

Codes and rules for earth building materials in Germany

The incorporation of the Lehm bau Regeln, (German rules for earthen architecture) into the respective building regulations of the majority of the German federal states, represents a milestone in securing the status of earthen constructions in modern building practice. Since 1998 it has been possible to use earth building materials for certain, clearly defined load-bearing and non-loadbearing applications without the need to obtain special consent in each individual case from the building authorities. The third revised edition of the Lehm bau Regeln was approved by the National Institute of Building Techniques (DIBt) in early 2008.

In addition to the basis of the Lehm bau Regeln, DIN-Codes and Technical Guidelines were developed for several prefabricated earth building products and techniques in the past years. The following DIN codes were established in 2013:

- DIN 18945:2013-08 for Earth blocks
- DIN 18946:2013-08 for Earth mortar for masonry
- DIN 18947:2013-08 for Earth mortar for plaster.

Product requirements, testing procedures and product declarations of these codes are much more detailed, compared to the Lehm bau Regeln. The experiences with these codes are very positive; they have a high acceptance by producers, architects and craftsman's.

Highly quality controlled earthen building materials enable the implementation of their codes into application standards of general product categories like DIN 18550, the German code for internal plastering. In this code, earth plasters are now listed in addition to cement-, lime- and gypsum plaster and approved for all standard indoor applications.

Currently the Dachverband Lehm is working on a draft regulation for earth panels which shall be finalised in 2017. The draft based on a huge on-going testing program which is carried out by the Federal Institute for Materials Research and Testing (BAM).

The next stage will be the development and/or implementation into codes at European level. Therefore a strong collaboration between the European earth building associations is highly appreciated.

Introduction

The use of earthen building materials – both in renovation and new construction – is common again in Germany. Even with larger public works, earthen plasters and earthen panels show an increasing application nowadays. However, detailed regulations were missing so far. As a consequence, it was often not possible for planners to precisely formulate the technical specifications for earthen building materials and components. Furthermore, there was no legitimate basis for the construction monitoring and for authorised experts to assess compliance or flawlessness. In 2013, the publication of DIN-standards for earth blocks, earth mortar for masonry and earth mortar for plaster provoked fundamentally changes, at least in these important subareas of Germany's earth building practice. The most important changes and new features will be described in this paper.

The existence of DIN-standards is perceived with pride within the earth construction industry: earth is finally considered a normal building material. Since these standards are applied only to prefabricated earth building products, their existence does not imply any limitations to the earth building material mixtures on site that are ideally locally acquired and tested for suitability. Here, the Lehm bau Regeln of

the Dachverband Lehm e.V. (DVL) will continue to apply to these mixtures on site.

The prior use of earth building materials in old and new buildings is documented, amongst others, in the book "Earth Building Practice" [1].

The often-published flagship projects in the field of renewable building materials were – and still are – able to be realized in countries without standardized renewable building materials. The success of these projects is due to the knowledge of individuals and despite recognition and a positive publicity effect to the outside; these exemplary buildings can hardly generate the broad scope of accepted use, which can only arise from rules and standards. In this article the major changes and innovations, as well as their effects on the practice of building with earth materials in Germany are described and analyzed in order to minimize the common misconceptions that can be observed when it comes to the discussion about standardization of still unregulated building materials.

Development and current state of regulations for earth building materials in Germany

During the post-war years of WW2, tens of thousands of housing units were built out of earth building materials in both parts of Germany. Extensive regulations and DIN standards were implemented back then, which embodied the contemporary state of earth building regulations in Germany. In the 1980ies, when earth building experienced its environmentally related renaissance in Germany, these regulations were already retired and did no longer meet the applied techniques and requirements at that time. In 1996, the need for regulation of earth building was stated by the regional building ministry of Mecklenburg-Vorpommern. The umbrella organisation Dachverband Lehm e.V. (DVL), which was founded in Weimar in 1992, was assigned by the German Institute for Building Technology (DIBt) to formulate a new building-authority foundation for earth building materials. At this time, the stakeholders in this process maintained a revision of the old DIN standards, and also the formulation of new standards, for impractical. Instead, a new technical guideline – the „Lehmbau Regeln“ [2] – should document the state of the art of earth building materials and earthen components used in the field of renovation and new buildings. The Lehmbau Regeln are part of the Sample List of Technical Building Regulations MTB of DIBt as well as part

of the List of Technical Building Regulations LTB, introduced in almost all federal states of Germany. The application of Lehmbau Regeln has been restricted to residential buildings with a maximum of two storeys, with a maximum of two units. This means that for further applications of earth building techniques, the approving ability must be clarified with the building authorities, which is then usually realized by applying for an „approval in individual cases“. By using this option, many buildings outside the limited field of application have been built out of earth building materials since then. In technical terms, this can be referred to the Lehmbau Regeln. For technically subordinated applications – like interior plasters in apartment buildings – the question of admission has more a technical than a professional character. However, the building authority approval with industrially relevant applications – like public works or more than two-storey buildings in load-bearing construction – is mandatory to clarify.

The Lehmbau Regeln are a component of MTB and LTBs, currently in the 3rd version. The latest version was introduced by the DIBt in 2009, with the condition of DIBt that prefabricated earth building products must be covered by product standards in the medium term, with the support of DIBt. This was due primarily to the growing importance of earth building materials.

In August 2013, the first new product standards for earth building materials – authored by DIN Working Committee NA 005-06-08 AA Lehmbau – got adopted and published. These are:

- DIN 18945:2013-08 „Earth blocks – Terms and definitions, requirements, test methods“
- DIN 18946:2013-08 „Earth mortar for masonry – Terms and definitions, requirements, test methods“
- DIN 18947:2013-08 „Earth mortar for plasters – Terms and definitions, requirements, test methods“.

The new DIN-standards for earth building materials pursue the goal of ensuring stability and serviceability. Furthermore, more attention was paid to softer ecological criteria when creating this version, such as the establishment of a procedure to determine the CO₂-equivalent characteristic value or the indoor environment affecting water vapour sorption capacity. The content of natural radioactivity, that needs to be declared on all mineral construction materials,



Photo: ZRS

Figure 1 Earth blocks of Application Class AK Ia for the masonry infill of half-timbered external walls on a weather-exposed facade. The panels will be plastered, the timber elements left exposed.

was moreover implemented at a very low prevention guidance level in accordance with the European legislative process as well as in accordance with the critical user.

The DIN-standards are well established in the daily work of the architects and engineers in all design processes. Also the producers of the earth building products apply the testing procedures and declaration systems and there is no major criticism on the standards in general and in detail.

DIN-regulated earth building materials are not allowed to be labelled by the CE-mark due to the fact that these building materials do not concern European standard, but national standard building materials. A European standard initiative was initiated by the Dachverband Lehm e.V. before the development of the national DIN-standards. However, it was not sufficiently supported by the European partner organizations, which is why DVL has then decided to focus on national standards. Meanwhile, tendencies consist that the DIN-standards could be adopted – in part or entirely – in other European countries.

The Lehmregeln still apply for all on site produced earth building materials that are neither regulated by the DIN-standards nor industrially produced, e.g. rammed earth. Both the Lehmregeln as well

as the new DIN-standards of earth building exclude earth building materials consisting of clay in addition with other binders, such as gypsum or cement. Such stabilized earth building materials do not comply with the Lehmregeln or DIN-standards of earth building.

DIN 18945:2013-08 Earth blocks

The standard DIN 18945 specifies the requirements for industrially produced adobes for the load-bearing as well as for the non-load-bearing earth masonry. Earth blocks are divided into application classes (AK), which are essentially characterized by different humidity- and frost stress:

- plastered, the weather exposed exterior masonry of half-timbered walls with visible structure (AK Ia)
- consistently plastered, the weather exposed exterior masonry (AK Ib)
- cased or otherwise structurally weather protected exterior wall works and interior masonry (AK II)
- dry applications, e.g. ceiling panels or stacking techniques (AK III)

The application classes are relevant for determining the permitted share of voids and minimum web thicknesses as well as for the specifications for the humidity and frost behaviour. Earth blocks are neither moisture- nor frost-resistant. But according to the applications, adobes need to be sufficiently resistant

to these stresses, which will be tested in the context of material testings in finely tuned trials.

Earth blocks are divided into 12 density classes. As with other artificial stones, the sizes and dimensions are based on the dimensional organisation in building construction.

Unless Earth blocks are to be used for load-bearing structures, they are differentiated according to compressive strength classes from 2 to 6. Adobes for non-structural applications (e.g. infill of half-timbered walls) must be sufficiently strong for the intended application.

The designation of earth blocks must contain the following information: Earth blocks according to DIN 18945: 2013-08, format code, compressive strength class (only with supporting application), application class, density class. The complete declaration contains additional information, such as the type of additives etc.

For earth blocks for the rehabilitation of historic solid earth buildings, for example, class Ib must be used, corresponding at least to strength class 2. The density class needs to be chosen in accordance to the density of the constituent materials.

DIN 18946:2013-08 Earth mortar for masonry

The standard DIN 18946 specifies the requirements for the production of load-bearing as well as for the non-load-bearing earth masonry. Earth mortar for masonry is divided into density classes from 0.9 to 2.2. With regard to the declaration of the thermal conductivity, the standards refer to the classification according to DIN 4108-4, with regard to the fire behaviour to DIN 4102-1 or 4102-4.

The strength classes for earth mortar for masonry must be graded into the classes M0, M2, M3 and M4, with corresponding demands on compressive

strength and adhesive shear strength. Here, M0 designates earth mortar for non-structural applications, e.g. the infill out of earth blocks.

The designation of earth mortar for masonry must contain the following information: Earth mortar for masonry according to DIN 18946: 2013-08, abbreviation, upper/lower sieve size (grain size), fibre or mineral reinforcement, strength class (only with supporting application), density class.

DIN 18947:2013-08 Earth mortar for plaster

The standard DIN 18947 specifies the quality requirements for earth mortar for plaster, which is used for plastering walls and ceilings in interior and weather-proof external applications. The standard applies only to earth plasters with application thicknesses of not less than 3 mm. Earth mortar for thin-layered plasters are regulated by the technical data sheet TM 06 "Thin-layered earth surface coatings" [4]

The linear shrinkage of drying earth mortar for plaster must not be more than 2%. For earth plasters that are less susceptible to cracking, higher values are permitted with 3% when fiber reinforced, and 4% for thin-layered fiber reinforced earth plasters.

Earth mortar for plaster is liable to 2 strength classes, each defining requirements regarding compressive strength, flexural strength, adhesive strength and abrasion resistance. Hence, the audited strength characteristics are more extensive compared to other plaster mortars. For normal use, the strength class S II is to be applied. The strength class S I is recommended only for subordinate spaces or certain special applications.

The designation of earth plasters must contain the following information: Earth mortar for plaster according to DIN 18947: 2013-08, abbreviation, lower/upper sieve size (grain size), fibre or mineral reinforcement, strength class, density class.

Table 1 Strength classes and minimum standards of earth mortar for plaster acc. to DIN 18947

Strength class	Compressive strength N/mm ²	Bending tensile strength N/mm ²	Adhesive strength N/mm ²	Abrasion g
S I	≥ 1.0	≥ 0.3	≥ 0.05	≤ 1.5
S II	≥ 1.5	≥ 0.7	≥ 0.10	≤ 0.7



Photo: Claytec

Figure 2 Grey thin-layer earth surface coating according to TM 06, Kolumba museum in Cologne

For the purposes of consumer protection, the indication of water vapour adsorption class WS is additionally recommended for earth plasters. This specification is optional, but is polled by most customers due to the sorption class that represents a measure of the stabilization of the room humidity. The best water vapour adsorption class WS III, for example, guarantees an about 5-fold humidity buffering capacity compared to gypsum plaster.

Due to the existence of material standards for earth blocks, earth mortar for masonry as well as for plaster, these product groups can now be incorporated into the superior standards of application. As a consequence, the standard of application for plaster DIN 18550-2:2015-06 „Plaster and plaster systems – execution (interior)“ contains earth mortar for plaster as a kind of plaster besides gypsum, lime, cement and polymer-bound plasters. Furthermore, the restrictions on the use of Lehm bau Regeln get successively lifted, e.g. for earth plasters. Operated by DVL, earth mortar for plasters could at least be partially implemented into the European standard for interior plasters – EN 13914-2 Internal Plastering – by the following sentences: “Earth mortar for plaster is usually made with clay and, if necessary, with mineral additives and fiber reinforcement. Depending on the manufacturer and the raw materials, earth mortar for plaster may have different strength properties.

Earthen plasters must be used in accordance with the manufacturer’s recommendations or the corresponding national regulations.”

A detailed implementation, corresponding to the level of DIN 18550, failed due to French and English standardization members, who considered the application of earth mortar for plaster as being irrelevant in these countries.

Technical data sheets of DVL

The technical data sheet Technisches Merkblatt TM01:2014-06 [3] was provided by the Dachverband Lehm e.V. (DVL) for evaluating earthen plaster as a building component. The TM 01 controls, for example, the flatness and abrasion resistance of earthen plaster surfaces, the assessment of possible cracks etc. Therefore, this technical data sheet is regarded as an ideal guideline when it comes to disputes on construction works.

Even products whose national technical relevance is low, but which are used frequently, should be controlled successively on technical data sheets, e.g. earth surface coatings. This product group includes the high-end colour plasters, the so-called earth brush on plasters (clay colouring with granulation) and clay colours and a clay based knifing filler. Since June 2015, these products are regulated by the tech-

nical data sheet Technisches Merkblatt TM 06:2015-06 "Thin-layered earth surface coatings" [4].

Conclusion

The new standards for prefabricated earth blocks, earth mortar for masonry as well as for plaster, are defining requirements and features for this building material group to such an extent, as it is common for modern building materials. These standards can therefore be regarded as a contemporary consequence to the regulation of earth building, configured upon the building-authority introduction of the very general formulated Lehm-Regeln. In addition to the aspects of stability and serviceability, environmental characteristics have also been taken into account, which is exemplary for standards in the field of mineral building materials. For planners and experts, it is finally possible to check the terms of reference of earth building materials.

As a proponent of DIN Standards Committee Lehm-Regeln, the umbrella organization DVL plans to issue additional standards for prefabricated earth building materials and products. The formulation of the standard for earthen panels, for example, is currently in the design process.

With the presence of product standards, it is possible to obtain an enrollment in higher-level application standards. This was already achieved in Germany with the entrance into the DIN 18550-2 for earth mortar for plaster. Earthen plasters are now admitted on an equal footing as other interior plasters. For earth blocks, the entrance to the general masonry standard would also be desirable.

The next stage will be the development of further codes and/or the implementation into codes at European level. Therefore, a strong collaboration between the European earth building associations is highly appreciated.

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