UNFIRED INDUSTRIAL LOAM BRICK BUILDINGS WITH PASSIVE HOUSE STANDARD

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Summary

The target of the Austrian research project LEHM.konkret was to develop a sustainable building solution that takes all three dimensions of sustainability into account. Besides environmental aspects such as the recyclability, energy efficiency in production and use phase of the building, aspects of social sustainability like health and comfort as well as the achievability of the building solution have been considered. By joining forces, partners of industry, science and building practice developed a solution for the Passive House Standard based on unfired, industrially produced and ecologically optimized loam bricks.

Within the research project, two building prototypes were realized with unfired loam bricks: two-storey family houses with the Passive House Standard. One of the challenging steps was to implement a sufficient load bearing use of the unfired loam bricks, which would allow a realization of passive houses with nearly 100 % unfired loam brick walls. The projects were completed in summer 2006. The evaluation results regarding the practicability of the scientific solutions were documented and first experiences of the house owners were collected.

The current challenge is the realization of building projects of a larger scale like the residential house “Orasteig” with 170 apartments, where parts of the project will be constructed with the newly developed building solution.

1 Introduction

The urgent demand for energy efficiency in the building sector is realized by a constantly growing group of stakeholders and policies. Consequently, this energy efficiency includes the improvement of the energy use during the production of the building products as well as the energy use of the building during its use phase. The Passive House Standard is one answer to this requirement regarding the energy efficiency of the building sector.

The traditional and natural building material, unfired loam, with its positive influence on health and comfort, as well as its ecological properties has been rediscovered by many stakeholders. Its excellent life cycle performance due to the low energy consumption during production also has a very positive influence on the life cycle assessment of the concerned building elements. The interest is increasing constantly. Unfortunately, loam constructions in general have been driven out of the industrial building sector and at the moment there are no building systems for industrial loam constructions available on the market. The market is restricted to some small providers of loam products, primarily loam plaster.

The main idea within the project LEHM.konkret was to combine the advantages of the passive house solution with the advantages of the traditional building material, unfired loam. The industrialized production of the traditional building material, unfired loam brick, served the purpose to provide the comfort and safety-guarantee of an industrially produced product.

Within the research project, an unfired and industrial produced loam brick was developed and improved to a satisfying level of quality.

Based on the performance of the newly developed unfired industrially produced loam brick, necessary construction details were developed in order to reach the Passive House Standard as well as consider the special properties of the unfired loam brick.

The most important step was the demonstration of the research results within two building projects. The realization of two building prototypes offered an excellent opportunity to evaluate the practicability of the newly developed construction details and building solutions. The results of the two projects partly confirmed the theoretically developed solutions but also answered some open questions.

2 The Research Project

2.1 Previous Scientific Steps before Realization of the Pilot Building Projects

In order to reach the final target of the research project several new technical solutions had to be found; starting with the optimized performance of the unfired loam brick, and ending with the solutions for the execution procedures and the construction details for the building.

2.1.1 Optimization of the Building Product "Unfired Industrial Loam Brick"

The first step was the improvement of the unfired, industrially produced loam brick that can be used for load bearing masonry in two storey houses, under consideration of some static parameters. Based on an analysis of a conventional unfired loam brick, the main target here was the revision of the material mixture, the brick geometries and the format. The development has been executed with focus on the advanced development of the following properties:

- Compressive strength
- Bending tensile strength
- Thermal capability
- Sound insulation
- Drying properties
- Processing performance
- Ecology, health and hygiene of material mixture

Figure 1: Several tests regarding the strength properties of the unfired loam brick walls have been done

2.1.2 Solutions for Building Execution, Construction Details

Essential for a successful execution of unfired loam constructions is the durable protection against water and intense, long-term moisture during the construction and the use of the building. Different parts of the unfired loam brick walls need a particular treatment during the execution. The research focused on simple solutions that are achievable, effective and allow an efficient integration within the framework of a construction site's conventional operation routine.

The limits, special properties and necessities of the unfired loam brick, which have to be considered, were identified by test results. Of course, the requirements for Passive House Standard, including air tightness, heavy windows and doors, as well as excellent heat insulation and particular HVAC equipment were taken into consideration by the project group. The most challenging and important part of the research activities was the creation of construction details that met, and are meeting the requirements for Passive House Standard under consideration of the limits and special necessities of the unfired loam bricks.

As the intention was to construct buildings with an excellent performance regarding health and comfort, another research target was to define wall systems and indoor materials which respond to the high level of the purely natural building, material unfired loam.

2.1.3 Static Calculations

In its current evolution the unfired loam brick does not have the same strength as fired brick. With static calculations, the limits and possibilities of the load-bearing, unfired loam brick walls were appointed. Recommendations for the building structure have been set and considered during the planning and realization of the pilot building projects.

3 The Pilot Building Projects

3.1 Function and Basic Data of the Pilot Building Projects

The following two pilot building projects that have been realized within the research project are:

3.1.1 Detached Family Home

The two storey house with 118,79 m² living space and 13 kWh/(m²a) was realized with 20 cm load bearing, unfired loam brick walls, 30 cm of mineral wool for the outer walls and 12 cm inner walls of unfired loam bricks. The outer walls have a U value of 0,12 W/m²K.

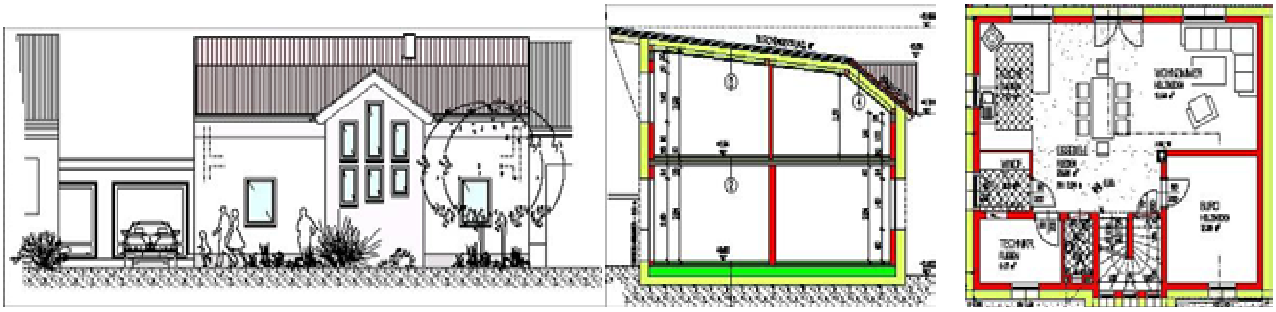

Figure 2: Construction plans for the detached family home. All red marked walls are unfired loam brick walls.

3.1.2 Organic Farm with Integrated Guest Rooms

The house for a farmer and his family with a 290 m² living space is also divided into two stories. The family wanted to provide guests with the opportunity to experience the excellent indoor air quality in rooms which are built only with natural building products. For this reason, two additional guest rooms available for renting are integrated into the project.

4 Construction and Experience

Within both projects many different trial experiences have been collected. In the following section the main conclusions are summarized.

4.1 Protection against Water and Long-Term Moisture

Currently, the unfired loam bricks do not have the same water resistance as fired bricks. They must receive a durable protection against water and long-term moisture during the construction as well as use phase of the building. The unfired bricks were delivered on conventional palettes, which were properly covered to avoid water inside the packages.

4.1.1 The Basis / First layers

During the construction period, the floors can become flooded by melting snow or rain. During the use phase of the building the flooding can occur due to an overflowing bath tub or faulty washing machine. Any contact between the base of the unfired loam brick walls and water on the indoor floors has to be avoided. To guarantee the protection of the wall base, the first one to two layers of the walls have been constructed with fired (water resistant) bricks. Furthermore, the water was lead off in a controlled way, which was ensured within the slope in the floors and water pipes at the lowest point.

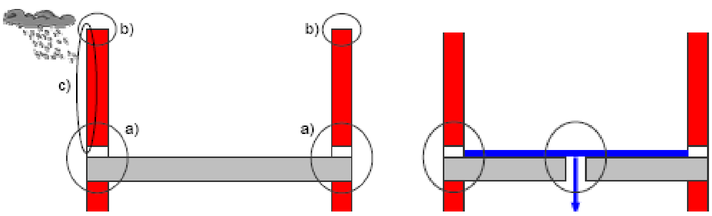

Figure 3: Certain parts of the unfired loam brick walls need durable protection against water and long-term moisture during the construction as well as use phase of the building.

4.1.2 The Top / Final Layer

As the unfired loam bricks have a perforation for technical reasons, it is important to make sure that no rain or snow gets inside the perforation during the construction of the walls. For this reason, during the construction phase, the top layers were covered with a waterproof material that was easily removable.

The supports of the concrete floors got a waterproof leveling course (bituminized felt on a leveling concrete course) which prevents great amounts of water, affected by the concrete flooring, inside the perforation of the top layers.

During the construction phase of the walls, the layer for the sills was covered.

4.1.3 The Wall Surface

During a long lasting rain period, the side of the unfired loam brick walls that were most affected by weather was protected with a waterproof cover. Limited contact of the wall surface with water by rain- or snowfall during the construction period or by water splashed by the user during any other time does not have any significant negative influence on the walls.

4.1.4 Inside the Walls

For the wall parts with water pipes inside, it is recommended to construct those areas with fired bricks or to furnish them with a waterproof sealing coat.



Figure 4: The first two layers were constructed with fired loam bricks. The last layer under the sills and top layers of the walls have been covered with a waterproof material to prevent water inside the brick perforation.

4.2 Attachment of Heavy Doors and Windows with Passive House Standard

The windows and doors with Passive House Standard usually are heavier than conventional windows and doors. An airtight fixing of those kinds of windows and doors was achieved by a leveling concrete course around the wall opening. The heavy windows and doors were only fixed at the fired lintel element (top) and at the concreted sill (bottom). The bearing length of the lintels always had a minimum length of 25 cm inside the wall. The side parts only have been attached with spacer screws (7,5 x 152 mm, each 80 cm). One third of the window frame was positioned to the inside part the insulation level.

Tests with a certain glue and insulation foil confirmed that the insulation foil for airtight connections has the same adhesion quality on unfired loam bricks as on conventional fired bricks.



Figure 5: Fired lintel element, leveling concrete course around wall opening and airtight connection of windows and doors for Passive House Standard.

4.3 Static Strengths and Limits

The specific properties of the unfired loam brick wall regarding strength (f_k = 2,0 N/mm²) and mechanical resistance require for some considerations during the planning and construction phase of the building. For both pilot projects, static calculations have been done to appoint the peak loads and to guarantee the structural resistance of the buildings.

4.3.1 Point Loads

In general, point loads should be avoided. If this is not possible, additional support for point loads could be, for example, integrated columns inside the unfired loam bricks.

4.3.2 Support of Ceilings

Experience regarding peak loads in ceiling supports showed that the particular ceiling, constructed from prefabricated element, affects a high linear distributed load on the inner side of the top brick layer. An optimized load distribution was reached due to a levelling course of concrete on top of walls, which provides an even surface and a solid connection between walls and ceiling. Ecological concrete solutions are already possible with new concrete products without cement. The consideration of the maximum span between the load bearing walls is very important.

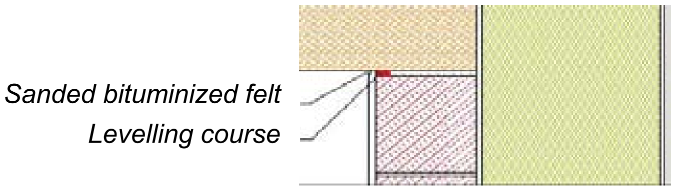

Figure 6: Optimized distribution of the high linear distributed load, affected by the ceiling.

4.3.3 Installation Lines in the Walls

Regarding electrical installations and other works on the wall, horizontal electrical installation lines have been avoided. Exceptions have a maximum depth of 10 % of the wall thickness. Water pipes are mainly led into the floor.

Figure 7: Water pipes are mainly led into the floor. Installation lines in the unfired loam brick walls are not a problem.

4.4 Indoor Air Quality

The inner surface of the walls has the highest influence on the indoor air quality and thereby on the health and comfort of the inhabitants. To make sure that the positive influence of the unfired loam brick walls on the indoor air quality is continued with a plaster material that has the same properties, loam plaster was used for the inner sides of the walls.

It is recommended to do the plasterwork during the months where there is a minimum of 5 °C outside temperature to guarantee conditions for fast drying of the loam plaster. Due to a very tight time schedule on one of the building projects the plasterwork of the family house was done during winter time. Resulting from the low temperature on the outer walls as a result of the very low temperature outside and the air tightness of the building, the ventilation system was used during the drying process to avoid cracks in the loam plaster. When the drying process was finished, and before the inhabitants moved into the house, the filter of the ventilation system was changed.

Figure 8: The loam plaster was executed with two layers and a reinforcement fleece in the first layer to ensure a good adhesion on fired as well as unfired loam bricks. The sorption capacity of the loam has a positive influence on the humidity of the rooms.

4.5 User Experience

Figure 9: Regarding operation costs, indoor temperature, indoor air humidity, the feed-back of the house owners was very positive. A challenging experience was to affix heavy weight onto the walls.

4.5.1 Operation Costs

In general the feedback of the house owners was very positive. The energy consumption responds to the expectations on a Passive House Standard (€ 200, - per year for heating and warm water). During the winter period the house owners of the detached family home had a usage of 15 kg of wood-pellets per week.

4.5.2 Indoor Temperature

The buildings are cold during the summer and warm during the winter season. During the first year the detached family home had no window coverings as protection against the sun. Even considering this circumstance, a slow increase in indoor-temperature was realizable, which started with an outside-temperature of 29 °C.

4.5.3 Indoor air humidity

Regarding the balance of the indoor air humidity, the inhabitants confirmed an observation, which is mentioned very often in connection with unfired loam constructions: due to the excellent sorption ability of the unfired loam, the mirror in the bathroom does not steam up, even after a long hot shower.

The inhabitants also made an interesting observation during winter: the influence of the sorption capacity and, by this, the balance of the indoor air humidity is, of course, limited by available humidity in general, inside or around the building. During the cold season, outside air becomes very dry, having a big impact also on the quality of the indoor air. Another very desirable aspect of the unfired loam is that it can keep a balance in terms of indoor-air humidity, which is providing a very pleasant indoor climate. But of course the unfired loam cannot "create" humidity when there is no moisture available.

4.5.4 Resistance of walls

Up until now, nearly two years after the finalization of the building projects, no cracks have been found in the unfired loam brick walls.

One criticism was the low resistance regarding dowel extraction. This problem was solved with injection dowels at certain spots bearing high loads on the walls. Lower loads were hung using long screws.

5 Current Challenge

Within the next months a large residential project incorporating 170 apartments will be built in Vienna. The cost efficient and government subsidised project won first place in the housing competition and foresees a big variability in floor plans and sizes. Within the project, sustainability in construction works goes hand in hand with high level architectural urban planning.

The building demonstrates excellent technical and ecological performance with an advanced energy standard, and the use of ecological building materials like, for example, unfired loam bricks. The upper two of the four stories will be constructed with unfired loam brick walls. Several feasibility studies have been conducted, and a static calculation has approved the intention.

Figure 10: The results of the research project LEHM.konkret and the experiences due to the pilot building projects will be important for the realization of a large-scale project like "Orasteig" with its requirements regarding the operation routine.

6 Conclusion

The traditional building material, unfired loam, in combination with the well developed and highly sophisticated technology of the Passive House Standard, provides a perfect example for sustainability in construction works.

The unfired loam shows an excellent performance regarding:

- Minimised CO2-emission and minimised emissions of SOx, NOx, OrgC, HF
- Low energy consumption in production
- Recyclability
- Thermal capability due to high mass
- Acoustic protection due to high mass
- Indoor air quality by humidity sorption
- Protection against electromagnetic fields
- Fire safety

During the execution of the walls with unfired loam bricks, the main experiences have been that the processing is very similar to fired bricks. For this reason the efficient training of building labourers is no problem at all. A fast execution was realised with a mortar carriage and the tongue and groove system was experienced as very practicable due to the similarity with conventional brick constructions.

In general, the current result is very satisfying, but for the successful planning and execution of an unfired loam brick building with Passive House Standard, the consideration of certain requirements are needed.

Each unfired loam material mixture has a different properties; some have necessary properties for being a construction material, others not. Nevertheless, there is still a real need for further research activities, especially regarding the compressive strength and the water resistance of the unfired loam brick. Due to the special sorption ability, the air humidity has a very big influence on the strength performance of the unfired loam brick. Also the significant shrinking and swelling of certain loam material mixtures has to be reduced. An improvement regarding those properties is absolutely necessary, and potential for improvement is foreseen.

Standardisation criteria still do not exist apart from some German recommendations of the last century. A harmonised standard will be important for the marketability of this building system.

Also specific training tools for architects and labourers would be very important to maximise the marketability of the building solution.

7 References

Adamson 1987 and Feist 1988; Definition "Passive House Standard" by Passive House Institute, University Darmstadt; *www.passiv.de.*

Kunze and Waltjen 2006; "LEHM.konkret final report"; published by Green Building Cluster, ecoplus GmbH; Landhausboulevard 29-30, 3109 St. Pölten.

Green Building Cluster, ecoplus GmbH; initiator of the project LEHM.konkret, project management and quality control.

Wienerberger Ziegelindustrie GmbH, BauConsulting, Mag. Arch. Andreas Lang GmbH, Haus der Baubiologie BM, Heribert Hegedys, natur&lehm, Lehmbaustoffe GmbH, Österreichisches Institut für Baubiologie und –ökologie GmbH; project partners of the project LEHM.konkret.

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Macho Karl Bmst.Ing., AUST-BAU GmbH; construction plans for pilot building projects, construction supervision and execution of construction work.

Raum und Kommunikation; project management and project developer of "Orasteig".