LOAM CONSTRUCTION – FROM A NICHE PRODUCT TO AN INDUSTRIAL BUILDING SYSTEM

Gerhard KOCH Dipl.-Ing.[1]
Christine KUNZE Dipl.-Ing.[2]
Josef SEIDL [3]

[1] Verband Österreichischer Ziegelwerke, Wienerbergstraße 11, A-1100 Wien, Austria, koch@ziegel.at
[2] Lower Austria's Green Building Cluster Landhausboulevard 29-30, Haus 5, A-3109 St. Pölten, Austria, c.kunze@ecoplus.at
[3] Lower Austria's Green Building Cluster, Landhausboulevard 29-30, Haus 5, A-3109 St. Pölten, Austria, j.seidl@ecoplus.at

Keywords: loam, adobe, clay, brick, total quality, eco-balance

Summary

Loam construction has an old tradition – in many ancient cultures impressive examples of loam architecture were built; some of them still exist today. It is only in the recent past – approx. since World War II – that loam construction has been driven out of the industrial building sector. Today it is only very seldom used in Europe as a niche product in the handicraft sector.

The old building material loam, its ecological and healthy properties, especially the improved living quality, is re-discovered by many architects and house builders, the demand is increasing steadily. Unfortunately there are no industrial building systems for loam construction available on the market at the moment. The market is restricted to some small providers of loam products, primarily loam plaster.

WIENERBERGER AG, the world market leader in bricks, has now reacted to this development and has initiated a research project together with Lower Austria's Green Building Cluster and other partners from industry, science and building practice, which has the target to develop an industrial building system on the basis of unfired clay blocks to reach a highest possible level of sustainability.

1. History of loam construction

Loam construction (in some parts of the world also called adobe construction, especially when unfired clay bricks or blocks are used) is probably the oldest technology in the world to build houses. Today approximately 1.5 billion people (more than one third of the world's population) live in loam houses. Already in the antiquity, the material loam was widely used in Mesopotamia and the Egypt of the pharaohs. In Europe, in Africa and in the Middle East the Romans and later on the Muslims built with loam. In Asia it was used by the Indian people, the Buddhist monks or the Chinese emperors, in America it was widely used by the Indians in the Southern parts of North America, in Middle America and in the South American mountains. After the invasion of the Spaniards in South and Middle America, the old European traditions and techniques of loam construction were mixed with the local adobe tradition. When Francisco Vasquez de Coronado entered northern New Mexico in 1540, he encountered over 100 occupied villages, mostly located along the Rio Grande River. Called pueblos (the Spanish word for villages) by the conquistadors, these communities consisted primarily of flat-roofed, apartment-like dwellings, with numerous rooms and multiple stories, most of them built in adobe construction. Many of the cities which were founded in the period of the Spanish conquest in America still demonstrate the use of loam/adobe construction today, like e.g. Santa Fe, the capitol of New Mexico. Also the mighty people knew very well about the many advantages of loam as building material from the antiquity until modern times. Therefore many famous buildings exist, which were constructed with loam: e.g. the palace of king Minos of Crete (2000 BC), the palace of pharaoh Amenophis III in Achet-Aton near Theben (1400 BC), the palace in Raqchi in Peru, the Bedi-palace in Marrakech (1578), the residence of the Dalai-Lama in Tibet or the palace of the governor in Santa Fe (1609). Even the biggest building on earth – the Chinese wall built in the third century BC – was in main parts built with loam. The most famous loam building of all is the tower of Babylon, constructed in the seventh century BC, which reached a height of 90 meters. Even in Central Europe with its sometimes wet and cold climate, loam construction was widely used in history. Besides the century old examples in France, Germany or in Southern Europe – mainly in rural areas, it is especially interesting that most residential buildings in the former German Democratic Republic in the first decade after World War II were built with loam.

There are more than twenty traditional technologies on earth for the use of loam for construction purposes. But nevertheless there are only two main technologies: to use stamped earth/clay/loam ("pise de terre" in French, a wording created in Lyon in the 16^{th} century) or the use of unfired clay/loam bricks called "adobe". The term adobe generally refers to all structures made of unfired earth, usually built with cast, sun-dried bricks made from a mixture of mud and straw. The history of the word traces the development of adobe architecture through time and around the world. The Egyptian hieroglyph tob, the Arabic word at-tub (or attuba), and the Coptic word tobe all mean "brick." From Egypt the term entered the language of the Arabs and then the Spanish, moved from North Africa to Spain to Latin America, and finally to the Southwest United States.

Figure 1 Examples of historical loam/adobe construction

Although loam construction has such a long tradition and a wide spread around the world, there are today (as also already in history) many prejudices against this building method. It was often said that the buildings constructed with loam are not resistant, old-fashioned or technically not sophisticated enough. Especially in the last fifty years, this building method has lost its importance in the industrialized countries. It is only very recently, that architects and ecologically motivated house-builders have re-discovered this traditional technology and are demanding for it on the construction market. Unfortunately there are no industrial building systems available on the market at the moment. The market is restricted to some small providers of loam products, primarily loam plaster. WIENERBERGER AG, the world market leader in clay bricks and blocks, has now reacted to this development and has initiated a research project together with Lower Austria's Green Building Cluster (an ecological non-profit organisation in Austria) and other partners from industry, science and building practice, which has the target to develop an industrial building system on the basis of unfired clay blocks to reach a highest possible level of sustainability with the following main benefits:

- minimum use of fossil fuels,
- minimum CO_2-emission – this is also economically very interesting, because CO_2 emissions are an important cost factor in the production of building materials today (e.g. EU ETS),
- minimum emissions of SO_x, NO_x, OrgC, HF,
- optimum indoor climate through high mass and high absorption,
- full recycling.

The project started in summer 2004 and will be finished within two years. First results are now available.

2. Description of the research project

The research project is structured in four phases:

1. Improvement of unfired clay bricks
2. Building execution
3. Construction of prototypes
4. Networking and dissemination

2.1 Improvement of unfired clay blocks

In the past clay mixtures and brick/block geometries were developed under consideration of the firing process, unfired clay blocks open new possibilities. It is the aim of the research to develop new formats, geometries, clay mixtures, which shall provide better structural and physical performance, like e. g. edge strength, abrasion resistance, bending tensile strength, mechanical resistance and swelling and shrinking behaviour. Starting point of the development was the performance of blocks, which are normally fired and which were simply taken out from the production process before the firing. In an average dry state these blocks already reached compressive strength values of approx. 8 N/mm^2.

2.1.1 Composition of the raw material

So far, different additives were checked concerning their influence on the mechanical performance (compressive strength and bending tensile strength) of the clay material in a series of tests. The following additives were considered:

- straw (0,5-2 cm),
- sodium silicate (water glass),
- special water glass,
- wood ash,
- tennis sand (ground fired clay, 0-2 mm)

and also combinations of these materials.

Loam from the clay pit of the Wienerberger factory in Hennersdorf in Austria was mixed with approx. 10% water in a stirrer. Then the different additives were intermixed in various percentages. For the mechanical tests 4 x 4 x 16 cm prisms were produced. The test samples were dried in a conditioning chamber at 40°C and 50% relative humidity. The test samples were then tested at the Technical University in Vienna, Institute for Building Materials. 3 test samples were produced for each mixture. With these 3 samples bending tensile strength tests were carried out. Afterwards compressive strength tests were done on the resulting 6 test samples. Tests were carried out in dry state and in moist condition (conditioning at 40°C and 80% relative humidity). Altogether 73 test series were made with 219 test samples.

The results are as follows:

Compressive strength – dry condition: an improvement of the compressive strength in dry state compared with the reference sample (without any additives) could be reached with the addition of wood ash (3,5%) or tennis sand (17,5%). The increase is 6,0% from 6,6 N/mm^2 to 7,0 N/mm^2. The combination of different additives brought partially great deteriorations of compressive strength up to minus 25% compared with the reference sample.

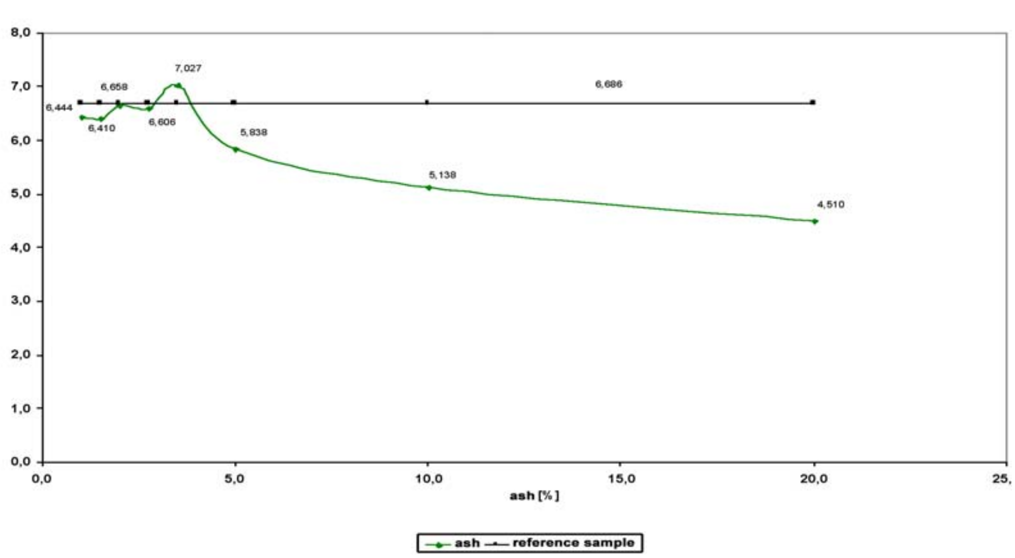

Figure 2 Example: influence of wood ash as additive on the compressive strength of the loam

Compressive strength – moist condition: in general the compressive strength is significantly lower in moist state. The compressive strength of the reference sample dropped down from 6,6 N/mm² to 4,8 N/mm², which is a loss of minus 27,3%. The addition of tennis sand or a mixture of tennis and wood ash has a positive effect in moist state. With 20% tennis sand a compressive strength of 5,6 N/mm² is reached, which is an increase of 16,7% compared with the moist reference sample.

Bending tensile strength – dry condition: the bending tensile strength could be increased by 4,7% compared with the reference sample through the addition of ash (2,75%). All other additives or mixtures lead to partially significant reductions (e.g. minus 61,6% in case of water glass).

Bending tensile strength – moist condition: in contrary to the dry state, the addition of ash and tennis sand lead to a significant increase compared to the reference sample in moist state. The addition of 20% tennis sand brought an increase of 39,9%, 1,5% wood ash brought 29,5% increase compared with the reference sample. On the other hand the mixture of ash and tennis sand resulted in a deterioration of 2,5%.

Further additive materials will be tested in near future and attention will also be given to other properties of the unfired clay blocks, like e.g. the edge strength, abrasion resistance and swelling and shrinking behaviour.

2.1.2 Shape of the unfired clay blocks

On the basis of existing (fired) clay blocks a new shape for an unfired block was developed. The criteria for the new shape were: optimum mechanical resistance, optimum weight, sufficient voids for economically sensible drying, and thick external shells for optimum thermal capacity. It was decided to use a tongue and groove system in the vertical joints.

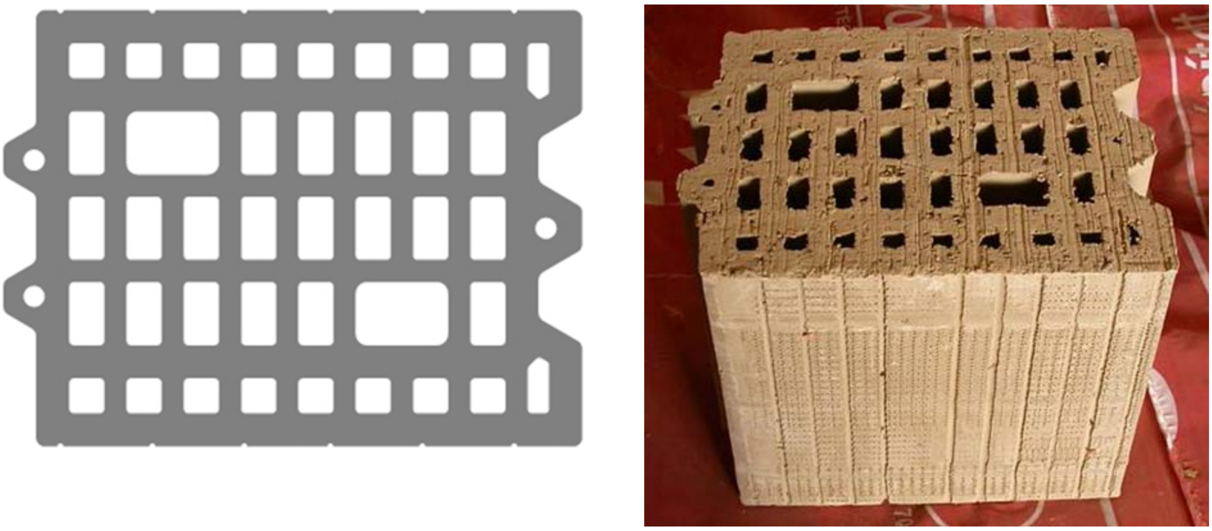

Figure 3 Shape of the newly developed unfired clay block

At the moment, compressive strength tests on wall samples produced with the new unfired clay blocks are carried out with different kinds of mortars. First results show very good masonry compressive strength values, which are in line with calculation results according to the European design code EN 1996-1-1 (Eurocode 6). The best results are achieved with a special loam mortar.

2.2 Building execution

It is also aim of the project to work out recommendations for execution and construction details of load-bearing inner and outer walls. A central requirement in loam construction is a durable protection against moisture during construction and in use. This concerns e. g. the ground course or supports of concrete floors. For safety reasons it is recommended that the ground course of a load-bearing wall made of unfired clay blocks is always made with fired clay blocks. The development of new fixing systems and prefabricated insulation systems for the use of e.g. straw, cellulose and similar insulation materials to reach passive-house standard (U-values between 0,1 and 0,15 W/m²K) are also parts of the project. A first version of the execution guidelines and construction details will be available in April 2005.

2.3 Construction of prototypes

It is part of the project to produce prototypes, both a multi-storey residential building and a one-family house. They will be realised in the second project phase using the new loam products and applying the construction details and execution guidelines. A first demonstration project has already been finished, although in this case the unfired clay blocks were only used for non-load-bearing inner walls. In this ecological office building “SOL4” in Mödling in Austria the unfired clay blocks were used as facing brickwork, without any render.

Figure 4 Demonstration project “SOL4” in Mödling/Austria (Photo: Thomas Kirschner)

In Schlins in the most western part of Austria, the multi-storey demonstration project will start soon. The project has 12 apartments on 3 floors, the external load-bearing walls are constructed with the new unfired clay block and have an external cork insulation. The building has passive-house standard with a heating energy requirement of 9,7 kWh/m^2a.

Figure 5 Demonstration project “Sonnenquartier Schlins” in Schlins/Austria

For both projects – “SOL4” in Mödling and “Sonnenquartier Schlins” – a Total Quality (TQ) certification will be made. Total Quality is the national Austrian application of the international GBC assessment framework and takes into account 51 different quality criteria.

2.4 Networking and dissemination

The research results and experiences from the prototypes will be disseminated in workshops, events, excursions, fares and conferences. By that, the building material loam will be made available to customers as a certified, tested industrial system with guaranteed quality. Starting from March 2005 a website will be online with the domain name “lehm-bau.at”, where the progress of the research project as well as the progress of the demonstration projects will be shown. A webcam and an online diary will document the demonstration project in Schlins.

3. Eco-balance of unfired clay blocks

The probably most important argument for the use of unfired clay blocks is their very good ecological performance. To proof this fact on a scientific basis, an eco-balance was calculated for the new block type. Basis for the calculation was an eco-balance for fired clay bricks and blocks, which was worked out by Prof. Manfred Bruck in Vienna on the order of the three associations of the clay brick industry in Germany, Austria and Switzerland (D-A-CH) in 1996. This eco-balance was updated in 2004 using the energy consumption data for the factory in Hennersdorf from the emission trading scheme. The eco-balance for the unfired clay blocks was calculated in two variations:

- the heat for drying of the blocks is provided through a gas firing,
- the heat for drying is excess heat from the kiln (which is used for firing bricks) – this variation also applies if the blocks are air dried.

For the ecological evaluation the following criteria were taken into account:

- KEA - cumulated energy (Wh/kg product)
- GWP – Global Warming potential (g CO_2-equ./kg product)
- UBP – “eco-points”
- Ecoindicator 95/99 (Acidification + Nutrification, Ozone depletion, Respiratory effects).

The results of the calculations demonstrate the exceptionally positive performance of unfired clay blocks. The values are of course even better, when the energy for drying is not taken into account, but they are already very good – in comparison with other building materials – if the drying energy is provided by gas firing. The use of excess heat from a tunnel kiln for firing bricks proofs to be very efficient. Therefore a technical solution of a combined factory for both fired and unfired clay blocks seems to be economically and ecologically very sensible.

Table 1 KEA – cumulated energy

Primary energy [Wh/kg product]	Fired clay blocks	Unfired clay blocks (Var. 1: gas)	Unfired clay blocks (Var. 2: excess heat)
Primary energy (total)	624,7 (100%)	380,9 (60,97%)	168,3 (26,94%)
Primary energy (non renewable)	573,3 (91,77%)	330,1 (52,84%)	118,1 (18,91%)
Primary energy (renewable)	51,4 (8,23%)	50,8 (8,12%)	50,2 (8,04%)

Table 2 UBP – eco-points

UBP (eco-points) [points/kg product]	Fired clay blocks	Unfired clay blocks (Var. 1: gas)	Unfired clay blocks (Var. 2: excess heat)
	49,97	35,43	22,75

Table 3 GWP – Global Warming Potential

GWP (Global Warming Potential) [g CO_2-equ./kg product]	Fired clay blocks	Unfired clay blocks (Var. 1: gas)	Unfired clay blocks (Var. 2: excess heat)
	110	64	24

References

Dethier, J. 1982, Der Genius der Erde. In: Lehmarchitektur – die Zukunft einer vergessenen Bautradition.

Trojan. M. 2005, Master Thesis Lehmbauziegel.

Bruck, M. 2004, Ökobilanz Lehmziegel.