Supplements the SIA 180:2014 standard

Wärmeschutz, Feuchteschutz und Innenraumklima in Gebäuden

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Earth Comfort - Guidelines to SIA 180:2014

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FORWORD

The aim of this supplementary standard is to ensure a comfortable and healthy indoor climate, while exploiting the specific qualities of earth as a building material. It also aims to prevent damage to the building that may result from inappropriate use of this material or inadequate maintenance.

This standard describes the principles and requirements specific to the use of earth, making it possible to achieve the objectives of thermal, hygrometric and acoustic comfort in the context of normal use and maintenance of the building. It complements the SIA 180 standard, focusing on aspects relating to hygrothermal behaviour, thermal inertia, natural moisture regulation and indoor air quality, all of which are made possible by the use of earth.

A comfortable indoor climate should be ensured primarily by passive construction measures. The building, excluding technical installations, must offer a level of comfort at least equivalent to that required by the SIA 180 standard, taking advantage of the earth's properties such as its ability to buffer variations in temperature and humidity. An overall comfort concept that takes account of the specific characteristics of the earth must be developed from the earliest design phases. It must also be demonstrated that the use of earth does not compromise the integrity of the construction or the quality of the ambient air.

The requirements are based on standard occupant behaviour assumptions. If the conditions of use change significantly, this standard can be used to assess whether the comfort criteria are still being met. However, the designer cannot be held responsible for any damage resulting from such changes.

The standard describes both simple assessment procedures and more complex approaches requiring specialist skills. It provides measurement methods for verifying whether the expected performance has been achieved.

This standard has been developed with a view to reinforcing the transition to sustainable building practices, rooted in local know-how and available resources, while ensuring comfort conditions equivalent to or better than current standards.

SIA RIOT EPFL Commission - Earth Comfort

0 FIELD OF APPLICATION

0.1 Scope

0.1.1 This standard applies to all buildings whose interior comfort is partly or entirely ensured by the use of raw earth (adobe, pisé, cob, compressed earth blocks, earth plaster, etc.) as a construction material. It specifies the expected performance of the envelope and earth components in terms of protection against heat, cold, humidity and variations in indoor air quality.

0.1.2 It applies to new buildings, as well as to major renovations or conversions in which earth is (re)introduced as a building material. It also includes changes of use of buildings where these involve increased requirements in terms of indoor comfort.

0.1.3 Major alterations include, for example :
- integrating earth walls or partitions into existing buildings ;
- the renovation or restoration of surfaces or volumes built of earth ;
- replacing finishing materials (plaster, partitions, slabs) with earthen elements;
- any modification involving a significant interaction between earth materials and the indoor climate.

0.1.4 The standard is based on indoor climatic conditions considered comfortable for the majority of users, as defined in standard SIA 180, with additional details taking into account the specific properties of earth materials.

0.1.5 It is based on the usual and reasonable use of buildings, including the behaviour of occupants, owners and operators. These conditions presuppose regular maintenance and operation in accordance with the design recommendations and the specific characteristics of earth materials.

0.1.6 The standard recognises, on the basis of a usage agreement, that :
- spaces are used in accordance with their original purpose ;
- occupants adapt their clothing to the season and the activity;
- sun protection devices are used correctly;
- technical installations (where applicable) are used in accordance with the recommendations;
- air exchanges (natural or mechanical ventilation) are adapted to the production of indoor humidity, taking into account the earth's capacity to regulate humidity;
- the earth walls are not covered with impervious materials, nor altered by treatments incompatible with their hygrometric function;
- the building and the earth elements are maintained, in particular by monitoring their structural integrity, their permeability and their interaction with humidity.

0.2 Derogations

0.2.1 Deviations from this standard are permitted where they are justified by scientific or empirical knowledge, by the results of laboratory or in situ tests, or by consolidated construction experience. Such deviations may concern, in particular, wall thicknesses, acceptable humidity levels or passive ventilation methods specific to earth constructions.

0.2.2 Any derogation must be explicitly documented and justified in the project file. It must demonstrate that the objectives of comfort, durability and air quality are achieved to at least an equivalent level to that required by the standard.

0.2.3 Specific uses (e.g. museum spaces, agricultural buildings, light or temporary housing) may be subject to specific adaptations to the conditions of use and functions of the building, provided that the derogations are analysed and justified in the context of the project.

1 TERMINOLOGY

1.1 DEFINITIONS

1.1.1 General concepts

1.1.1.1	Earth	It is a heterogeneous mixture of different elements (gravel, sand, silt, clay), to which other materials such as salts, oxides or organic matter may be added.
1.1.1.2	Pisé (rammed earth)	Pisé is a raw earth building material made from clay, which is compacted in formwork.
1.1.1.3	Compressed earth brick (CEB)	A building material made from raw clay, which is highly compressed to produce a dense, resistant brick. It can be stabilised with hydraulic binders such as lime or cement, or unstabilised.
1.1.1.4	Adobe	Adobe is an unfired mud brick that is dried in the sun. It is made from a mixture of clay, water and sometimes chopped straw or dry grass. These bricks are traditionally moulded by hand, then air-dried before being used for construction.
1.1.1.5	Bauge	Bauge is a construction technique that uses raw earth to build massive, often load-bearing, walls. It involves stacking clods of earth, usually mixed with plant fibres, to create a monolithic wall.

1.1.2 Humidity

1.1.2.5	Humidity	Humidity is the presence of water or water vapour in the air or in a substance.
1.1.2.5	Condensation	Condensation in a building is the passage of water vapour from a gaseous state to a liquid state, generally on cold surfaces. This happens when warm, moist air comes into contact with a colder surface, which cools the air and causes the water to condense.
1.1.2.4	Perspirant materials	Perspirant materials are those that allow water vapour to pass through their thickness, making it easier to evacuate moisture and regulate humidity levels.

1.1.3 Ventilation

1.1.3.2	Natural ventilation	Natural ventilation, or natural aeration, is a simple, environmentally-friendly way of renewing the air inside a home, providing improved thermal comfort and air quality. This system uses the differences in pressure and temperature between inside and outside to create an air flow.
1.1.3.2	Mechanical ventilation	Mechanical ventilation in a building is a system that uses fans and ducts to renew the air inside, thereby improving air quality and the comfort of occupants.
1.1.3.3	Chimney effect	Thermal draught, or chimney effect, is the movement of air (in buildings, chimneys, ducts, etc.) under the effect of Archimedes' buoyancy.

1.1.4 Thermodynamics

1.1.4.1	Inertia	A material's inertia is its ability to store heat inside a home and then release it slowly and evenly. A key element of good thermal comfort, inertia depends on the materials used and their density.

2 EARTH

2.1 General information about Earth

2.1.1 Earth definitions

2.1.1.1 Soil is a natural mineral material composed mainly of particles derived from the weathering of rocks, combined with water, air and a small organic fraction. It is locally available, abundant and reusable.

2.1.1.2 It is stratified into several layers, the thickness of which varies according to the soil environment. These layers are called horizons:

- Horizon 0 (Humus): organic layer belonging to Horizon A. It forms the organic litter that covers the soil.
- Horizon A: organic layer (0-30 cm)
- Horizon B: clay-enriched mineral layer (< 150 cm)
- Horizon C: weathered bedrock (> 60 cm), rich in heavy mineral particles.

2.1.1.3 The density of dry soil varies between 1000 and 2000 kg/m³. This varies according to the composition of the soil. A distinction is made between :

- Sandy soil: good aeration and resistance to compression, but low cohesion.
- Silty soil: balanced but sensitive to water.
- Clay soil: high cohesion, but shrinkage on drying.

Note: too high a clay content (> 35%) reduces bearing capacity and increases shrinkage.

2.1.2 Earth construction

2.1.2.1 On a building site, pisa can be used to build solid load-bearing walls directly on site by compacting moistened earth in a formwork. Cob, a mixture of earth and plant fibres (straw, hemp), is used as a light, insulating filling in timber-framed structures. Compressed earth bricks (CEB), which are moulded and then mechanically pressed, can be prefabricated or produced in situ, for load-bearing or partitioning purposes. Finally, adobe bricks, which are hand-moulded and air-dried, are mainly used for non-load-bearing or semi-load-bearing walls.

2.1.2.2 The performance of raw earth lies in its composition. This natural material mainly combines clay, which acts as a natural binder, and aggregates (sand, gravel) which form the structure. This composition can be optimised according to the construction techniques used, with, for example, a ratio of 70% sand to 30% clay in the case of modern rammed earth and 20% clay for CEB. These proportions are very difficult to define precisely in advance and require specific expertise for each soil.

2.1.2.3 The density of each raw earth construction method varies because each method requires a specific particle size profile.

- Torchis: approx. 1,400 to 1,800 kg/m³.
- Adobe: approx. 1,600 to 1,800 kg/m³
- Pisé: approx. 1’800 to 2’000 kg/m³
- CEB: approx. 1,900 to 2,100 kg/m³

2.1.2.4 Compressed raw earth, whether adobe, rammed earth or compressed earth blocks (CEB), achieves compressive strengths of up to 7 MPa for unstabilised elements.

- Torchis: < 0.5 MPa
- Adobe: 0.5-1.5 MPa
- Pisé: 1.0-5.0 MPa
- CEB: up to 7.0 MPa

For stabilised elements such as CEB, these can reach up to 13 MPa.

2.1.3 Earth Technical properties

2.1.3.1 Raw earth has a good fire resistance value, classified as RF1 (resistance to fire and smoke development) according to the AEAI standard. Raw earth is a naturally fire-resistant material, capable of withstanding flames and high temperatures.

2.1.3.2 Raw earth is a very good moisture buffer. It maintains relative humidity between 45-60% in rooms (optimum humidity). Thanks to the clay it contains, raw earth can absorb up to 3% of its weight in water vapour (variation from 4% to 7%). In this way, the clay absorbs the excess water vapour contained in the indoor air, and releases it if the air dries out.
The water vapour diffusion resistance of raw earth is very low: μ = 5 to 10 (100 for concrete), which makes it very breathable and allows natural regulation of indoor humidity by encouraging the exchange of moisture without condensation.

2.1.3.3 Depending on its density, the thermal conductivity of unbaked clay is around λ ≈ 0.75-1.1 W/m-K, which makes it a poorly insulating material. However, its high thermal capacity (C ≈ 1’000-1’400 J/kg-K) and inertia due to its mass (~2000 kg/m³) make it an excellent regulator of indoor temperature.

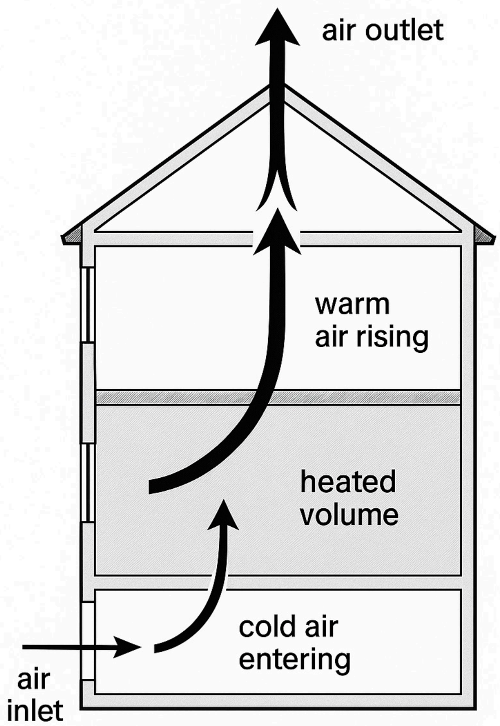
2.1.3.4 Earth walls have good acoustic insulation, up to 60 dB Rw+C to airborne sound, due to their mass and porous texture. Unsmoothed raw earth finishes are open porosity materials, which gives them good sound absorption capacity and therefore interesting acoustic correction properties. The use of raw earth makes it easy to create organic, rounded and irregular shapes, ideal for improving interior acoustics by diffusing sound naturally and avoiding parasitic echoes.

2.2 Earth Comfort

2.2.1 Earth natural Ventilation and Humidity

2.2.1.1 Natural ventilation refers to all air movements generated without recourse to mechanical systems. It is based mainly on differences in air pressure, temperature and density, generated by the wind or thermal gradients.
Earth, as a solid, breathable material, plays a complementary role in natural ventilation systems: it stabilises the interior temperature and promotes air circulation through differentiated thermal effects.

2.2.1.2 The stack effect is a physical phenomenon in which warmer, less dense air rises naturally to the top of an enclosed space, drawing in cooler air from below. This principle is the basis of many natural ventilation strategies in buildings.



$$Q = C_0 A \sqrt{2gH\left(\frac{T_i - T_o}{T_i}\right)}$$

A = flow area, m^2

C = discharge coefficient (usually taken to be from 0.65 to 0.70)

g = gravitational acceleration, 9.81 m/s^2

h = height or distance, m

$\boldsymbol{T_i}$ = average inside temperature, K

2.2.1.3 Good natural ventilation also relies on appropriate architectural design: opposing, well-oriented openings channel the prevailing wind and promote air renewal.

2.2.1.4 The earth's thermal inertia slows down temperature variations. This thermal differential, particularly between the earth walls and the ambient air, can encourage micro-circulation of air, which is useful for indoor comfort.

2.2.1.5 Earth's ability to absorb and then release moisture prevents indoor air from becoming saturated, reducing the risk of condensation and maintaining healthier air, compatible with gentle ventilation.

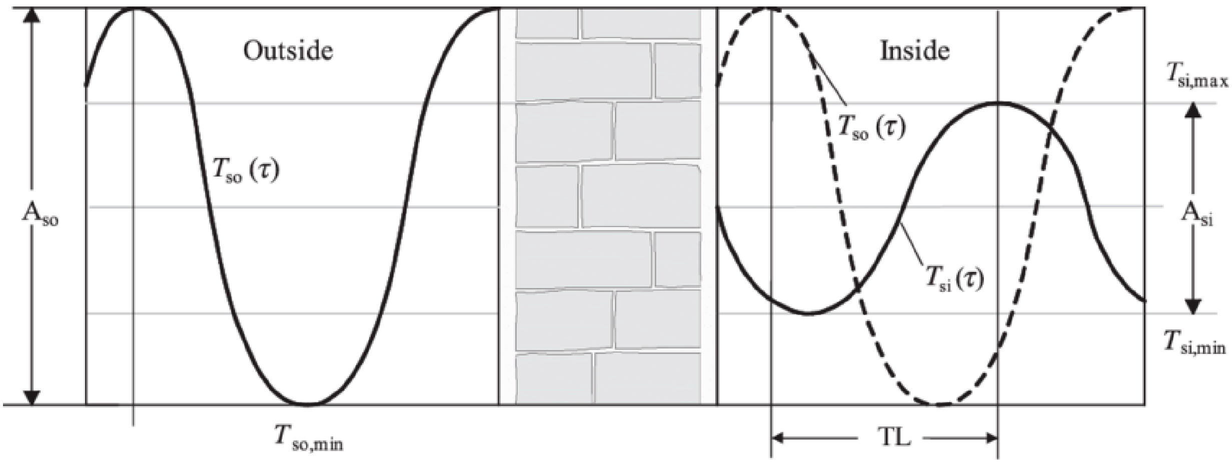
2.2.1.6 Devices such as wind towers (badgir), often made of earth in traditional architecture, illustrate the effectiveness of earth in natural ventilation. Their shape guides the air and their thermal mass accentuates pressure differences.

2.2.2 Earth Inertia

2.2.2.1 As a building material, raw earth is renowned for its passive qualities in terms of thermal comfort. One of its key properties is thermal inertia, which plays a decisive role in regulating the indoor climate, temperature stability and energy efficiency.

2.2.2.2 Thermal inertia is the ability of a material to store heat and then release it slowly. This property depends directly on the density (ρ), the mass heat capacity (c) and the thickness (e) of the material.

2.2.2.3 A rammed earth wall acts as a thermal buffer: it absorbs heat during the day and releases it at night, with a time lag that improves indoor comfort, especially in hot or continental climates.



2.2.2.4 Thanks to its inertia, unbaked clay attenuates rapid variations in outside temperature. This makes it possible to maintain a more constant indoor temperature, without the need for intensive heating or air-conditioning systems.

2.2.2.5 In summer, thermal inertia prevents overheating by absorbing excess solar energy.

In winter, it retains indoor heat for longer, especially if combined with passive solar gain.

2.2.2.6 Well-designed earth buildings have reduced energy consumption: thermal inertia avoids the need for active systems (heating/cooling), thus reducing costs and emissions.

2.2.2.7 The inertia effect can be combined with natural night-time ventilation: the earth walls, cooled by fresh air at night, limit temperature rises the following day.

2.2.2.8 In addition to the physical data, thermal stability creates a soft indoor environment, without draughts or sudden changes in temperature, which improves the feeling of well-being.

2.2.3 Earth acoustics

2.2.3.1 Raw earth offers excellent potential for acoustic comfort, thanks to its density, absorption capacity and formal plasticity. Properly used, it can limit internal and external noise pollution while improving the sound quality of living spaces.

2.2.3.2 The acoustic performance of a material depends mainly on its mass and its ability to absorb or reflect sound. Raw earth, with its high density, is naturally suited to sound insulation.

Massive earth walls: the heavier a material, the better it is at attenuating airborne sounds (voices, traffic, music). Raw earth, particularly rammed earth or compact blocks, greatly limits the transmission of external noise.

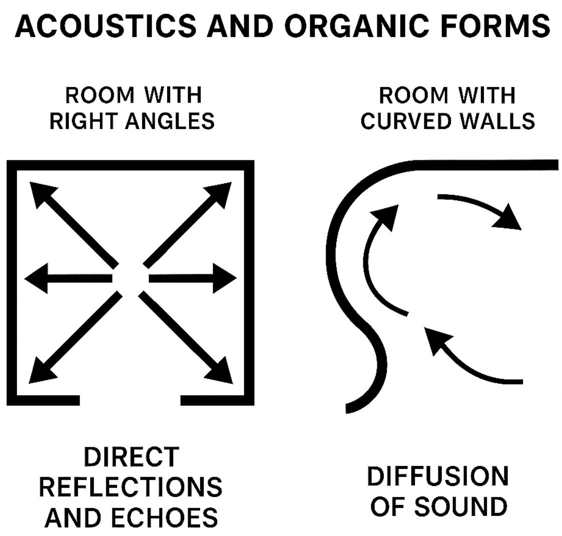
Thickness = performance: a 30 to 40 cm rammed earth wall can reduce airborne noise by up to 50 dB, depending on the configuration.

2.2.3.3 Flat, hard surfaces encourage direct sound reflections, creating echoes and harsh acoustics. Conversely, curved, hollow or irregular shapes help to :

- Diffuse sound rather than reflecting it head-on.
- Avoid focal points or localised resonances.
- Create a soft atmosphere conducive to listening or relaxation.

Examples:

- Undulating mud walls in meditation rooms or libraries.
- Curved adobe partitions in living rooms.



2.2.3.4 Earth plasters (clay + fibres) provide a natural roughness that acts as a high-frequency absorbing material. This reduces the effect of reverberation in enclosed spaces.

2.2.3.4 The combination of mass (soundproofing) and shape (sound diffusion) enables raw earth to play a dual role:

- Insulation between spaces.
- Creation of soft acoustics inside rooms.

2.3 Other forms of Comfort

2.3.1 Natural Light

2.3.1.1 Natural light is essential for the physical and mental health of users. Good design ensures :

- Reduced glare and even light distribution.
- Energy savings by reducing the need for artificial lighting.
- A more balanced circadian rhythm, notably by encouraging exposure to morning light.
- Raw earth buildings, often designed with deep openings and thick walls, allow light to filter through gently, creating serene interiors.

2.3.2 Presence of nature

2.3.2.1 Vegetation plays an important role in comfort:

- Psychological: it soothes, reduces stress and improves the perceived quality of the space.
- Thermal: it provides shade, cools through evapotranspiration and filters the wind.
- Acoustics: plants absorb and diffuse certain sound frequencies.
- Air quality: by absorbing CO2 and humidifying the air, they contribute to a better indoor atmosphere.
- The integration of patios, planted walls or planted courtyards is proving particularly relevant.

2.3.3 Natural materials

2.3.3.1 Unprocessed or minimally processed materials (wood, stone, plant fibres, earth, lime, etc.) offer a high level of sensory comfort:

- Warm to the touch (unlike metal or plastic surfaces).
- Subtle, non-polluting odours.
- Soft colours, often derived from earthy palettes.
- The presence of these materials also promotes a healthy atmosphere, by limiting VOC (volatile organic compound) emissions.

2.3.4 Sensorial athmosphere

2.3.4.1 The ambience of a space does not depend solely on its measurable performance. Intangible elements also contribute to comfort:

- The texture of the surfaces: the irregularity of earth plaster gives a rich tactile and visual reading.
- Ambient sound: porous materials + organic shapes = soft acoustics.
- Temperature: thermal inertia gives a reassuring feeling of stability.

2.3.5 Outside World

2.3.5.1 The visual and physical link with the outside contributes to well-being:

- Distant views: opening onto a natural landscape = stress reduction.
- Low openings and walk-through spaces: better ventilation, light and perceived quality.
- The transition between inside and outside: thresholds, loggias and galleries help you to adapt to the local climate.

Organizations represented on the SIA 1800 Commission

Down to Earth remedies Association

Commission SIA 1800

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