (probably forms driven). This interface should be programmable to allow the invocation of external programs (such as statistical software).
- The database should be contained within an expert system framework to ensure that data are extracted against the ‘correct’ use context.

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