

Straw as insulation material

Anisotropic behavior. The effect of anisotropic behavior is well known from timber. If thermal flux is perpendicular to the fiber, the conductivity (λ) of softwood is around 0.13 W/(mK). In the direction of the fiber, the conductivity is about 0.29 W/(mK). In the process of straw bale production, the straw stalks are pressed into bales with a certain orientation. A high proportion of the stalks are oriented perpendicular to the binding strings, which causes a similar effect to that reported for timber. In the case of 2-string bales (small bales 0.36 m high, 0.48 m width and 0.6 ... 1.2 m length of a density around 100 kg/m³), the rated thermal conductivity λ_R can be assumed as 0.052 W/(mK) where thermal flux is perpendicular to the direction of the stalks, and 0.080 W/(mK) in direction of the stalks.



Figure 1, left: thermal flux perpendicular to the direction of the stalks, $\lambda = 0.052$ W/(mK) © PHI. **Center:** Thermal flux in the direction of the stalks: 0.08 W/(mK) © PHI. **Right:** 2-string baler. © Welger.

Due to a different production process, the stalks are more homogeneously oriented in big bales, The density is also higher. Here a λ_R of 0.065 W/(mK) can be assumed. Simply measured values or non-rated values (λ , λ_D) should not be used in calculations as these values do not incorporate safety factors to take into account potentially higher moisture content or different temperatures. The European Technical Approval ETA-17/0247 for “Baustroh” of BauStroh GmbH, gives a rated thermal conductivity λ_R -of 0.049 W/(mK) for small bales of 100 +/- 15 kg/m³ density, with thermal flux perpendicular to the direction of the straw stalks (figure 1, left).

Best: Bales on edge or upright. Here, the thermal flux is perpendicular to the direction of the straw stalks, called ‘on edge’ or ‘upright’, see figure 2; the thickness of insulation is in this case 36 cm. Taking into account a wooden frame construction with 6 cm posts at 1 m centres, with clay plaster on the inside and lime plaster on the outside, the U-value of the wall will be 0.15 W/(m²K) at an overall thickness of 42 cm. With bales laid flat, resulting in 48 cm insulation thickness and 54 cm overall thickness

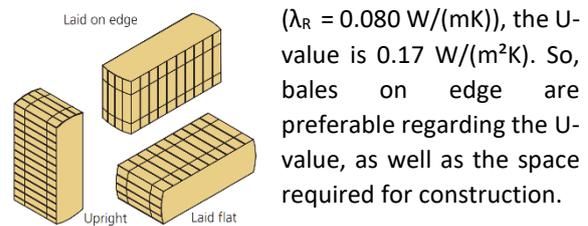


Figure 2: Bale orientation © PHI.

($\lambda_R = 0.080$ W/(mK)), the U-value is 0.17 W/(m²K). So, bales on edge are preferable regarding the U-value, as well as the space required for construction.

Checklist for straw bales. The following characteristics should be assessed for construction bales:

- Bound by plastic twine or wire, bindings should be tight
- Dense bale structure (100 +/-15 kg/m³), ends must be square
- Straw stalks should be mostly undamaged
- Golden yellow colour (not grey or black)
- No mouldy odour, Relative air humidity within the bale lower than 75% (mass-related humidity below 15%)

Blow-in insulation. Straw is also available as blow-in insulation. The ETA-18/0305 for the company “Sonnenklee” gives a $\lambda_D = 0.055$ W/(mK), resulting in a λ_R of approx. 0.057 W/(mK) at a density of between 105 and 140 kg/(m²). Taking into account a wooden frame construction with 6 cm posts at 62.5 cm centres, with OSB-board on the inside and 4 cm wood-fiber board on the outside, the use of 35 cm of blow-in insulation will achieve a U-value of 0.15 W/(m²K). This corresponds also to a wall-thickness of 42 cm.

Further notes: Both straw bales and straw blown-in insulation is an untreated organic material. Because of that, it is of highest importance that the construction is airtight in order to prevent warm and humid air from getting through gaps into the wall, where condensation followed by mould growth would occur. This can be achieved by covering the straw from the inside with plaster, OSB-boards or membranes, in combination with proper sealing of the junctions (see PHI recommendations for “airtight construction”). Furthermore, it is favourable to have a higher vapour resistance inside than outside. For exemplary straw bale building systems see

<https://database.passivehouse.com/en/components/>