FROM HIGH-TECH TO HIGH-QUALITY AND LOW-TECH – THE SUSTAINABLE POTENTIAL OF EARTH AS A BUILDING MATERIAL

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Summary

Earth is more than just an ecological raw material for making building materials: it also fulfils many criteria for sustainability in the holistic consideration of building constructions. The advantages of lower primary energy requirement, less burden on the environment and a lower CO_2 equivalent value in construction with earth-building materials are just as significant compared with conventional building methods as year-round thermal comfort and the potential for recycling, to name but a few qualities of earth as a material.

To better assess the advantages of building with earth compared to using conventional materials, this paper conducts a qualitative analysis on the basis of the German BNB Assessment System, an external assessment system for sustainable building approved by the German Federal Ministry of Transport, Building and Urban Development. The performance of typical conventional construction methods are compared with comparable earth constructions using selected aspects of this assessment system.

Keywords: Earth Construction, Earth Building Techniques, Sustainable Building, Assessment Methods

1 Introduction

Earth is more than just an ecological raw material for making building materials: it also fulfils many criteria for sustainability in the holistic consideration of building constructions. The advantages of lower primary energy requirement, less burden on the environment and a lower CO_2 equivalent value in construction with earth-building materials are just as significant compared with conventional building methods as year-round thermal comfort and the potential for recycling, to name but a few qualities of earth as a material.

Many discussions on the sustainable quality of building materials are coloured by subjective opinions or selective representations by interested parties. This paper instead aims to base this discussion on objective criteria as set out in an impartial assessment system: the BNB Assessment System [1]. This system was developed by the German Sustainable Building Council (DGNB) in consultation with the German Federal Ministry of Transport, Building and Urban Development (BMVBS).

2 The BNB Assessment System

The BNB System examines the sustainability aspects of building according to a comprehensive list of sustainability criteria, which are grouped into six main groups: economy, ecology and sociocultural and functional aspects, as well as technical quality and process quality and location-specific aspects. Each aspect is considered one by one and weighted to take into account their respective importance. It should be noted that sustainable building depends on many factors and not just the choice of building material or technique. This comparison can, therefore, only consider specific aspects of the table.

On 22 September 2011, version 2011_1 of the table was introduced and recommended by the Federal Government for use with “New-build office and administrative buildings” [2]. Evaluation systems for residential buildings and housing are in preparation and will be similar in many respects.

1 – Ecological Quality	**22.5 %***
Effects on Global and Local Environment	**in %***
1.1.1 Global Warming Potential (GWP)	3.375
1.1.2 Ozone Depletion Potential (ODP)	1.125
1.1.3 Photochemical Ozone Creation Potential (POCP)	1.125
1.1.4 Acidification Potential (AP)	1.125
1.1.5 Eutrophication Potential (EP)	1.125
1.1.6 Risks to the Local Environment	3.375
1.1.7 Sustainable Logging / Wood	1.125
Demand of Resources	
1.2.1 Primary Energy Demand Not Renewable (PEne)	3.375
1.2.2 Total Primary Energy Demand (PEges) and Amount of Renewable Energy (PEe)	2.250
1.2.3 Fresh Water Demand and Quantity of Wastewater	2.250
1.2.4 Demand of Space	2.250
2 – Economical Quality	**22.5 %***
Life Cycle Costs	**in %***
2.1.1 Building-related Life Cycle Costs	13.50
Performance	
2.2.1 Value Stability	9.00
3 – Sociocultural and Functional Quality	**22.5 %***
Health, Comfort and User Satisfaction	**in %***
3.1.1 Thermal Comfort in Winter	1.607
3.1.2 Thermal Comfort in Summer	2.411
3.1.3 Indoor Air Quality	2.411
3.1.4 Acoustic Comfort	0.804
3.1.5 Visual Comfort	2.411
3.1.6 Influence of the User	1.607
3.1.7 Building-related Outdoor Qualities	0.804
3.1.8 Safety and Incident Risks	0.804
Functionality	
3.2.1 Barrier-free Building	1.607
3.2.2 Space Efficiency	0.804
3.2.3 Capability of Conversion	1.607
3.2.4 Public Accessibility	1.607
3.2.5 Bicycle Comfort	0.804
Ensuring Design Quality	
3.3.1 Design and Urban Quality	2.411
3.3.2 Art in Architecture	0.804
4 – Technical Quality	**22.5 %***
Technical Execution	**in %***
4.1.1 Sound Insulation	5.625
4.1.2 Heat Insulation and Protection against Condensate	5.625
4.1.3 Cleaning and Maintenance	5.625
4.1.4 Dismantling, Separation and Utilisation	5.625
5 – Process Quality	**10.0 %***
Management and Design	**in %***
5.1.1 Project Preparation	1.429
5.1.2 Integrated Design	1.429
5.1.3 Optimisation and Complexity of Planning	1.429
5.1.4 Sustainability Issues in Tender and Placing	0.952
5.1.5 Requirements for Optimal Utilisation and Management	0.952
Building Construction	
5.2.1 Building Site / Building Process	0.952
5.2.2 Quality Assurance of the Building Construction	1.429
5.2.3 Controlled Commissioning	1.429
6 – Location Profile	
6.1.1 Risks at the Micro-Site	
6.1.2 Conditions at the Micro-Site	
6.1.3 Image and Character of Location and Quarter	
6.1.4 Public Transport Connections	
6.1.5 Vicinity to Use-Specific Services	
6.1.6 Supply Lines / Site Development	

** maximum achievable percentage for each main criteria group or criterion*

Fig. 1 *Table showing the structure of the BNB Assessment System (v2011_1)*

2.1 Criteria group 1 – Ecological Quality

The ecological quality describes the effect on the global and local environment: **Fig. 2** shows a comparison of the primary energy demand of different building materials:

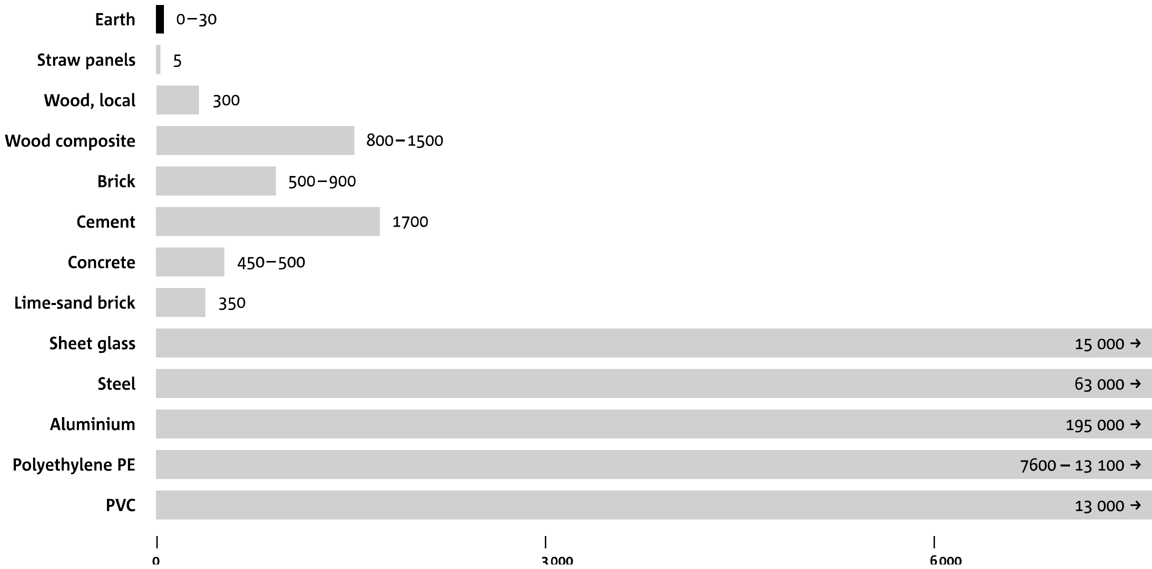

Fig. 2 *The Primary energy demand of different typical building materials [3]*

- **1.1.1 Global Warming Potential (GWP) – an example:**
  By merit of their manufacturing process, air-dried earth blocks have a substantially lower global warming potential than fired bricks.

Global warming potential	kg CO_2-equivalent
Masonry brick*	209.20
Earth block ~1200 kg/m³ **	84

**Source: Product declaration: EPD-POR-2008111-D [4]*
***Source: Data from Claytec KG*

- **1.2.1 Primary energy requirement of non-renewable (PE ne) – an example:**
  Compared with the primary energy requirement of non-renewable energy, the advantages of air-dried earth blocks is even greater:

Primary energy demand not renewable	MJ/m³
Masonry brick*	1031.08
Earth block ~1200 kg/m³ **	155–185

**Source: Product declaration: EPD-POR-2008111-D [4]*
***Source: Data from Claytec KG*

2.2 Criteria group 2 – Economic Quality

The misconception that building with earth is costly compared with conventional building methods is very persistent. This is a fallacy, as established cost analyses prove:

Tab. 1 *Example of a cost comparison of earth building vs. conventional building methods*

Internal earth plasters*	**Mean value****	**From–to spread**
Earth render, single coat	20.50 €/m²	18–27 €/m²
Earth render, two coat	32.00 €/m²	30–40 €/m²
Conventional construction*	**Mean value****	**From–to spread**
Lime plaster, single coat	19.00 €/m²	17–22 €/m²
Lime plaster, two coat	29.00 €/m²	25–38 €/m²
Gypsum plaster	18.50 €/m²	16–20 €/m²

** on various sub-structures, incl. necessary preparation, reinforcement, junctions and smoothing the surface*
*** All prices gross, i.e. incl. prevailing rate VAT at 19 % [5]*

Table 1 shows clearly that the advantages of building with earth for general quality of life and comfort can be had for a modest extra cost.

2.3 Criteria group 3 – Socio-cultural and Functional Qualities

Socio-cultural and functional qualities cover health, comfort and user satisfaction. Of these, *3.1.1 thermal comfort in winter* (impact factor 2) and *3.1.2 thermal comfort in summer* (impact factor 3!) are particularly important. Here earth provides excellent properties:

- High thermal storage capacity to balance day-time temperature fluctuations, and
- Good ability to store solar energy (for passive solar energy use) and a capacity to regulate temperature at the wall surface (heating or cooling).

- **3.1.3 Indoor air quality** *(impact factor 3!)*
  Earth is not only a healthy material for the inhabitants of buildings but also for tradesmen and manufacturers of earth building products:
  - Due to its sorption behaviour it regulates the ambient air humidity to a comfortable level of around 50 %.
  - It is able to bind contaminants (in a manner similar to an active carbon filter).

  Earthen surfaces are subjectively felt to be warmer than many other surfaces, a factor that can be attributed to its open pore structure. Similarly, its ability to improve the indoor air climate is also a factor that is important for user satisfaction, as has been confirmed by a study at the Chair for Building Physics, Bauhaus University Weimar. In a study entitled “Criteria for User Orientated Building” [6] conducted among over 1000 people of all ages and occupations, the most important living criteria for occupiers were found to be:
  - Air quality
  - Thermal comfort
  - Energy requirement, consumption costs

- **3.2.3 Capability of conversion**
  For sustainable building, refurbishment is always preferable to new building (as stated in the “Guidelines for Sustainable Building” by the Federal Government). Earth building materials are currently used in Germany predominantly for refurbishing existing buildings. Earth offers considerable potential for improving the quality of refurbishments, for example, when used as internal insulation, a refurbishment variant that is still often viewed critically, though largely due to a lack of knowledge.

- **3.3 Ensuring design quality**
  Earth can fulfil many aesthetic requirements in refurbishment (**Fig. 3**) as well as in new-building. Earth can also lend interiors a particular artistic quality, and rammed earth is often left exposed to view as a design element (**Fig. 4**).

Fig. 3 Refurbishment of a timber-framed house with internal insulation and earth-building materials

Fig. 4 House of Sustainability, Rhineland-Palatinate, Trippstadt

2.4 Criteria group 4 – Technical Quality

Earth building also fulfils high physical requirements in building constructions and harmonizes well with other materials, for example in wood-framed construction (**Fig. 5**):

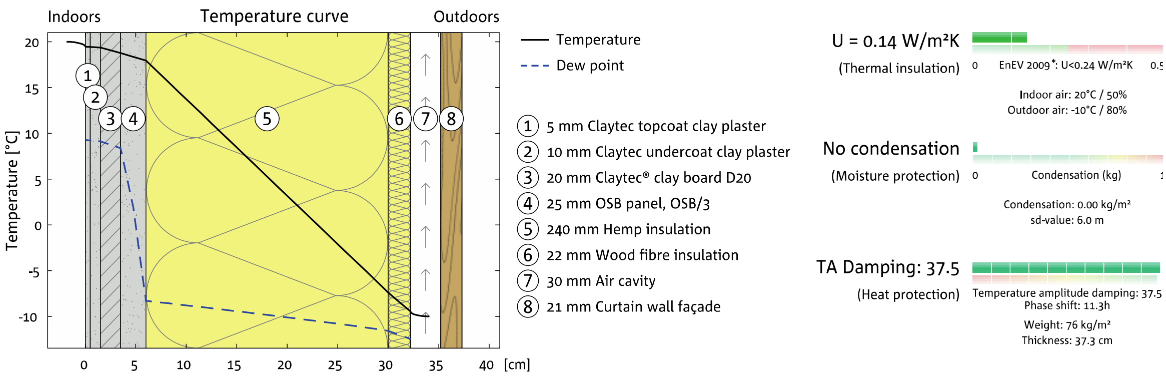

Fig. 5 U-value calculation ([7])

- **4.1.4 Dismantling, separation and utilisation**
  Because earth does not chemically harden and can be softened through the addition of water, earth building materials (without additives) can be broken down and recycled when a building or element is demolished, a process that requires comparatively little energy.

2.5 Criteria group 5 – Process Quality

Process quality covers design confidence, tendering procedures and specifications for contracts. Since 1999 the *Lehmbau Regeln* (issued by the Dachverband Lehm e.V.) have provided design confidence in the form of a recognised guidelines for building with earth.

The new DIN standards for earthen building

In September 2011, the German Standards Institute (DIN) founded a new Standards Committee – NA 005-06-08 AA "Lehmbau" – at the request of Dachverband Lehm e.V. (DVL). This step was based on the advanced state of the Technical Information Sheets TM 02 to TM 04 published by the DVL, which have formed the basis for a series of new norms for industrially produced earth-building materials that entered **draft status in 2012:**

- DIN V 18945 Earth blocks
- DIN V 18946 Earth masonry mortar
- DIN V 18947 Earth render mortar

- **5.1.5 Requirements for Optimal Utilisation and Management**

When one considers susceptibility to faults and the resilience of buildings, the degree of technical equipment and mechanisation can play a significant role. In our view, the prevailing tendency towards using ever more *high-tech* is not the right answer in all situations. On the contrary, *low-tech* paired with *high-quality* can be a better alternative.

For example, the use of earth-building materials can reduce the degree of mechanical ventilation needed it a building, and in turn the associated heat loss. Clay plaster is highly prized for its unique physical properties and its ease of use as a low-tech component, and not just among friends of ecological building. The following examples illustrate this:

Reichenow House, timber construction with cellulose installation and clay plaster

The building has a lightweight construction and the use of clay plaster helps to regulate the humidity and warmth of the interior. The room temperature and indoor air climate is optimal in this house which was built to be sustainable and as self-sufficient as possible. "In a house of this kind, this approach obviates the need for a conventional ventilation system," explains the architect Eike Roswag (ZRS Berlin) of his low-tech building. *[8]*

Fig. 6 *Clay plaster used in the bathroom to regulate the indoor air humidity*

Winning design for the New Bauhaus Museum in Weimar, Germany

In this project, clay plaster is used for the interior walls to minimise the degree of air conditioning and climate control equipment required. According to the architects of the winning entry, Prof. Heike Hanada and Prof. Benedict Tonon, “the use of a hygric clay plaster on the interior wall surfaces helps to keep the relative humidity at a comparatively constant level even if the amount of moisture brought into the building changes. This in turn reduces the latent energy required to ventilate and dehumidify the spaces.” *[9]*

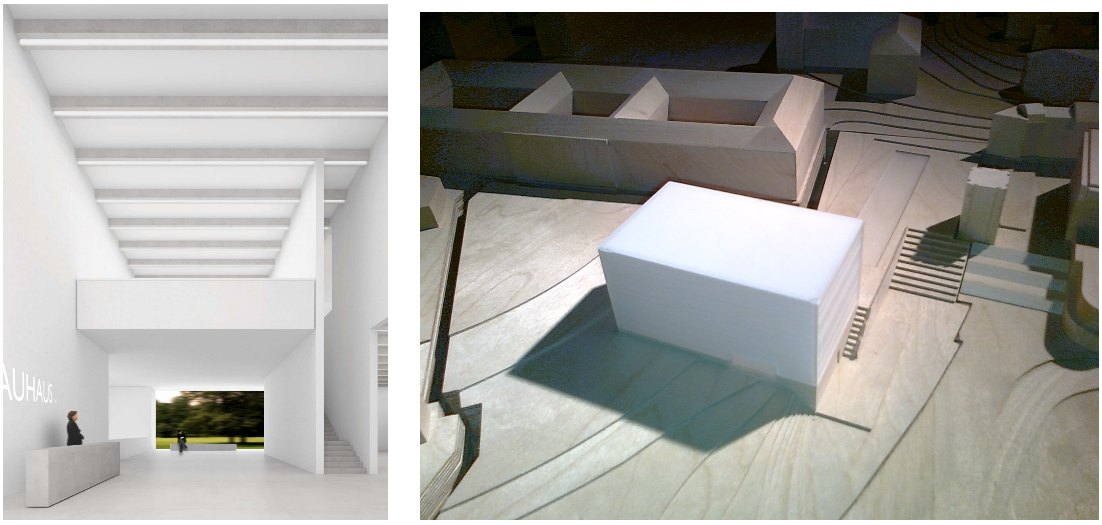

***Fig.** 7 Winning entry for the New Bauhaus Museum, Weimar, Germany*

Tithe Barn at Lippe Regional Museum in Detmold, Germany

As part of the special exhibition “Imperium – Conflict – Myth” to commemorate the 2000th anniversary of the Battle of the Teutoburg Forest, clay plaster is used in combination with a wall heating system to gently heat and stabilise the relative humidity of the exhibition spaces. For the exhibits, some of which were on international loan, it was important to ensure balanced temperature and humidity levels in the interior as large fluctuations of either could damage the exhibits. *[10]*

Fig. 8 *Wall heating system before application of clay plaster*

Fig. 9 *Exibition "Imperium – Conflict – Myth"*

References

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