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# Straw - renaissance for an old building material?

*Straw bales represent a very old building material which has been replaced over the ages by more "modern" materials such as bricks and concrete. In recent years the natural construction material straw with its advantageous characteristics has been rediscovered in Europe, helped by an increasing tendency towards sustainable building and its contribution towards environmental protection and good living and room climate which is of ever-increasing importance nowadays. However, the way towards a house of HD (= high density) straw bales is still hindered with many obstacles. A large number of investigations have begun towards the solving of these.*

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Straw bales have been used in house construction for more than 100 years, following the introduction of the first balers in North America. They offer a cost-effective construction, rediscovered under today's conditions and planning requirements. Based on cooperation with Zagazig University, Egypt the investigation of possible uses of excess straw from Egyptian agriculture in house construction developed, after contact with German straw house owners and architects, into an intensive information exchange. This led to the material and construction technique being intensely investigated under European conditions too. To be looked at here is straw bale construction as a total concept starting from clarification of the best sort of straw over optimum bale production for the best properties and material-based use and architecture.

Even if only 20% of straw production from a region such as Lüchow-Dannenberg (~28000 t) was used for this, 1500 detached houses could be built per year. Normally in this region an average 40 detached houses are built annually. Because of lack of information regarding fire protection and insulation properties, as well as reticence by the planning authorities, it is unfortunately currently only possible to receive building permission in individual cases.

Alongside knowledge of straw bale characteristics, information on the production of bales suitable for house construction is important. To be clarified also is the cereal sort required and the baling procedure. For investigating this complex first trials featured a modern HD baler (AP 730) lent by Lely-Welger. Winter barley and wheat straw was baled at different pressures for determining required machinery settings and the investigations proceeded with those bales.

### Heat conductivity capacity

The fibrous structure of straw bales gives low heat conductivity. Own investigations as well as results from other institutes indicate a good insulation value [1]. Despite moisture absorption of 20% for organic bales of differing density (80 to 140 kg/m$^3$) achieved ($\lambda_R$-values were 0.04 to 0.05 W/m•K). These values allow wall standards equal even to low energy housing standards. Results so far indicate that an increasing of density is associated with a reduction in heat conductivity and therefore improved insulation.


*Fig. 1: Medium range measuring (temperature and rel. humidity) in a straw bale wall (wood framing) in a house in Junkershausen*

### Fire properties

Burning properties of baled straw are mostly wrongly estimated. New Austrian investigations show that untreated straw bales (density from 90 to 150 kg/m$^3$) are to be classified under the fire class B2 (normal fire risk). Investigations with building elements (lime-plastered straw bale walls) showed these to be so fire resistant that they represented fire resistance class F 120 [1]. In these investigations, construction elements have to withstand a fully developed fire for a certain time - in this case 120 minutes - without the fire burning through to the other side of the element. This performance relies on the bale density. The same effect also occurred with timber, and here the fire was prevented from burning further through surface charring.

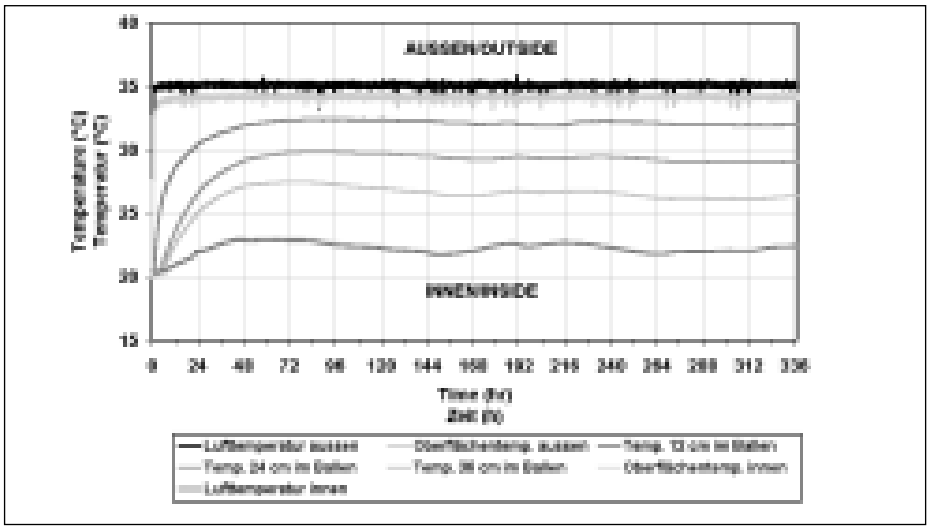


*Fig. 2: Temperature distribution inside the wall fmade of wheat straw (density: 110 kg/m³; thickness: 48 cm) under simulated Egyptian outside climate conditions (35 °C; 60 % rel. humidity).*

### Moisture performance

Because straw is an organic material its sensitivity to moisture has to be determined so that damaging fungus development can be avoided. For this, investigations were carried out on the original material straw as well as with bales (laboratory and climate chamber trials) as well as temperature and moisture properties being investigated in a partially completed straw house (*fig. 1*). Based on experiences so far with other organic insulation materials it was to be expected that here too, a very high air moisture content (>90%) in combination with higher temperature (>20°C) would first be required to contribute to a microbial attach [2, 3]. This should however be avoidable with appropriate protection measures such as avoidance of heatbridges.

### Climate chamber investigations

For determining the combined moisture-temperature relationships of straw bale walls under simulated conditions (at first Egyptian conditions were simulated; 35°C and 60% rel. air moisture; *fig. 2*), different samples were investigated in a dual-room climate chamber. Alongside the influence of different bale densities the direction of straw stalks was also involved, in that a vertical positioning of the bales is also possible. The results so far confirm the investigations on heat conductivity capacity. Increasing density improved insulation. And where vertical setting of the bales meant straw stalks were vertical to the heat flow direction this also increased insulation properties. The measured moisture absorption of the bales under these conditions was only small (~1 to 2%), even over a longer period of time (14 days).

### Mechanical properties

The mechanical properties of the bales used are important for the stability and rigidity of a wall made of straw bales. Straw bale buildings in general are constructed in two ways:

1. timber frame construction whereby the straw bales either fill out the timber frame as wall material (infill wall method) or the frames are introduced as enclosing walls (fig. 1), or
2. in a load bearing constructional method where the straw bale wall bears the weight of the roof.

The rigidity under load is important, especially for the second method. Investigations together with the Institute for Agricultural Machinery and Fluid Technology, TU Brunswick, showed that the density is an important parameter for this (*fig. 3*). High density from 130 to 140 kg/m³ showed a positive influence on the stability of the bales with less malformation (horizontal as well as vertical) and less loss of rigidity.

### Summary

Investigations of HD straw bales so far indicate that they are suitable for using as building material. The results must be further gone into and added to. It is practical for further use to use bales with high density (130 to 150 kg/m³) because these offer multiple advantages such as better insulation and mechanical properties, improved heat insulation capacity and sound proofing. Following the determination of the properties a straw bale used in building construction must have, a suitable production can be developed, a sort of standard bale. Alongside these investigations others, looking further into the associated architecture and statics as well as straw type, should be followed to ensure optimal application of the straw bales. All these investigations can also help to achieve a general planning permission for building with straw bales.

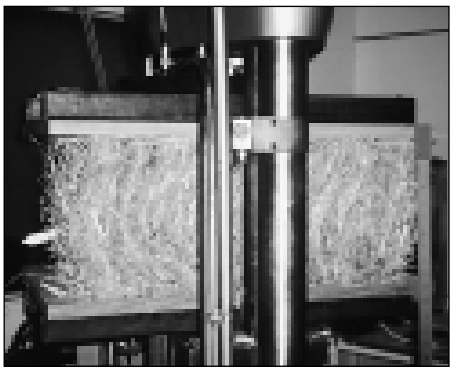

*Fig. 3: Investigations on the behaviour of straw-bales under pressure of the 40 t MAN test machine of the Institute for Agricultural Machinary and Fluid Technology*

## Literature

[1] *Wimmer, Robert, H. Hohensinner und L. Janisch*: Wandsysteme aus Nachwachsenden Rohstoffen. Wirtschaftsbezogene Grundlagenstudie im Auftrag des BMVIT, Wien, 2001

[2] *Murphy, D. P. L., F.-J. Bockisch und A. Schäfer-Menuhr* (Hrsg.): Möglichkeiten und Chancen von heimischen nachwachsenden Rohstoffen zur Nutzung als Dämm-Material. Landbauforschung Völkenrode, Sonderheft 203, (1999), ISBN 3-933140-25-0

[3] *Bockisch, F.-J., H. Wieland, W. Groth und D. P. L. Murphy*: Beurteilung der raumklimatischen Wirkungen von Dämmstoffen aus nachwachsenden Rohstoffen. Landbauforschung Völkenrode, Sonderheft 221, (2000) ISBN 3-933140-43-9