STANDARDIZATION OF A SUSTAINABLE AND ECO-EFFICIENT BUILDING MATERIAL: EARTH – A GERMAN PERSPECTIVE

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Summary

In Germany earthen materials are once again increasingly being used from the mid eighties of the last century as an eco-friendly and sustainable building material. Since then the market for earth is constantly expanding. One disadvantage for marketing these products is their inferior regulatory status as an approved material. Though, in Germany earthen materials are regulated by an acknowledged national guideline but actual products standards do still not exist. This situation was the motivation to initiate a project for the standardization of industrially produced earthen building products (StandardLehm), which is funded by our Federal Ministry of Economics and Technology (BMWi). A consortium consisting of a research institute (BAM), a medium sized enterprise (Claytec e.K.) and an associated partner in form of our National Association for Building with Earth (Dachverband Lehm e.V.) are currently developing strategies for standardizing earthen building products concerning test methods, material characteristics and requirements, quality control and declaration procedures as well as sustainability issues (CO_2 equivalent).

Keywords: Earthen materials, standardization, sustainability, quality control

1 Introduction

In Germany earthen building products have been increasingly used for indoor and outdoor construction purposes for the last 25 years. This is partly due to their outstanding climatic properties as well as their very low primary energy consumption during production and application, which predestines this material for eco-friendly housing projects. What began with hand crafted earthen products with small production numbers and only made for friends and interested enthusiasts some 30 years ago developed into an own SME dominated sector of industrially produced earthen construction materials (**Fig. 1**). Over the years this sector is expanding and production numbers increased constantly not only for the domestic market but increasingly also for export.

Fig. 1 Examples for industrially produced earthen building products

Despite the success in marketing these types of products development in this sector is, compared to other building products, impaired due to the fact that the regulation of earthen materials is still on a basic level. At the moment, in Germany there is one guideline (Lehmbau Regeln) [1] for the regulation of earthen building materials, which is officially approved and legally acknowledged by our authority for the approval of building products (Deutsches Institut für Bautechnik, DIBt). This guideline describes rules for the application of earthen materials, includes also industrial products and is mostly intended for the planning engineer, architect and the building contractor. Not included in this guideline is information for producers in how to control the quality of their ongoing production or test procedures and threshold values for independent testing institutes. But exactly this information was demanded by the DIBt on a long term in form of product standards for earthen building materials.

This was the motivation to initiate the project ***StandardLehm*** with the topics of the development of testing procedures and quality control strategies, as well as sustainability aspects with life cycle analysis and the formulation of declaration procedures. The results are going to be used for the design of pre-normative guidelines as basis for the future standardization process. The project partners consist of an SME (Claytec e.K.) producing earthen construction materials, a materials research institute (BAM) and the national association for building in earth (Dachverband Lehm e.V., DVL) as associated partner. The consortium is in close contact with national authorities (DIBt, BMWi) and our institute for standardization (DIN).

2 Types of earthen building products

At first glance earthen building products are often seen as inferior to other materials such as concrete, steel, brick or other materials. This perception is mostly based on two facts inherent with earth: its considerably low strength and its susceptibility against liquid water. Against these seemingly disadvantages stand good indoor climatic properties, versatility, availability and the low primary energy consumption during the entire life cycle of earthen building products.

Within the project ***StandardLehm*** not all of the industrially produced building products on the market are dealt with since the scope would have been too broad for

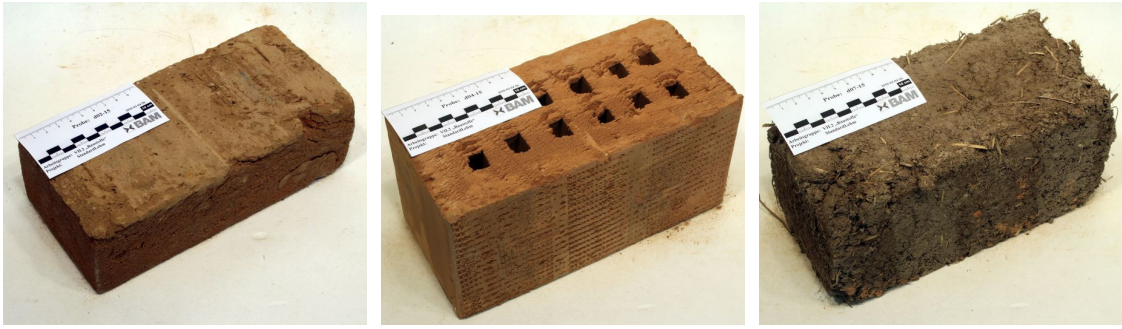

Fig. 2 Three examples for industrially produced earth blocks: Uncompressed normal format block (left), double format perforated block (middle), compressed low density block (right)

a three year project. Nevertheless, the project made possible the initial steps of the standardization process of four groups of materials which are listed in **Table 1**.

Tab. 1 Earthen building materials investigated in StandardLehm

Material	Description	Topics addressed
Soil	Earth as a raw material suitable for industrial building products	Selection of test methods suitable for quality control
Earth blocks	Block shaped building product with clay as an only binder	Testing methods, declaration, life cycle analysis, quality control, national pre-standards
Masonry mortars	Mortar consisting of earth with clay as an only binder	
Plasters	Plaster consisting of earth with clay as an only binder	

The products in **Table 1** are not stabilized. That means earthen products amended by cement, lime, synthetic (e.g. acrylic) or natural (e.g. bituminous) polymers are not the subject of the standardization because of the lack of experience concerning material properties and safety in application and utilization. This was reason for hotly debates but in the end also in agreement with our legal bodies. The materials investigated were commercial products from several German producers. Earth mortars and plasters were ready mixed materials including fiber reinforcement in some of the plasters. Earth blocks (**Fig. 2**) were made with different techniques consisting of uncompressed, compressed and extruded blocks. In the latter technique all perforated earth blocks were manufactured. Soil itself is not an end user product but rather the starting material for the producers. But nevertheless it was included into the program since some of the requirements of the end products are defined by specific properties of the soil.

3 Standardization process

3.1 Testing procedures and quality control

There are already many testing procedures for earthen materials used all over the world. However, for the product standards, only those were considered dealing with the properties of the end product, with the exception of the few methods for testing the quality of soil. Many of the test methods were adapted from standards of other building materials. For earth mortars and plasters test procedures for cement, lime and gypsum mortars and

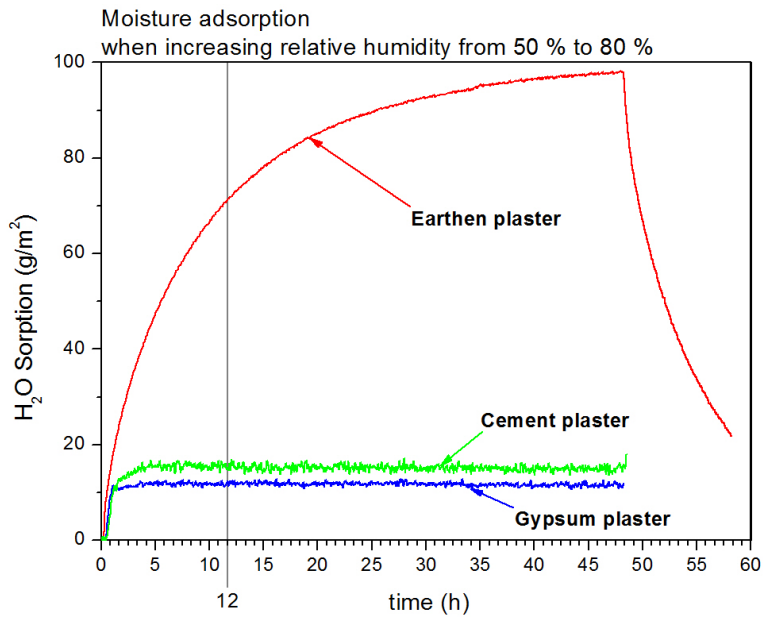

Fig. 3 Moisture uptake of three different plaster samples when changing the relative humidity of the ambient air from 50 % to 80 %

plasters were modified and refinded. The following testing procedures were incorporated and are essentially following DIN EN 1015 [2] and DIN V 18550 [3]:

- consistency of fresh mortar and plasters
- linear shrinkage, apparent density
- flexural and compressive strength
- modulus of elasticity
- adhesion strength (plasters only)
- abrasion resistance (plasters only)
- temporal water vapor adsorption (plasters only)

Temporal water vapor adsorption is quantifying the humidity buffering capacity of a plaster and measures the moisture uptake periodically after 1, 3, 6, 12, 24 and 48 h (optional) when changing the relative humidity from 50 % to 80 %. The actual sorption value is the 12 h reading. It can be assumed that 12 h represent a average night/day cycle and the linked change in relative humidity in the indoor air. This feature will be included in the future standard and in the declaration as a specific property. **Figure 3** shows the moisture uptake of an earthen plaster, a cement plaster and a gypsum plaster in a period of 48 h. Clearly the earthen plaster has a much higher moisture uptake from the air as the other materials, which demonstrates the high capacity in buffering changes of indoor humidity.

For earth blocks standard methods from brick were adapted and modified, some of them following DIN V 105 [4]. Important were the mechanical properties because strength and deformation behavior of industrial earth blocks are not well known. **Figure 4** shows the results of strength testing of various earth blocks vs. their apparent density. The data indicate a certain variety in strength ranging from below 2 to almost 12 MPa. From those results strength classes were formulated following DIN V 105 in order to define minimum strength requirements for different types of applications. In **Figure 5** an example for the deformation behavior of three blocks is given, conveying totally different load-strain

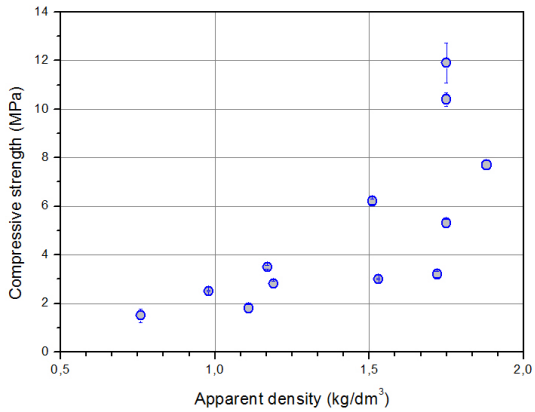

Fig. 4 Compressive strength vs. apparent density of 12 earth blocks of various type

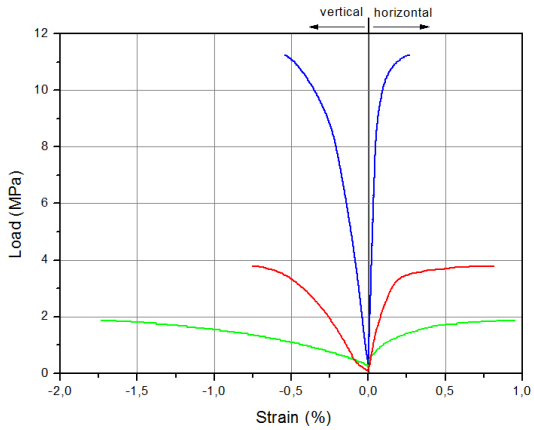

Fig. 5 Load-strain relationship of three different earth blocks

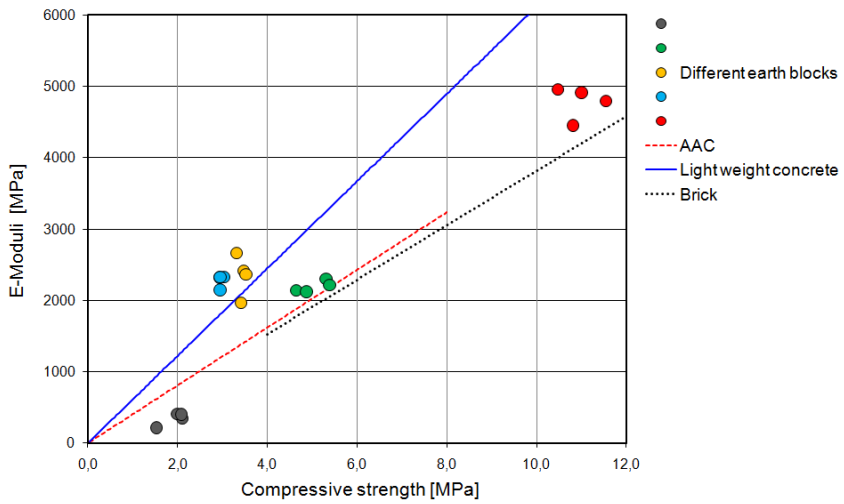

Fig. 6 Modulus of elasticity vs. compressive strength of 5 different earth blocks, including the data range of autoclaved aerated concrete (AAC), lightweight concrete and masonry brick

behavior. From the graph it is evident, that some blocks can have substantial deformation before failing. The determination of the modulus of elasticity for the earth blocks showed a similar pattern as for other building materials, in particular under consideration of the compressive strength (**Fig. 6**). Based on this data minimum requirements for the modulus of elasticity of earth blocks utilized for load bearing applications were formulated.

New test methods are being developed for testing the water and frost resistance, which allow the classification of earth blocks in three application classes (class I: outdoor masonry, plastered; class II: outdoor masonry, protected as well as indoor masonry; class III: indoor, dry wall construction). The test methods are simple in execution but effective in determining the resistance towards liquid water and towards frost.

Additional methods are being refined for judging the quality of soil. These include determination of the grain size distribution, the adhesion force vs. compressive and flexural strength as well as compositional analysis in particular with respect to the concentration of soluble components.

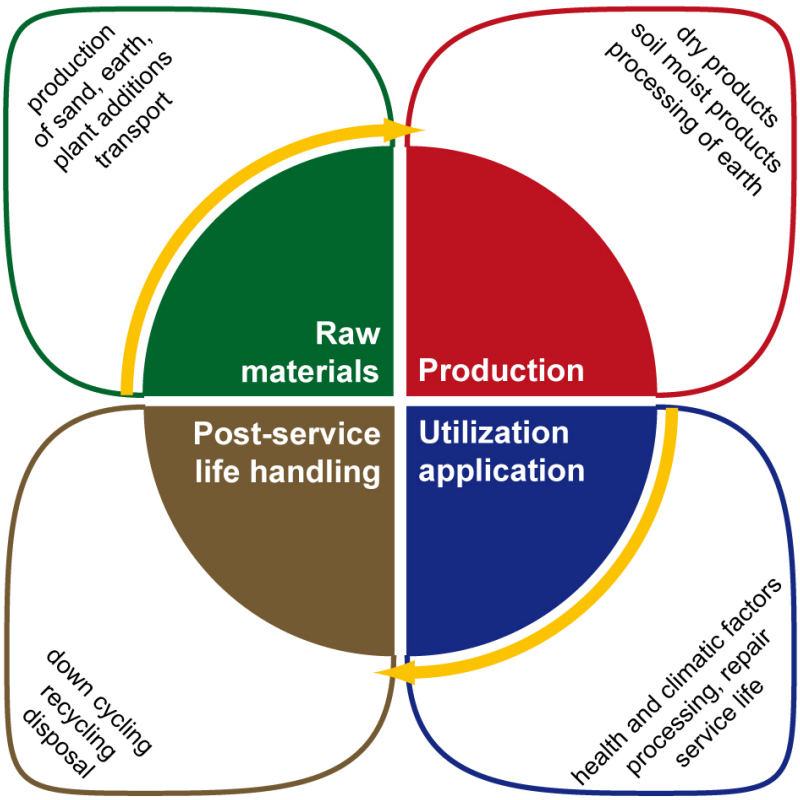

Fig. 7 Life cycle for earthen building products with some of the factors considered in the eco balance calculation

These test procedures are now internally validated and partially already in use for controlling the properties of the building products of the ongoing productions. The intention is to define cycles for the in-house and external quality control, the latter to be performed by an independent testing institute.

3.2 Sustainability, life cycle assessment and declaration

One of the outstanding characteristics of earthen building materials is their high degree of sustainability. This is the reason why earth was and is used so widely in the first place: Almost everywhere available and to produce with almost no energy, except manual labour. Industrially produced earthen materials have, when they are not amended, a much lower primary energy consumption than any other building material. This is due to the fact that the most energy intensive process consists in drying products from a soil moist state to a dry state. Any other process includes machine time and transport.

At the moment an analysis is being performed of the earth blocks, mortars and plasters assessing the energy consumption during their life time (**Fig. 7**) according to DIN EN ISO 14025 [5]. This includes quarrying, manufacture, application and recycling/disposal (essentially un-stabilized earth can be recycled to 100 %). The preliminary results show that the selected materials have a primary energy consumption which is one half to one tenth of other building materials. From this the CO_2 equivalent will be calculated and included into the declaration of the end product.

3.3 Further steps

At the moment a first pre-standard for earth blocks is in revision and pre-standards for earth mortars and plasters in development. A preliminary technical committee for standardization has been established inside the DVL. In the meantime the validation of the testing procedures is ongoing but need to be also validated by other institutions in form of round robin tests. This will be part of the next step together with the establishment of a technical committee under the umbrella of the German Standardization Institute (DIN) for the creation of national standards.

4 Conclusions

In Germany industrially produced earthen materials are regulated by a national guideline [1], which covers their use and application. However, in order to increase competitiveness of these materials the regulation has to be brought to a similar level as for other building products. An initial step has been made to start the standardization process on a national level with four groups of materials and more to come. However, it will take more time to create actual products standards for earthen building materials on a national level and even longer on a European scale. But nevertheless, these standards will help to integrate earthen materials as a highly sustainable alternative to other building products and increase the range of low energy materials for the construction of highly eco-efficient buildings.

Acknowledgments

We would like to thank our German Federal Ministry of Economics and Technology (BMWi) for funding the project under the umbrella of their funding instrument MNPQ.

References

[1] VOLHARD, F. AND U. RÖHLEN, EDS. *Die Lehmbau Regeln - Begriffe, Baustoffe, Bauteile.* 3rd ed., ed. Dachverband Lehm e.V. 2009, Vieweg & Sohn.

[2] DIN EN 1015. *Testing methods for mortar in masonry*. Deutsche Norm. Berlin, Beuth-Verlag, 2007.

[3] DIN V 18550. *Putz und Putzsysteme - Ausführung*. Deutsche Norm. Berlin, Beuth Verlag, 2005.

[4] DIN V 105. *Mauerziegel*. Deutsche Norm. Berlin, Beuth Verlag, 2002.

[5] DIN EN ISO 14025. *Environmental labels and declarations - Type III environmental declarations - Principles and procedures (ISO 14025:2006)*. Deutsche Norm. Berlin, Beuth Verlag, 2009.