3961

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Heat losses through ground floors

Digest 108 explains the basis of calculating standard U-values and deals in some detail with wall and roof constructions. For ground floors, either solid or suspended, it is not possilbe to calculate U-values from first principles but the value of a basic construction can be adjusted according to the nature of the floor finish and any insulation.

Solid ground floors

A solid floor, laid in contact with the ground, with or without a bed of hardcore, is exposed to the air on only one face. The heat flow from inside the building to the outside air is indicated by the flow lines in Fig 1. The greater the distance it has to travel the less is the quantity of heat lost. A U-value for a solid ground floor must, therefore, take account of the size and edge conditions of the slab.

The results of an examination of this problem, published over twenty years ago,[1] still form the basis of the conventional method of dealing with heat loss calculations through ground floors as set out in the CIBS 'Guide'.[2] Table 1 shows the basic U-values for a range of sizes and shapes of solid floor in contact with the ground; the values given are applicable to dense concrete floors, with or without a bed of hardcore. Because the thermal conductivities of ground and slab are similar, the values may be used for slabs of any thickness. They will not be affected by a hard dense floor finish such as granolithic concrete, terrazzo, clay tiling etc or by a thin finish of little insulation value such as thermoplastic tiles.

Table 1 U-values for solid floors in contact with the earth

Dimensions of floor	U-values: Four exposed edges		Two exposed edges at right-angles	
metres	*W/m² °C*		*W/m² °C*	
Very long × 30	0·16*	*6·25*	0·09	*11·11*
× 15	0·28*	*3·57*	0·16	*6·25*
× 7·5	0·48*	*2·08*	0·28	*3·57*
150 × 60	0·11	*9·09*	0·06	*16·67*
× 30	0·18	*5·55*	0·10	*10·0*
60 × 60	0·15	*6·66*	0·08	*12·5*
× 30	0·21	*4·76*	0·12	*8·33*
× 15	0·32	*3·12*	0·18	*5·55*
30 × 30	0·26	*3·84*	0·15	*6·66*
× 15	0·36	*2·77*	0·21	*4·76*
× 7·5	0·55	*1·82*	0·32	*3·12*
15 × 15	0·45	*2·22*	0·26	*3·84*
× 7·5	0·62	*1·61*	0·36	*2·77*
7·5 × 7·5	0·76	*1·32*	0·45	*2·22*
3 × 3	1·47	*0·68*	1·07	*0·93*

* Applies also to any floor of this breadth and losing heat from two parallel edges (breadth then being the distance between the exposed edges)

Figures in italics are reciprocals of the U-values ie the air-to-air resistance

In applying these values, the full temperature difference between inside and outside should be used. During the early life of a building, heat flows into the ground to raise it to its final equilibrium temperature; because of the high thermal capacity of the ground, this may take 6–12 months, with an increased demand on the heating during the early period. Steady-state conditions are applicable only to a narrow band round the edge of the floor slab but, nevertheless, the convention is adopted of basing heat loss calculations on a U-value for the whole floor and this will not lead to great error after the ground has been warmed to its equilibrium temperature.

The effect of moisture content on the thermal conductivity of masonry materials is discussed in Digest 108,[3] which describes the standard assumptions to be made for moisture contents of walls in protected and exposed situations. No such assumptions are required for solid ground floors.

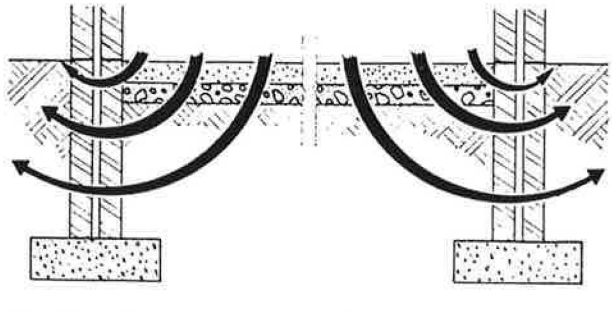

Fig 1 Heat flow through ground slab

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Technical enquiries arising from this Digest should be directed to Building Research Advisory Service at the above address.

Insulation of a solid ground floor

If a floor finish or screed affording some useful degree of thermal insulation is to be used, the U-value of the floor can be calculated accurately enough for most design purposes by taking the reciprocal of the basic U-value, ie the total air-to-air resistance (shown in italics in Table 1), adding the resistance of the additional material and then calculating the reciprocal of the combined resistances to obtain the U-value of the floor.

Assuming, for example, that a concrete floor size 15 m × 7·5 m exposed on all four edges is to be covered with 20 mm softwood flooring:

From Table 1, the basic U-value is 0·62 W/m² °C and its total resistance, the reciprocal, is 1·61

From Table 5, the thermal resistivity of softwood is 7·7 m °C/W; the thermal resistance of 20 mm material is therefore $\frac{7{\cdot}7 \times 20}{1000} = 0{\cdot}15$

total air-to-air resistance of insulated slab $= 1{\cdot}76$

U-value $= 1/1{\cdot}76 = 0{\cdot}57$

The effect of an overall layer of insulation (Fig 2) can be calculated in the same manner, by adding the thermal resistance of the insulation to that of the basic floor. The efficiency of the insulation is not, however, constant over the whole area of the floor because the greatest loss through an uninsulated floor is from the edges and the cost of overall insulation is seldom justifiable. An alternative that will give nearly as good results is to treat only the edges of the slab. This can be done in various ways (Fig 3). A vertical layer of insulating material (a) can be used; this should extend from finished floor level down to a depth of not less than 250 mm, but can with advantage be taken down to the top of a strip foundation. Alternatively (b) a horizontal strip about one metre wide can be laid in conjunction with a vertical strip through the full thickness of the floor around all exposed edges. Insulating material used in any of these positions should be of a type that is unaffected by moisture either in its performance or durability, or it should be protected from ground moisture.

Table 2 Corrections to Table 1 for edge-insulated floors

Dimensions of floor	**Percentage reduction in U for 25 mm min edge insulation extending to a depth of:**		
metres	0·25 m	0·5 m	1·0 m
Very long × 30	3	7	11
× 15	3	8	13
× 7·5	4	9	15
60 × 60	4	11	17
30 × 30	4	12	18
15 × 15	5	12	20
7·5 × 7·5	6	15	25
3 × 3	10	20	35

Corrections to Table 1 to allow for the effects of edge insulation as in Fig 3 (a) are given in Table 2. The detail shown in Fig 3 (b) will have a performance at least as good as with the same amount of insulation used as in 3 (a).

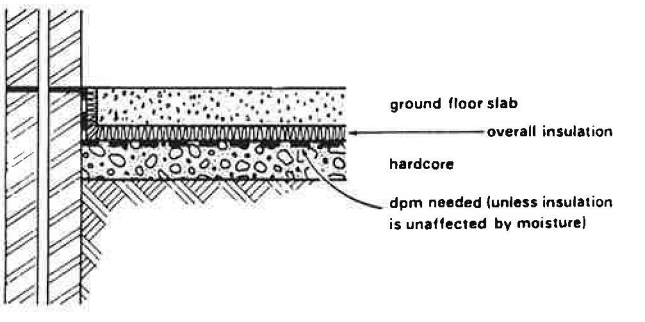

Fig 2 Overall floor insulation

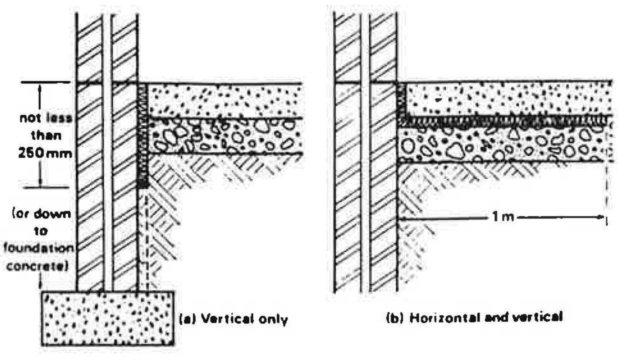

Fig 3 Edge insulation

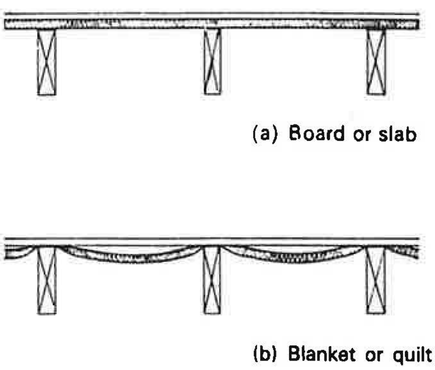

Fig 4 Insulation above joists

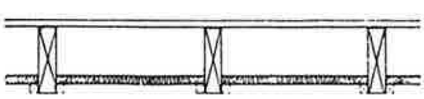

Fig 5 Insulation between joists

Table 3 Suspended floors directly above ground

Dimensions of floor	Basic thermal resistance (any floor structure) $R_{si}+R_a+R_e$	U-values: timber floors — Bare or with linoleum, plastics or rubber[1]	With carpet or cork[2]	With any surface finish and 25 mm quilt[3] (as Fig 4b)
metres	*m² °C/W*	*W/m² °C*	*W/m² °C*	*W/m² °C*
Very long × 30	5·35	0·18	0·18	0·16
× 15	2·82	0·33	0·33	0·26
× 7·5	1·67	0·53	0·52	0·37
150 × 60	7·13	0·14	0·14	0·12
× 30	4·58	0·21	0·21	0·18
60 × 60	5·90	0·16	0·16	0·14
× 30	4·02	0·24	0·23	0·20
× 15	2·54	0·37	0·36	0·28
30 × 30	3·42	0·28	0·27	0·22
× 15	2·34	0·39	0·38	0·30
× 7·5	1·55	0·57	0·55	0·39
15 × 15	2·03	0·45	0·44	0·33
× 7·5	1·44	0·61	0·59	0·40
7·5 × 7·5	1·27	0·68	0·65	0·43
3 × 3	0·75	1·05	0·99	0·56

(1) assuming $R_s = 0{\cdot}20$
(2) assuming $R_s = 0{\cdot}26$
(3) assuming $R_s = 0{\cdot}86$

Suspended ground floors

A suspended ground floor above an enclosed airspace is exposed to air on both sides but the air temperature below the floor is higher than the outside air temperature because the ventilation rate of the underfloor air space is very low.

Table 3 gives the basic thermal resistances of suspended ground floors excluding the resistance of the structure, which must be added in order to calculate the U-values. The figures in column 2 are the sums of the inside surface (ie the floor surface) resistance R_{si}, the resistance of an airspace R_a ventilated by 2000 mm² gaps per linear metre of boundary and the resistance of the earth R_e. To these basic resistances must be added the resistance of the proposed floor structure together with any added insulation R_s. The reciprocal of the sum of these resistances is the U-value.

The results of this calculation for timber floors, either bare or covered with a thin finish of low thermal resistance (R_s assumed to be 0·20), are given in column 3. U-values obtained with a covering of higher thermal resistance (R_s assumed to be 0·26) are given in column 4. U-values obtained with any surface finish and 25 mm quilt, as shown in Fig 4b (R_s assumed to be 0·86), are given in column 5.

Table 4 Standard thermal resistance of unventilated airspaces

Type of airspace — Thickness	Surface emissivity	Thermal resistance* m² °C/W
5 mm	High	0·10
	Low	0·18
25 mm or more	High	0·22
	Low	1·06

* Including internal boundary surface

Insulation Additional insulation of a suspended wooden ground floor is commonly provided either in the form of a continuous layer of semi-rigid or flexible material laid over the joists (Fig 4) or semi-rigid material between the joists (Fig 5). With concrete or hollow pot floors it will usually be more convenient to place the insulation above the structural floor.

The thermal resistance of boards or slabs laid over joists (Fig 4a) and of airspaces, or of overall insulation above the structural floor must be added to the basic resistance (column 2 of Table 3) and the resistance of the floor structure to calculate the U-value. Standard thermal resistances for airspaces are given in Table 4. Blankets and quilts laid over the joists will be effective only over their uncompressed area between the joists. This is unimportant, however, because the resistance of the joists compensates for the absence of insulation.

Vapour barriers The introduction of an insulating layer on the underside of the floor raises questions as to the incidence of condensation on the colder faces of the construction and, consequently, of the need for a vapour barrier. A vapour barrier could set up a dangerous situation in a wood floor in the event of the space within the floor collecting water either by spillage or by leakage from plumbing or heating installations. The water could not then escape by draining or evaporating to the airspace below the floor and evaporation through the flooring would be so slow that dangerous conditions conducive to fungal attack could persist for a long period. The designer usually has no control over future treatment of the floor, particularly as to the nature of any finish that may be laid later. An impervious or nearly impervious finish such as pvc, rubber or linoleum sheeting would give good protection against spillage but in the event of leakage within the thickness of the floor it would further aggravate the situation. The safest course is not to provide a vapour barrier to a floor that is constructed of or incorporates wood.

References

1 Journal IHVE Vol 19 (Nov 1951) pp 351–372

2 CIBS Guide Section A3, 1980. The Chartered Institution of Building Services, 222 Balham High Road, London SW12 9BS

3 BRS Digest 108: Standard U-values

Table 5 Thermal properties of some materials

Material	Density kg/m^3	Conductivity (k) $W/m°C$	Resistivity (1/k) $m°C/W$
Asbestos insulating board	750	0·12	8·3
Carpet		0·055	18·2
—wool felt underlay	160	0·045	22·2
—cellular rubber underlay	400	0·10	10·0
Concrete	2400	1·83	0·55
Cork flooring	540	0·085	11·8
Fibre insulating board	260	0·050	20·0
Glasswool quilt	25	0·04	25·0
Linoleum to BS 810	1150	0·22	4·6
Mineral wool			
—felted	50	0·039	25·6
	80	0·038	26·3
—semi-rigid felted mat	130	0·036	27·8
—loose, felted slab or mat	180	0·042	23·8
Plastics, cellular			
—phenolic foam board	30	0·038	26·3
	50	0·036	27·8
—polystyrene, expanded	15	0·037	27·0
	25	0·034	29·4
—polyurethane foam (aged)	30	0·026	38·5
PVC flooring / Rubber flooring		0·40	2·5
Wood			
—hardwood		0·15	6·7
—plywood		0·14	7·1
—softwood		0·13	7·7
Wood chipboard	800	0·15	6·7
Woodwool slab	500	0·085	11·8
	600	0·093	10·8

For a more comprehensive list, see CIBS 'Guide' (2)

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