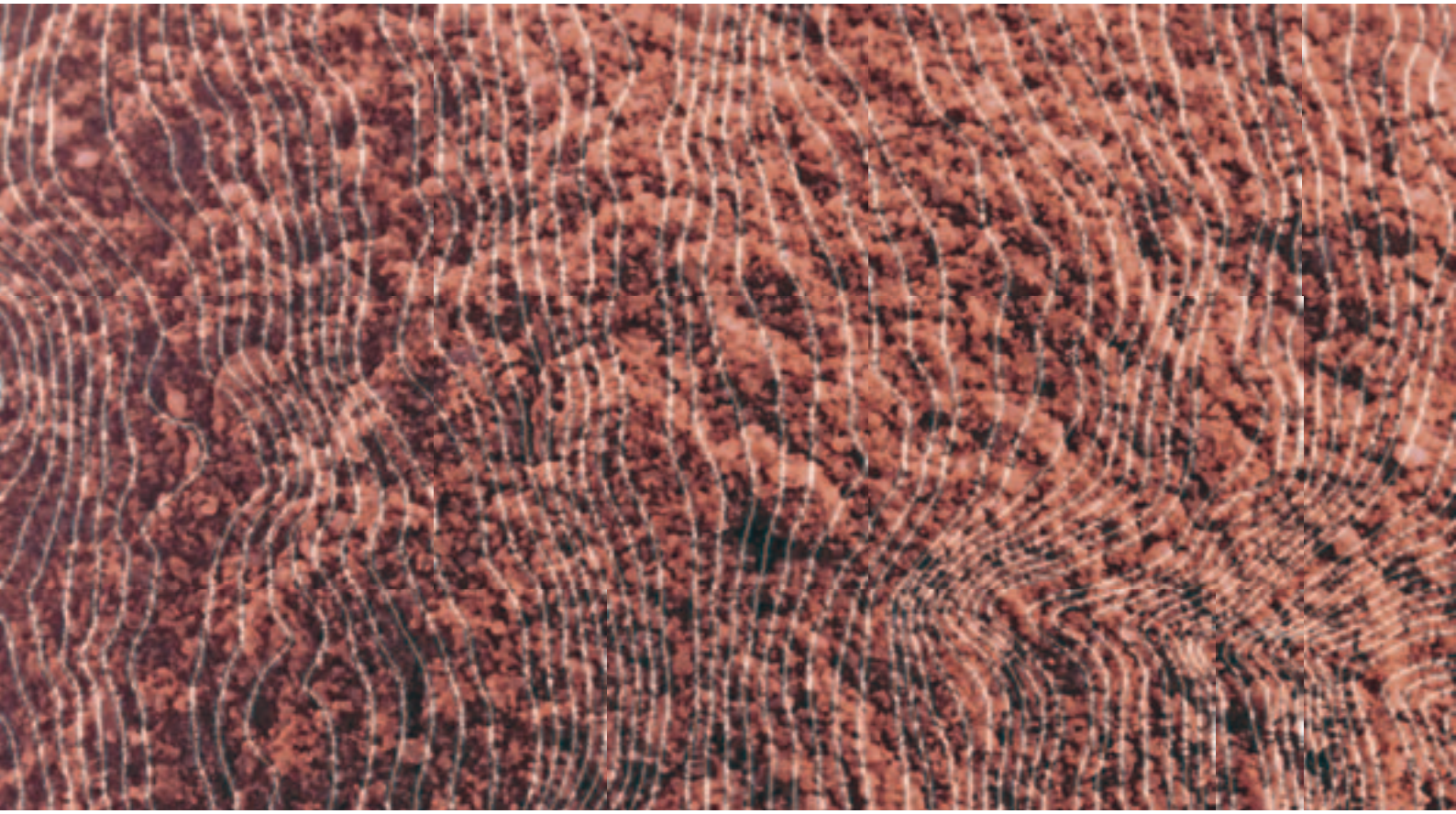
Building with Earth

Consumer information



Note: This brochure aims to provide an understandable and factually-grounded general introduction to building with earth. It details information about earth as a building material and its properties, as well as an overview of construction techniques, their application and individual requirements. However, it does not provide specific information for preparing earthen building materials, design details or technical guidelines for building with earth.

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Consumer information – who is it for?

Much has already been written about building with earth in its various forms. In addition to standard works there are a number of publications and information brochures primarily aimed at architects, planners and producers of earth-based products. These include the Earthen Building Regulations (Franz Volhard and Ulrich Röhlen, ISBN 3-528-02558-1) published by the Dachverband Lehm e.V. in 1998, a selection of producer's catalogues (for example the claytec architect's folder) as well as various other independent publications, books and newsletters.

The "consumer group" of people interested in building with earth is broadening steadily. This brochure is for all those looking for an easily understandable introduction to earthen building and earthen building techniques:

- **Private individuals and builders** interested in using earthen building materials who are looking for further information about building with earth in the home.
- **Public organisations & ecclesiastical institutions** commissioning building works.
- **Public authorities & decision makers** in the fields of both conservation and new building.
- **Educators and trainers** in the building construction trade.
- **Financial and insurance institutions** who need to make informed decisions about building financing and insurance costs.
- **DIY builders**.
- **Ecologically oriented organisations** with an interest in self-help, self-build and renovation work.
- **Health insurance advisers, doctors and politicians** with a responsibility for building healthy environments.
- **The media**: newspapers, journals and television.

1

2

Earth – a building material for the future

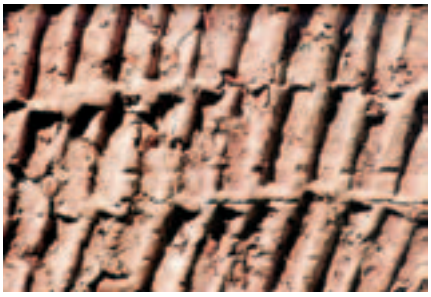
3

Earth has been used as a building material for thousands of years. Almost a third of the world's inhabitants live in houses made of earth. In Germany alone, there are more than two million buildings in which earth has been used as a building material.

The use of earth in building first began to decline as the industrialised manufacture of building materials increased from the end of the 19th century onwards. Immediately after each of the two world wars when building material supplies were scarce, earth briefly regained importance as a readily available building material. After the destruction of the wars, the building industry was reinstated and the provision of housing became a priority. The solution was seen in high-rise rationalised housing systems made of prefabricated concrete building elements. As a result, the West German DIN norms for building with earth were withdrawn in 1970. The regulations in the former German Democratic Republic (DDR) remained in force until the reunification in 1990, however here too concrete prevailed and earth was not used for reconstruction. Earthen building declined once again.

Since the 1980s environmental considerations have become increasingly important throughout Germany and Europe as well as internationally. Environmentally friendly, energy conscious and sustainable building using healthy and recyclable building materials is experiencing a renaissance. Where earthen building had previously been limited to the realm of conservation and renovation work, earth has been 'rediscovered' in recent years as an ecologically sound and healthy building material. Throughout Europe, internationally and particularly in developing countries, earth is now regarded as an ideal building material for the future.

1 Settlement, Ghana
2 Half-timbered house, Oberfranken
3 Chapel of Reconciliation, Berlin



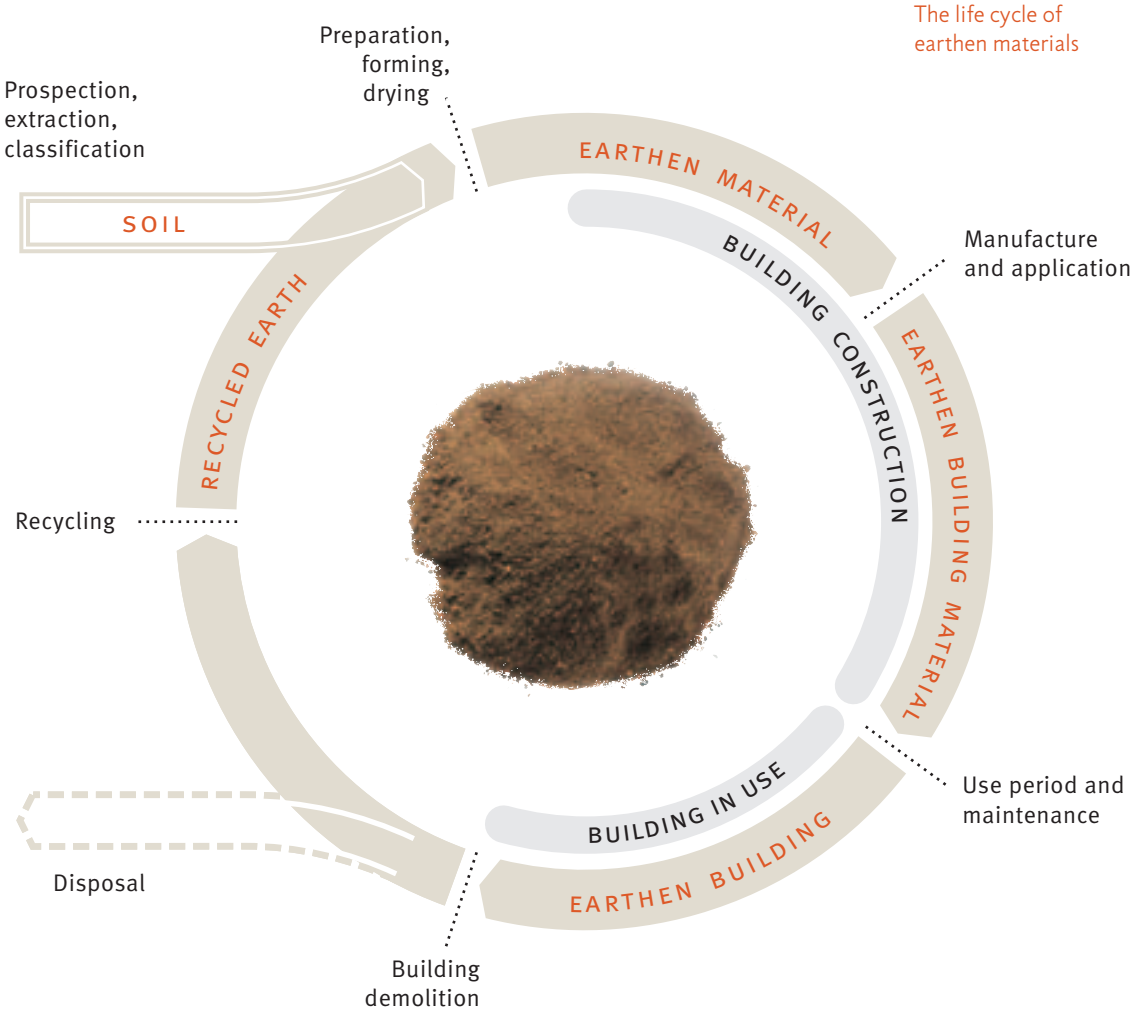
Clay and earth

Earth is a natural weathering product of solid rock and forms the uppermost surface of our planet. Loam and clay that remains at the place of origin is known as weathered clay. Soil that has been transported elsewhere by ice, wind or water is known as moraine clay or loess soil.

Earth consists of a mixture of different-sized grains of gravel, sand, silt and clay. Clay contains microscopic attractive particles, so-called clay minerals, which act as a binding agent holding together the larger sand and gravel particles within the earth mixture.

Earth is a reusable material. After its useful lifetime as a building material, it can be broken down and recycled for use again as a building material or returned to the earth. It forms a self-sustaining life-cycle, and therefore fulfils one of the primary criteria of ecological building.

The life cycle of earthen materials



The uses of earth

1

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The history of building with earth reaches back many thousands of years. A wide variety of different techniques have been employed to build all manner of structures and buildings. When correctly constructed and maintained, earthen buildings can last hundreds of years.

The natural raw material earth can also be used for many other purposes:

Heating stoves: The soft radiant warmth emanating from an earthen or tiled heating stove is much more tangible than the warmth provided by conventional central heating. Stoves made with earthen materials offer many possibilities for artistic expression. In developing countries stoves made with earth are often used as an oven for cooking.

Pottery: Earth with a high clay content has traditionally been used to make household vessels and containers of all kinds as well as artistic objects and sculpture. They can be formed by hand or turned on a wheel, be left as pure form or be decorated in various ways.

Dikes and pond sealing: Unlike its use in building, earth can also be used to seal surfaces when moist and wet. The clay minerals swell giving clay-rich earth an impervious quality. This contrasts with its use for building purposes, where other properties are important such as stability of form and load-bearing capacity.

In addition, mud and earth are also used in medicine, both internally and externally, as well as for cosmetics.

1 Earth heating stove
2 Frafra drinking vessel, Ghana

The properties of earth as a building material

Earth has a series of individual characteristics and qualities:

Earth **dries and hardens in the air**. In contrast to concrete and cement or to lime and plaster, hardened earth can be softened again to a plastic mass by adding water. This hardening and softening quality of earth can be repeated infinitely. It can therefore be recycled as often as required with minimum energy input, and is one of the particularly ecological qualities of the material. Note that the use of binding additives may adversely influence the plasticity of earth.

The **solubility of earth** in water is the primary reason for its malleability and ease of use. It is however often seen as its major disadvantage. The application of earthen building materials is limited to areas where it is less exposed to water.

Earth has **good sorption properties**[1]. Humidity in the air can be absorbed by the pores of the earthen building materials, and as the interior room climate becomes drier the earth can release moisture back into the air. This absorption and dissipation is accompanied by regulatory processes. Earth "breathes". Earthen building materials act like air filters – they help regulate and filter the interior room climate. A healthy indoor room climate is beneficial for all those who live in it. The healthy properties of earth are dependent upon the pores in the material being allowed to breathe. This means earthen plasters should not be painted with water impervious finishes (such as oil-based paints) or coverings. When kept dry, earthen building materials are resistant to fungal attack. Earthen building materials which are applied in moist condition must be allowed to dry thoroughly in order to avoid temporary mould during the building process.

Earthen materials exhibit **high capillary conductivity** at low relative humidity levels. This means they are ideal for use as panel infill when renovating timber-frame buildings: the earth absorbs moisture thereby keeping the wood dry. In addition earth can be used as insulation where vapour barriers are not required.

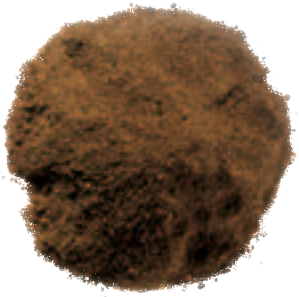
The **thermal capacity** of earthen materials to absorb and re-radiate heat can be used to harmonise the degree of air temperature fluctuation in rooms within buildings made with lightweight constructions.

New scientific investigations have also shown that, in comparison to other mineral building materials, earthen building materials are particularly good at **shielding against high-frequency electromagnetic radiation** of the kind emitted by mobile services and cordless DECT telephones[2].

Last but not least, earthen building materials are **attractive**. Their natural warm and even colouring means they are aesthetic and attractive even when left unpainted.

1 Heinz-Gerd Holl and Christof Ziegert: **Vergleichende Untersuchung zum Sorptionsverhalten von Werktrockenmörteln** in: Moderner Lehmbau 2002, p. 91-101, Fraunhofer IRB Verlag, ISBN 3-8167-6118-6

2 Pauli, P.; Moldan, D.: **Reduzierung hochfrequenter Strahlung im Bauwesen – Baustoffe und Abschirmmaterialien**, unpublished investigation; Iphofen 2000



Earthen building materials

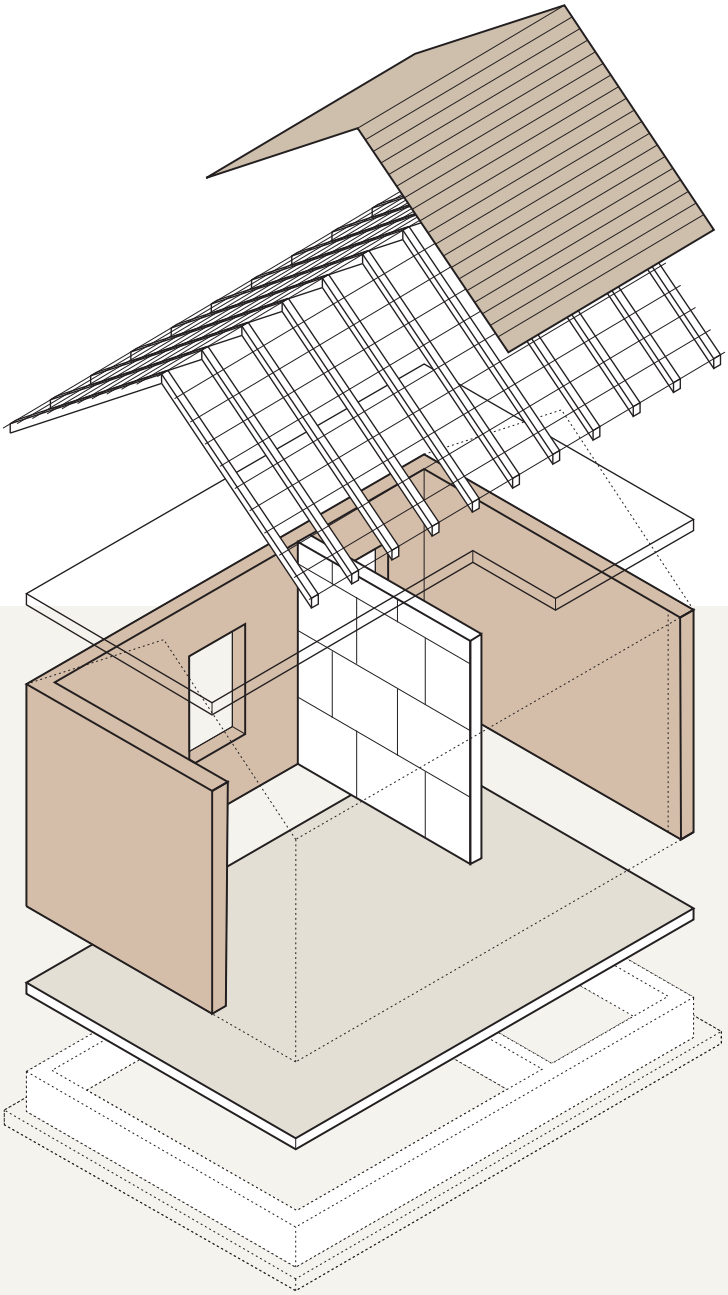
Just as with brick and concrete, a broad palette of building products have been developed covering a wide range of different applications. In comparison to other mineral-based building materials, modern earthen building products are still relatively new, and the product range is innovative and expanding. And like their brick and concrete cousins, they have to fulfil the same general requirements as regards noise insulation, fire safety, stability and thermal insulation.

The German earthen building regulations, the Lehmbau Regeln, describe the main classes of earthen building products currently available. Earth is available in shaped and shapeless form, wet or dry, and loose or packaged in sacks or on pallets. Commercially available products range from loose light clay and loam fill material, through diverse earthen renders and mortars, to dried clay blocks, unfired bricks and pressed clay panels of different thicknesses.

	Rammed earth	Mud	Clay straw	Light clay	Loam filling	Earth mortar	Earth blocks	Earth panels
	UNSHAPED BUILDING MATERIALS						SHAPED	
Floor	O				O			
Wall loadbearing	O	O				O	O	
Wall freestanding	O	O	O	O		O	O	O
Ceiling & Roof			O	O	O		O	O
Dry board cladding							O	O
Plaster			O	O		O		

The uses of earthen building materials

Earthen materials in building construction



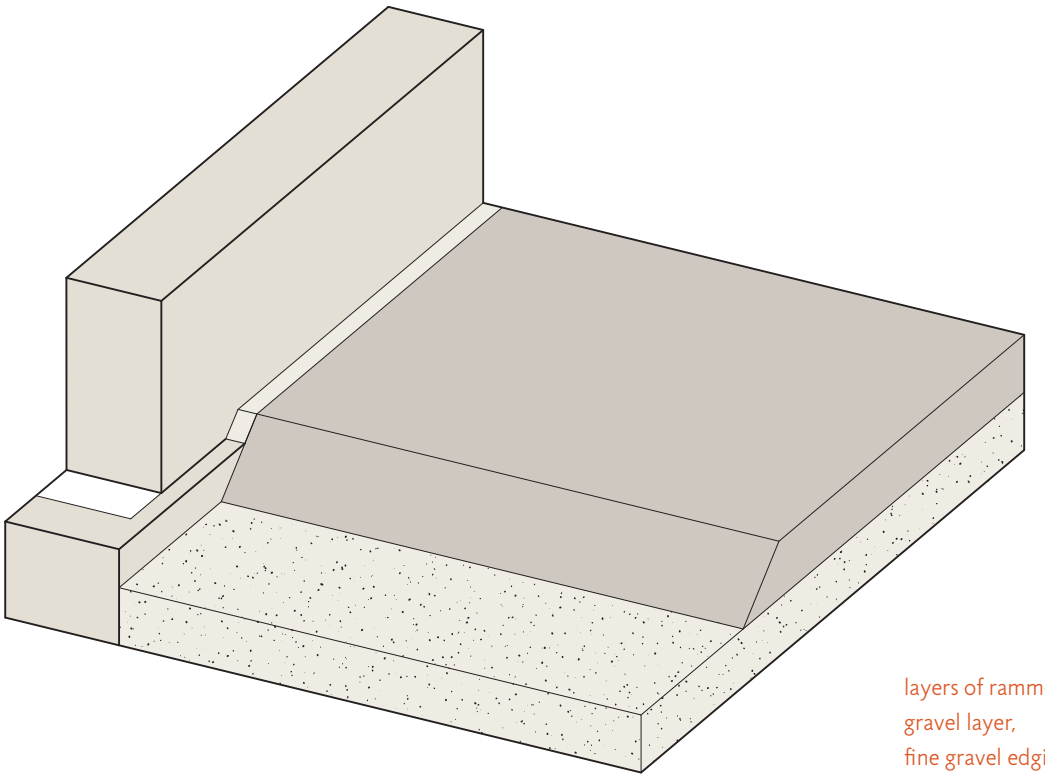
The primary elements of a building

In principle, earthen building materials can be used in all areas of building construction, most notably in housing, public buildings (for instance children's nurseries and schools), social and ecclesiastical buildings, as well as in industrial buildings.

Earth can be used in a variety of different ways for most parts of a building from floors and ceilings to walls and roofs. The proportion of earthen building materials used varies according to situation and construction method – the term "earthen building" is therefore relative. Supporting walls can be made entirely of rammed earth or in combination with wood as a timber-frame construction. Earthen plasters are becoming increasingly widespread and can be applied to almost any surface.

Earth should not, however, be used in the construction of footings and foundations. Even in buildings with a high proportion of earthen materials, the foundations are typically executed as reinforced concrete strip foundations, or in older buildings are made of stone blocks.

For ease of reference, a LR-number is provided for each of the techniques on the following pages. These refer to the relevant chapter of the Lehmbau Regeln, the German earthen building regulations.



layers of rammed earth,
gravel layer,
fine gravel edging

Earth in floors

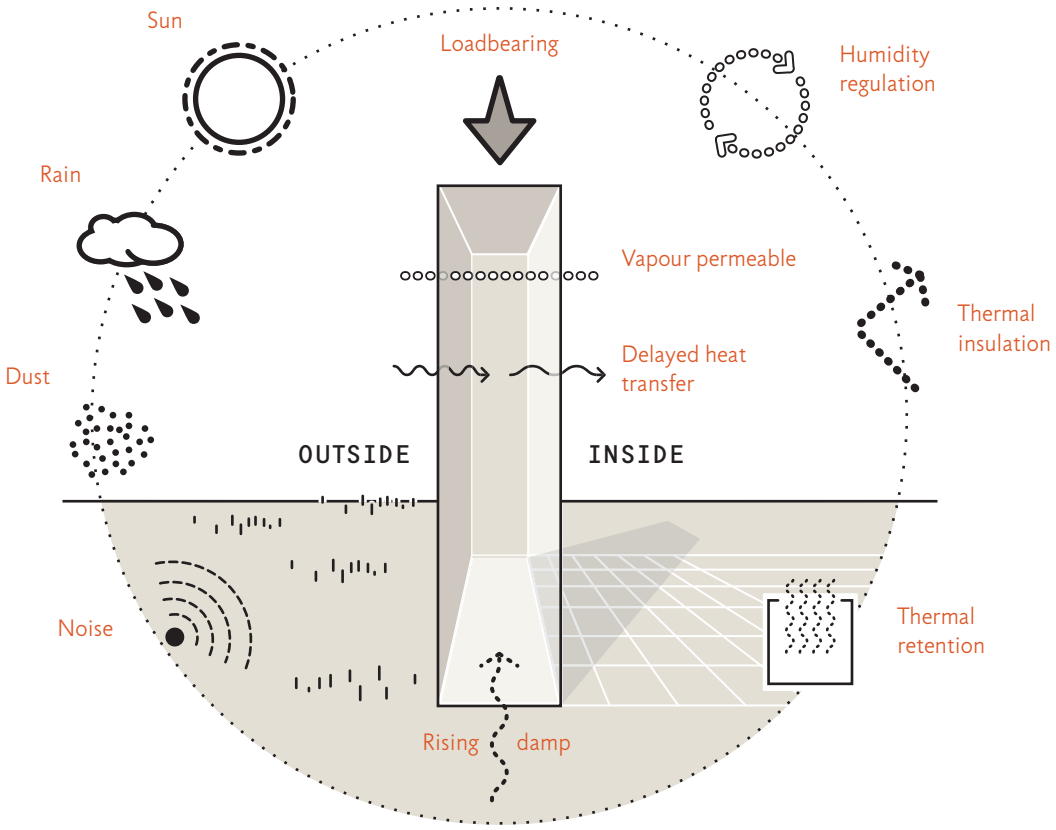
LR 3.2

Rammed earth is the primary technique used for floors made with earth, and is most common in renovation and conservation works, or for agricultural buildings, barns and storage cellars. Thicker floor-sections must be executed in several layers of earth and each layer must be compacted well.

Floors made of earth are **vapour permeable**, a characteristic that is ideal for storage and wine cellars. The firmness of rammed earth floors can be improved by wetting and renewed compaction.

The surface can be further hardened by the addition of primer oils, hard wax or linseed oil. Rammed earth floors can also be used as a base for laying brick or stone slab floors.

Important: As with other floor materials, floor constructions made with earth require a damp-proof course and in some cases insulation depending upon the intended use of the room. Earth floors are not suitable for wet environments.



Walls made of earth

A variety of different methods are appropriate for constructing walls out of earthen materials: rammed earth, cob, adobe bricks, unfired bricks, clay panels and boarding or light clay as moist fill mixture.

Earthen building materials can be used for loadbearing and non-loadbearing walls. A load-bearing wall is designed to be able to support weight from ceilings, roofs etc. (LR 4.1). Where non-loadbearing earthen building materials are used in loadbearing walls, a different material and construction carries the load. For example, a timber-stud construction can be used in conjunction with an earthen infill material, both in new-build and traditional timber-frame constructions (LR 4.3). Non-loadbearing wall elements include infill panels, wall linings and separating walls which are not part of the supporting structure.

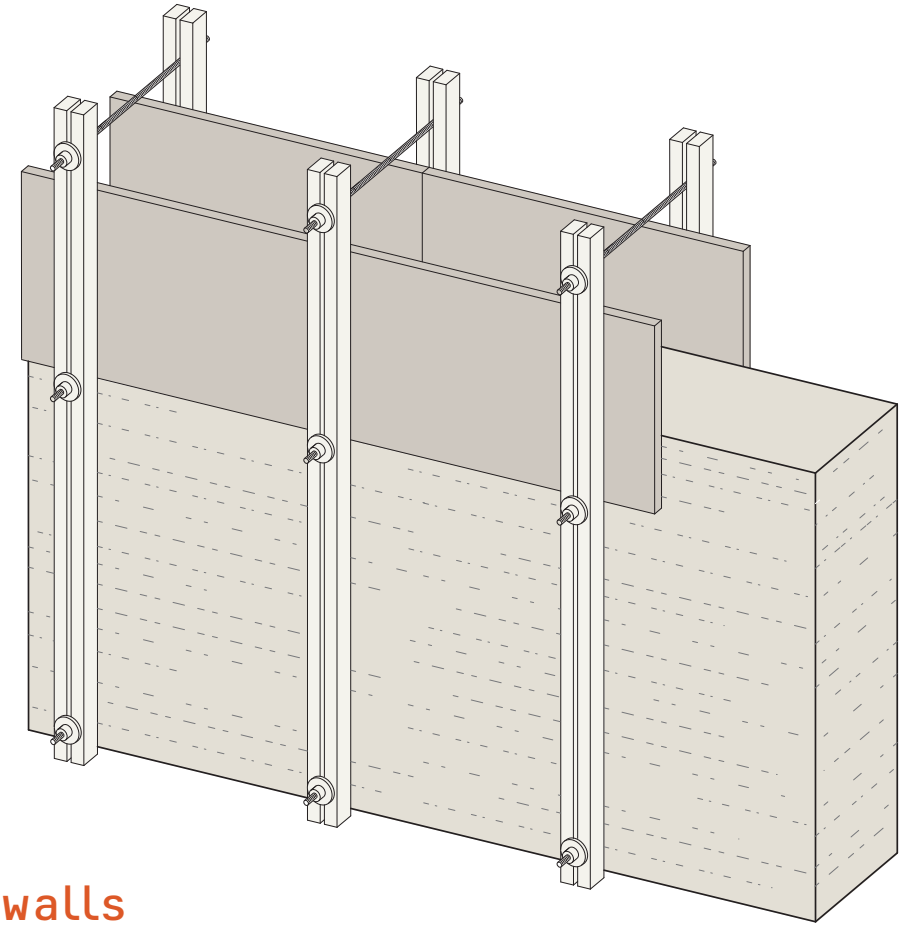
External walls have to fulfil a series of different requirements in addition to acting as a structural support:

Thermal and physical: a wall must provide sufficient insulation against cold, heat and noise, it must be resistant to wind and draughts, should not collapse in case of fire and be resistant against weathering particularly on the outside.

Aesthetic: wall surfaces should be attractive. The surface finish can be smooth, roughened, textured or coloured. This applies primarily to the interior surface of external walls.

Likewise, interior walls should also fulfil similar requirements. The thermal, physical and aesthetic requirements depend upon the function of a wall. For example, internal separating walls made with heavy and dense earthen materials can be used as a thermal heatsink which absorbs and stores warmth and releases it again back into the room as the air temperature grows cooler. As a result, fluctuations in room temperature during the day are balanced out.

Important: All walls made with earthen materials must be protected against the weather during the building process. When planning new buildings it is advisable to protect earthen wall constructions against the effects of water and moisture at their base, both from below and from the side. A water impervious splash protection (min. 50 cm above outside surface) protects against splashing rainwater, a damp-proof course against rising damp.



Rammed earth,
with formwork and
supporting construction

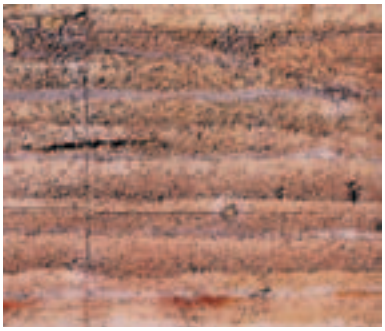
Rammed earth walls

LR 4.1.4 · LR 4.3.2

Rammed earth or Pisé wall construction can be used both for new-buildings as well as renovation work. Compared to monolithic or masonry constructions in other materials, rammed earth construction is relatively expensive. It is very often used for architectonic and aesthetic reasons rather than for functional reasons.

Rammed earth walls are constructed using formwork (typically made of steel) which is filled layer by layer with a moist earth mixture. Each layer is mechanically compacted. The formwork can typically be removed after the earth has been compressed as the earth maintains it shape. The addition of different coloured clays and earth to successive layers produces a particularly attractive surface structure which can be left exposed without further surface treatment.

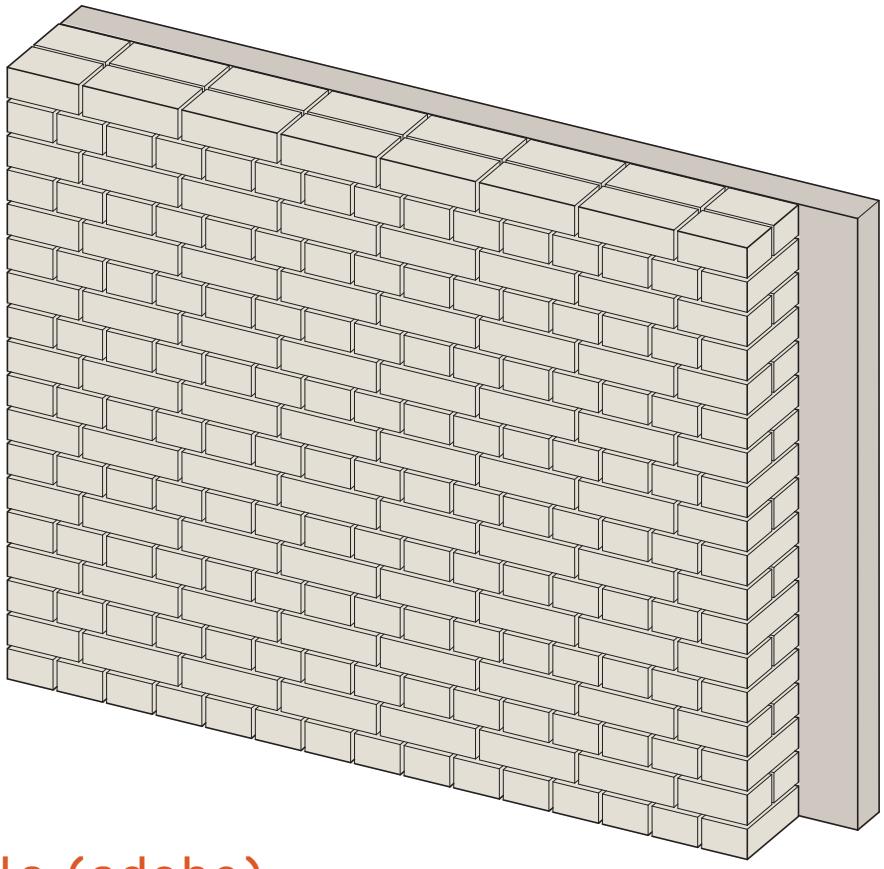
Important: Rammed earth walls should be allowed to dry out thoroughly before applying loads.



Cob walling

LR 4.1.5

Cob walling is used almost exclusively for the restoration and renovation of the large heritage of rural buildings made with cob walling. The earth mixture contains a higher proportion of straw than rammed earth and contains little to no mineral substance. Formwork is not used for cob walling, instead earthen clumps are layered on top of each other and the irregular sides are then 'shaved' flat with a spade to achieve an even wall surface.



Earth brick masonry,
External insulation

Earth block walls (adobe)

LR 4.1.3

Earth blocks can be made in a number of different ways with different densities:

Hand-moulding or throwing: a light malleable earth mixture is pressed or thrown into a mould made of wood or metal. The surface is drawn smooth, the mould removed and the blocks left to dry in the sun or with an oven.

Compacted blocks: larger format blocks are made using almost dry earth mixtures filled into a mould and compressed layer by layer, either manually or mechanically. The mould is removed immediately after compression and the blocks are dried naturally or artificially.

Manual or mechanical compression: A semi-solid earth mixture is filled into a press and compressed manually or using a machine. The block is removed from the compression chamber and dried naturally or artificially.

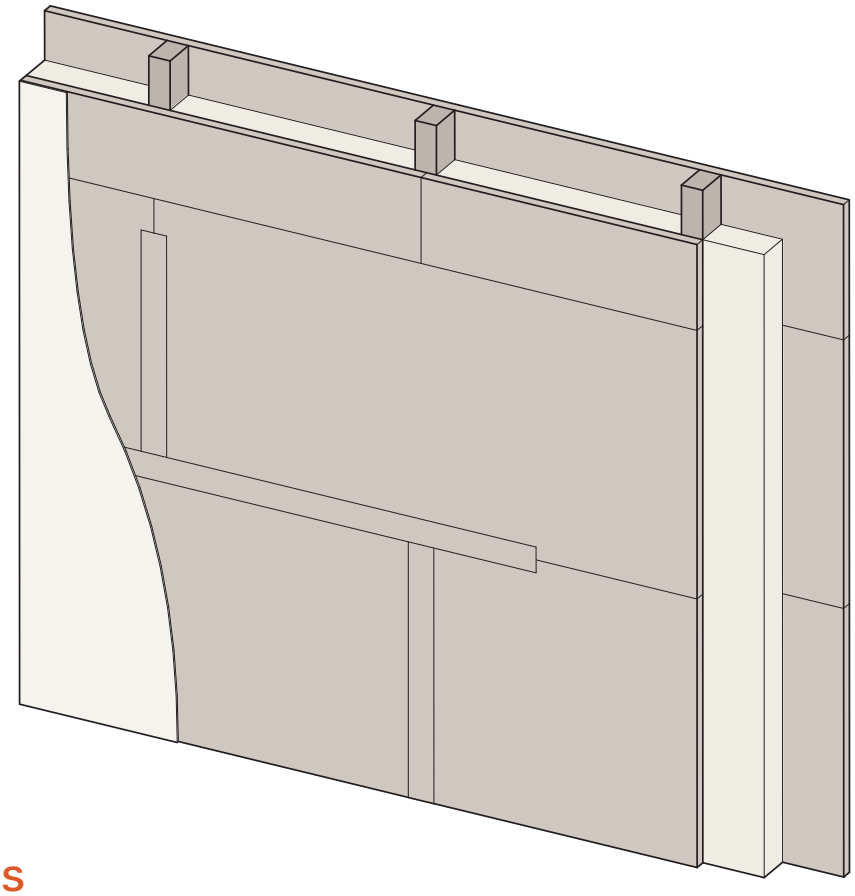
Extrusion: a pre-mixed barely kneadable earth mixture is compressed in an extrusion press (as used for manufacturing bricks) and pressed through an extrusion nozzle of the desired block dimensions. The endless extrusion is then cut to the block size. The blocks can be left to dry naturally in the air or artificially in an oven. Blocks produced in this manner but not subsequently fired are known as 'green' or unfired bricks.

Earthen blocks can be laid like any other masonry brick in coursing and bond with fully mortared joints, preferably with earthen mortar rather than cement or cement-lime mortar. Earthen mortars are a mixture of earth and sand, sometimes with organic additives.

Earth blocks are used primarily for wall constructions (loadbearing and non-loadbearing) both for internal walls as well as external walls. They can be left visible as facing earthen brickwork or plastered.

A single or double coat of earthen plaster makes best of use of the characteristics of earth.

Important: 'Green' unfired bricks are susceptible to moisture and frost. They should therefore not be used for supporting walls or for external walls where they are separated only by plaster from the elements.



Clay building board,
insulated wall,
clay building board,
joint reinforcement tape,
fine clay plaster

Clay panel walls

LR 4.3.5

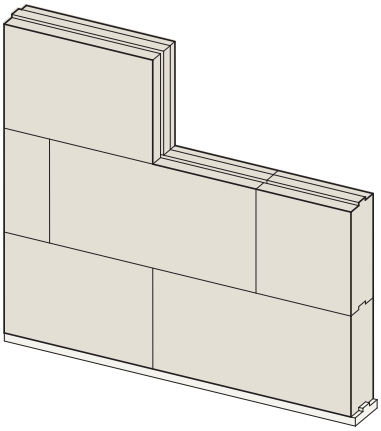
Clay panels differ from earth blocks in size and thickness as well as method of manufacture. Thick panels are available as large-format blocks with or without tongue and groove joints and are laid with mortar or glued. They can be used as self-supporting blocks for interior walls without the need for a supporting construction.

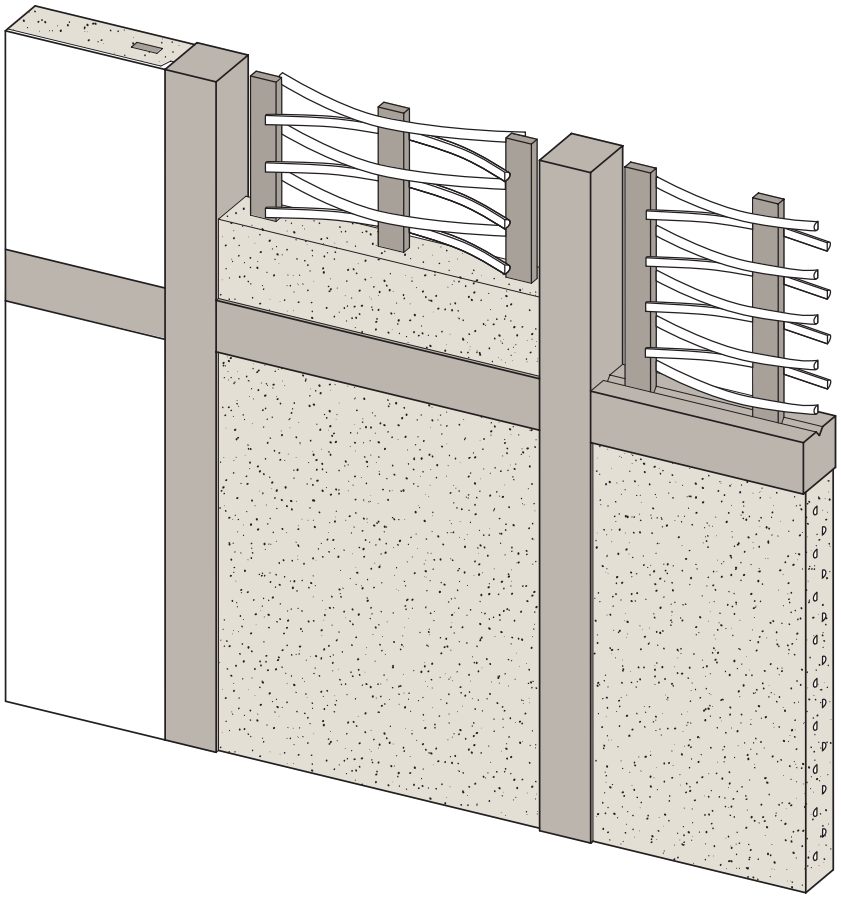
Important: Due to their precise dimensions and minimal joint gap, a thin layer of fine clay render is in many cases sufficient for the surface treatment of clay panel walls

Lightweight clay building boards

LR 4.3.5

Thin clay panels are normally 2 to 3 cm thick and of a similar size to conventional plasterboard panels. They are used primarily for non-loadbearing partitioning walls and are mounted on a supporting construction of wood or metal studs. Thin lightweight clay building boards are reinforced using organic fibres (for instance reed matting) so that they remain stable and transportable. They can therefore also be cut to size. The joints between the panels should be covered with reinforcement tape and plastered over. The cavity between two sets of panels should be filled with insulation material.





Timber frame,
straw clay "daub"
on hardwood stake and
willow branch "wattle",
External render

Earthen infill

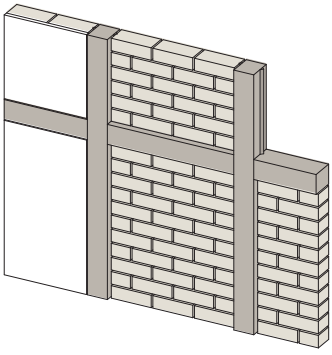
LR 4.3.1

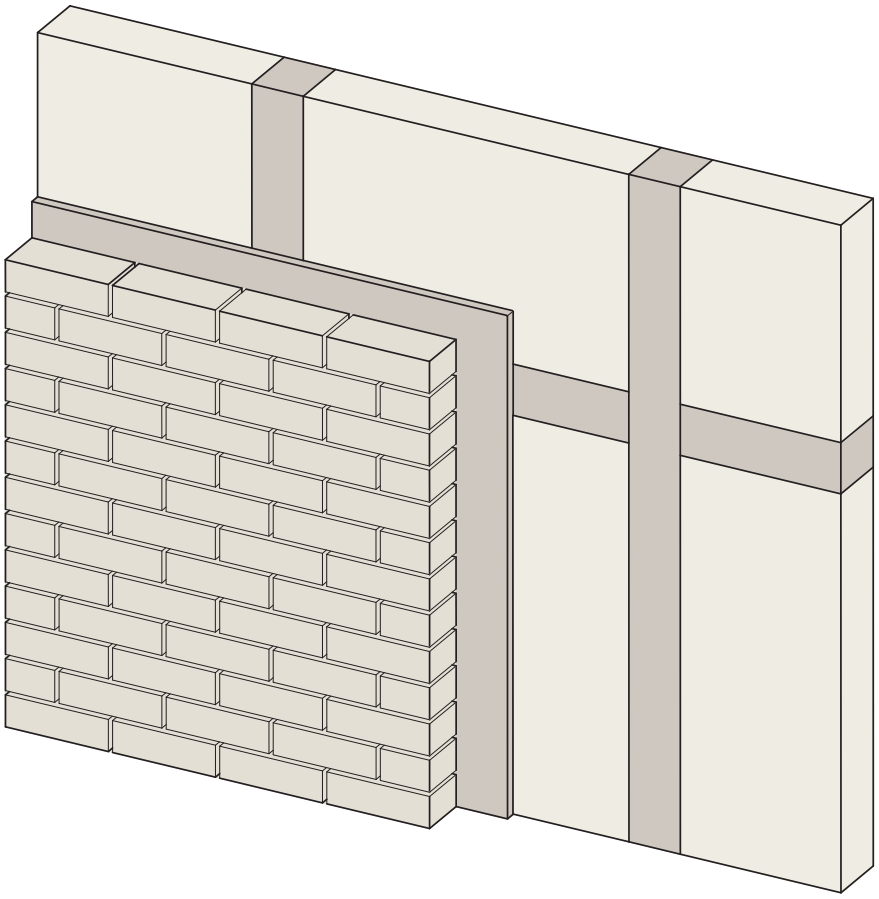
In framed or half-timbered constructions, the spaces between the timber studs, rails and braces are filled with a non-structural walling "infill" or "nogging" in a variety of different techniques. One of the oldest methods is known as "wattle and daub": Wooden struts are jammed between the timber members and woven with a wickerwork of split willow branches. This supporting "wattle" is then daubed from both sides with a clay straw mixture. This technique is used today only for renovation work.

Infill panels can also be filled with earthen brickwork or loose mixtures of moist clay straw or light clay. Where external walls are exposed to the elements, 'green' unfired bricks should not be used. As loose earthen materials dry the material can shrink leaving a gap between the timber members and infill material which should be plugged with more or the same material. Shrinkage gaps between the timber members and earthen brickwork is usually a result of the expansion and shrinkage of the timber rather than of the earth bricks. These will only become visible once the frame and infill have dried thoroughly.

Light clay infill panels that are exposed to rain should be protected by a double coat of external lime render. The adhesion between render and earth brick infill can be improved by scratching out the mortar joints to a depth of ½ cm to form a contact key. Render on walls exposed to heavy weather can be additionally strengthened by applying a plaster base to the brickwork.

Important: Whichever method is used, it is important that after the infill has dried thoroughly, it sits firmly within its frame and is not loose. Expertise is needed in the renovation and rendering of historical infill panels in half-timbered constructions.





Existing wall,
light clay mortar,
earth bricks

Wall linings

The use of wall lining (an inner leaf) is a technique often used in renovation work to improve the thermal insulation, windproofing and noise insulation of thin existing external walls. They are often used for situations where external insulation is not an option, for example where half-timbered elevations should remain visible. Wall linings are also used to improve the thermal mass of modern light-weight timber-stud and timber-frame constructions.

Wall linings can be executed as masonry wall linings using earth blocks, as light clay wall linings using moist material or as dry stacked brick lining. Clay panels and lightweight clay building boards can also be used.

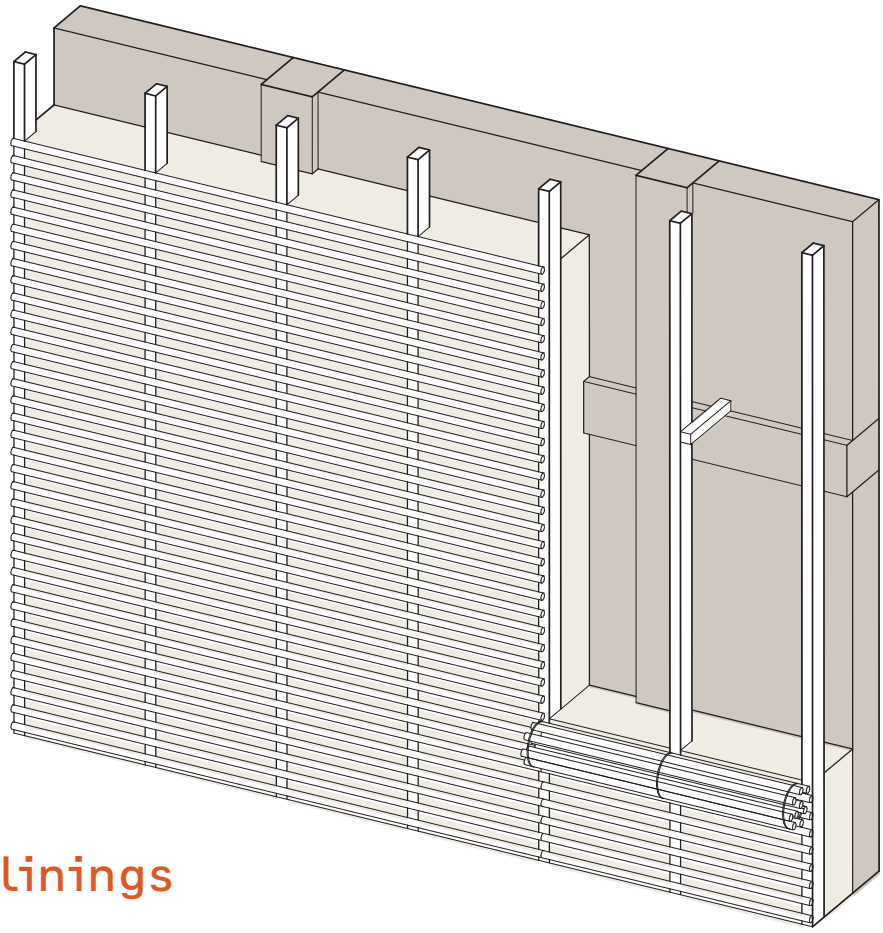
Earth block masonry wall linings

LR 4.3.3

Light clay block walling can be erected directly in front of the inner side of an external wall. Typically the earth blocks are erected slightly set away from the wall and the resulting cavity filled with a loose clay mortar mixture so that no voids result between wall and lining. This method is often chosen to increase thermal mass and insulation where no special workman's skills are required and drying times need to be kept to a minimum.

For added stability wall ties can be used where necessary to anchor the wall lining to the supporting construction.

Important: It is important to ensure that existing structures are able to support heavy wall linings. Masonry wall linings must be protected against rising damp or surface water.



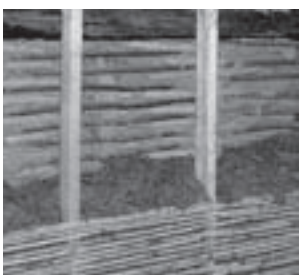
Existing wall,
light clay (loose fill),
supporting construction,
reed matting

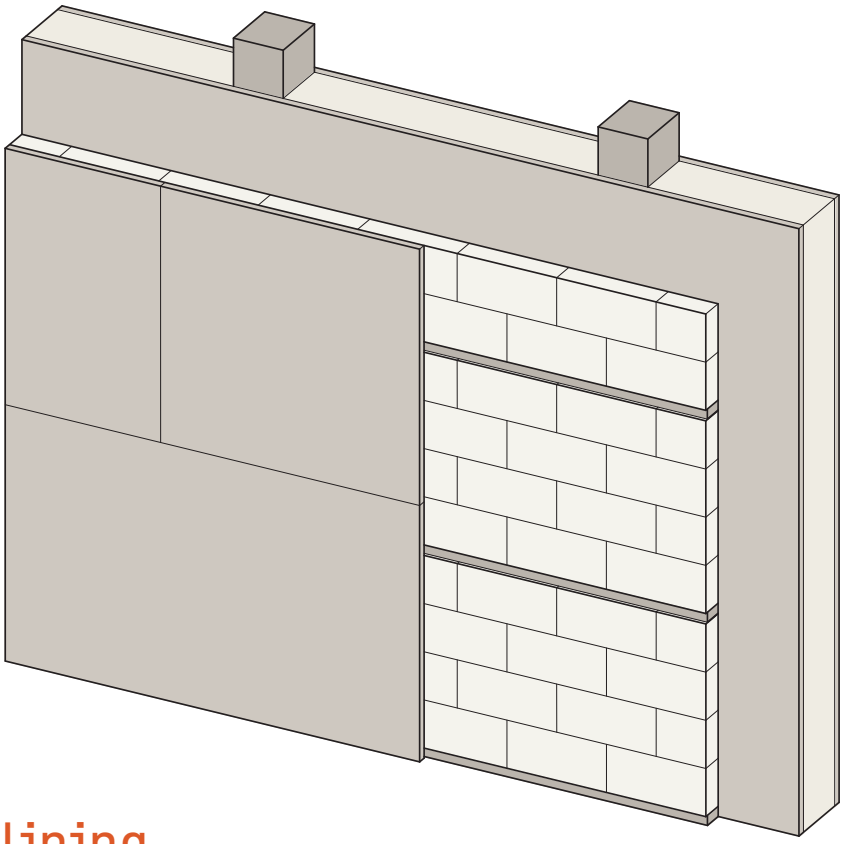
Light earth wall linings

LR 4.3.4

Wall linings of light clay use moist loose material to fill out uneven existing walls, protrusions and recesses, or where fittings or technical installations are to be flush-fitted or hidden within the depth of the wall. A supporting construction of vertical wooden battens is erected in front of the inner side of the wall and anchored to the wall, floor and ceiling. Formwork is then fixed or mounted on the battens, either as temporary sliding formwork or very often as permanent formwork (i.e. which is not subsequently removed) in the form of reed matting or laths. The moist light clay mixture is filled into the resulting space between the formwork and external wall taking care that no voids result. The mixture is compacted so that it forms a stable and solid mass when dry. Drying times can be considerable.

Important: Moist constructions must be allowed to dry thoroughly and quickly. This should be considered during the planning of the thickness, construction and formwork material. The construction must be exposed to continual ventilation during the drying period or dried artificially.



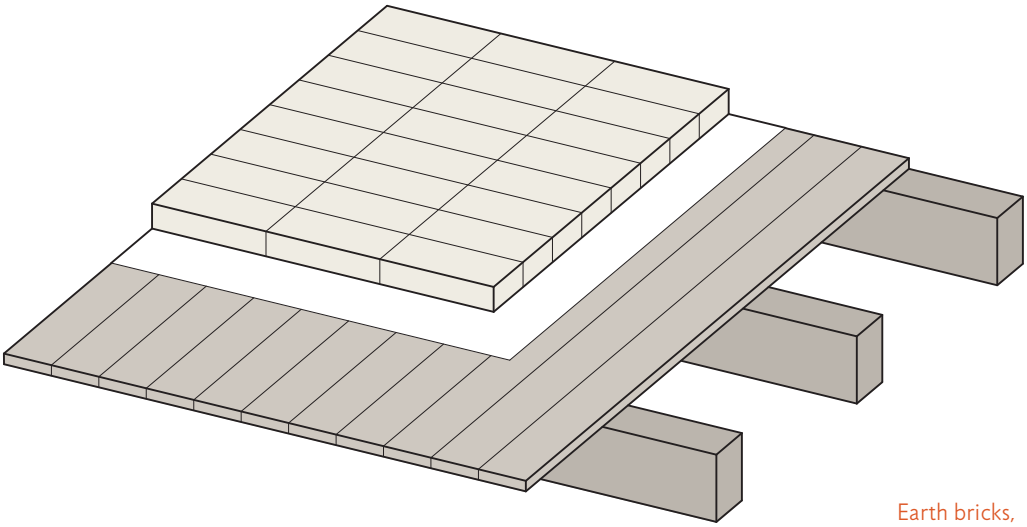


Existing wall (new-build)
with even surface,
stacked earth bricks
between horizontal battens,
clay building board,
fine clay plaster

Dry stacked wall lining

LR 4.3.6

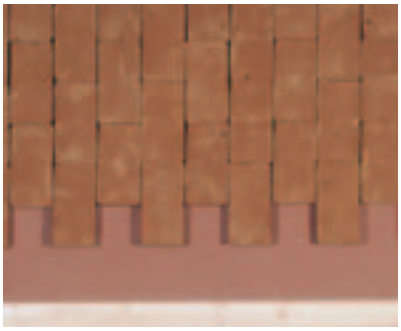
Earth blocks, bricks or 'green' unfired bricks are simply stacked without mortar against an existing supporting construction and then clad. This technique can easily be carried out as self-build method for new buildings without requiring any special workman's skills.
Important: To prevent the bricks from falling out, horizontal wooden battens are fixed to the supporting construction at intervals of approximately 50 cm.



Earth bricks,
building paper lining,
boarding,
floor joists

Earth in timber floor constructions

Earthen building materials can be used in or on timber upper floor constructions. Earth can be used in loose form as a fill material between joists, as a moist mixture wrapped around stakes or pre-formed as clay bricks laid on top of the floor surface. Wooden boarding or sheathing laid either on top of the floor joists or inserted between the joists, serves as a bearing surface and can be made of slats, round or half-section logs, timber planking or composite wood boarding. Alternatively clay panels cut to size can be inserted in between the joists. Lightweight clay boarding can be used as ceiling cladding on the underside of the floor joists.

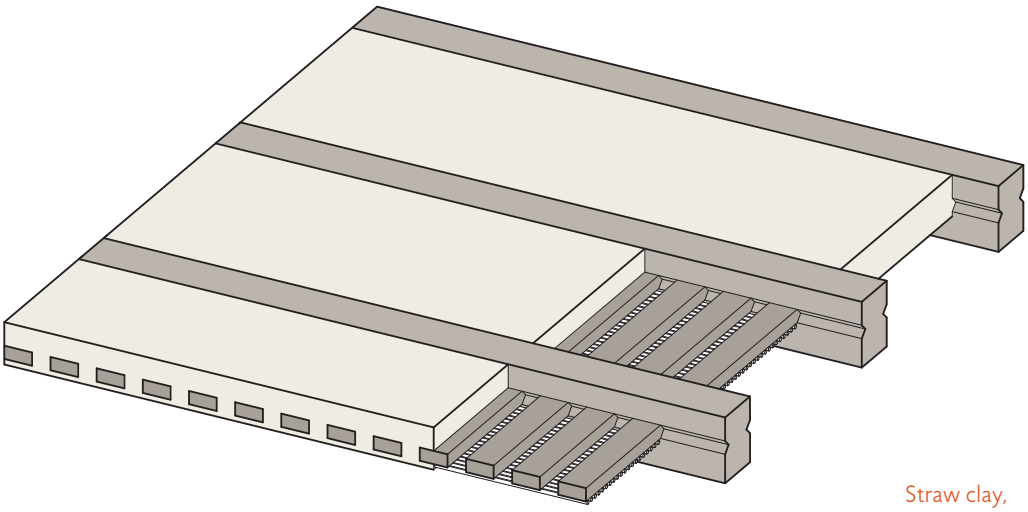


Weighted floors

LR 4.4.3

Weighted floors are used to increase the thermal mass and reduce the noise transmission of timber floor constructions in new buildings. Wooden panelling or boarding is laid on top of the floor joists so that the joists are visible from below. Earth blocks or unfired bricks are laid on a layer of building paper on top of the boarding, where necessary on an additional layer of felt matting to reduce impact noise transmission.

Important: The building paper lining must be laid with care so that earth and sand particles cannot fall into the room below.



Straw clay,
stakes between
floor joists,
reed matting

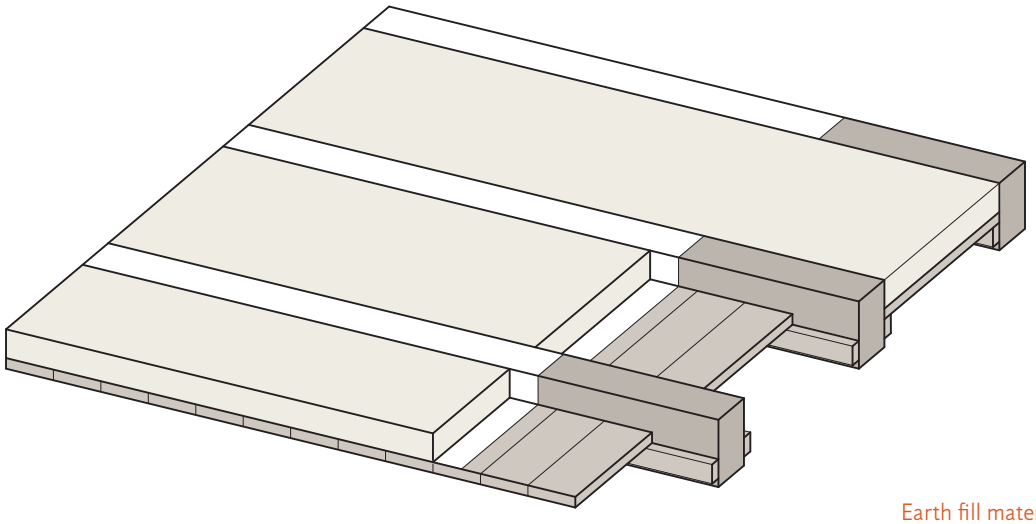
Slatted timber ceilings

LR 4.4.1

Slatted timber ceilings are typically found in half-timbered constructions and this method is therefore mostly used for renovation works. Wooden slats are either wedged between slots cut into the sides of the joists or laid upon battens fixed to the sides of the floor joists. A layer of clay straw is applied to the thickness desired. Material hanging down between the slats is pressed against the underside of the slats and smoothed off. Plaster reinforcement mesh can also be applied to the underside of the slats before the clay straw is applied.

A variant of this technique is the "earthen reel". Wooden stakes, pre-cut to length to fit the space between the floor joists, are wrapped in a thick layer of clay straw like a "reel". The wrapped reels are left to dry slightly and then inserted between the joists next to each other when still moist to form a closed surface. The protruding stake at the ends of the reels are either inserted into slots in the sides of the joists or rest upon battens fixed to the sides of the floor joists.

Important: The slats or battens must be cut exactly to fit. Too short, and there is a danger that the slats may fall out as the timber floor joists dry and warp. Too long, and they may exert pressure on the beams forcing the whole construction out of shape.



Earth fill material, building paper lining, timber panelling between floor joists

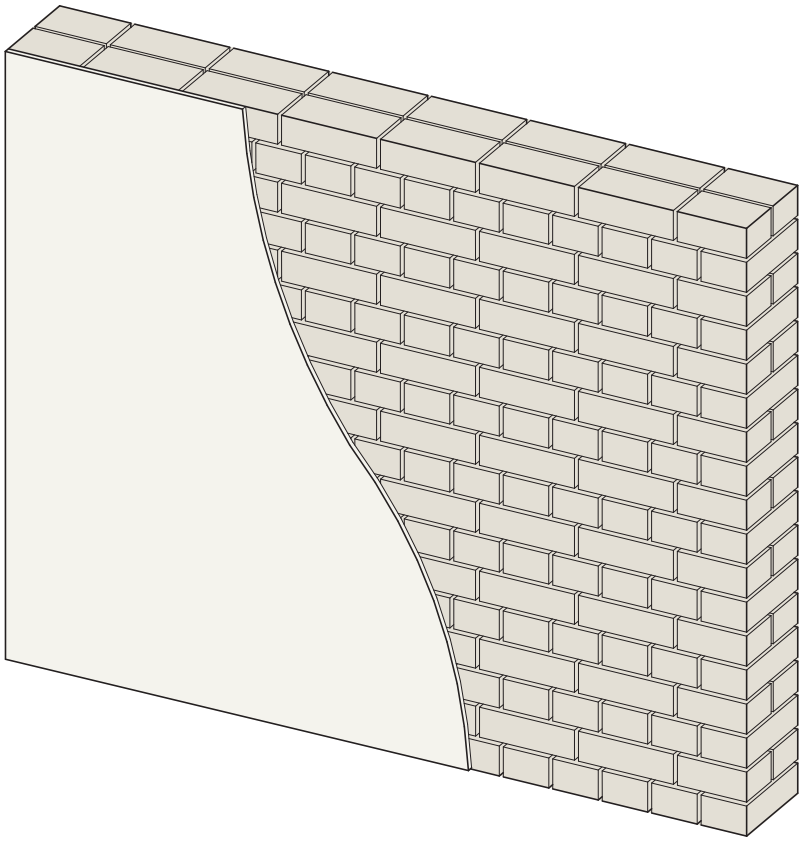
Timber panel ceilings

LR 4.4.2

Timber panel ceilings were most commonly used before and around the turn of the 19th century. Correspondingly this technique is less common in new buildings and is primarily used for the repair, completion or replacement of existing floors in historic buildings.

Timber panelling or boarding is inserted between the floor joists and provides a closed surface upon which loose or formed earthen building materials can be laid. The boarding is slotted into grooves in the sides of the floor joists or laid on battens fixed to the sides of the floor joists. Earthen materials such as unfired bricks or heavy fill material are laid on top of the boarding between the joists and help increase the thermal mass of the floor.

Important: Moist earthen fill material must be allowed to dry thoroughly. The structural capacity of the floor and joists must be able to withstand the weight of heavy earthen building materials



Existing wall,
earth plaster or render

Earth plasters

LR 4.5 · LR 4.6

Earth can be used as plaster for internal walls and ceilings as well as for external renders where walls are protected against heavy weather. Earth plasters can be applied to most typical surfaces not just those made of earthen building materials.

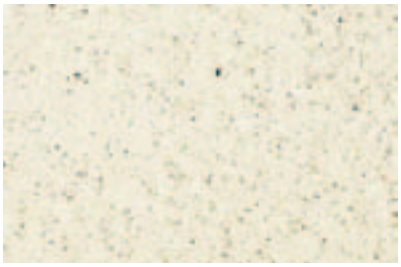
Walls and ceilings can be plastered with a variety of different surface treatments according to individual expression and comfort. Thicker layers of plaster of 1.5 cm or more make the most of earth's sorption properties and help improve the indoor climate by regulating humidity.

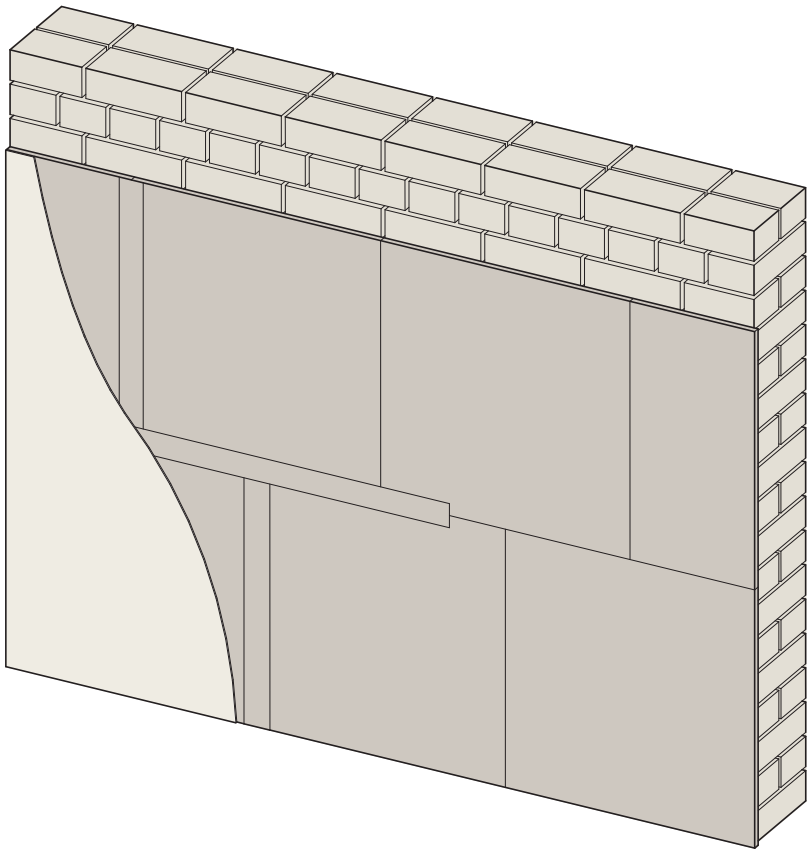
Earth plasters can be categorised in three main groups:

Coarse earth renders are a mixture of clay or loam and coarse aggregates. Fibrous additives improve the stability and abrasion-resistance of the plaster. They can be applied by hand or using a plastering machine up to a thickness of 4cm. Pre-mixed coarse renders are available commercially as moist or dry mixtures but they can equally be mixed from locally excavated earth. Coarse renders are usually painted with a finishing coat.

Fine clay plasters are made of clay and fine aggregates. They are usually applied by hand, seldom with a machine, with a thickness of 2 - 5 mm. Commercially produced fine clay plasters are available as powdered mixtures. Here too it is usual to apply a final surface coat of paint.

Coloured fine clay plasters are made of specially selected clay and earth with distinctive colourings and mixed with fine aggregates. Pigments can also be used to colour the clay mixture. These are also typically applied manually rather than with a machine, with a thickness of between 2 and 5 mm. The surface colouring is such that no further treatment or painting is required.





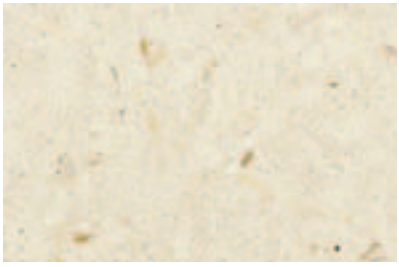
Existing wall
earthen plaster boarding,
joint reinforcement tape,
fine clay plaster

Brushable clay plasters are a recent addition to the range of commercially available plaster products. These are in essence a coating material in which earth and clay contribute only partially to the final surface hardening. In contrast to coloured clay plasters, these plasters contain coarse additives.

An alternative approach to wet plastering is offered by **earthen plaster boarding**. Pre-manufactured medium-sized boards are stuck to the backing surface much like tiles using earth mortars or adhesives.

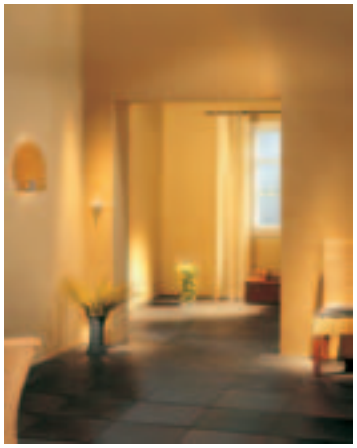
Important: Earthen plasters and renders are usually applied in two coats enabling a better surface treatment. Surfaces to be plastered must be free of rising damp and salt efflorescence, dry, firm and free of dust and loose particles. A roughened surface improves adhesion. Junctions between different surface materials should be covered with reinforcement mesh, reed-matting, jute or glass-yarn webbing to avoid cracking as a result of building movement. Earth renders must be allowed to dry quickly to avoid mould from forming temporarily. Artificial drying can help speed up the drying process.

Note: Professionally produced earth plasters and mortars have a stable and abrasion-resistant surface and are suitable for wall surfaces in domestic and similar situations. The consumer is advised to check and compare the different products on the market depending upon personal requirements.



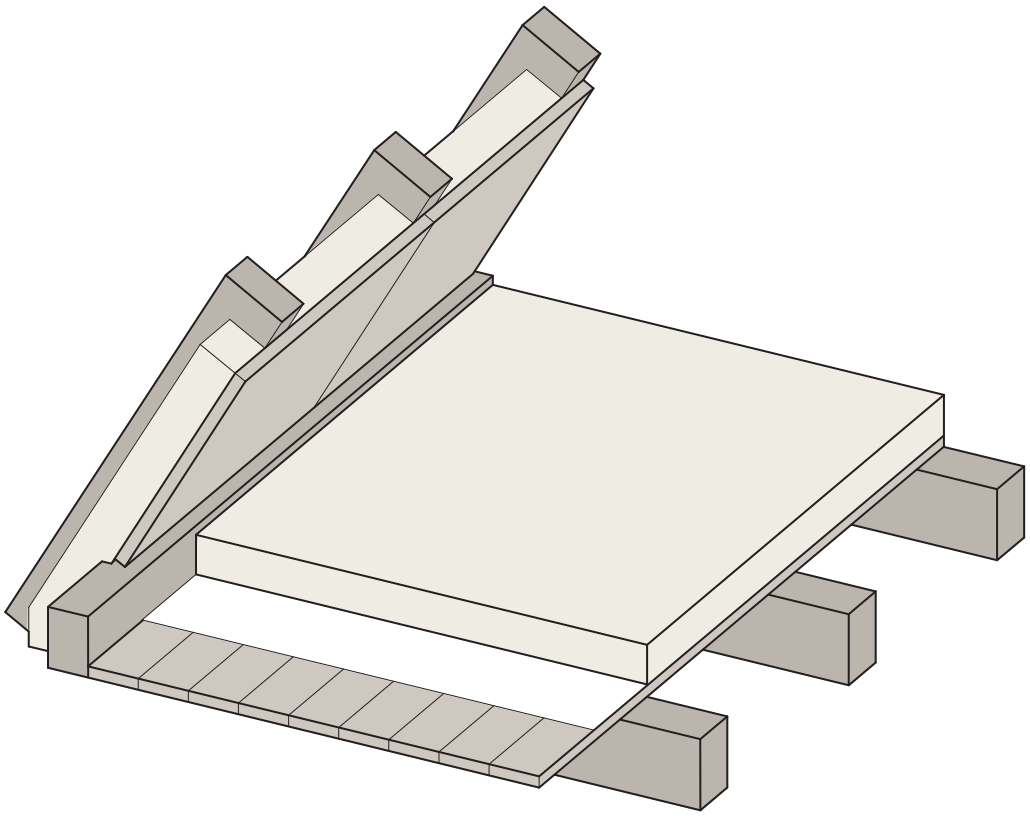
Surface finishes and coverings

LR 4.6.3



When coating or covering walls plastered with earth plasters, it is important that the porosity of the wall and material is not impaired. Typical paints include coloured clay paints, lime-casein paints and mineral-based paints (such as mineral emulsions).

Walls plastered with earth are not usually covered with wallpaper. A direct contact between earth plaster and the indoor air is hampered by the extra layer of wallpaper and most people enjoy the special aesthetic appearance of walls plastered with earth. If wallpaper is nevertheless required, then normal paper wallpaper should be used, not plasticised vapour-retardant wallpapers.



Rafters,
fill material or insulation,
lightweight clay building
board cladding

Earth in roof pitches

LR 4.4.5

Earth can also be used for the renovation and internal fitting out of roof spaces. Light earth as a loose fill material can be filled between the rafters and held in place with reed matting or laths to improve the thermal mass of the roof. Alternatively light clay panels can be cut to size and inserted between the rafters.

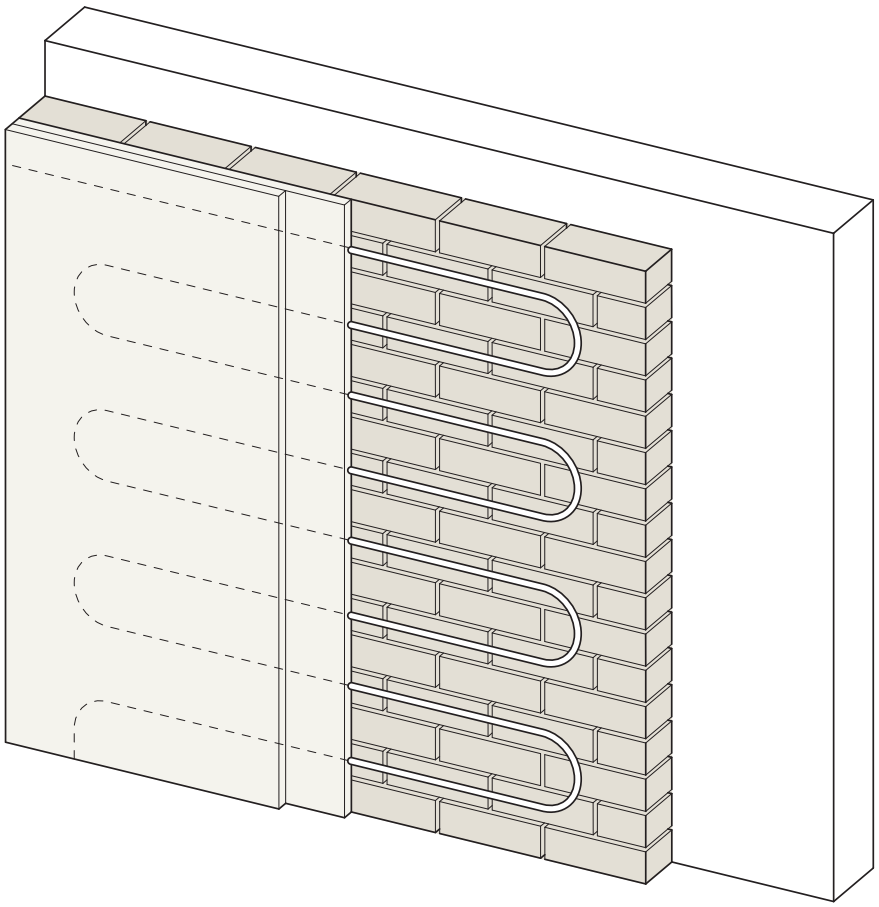
Likewise, regardless of the roof insulation material used, lightweight earth building boards can be used to clad inner surfaces of roof spaces instead of plasterboarding.

Earth brick vaults and domes

LR 4.2

A dome or vault is both wall and roof in one. Both of the two most common forms, barrel vaults (tunnel-like) and dome vaults (radial) can be made using earth bricks in a variety of different techniques.

Depending upon how the coursing of bricks are arranged domes are known as "true" or "false". The brick coursing of a "true" dome slopes inwards slightly more with each new brick course describing a segment of a curve. In contrast, the coursing of "false" domes always remains horizontal and each layer of bricks projects slightly over the next to form a roof. Either way, earth brick domes are an impressive construction with their own particular interior atmosphere.



Existing wall,
earth brickwork (optional),
loops of heating-pipe,
double-layer earth plaster

Earth and technical installations

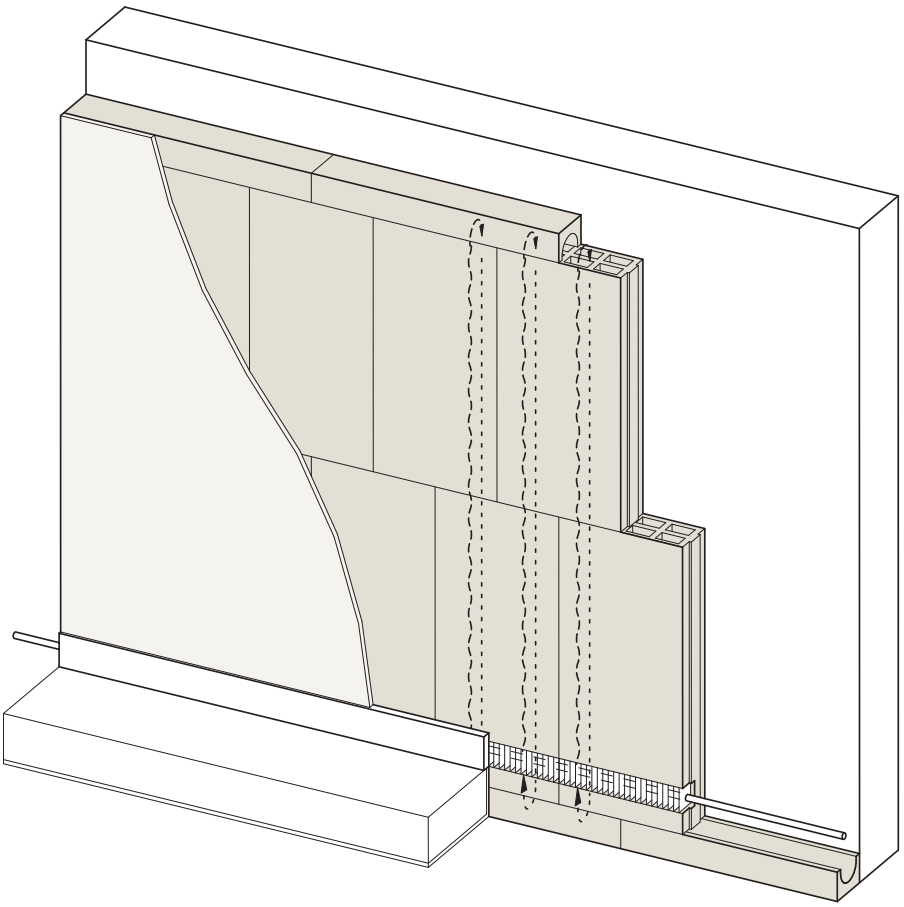
The use of earth in areas where technical installations are to be found requires careful planning, particularly in wet area. Earth is water-soluble, a factor that must be considered in kitchens and bathrooms. Earth should not be exposed to running water or where water collects. Areas that may be exposed to splashing, such as around a shower, wash hand basin or bath should be covered with water-resistant materials such as tiles. Walls made of earthen materials that are to be tiled need to be suitably prepared and primed. However, as the beneficial effects of earth cannot be experienced once tiled, conventional mineral plasters or plasterboarding can also be used.

Where heavy objects such as a toilet or other hanging sanitary installations are to be fixed, supporting timbers or a separate supporting frame should be arranged in the wall to take the weight.

An alternative to conventional radiators is **wall heating** where the entire wall or part of wall acts as a gentle heat radiator. Wall heating typically consists of loops of heating pipes made of copper, plastic-sheathed aluminium or plastic which are fixed directly to the wall in a regular pattern and plastered over with an earth plaster. The water in the pipes heats the wall which radiates heat into the room. A variety of fixing systems are available, ranging from earth bricks with pre-formed channels to prebaricated clay thermopanels in which the piping is already integrated.

Wall heating has both advantages and disadvantages:

- Wall heating is space saving. The wall itself acts as a radiator so separate radiators are not usually required. In addition the larger heat radiating surface of wall heating compared to conventional radiators means that the same feeling of warmth and room comfort can be achieved at a lower temperature level.
- Wall fixings have to be applied with care to avoid the danger of damaging pipework and water leakage when fixing items to the wall. Furniture placement possibilities are also reduced - placing large items of furniture such as shelves and wall units in front of wall heating reduces its warming effect for the room.



Existing wall,
hollow earth blocks,
U-bricks at top and bottom,
tubular heat exchanger,
fine clay plaster

So-called "hypocaustal" wall heating systems use air rather than water to warm the wall. A wall lining of hollow earth blocks forms a closed cavity in which air can circulate. The air is heated using a tubular radiator or heat exchanger at skirting board level that is connected to the heating pipework.

With this method, wall fixings can be mounted without fear of damaging pipework. Due to the several stages of heat transfer, the hot water supply temperature must be higher, similar to that of a conventional radiator.

Sanitary **pipework** for water, waste water and heating should be insulated. Depending upon the plaster thickness, electrical cables can be mounted on the surface of the unplastered wall or in slots cut into the wall, with or without conduits. Recessed socket-housings can be fitted in drilled recesses and fixed with plaster. Cables can also be fixed in earthen materials using long screws.

A variety of **fixings** are appropriate for use with earthen materials: wall plugs, dowels, tapered wooden battens, blocks or rails, plastic expanding anchors or injection anchors. Nails can also be used depending upon the density of the earthen material. Long screws are mostly suitable.

Plaster beading and reinforcement is important especially around doors and windows. Corner and edge beads made of light metal or other materials are suitable. Alternatively smooth gradually rounded edges can be achieved using earth plasters reinforced with webbing or mesh.

1

The cost of building with earthen materials

2

3

"How much does an earthen house cost?" This commonly asked question is in itself not very helpful. Houses are generally not "earthen" throughout, both in terms of construction and from an economic point of view. The most costly elements of a typical house are the cellar, foundations, roof, interior outfitting and sanitary and heating installations.

The extent to which earthen building materials are used within the entire construction varies according to the specific situation, as well as between countries. For instance, in a typical timber-frame construction using earthen infill materials, the earthen materials can account for around 10% of the total building costs depending upon the type and extent of earthen building materials used.

As the use of earthen building materials grows more widespread, current prices will become more attractive to the consumer as competition in the marketplace increases and new innovative products are developed. A truly useful cost comparison can only be achieved by requesting material costing quotes from manufacturers, producers or building supplies wholesalers, as well as labour cost estimates from a builder.

Earthen building materials have many significant advantages that cannot be expressed in terms of cost: the primary energy use for their manufacture is low, they can be recycled, are naturally occurring, provide a healthy indoor environment and are durable when correctly maintained. These are nevertheless fundamental considerations when realistically comparing building materials and construction methods. A detailed and realistic comparison will show that building with earthen materials is both cost-effective and ecologically sound.

1,2 Neues Wohnen, Saarbrücken
3 Waldorfschule, Weimar

Training opportunities in earthen building

Vocational training programme
"Specialist in Building with Earth"

The decline in the use of natural earthen materials in building as a result of increased industrialised building material production from the end of the 19th century onwards has led to a corresponding loss of earthen building expertise in the trade. Where the skills of bricklayers, carpenters and plasterers have been handed on from generation to generation, those of the practised earthen builder had been neglected for nearly a century. Practical skills and general knowledge about the material and its handling have been forgotten over the years,

Both the necessary restoration, repair and conservation of historic buildings using earthen building materials and the increased awareness of ecological and sustainable building since the 1980s have led to an increased interest in and production of earthen building materials over the last twenty years. A need has arisen for professional training in earthen building techniques. Many private professionals have offered courses since the 1990s, sharing their personal experience with interested individuals. With the increased industrialised production of earthen building materials, many manufacturers also offer company seminars for distributors and wholesalers.

The introduction of the German earthen building regulations, the Lehmbau Regeln, in 1998 provided a basis for generally agreed German standards for executing building works with earthen materials. In order to re-establish the skills and knowledge set out in the Lehmbau Regeln, the DVL, in conjunction with the Environmental Centre for Crafts and Trade, the Thuringian Chamber of Crafts and the Federal State of Thuringia, has developed a vocational training programme entitled "Specialist in Building with Earth". The course leads to a state-approved vocational certificate and an entry in the registry of qualified craftsmen for the skills area of earthen building.
More information about seminars and training programmes is available online at www.dachverband-lehm.de, the Dachverband Lehm homepage.

Photos: 22 – Inge Breidenbach; 2, 4, 5, 6, 8, 12, 14, 15, 16, 17, 20, 22, 26 – claytec; 25 – lehmprojekt; 23 – lesando; 24 – Prof. Gernot Minke; 2, 3, 8, 10 – Martin Rauch/Bruno Klomfar; 1, 2, 4, 28 – Hannah Schreckenbach; 18 – Tietz Bau; 15, 18, 19, 22 – Volhard + Schauer

What are the advantages of building with earth? What earthen building materials are available? How is earth used in building? What does it cost to build with earth?

The consumer information answers these and other questions and provides a competent and understandable general introduction to building with clay and earth.

More information about building with earth including background knowledge and reference material, addresses of builders, planners and manufacturers as well as links to other useful resources is available online from the Dachverband Lehm homepage.

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