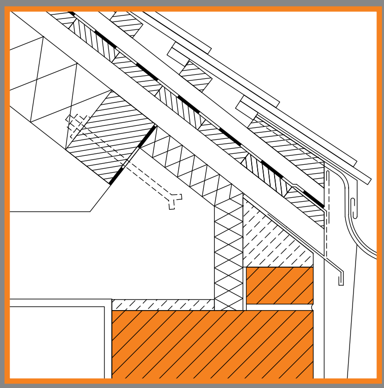
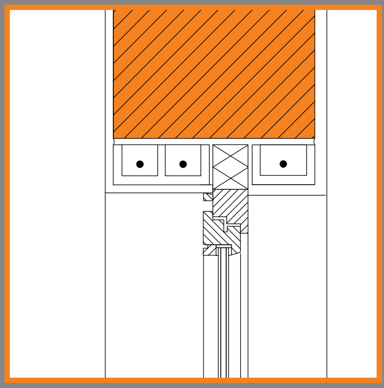
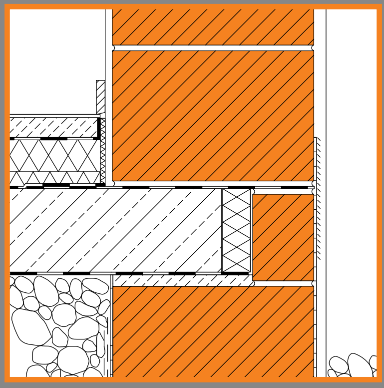
DETAIL Practice

Building with Large Clay Blocks

Details
Products
Examples







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Klaus Greilich
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Authors:

Theodor Hugues, Prof. Dr.-Ing., architect
Chair of Building and Building Materials,
Munich Technical University
Klaus Greilich, Dipl.-Ing., architect
Christine Peter, Dipl.-Ing., architect

Drawings:
Editors for Detail
Ina Philipp, Dipl.-Ing.
Anna Werth, Dipl.-Ing.

Secretariat:
Marga Cervinka

Editing and proof-reading:
Nicola Kollmann, Dipl.-Ing.
Andreas Gabriel, Dipl.-Ing., architect

Translators (German/English):
Gerd H. Söffker, Philip Thrift, Hannover

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Peter Gensmantel, Cornelia Kohn,
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Institut für Internationale Architektur-Dokumentation GmbH & Co. KG
Sonnenstr. 17, 80331 Munich, Germany
Tel: +49 89 38 16 20-0
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Internet: www.detail.de

in cooperation with:
Ziegelforum e.V.
Bavariaring 35, 80336 Munich, Germany
Tel: +49 89 74 66 16-0
Fax +49 89 74 66 16-30
Internet: www.ziegel.com
e-mail: postmaster@ziegel.com

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They represent typical solutions which must be coordinated with the respective boundary conditions and requirements, the relevant statutory instruments, standards and manufacturers' information valid in each specific, individual case. Neither the authors nor the publisher shall be liable for any claims for damages arising from the content of this book. Decisions relating to the construction, construction law and building performance characteristics are based on the situation in Germany and the DIN standards plus – if already introduced – the EN standards valid in Germany.

DETAIL Practice
Building with Large Clay Blocks

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Klaus Greilich
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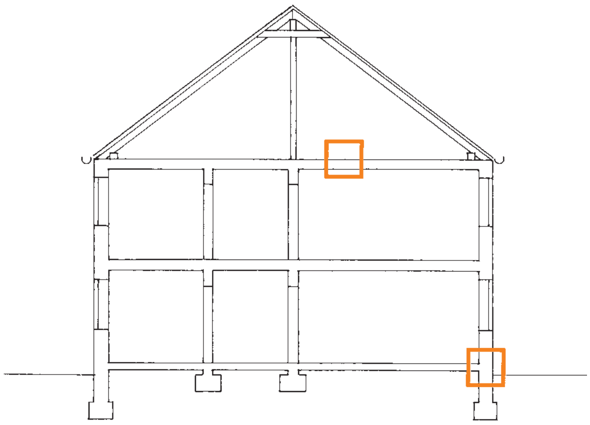
Contents

Bauen mit großformatigen Ziegeln, a book of practical exercises and the forerunner of this book, originated at the suggestion of the Munich-based Ziegelforum e.V. The graphic layout and the production of the original edition was carried out at the offices of Schweiger Winscherman, also in Munich.
The authors are grateful to the assistance given by Dr.-Ing. Bernhard Behringer (structures) and Dr.-Ing. Peter Roeke (plaster/render and masonry technology).

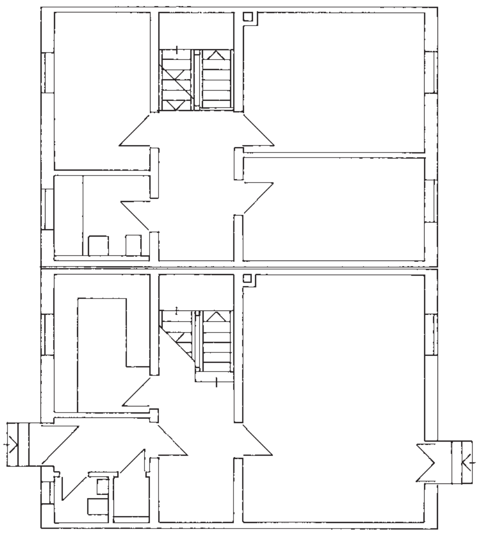
In order to illustrate the problems and relationships, two, basically similar, terrace house types, A and B, were devised. These do not claim to be special in any way but rather are intended to represent the "standard case". The differences between the two house types lie in the degree to which the interior space is used as well as the building methods and building materials employed.

A

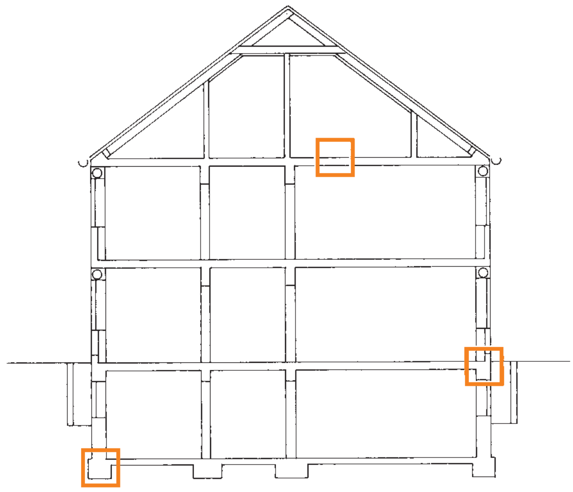
is a simple house. A has no basement and the roof space is not used as living accommodation. The intended high degree of self-build involved is helped by omitting the central heating and hot-water systems, the use of clay hollow pot or timber joist floors, and the use of conventional building elements. The separate electric or gas-fired heaters required are placed in front of the wall.



Cold roof space
No basement
Raised ground floor
High degree of self-build

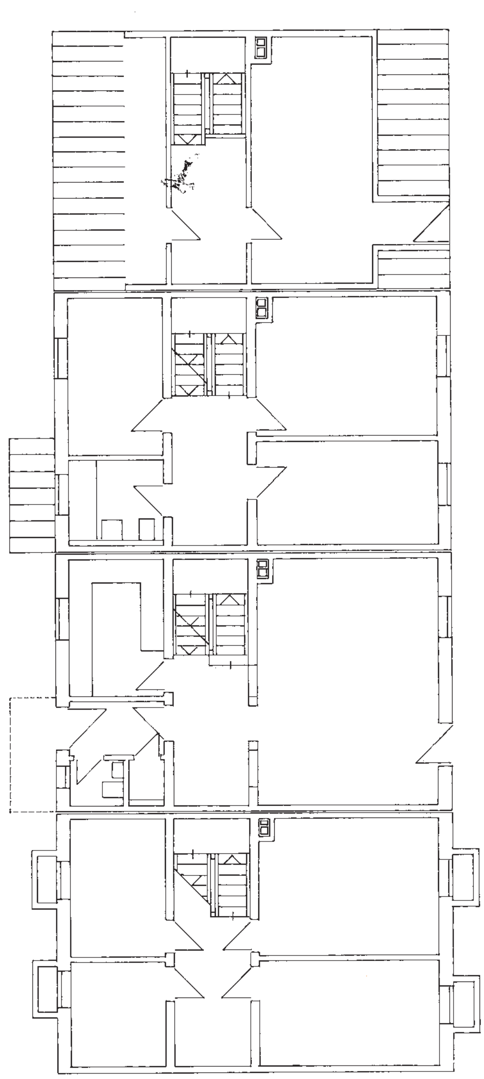


Longitudinal loadbearing walls
Timber stairs
Minimal chimney
False walls concealing services



B

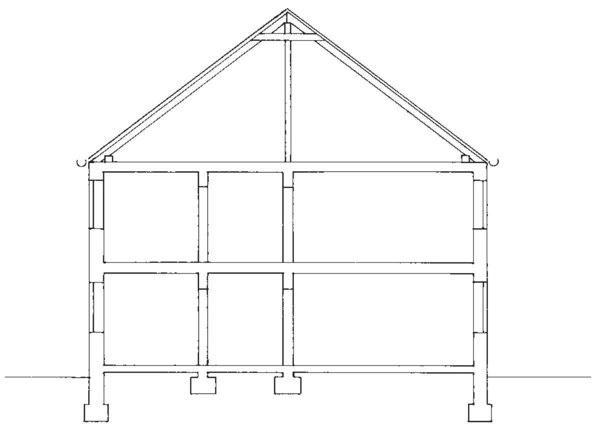
is a more elaborate design. B has a basement and a roof space for use as living accommodation. Solid reinforced concrete floors and central hot-water heating and hot-water supply systems call for a higher standard of construction, likewise the windows with roller shutters. The use of experienced contractors is highly advisable. The couple roof is supported on abutments monolithic with the topmost reinforced concrete floor and provides a roof space free from intermediate columns. Easy access for handicapped occupants is guaranteed by having the ground floor at the same level as the surrounding ground.

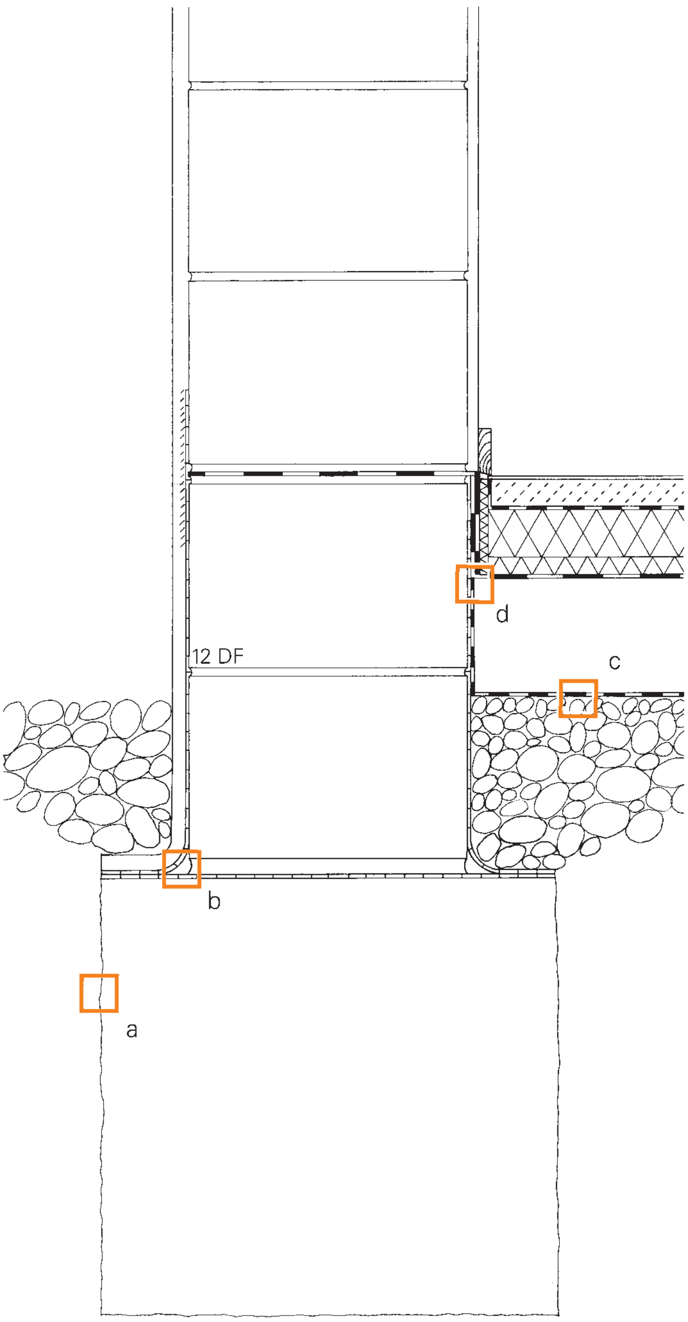


Converted roof space
Heated and unheated basement
Same-level access
False walls concealing services
Radiators and chimney
Construction by contractors

House A

12	External wall, rendered plinth
16	External wall, concrete plinth
20	External wall, window
22	External wall, window and clay hollow pot floor
24	Double-leaf party wall
26	Loadbearing and non-loadbearing partitions
28	Clay hollow pot floor
30	Double-leaf party wall and clay hollow pot floor
32	External wall and unused roof space
38	Double-leaf party wall and clay-tile roof





☐ a
Use an excavator to dig the trenches for foundations in stable subsoils. The width of the foundation is therefore determined by the width of the excavator bucket and must also be checked with respect to the permissible bearing pressure. The necessary depth to prevent frost heave (min. 800 mm, in exposed locations as much as 1200 mm) can be achieved with a strip foundation of adequate depth.

☐ b
Build a plinth wall on the levelling bed joint on the plain concrete (grade C 12/15) foundation and protect this wall against saturation on both sides.

One approach well tested for render makes use of a waterproofing system made from an elastic sealing coating. Apply a suitable filler to achieve a smooth surface and then paint on the coating with a brush in several layers to achieve a minimum thickness of 2 mm; on the outside apply a coat of plastering mix group P III suitable for plinths.

In order to ensure that water running down the facade drains clear, both waterproofing and render continue to the outside edge of the foundation via a rounded corner fillet.

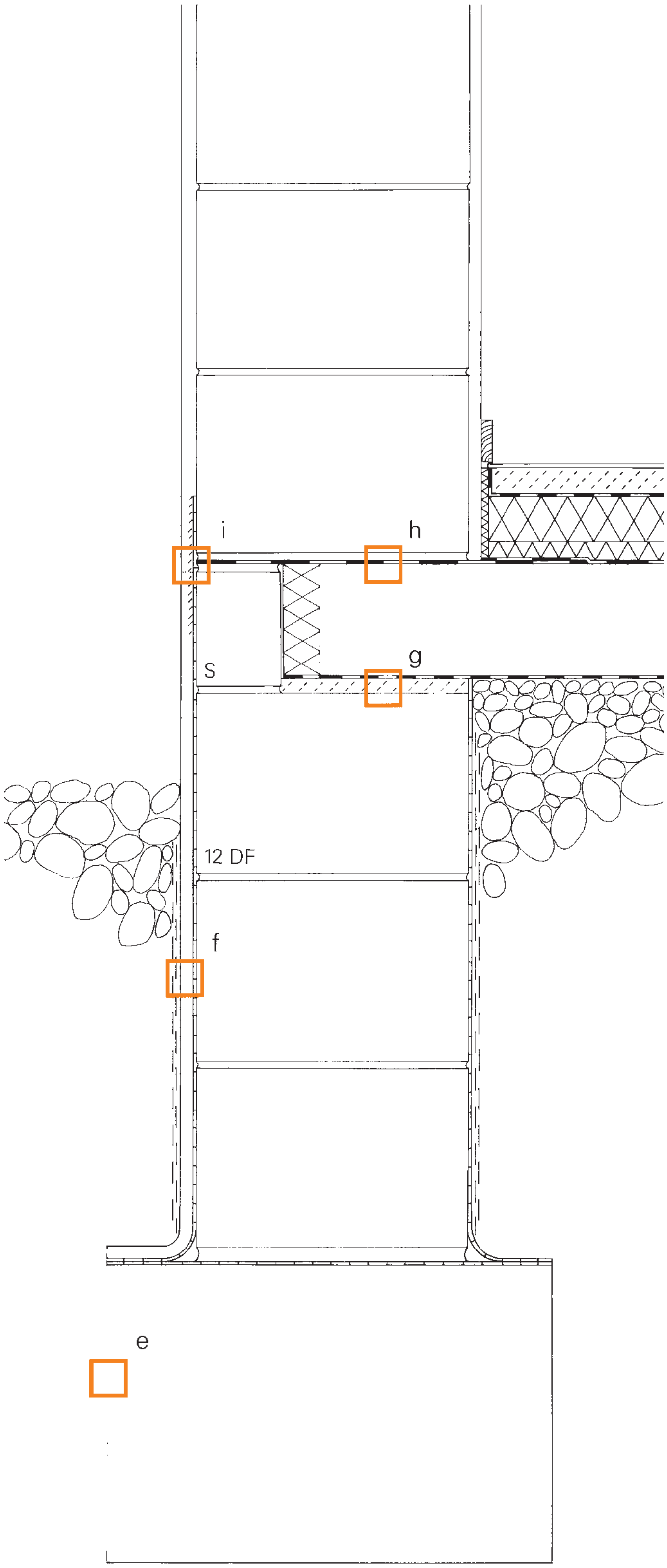
The surrounding strip of coarse gravel reduces the amount of water splashing up on to the plinth.

☐ c
Spread a layer of hardcore over the excavation between the walls to prevent capillary action and permanent saturation from underneath, and to provide relief for a temporary build-up of water. This layer should consist of 150 mm of coarse-grained, clean gravel (DIN 18195), ideally grading curve 16/32, which is readily compacted but is still sufficiently permeable. In order to prevent concrete seepage when casting the ground floor slab, cover the hardcore with a sheet of 0.2 mm polyethylene.

☐ d
To protect against moisture rising through capillary action, a continuous damp-proof membrane (dpm) is required. The dpm and the damp-proof course (dpc) in the wall must be joined together.

In order to minimise the differential settlement between wall and ground floor slab, careful compaction of the subsoil and the anti-capillary hardcore is necessary. It is helpful to cast the floor slab as late as possible. The floor waterproofing, assuming non-hydrostatic pressure and a moderate loading, should consist of one layer of bitumen felt (e.g. G 200 DD with glass cloth inlay) or one layer of built-up bitumen felt (e.g. V60 S4 with glass fleece inlay) with 100 mm bonded laps: laid loose, fully or partially bonded.

Bond the dpm under the floor to the dpc in the wall with 100 mm overlapping joints. As these are made at different times, a robust dpc using a bitumen felt with a metal foil inlay (e.g. Cu 0.1 D) is to be recommended.



☐ e
If the subsoil around the foundation trench is unstable, formwork is required on both sides of the strip foundation. Setting up the formwork in turn requires a working space of 500 mm. In addition, the sides of the excavation must be sloped back (60°–40°) to suit the angle of repose of the particular soil.

☐ f
The masonry plinth wall constructed on the foundation must be waterproofed and the waterproofing must be protected against mechanical damage. This can be achieved by means of, for example, corrugated bitumen sheeting or synthetic studded sheeting.

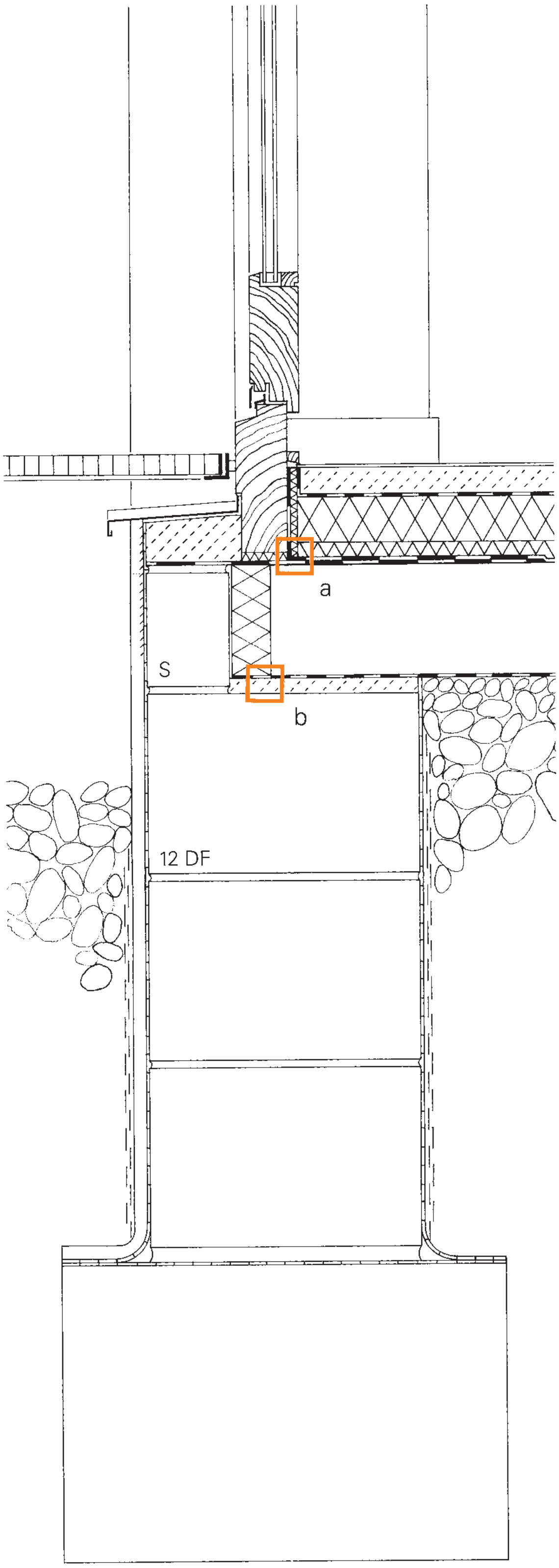
Backfill the foundation trench in layers and compact the backfilling material inside and outside simultaneously.

☐ g
Build the ground floor slab into the masonry plinth. In order to accommodate stresses due to differential settlement, the slab must be reinforced, at least around the edges.

Covering the anti-capillary hardcore with polyethylene sheeting is the simplest approach. However, damage caused by the reinforcement or while casting the reinforced concrete floor slab is a risk here (see p. 12, b).

☐ h
One key advantage of the reinforced concrete ground floor slab is that the junction between the damp-proof membrane (dpm) and the damp-proof course (dpc) is not vulnerable to settlement. The continuous dpc in the wall at the same level, together with the standard plinth height of approx. 300 mm (DIN 18195), determines the position of the ground floor slab above the surrounding ground. Waterproofing against ingress of moisture from the side “must be designed to continue up the wall for max. 300 mm above ground level in the standard case in order to guarantee sufficient adjustment options in the ground level. Upon completion, this dimension should not be less than 150 mm.” (DIN 18195 part 4)

☐ i
The moisture-resistant render to the plinth continues to the top of the plinth. It is possible to achieve no difference in texture between plinth render (P III) and lightweight render (P II) by choosing suitable plastering systems. The dpc continues to the outside edge of the structural masonry. Attach a strip of expanded metal over this problematic interruption in the substrate to provide a background for the render.



☐ a
Set up the frame to the glazed door on the ground floor slab. Align the frame, wedge it in place and fix it to the floor slab with steel fixing cramps. Join the floor waterproofing to the frame.
After positioning the frame, add a concrete topping with an approx. 10% fall to the outside. To prevent saturation, the wood of the frame is wrapped in polyethylene sheeting or crêpe paper.

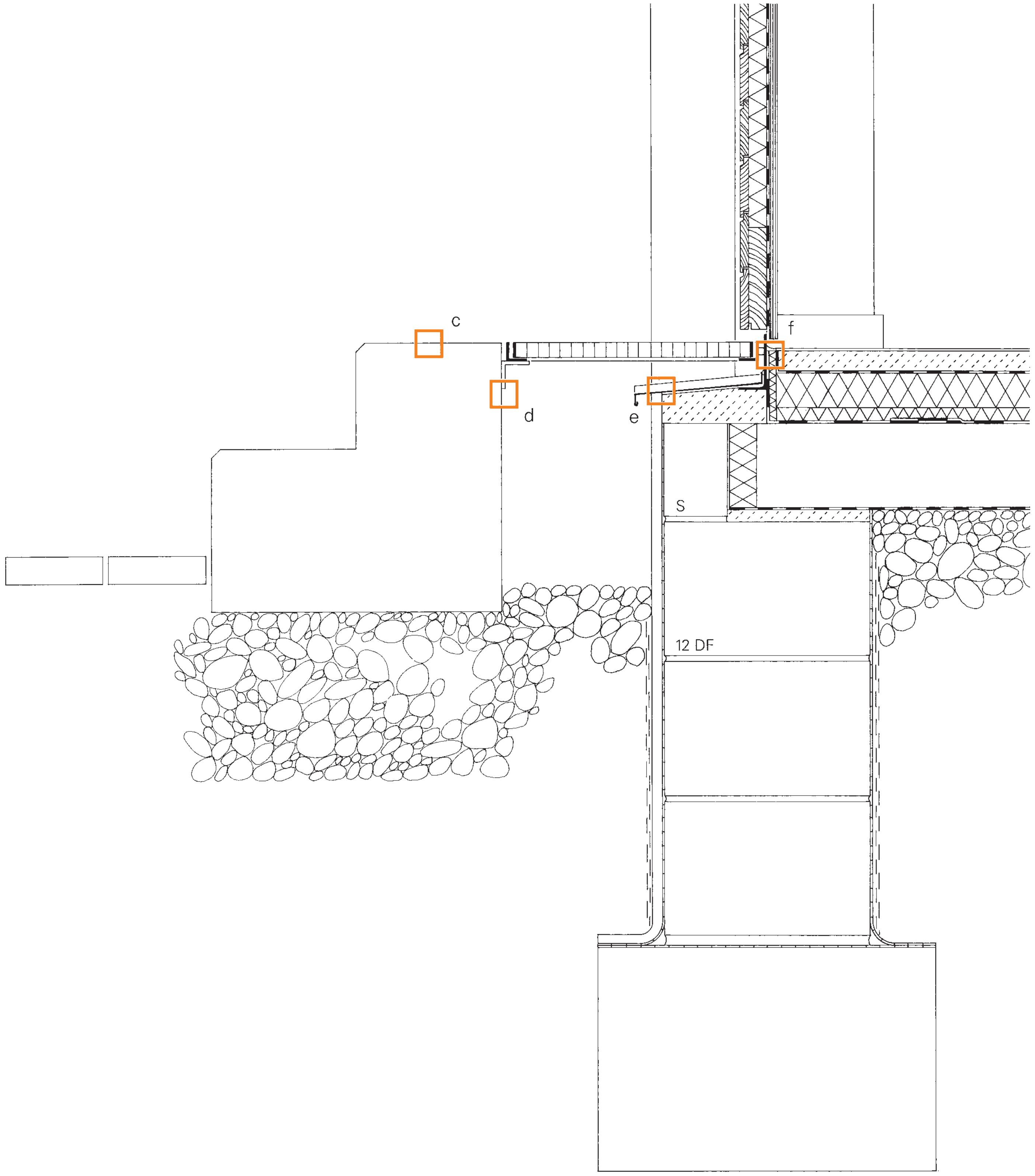
☐ b
The strip of insulating material (moisture-resistant polystyrene, mineral fibre or perlite batts) required at the wall junction continue uninterrupted. Add the thermal insulation after casting the concrete ground floor slab in order to avoid damage to masonry and insulation. The facing of cut clay blocks creates a uniform substrate for the render.

☐ c
Place the step (precast concrete, reconstituted stone or in situ concrete) in front of the door on the compacted backfilling but separate from the house; better still, on 300–400 mm of properly compacted gravel to prevent frost heave. All surfaces should have a 1–2% fall.

☐ d
Supporting the open grid flooring on an angle bracket screwed into the step en--ables the sequence of operations to be separated.

☐ e
Tuck the sheet metal sill over the screed behind the render on both sides, screw it to the galvanised water bar and seal it at that point with a fillet of sealing compound.

☐ f
Fix the galvanised, close-mesh open grid flooring by means of spacers and self-tapping screws, or by means of bolts welded to the flooring. The floor waterproofing must remain permanently bonded to the water bar.
This robust detail with water bar and single-rebate frame is only possible in a lobby that is not permanently heated.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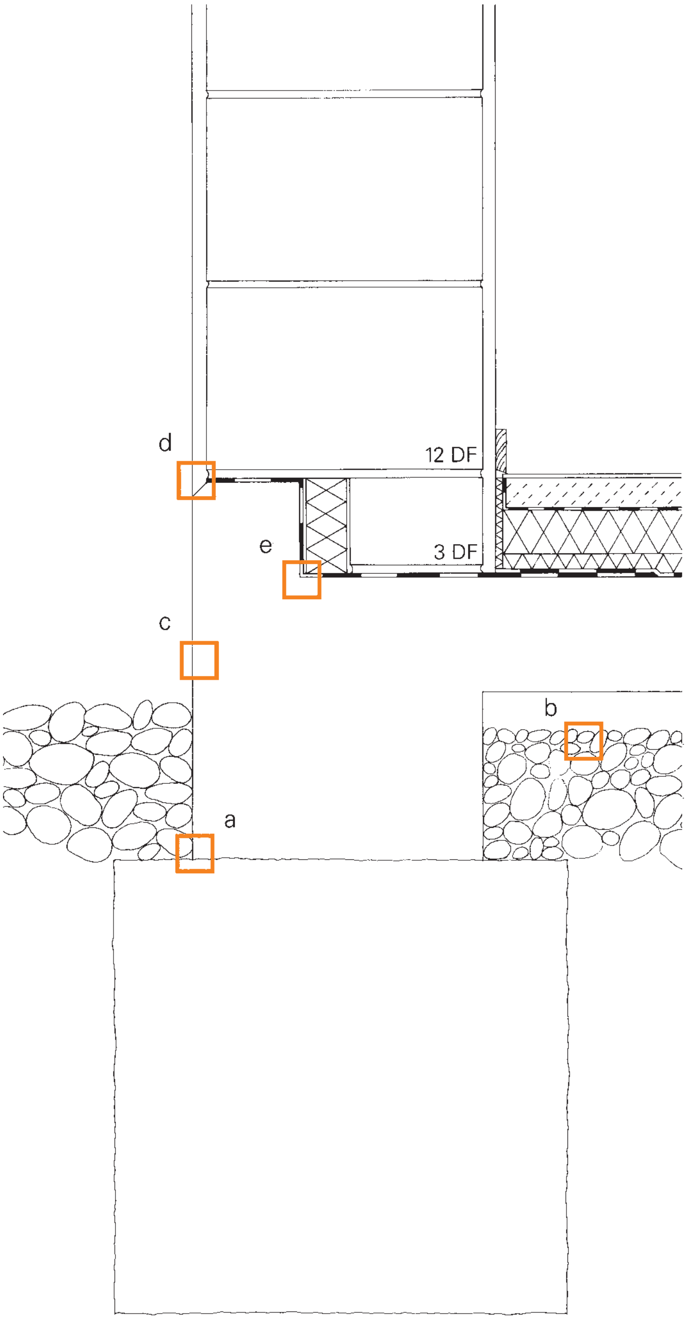


☐ a
Build the foundation only on virgin subsoil (no fill) and deep enough to prevent frost heave. Set out the external wall exactly on the strip foundation, which is wider than the wall and is cast directly against the sides of the trench. Set up the formwork for the concrete plinth on this.

☐ b
Cover the anti-capillary hardcore with an approx. 50 mm layer of blinding concrete (grade C 8/10) to prevent seepage of the cement slurry. This also eases the positioning of the reinforcement required for the reinforced concrete floor slab.

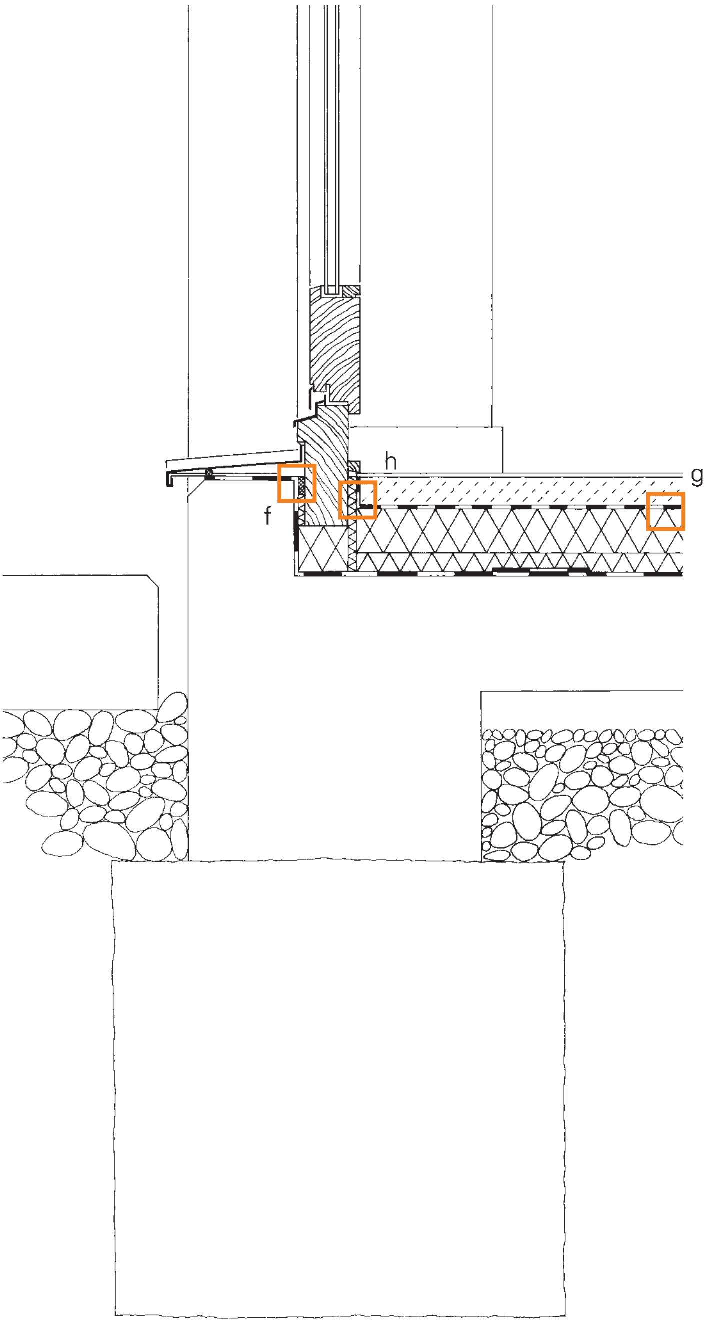
☐ c
To prevent damage caused by splashing water, construct the plinth with adequate concrete cover to the reinforcement and without any construction joints, and compact the concrete carefully.

☐ d
A flush finish with the render above is achieved by creating a chamfer to the top outside edge of the concrete by means of a triangular fillet (15 x 15 mm). Separation at this point is necessary owing to the different deformations. Use a galvanised, better still stainless steel, stop bead at the bottom of the render and fill the joint between stop bead and concrete with an elastic sealing compound to accommodate the different changes in length due to shrinkage and thermal expansion.

☐ e
As bitumen felt can split when subjected to bending, employ a bitumen felt with a metal foil inlay for the damp-proof course (dpc) in the wall.

Insert approx. 50 mm thick insulation (mineral fibre, rigid expanded polystyrene foam) into the middle of the wall to guarantee the necessary thermal insulation.

Reduce the effect of the thermal bridge – masonry backing/plinth concrete – by extending the insulation downwards.



□ f

The damp-proof course (dpc) in the wall continues across the door opening and must be protected for the duration of construction work. Carefully bond the exposed edge to the substrate in order to prevent moisture seeping underneath.

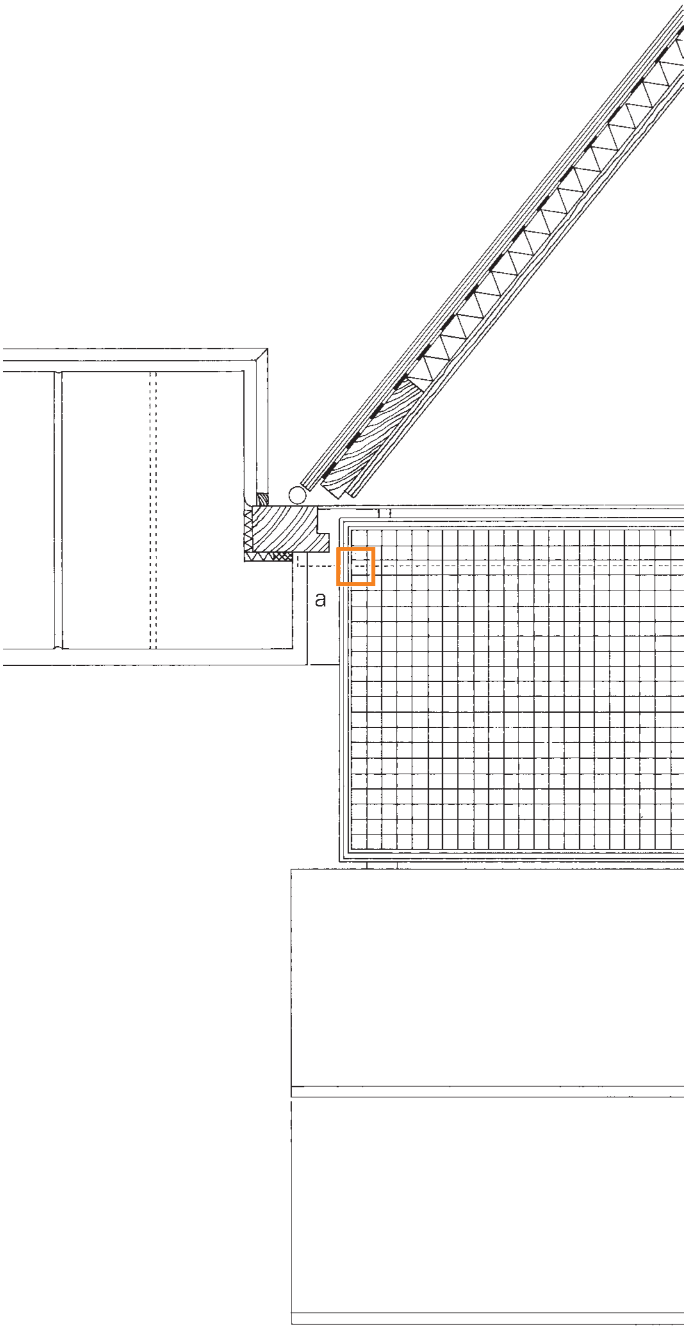
Build in the door threshold on preformed compressible sealing strips glued in place.

□ g

Lay the stiffer thermal insulation on the more elastic impact sound insulation and cover this with a separating layer before pouring the screed.

□ h

Pour the floating screed without any material connection to the adjoining parts of the construction; only in this way can the sound insulation qualities be guaranteed. The peripheral strips of insulation (mineral fibre, expanded polystyrene foam 8–10 mm thick) should extend 20–30 mm above the finished floor level. Cut this off flush after laying the floor finish.



□ a

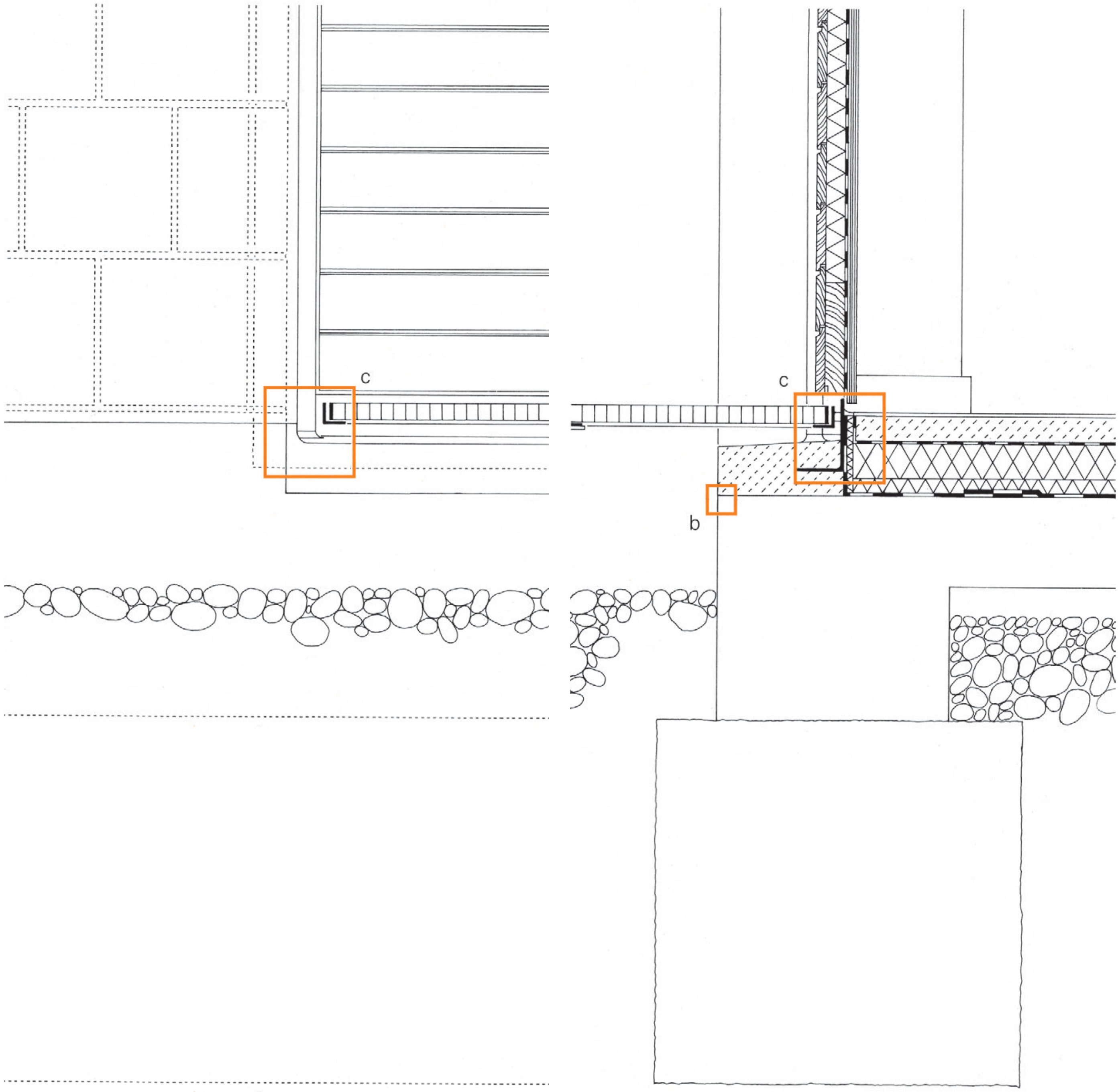
The “bridge-like” arrangement of the open grid flooring has advantages: the space between the flooring and the door reveal is wide enough to allow easy cleaning, and the door frame does not need to be notched to accommodate the flooring.

□ b

After positioning, aligning and fixing the door, cast the galvanised water bar into the concrete. Then clean the concrete ground floor slab and remove all loose debris. To improve adhesion, roughen the surface and wet it; alternatively, apply a bonding coat.

□ c

The door frame finishes just above the screed and is screwed to the continuous water bar. Protect the end grain of the wood and seal the joint on all sides with a permanently elastic sealing compound.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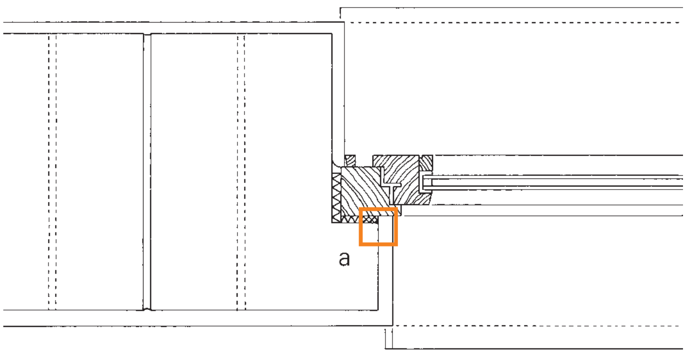
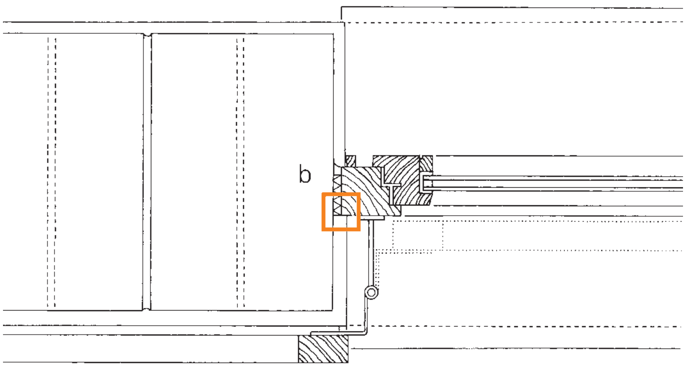
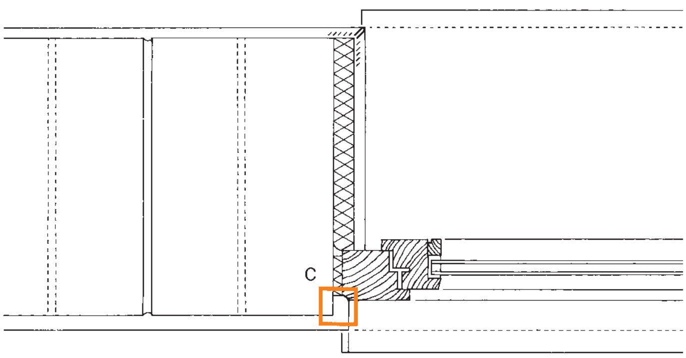






☐ a

The masonry shoulder at doors and windows has a long tradition. Derived from brick masonry bonds, the depth is 115 mm (1/2 brick) and the width approx. 60 mm (1/4 brick). In lightweight clay block masonry the shoulder can be created with specials or by sawing whole blocks to suit.

This somewhat more elaborate detail is becoming popular again for practical and other reasons. For instance, it improves thermal insulation and moisture control aspects, and the joint between window frame and render is set back and thus protected.

Install the window frame, primed and given a first coat of paint, on a preformed, compressible and impregnated sealing strip; this compensates for irregularities as it tries to return to its original size. Fill the joint between frame and masonry with a moisture-resistant insulating material (e.g. non-CFC foam). Sealing the joint on the inside with a moisture-resistant sealing compound prevents saturation due to condensation water and ensures that the sealing compound remains fully effective over the long term. Prefabricated sealing gaskets are available to ensure airtightness and moisture tightness between wall and window; the use of these helps to guarantee a good detail.

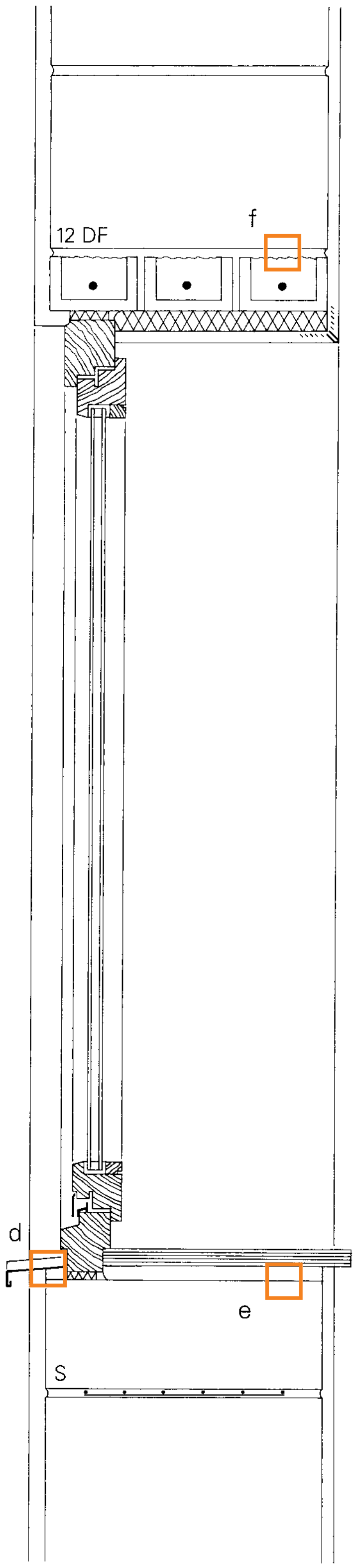
☐ b

The omission of shoulders at the head and reveals simplifies the detail considerably. However, many problems have to be overcome at the resulting “straight” joint:
– accommodating dimensional and flatness tolerances (DIN 18202);
– fixing the frame (fixing cramps, screws every approx. 800 mm);
– accommodating temperature-related changes in length, deformations and movement without damage;
– sealing against wind (from the outside) and water vapour (from the inside) because condensation water can be expected in the joint due to the temperature difference of 15–20°;
– protection against rain and driving rain – the most favourable values in terms of moisture control have been measured in the middle of the reveal, the isotherms are distributed over the entire width of the reveal.

☐ c

If the window moves further outwards, it is not just the stresses on the components and their joints due to sun, wind and rain which increase. We find with high-quality wall insulating materials in particular that the temperature in the reveal can drop below the dew point in the winter. The result is condensation water and mould growth. Insulation across the reveal is advisable.

Positioning the window at least 20 mm back from the line of the structural wall helps to achieve a decent return for the render.



d

Irrespective of the type of reveal and the position of the window within the thickness of the wall, there is never a masonry shoulder at the sill. Fix the standard type of window sill – made from 2 mm sheet aluminium with a fall of approx. 1:10 – to the wall with brackets in such a way that the rainwater drip projects approx. 30 mm beyond the render. Attach L- or C-shaped sections to both ends of the aluminium sill for tucking behind the render on both sides. Do not remove the factory-applied plastic wrapping around the aluminium sill until all the rendering and painting works have been completed in order to avoid, for example, splashes of lime or cement.

e

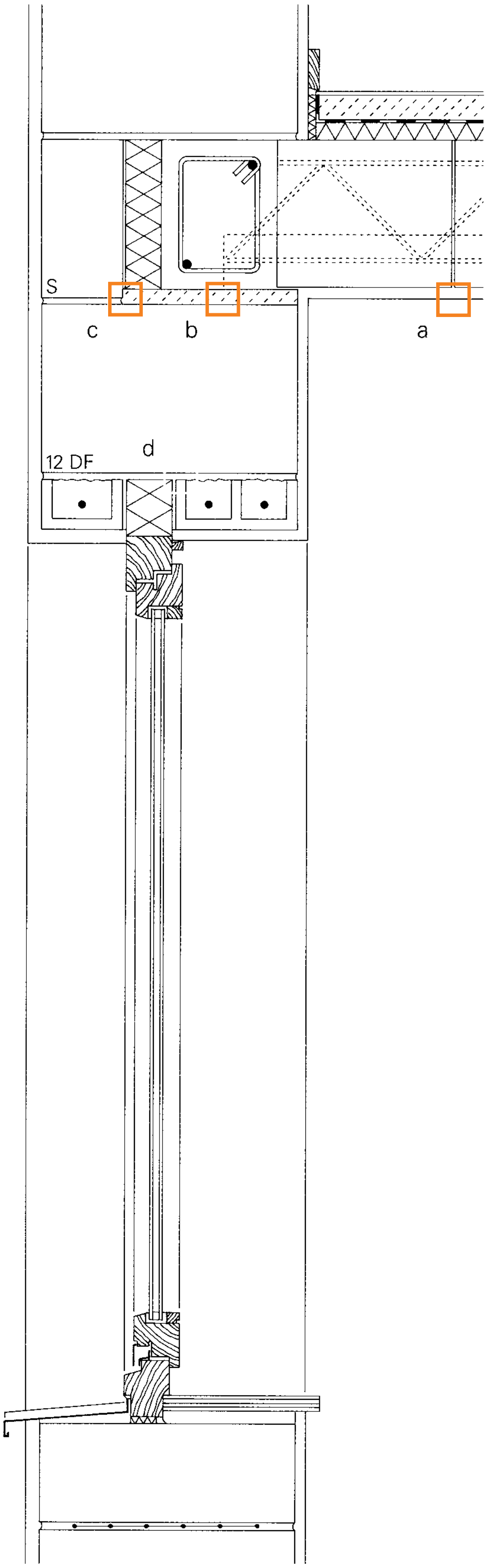
If the desired sill height is not a multiple of the size of blocks being used, saw blocks to form appropriate make-up units.
Rustproof masonry reinforcement laid as high as possible in the spandrel panel helps to prevent cracking.

f

The lintels used here consist of shallow U-shaped clay channels in which the conventional or prestressed reinforcing bars are laid and cast in. In structural engineering terms these bars form the tension tie of the lintel. A “compression zone” of masonry should therefore be built over such shallow lintels; use lightweight clay blocks of compressive strength class 12.

Shallow clay lintels are available in depths of 71 and 113 mm, and widths of 115 or 175 mm. Without a structural analysis, shallow clay lintels may be used only as single-span beams up to a span of 3.00 m. Temporary supports during erection are necessary for clear spans exceeding 1.25 m. Prefabricated conventionally reinforced or prestressed shallow clay lintels are covered by approvals.

Sawn make-up blocks are required at the supports for shallow clay lintels, either above or below, in order to match up with the bed joints in the wall (every 250 mm).



☐ a

Clay hollow pot floors can be laid quickly without formwork for self-build projects. Merely the beams require temporary support during erection.

The floor units – the hollow clay "pots" – are laid on in situ concrete ribs with prefabricated lattice beams acting as the reinforcement (see p. 28).

☐ b

To allow height adjustments, but also to avoid excessive bearing pressure at the edge and to prevent the voids of the clay blocks being filled with concrete, provide a levelling bed of mortar 20 mm thick.

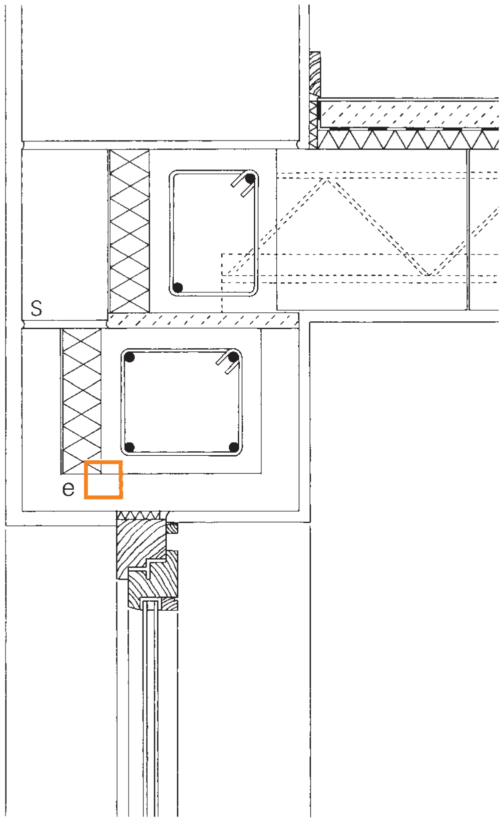
☐ c

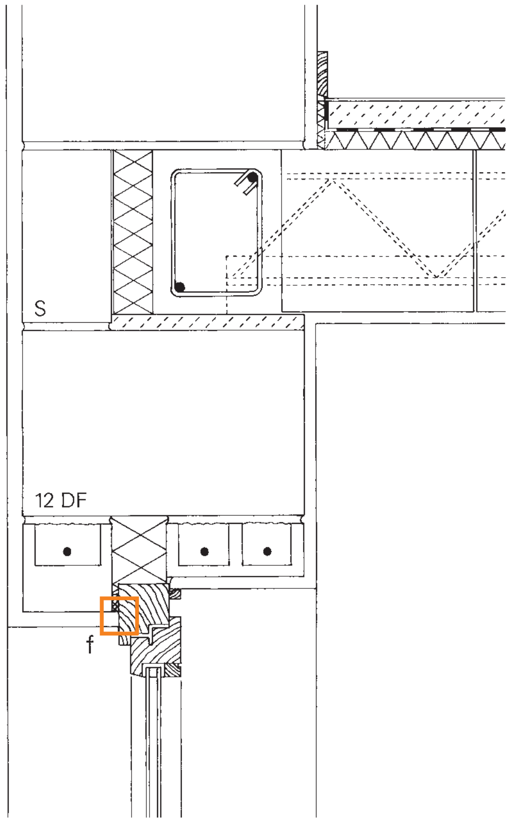
Lay the lattice beams of the ribs with a min. 100 mm bearing on the bed of mortar and connect them together by means of an in situ concrete ring beam. The insulation, about 50 mm thick, between beam and blockwork is best inserted after casting the beam.

To create a uniform substrate for the render, saw a large-format clay block to suit.

☐ d

If shallow clay lintels with different widths (115 and 175 mm) are being used, the thermal insulation can be considerably improved by fitting insulation approx. 80 mm thick (mineral fibre or extruded polystyrene) between the lintels. Position the window in line with this insulation.





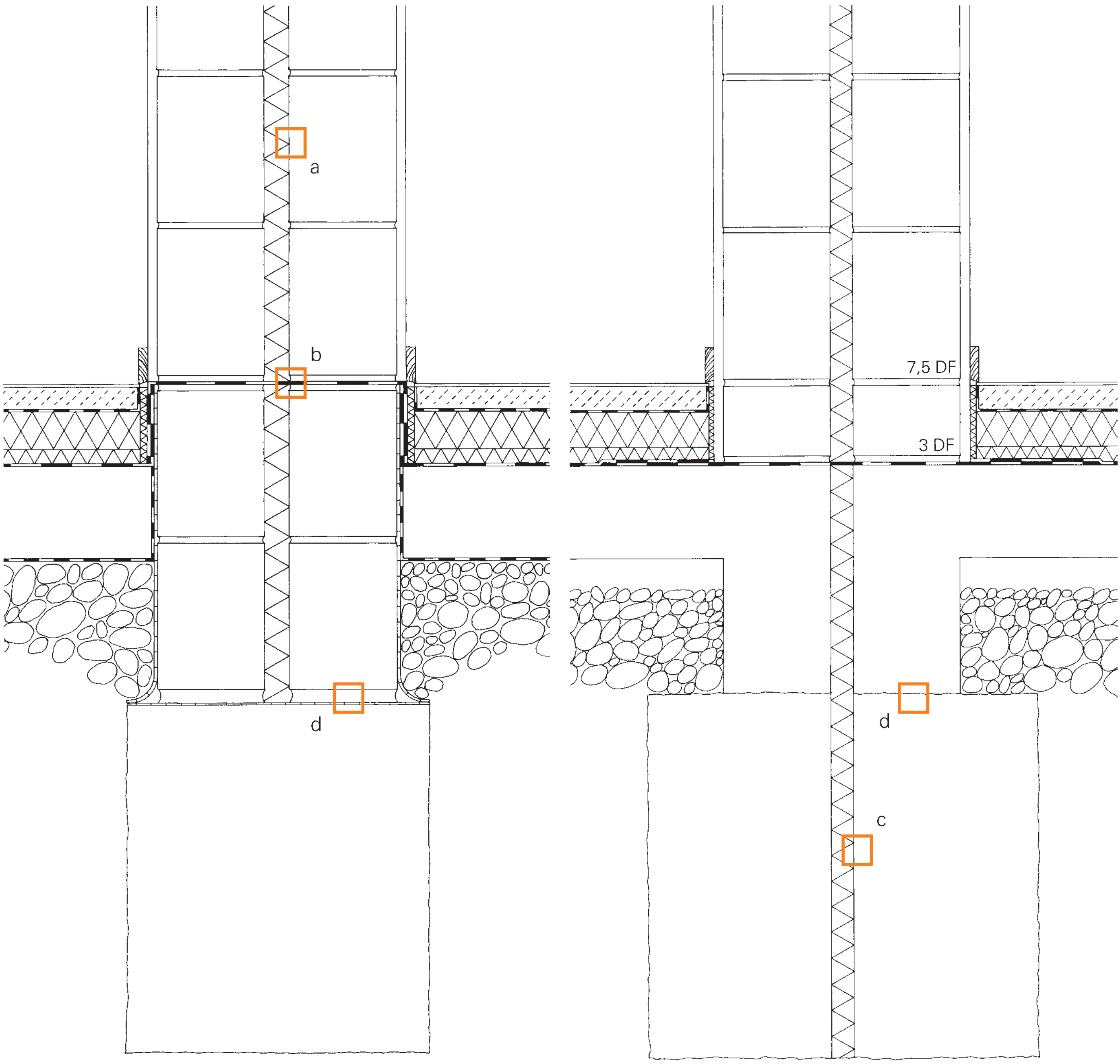
e

Lightweight clay channels matching the thickness of the wall, 238 mm deep and 240 mm long, serve as permanent formwork and provide a uniform substrate for the render. Position the insulation and the reinforcement, then fill the channels with concrete. This type of reinforced concrete lintel can span clear openings up to about 2.75 m.

f

The use of shallow clay lintels with different depths and widths permits the construction of lintels with shoulder and thermal insulation.

Double-leaf party wall
Vertical section through foundation



☐ a
The sound reduction index (57 dB, DIN 4109) required for the party wall can be achieved with a double-leaf wall comprising two leaves of 175 mm lightweight clay blocks, gross density class 0.8, plus min. 30 mm thick semi-rigid mineral fibre insulating batts. The batts are positioned loose and held in place by the masonry leaves.

The sound reduction index can be increased to 67 dB (enhanced requirements, DIN 4109) and the wall classed as a fire compartment wall (Bavarian Building Code) by using vertically perforated clay blocks with B-type perforations and gross density class > 1.2.

☐ b
Continuing the damp-proof course (dpc) across the separating joint has no adverse effect on the acoustic properties of the wall. Build the leaves of the party wall in succession, not simultaneously, in order to rule out – as far as possible – acoustic bridges for structure-borne sound caused by debris and mortar droppings. Separating joint boards with an inorganic coating on one side, developed for double-leaf concrete walls, can be used here to help keep the work clean.

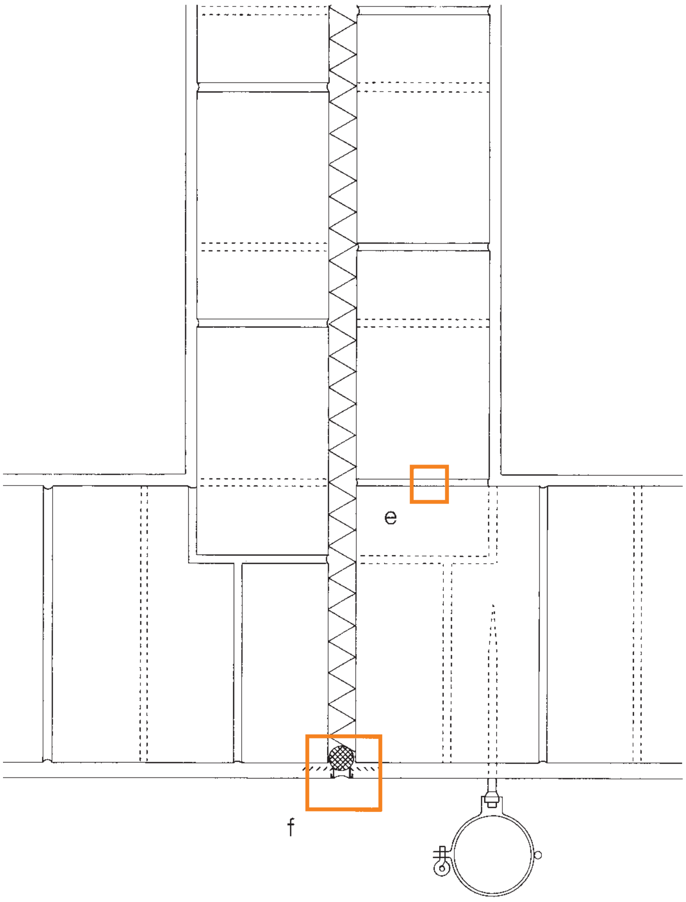
☐ c
The separating joint must continue through the foundation if the enhanced requirements are to be met. To do this, cast the strip foundation in two halves. Place the separating joint board against the part cast first and cast the other half against the coated side of the board.

☐ d
In both variations, continue the construction of the party wall as for the external walls and plinths shown on pp. 12 and 16.

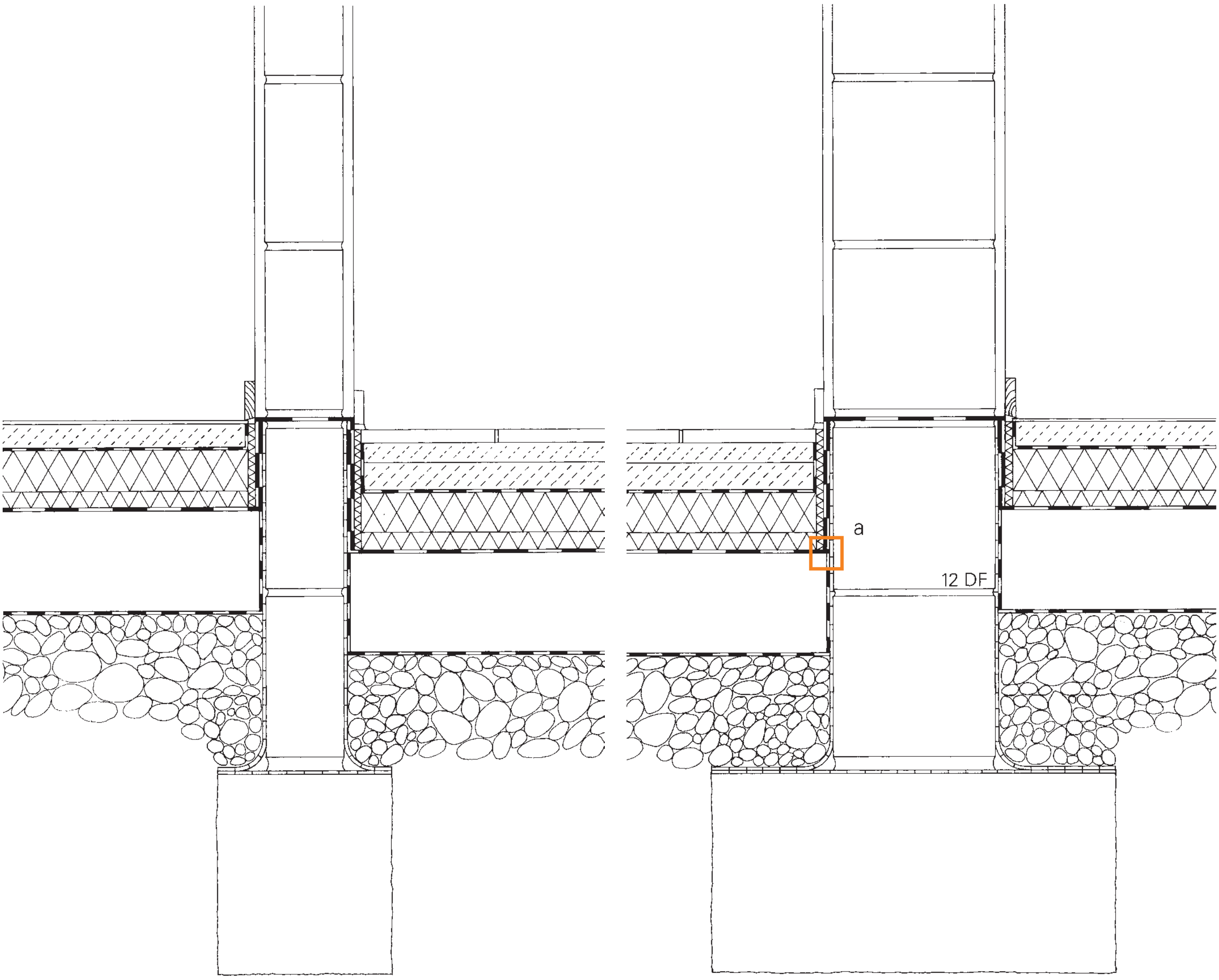
☐ e
Shear walls do not need to be built into the external walls – a butt joint is adequate – when other means (e.g. flat anchors cast in) are provided at the junction to resist the tensile and compressive forces.

☐ f
The separating joint, filled with elastic insulating material, must continue through to the render and be sealed there with an elastic material. Stop beads, fixed with a background to the wall, are frequently used. The joint itself is then covered with a folded PVC profile.

The solution shown here makes use of two stainless steel stop beads along the sides; the render continues right up to these stop beads. The space between the stop beads is filled with a closed-cell foam profile and after suitable treatment the joint is closed off with a permanently elastic sealing compound.

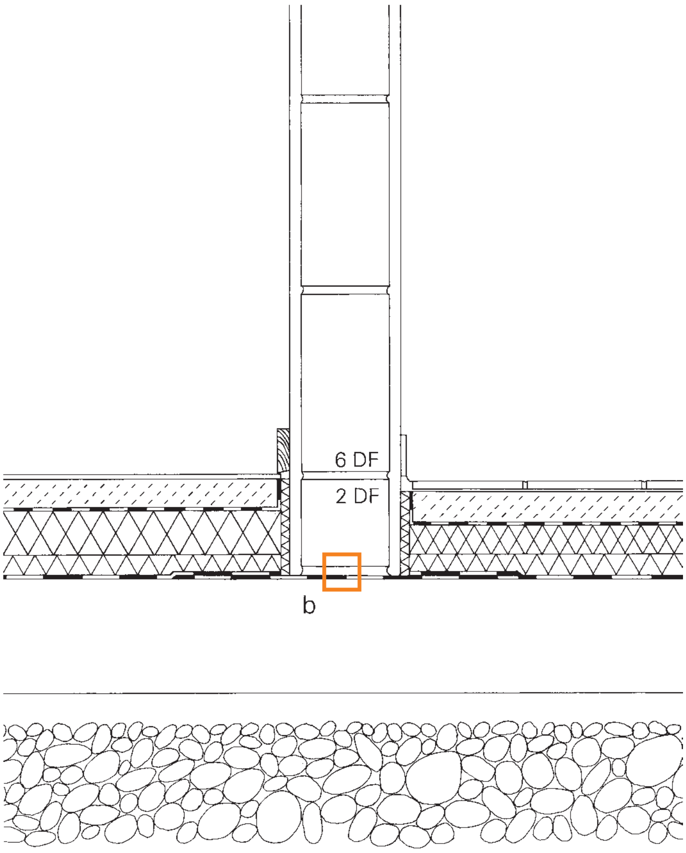


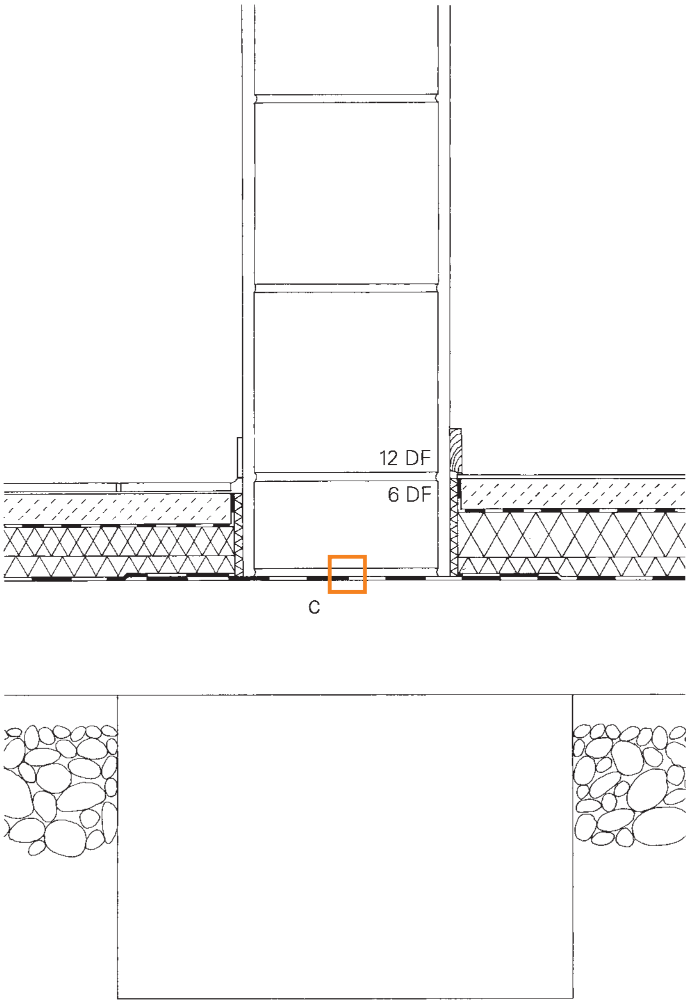
The ideal place for the rainwater downpipe would be directly over the joint. However, it is difficult to fix the pipe clips securely to the soft joint material – special fixings would be required.



□ a

If separate concrete ground floor slabs are used in each room, this saves concrete and reinforcement and also enables the use of different floor constructions. However, this does subject the damp-proof membrane (dpm) to an increased risk of differential settlement and hence damage.





☐ b

The constructional advantages of the continuous reinforced concrete ground floor slab become clear at the partitions.

Non-loadbearing partitions can be “carried” by a reinforced concrete ground floor slab if the slab is provided with suitable reinforcement to distribute the load.

☐ c

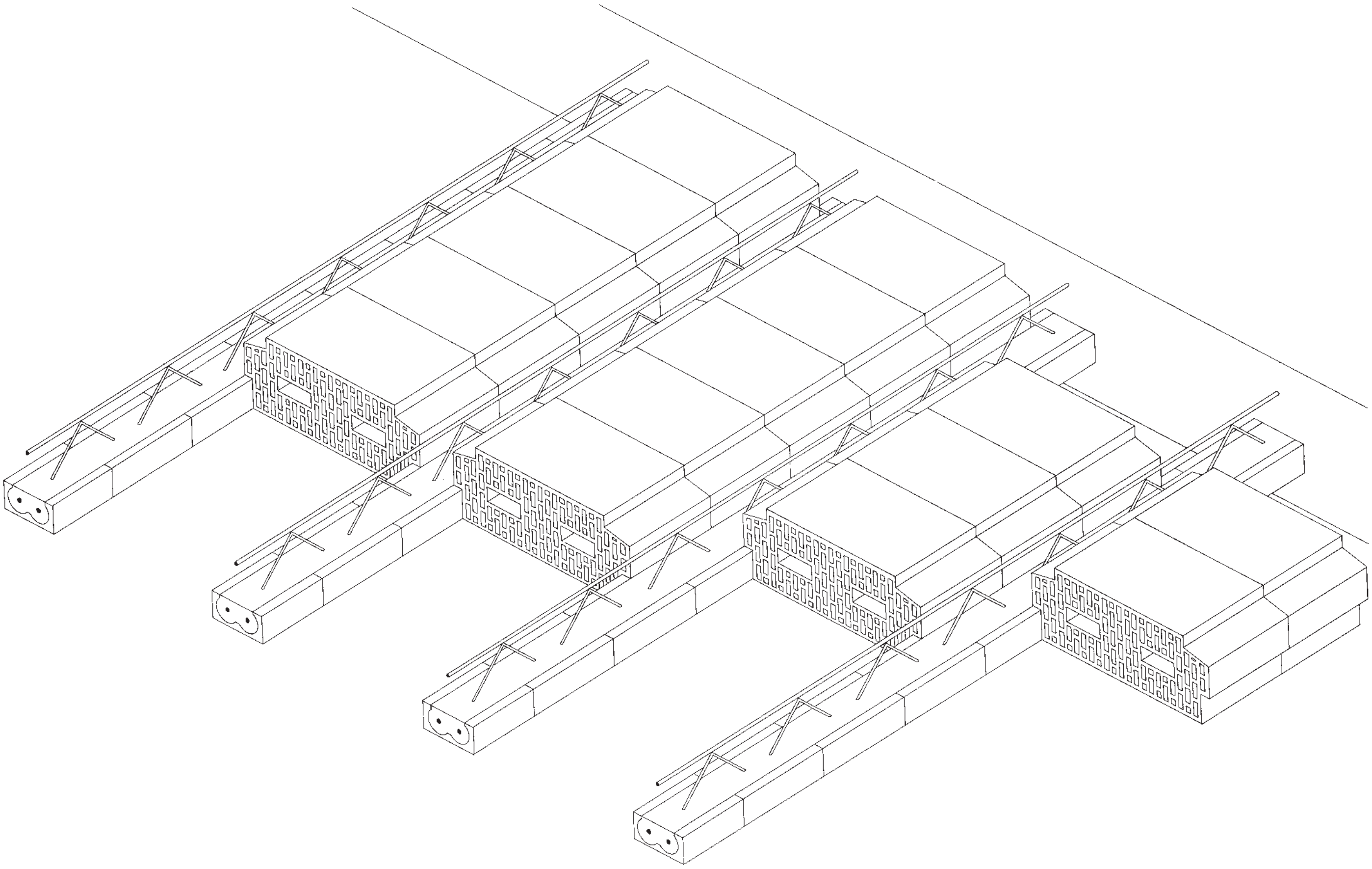
Secure joints in the dpm are also necessary below loadbearing partitions.

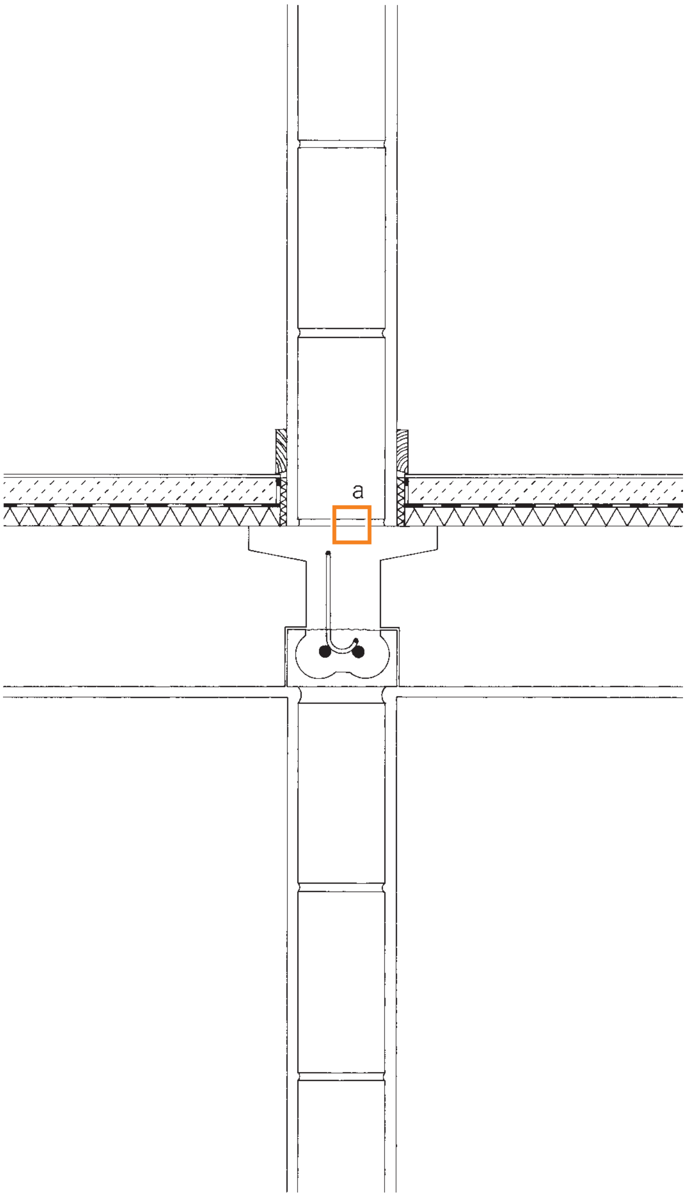
The foundation to the partition, which is not affected by frost heave and can therefore be shallower, is connected to the deeper foundation at the external wall either via a shoulder or, if the difference in depth is only small, by a sloping (30°, approx. 2:1) arrangement.

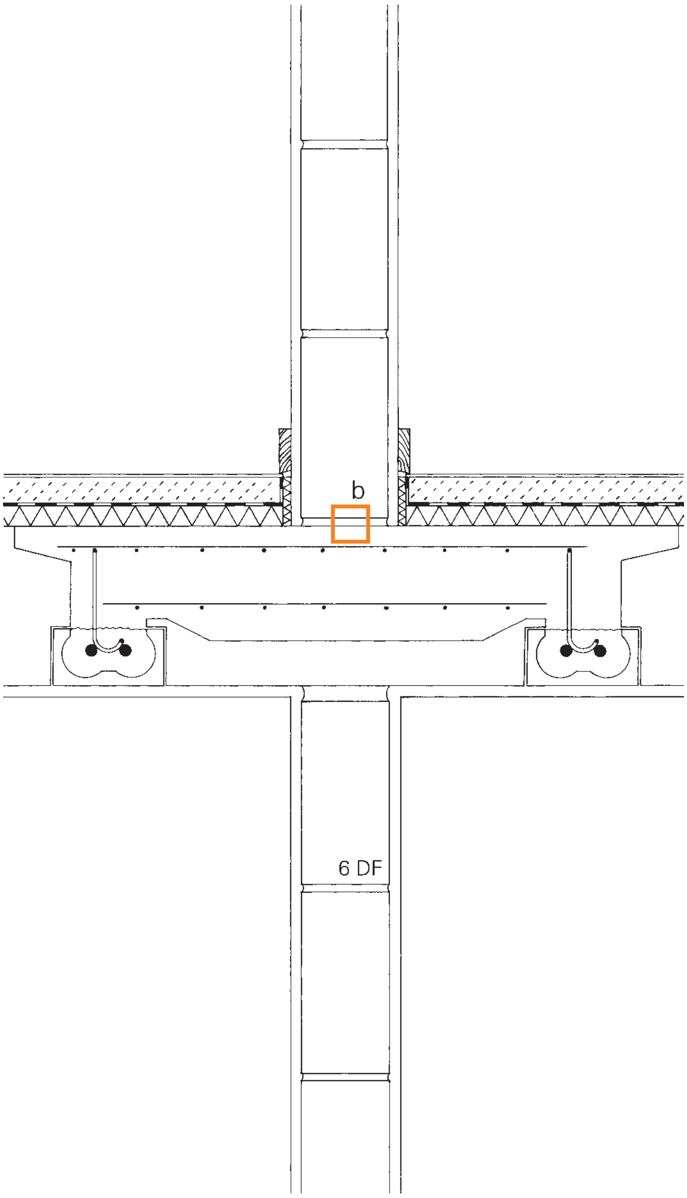
Isometric view of clay hollow pot floor

Clay hollow pot floors consist of beams, or rather ribs, with non-structural clay hollow "pots" in between. The prefabricated ribs must be temporarily supported during erection, but further formwork is unnecessary.

The compression zones of the ribs, reinforced as lattice beams, are finished on site with in situ concrete. Spans of 5–7 m are possible by using floor units of different depths (between 160 and 250 mm) and by varying the spacing of the ribs (500 or 625 mm centres). An in situ structural concrete topping added on site improves the load-carrying capacity and sound insulation.





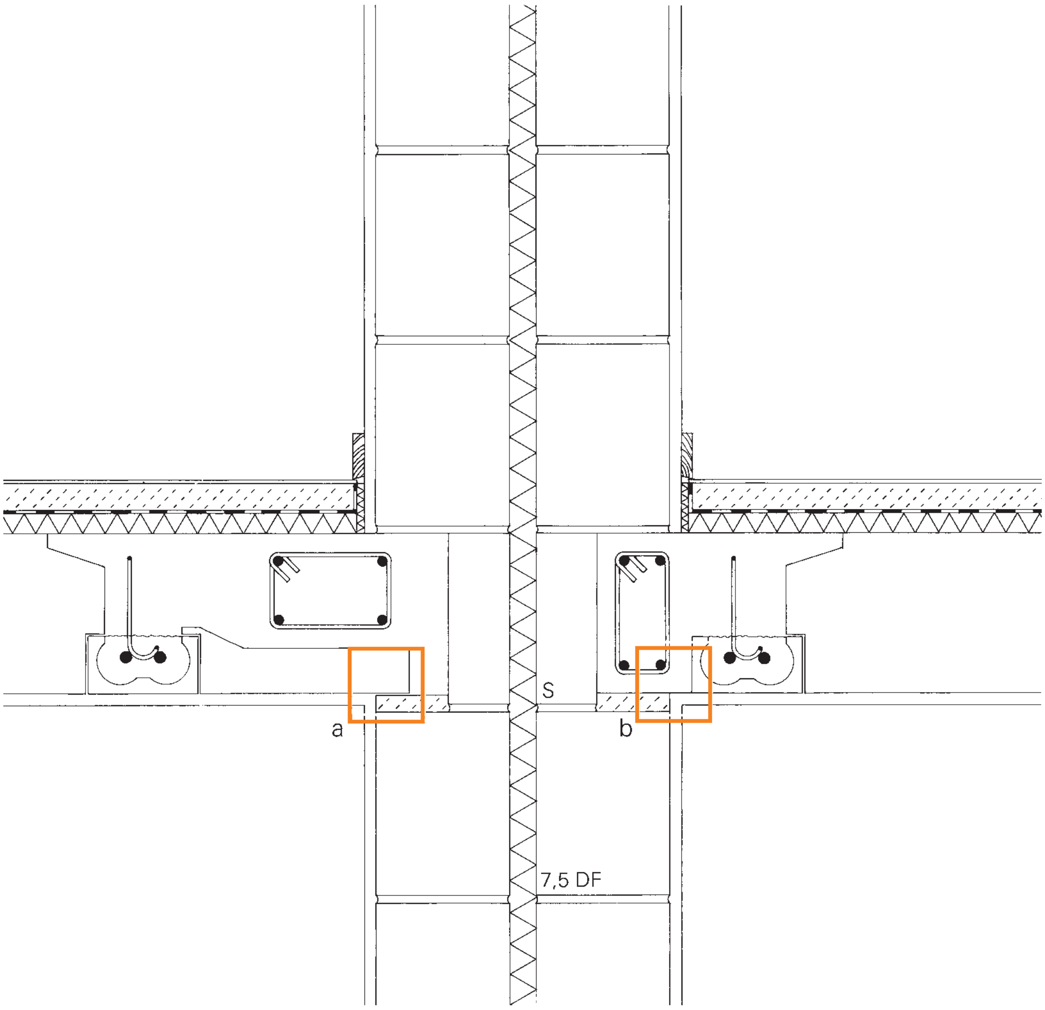


a

In this detail the partition and the rib are on the same axis.

b

If the partitions do not coincide with the ribs, a reinforced trimmer formed by a row of concrete-filled “negative pots” is required.



If the structure is not a multiple of the size of the clay hollow pot floor units, construct make-up (end) bays.

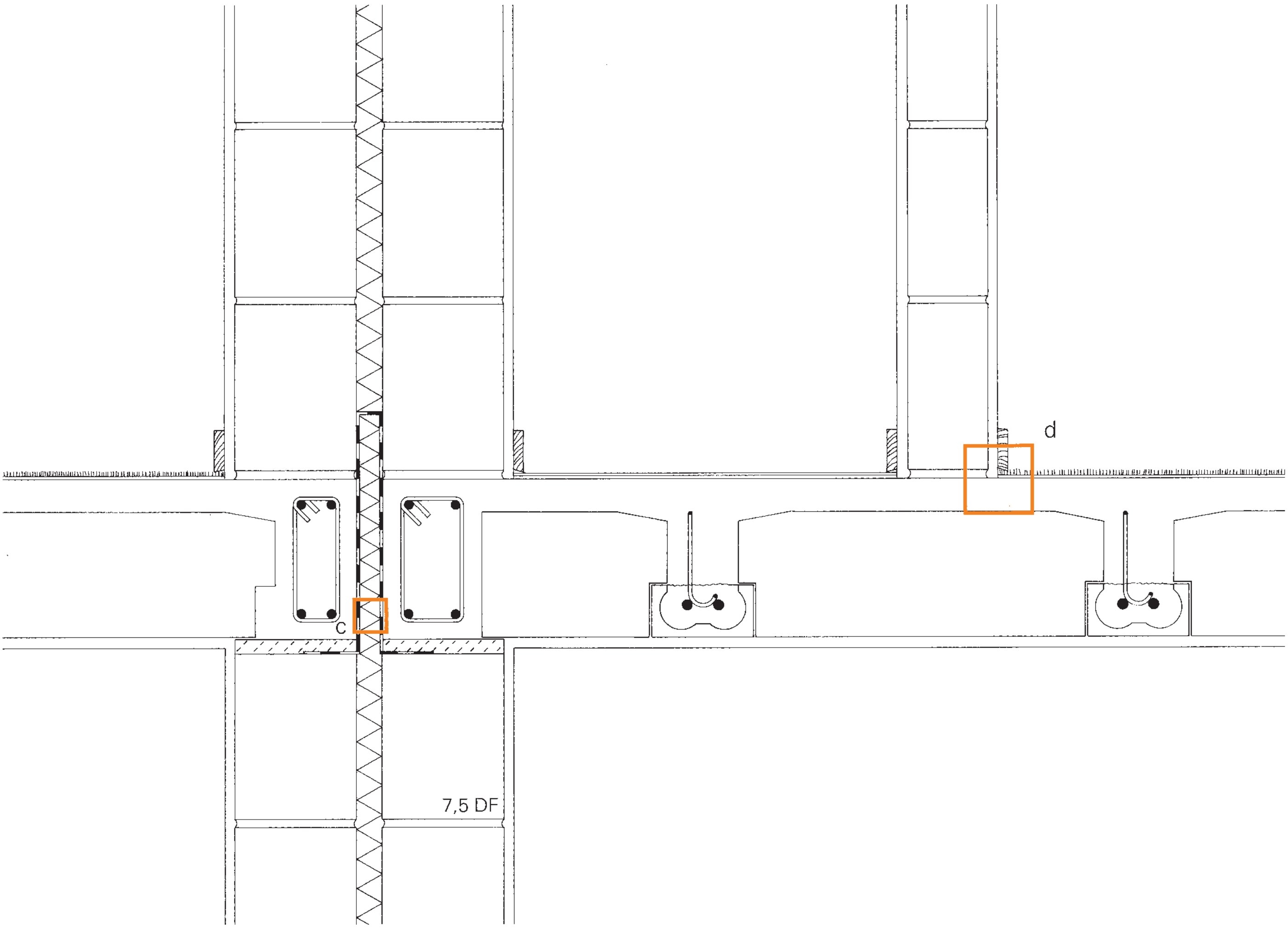
☐ a
With large edge margins lay flat “negative pots” and fill them with concrete to form an edge beam (reinforced as required). The brick-on-end masonry units guarantee the function of the separating joint.

The bearing for the floor units, a bed of mortar approx. 20 mm thick, should be at least 30 mm deep.

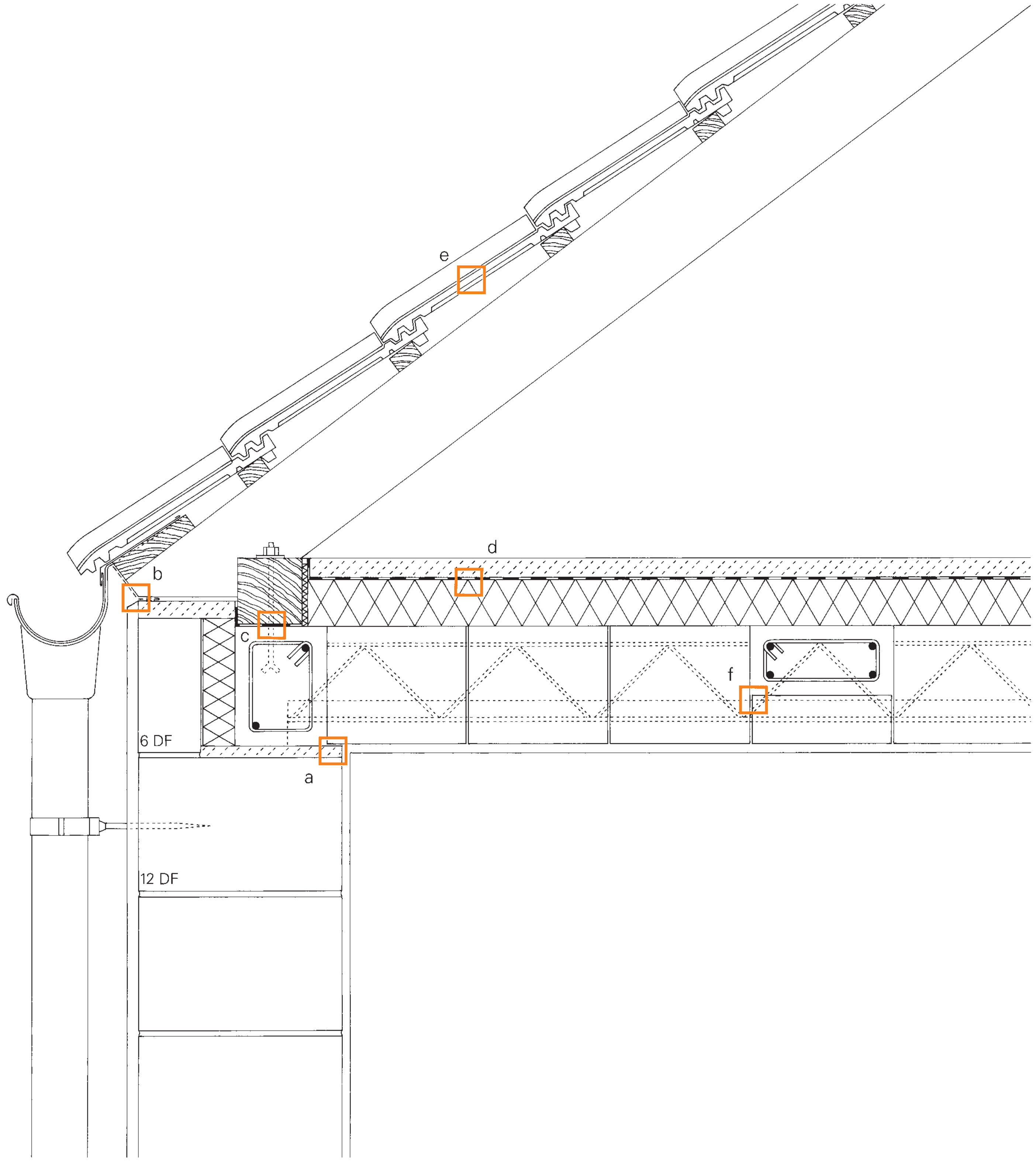
☐ b
With small edge margins between lattice beam, or rather the rib, and wall, fill the space between the floor units and the brick-on-end masonry units with concrete (reinforced as required) to form a ring beam.

☐ c
If the ring beam has to continue up to the separating joint, then it should be cast in two pieces, with the sound insulation being positioned after the first concrete pour and kept clean with a polyethylene sheet. The polyethylene sheet underneath the mortar levelling bed prevents cement slurry seeping into the separating joint.

☐ d
A concrete topping considerably improves the load-carrying capacity with regard to imposed loads and lightweight partitions, but also the acoustic performance of the clay hollow pot floor. In terrace houses – assuming no high demands on impact and airborne sound insulation within the same residential unit – a carpet with good sound insulation properties could well be adequate.


d
c
7,5 DF

External wall and roof space not used as living accommodation
Vertical section through eaves, purlin roof and clay hollow pot floor



☐ a
The floor units should bear max. 30 mm on the external wall, or rather mortar levelling bed. They are joined together and to the ribs with an in situ concrete ring beam.

☐ b
It is easy to construct a ventilated, “cold” roof space and this presents no problems in terms of insulation, moisture control, etc. The roof is simply an “umbrella” over a heated, heavyweight structure. It is little trouble to provide the topmost floor with thermal insulation. This type of floor is airtight and, thanks to its mass, stores heat well.

Ventilation in shallow-pitched roofs (< 10°) takes place from eaves to eaves (min. 20 mm net per m), controlled by wind pressure and wind suction. On steeper roofs ventilation at the ridge or near it (e.g. in the second row of tiles from the top) is necessary.

As it is not possible to prevent dust and driving snow from entering the roof space through the joints in the roof covering, this limits the use of the roof space.

☐ c
Connect the eaves purlin to the ring beam with ragbolts. The ragbolts are inserted into corresponding pockets which are filled with concrete after aligning the purlin.

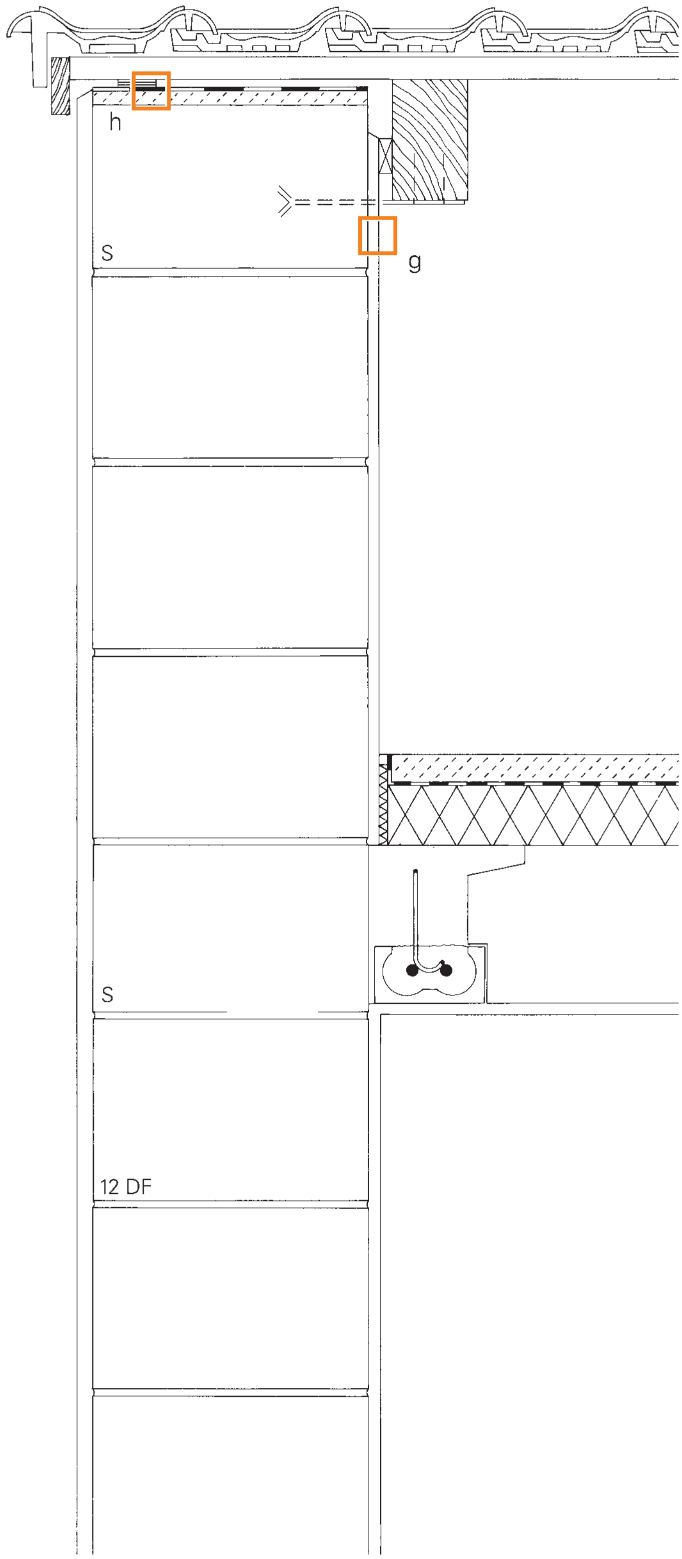
☐ d
The thermal insulation laid over the clay hollow pot floor is afterwards covered with a screed, which has joints around the edge and every 25–40 m^2. The screed serves as a wearing course, prevents damage caused by any moisture present in the roof space and also acts as fire protection.

☐ e
When using interlocking clay roof tiles, check the length of the rafter to ensure that it is suitable for the cover length of the particular tiles chosen.

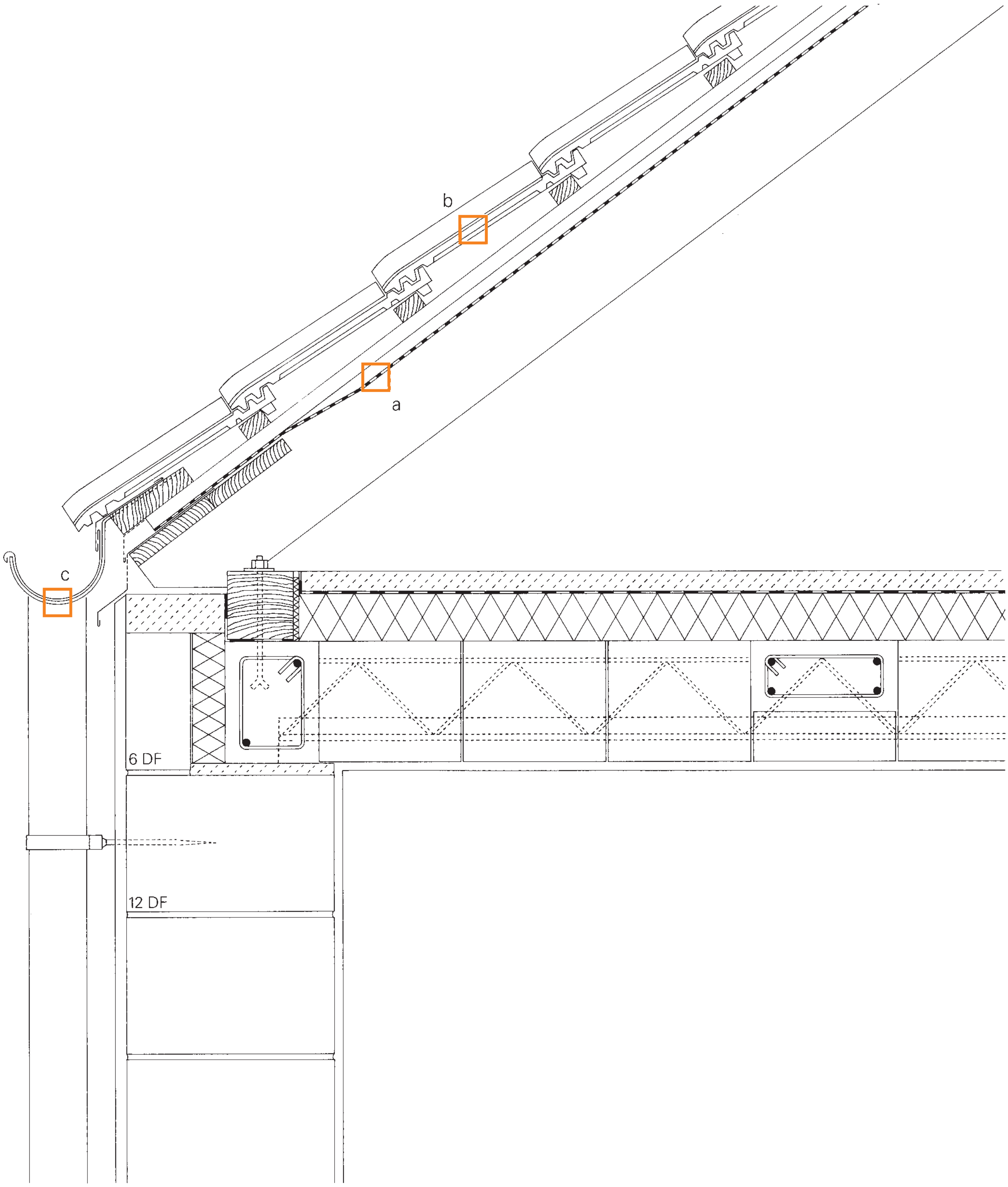
☐ f
“Negative pots” act as permanent formwork for the stiffening transverse rib.

☐ g
Gable walls, if not supported by masonry piers or cross-walls, must be fixed to the roof structure (DIN 1053), e.g. by means of galvanised steel flats or rustproof ragbolts. The joint between the final rafter and the masonry of the gable must be able to transfer the forces involved.

☐ h
After setting up the rafters, finish off the top of the gable wall with a screed, flush with the rafters. Cover this with a flashing of, for example, fully bonded bitumen roofing felt V 13. The 10—15 mm deep counter battens of AW 100 plywood prevent water collecting behind the tiling battens. The cover width of the clay verge tiles must coincide with the width of the building.



External wall and roof space not used as living accommodation
Vertical section through eaves, purlin roof and clay hollow pot floor



☐ a

The roofing felt under the tiles is a water-repellent but vapour-permeable material which remains stable despite temperature changes, e.g. mesh-reinforced polyethylene. It prevents the ingress of dust, rain and driving snow. Stretch it taut, secure it with counter battens and ensure that water can drain away at the eaves – ideally into the gutter (see p. 36, d).

☐ b

As on p. 32, flat-pan tiles are used here as well. The roof pitch of approx. 37° chosen for our example is suitable for virtually all types of clay roof tile: bullnose tiles as crown or slip tiling, pantiles, interlocking tiles with single or double troughs, right up to the ever more accurately interlocking varieties.

☐ c

Determine the cross-sectional areas of gutters and downpipes based on the size of the roof area to be drained. Create the fall of the gutter – min. 1 mm/m – by bending the gutter brackets to suit.

☐ d

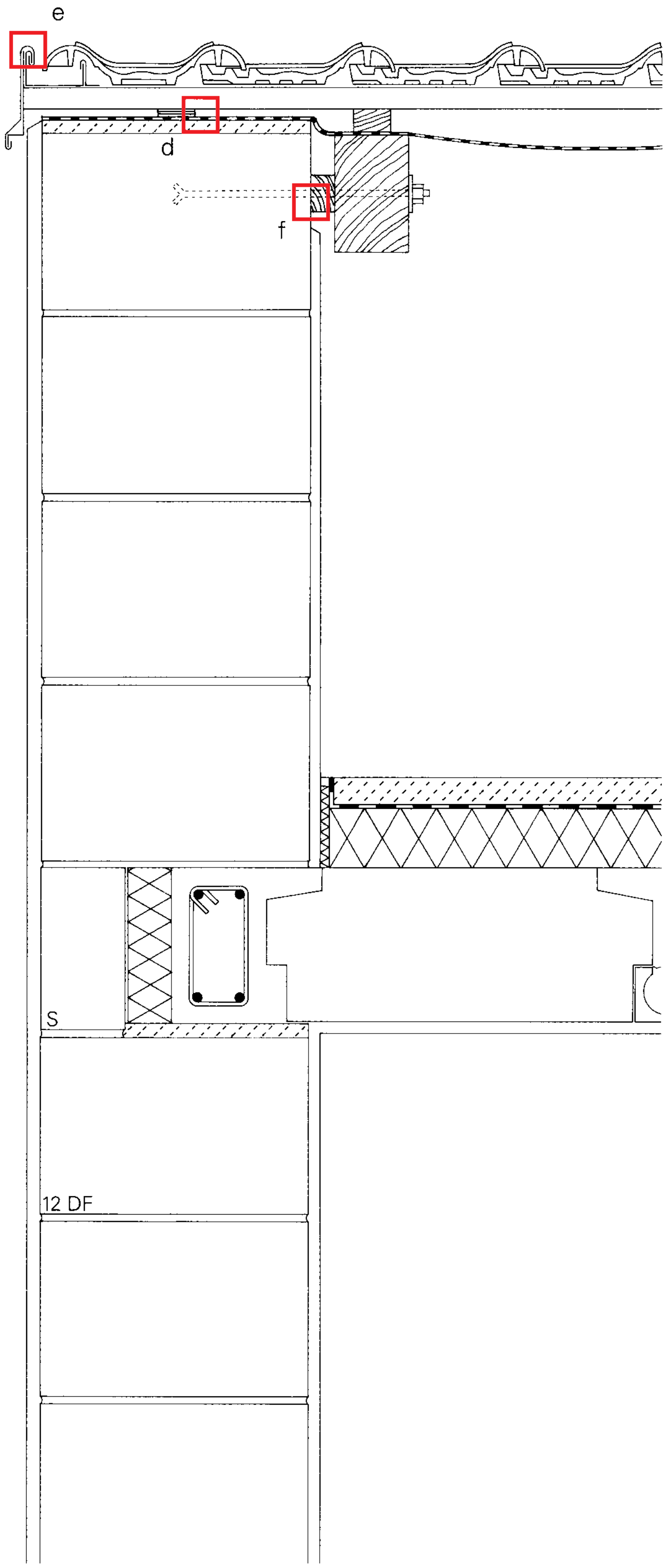
The roofing felt below the tiles continues over the top of the masonry, to which it is bonded. The thin counter battens prevent water collecting behind the tiling battens.

☐ e

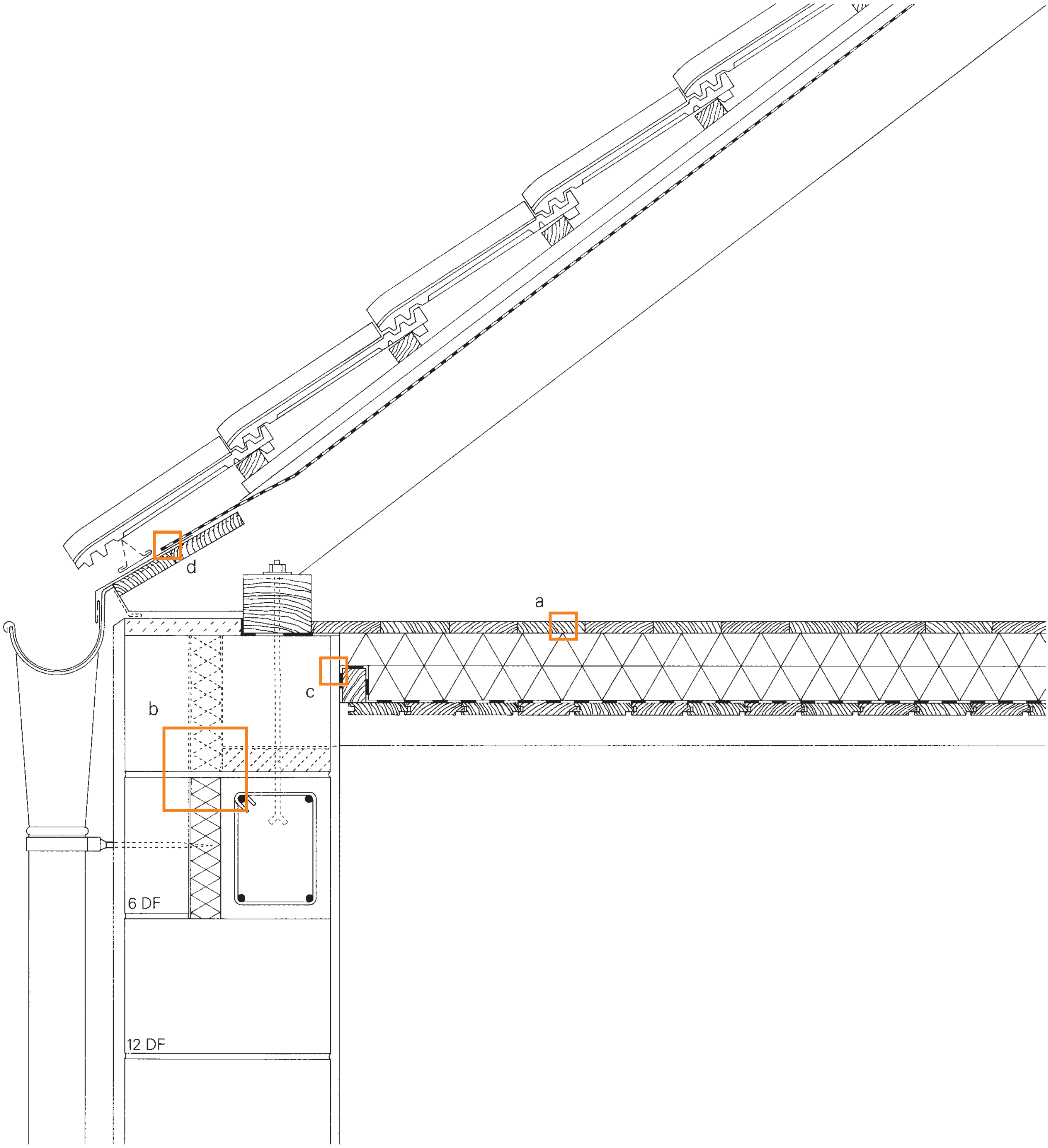
Use the two-piece bent sheet metal verge when, for example, the width of the building is not a multiple of the cover width of the interlocking clay tiles. Otherwise, special or cut tiles are necessary.

☐ f

Connect the masonry gable to the roof structure by means of cast-in ragbolts. Bracing in the plane of the roof is thereby necessary.



External wall and roof space not used as living accommodation
Vertical section through eaves, purlin roof and timber joist floor



☐ a
The timber joist floor over the upper storey represents an inexpensive and, for self-build projects, simple form of construction. Virtually any depth of thermal insulation is possible with loose materials, and easily laid. It is possible to improve the low heat storage capacity by using heavy loose materials or by laying solid bricks 50–70 mm thick below the loose material.

☐ b
The stability of the building in all directions is guaranteed by joining all loadbearing and shear walls to the floors with proper structural connections. If ring beams are provided, the walls can be regarded as being supported on all four sides; the floor joists only need to be held in position in that case. Line the joists pockets in the masonry with a moisture-resistant thermal insulation, at least at the end of the joist, preferably on all sides, to reduce the risk of damage by condensation water.

☐ c
The airtight connection between the 0.2 mm polyethylene sheet and the wall is achieved with adhesive and by using a clamping batten pressed onto a preformed compressible sealing strip along the wall. The most secure connection is when the polyethylene sheet is wrapped around a batten and screwed through this into the wall.

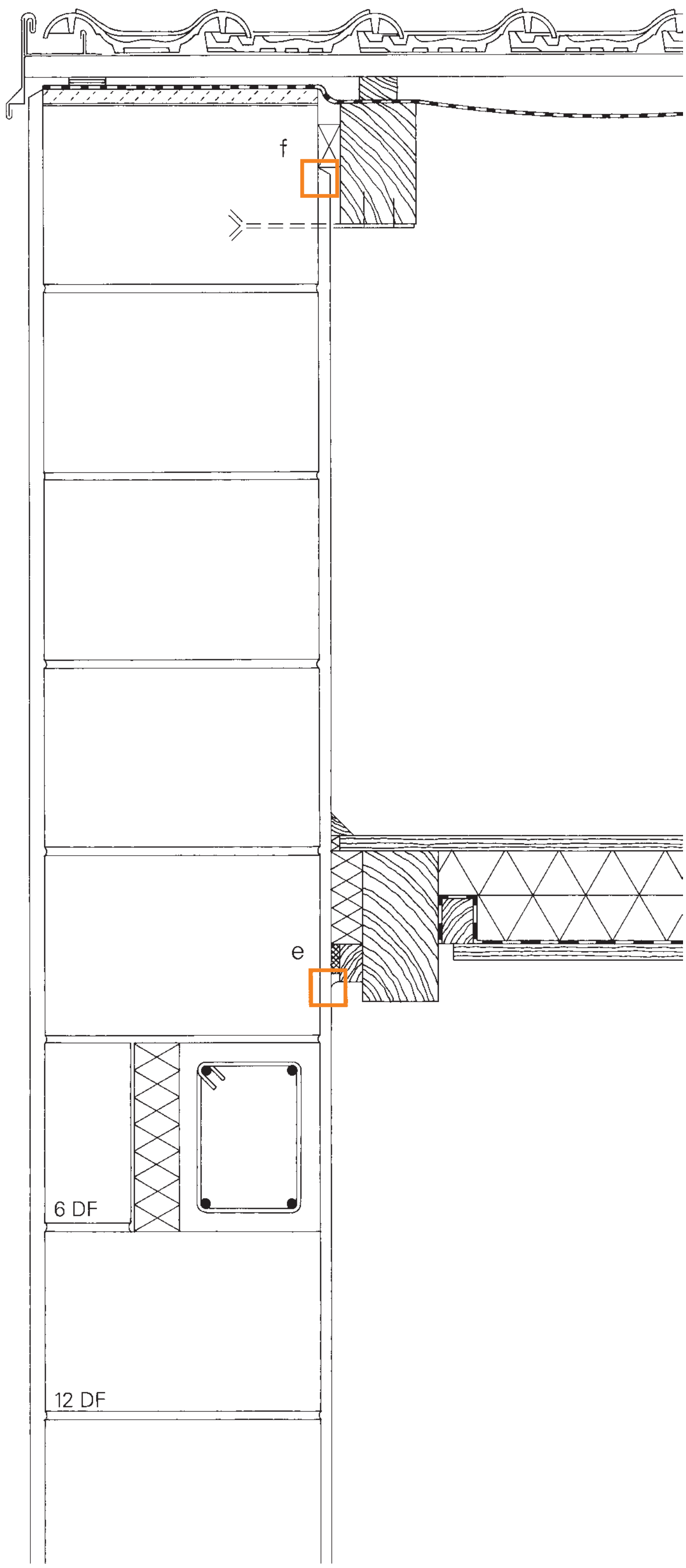
☐ d
Glue the roofing felt below the tiles to the nailed sheet metal. The perforated sheet metal bent into an inverted V-shape ensures ventilation below the clay roof tiles.

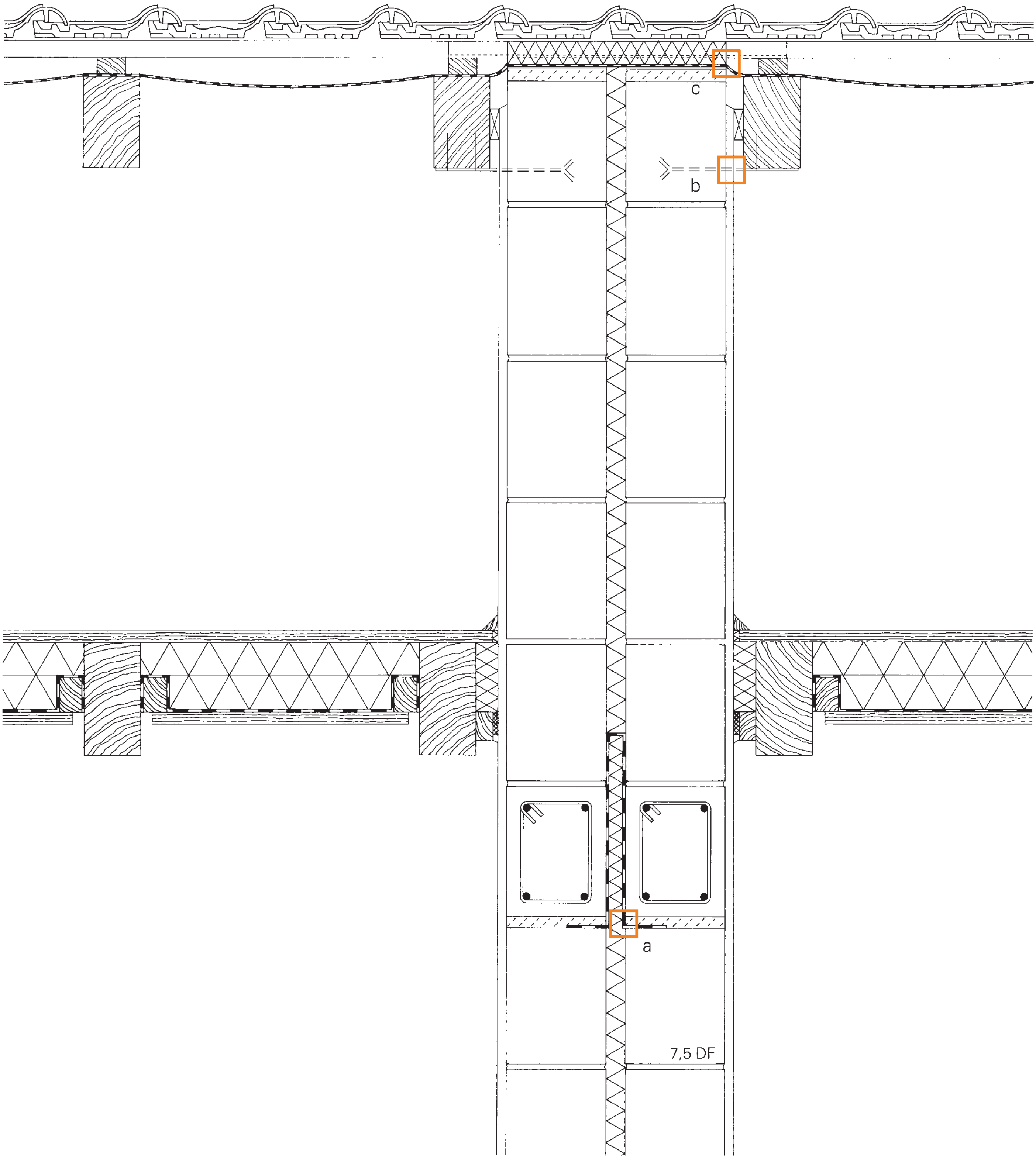
☐ e
Even if the plastering work is carried out before laying the timber joists, the unevenness of the wall and the ring beam must be evened out with an adaptable “system” which closes off the joints airtight.

This can be achieved with a batten nailed through a preformed compressible sealing strip. Fill the void between joist and wall completely with an uncompacted mineral fibre material.

After filling the bays between the joists with a loose insulating material, nail on the actual flooring material. The gaps at the edges, necessary to allow movement of the flooring, can be covered with a triangular fillet.

☐ f
Connect the gable wall to the roof construction in such a way that forces can be transferred.



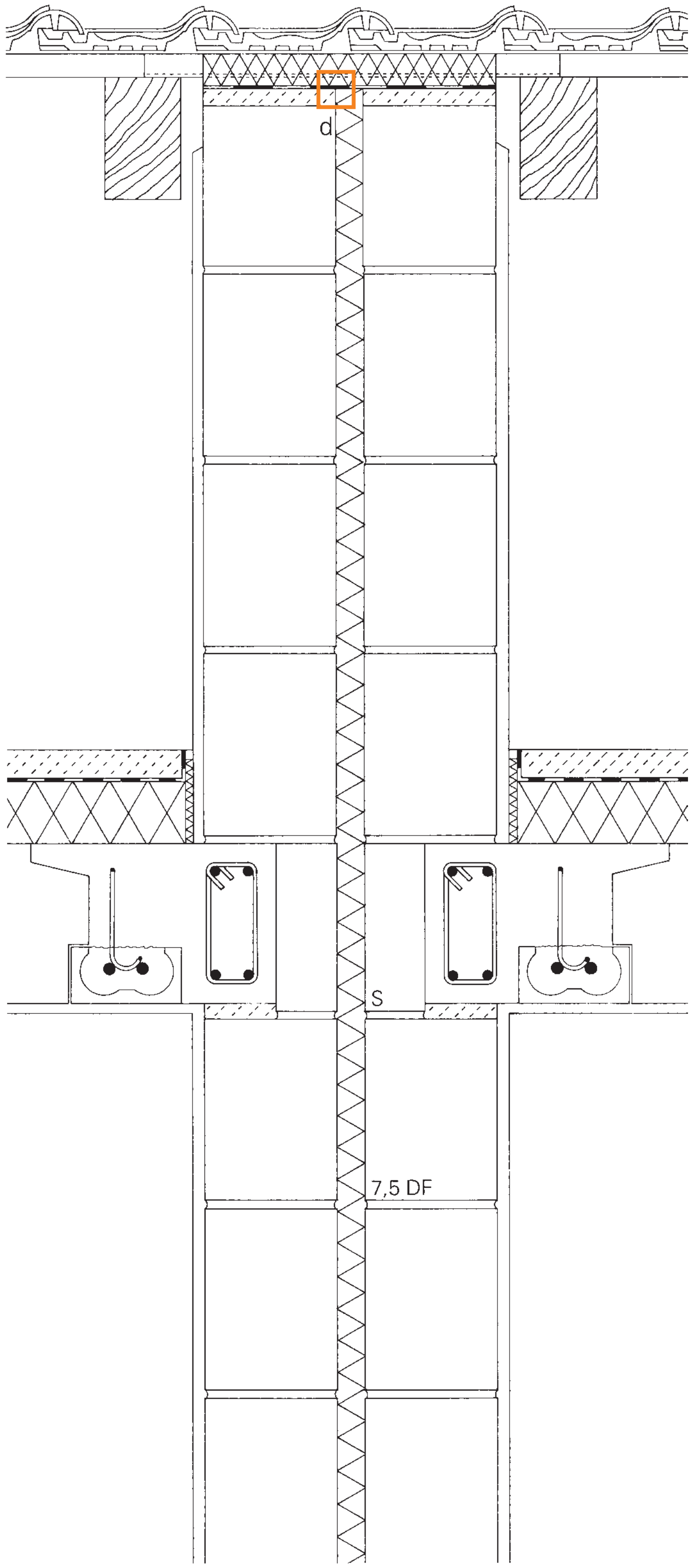

c
b
a
7,5 DF

☐ a
If the floor joists are parallel with the wall, the slender, tall party walls must be secured with ring beams if they are not connected to the braced roof structure.

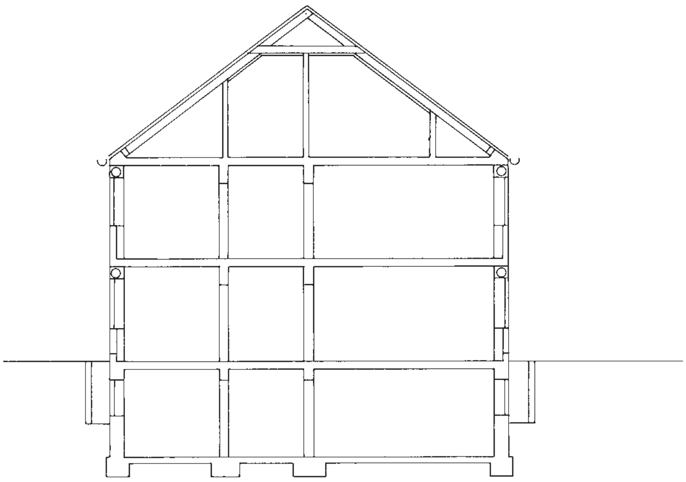
☐ b
Connect the unsupported tops of the walls to the braced roof structure such that forces can be transferred. Continue the separating joint through to the roof even in a roof space not used as living accommodation.

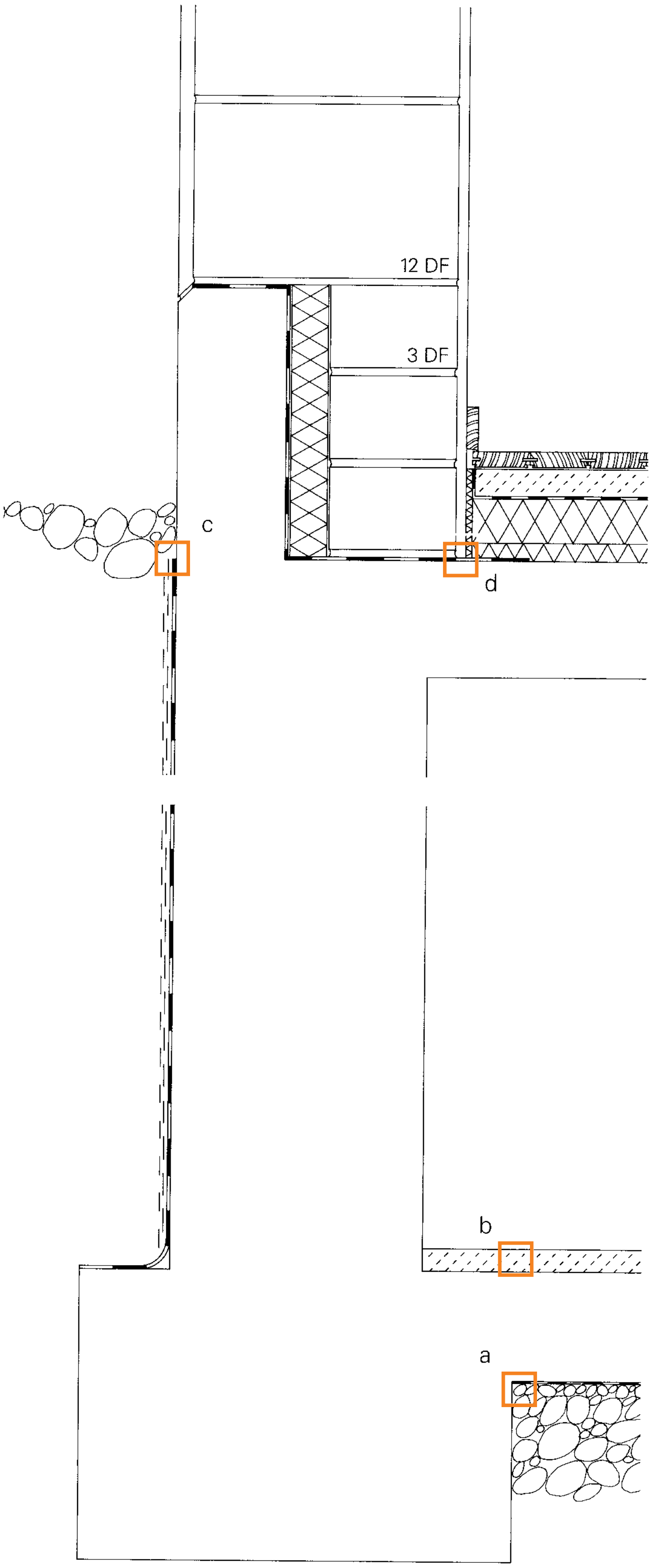
☐ c
The roofing felt held by the counter battens – essentially taut but sagging slightly due to temperature changes and extension of the material – is bonded to the mortar levelling bed.

☐ d
It is advisable to replace the tiling battens by galvanised steel angles. A clearance of 10–20 mm between the angle and the top of the masonry enables the roof structure to deform without restraint. Fill the space between the angles with an incombustible, volumetrically stable insulating material. If the roof space is to be converted into living accommodation at a later date, the separating joint must continue up to the roof covering and the tiling battens must be divided.



House B





a

Cast the upper, and reinforced, part of the strip foundation together with the reinforced concrete basement floor slab in one pour, then strike the outside formwork. The depth of the reinforced concrete basement floor slab depends on the loads from the basement partitions but should be min. 120 mm in order to ensure the necessary concrete cover to the reinforcement.

b

A damp-proof membrane (dpm) beneath the screed is not required when the building is founded on a quick-draining subsoil and neither a high-quality floor covering nor impact sound insulation or thermal insulation is required. However, if a damp-proof membrane is not included, a layer of hardcore to prevent capillary action is necessary. An approx. 30 mm bonded cement screed is adequate as the wearing course in simple basement rooms.

c

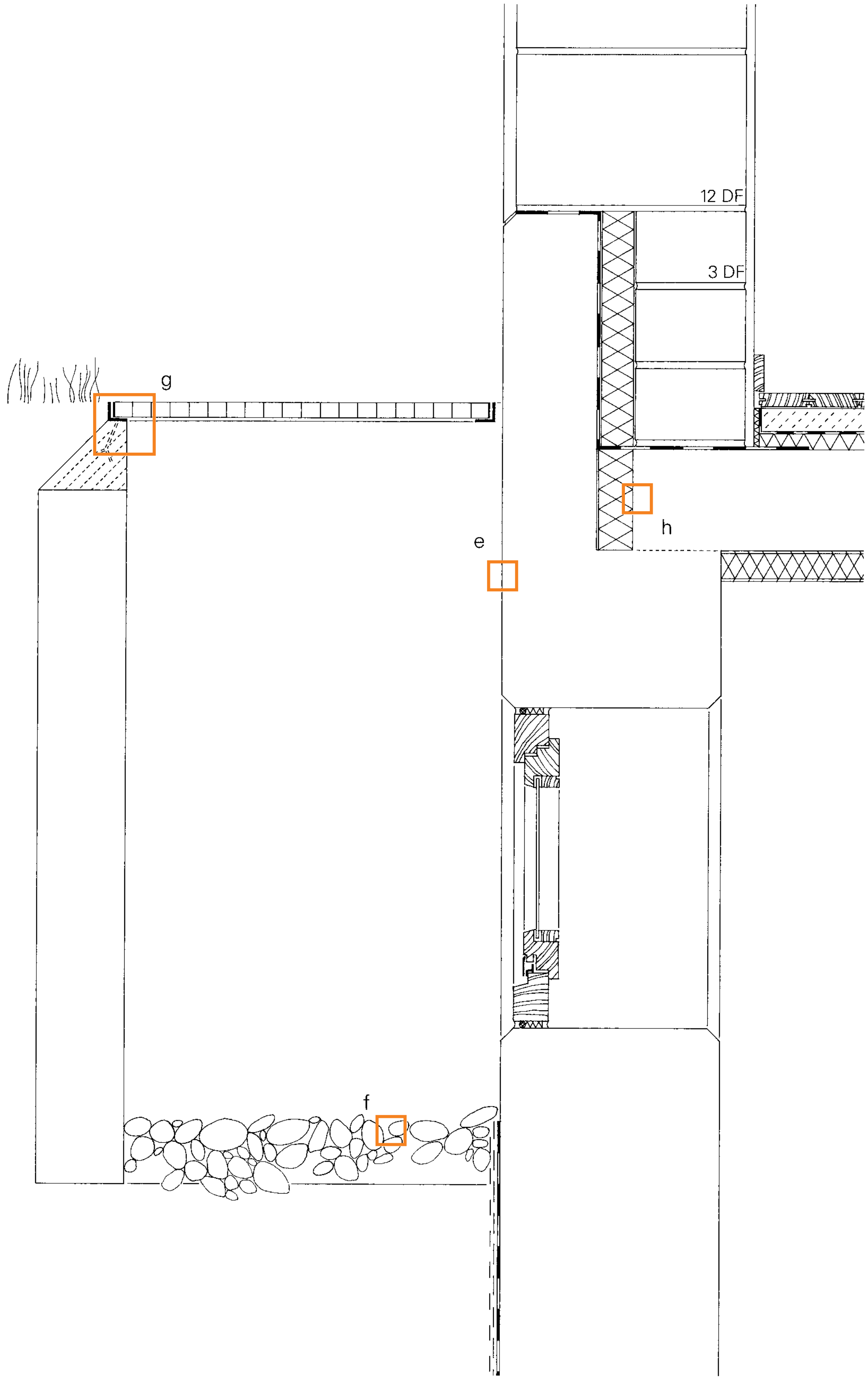
Basement walls constructed in normal-weight concrete – even if they are reinforced – must be waterproofed on the side in contact with the soil. The type of waterproofing depends on the level of moisture to be expected on the outside. DIN 18195 part 1 table 1 categorises types of waterproofing according to moisture load and soil type. Moisture in the soil must always be reckoned with. Furthermore, in cohesive soils and/or on sloping sites the presence of water in droplet/liquid form is to be expected. This means that waterproofing to protect against non-hydrostatic pressure must be backed up with a drainage system which prevents short-term hydrostatic pressure (see pp. 48 and 52).

Special measures must be taken for hydrostatic pressure on the outside.

For moderate loads waterproofing to the normal-weight concrete of the external basement wall can be achieved in various ways: e.g. with one layer of bitumen felt, bitumen built-up felt, in each case with a fabric inlay and 100 mm laps on a priming coat; with bituminous coatings in several layers; with two layers of a mineral sealing coating with building authority approval. Whereas in the case of flexible sheeting good protection is required during backfilling and the upper “exposed” end must be sealed, the mineral coatings cannot bridge over any cracks owing to their inherent brittleness.

d

The ground floor construction in this example includes thermal insulation to insulate against the unheated basement. Take the presence of heavy concentrated loads into account when choosing the insulating material. Place the impact sound insulation beneath the thermal insulation and around the edges – without interruption – in order to produce a “floating” floor construction. Consequently, the floor finish must be fully isolated as well; continuing the edge insulating strip up to finished floor level is advantageous.



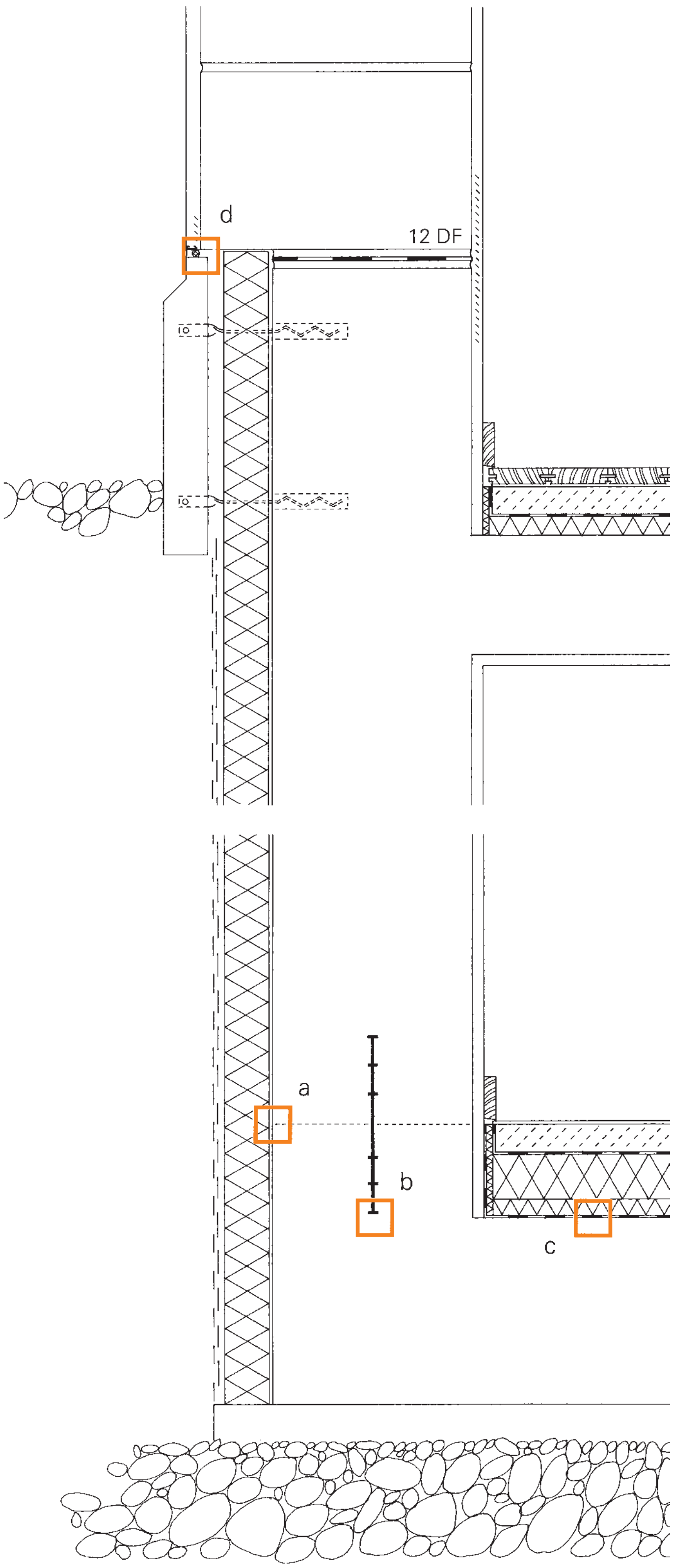
e
Lightwells of in situ concrete "hang" on the basement wall and must be connected to this – possibly with folding anchors which are placed in the formwork and, after striking the formwork, are exposed again and folded out into position.

f
The base of the lightwell can be covered with a coarse gravel, which will have to be replaced from time to time – assuming a quick-draining subsoil and backfilling.

g
The top edge of the lightwell in this example is reduced to match the size of the grating so that any paving or grass can continue right up to the edge of the frame. Cast the top edges of the lightwells later to match the level of external works and external doors, also with falls if necessary.

h
If the thermal insulation is attached to the underside of the ground floor slab, this results in a thermal bridge to the external wall. This has to be minimised by including insulation within the thickness of the wall which extends down at least to the underside of the ground floor slab.

External basement wall with perimeter insulation
Vertical section through prefabricated plinth



a

The basement wall can also be waterproofed by using impermeable concrete. This type of concrete is achieved with min. grade C 25/30 concrete having a limited water penetration depth (max. 50 mm), and by ad-hering to the required water/cement ratio and grading curves. Reinforcement to prevent/limit cracking is essential. Careful compaction and subsequent treatment is required. The minimum thickness is not prescribed but should not be less than 250 mm.

External – perimeter – thermal insulation to components in contact with the soil is produced from close-cell extruded, polystyrene foams or cellular glass, which absorb little or no moisture and are attached to the waterproofed basement wall with dabs of, for example, bonding mortar.

Cover the insulation with corrugated bitumen sheeting or studded flexible sheeting to protect it against mechanical damage during backfilling.

b

Foundations to small houses are often simplified and constructed together with the ground slab as a raft foundation, which must be properly designed and reinforced accordingly. Thickening of the slab may be necessary under heavy loads, e.g. individual columns, intermediate loadbearing walls with larger openings.

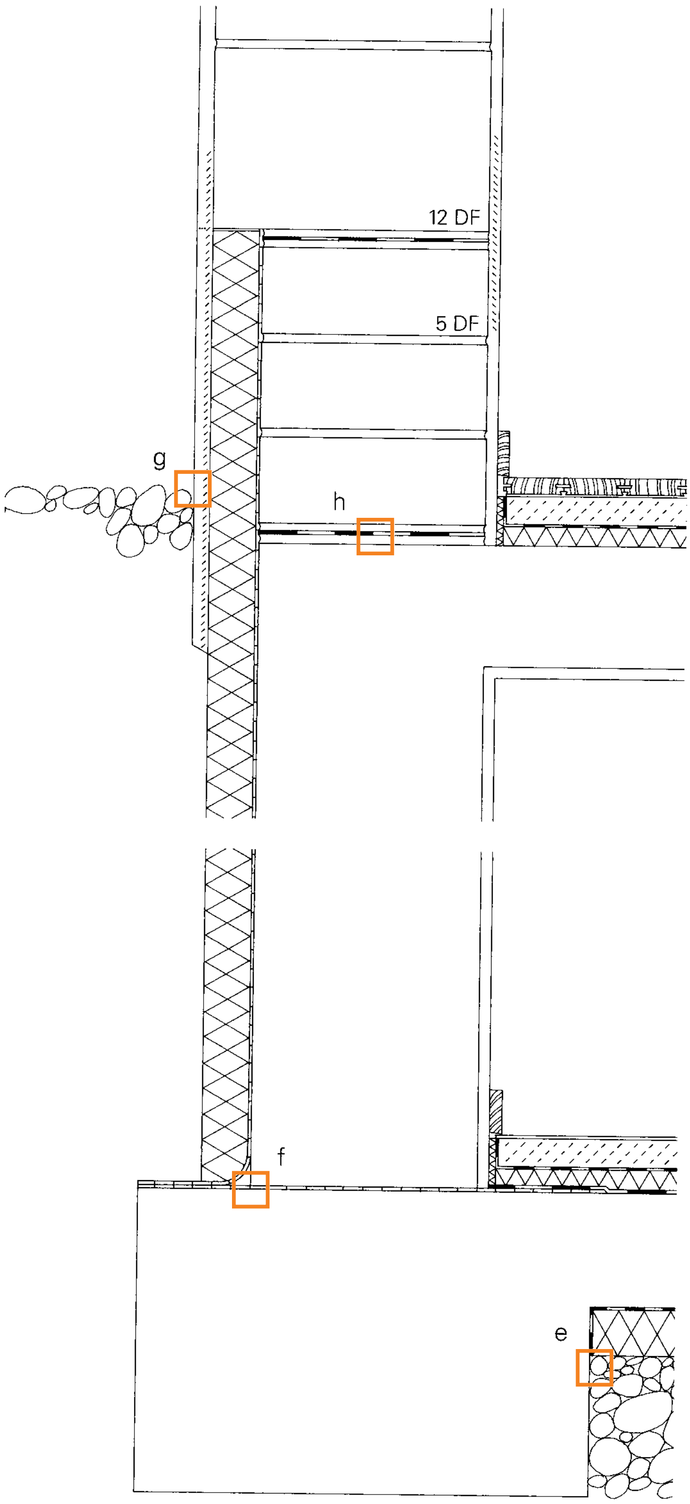
If the raft foundation is constructed from impermeable concrete like the external wall, seal the joint between the two concrete components with a water-stop or water bar.

c

A heated basement forming part of the living accommodation requires an acoustically and thermally insulated, waterproofed floor slab with a floating screed. To prevent saturation of the impact sound insulation by the construction moisture in the concrete floor slab, provide a separating layer of, for example, polyethylene sheeting.

d

Protect the transition between basement wall and external wall – the plinth – against splashing water and mechanical damage by means of precast concrete or natural stone panels. Support these on cast-in anchors. Finish the render at a stop bead and close off the joint to the plinth with a permanently elastic sealing compound. The external masonry projects approx. 90–100 mm beyond the concrete wall. The underside of the perforations in the clay blocks should be closed off at the projection. On the inside, reinforce the plaster with a textile mesh at the transition between the two materials.



e
Lay the insulation below the reinforced concrete basement slab on a filter gravel or layer of blinding and cover over with a separating layer. Cast the basement slab on this. A covering of lean-mix concrete is advisable.

When calculating the heating requirements allow for small heat losses via the thermal bridges at the strip foundations under the external walls and loadbearing walls.

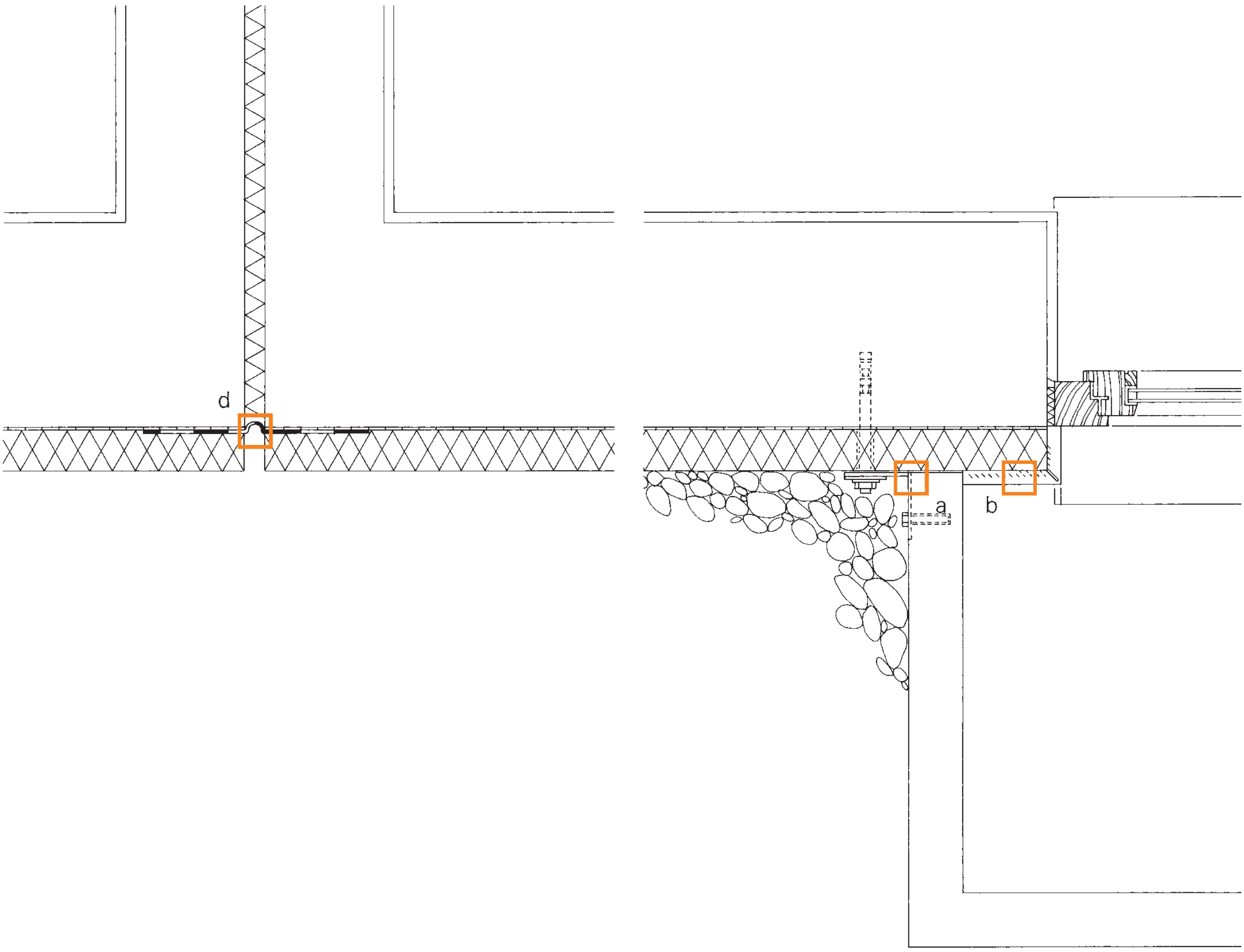
f
Continue the mineral sealing coating beneath the external wall and join it to the flexible sealing coating on the outside of the external basement wall.

g
The building trade is divided on the best method of constructing a rendered plinth on properly fixed perimeter insulation batts. At least two coats of impermeable render (suitable for plinth work) will be necessary on splatterdash and a galvanised background, additionally reinforced if necessary.
Whether the normal render thickness of 20 mm is sufficient for this type of detail is questionable. The render that extends into the ground must be protected against long-term saturation.

h
DIN 18195 part 4 calls for at least one horizontal damp-proof course (dpc) in the internal and external walls.

The number of horizontal damp-proof courses is left to the discretion of the design team.

The damp-proof course beneath the masonry of the wall represents a precautionary measure preventing moisture rising from the concrete below.

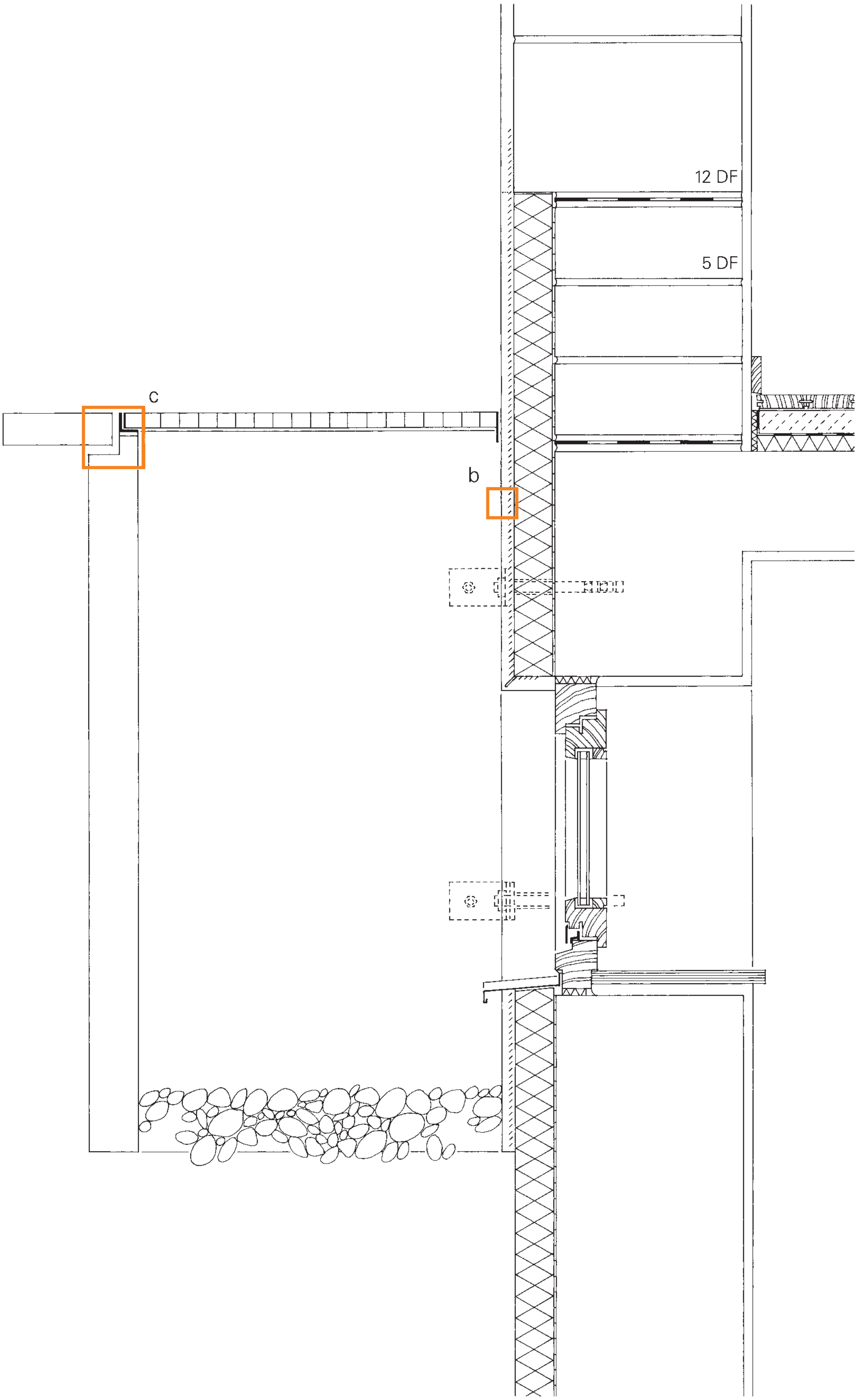

d
a
b

☐ a
Fixing a lightwell to a wall with perimeter insulation is not without its problems because the insulation should not be penetrated or, at best, only minimally. Individual fixings using heavy-duty anchors and spacers with building authority approval are therefore employed. The approved edge distance between anchor and window opening must be assured.

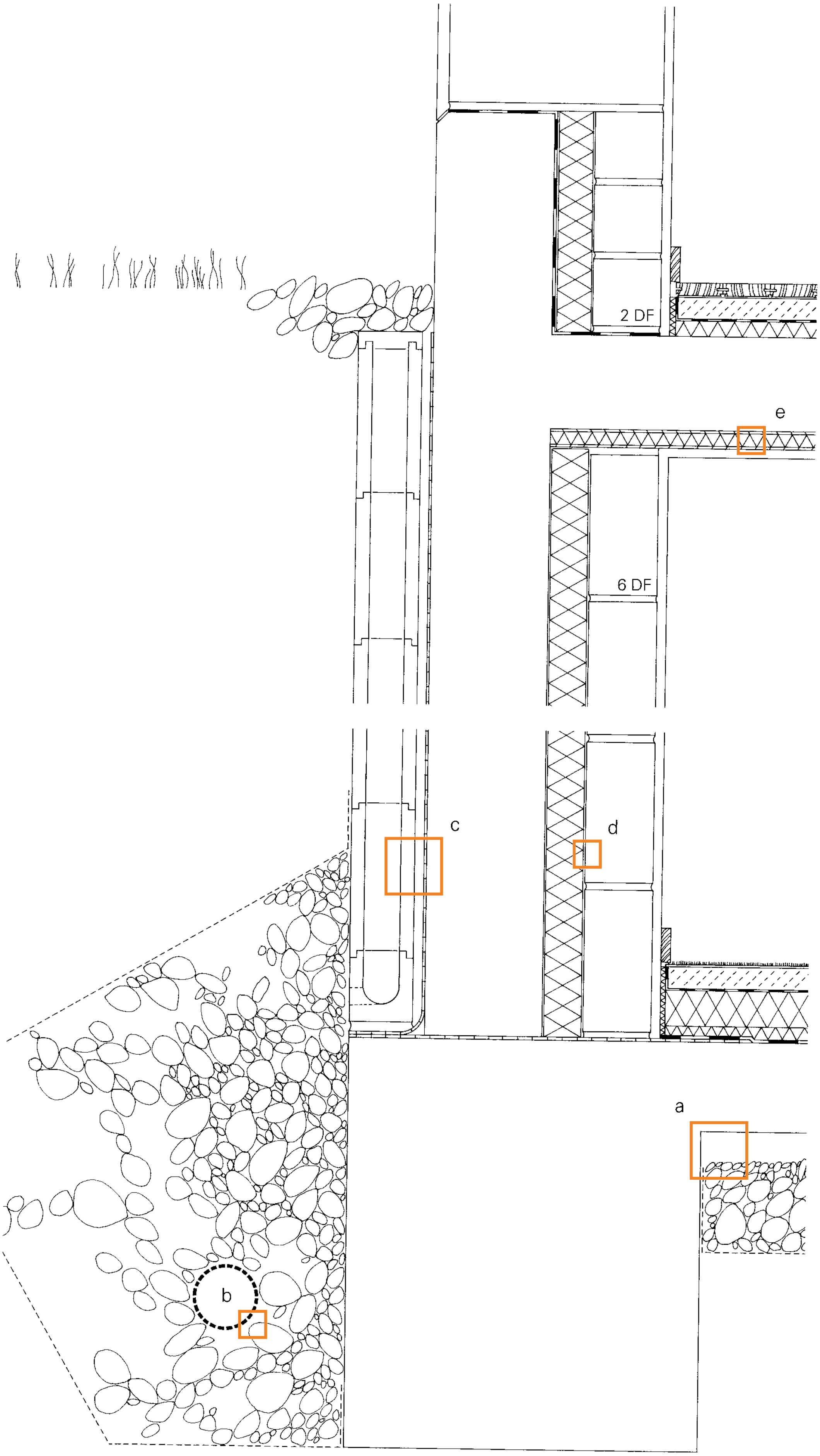
☐ b
Furthermore, the "surface of the wall" presents problems. Although the render to the plinth can continue down into the lightwell together with the background, such small areas of render complicate the construction. The area can be rendered before mounting the lightwell.

☐ c
If requested, some manufacturers will position the rebate at the top of the lightwell externally. An inconspicuous edge is thus possible.

☐ d
Below ground level seal the joint between the buildings with flexible sheeting. The small loop of excess material is necessary to accommodate movement. The joint between the buildings must continue through the plinth.



External basement wall with cavity insulation
Vertical section through concrete plinth



a

The reinforced concrete strip foundation requires formwork to both sides. Cover the anti-capillary hardcore layer, included for additional security, with a layer of blinding concrete, grade C 8/10, and then cast the reinforced concrete ground slab on top of that. This forms a good base for working in difficult, e.g. clayey, subsoils during rainy periods.

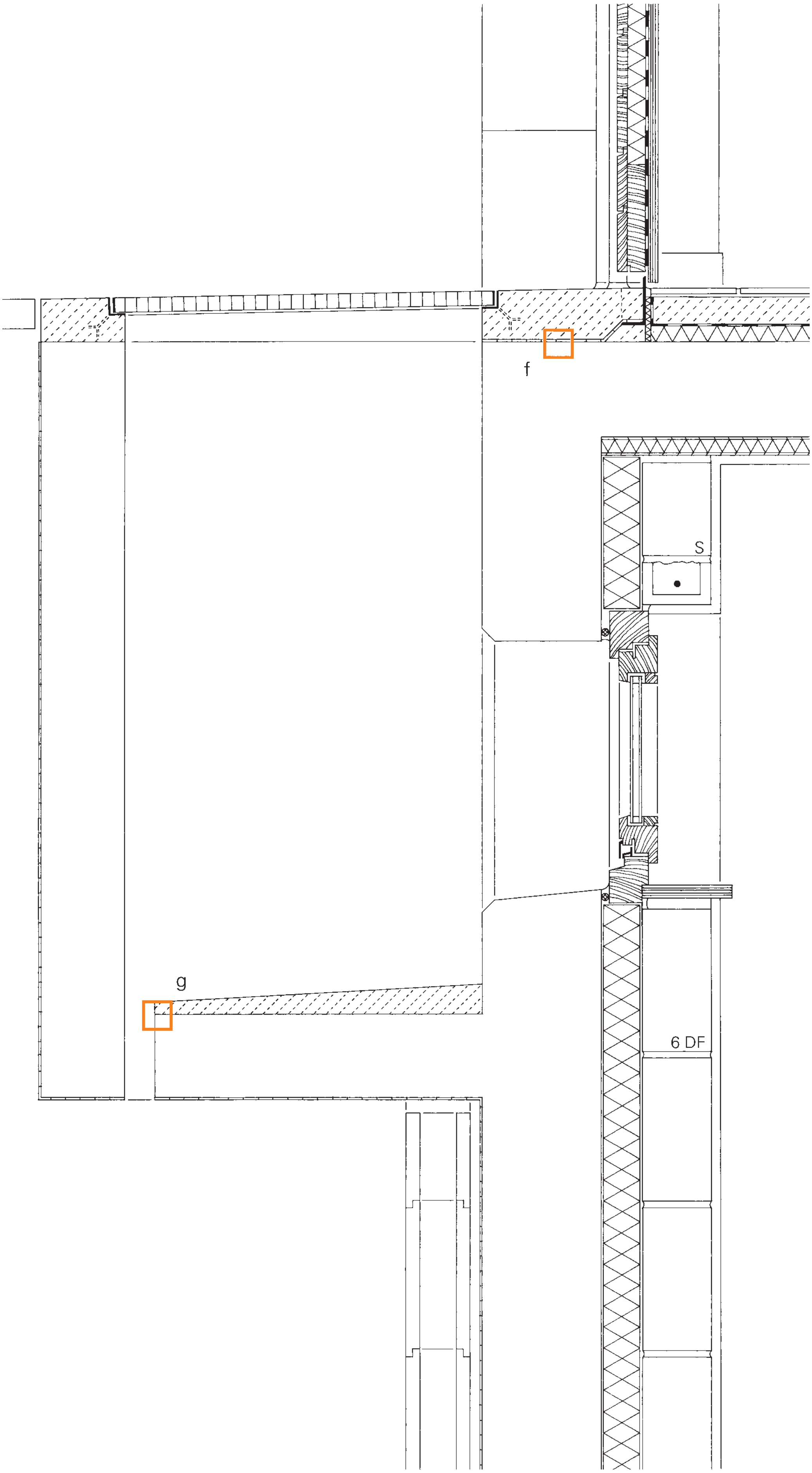
Drainage around the perimeter is necessary on sloping sites or in cohesive soils.

b

Lay the pipes, min. 100 mm NB, for the perimeter drainage on a gravel bed to a fall of 0.5%, better 1%, and surround them with a filter mat in order to keep out the finest soil particles. In order to avoid undermining the foundation, do not lay the drainpipe and the filter bed lower than the underside of the foundation. A distance of min. 200 mm between the top of the structural slab and the underside of the drainpipe is mandatory.

c

The concrete drainage units protect the waterproofing against mechanical damage and ensure that water is drained away from the external wall.



d

The detail with moisture-resistant cavity insulation, e.g. polystyrene or mineral fibre batts, and an inner leaf ensures adequate thermal insulation and a good moisture balance in heated basement rooms. It is not usually necessary to include a vapour barrier on the inner side of the thermal insulation.

e

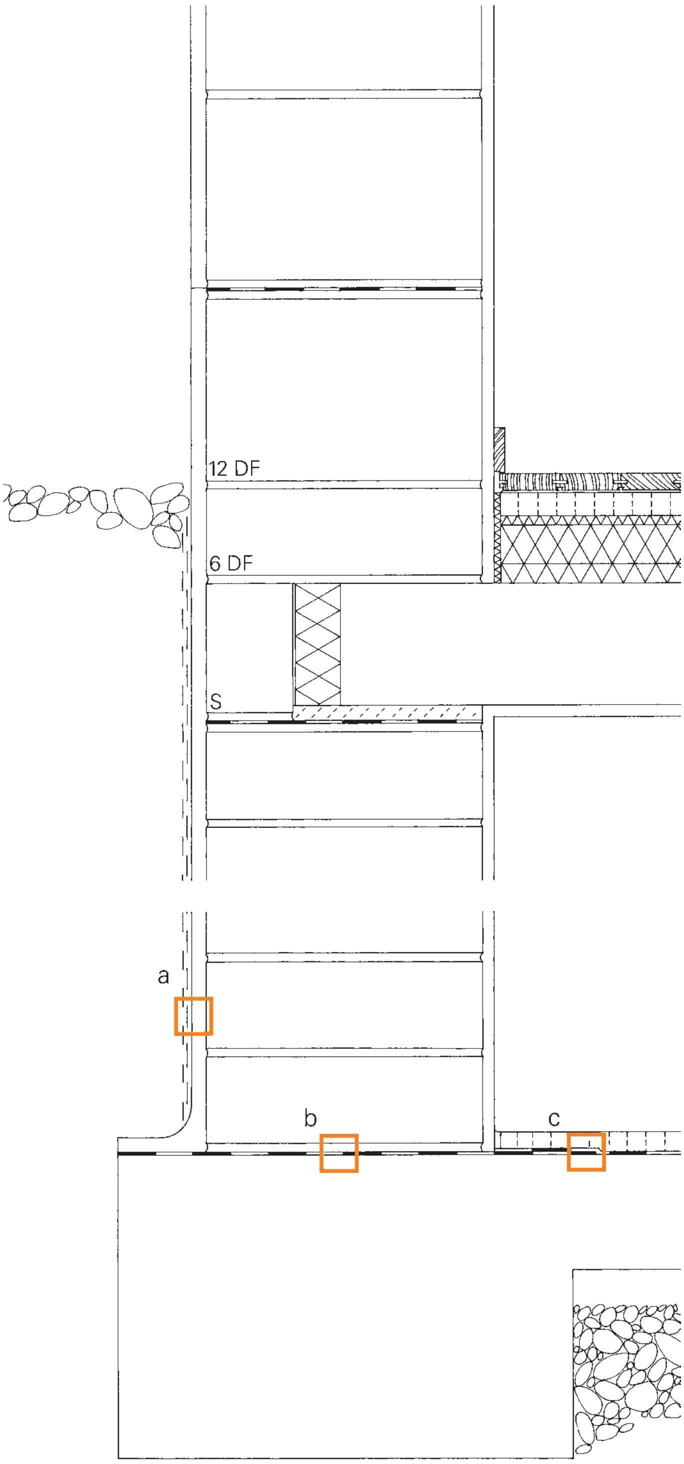
The thermal insulation on the underside of the slab over the basement is necessary in this case in order to reduce the thermal bridge effect of the monolithic reinforced concrete construction.

f

If complicated junctions are to be avoided, seal the projecting basement wall with a dense, mesh-reinforced screed. Such a detail requires a location protected from the weather and preferably roofed over.

g

A continuous slot in the base of the lightwell ensures water can drain away into the quick-draining backfilling material.



☐ a

The walls to unheated basements are built using vertically perforated clay blocks, e.g. HLz 12-1.2-6 DF, which have a greater compressive strength but, mainly, a higher gross density.

As masonry basement walls can only resist lateral soil pressure once the vertical load of the building is available, backfilling is carried out later, e.g. after completing the structural works.

A water-repellent basement wall render of group P III provides the waterproofing. As this rendering is relatively expensive and time-consuming, is also rigid and therefore vulnerable to cracking, flexible sealing coatings which can be rendered over may also be used.

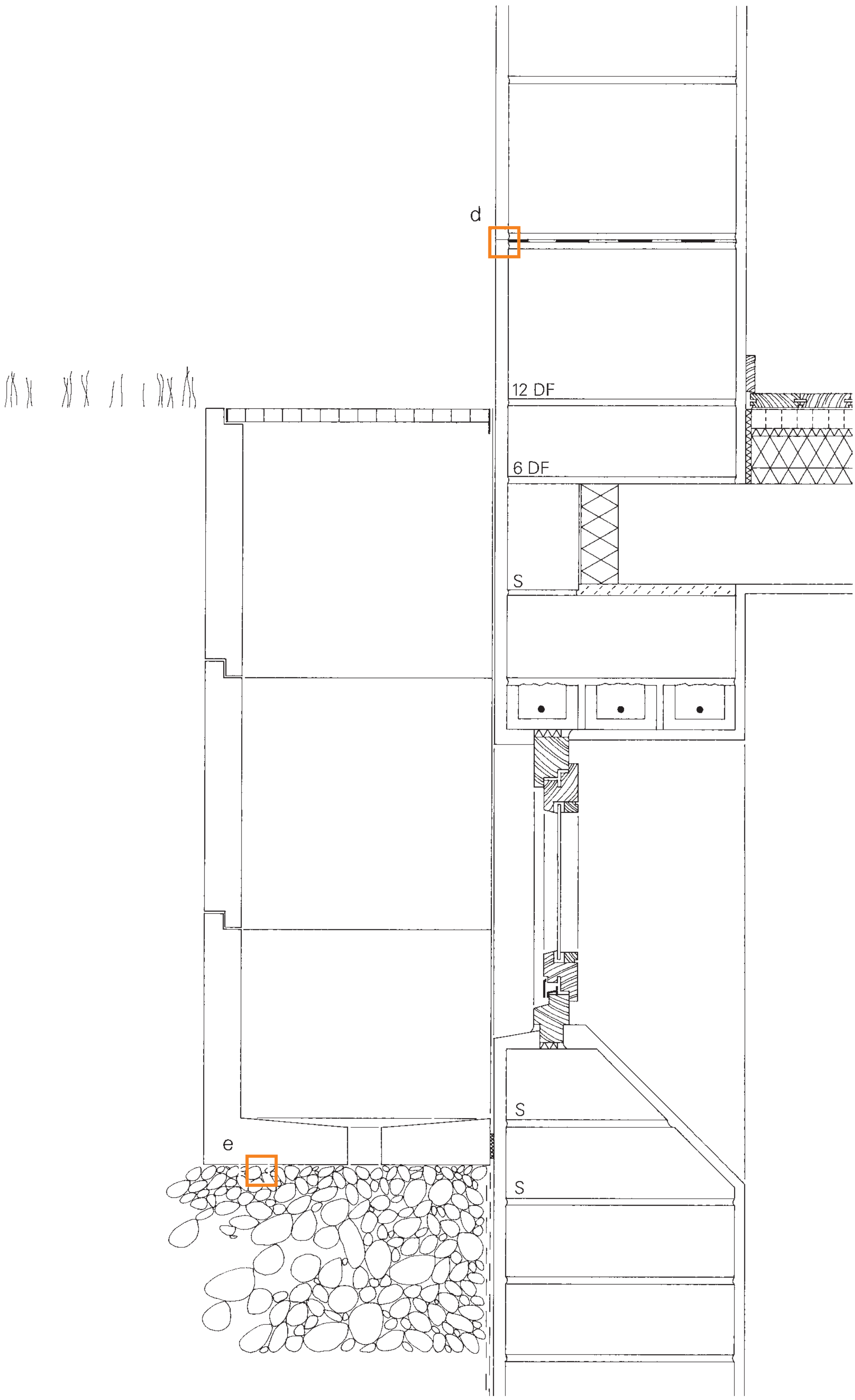
Drainage mats, e.g. corrugated or studded sheeting, protect against mechanical damage during backfilling.

☐ b

Lay a damp-proof course (dpc) of R 500 bitumen roofing felt, better still Cu 0.1 D waterproof sheeting (DIN 18195), on the strip foundation and bond this to the damp-proof membrane (dpm) over the reinforced concrete ground slab. Great care must be taken with the joint where the strip foundation projects beyond the basement wall; the provision of a rounded fillet and a fall to the outside is advisable. The dpc beneath the walls should be joined to the ground slab dpm in order to produce an ideal, controlled horizontal waterproofing system.

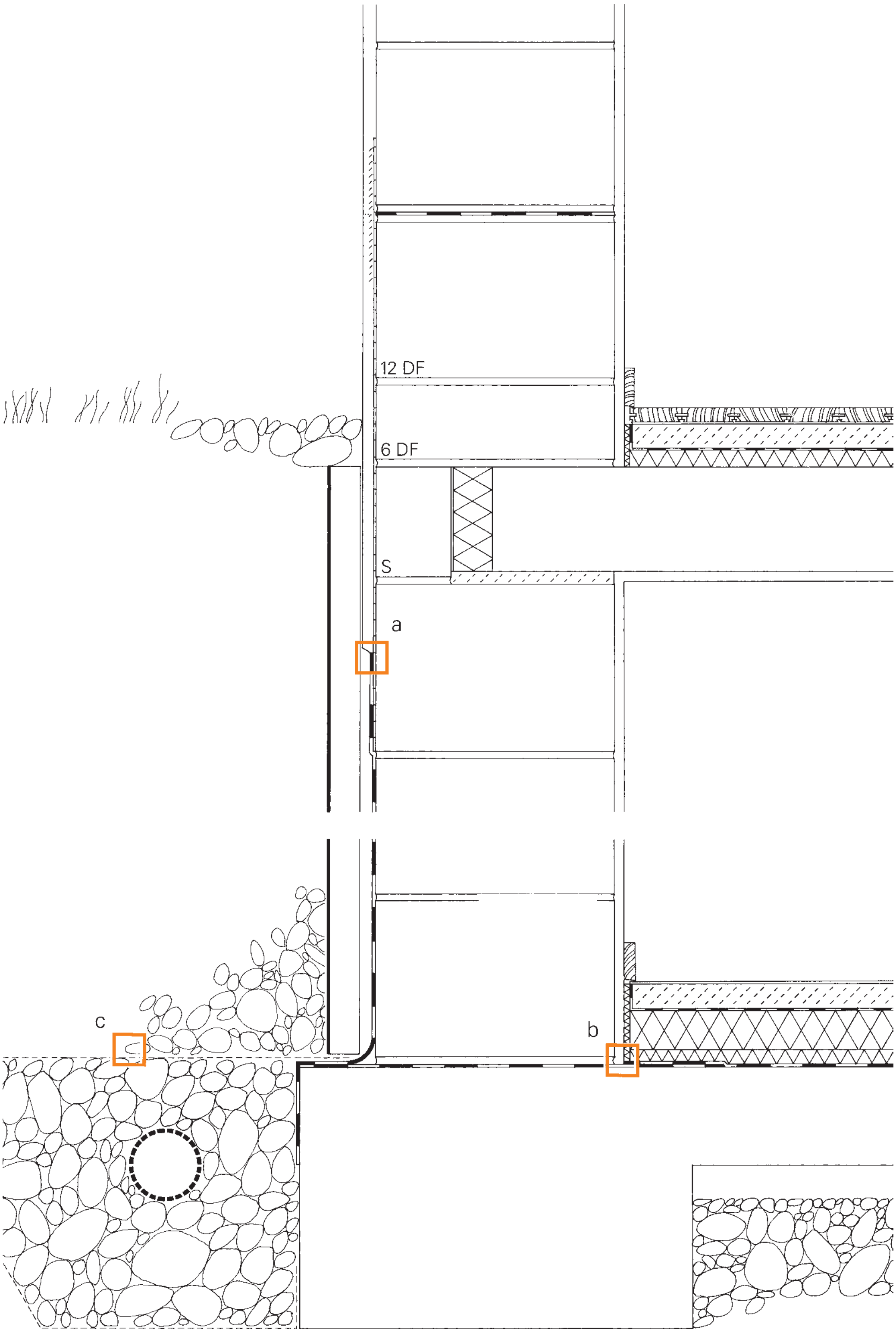
☐ c

The 25 mm mastic asphalt floor finish (surface finished with a smoothing compound) laid on a special bitumen built-up felt satisfies basic requirements regarding thermal insulation and impact sound insulation.



d
The plinth render up to the level of the damp-proof course has the same composition and thickness as that on the external basement wall. It is finished flush with the render to the masonry above; slit the joint between the two types of rendering with a trowel. An angled undercut is recommended.

e
Build up the prefabricated lightwell units on the backfilling separate from the house. This arrangement overcomes the need to fix complicated anchors into the masonry but does require the backfilling to consist of clean, compactable material. It is essential to compact the material carefully and properly in order to reduce settlement of the free-standing lightwell and hence damage to the masonry.



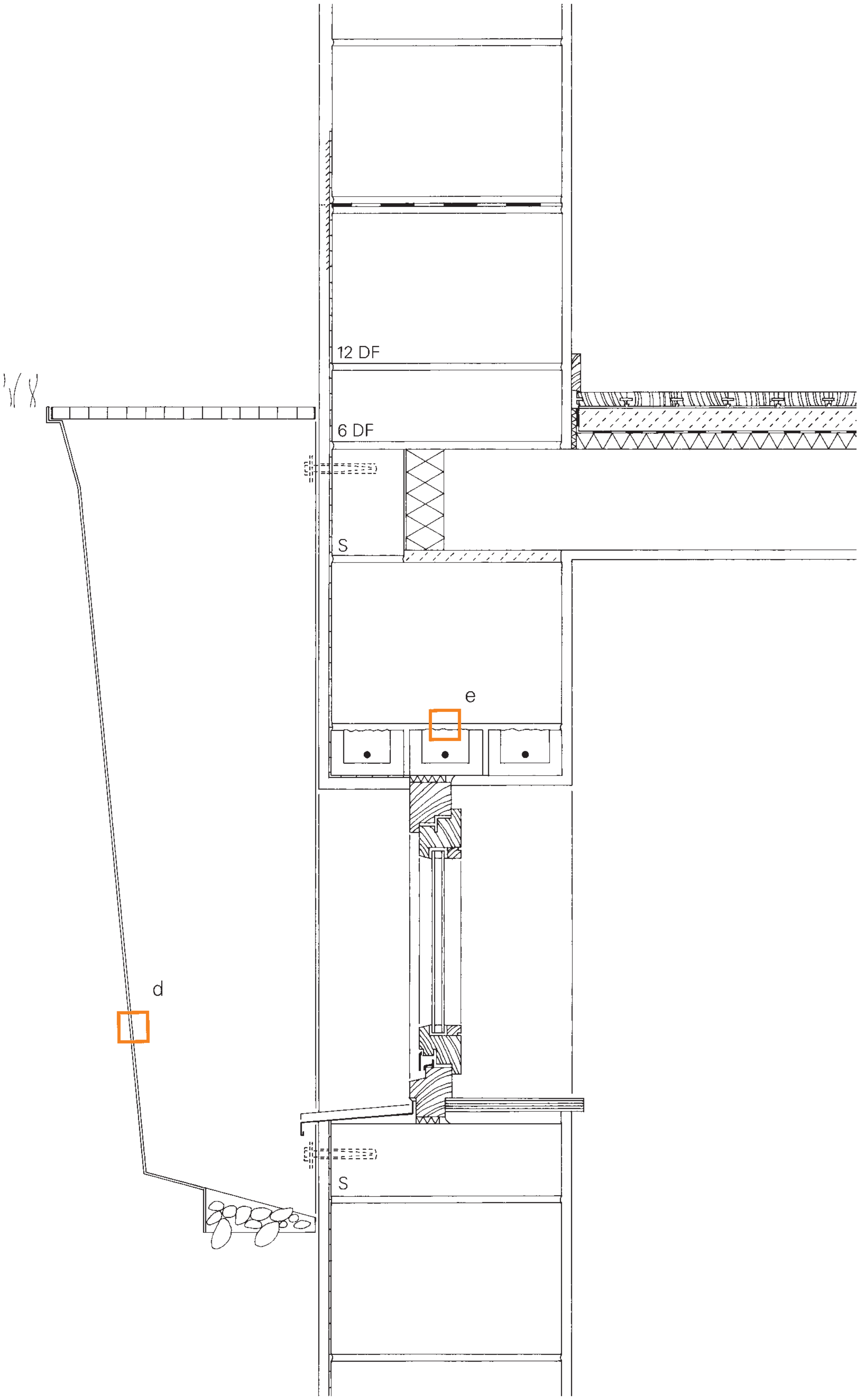
a
Basement walls made from large lightweight clay blocks provide the necessary thermal insulation for heated basement rooms and all the conditions for a comfortable interior climate.

A structural analysis must be carried out beforehand to ensure that the wall thickness combined with the vertical load are able to resist the lateral soil pressure over the depth of the basement.

Waterproof the wall with an elastic coating, e.g. made from a bituminous material, which continues as a flexible sealing coating in the area of the rendered plinth. Drainage mats guarantee protection for the waterproofing.

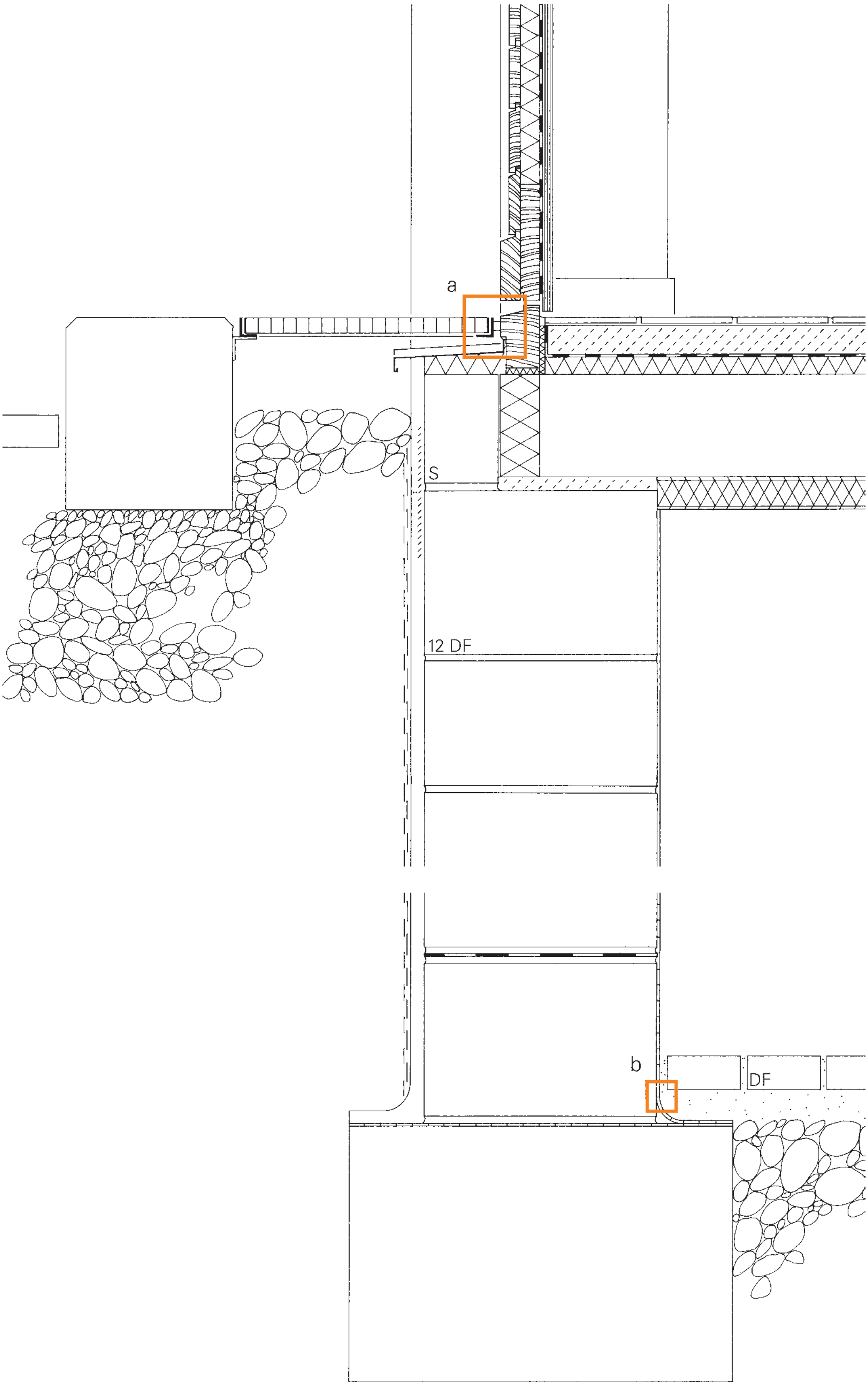
b
The damp-proof membrane (dpm) to the ground slab, required to protect against water held or flowing in the soil due to capillarity (suction water, retained water, capillary water), should be securely bonded to the damp-proof course (dpc) beneath the masonry wall (protection against capillary moisture) and also the ex-- ternal waterproofing.

c
Lay the perimeter drainage on a gravel bed and protect it on all sides with a filter mat against ingress of fine particles.



d
A number of manufacturers produce prefabricated plastic lightwells fitted with a suitable grating. These are anchored in the masonry.

e
If the reinforced concrete floor slab spans over the window opening, it is not necessary to provide a masonry "compression zone" over the shallow clay lintels (see p. 21).



☐ a
The wooden threshold to the door prevents condensation water and the formation of ice in winter; the rebates and seals can continue right around the door. However, special precautions for this detail are necessary, also because it is subjected to high mechanical loads: the choice of a suitable species of wood, e.g. oak; the provision of falls to the outside; keeping out heavy or driving rain by means of the close-mesh open grid flooring screwed on clear of the wood; the formation of a water bar with drip throat to repel incoming water.

This latter task is only fulfilled by the bottommost board of the outer leaf to a very limited extent. To do this, the entrance door must be protected from the wind and weather.

As mechanical damage is hardly avoidable, this detail is not suitable for heavily trafficked areas.

☐ b
The building of a “naturally” cool and damp basement for storage purposes requires a subsoil in which drainage is absolutely guaranteed. A build-up of water must be ruled out. An anti-capillary hardcore layer min. 150 mm deep below the floor of solid clay bricks bedded in sand is advisable for extra security. The inside of the basement walls should be provided with an elastic sealing coating painted over with a mineral whitewash, limewash or mineral paint.

c

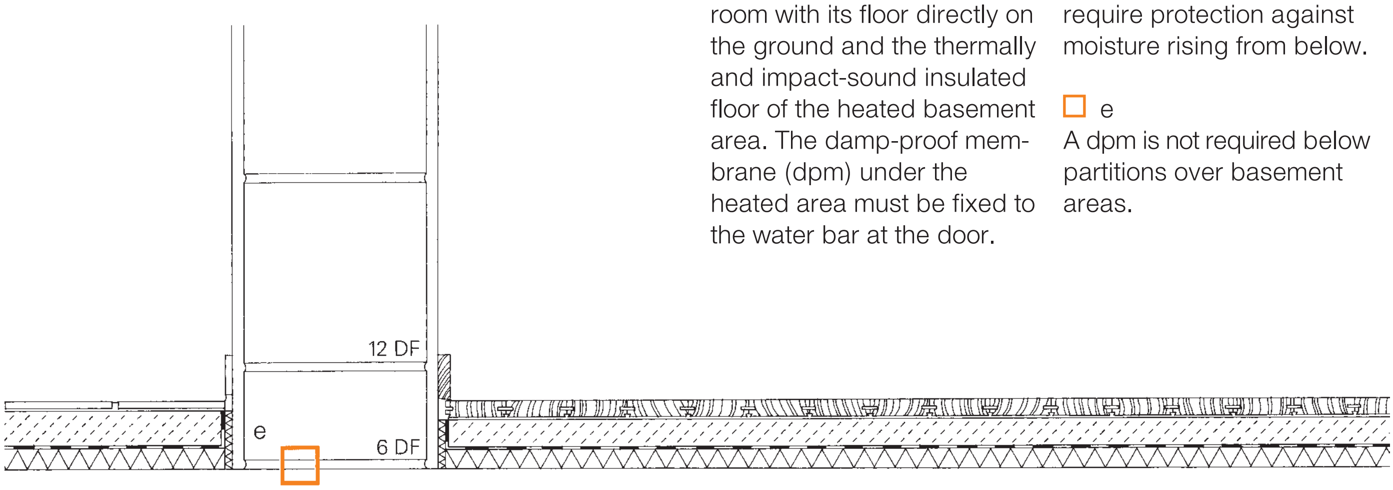
The drawing shows the transition between the storage room with its floor directly on the ground and the thermally and impact-sound insulated floor of the heated basement area. The damp-proof membrane (dpm) under the heated area must be fixed to the water bar at the door.

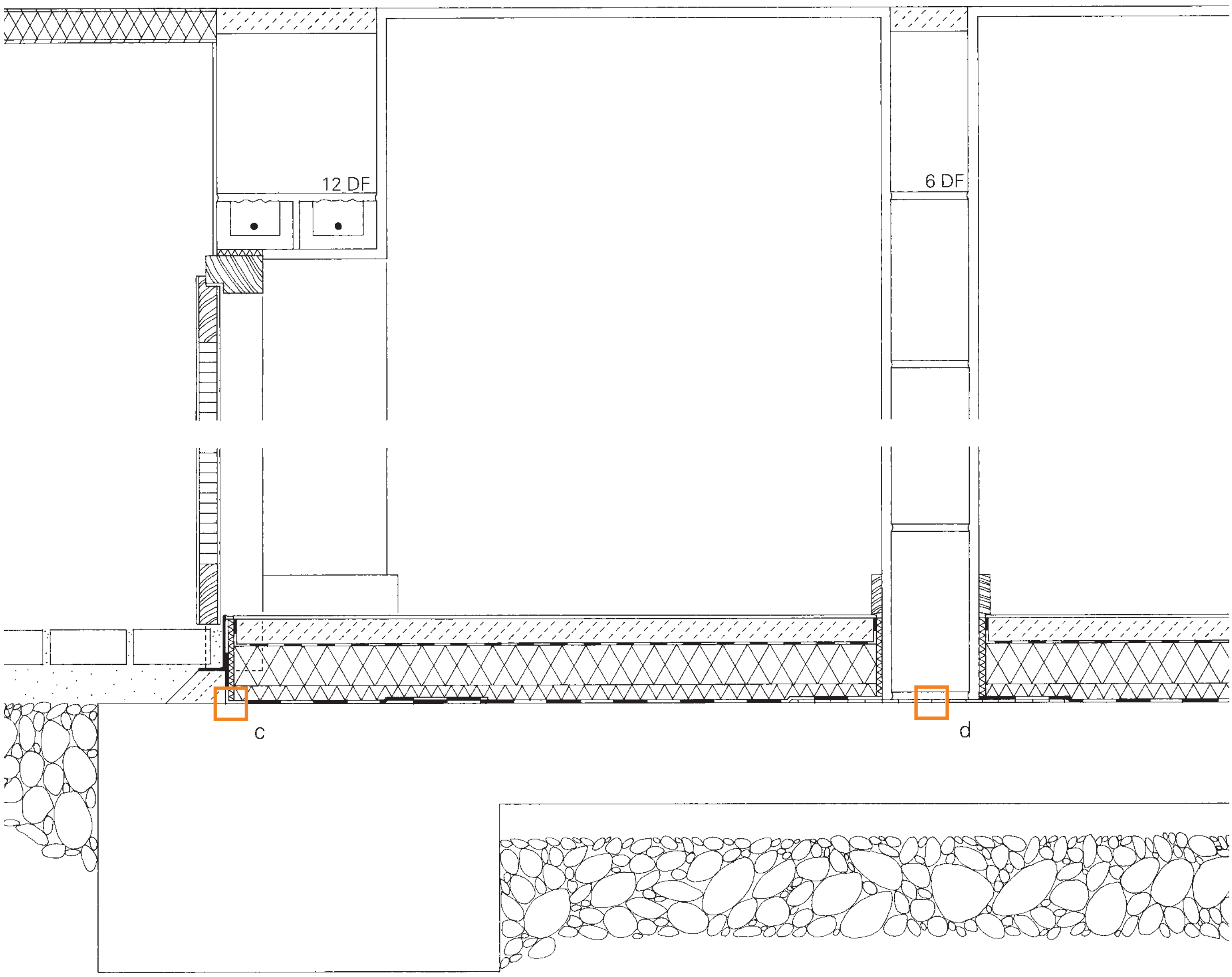
d

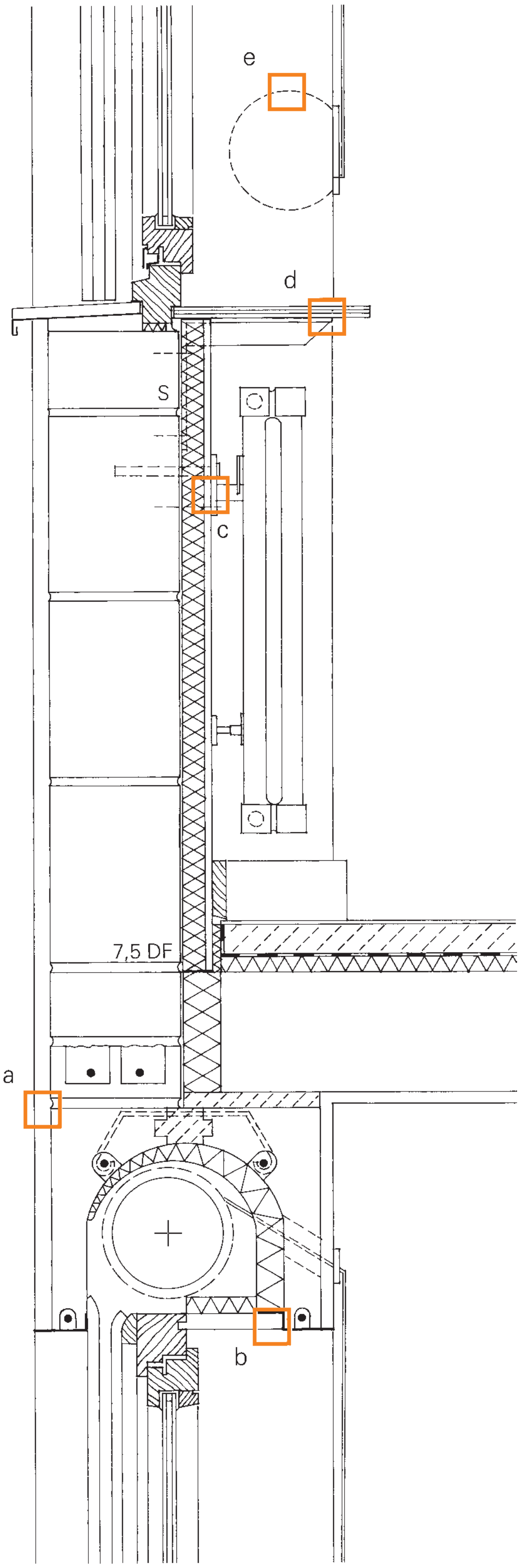
Partitions in the basement, just like external walls, require protection against moisture rising from below.

e

A dpm is not required below partitions over basement areas.







a
The roller shutter box and the outer leaf concealing the floor slab form a uniform substrate for the render. Such boxes are factory-prefabricated, non-loadbearing items which can carry their own weight over openings up to about 5 m wide thanks to their integral reinforcement. They are approx. 300 mm deep and available for wall thicknesses of 300 or 365 mm.

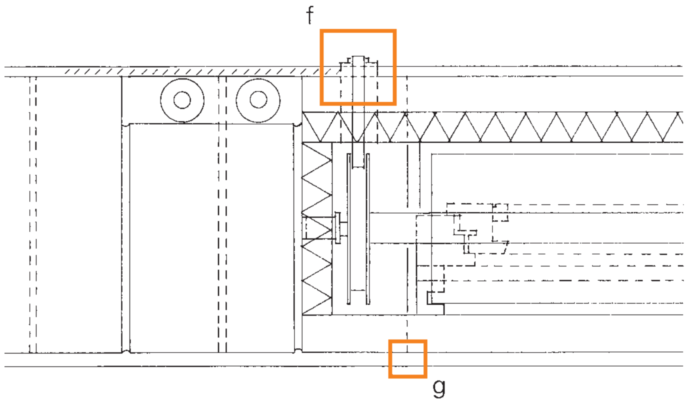
b
The maintenance opening cover, made from 12–15 mm BFU plywood and a layer of thermal insulation, e.g. min. 30 mm rigid polystyrene foam, is screwed into a rebate formed by an aluminium angle.

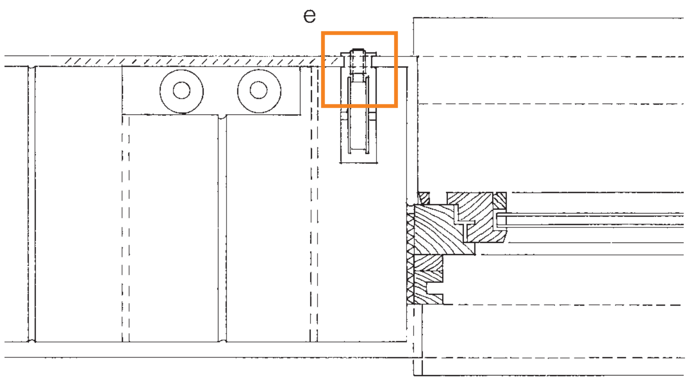
It is rare for any attention to be paid to the detail at the ends of the maintenance opening cover; heat losses and draughts are the result. Continuing the angle frame around all four sides and joining it to the thermally insulated supports for the roller shutter box would be necessary.

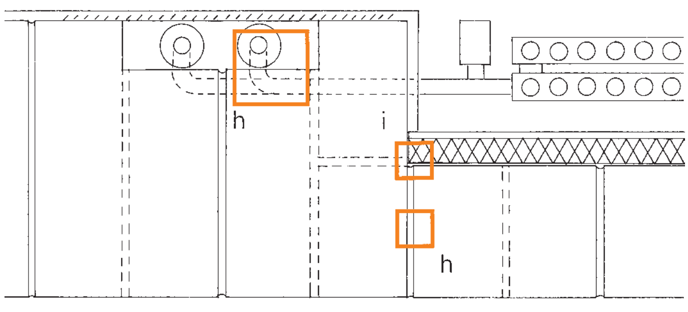
c
The 175 mm masonry leaf behind the radiator recess enables the radiator to be mounted in the usual way on cast-in wall brackets. The interruptions to the thermal insulation simply have to be accepted.

d
Fit the thin window board, e.g. 25 mm natural stone, into chases in the masonry reveals and support it on brackets every approx. 600 mm.

e
Cut an opening in the masonry for the shutter operating cord if a special brick with a ready-made opening is not being used.







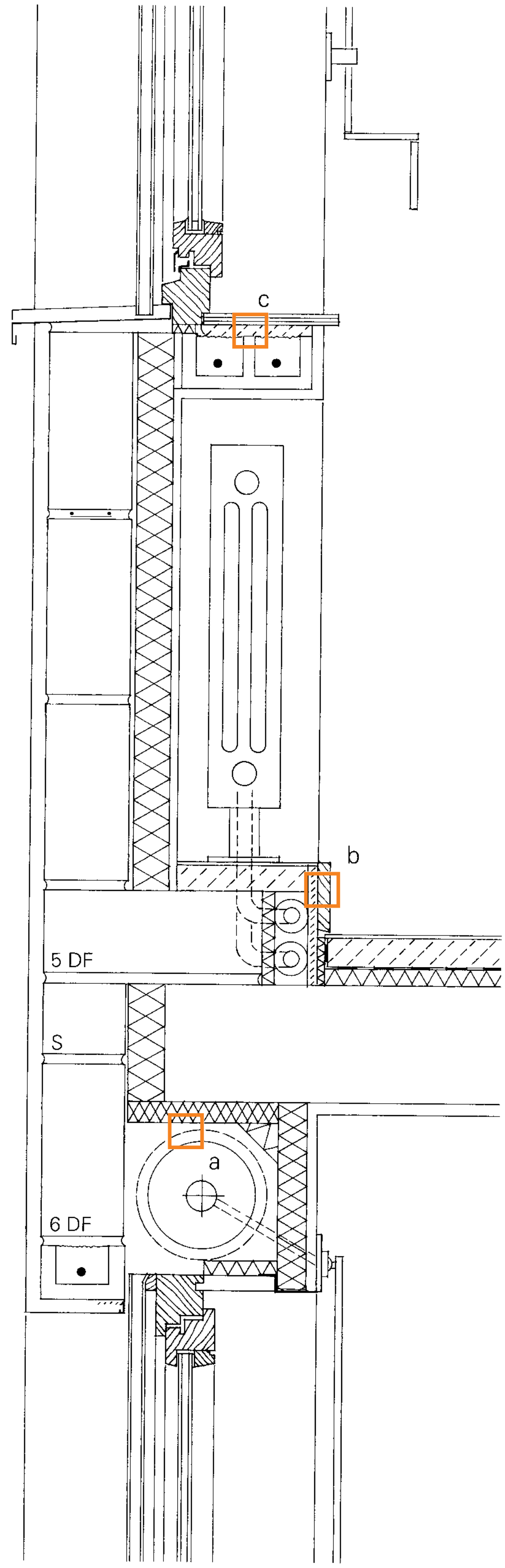
☐ f
The brush or lip seals to the opening for the shutter operating cord cannot completely rule out heat losses at this point.

☐ g
A clay roller shutter box requires a min. 80 mm bearing, 150 mm on the operating cord side. Cut off the render stop bead at the underside of the shutter box to match the clear opening of the window.

☐ h
Radiator recesses must be constructed to match the masonry bond of the wall.

Running the pipes in vertical slots in the external wall and weakening the sides of the recess for connecting the radiator pipework was for a long time the standard solution. In order to meet the enhanced thermal insulation requirements of newer legislation, insulate the slots at least on the outside, preferably on three sides. Cut the slots for connecting the radiator pipework with a masonry saw.

☐ i
Cutting the thermal insulation to fit exactly in the recess is the standard solution. Heat losses through the non-insulated sides are ignored; any condensation water that does occur here is simply driven off by the heat from the radiator. Wood-wool slabs or sandwich panels with a polystyrene core have sufficiently rough surfaces to provide a key for plaster.



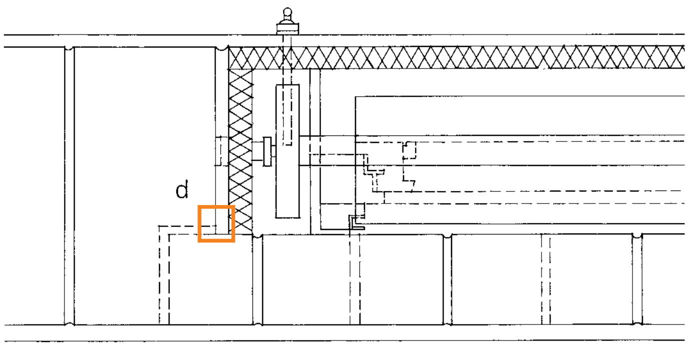
☐ a
“Half” roller shutter boxes are available for windows with a masonry shoulder at the window head.

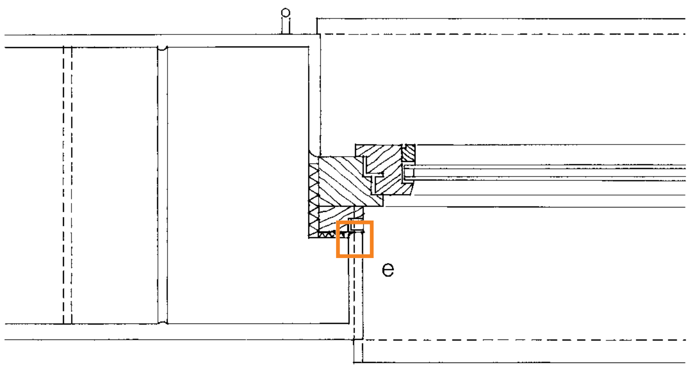
A lintel flush with the ceiling or a shallow clay lintel spans over the opening in the masonry. This determines the size of the rolled-up shutter and in turn the height of the window.

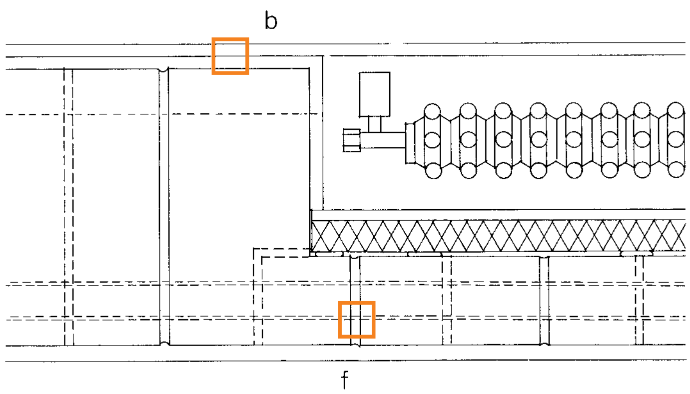
From the point of view of thermal insulation, operating the shutter with a winding mechanism fitted in the reveal or on the wall is preferable to the operating cord.

☐ b
Incorporating a 300 mm clay masonry unit (5 DF) in the 365 mm external wall (6 DF or 12 DF units) but flush on the outside creates a recess in the wall, 135 mm high x 65 mm deep, above the reinforced concrete floor. With insulation at the back of the recess, this can be used for the radiator pipework. Connect the pipes to the radiator underneath in the radiator recess. Smooth, fill and coat the screed. A structural analysis is required for this horizontal slot.

☐ c
Span over the radiator recess with a shallow clay lintel. The window board can be correspondingly thinner in this case.







☐ d

The ends of the roller shutter box bear min. 40 mm on the external wall. The bond of the masonry above the shallow clay lintel must match the masonry bond of the large clay blocks of the external wall.

☐ e

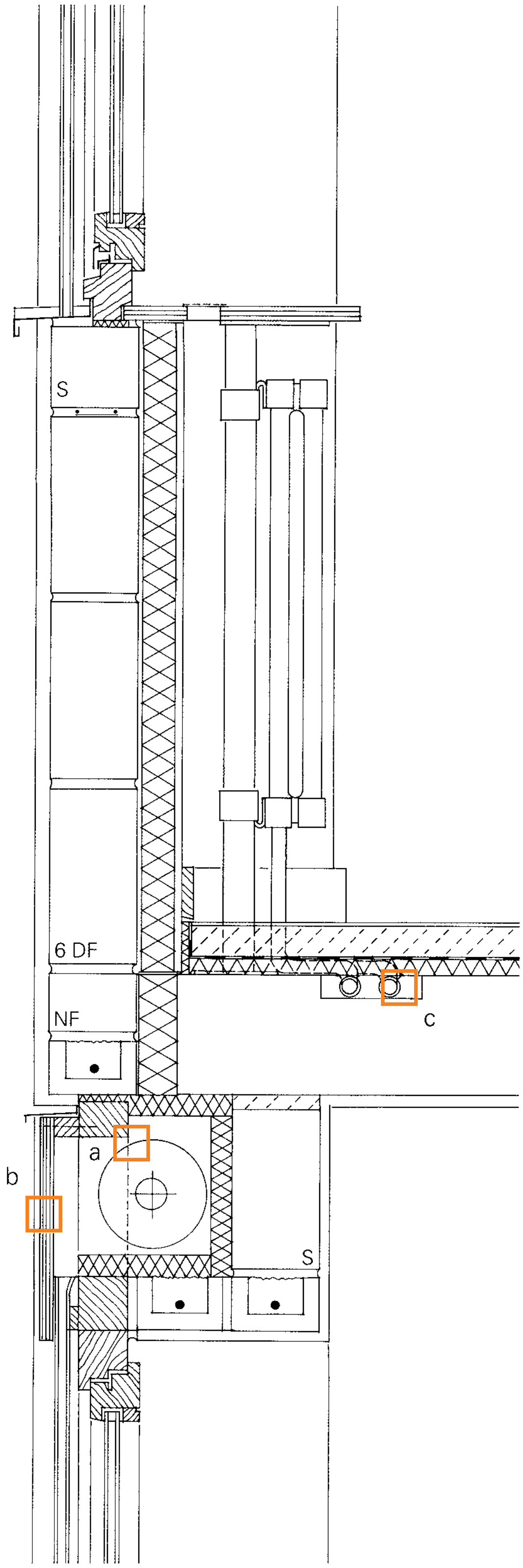
The masonry shoulder en-- ables the guide track for the roller shutter to be fitted virtually flush with the render. The bottom end of the track is welded closed and rests on the sheet metal window sill. The U- or L-shaped bent-up ends of the window sill are notched to suit.

Precautions to prevent galvanic corrosion are necessary if the metal of the track and the metal of the window sill are different.

Slit the joint between rendering and roller shutter track with a trowel, or fill the joint with sealing compound.

☐ f

Continuous reinforcement in the masonry, at least in the uppermost bed joint, is necessary to minimise cracking.

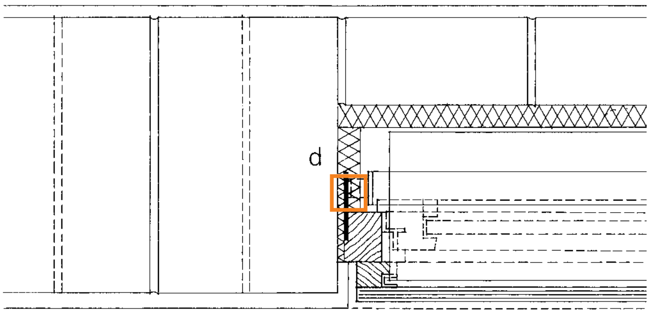


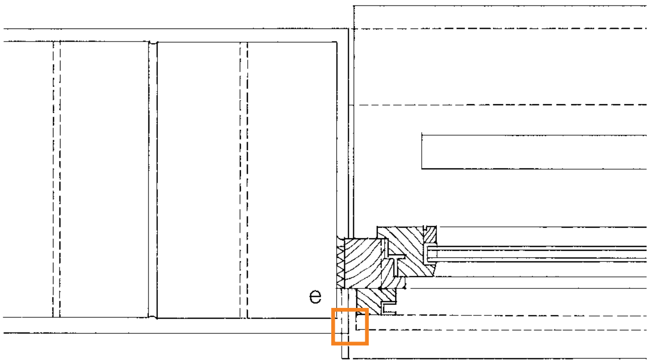
☐ a
The removable external fascia board of this special construction overcomes the problems of a maintenance cover that does not close tightly. The inside face of the wall can continue uninterrupted. Roller shutter and window are incorporated as a single element from the outside, with a neat transition to the render.

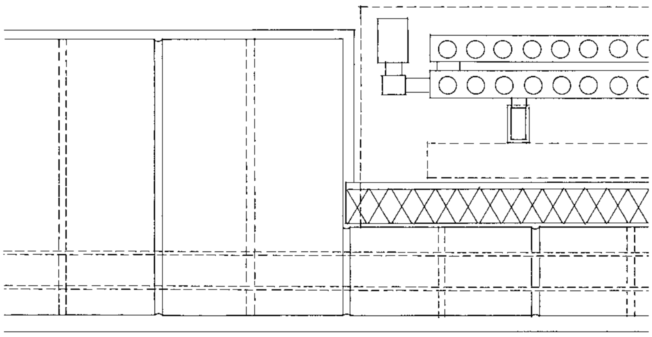
Operating the roller shutter by means of an electric motor is more complicated but does avoid the weak points described earlier.

☐ b
Screw the fascia board to the shutter box, e.g. waterproof-glued grade AW 100 plywood, to the frame tucked behind the render. Leave a small gap to highlight the joint and protect the top of the fascia board with a metal Z-section.

☐ c
The radiator pipework runs in a slot (parallel with the external wall) in the reinforced concrete floor slab. Thermal insulation is not necessary because the existing thermal performance is unaffected and any heat lost from the pipes still benefits the same residential unit, in this case a terrace house.





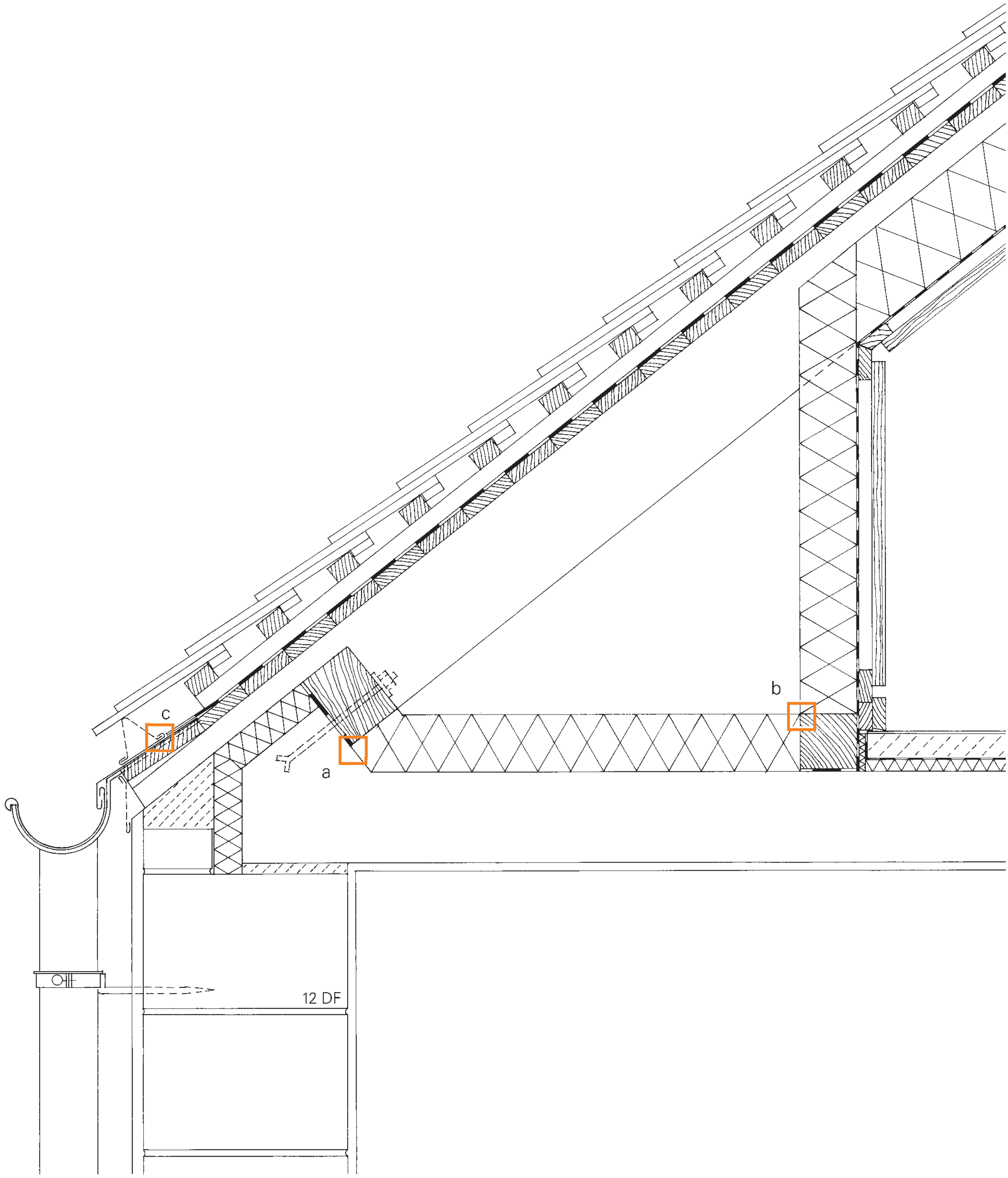


d

A steel flat bracket fixed to the frame supports the shaft of the roller shutter.

e

This detail permits the window element to be fitted flush with the render. However, it is advisable to inset the window by min. 10 mm, preferably 20–30 mm, in order to allow for tolerances and to provide some protection from the weather.


c
a
b
12 DF

☐ a
The reinforced concrete floor slab can be used as the tie for the rafters and therefore eliminates the need for any columns in the roof space. Fix the eaves purlin with ragbolts every approx. 1.5–2.0 m cast into pockets in the reinforced concrete abutment monolithic with the slab. Notch the continuation of the rafters to suit or provide counter battens.

☐ b
The areas outside the converted roof space are cold. Continue the thermal insulation to the roof together with the airtight membrane or vapour barrier down the outside of the timber stud wall. Provide thermal insulation on top of the reinforced concrete slab.

☐ c
Bond the roofing felt below the roof tiles to the eaves flashing. The bottom course of clay roof tiles rests on a strip of bent-up perforated sheet metal fixed to the eaves flashing with clips. The perforated sheet metal guarantees ventilation and allows any moisture to drain away.

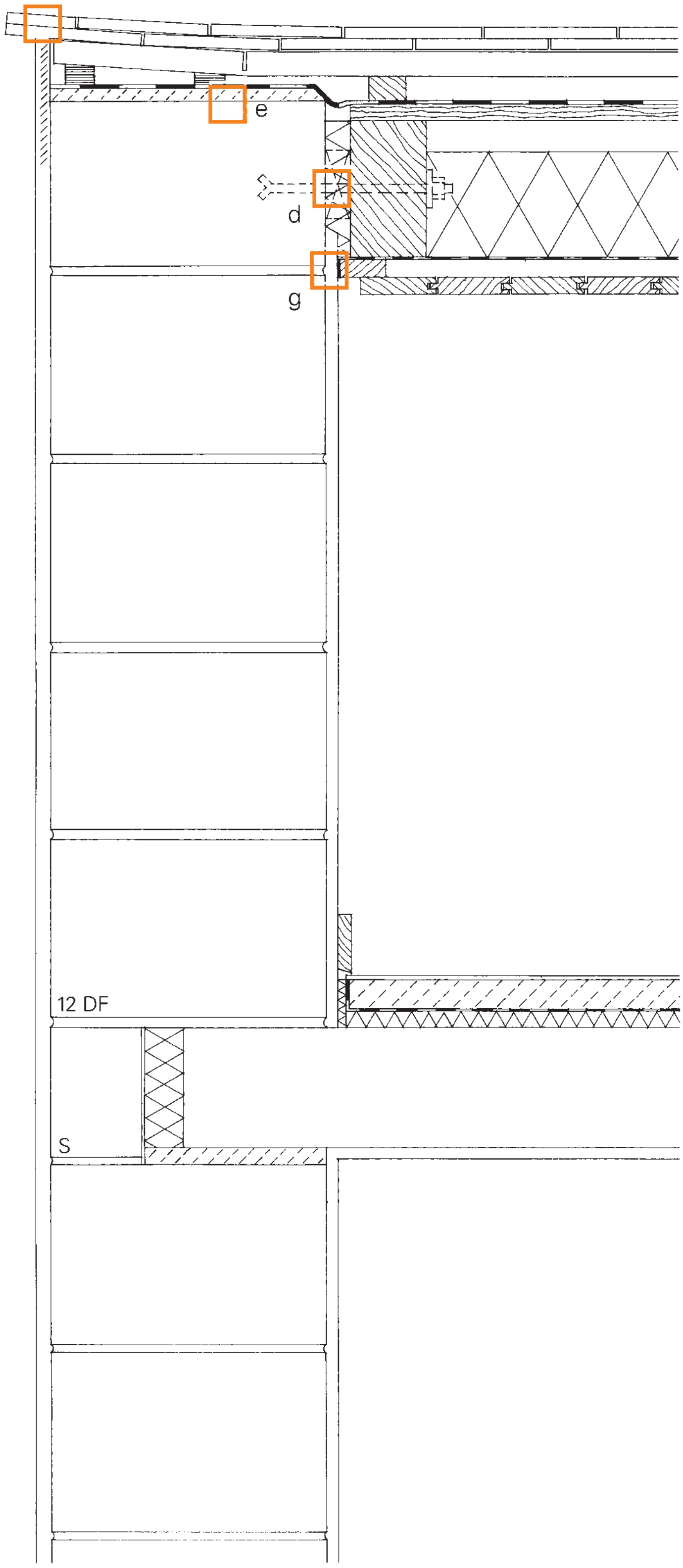
☐ d
If the roof surface is in the form of a "stiff plate", the connections to adjoining components around the edges of the roof plate must be capable of transferring the forces which occur. The gable wall is attached to the roof structure. Ragbolts fitted carefully into the masonry every approx. 1.5–2.0 m are suitable. In order to prevent corrosion caused by condensation water, it is advisable to select stainless steel fasteners. Insert plywood spacers as necessary.

The junction with the gable wall may also include a reinforced concrete capping beam along the top, unsupported edge of the masonry. As the reinforced concrete beam is cast in "steps", which are determined by the masonry bond and the size of the masonry units, special care should be taken to ensure that no thermal bridges through the concrete ensue.

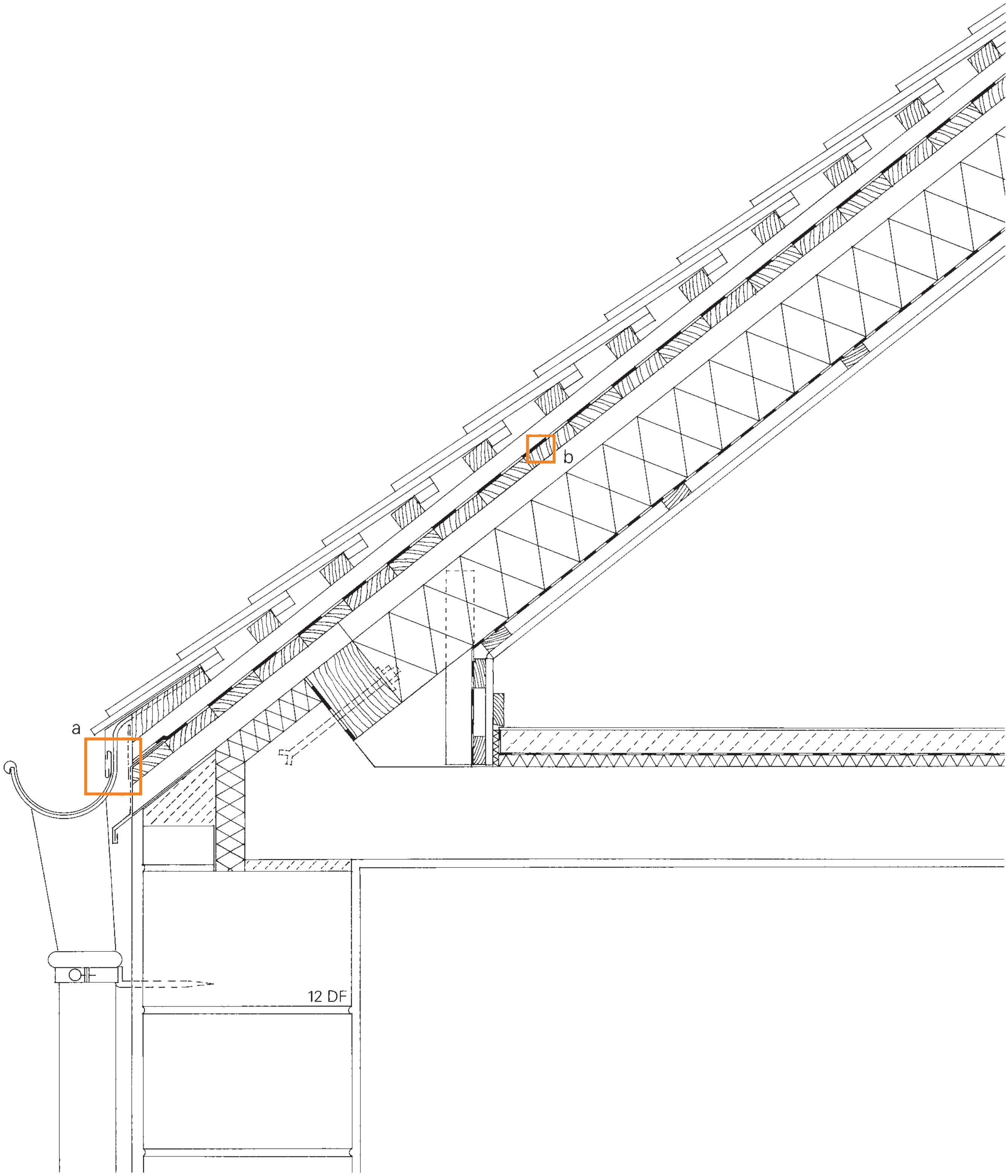
☐ e
Bond the roofing felt under the roof tiles to the screed with a small loop. Any rainwater reaching this point can drain away safely thanks to the strips of waterproof-glued grade AW 100 plywood screwed to the top of the wall.

☐ f
Continuing the render right up to the underside of the clay bullnose tiles is a simple and elegant detail. The tiles should project min. 30 mm, preferably 50 mm, beyond the render. Reinforce the render with a textile background. In order to reduce the amount of rainwater draining off the verge, the roof tiles along the edge are raised slightly.

☐ g
Clamp the airtight membrane/vapour barrier tightly against the plastered inside face of wall with a continuous board.



External wall and converted roof space
Vertical section through eaves of couple roof



☐ a
The gutter adjoins the roof covering directly and is joined to the downpipe via a conical header. The ventilation layers below the roofing felt and above the thermal insulation end at the perforated plate through which fresh air can enter. This plate is fixed to the tilting board with concealed nails, held in place by a continuous clip, and the bottom edge is finished as a rainwater drip.

☐ b
The "ventilated" roof, also known as a "cold deck", requires a continuous air inlet along the eaves (2 ‰ of the associated sloping roof area, min. 200 cm²/m unobstructed opening) and with this roof pitch an air outlet at the ridge too (0.05 ‰ of total sloping roof area).

In this case a vapour barrier is not required, which is difficult to install properly on site anyway. Instead, a "vapour check" is included which only allows as much vapour through as can be carried away by the movement of air in the ventilation layer.

Airtightness is absolutely imperative. Use, for example, impregnated paper, crêpe paper or polyethylene sheet for the airtight membrane and vapour check. Care should be taken to ensure that all joints are adequately overlapped or bonded and, above all, continuous and tightly sealed junctions with other components. Provided the material chosen has a suitable vapour diffusion resistance, the airtight membrane can also act as a vapour check.

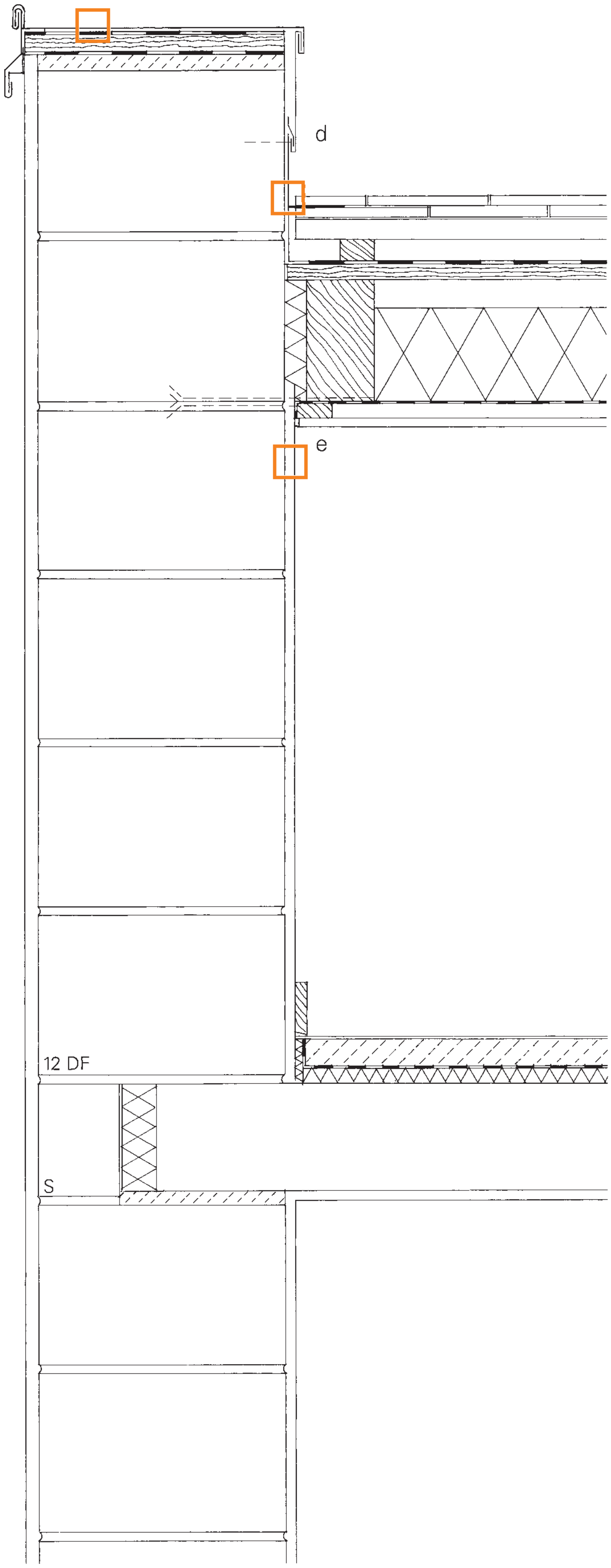
☐ c
The gable wall is constructed as a parapet projecting well above the roof surface and thus accentuating the edge of the roof. Clad the inner face of the parapet with sheet metal.

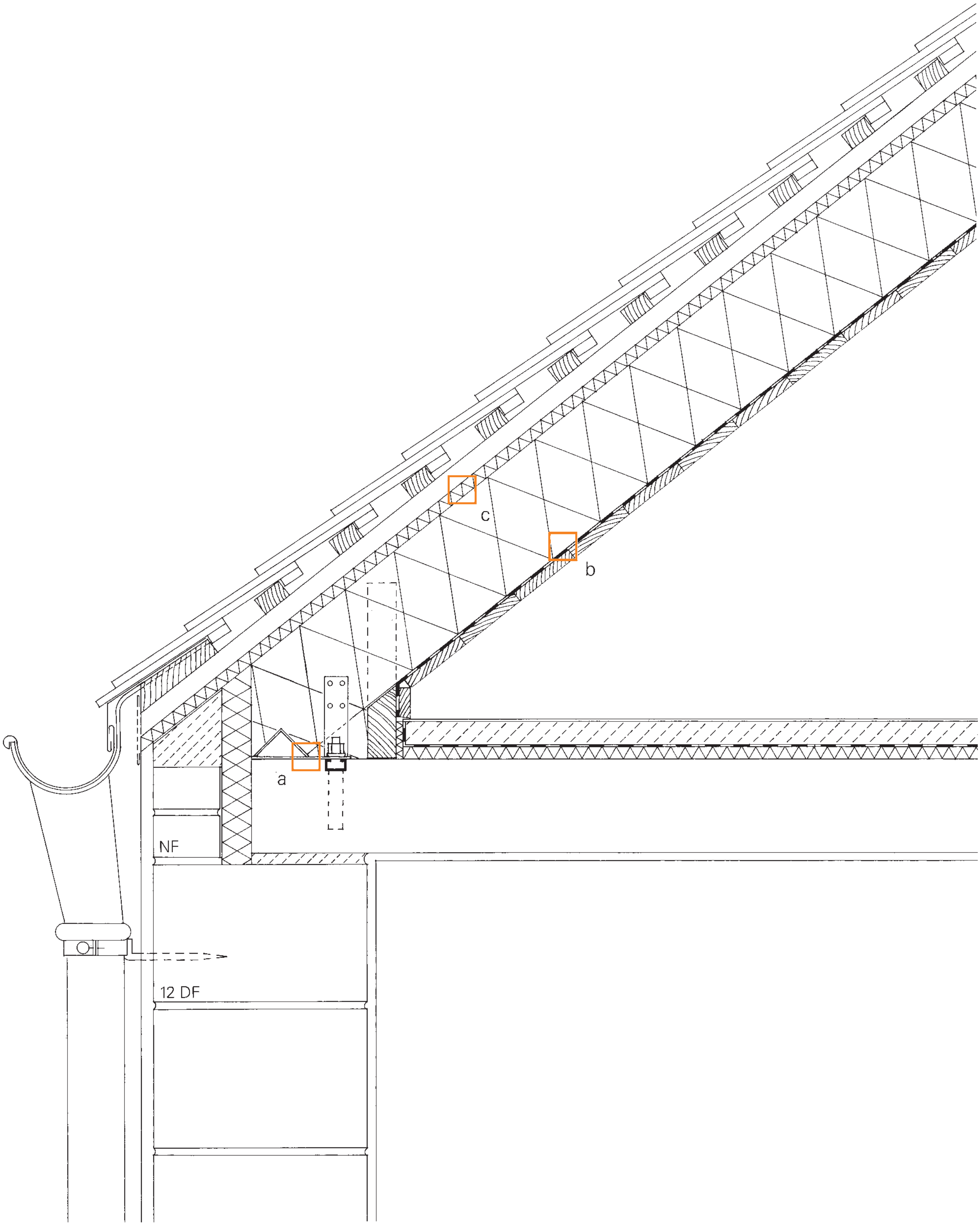
The parapet also has a sheet metal capping. Lay this on a separating layer – bitumen roofing felt, PVC sheet, oiled paper depending on the metal – and on approx. 25 mm grade AW 100 plywood battens fixed with clips.

The capping overhangs the render by about 30 mm and the bottom edge finishes with a rainwater drip. Bending up the capping along the outside edge and/or providing a gentle fall towards the roof surface avoids saturation of the gable wall.

☐ d
Use sheet metal soakers at the junction between the overlapping plain bullnose tiles and the masonry parapet. Fix the sheet metal parapet cladding with clips and provide a generous overlap to the soakers.

☐ e
After fixing the airtight membrane/vapour check, seal the plasterboard ceiling against the gable wall with a permanently elastic material.




c
b
a
NF
12 DF

a

A patented rafter abutment made from galvanised sheet steel and screwed to a cast-in proprietary channel eliminates the need for a concrete abutment. Side plates hold the rafter in place.

b

Providing full-depth insulation between the rafters in the form of a loose material (e.g. cellulose fibres or perlite) requires the construction of a box. Attach an airtight membrane/vapour check to the underside of the rafters and cover this with 19 mm tongue-and-groove or plain-edge floorboards. This ensures thermal insulation right down to the eaves. Dwarf walls can be provided as required to close off areas of the roof space. Additional counter battens only at the rafters reduce the number of perforations in the vapour check, compensate for building tolerances and provide space for electric cables.

c

According to the manufacturer, the 22 mm bitumen-impregnated wood fibre insulating board attached to the top of the rafters can function as a water run-off layer below the roof covering. The vapour permeability of this material should be such that it is suitable for use with the airtight membrane/vapour check. Rule of thumb: the vapour permeability should increase towards the outside.

Fire protection requirements with respect to the roof structure, e.g. F 30B, must be taken into account and may require different sizes of loadbearing timber members or a fire-retardant lining or cladding.

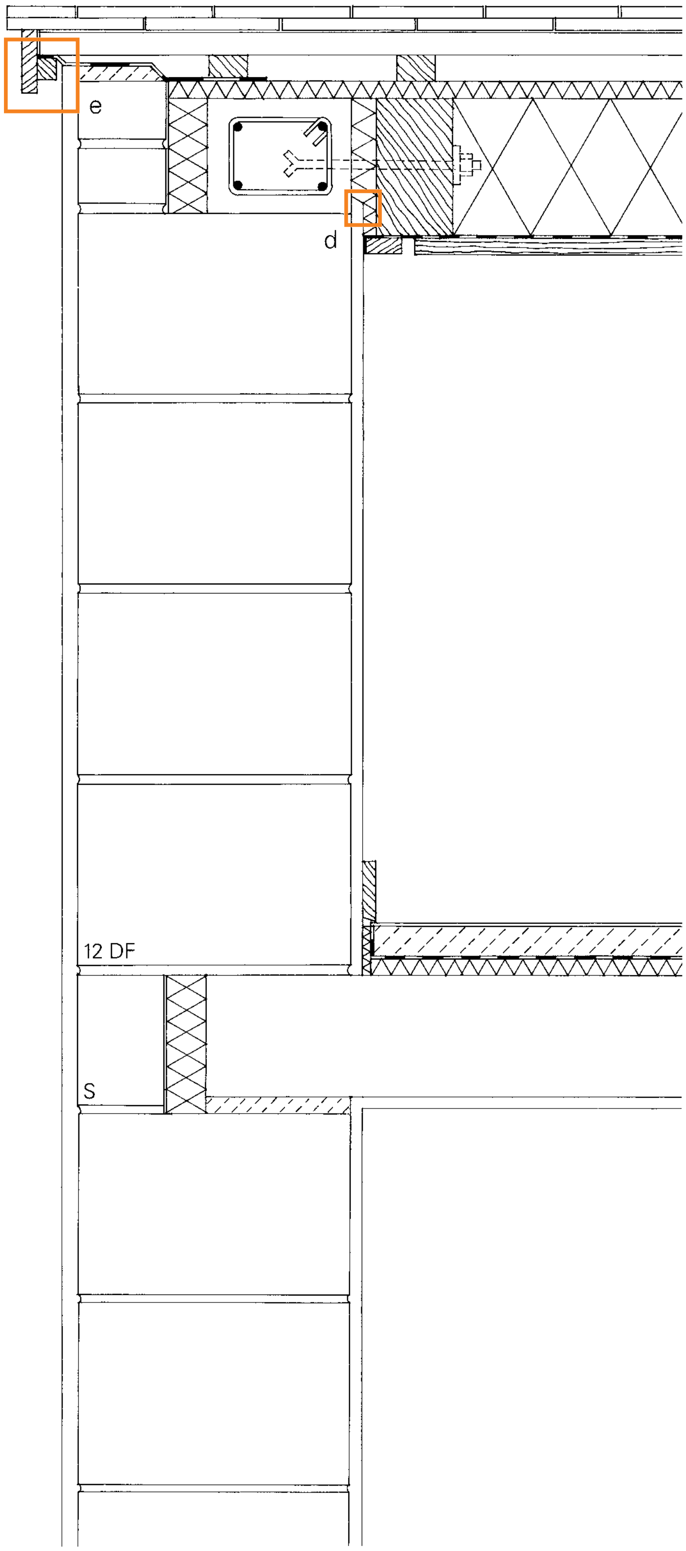
d

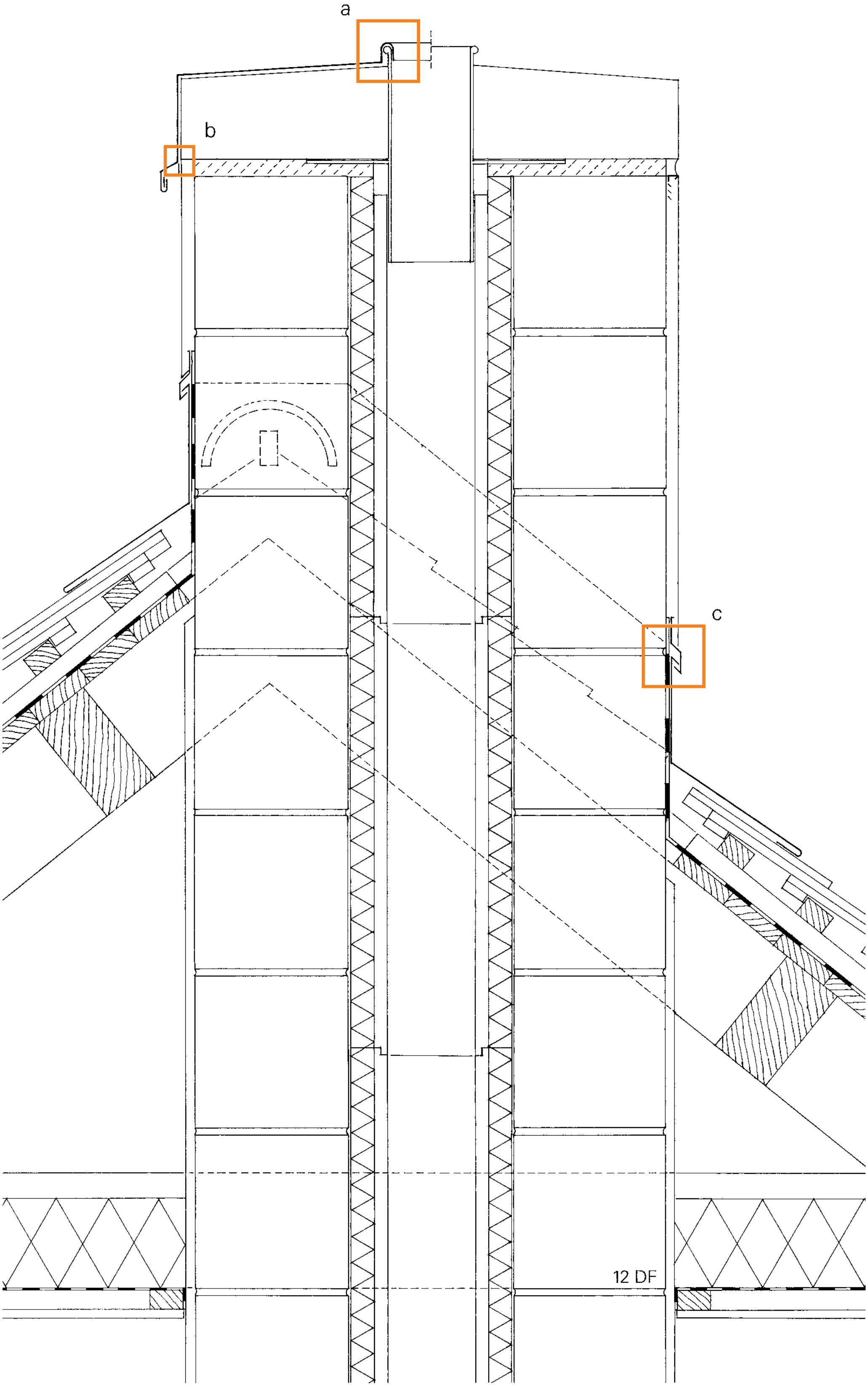
In roof structures with vertical framing the purlins, kneebraces and posts or common rafters are responsible for transferring the wind loads.

The gable wall is "suspended" from the roof structure. The junction detail here is no different to that for a roof plate (see p. 63). Cast the reinforced concrete capping beam on the stepped gable wall. Thermal insulation to the top of the beam is required because owing to the stepped arrangement the concrete extends into the heated area below and would otherwise result in a thermal bridge. The anticipated deformation of the reinforced concrete beam (as a result of the unavoidable shrinkage, aggravated by temperature fluctuations) must be taken into account when designing this detail. The use of a gable wall without a reinforced concrete capping beam overcomes this problem (see p. 33). Whatever the situation, carefully fill the gap between the wall and the final rafter fully with insulating material and connect the vapour check at least airtight.

e

Cut the outer leaf at the top of the wall to suit and finish it off with a cement screed. The "serrated" bargeboard, cut to match the line of the bullnose tiles, is screwed to a batten and that in turn to the overhanging tiling battens.





a

The advantageous position near the ridge means that the chimney only needs to continue 400 or 500 mm above the ridge capping, depending on the applicable German building code.

Cast the in situ concrete flaunching on a levelling bed of mortar. The cast-in expansion sleeve allows for the changes in length of the flue lining, which is insulated and enclosed in masonry.

b

A rendered chimney stack requires a sufficiently well insulated flue.

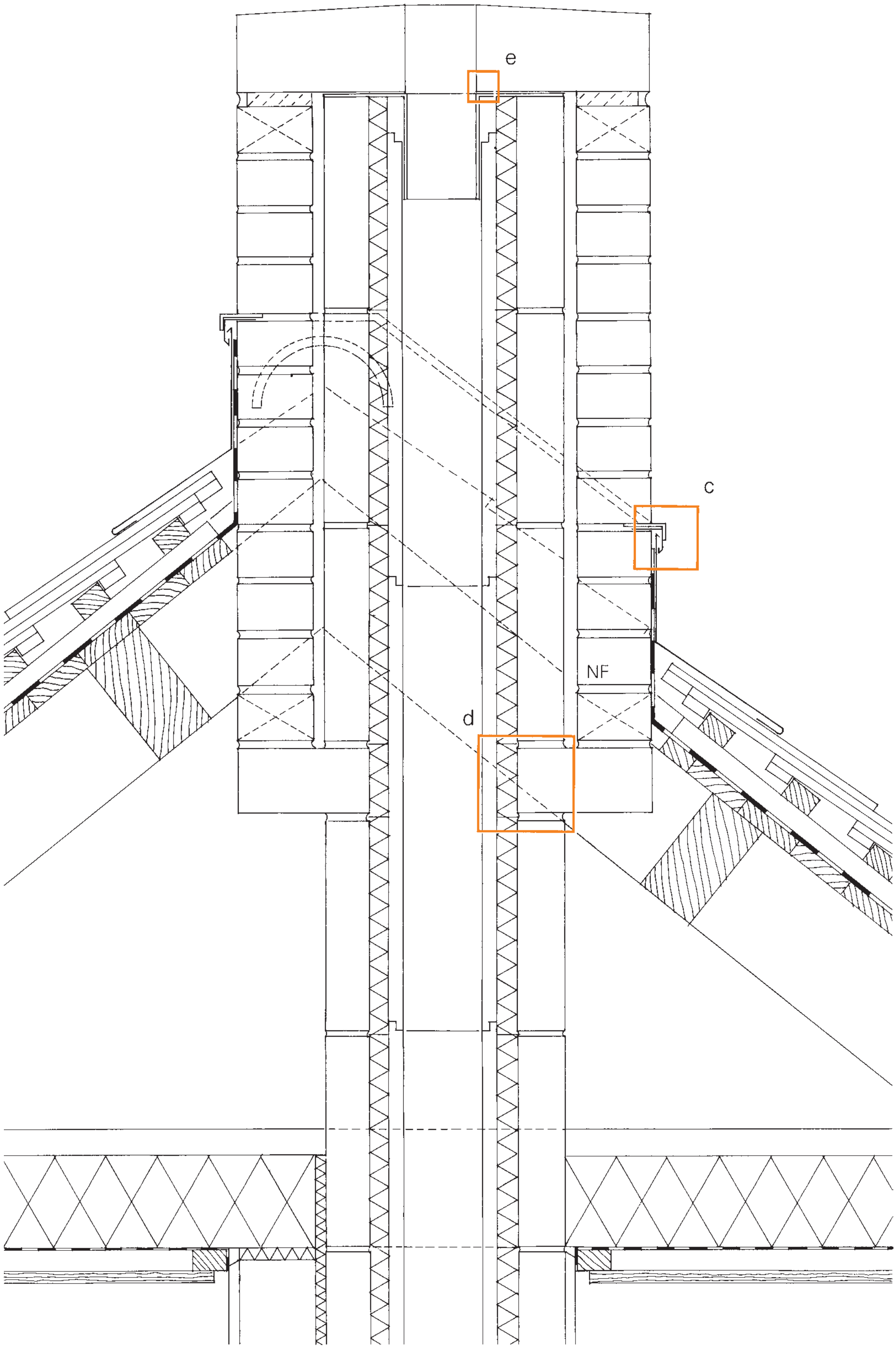
The chimney stack should be as smooth as possible in order to improve flow characteristics. On the other hand, to protect the render and accommodate movement, a sheet metal capping with a large overhang is desirable.

If there is no risk of corrosion, this conflict can be overcome by providing a sheet metal capping of, for example, stainless steel. Connect the capping to the expansion sleeve with a welted joint. The rainwater drip around the edge of the capping stands well clear of the render.

c

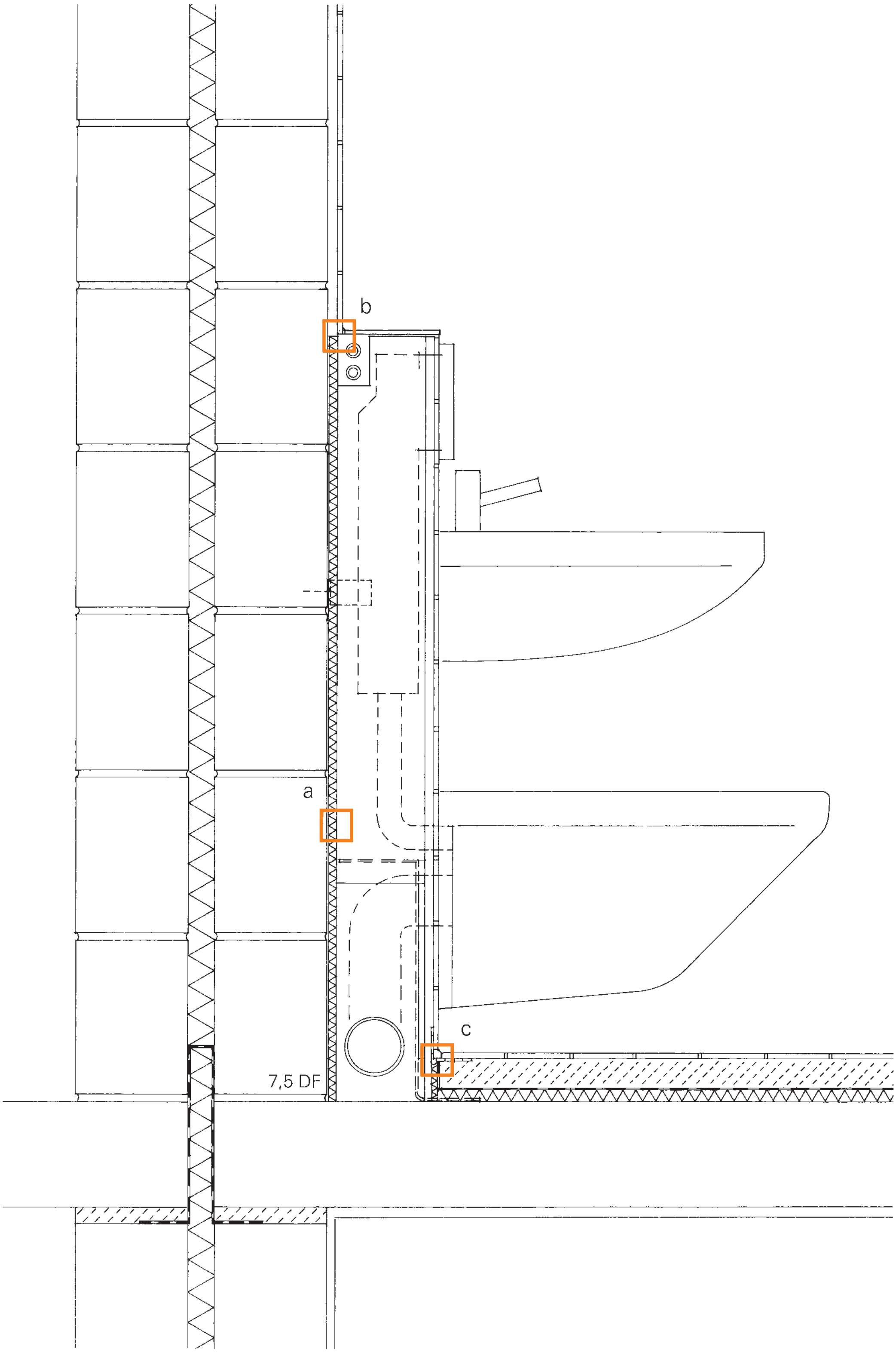
If joints filled with permanently elastic material are deemed undesirable, the only option is to accept the risks and fit a capping strip flashing behind the render. Separate the render and the sheet metal with a 2–3 mm wide slit.

Sheet metal flashings in facing masonry are fitted into raked-out joints, fixed with clips and sealed.



☐ d
The chimney here consist of lightweight concrete flue blocks around a thermally insulated flue lining of refractory clay.
The min. 115 mm facing masonry of frost-resistant clay bricks – VMz or VHLz – is seated on a built-in precast concrete element and must be built and pointed particularly carefully. Perpends left open act as inlets and outlets to the ventilation cavity.

☐ e
Place the prefabricated flaunching on a bed of mortar, rake out the joint min. 20 mm deep and fill it with a permanently elastic material to secure the joint against driving rain. If the flaunching oversails the masonry, this protects the joint to some extent.



☐ a

False walls for concealing services are desirable owing to the rational installation. There is no need to modify the masonry in anyway.

In those cases in which the sound insulation to the wall, particularly a party wall, is adversely affected by pipework, a false wall installation is indispensable.

The system shown here makes use of prefabricated installation elements made from polymer concrete for the respective sanitary fittings.

☐ b

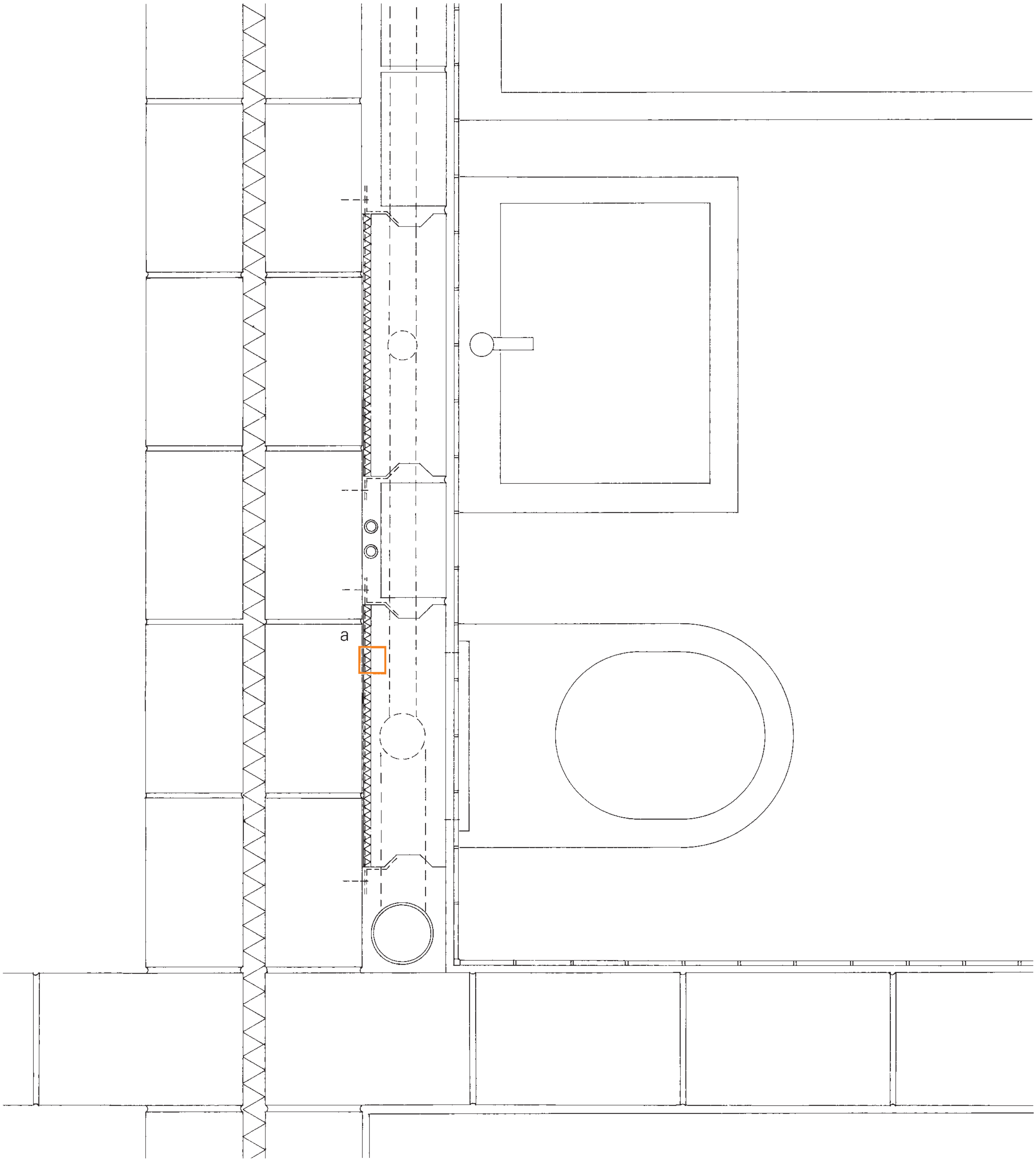
The false wall can terminate at a typical shelf height, and be finished off with ceramic tiles, or it can continue up to the ceiling.

The vertical soil pipe is vented above roof level.

☐ c

The junction between the flexible floating screed and the rigid false wall must allow for movement. Include a sealing strip with a loop, continue this up the wall and bond it to the wall. Seal the joint between floor and wall with a permanently elastic material.

As neither a shower nor a floor outlet are intended, this bathroom is classed as a wet area (but not a flooded area) and does not require waterproofing beneath the floor covering and screed. It is usually sufficient to lay the ceramic floor tiles in a waterproof tile adhesive with narrow joints.


a

The following section deals with the most important principles for building with large clay blocks:

– Clay block formats and dimensional tolerances
– Clay block types and mortar
– Masonry bonds
– Dimensional coordination

The essay “Masonry of large clay blocks – structure and construction” by Dr.-Ing. Bernhard Behringer clearly illustrates the interaction of the components to form a complete structure.

The report “Plaster/Render on clay masonry” by Dr.-Ing. Peter Roeke explains the basic rules for applying plaster/render to clay masonry by way of the behaviour of the wall and its “cladding”.

Just how building with large clay blocks is affected by the *Energieeinsparverordnung* (EnEV – Energy Economy Act) – which has replaced the 1995 *Wärmeschutzverordnung* (WSchVO – Thermal Insulation Act) – is not considered in this publication. The new Act is a comprehensive document which has repercussions for building design and building services: the heat gains and/or losses associated with orientation and fenestration, airtightness, thermal bridges and also the heating systems.

The various sizes of clay bricks and blocks are derived from a basic module, the thin format designated by the format code DF. This allows different brick/block formats to be combined in a masonry construction. Larger formats made up of this format are easily imagined, whereby the units – as in the masonry construction – are assembled with joints. Clay bricks/blocks without conventional perpend mortar are given the nearest format code (DIN 105).

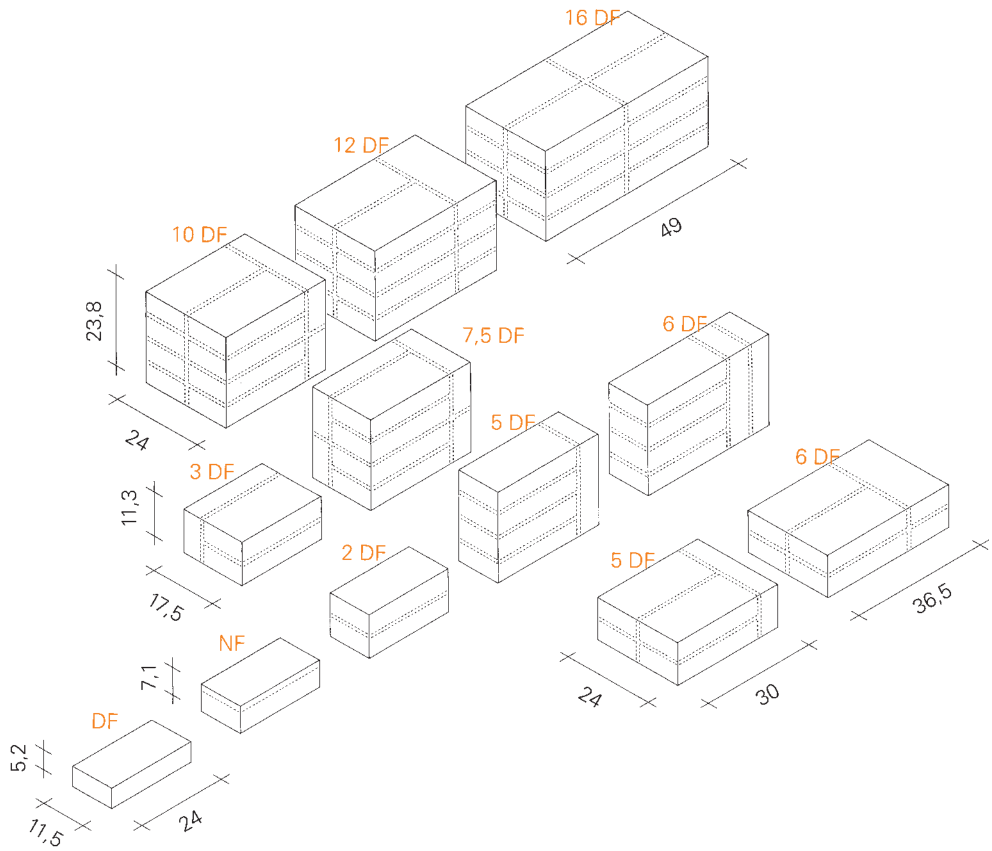
When designating large vertically perforated clay blocks it is necessary to specify the thickness of the masonry in order to distinguish the blocks exactly. For example: clay blocks with the code 6 DF are available for various wall thicknesses and course heights; clay blocks with the code 12 DF can be manufactured for 240 mm and 365 mm walls. In these cases the webs and fins separating the perforations or special perpend arrangements are designed for a particular wall thickness.

The dimensions given for the clay masonry units are reference sizes. DIN 105 permits dimensional deviations from the reference sizes: minimum sizes and maximum sizes.

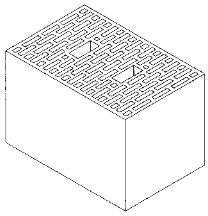
So the actual dimensions of a clay masonry unit 240 mm long may vary between 230 and 245 mm; for a 300 mm unit a length of 290–308 mm is permissible; for a 365 mm unit, 355–373 mm.

However, on the building site it is important that the deliveries for a certain structure all lie within a certain tolerance: the dimensional deviation is ± 10 mm for 240 mm units, and ± 12 mm for 300 and 365 mm units.

The deviations for the height of a unit are stricter: 233–243 mm for a reference height of 238 mm, and a dimensional deviaton of ± 6 mm.



Lightweight vertically perforated clay masonry units are clay bricks and blocks perforated perpendicular to the bed joint (DIN 105 part 2). The difference between these and vertically perforated clay masonry units type HLz is their low gross density, which may not exceed 1000 kg/m³. They are available as type HLzA with type A perforations (15–50% of bed face area, each single opening ≤ 2.5 cm²), as type HLzB with type B perforations (as type A but with size of openings specified), or as type HLzC with type C perforations (closed on five sides, total cross-section of perforations max. 50%, each single opening ≤ 16 cm², size of opening specified). Lightweight vertically perforated clay masonry units type W (HLzW) of height 238 mm have type B perforations and must also comply with requirements regarding gross density and the number of rows of perforations in the direction of the wall thickness. New developments outside the DIN standard are covered by building authority approvals.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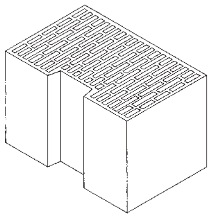
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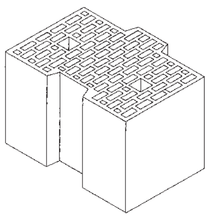
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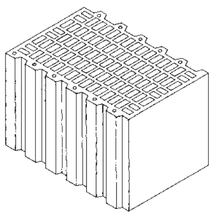

d

Lightweight vertically perforated clay masonry units are available with different perforations and perpends.

Here are a number of examples of clay blocks of format code 12 DF for 365 mm external walls:

☐ a
Block with grip (thumb) openings for masonry with mortar to the perpends.

☐ b
Block with mortar slot for two methods of laying: laid individually with mortar to the perpends but the slot left empty, or laid in rows brick to brick and the slot filled with mortar.

☐ c
Block with grip (thumb) openings for interlocking perpends without mortar.

☐ d
Toothed block for multiple interlocking perpends (no mortar) or as a gauged block for thin-bed mortar joints.

The method of laying the blocks without mortar to the perpends reduces the workload during laying and the amount of mortar required, and also improves the thermal insulation value of a plain external wall. However, deviations in the sizes of the individual units cannot be compensated for in the mortar joints like with conventional masonry. At corners and junctions with other walls the perpends still have to be filled with mortar; and at door and window reveals mortar joints or make-up units are necessary.

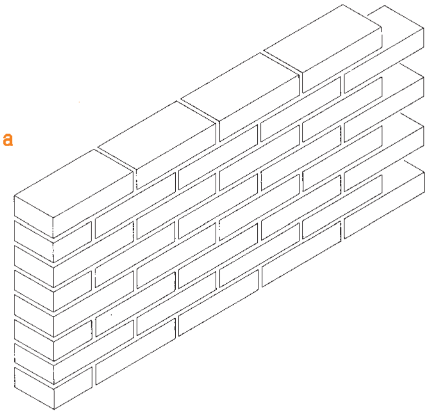
Mortar for masonry work is a mixture of sand and binder (lime or cement) plus admixtures and additives which alter the properties of the mortar by physical or chemical means (DIN 1053).

Normal-weight mortar is either mixed on site or supplied ready mixed (DIN 4226 part 1). We distinguish between mortar groups MG I, II a, II b and III, and each group has to comply with certain conditions (DIN 1053).

Lightweight mortar is supplied ready mixed or as premixed dry mortar. Due to its lower oven-dry bulk density and the use of a lightweight mineral aggregate, this type of mortar improves the thermal insulation properties of single-leaf external walls. We distinguish between groups LM 21 and LM 36 (DIN 4226).

Thin-bed mortar is a fine-grain premixed dry mortar (DIN 4226). It must be used with a bed joint thickness of 1-3 mm. It is classed as a mortar group MG III.

a



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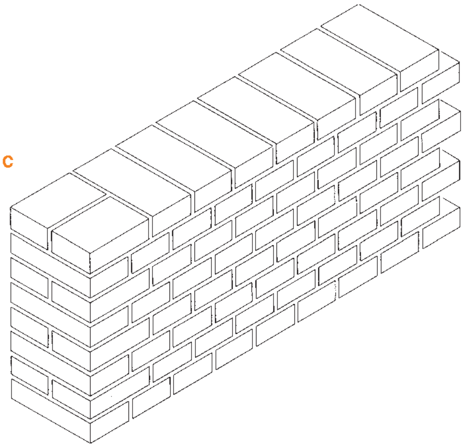

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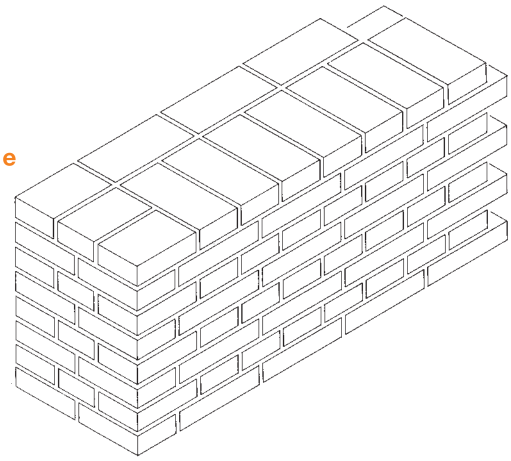


Walls are built according to the following basic principles – the bonding rules (DIN 1053):
– Units in one course shall be of equal height, the bed joints shall be continuous.
– The perpends and wall joints of successive courses must be offset. This offset – the bonding dimension – must be 0.4 x unit height, but not less than 45 mm (e.g. 95 mm for a unit 238 mm high). Large clay blocks are usually offset by half the length of the block. Crosswalls – including shear walls – do not necessarily have to be bonded in – a butt joint is adequate when other means are provided to resist tension and compression, e.g. flat anchors built in.

Simple masonry bonds are used for large clay blocks, which usually match the thickness of the wall. For example, stretcher bond for partitions 115, 175 and 240 mm thick, header bond for external walls 365 mm thick.

For estimating purposes, the approximate working times are as follows:

per square metre of 115 mm partition:

DF	1.5 hours
2 DF	0.9 hours
6 DF	0.3 hours

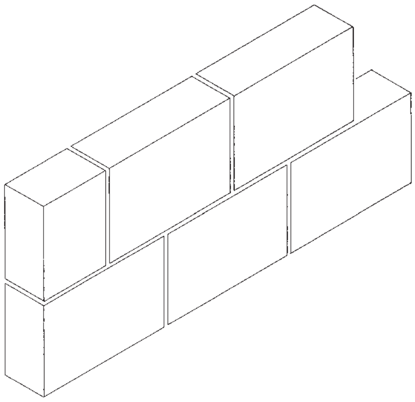
per square metre of 240 mm partition:

DF	2.1 hours
2 DF	1.5 hours
12 DF	1.2 hours

per square metre of 365 mm external wall:

DF	3.3 hours
2 DF	2.1 hours
12 DF	1.4 hours

b



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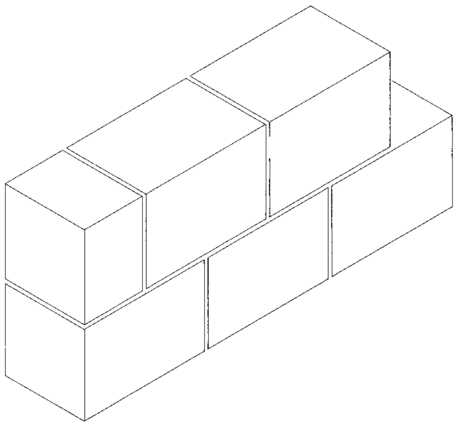
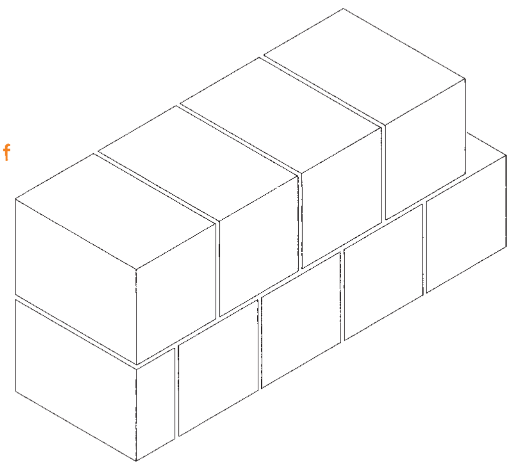


f



□ a
115 mm wall
stretcher bond with DF units

□ b
115 mm wall
stretcher bond with 6 DF units

□ c
240 mm wall
header bond with DF units

□ d
240 mm wall
stretcher bond with 12 DF units

□ e
365 mm wall
English bond with DF units

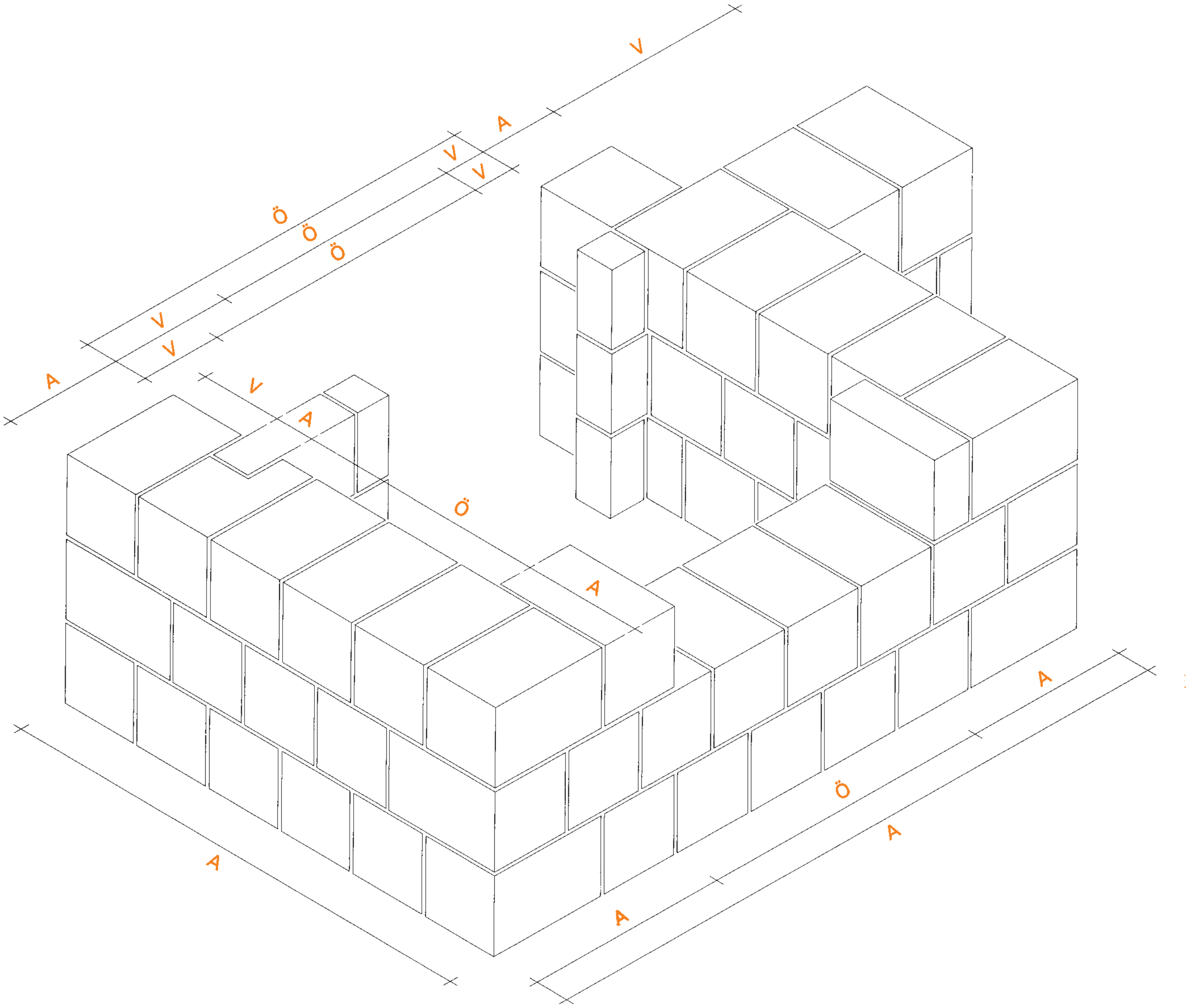
□ f
365 mm wall
header bond with 12 DF units

Stretchers are masonry units laid with their longitudinal, i.e. stretcher, faces parallel with the line of the masonry. Headers, however, are laid perpendicular to the line of the masonry. The outward appearance of both bonds is therefore similar, i.e. successive courses offset. But the appearance of this blockwork masonry is different from the familiar brickwork bonds – in this case English bond – characterised by their regular alternation between stretchers and headers.

Masonry dimensions are based on the “octametric” system: the 115 mm unit plus 10 mm joint form the basic module of 125 mm. By adding or subtracting joints we arrive at the three basic dimensions:

External dimension
A = n x 125 - 10 mm
Opening dimension
Ö = n x 125 + 10 mm
Projection dimension
V = V = n x 125 mm

Dimensional coordination also applies to clay masonry units laid without mortar to the perpends. In this case the perpends are taken to be 3 mm wide and the units 247 mm long. Smaller units, ends and junctions are cut to suit. Even though these days cutting and sawing on site can be carried out accurately and efficiently, wastage due to cutting should be avoided when structures are designed according to the masonry dimensions of the “octametric” system. It should be remembered that standard windows and doors are also designed to fit the “octametric” system.



1.
Three-dimensional construction

Buildings, with their load-carrying and bracing elements, are loadbearing structures whose stability must be guaranteed. That concerns both the individual loadbearing elements and the overall three-dimensional construction of the loadbearing structure.

The primary loadbearing elements (apart from roof structure and foundations) are the walls and the floors. In the construction an individual wall acts together with other walls with which it is directly connected or coupled via floor plates or capping/ring beam systems.

1.1
Walls

Masonry walls forming part of the load-carrying construction ("loadbearing walls") usually assume two different structural functions:

Load-carrying:
– vertical dead and imposed loads from floors, other walls, roof
– horizontal loads perpendicular to the wall due to wind or soil pressure

Bracing:
– horizontal loads parallel to the wall due to floors, capping/ring beams, crosswalls

Walls without such functions are designated "non-loadbearing".

1.2
Floors, capping/ring beam systems

The primary structural function of the floor is always to the transfer the load per unit area to the loadbearing elements (walls/beams/columns). In addition, floors also act as horizontal restraints for the walls; when designed as shear-resistant plates they form, together with the shear walls, a construction braced in all directions.

If a floor element is not designed to act as a plate (e.g. timber joist floor, clay hollow pot floor without concrete topping), the function of the three-dimensional coupling of the walls is achieved with capping and ring beam systems. Capping beams are components subjected to bending which provide restraint transverse to the plane of the wall, i.e. resist forces due to wind or soil pressure. Ring beams accommodate axial forces (tension or compression), i.e. "anchor" together, for example, the walls – normally provided with capping beams – transverse to the beam. Capping and ring beams – normally of reinforced concrete – can be omitted in certain circumstances (max. 2 proper storeys, length < 18.00 m, window/door openings < 60% of wall length, or if width of opening > 2/3 x storey height, then < 40% of wall length). In these cases the floor beams (every 2.00 m) must be suitably anchored.

1.3
Simplified structural analysis

DIN 1053 prescribes conditions which, if complied with, enable a wall to be designed using a simplified structural analysis with simpler stress verification. In addition, for simple types of building, like the terrace houses considered in this book, the stability is also guaranteed for:

– max. 2 storeys with storey height up to 2.75 m
– loadbearing walls: d = 365 or 240 mm for internal and external walls
– non-loadbearing walls: d = 115 mm
– upper floors of concrete, timber joists or clay hollow pots, max. span 4.20 m
– normal imposed loads for residential use (max. 5.0 kN/m^2)
– proportion of windows < 60%, for windows > 1.80 m wide < 40%

In these cases the only structural analysis required for all loadbearing masonry walls is to show that the actual compressive stress $\sigma = N/A$ is less than the permissible compressive stress.

N is the vertical compressive force due to the self-weight of the wall plus the floor and roof loads carried by the wall. A is the cross-sectional area of the wall on which this compressive force acts. The permissible stress is the "basic permissible stress" σ_o, which is merely dependent on the type of clay masonry unit being used (masonry unit strength) and the mortar (mortar group).

1.4
Detailed structural analysis

Exceptions or special cases in which the geometric framework conditions given in 1.3 above are not complied with are dealt with in section 2 below. In these cases the components covered by the simplified stress verification according to DIN 1053 part 1 must be checked for various other effects.

One primary parameter for assessing the stresses in a wall is its “slenderness”, i.e. the ratio of buckling length h_k to wall thickness d. The buckling length of a wall is the clear storey height multiplied by a factor β which takes into account the lateral restraint and the type of connection to the floors. The factor β lies between 1.0 (wall held on two sides, no restraint due to reinforced concrete floors) and 0.35 (wall held on four sides, spacing of lateral restraints max. 2.00 m). The value h_k/d may not exceed 25.

The basic permissible stress σ_o must be reduced by a factor k, which in turn depends on the coefficients k_1 and k_2 or k_3. The reduction factors take into account the length of the wall (k_1 = 1.0–0.8), the slenderness (k_2 = 1.0–0) and the effects of floor deflection (angle of rotation at supports) for floor spans between 4.20 and 6.00 m (k_3 = 1.0–0.7). The background to these coefficients will not be explained in detail here; the reader is referred to DIN 1053 part 1 (7.2).

2
Special situations (“disruptions”, special cases)

A detailed structural analysis for the simple houses considered here includes the roof structure, floors, concrete components and foundations (structure/subsoil interaction). The masonry walls can generally be assessed according to 1.3 above. Special situations may make it necessary to perform calculations according to 1.4, or the construction may require special consideration.

2.1
“Disruptions” to the overall construction

The overall loadbearing structure, the walls and floors, is weakened if the connections between the elements are ”disrupted”. We distinguish between two main cases:

a
The lack of a connection between wall and floor, e.g. at large floor openings in areas with galleries or stairs, where rooms (and hence walls) are two storeys high.

b
The floors do not act as plates (e.g. timber joist floors, clay hollow pot floors without concrete topping).

2.2
“Disruptions” to the masonry wall

The stability of a loadbearing wall element can be impaired if local ”disruptions” impair the restraint within the overall construction or reduce the thickness of wall:

a
Openings in the wall (windows, doors) interrupt the wall plate effect locally and the sections of wall between the windows represent ”unsupported edges” without lateral restraint. The slenderness of the wall increases, the load-carrying capacity decreases.

b
Horizontal chases in the wall reduce the structurally effective cross-section; vertical chases or recesses can, beyond a certain depth, weaken the wall so severely that the slenderness increases because at these points an “unsupported edge” must be allowed for. However, chases up to a certain depth (depending on length) are permitted which do not have to be considered in the structural analysis. We distinguish here between the way in which the chases are produced (milled or chiselled). DIN 1053 table 10 contains more detailed information.

2.3
Special case “column”

Masonry columns are usually constructed using small masonry units (i.e. bricks). They represent a special situation in two respects:

a
The lateral restraint to this “short wall” is missing on both sides, so columns are always held only on two sides (i.e. the ends). Column cross-sections < 0.10 m^2 may carry only 80% of their permissible design load, those < 0.04 m^2 are not permissible as loadbearing elements.

b
Columns are generally positioned at points where loads from floors or walls above concentrate. The load-carrying capacity with respect to these increased loads must be proved.

2.4
Special case “basement wall” (in contact with the soil)
Masonry external basement walls have to resist the soil pressure of the backfilled excavation. This horizontal load is much greater than the horizontal load due to wind. The soil pressure causes the wall to bend, which in turn sets up tensile and compressive stresses. As it is not permissible to design masonry for tensile stresses, it is necessary to cancel out the tension by means of appropriate compressive stresses (minimum vertical load!). On the other hand, the vertical load should not be so high that the compressive stresses due to bending can no longer be resisted (maximum vertical load!). An accurate structural analysis is not required when it can be guaranteed that the vertical load lies between these minimum and maximum figures (see 3.4 below).

3
Measures to allow for “disruptions” and special cases
The “disruptions” described in 2.1 above generally call for additional constructional measures to be taken. In some circumstances, however, an accurate structural analysis may show that the stability is still guaranteed and additional measures are superfluous.

3.1
“Disruptions” to the overall construction, the walls and floors

a
The lack of horizontal restraint to the wall provided by the floor (e.g. at large floor openings, galleries, stairs) is solved in constructional terms by providing a capping beam at the level of the floor and parallel to the opening. However, this is not necessary when the two-storey wall at this point can be shown to be structurally adequate. This is possible when appropriate lateral restraint from crosswalls (”wall held on three sides”) is available.

b
Floors that are not designed as plates (e.g. timber joist floors, clay hollow pot floors without concrete topping) can provide horizontal restraint for walls if suitably anchored (see 1.2 above). However, in terms of the construction it is better to include capping/ring beam systems, i.e. restraining and coupling the walls at floor level by way of concrete components. In certain cases capping/ring beam systems can be provided in the form of reinforced masonry.

Capping and ring beams:
The width is governed by the thickness of the wall minus any insulation necessary. The depth is equal to a course of masonry. Capping and ring beams must be reinforced.

Reinforced masonry:
Reinforcing bars in the bed joints must be protected against corrosion (galvanised, coated) or of stainless steel. Ring beams in the form of reinforced masonry are only permissible with corresponding perforations in the units (proportion of perforations < 35%, webs and fins not offset with respect to each other). This requirement is not met by large aerated clay bricks. Reinforced masonry is therefore to be regarded as a special solution hardly used in practice and not advisable for the simple buildings considered here.

3.2
“Disruptions” to the masonry wall

a
Openings in the wall (windows, doors) are to be spanned over with clay or concrete lintels, or by the reinforced concrete floor slab (beam within depth of slab). Critical points here could be the supports (end of wall or column) because the concentration of load here results in higher stresses and the wall is restrained on only two or three sides, which calls for a buckling analysis (see 1.4 above).

Clay lintels:
Clay lintels are prefabricated tension chords for a loadbearing element consisting of lintel plus masonry or concrete compression zone. The load-carrying capacity of clay lintels is generally defined in tables specifying width, depth and span. The maximum permissible span of clay lintels is 3.00 m.

Concrete lintels:
Lintels not monolithic with the reinforced concrete floor slab should have dimensions like those of capping and ring beams. With h = 240 mm, spans of approx. 3.00–4.00 m are possible, depending on vertical load. In the case of a monolithic lintel/floor slab, the depth of the lintel should be chosen sensibly: e.g. slab depth 160 mm + masonry course 250 mm = 410 mm. Spans of 5.00–6.00 m are therefore possible, depending on vertical load.

Reinforced concrete floor slab:
Suitably reinforced, a beam can be produced within the depth of a reinforced concrete floor slab, which can then span over an opening without the need for a lintel. The spans possible depend on the depth of the floor slab, the direction in which the slab spans, and the vertical load. Deflection is critical for beams within the depth of the slab carrying vertical wall loads because cracks ensue in the masonry above. Without vertical wall loads, spans of 3.00–4.00 m are possible.

b
Horizontal chases with dimensions exceeding those given in DIN 1053 table 10 must be checked structurally. The analysis should take account of the eccentricity e. Additional bending stresses occur due to the moment M = n x e. The method of analysis is dealt with in 3.4 below.

3.3
Special case “column”
Special constructional solutions may be necessary for very slender columns or those carrying heavy loads. If the permissible stress is exceeded for a given column size, it may prove prudent to use masonry units with a higher strength and/or a higher grade of mortar. The use of reinforced concrete columns or even steel stanchions is sometimes unavoidable.

3.4
Special case “basement wall” (in contact with the soil)
It is not necessary to check a masonry external basement wall in contact with the soil for compression (vertical load) and bending (soil pressure) if various conditions (vertical load/geometry) are complied with.

Geometric conditions:
– max. 2.60 m clear basement storey height
– max. 2.50 m depth of ground surcharge

The surcharge due to imposed loads may not exceed 5.0 kN/m^2.
The minimum and maximum vertical loads are as follows:

Wall thickness	Min. vertical load
240 mm	7.50 kN/m
300 mm	5.00 kN/m
365 mm	4.00 kN/m

The maximum vertical load is such that the resulting compressive stress does not exceed 45% of the permissible compressive strength of the masonry.

Thanks to the self-weight of the floor slab over the basement and the wall to the ground floor above, the necessary minimum vertical load is normally reached in the house types considered here with 365 mm external walls. At worst, the only problems occur at openings in the floor slab at ground floor level (e.g. stairs) or in areas without an external wall at ground floor level. Analyses may be required in such cases, maybe also constructional measures (e.g. capping beam or reinforced masonry) in certain circumstances. The maximum vertical load is normally never reached in these house types, even with low-strength masonry in the basement wall.
If the above conditions are not complied with, it is necessary to carry out a more accurate analysis of the stresses for the superimposition of the compressive stress due to the vertical load σ_D = N/A on the bending stresses (tensile and compressive) σ_β = +/-M/W. The tensile stresses due to bending must be cancelled out by the compressive stresses due to vertical loading. The same method of analysis should be used for an eccentric compressive load, as mentioned in 3.2 b above.

1. Preamble

Plaster and render are used to protect the building fabric and also for decorative purposes.

That the latter is particularly significant can be seen from the many different surface textures and colours that are possible. However, this aspect is also documented in practice by the many complaints concerning the appearance of plastered or rendered surfaces.

That shows just how much significance is attributed to the visual appearance of plaster and render.

In terms of appearance, the main complaints are:

- cracks
- spalling
- colour variations (streaks or blemishes)
- different textures in the finish coat
- uneven surfaces, offsets
- uneven edges at building corners and wall openings
- inaccurate junctions with other components

Careful selection and handling of the mix, observing all the recommendations associated with this technology and taking care with details can help to avoid such defects. These pages are intended to provide guidance.

2. Standards

Plastering and rendering is these days covered by DIN 18550 parts 1 to 4.

DIN 18550 part 1
- Plaster; terminology and requirements

DIN 18550 part 2
- Plaster; plasters made of mortars containing mineral binders; application

DIN 18550 part 3
- Rendering; rendering systems for thermal insulation purposes made of mortars consisting of mineral binders and expanded polystyrene (EPS) as aggregate

DIN 18550 part 4
- Plasters and rendering; lightweight plasters and rendering; execution

DIN 18558
- Synthetic resin plasters; terminology, requirements, application

3. Types of plaster/render

The standard defines plaster and render as wall/soffit finishes produced from mixes and coating materials.

Plaster and render are applied in a certain thickness in one or more coats. The plaster/render achieves its final properties after solidifying on the building and in conjunction with this.

We distinguish between the following types of plaster/render according to their constituents:

3.1 Plaster/Render with mineral binders

The mixes from which this type of plaster/render is produced are a mixture of binder, aggregate and water. And recently in particular, additives and admixtures have been added to influence the properties of the plaster/render and the workability of the mix.

The standard distinguishes between additives and admixtures:

• *Additives*
These affect the properties of the plaster/render by way of chemical and/or physical actions.
(Air entrainers, waterproofers, retarders, accelerators, stabilisers for increasing the water-retention capacity and additives to improve the adhesion between mix and substrate.)

• *Admixtures*
Admixtures in the meaning of the standard are finely distributed substances which also affect the properties of the mortar but whose volume, in contrast to additives, generally has to be taken into account.
(Fillers, e.g. stone dust, to improve workability; pigments to provide colour.)

The standard distinguishes between the following types of plaster/render in terms of the tasks to be fulfilled:

- plaster/render that satisfies general requirements
- plaster/render that satisfies additional requirements
  - water-retardant plaster/render
  - water-repellent plaster/render
  - render with enhanced strength
  - plaster with enhanced abrasion resistance
  - plaster for walls and ceilings in wet areas

- plaster/render for special purposes
  - thermal insulation plaster/render
  - plaster/render providing fire protection
  - plaster/render with enhanced radiation absorption

3.2
Plasters/Renders with organic binders

These are plasters/renders containing synthetic resins and produce a coating with an appearance resembling that of plaster/render.

If these types are applied to a mineral undercoat, this must be given a coat of primer first. (For further details of synthetic resin plaster/render see DIN 18558.)

The binders in synthetic resin plaster/render are synthetic resins. The other constituents, like sand and fillers, are the same as those for mineral plaster/render.

These types of plaster/render are primarily used for:

- the finish coat on mineral undercoats or other mineral substrates
- the final coat over thermal insulation composite systems

3.3
Silicate plasters/renders

These types are related to synthetic resin plaster/render. However, the binder is different – in this case consisting of potassium water glass with a dispersion additive for stabilisation.

The water vapour permeability of silicate plaster/render is higher than that of synthetic resin plaster/render.

This characteristic makes this type of plaster/render suitable for historical buildings, for instance, and, if incombustibility has been verified, as the final coat over thermal insulation composite systems.

This type of plaster/render cannot be used on substrates of wood, wood-based products or plastics.

4.
Plaster/Render

The standard distinguishes between mixes and coating materials.

4.1
Mixes

The standard classifies mixes in five groups P I to P V.

Mix groups

Mix group[1]	Type of binder
P I	non-hydraulic limes[2], semi-hydraulic limes, hydraulic limes
P II	highly hydraulic limes, plaster binder and masonry cement, lime-cement mixes
P III	cements
P IV	calcined gypsum with and without building lime
P V	anhydrite binder with and without building lime

1 For further subdivision of mix groups, see DIN 18550 part 2, 1985 edition, table 3.

2 A limited amount of cement may be added.

Mixes consist of one or more binders, aggregates and water, possibly also with additives and/or admixtures.

The grain size of the majority of the aggregate lies between 0.25 and 4 mm. In finish coats the proportion of grains > 4 mm can dominate.

The grain size has a great influence on the shrinkage behaviour of the plaster/render. The smaller the size of aggregate, the greater is the tendency to shrink. Mixes made from calcined gypsum and anhydrite binder mostly contain no aggregates.

Mixes are also distinguished according to their state and place of production.

- State:
  green (still workable)
  hardened (solidified)

- Place of production:
  in situ (constituents mixed together on the building site)
  ready mixed (constituents mixed together in a factory)

5.
Coating materials

These consists of organic binders and aggregates or fillers and are used for producing synthetic resin plaster/render.

The grain size of the majority of the aggregate is > 0.25 mm.

These materials are produced in a factory.

6.
Distinguishing plaster/render according to its application

6.1
Plaster/render for general requirements (normal-weight plaster/render)

This type of plaster/render is covered by DIN 18550 parts 1 and 2.

6.2
Lightweight plaster/render

This type of plaster/render is like a normal-weight type with a mineral binder. However, in contrast to these they have a limited bulk density.

The lower bulk density is achieved by means of mineral and/or organic aggregates with a porous microstructure.

DIN 18550 part 4 includes suitable provisions for applying lightweight plaster/render.

Lightweight plaster/render and the associated finish coats must be manufactured in the form of premixed dry materials.

Compressive strength of lightweight plaster/render (mix group P III):
between 2.5 and 5.0 N/mm^2

Bulk density of lightweight plaster/render:
between 600 and 1300 kg/m^3

If a lightweight plaster/render complies with the requirements of mix group P II, the compressive strength of the finish coat should be in accordance with the requirements for group P I c or P II.

Owing to its deformation behaviour, lightweight plaster/render is particularly suitable for masonry comprising thermally insulating, porous, lightweight vertically perforated clay masonry units.

Lightweight plaster/render is not a thermal insulating material in itself.
An organic finish coat, e.g. synthetic resin render, should not be applied to a lightweight render.

6.3
Thermal insulation plaster/render

This type of plaster/render was specially developed to provide good thermal insulation and exhibits a bulk density considerably lower than that of lightweight plaster/render.

Characteristic values for thermal conductivity λ_R = 0.07 W/mK are possible with thermal insulation plaster/render.

These types are manufactured as premixed dry materials. Thermal insulation plaster/render with a mineral binder and expanded polystyrene (EPS) as the aggregate are currently covered by DIN 18550 part 3.

The compressive strength of the hardened mix must lie between 0.8 N/mm^2 and 3.0 N/mm^2. Besides polystyrene as an aggregate, covered in the aforementioned standard, mineral aggregates (e.g. perlite and cellular glass pellets) are being increasingly employed. However, these do not generally achieve the aforementioned characteristic values for thermal conductivity.

6.4
Renovation plaster/render

This type of plaster/render exhibits a high porosity and water vapour permeability. The capillarity is considerably lower.

Renovation plaster/render is used on damp masonry and/or masonry containing salts. The high volume of entrained air allows the salts to crystallise within the plaster/render. In this way the salts are retained within the material and do not reach the surface.

The high water vapour permeability is useful for allowing the masonry to dry out.

7.
Plastering/Rendering systems

These systems are defined by the standard as all the coats of a plastered/rendered wall/soffit finish in conjunction with the substrate.

Even single-coat plastering/rendering can be classed as a system.

The system, in its entirety, must comply with the particular requirements of the specification.

Compatibility between the properties of the various coats in a system is essential. The same is true for the compatibility between plaster/render and substrate. The substrate must be prepared if necessary.

Apart from legitimate exceptions, e.g. render to basement walls and plinths, the strength of the finish coat for plaster/render with a mineral binder should be less than or equal to that of the undercoat.

This principle also applies to the compatibility between undercoat and substrate.

8.
Applications

8.1
Render

8.1.1
General

Basically, for render we distinguish between the following:
- wall render above the plinth
- basement wall render (in contact with the soil)
- plinth render
- soffit render (underside of slabs in contact with the outside air)

8.1.2
Wall render above the plinth

The render must be resistant to the effects of the weather, moisture, temperature changes, wind, etc.

In terms of protection from the rain, DIN 4108 part 3 specifies the exposure groups and the resulting requirements.

8.1.3
Basement wall render (in contact with the soil)

In areas in contact with the soil this render forms a substrate for the waterproofing.

Mixes with hydraulic binders must be used for this type of render, which must also exhibit a compressive strength of at least 10 N/mm². If mix group P III is employed, it is not necessary to verify the compressive strength.

If masonry units of compressive strength 6 N/mm² or less are used for the basement wall, the compressive strength of the mix should not be significantly higher than 10 N/mm², but may be less (≥ 5 N/mm²).

8.1.4
Plinth render

This type of render must be sufficiently hard. It may absorb only small amounts of water and must be resistant to the effects of moisture and frost.

Render made from mixes with mineral binders must exhibit a compressive strength of at least 10 N/mm².
It is not necessary to verify the compressive strength when using render according to the following table. If masonry units of compressive strength 6 N/mm² or less are used for the wall, the compressive strength may be lower (but at least 5 N/mm²). However, the requirements for water-repellent render systems must be complied with.

Plinth render

Mix group or coating material type for		
undercoat	finish coat[1)]	additive
–	P III	
P III	P III	none
P III	P Org 1	
–	P Org 1[2)]	

1) Finish coats can be finished with or without some form of surface decoration (e.g. on surfaces to be coated).

2) Only on a concrete substrate with a closed microstructure.

8.2
Plaster

Plaster must comply with the normal requirements, e.g. suitable as a substrate for paint and wallpaper.

The compressive strength must be at least 1.0 N/mm².

It is not necessary to verify the compressive strength when using the plastering systems classed according to the requirements or applications of DIN 18550 part 1.

9.
Thickness of plaster/render

A minimum thickness must be maintained in order to fulfil physical and other requirements. However, there is also an upper limit to the thickness.

The standard prescribes the following average thicknesses for general requirements:

Render:
20 mm (permissible min. thickness 15 mm)

Plaster:
15 mm (permissible min. thickness 10 mm)
single-coat plaster made from premixed dry materials:
10 mm (permissible min. thickness 5 mm)

The permissible minimum thickness must be confined to isolated patches.

In the case of additional requirements, the thickness should be chosen to meet those requirements.

Single-coat water-repellent render made from premixed dry materials: average thickness 15 mm (min. thickness 10 mm).

As a rule, the average thickness of lightweight render when used as an undercoat should be 15 mm. Here again, the minimum thickness must be confined to isolated patches.

The minimum thickness of thermal insulation plaster/render is given as 20 mm. However, in order to achieve a better thermal insulation effect, it is usually thicker.

Plaster/Render should be applied to achieve a consistent thickness.

10.
Substrate

A suitable substrate is a vital condition for durable plaster/render free from defects.

The properties of the substrate have a considerable influence on the adhesion of the plaster/render.

A detailed examination of the substrate is therefore especially important and must be carried out by the plastering/rendering contractor. Any objections must be recorded in writing.

Any work necessary to rectify defects in the substrate are the responsibility of the client (DIN 1961: Contract procedures for building works, part B: general conditions of contract for the execution of building works – cl. 4 para. 3).

Conditions for a suitable substrate:

- The substrate must be dry, free from dust, clean, firm and capable of supporting the plaster/render.
- Visible deposits that could damage the plaster/render should be rectified; lime bloom and minimal efflorescence do not represent any problems.
- The dimensions of the substrate must be such that the plaster/render can be applied with a consistent thickness.
- When used as a substrate for plaster/render, masonry must comply with the stipulations in DIN 1053:
  - all joints must be filled with mortar,
  - if perpends without mortar are used, these must be filled on the faces with a suitable mortar on both sides of the wall if they are wider than 5 mm,
  - the prescribed bonding dimension must be maintained,
  - defects, unfilled slots and the exposed header faces of dog-tooth courses must be filled with mortar.

The necessary mortar work should be carried out as the masonry is built. If the mortar is applied subsequently, a waiting time of at least four weeks is required before applying the plaster/render.

11.
Interdependence of plaster/render and substrate

The plastering/rendering system chosen must be suitable for the type of substrate available. The first move in selecting a plaster/render is to make sure that it is suitable for the substrate.

The choice of plastering/rendering system depends on:
- the suction rate of the substrate,
- the loads to be expected during usage,
- the properties of the masonry,

and other factors.

12.
Preparing the substrate

Preparation of the substrate includes all those measures that are necessary in order to guarantee a permanent bond between plaster/render and substrate.

After examining the substrate, the ensuing preparatory work should be carried out:
- Highly absorbent substrates may need to be pre-wetted (observe instructions of mix supplier). Other measures may also be necessary (high suction primer, priming, full-coverage spatterdash). In every case, follow the instructions of the mix manufacturer.
- Mixes suitable for highly absorbent masonry are available. In these the water-retention capacity of the undercoat is matched to the suction rate.
- On a low-absorption substrate, blobs of spatterdash (not full coverage) are preferred in order to improve the adhesion of the plaster/render. Adequate adhesion can also be achieved by other measures such as bonding coats or primers.
- If the substrate consists of different materials with different suction rates, a full-coverage spatterdash is necessary in order to achieve a uniform suction rate.
- If the substrate includes components made from materials that are unsuitable for use as a plastering/rendering substrate, some form of background must be provided.
- If stresses in the plaster/render are to be expected due to the type of construction or details, the plaster/render should be reinforced.
- Wood-wool slabs should be covered with spatterdash. Reinforce the plaster/render in such areas.
- Always follow the instructions of the mix manufacturer and the relevant technical information with respect to the substrate.

13.
Examining the substrate

- Visual inspection for:
  - cracks
  - moisture
  - dust and loose fragments on the surface
  - coatings or foreign matter on the surface
  - efflorescence
  - damage
  - protruding mortar
  - excessive unevenness
  - perpends and bed joints not fully filled (primarily substrates for render)
  - excessively wide perpends without mortar
  - correctness of bonding dimension
  - strength (scratch test)

- Wetting test with water for:
  - suction rate of substrate
  - different suction rates on varying substrates, if necessary also for different clay masonry units
  - excessive moisture (no discoloration)
  - release agents etc. on, for example, concrete components, wood-wool slabs

- Measurement for:
  - unevenness of wall surface (straightedge, plumb line, etc.)
  - surface temperature and air temperature

14.
Applying the plaster/render

- The deformations specific to the material of the substrate should be completed before starting to apply the plaster/render.
- When using spatterdash, this must be sufficiently firm.
- The substrate must be free from frost (not below +5°C).
- Owing to the constituents (e.g. additives) in premixed dry materials, the properties of the plaster/render are not usually identifiable for the user. Good contact with the customer service department of the manufacturer of the premixed plaster/render is therefore highly advisable.
- The undercoat for render, especially when spatterdash is not being used, should be applied in two operations. The first (dubbing-out) coat should even out any irregularities (approx. 7-10 mm). Only after this coat is stiff (after waiting at least three hours or longer, depending on the suction rate of the substrate) should the second undercoat be applied. The finish coat can be applied after the standard waiting time (1 day/mm thickness). The leading mix manufacturers point out in their technical information that the mix requires sufficient water in order to cure properly. With a thin coat or excessively fast drying, the finished surface of the plaster/render should be wetted at least once.
- If the finish coat is to be painted, then this should not be carried out on the “green” plaster/render. The paint must exhibit an adequate water vapour permeability. The substrate (i.e. finish coat) must be suitable for painting and the paint must be compatible with the plaster/render.

15.
Recommendations for obtaining plaster/render free from defects

15.1
Shrinkage

The setting process of the plaster/render is accompanied by shrinkage.

Every type of plaster/render – also those types with a small grain size to achieve good machine workability – produced from the ready-mixed varieties available today is subjected to shrinkage processes to some degree – large or small – after application.

These shrinkage processes cause stresses in the plaster/render and, consequently, deformations. If the shrinkage stresses can be transferred to the substrate, the plaster/render generally remains free from cracks.

Essential for this is a good bond between plaster/render and substrate. If this bond is not achieved, the stresses cannot be relieved and the plaster/render cracks in areas where an adequate bond is lacking. The tensile stresses resulting from the shrinkage are greater than the tensile strength of the plaster/render.

Continuous support for the plaster/render is therefore necessary over the entire surface of the substrate.

If, for example, there are voids in the plaster/render over joints, there is no adhesion and the plaster/render cracks at those positions; the crack will follow the line of the joint. The cause of the cracking is therefore not the clay masonry itself but rather the plaster/render in conjunction with inadequate adhesion at the joint. So the joint determines the course of the crack. For this reason it is absolutely essential to fill completely all the joints in the masonry.

However, cracks over the joints can have other causes. If the mortar in the joints of the masonry has a lower suction rate than that of the clay masonry units, the plaster/render over the surface of the clay masonry units will set earlier and the tensile stresses due to shrinkage cause cracks at the joints because there the plaster/render is still wetter and hence softer. This problem can be remedied by wetting the surface of the clay masonry units, following the instructions of the mix manufacturer.

The magnitude of the different effects also depends on the thickness of the plaster/render, and the spacing of the joints also plays its part. If the plaster/render is too thin, the influence of the joints is more noticeable.

The thickness of the plaster/render also affects its strength.

If the plaster/render does not adhere well to the surface of the clay masonry units, e.g. because the properties of plaster/render and clay masonry are not ideally compatible, it becomes detached due to the stresses; a network of cracks is the result.

Inadequate adhesion between finish coat and undercoat due to, for example, poor workmanship, can also cause the two coats to separate. If, for example, the surface of the undercoat is not roughened or, during hot weather, the surface is not wetted, an inadequate bond can be the outcome. This also happens when the finish coat is stronger than the undercoat.

The contractor would be well advised to keep to the tried-and-tested rule of decreasing the strength from inside to outside and to ignore what has been said recently about the opposite being better!

However, the plaster/render should not be too thick because otherwise excessive stresses occur in the surface of the plaster/render, which in turn lead to cracks. The shrinkage stresses at the surface can no longer be adequately relieved because the distance of the surface from the substrate is too large and the stresses cannot be properly transferred to the substrate.

Shrinkage is affected or increased by::

- a high proportion of binder
- a too rapid water loss
- too much water in the plaster/render
- the grading curve of the aggregate

15.2
Loads on the plaster/render

In most cases of damage, moisture in one form or another is at least partly to blame.

The constituents of the mix also play an important role with respect to the take-up and release of water through capillary action.

The greater the effects of moisture, the greater is the stress on the plaster/render.

Cracks which are frequently no cause for complaint become defects later due to the effects of water. This situation can often be seen primarily on the side exposed to the prevailing wind.

16
Patterns of damage

– A network of fine, irregular cracks not penetrating the full thickness

Cause:
- too much binder in the mix
- impurities in the aggregate
- plaster/render rubbed too early, too long and too vigorously

Shrinkage cracks:
- a too rapid water loss (due to sunshine, high temperature or draughts)

Network of wider cracks:
(inadequate adhesion to substrate)
- too much binder in the mix (cracks penetrate full coat thickness)
- a too rapid water loss

Hairline cracks not penetrating deep into the plaster/render:
- these cracks are caused by rubbing the surface of the plaster/render where the surface is rich in binder and water
- fine-grain aggregate with a smooth surface to the plaster/render

Cracks following the line of the masonry joints:

In this situation the stresses in the plaster/render over the joints are different to those over the masonry units themselves (capillary water absorption of masonry units and joint mortar is different and results in different drying conditions).

Cause:
- mortar remains damp for longer when the masonry units have a higher suction rate than the mortar
- defective substrate (joints not filled completely)
- perpends closed off only on the inner and outer faces (thermal bridge with formation of condensation water)

Plaster/Render separates like "puff pastry"
- excess water in the mix has frozen before it could escape
- mix was not yet strong enough
- frost progresses from outside to inside and the freezing water causes the mix to become detached in layers

Low mix strength
- too little binder, too rapid loss of moisture, poor grading of aggregate
- coat too dense when using P I (lime mix) (P I requires a regular supply of moisture to reach its strength)

Plaster/Render detaches from substrate
(with good bond between finish coat and undercoat)
- inadequate bond when the surface absorbs too little water – the binder paste is not absorbed to a sufficient extent (bonding forces are ineffective)
- excessively absorbent substrate (spatterdash recommended as regulating intermediate layer)
- absorbent clay masonry units should be pre-wetted during hot weather
- plaster/render is not compatible with substrate (regulated by means of high suction primer)

Inadequate adhesion between finish coat and undercoat
- undercoat was not pre-wetted (during hot weather), undercoat not roughened
- finish coat stronger than undercoat (dense coats transfer additional stresses as they dry out)
- temperature gradient – in thin plaster/render especially – due to direct sunlight (low heat dissipation inwards, particularly in thermal insulation masonry)

A masonry structure made from large lightweight vertically perforated clay blocks is much more efficient in terms of thermal insulation (in accordance with today's requirements) than the masonry structures of the past built from (small-format) clay bricks. This development has brought about a change in the gross density and the strength. In combination with other materials (principally concrete), careful design is necessary plus comprehensive foresight in weighing up the possible risks: Stresses due to deformations caused by
- thermal processes (hot – cold, sun – shade, day – night, summer – winter...)
- moisture-related processes (water – vapour, rain – snow – ice, moisture due to construction and usage and the associated shrinkage and swelling)
- material-related and chemical processes

Estimates or calculations of deformations together with the structural engineer are invaluable. In doing so, the loads from outside (orientation with incidence of solar radiation, prevailing wind side...) are to be included in the catalogue of risks to the same extent as the loads from the structure itself: its size and usage, the type of loadbearing structure and the materials used in its construction. Likewise, also any protective arrangements such as roof overhangs, canopies, balconies ... right up to projections, re-entrant corners and shoulders.

What are the consequences for this book? The detail drawings are "compatible" with each other but remain as typical, partial information. Their feasibility and compatibility must be carefully checked in each individual case because integrating these into the design of each new, different structure could necessitate fundamental changes.

Designers wishing to create durable structures must be prepared to learn from recent experiences in order to avoid vulnerable situations (see *Schadenfreies Bauen mit Mauerwerk, Katalog von Rissschäden und Maßnahmen zu deren Vermeidung*, Prof. P. Schubert; *Masonry Construction Manual*, Pfeifer et al., p. 106).

Differential deformations
As differential deformations represent a key problem, the primary parameters of wall materials are listed below (characteristic values but also ranges which indicate something of the diversity and scatter of the material). This will enable a rough estimate of differential temperature or moisture deformations to be made and hence the compatibility or incompatibility between materials.

Supports for reinforced concrete floor slabs
Deformations in reinforced concrete floor slabs cause stresses in the external masonry; these can be superimposed on and increase other deformations. If temperature-related deformations can be ruled out thanks to adequate and properly installed thermal insulation, deformations due to the loads plus shrinkage and creep of the concrete are the principal causes:

- Deflection of the slab and lifting of the slab at the supports due to the rotation of the edges of the slab, aggravated by the excessive slenderness of the slab and a low vertical load at the supports. The result is horizontal cracks at the supports or in the underlying courses. The corners of roof slabs without any vertical load are particularly at risk due to the "dishing" effect.

Deformation parameters for shrinkage, creep and temperature changes to DIN 1059 table 2

Type of masonry unit	Final moisture expansion shrinkage, chem. swelling		Final creep coefficient		Coeff. of thermal expansion	
	Char. value mm/m	Range mm/m	Char. value	Range	Char. value 10^{-6}/K	Range 10^{-6}/K
Clay	0	+0.3 to –0.2	1.0	0.5 to 1.5	6	5 to 7
Calcium silicate	–0.2	–0.1 to –0.3	1.5	1.0 to 2.0	8	7 to 9
Lightweight concrete	–0.4	–0.2 to –0.5	2.0	1.5 to 2.5	10 (8*)	8 to 12
Concrete	–0.2	–0.1 to –0.3	1.0	–	10	8 to 12
Aerated concrete	–0.2	+0.1 to –0.3	1.5	1.0 to 2.5	8	7 to 9

shortening (shrinkage): – sign; lengthening (chemical swelling): + sign
* for lightweight concrete with expanded clay as principal aggregate

- Shortening of the slab and "pulling" the masonry units at the support. The result is horizontal cracks at the support but also downward diagonal cracks in internal crosswalls at the supports or horizontal cracks in the middle of the wall.

- Eccentric load transfer at the support – also a consequence of the aforementioned deformations. The result can be cracks on the outside of the wall or also cracks beneath the support on the inside due to excessive edge bearing pressure.

Countermeasures

- Concrete technology and workmanship: the use of low-shrinkage concrete with a low water/cement ratio (beware of uncontrolled addition of concrete additives), careful curing (striking the formwork later, protecting concrete surfaces against sunshine and wind by covering keeping moist, sprinkling with water...).

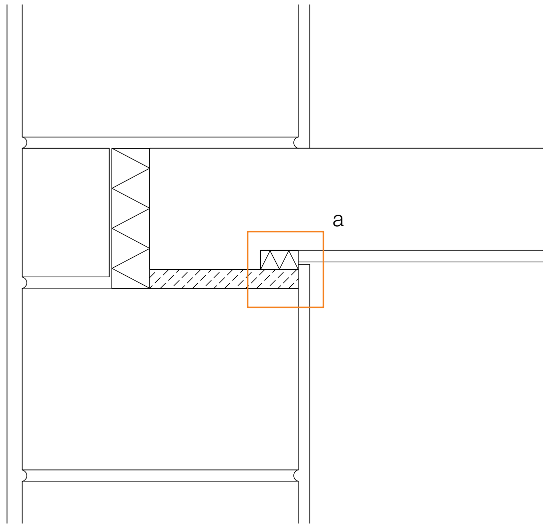
- A sufficient slab depth: DIN 18530 specifies maximum slenderness ratios for roof slabs (generally without vertical loads); it is also possible to replace the lack of vertical load by incorporating a vertical tie to the slab below.

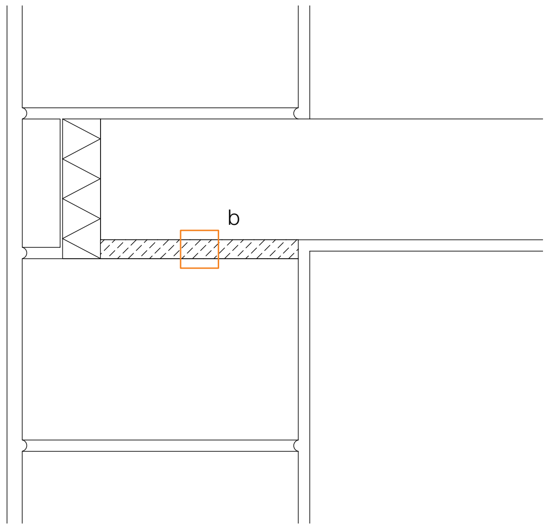
- Reduce the shortening due to shrinkage, especially that of the roof slab, by limiting the length of the slab or incorporating contraction joints.

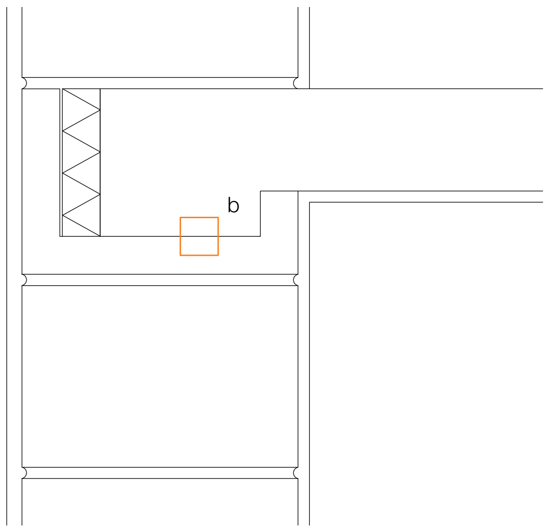
- Include a bed of high-strength mortar or a separating layer between the concrete slab and the masonry at the supports.

- A sufficiently wide bearing for slabs with larger spans:

□ a: Incorporate compressible strips on the inside of the support to centre the load transfer and avoid damage due to the bearing pressure on the edge
□ b: Reduce the thickness of the facing leaf (brick slips instead of half-brick units) or bed the concrete in a suitably prepared clay channel block.







Capping and ring beams

The shrinkage of ring beams, capping beams and other concrete and reinforced concrete components within the masonry can lead to damage if these processes are not considered when designing the details. Concrete components which are not absolutely essential should therefore be omitted.

Securing unsupported edges of masonry and the stability of the building can be achieved by providing structural connections to appropriately braced components, like roof or floor plates.

Openings in walls
In masonry structures well-known patterns of cracks can occur, e.g. in spandrel panels, which usually run diagonally downwards from the corners of openings. To avoid these, the drawings elsewhere in this book show “anti-crack reinforcement” in the spandrel panels. This “anti-crack reinforcement”, which merely limits the width and distribution of cracks, should comprise steel bars protected against corrosion, better still, specially designed brickwork reinforcing elements of stainless steel – such reinforcing elements have nodes and cannot be pulled out. The reinforcement should extend into the masonry adjoining, for example, an opening by about 600–800 mm.

At larger openings the reinforcement should be incorporated as “high” as possible, i.e. in the topmost bed joint. It is also possible to incorporate the approx. 5 mm reinforcing elements in lightweight mortar because this is not classed as reinforced masonry (DIN 1053 part 3).

Chases and recesses
These can severely weaken the load-carrying capacity of the homogeneous masonry due to the change in the cross-sectional area, the flexural stiffness and the eccentricity of the remaining area. Chases and recesses made in the finished masonry can lead to considerable damage because they are often cut unsupervised and in particularly sensitive areas without consultation. In external walls they also form undesirable thermal bridges. In other words, chases and recesses must be properly planned and integrated into the structure

Chases and recesses not requiring a structural analysis in loadbearing walls to DIN 1053 table 10

Vertical chases and recesses in a masonry bond

Wall thickness (mm)	Chase width (mm)	Residual wall thk. (mm)	Edge distance
115	–	–	–
240	max. 385	min. 115	min. 2 x chase width but at least 240 mm
365	max. 385	min. 240	

Distance between chases and recesses to be at least equal to minimum chase width.
The total width of chases per 2.00 m of wall length may not exceed the maximum chase width.

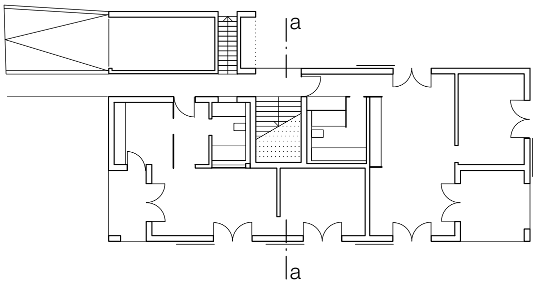
Chases and recesses cut subsequently (length of chase unlimited)

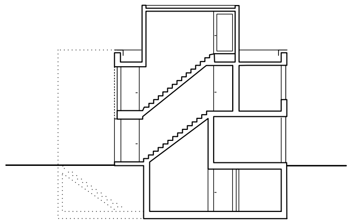
Wall thickness (mm)	Horizontal and diagonal depth (mm)	Vertical chases and recesses depth (mm)	Vertical chases and recesses width of single chase
115	–	max. 10	max. 100
240	max. 15	max. 30	max. 150
365	max. 20	max. 30	max. 200

Edge distance of chases and recesses from openings to be at least 115 mm.
Horizontal and diagonal chases are only permissible when at least 0.40 m above or below the structural floor slab and only on one side of a wall. When using tools with which the cutting depth can be set accurately, the depth may be increased by 10 mm and walls at least 240 mm thick may have chases cut on both sides max. 10 mm deep. Chases max. 80 mm deep and max. 120 mm wide that extend no more than 1.00 m above the floor may be cut in walls at least 240 mm thick.

Clay masonry buildings – examples

Housing complex in Munich





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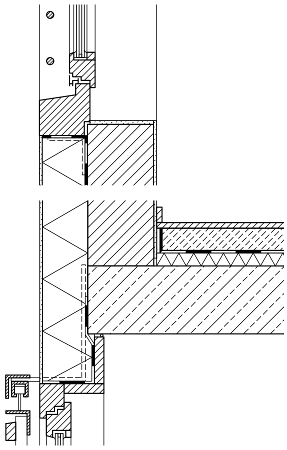
Christoph Wallner, Munich

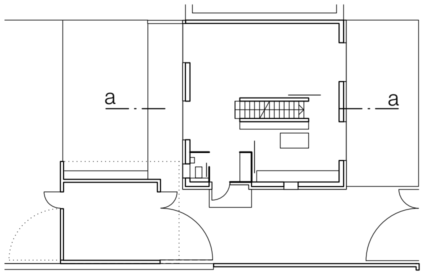
Ground floor plan • Section Scale 1:400
Detail Scale 1:20

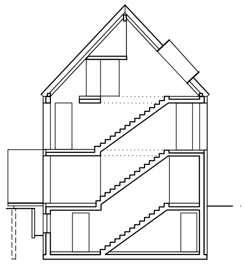


Situated to the north of Munich in a residential district with detached and terraced houses, this brightly painted oblong building immediately catches the eye. The complex, containing four apartments, is located on a corner plot with apple trees and is not out of scale with its surroundings. The flat sides of the box are broken up by openings for loggias at ground floor level and a spacious staircase to the apartments on the first floor. The walls are solid with a thermal insulation composite system. The windows are emphasised by their dark wooden frames flush with the wall. The client, a skilled painter himself, also had a hand in deciding on the final colour scheme. The entire external skin was first given two coats of an opaque yellow silicone resin paint. The final coat of outdoor glaze with a terracotta shade was applied with brushes and sponges in delicate wiping movements. From outside, the building looks as though it has been coloured with a pigment

DETAIL 12/2003

Semi-detached house in Munich





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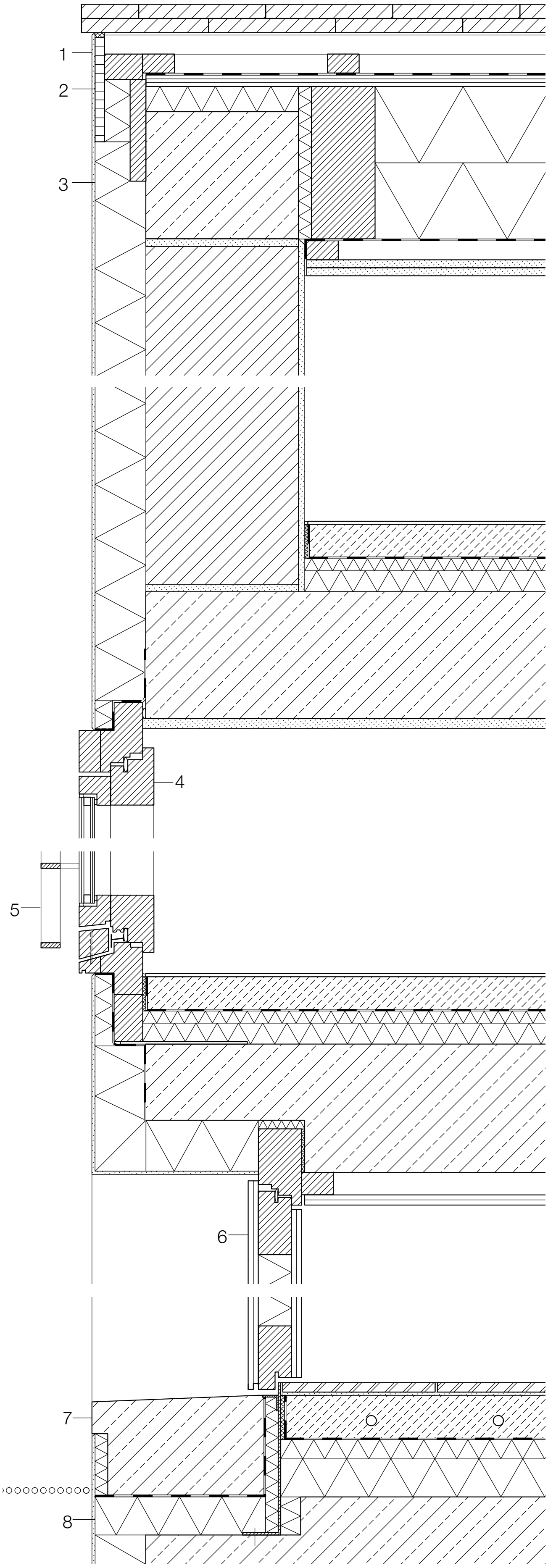
Andreas Meck and Brigitte Püls, Munich

At first sight this small semi-detached house seems to represent the archetypal housing development unit: a distinct, compact envelope with a steep pitched roof and eaves and verge virtually flush with the walls, standing out peacefully from the surrounding, inhomogeneous built environment. This is helped by restricting the number of different building materials. Only upon closer inspection do we appreciate the sensitive treatment of the everyday architectural language. Simplicity is the basic concept behind this building. Instead of the conventional Velux-type roof windows, conspicuous boxes with straightforward top-hung opening lights penetrate the roof surface. Untreated mahogany windows fit flush with the external wall but still seem to protrude just a little from the facade. The omission of glazing beads and the way the panes of glass are glued flush into their frames allow the windows to appear as flat elements without any depth. Only the entrance doors set back into the facade create a distinct accent and correspond to our idea of the customary “hole in the wall” so typical of masonry facades.
The 240 mm clay masonry is covered completely on the outside with a thermal insulation composite system; the smooth surface of the render has been given no further treatment. No coats of paint conceal the irregularities of the individual stages of the work or subsequent making good. The surface appears animated and can already tell its own story. The render on the gable terminates elegantly in classical style at the delicate, zigzag line of the clay bullnose roof tiles.
🕮 DETAIL 1/2 2002

Ground floor plan • Section scale 1:400
Section through facade scale 1:10

1 Mineral render, finished directly on the underside of the clay roof tiles
2 Render background: 30 mm wood-wool slabs
3 80 mm rigid polystyrene foam
4 Untreated mahogany window
5 Balustrade, welded 30 x 8 mm steel flats, galvanised and coated
6 Untreated mahogany entrance door
7 In situ concrete step
8 60 mm rigid cellular glass insulation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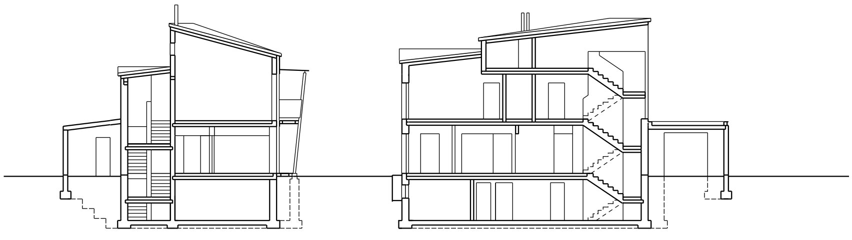
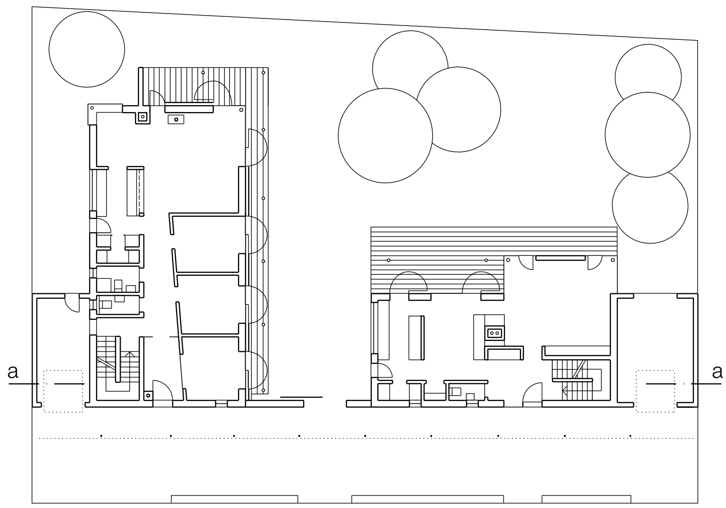
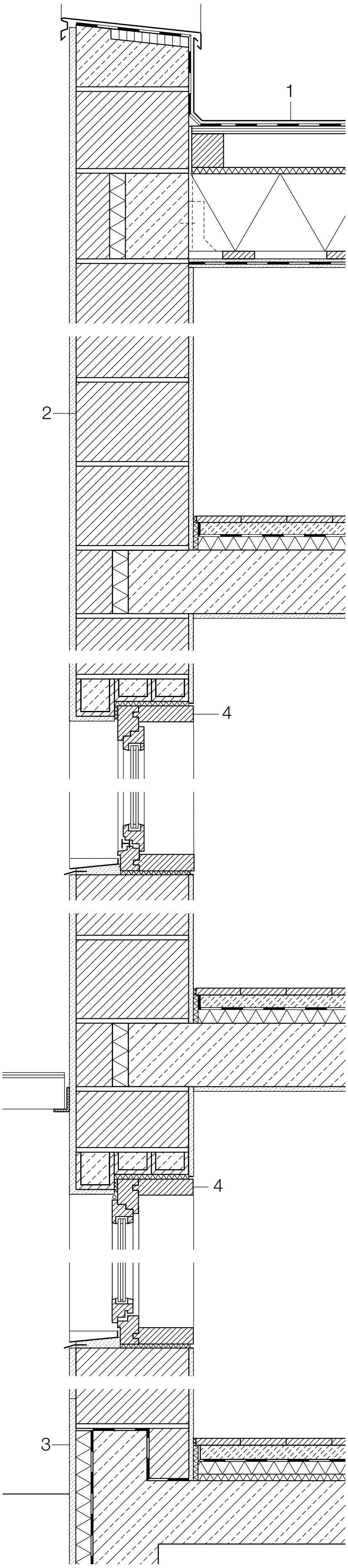
Houses in Munich



Thomas M. Hammer and
Doris Schmid-Hammer, Munich

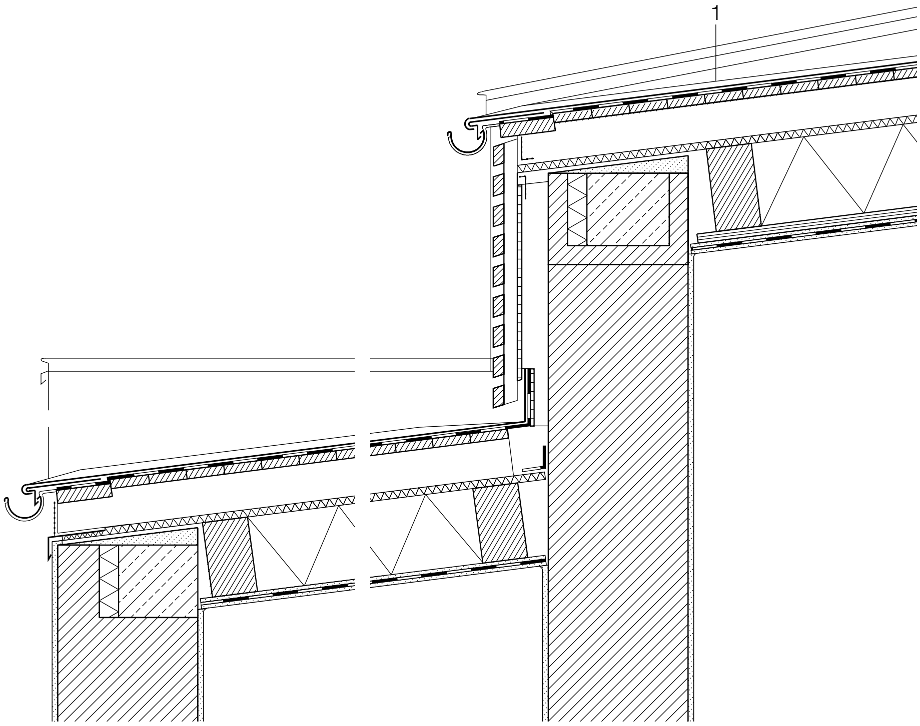


The governing idea for the design of this pair of houses was independent yet joint lifestyles. The loose coupling of the houses gives each of the clients – two brothers – space to enjoy his own lifestyle. Two different envelopes were created, linked by a tall wall on the road side. The entrance and garage doors along this facade are protected by a continuous canopy, signifying the access zone. The personal lifestyles of the brothers are primarily evident in the different interior layouts. One of the houses is partly in timber and takes account of the needs of a communal lifestyle. Here, the open-plan living room/kitchen forms the communal, communications hub of the house, although each occupant is provided with living and working areas, all the same size.
The external wall of the other house, which is parallel to the road, is of 365 mm lightweight clay masonry with a white render finish. The spacious open-plan living and dining area for the family occupies virtually the whole of the ground floor. The various private rooms are located on the upper floor and under the roof; these serve as bedrooms, studies or children's rooms depending on the size of the family. Despite the compactness of this building, skilful design has resulted in an interesting interior layout with diverse internal and external views. The ingenious use of natural lighting underlines and rounds off this effect.
🕮 in DETAIL *Single Family Houses*



Sections • Ground floor plan
scale 1:400
Details scale 1:20

1 Standing seam roof covering of sheet titanium-zinc
2 layers of bitumen roofing felt
24 mm rough-sawn tongue and groove boards
100 mm ventilation cavity between 100 x 100 mm rafters
19 mm bitumen-impregnated softboard
220 mm cellulose insulation between 120 x 220 mm purlins
24 mm open boarding
2x 10 mm plasterboard with vapour barrier between
2 365 mm clay masonry HLz 12-1,0-12 DF units
3 Basement wall:
cement render on bonding coat
cellular glass insulation
waterproofing
4 Solid wood lining, 50 mm larch



House in Hallertau

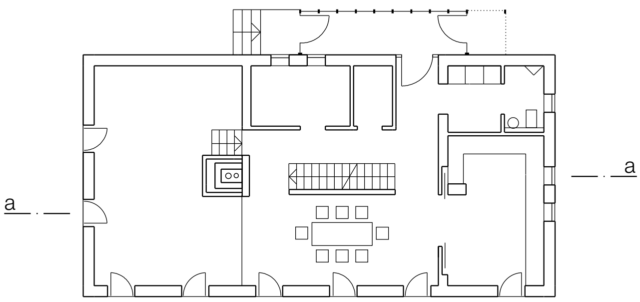
Walter Stolz, Rosenheim

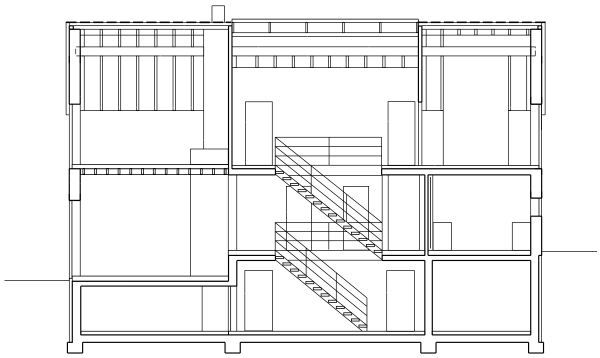
The plot is located in a new residential development with a variety of detached homes on the outskirts of this little town in Bavaria. The house and garage are positioned at the top end of this gently sloping site. Together with the wall in between, they form a boundary on the road side and enclose the west-facing garden with its view towards the town in the valley.

The north elevation of the main building has very few openings but includes a glazed porch, which acts as a climate buffer and lobby for the entrance.

Careful choice of materials and simple, precise detailing have resulted in a building that relates to both contemporary architecture and regional building traditions. The walls are of 365 mm lightweight clay masonry with a finish of three-coat lime render painted sienna red. The natural-colour concrete roof tiles terminate at the eaves and verges without an overhang, simply with sheet metal flashings.

🕮 DETAIL 1/1999





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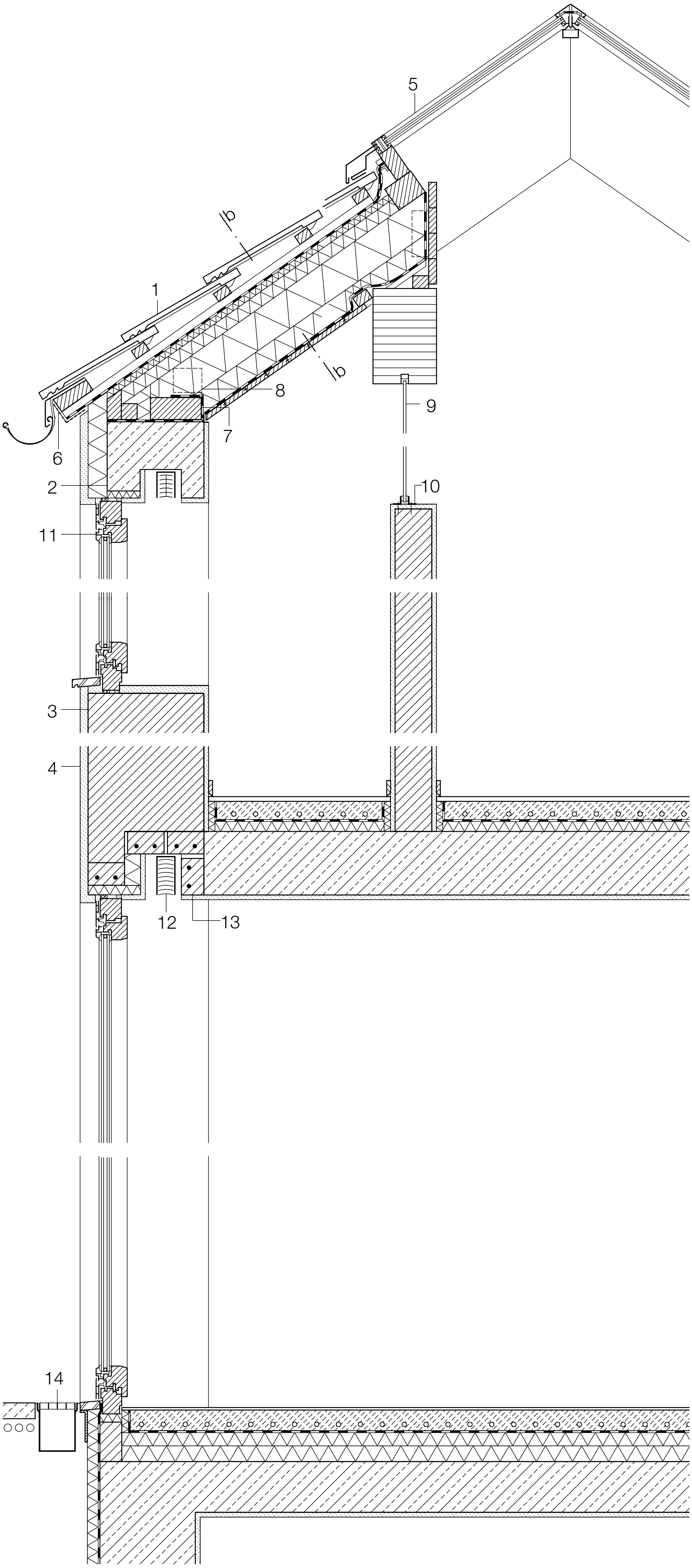
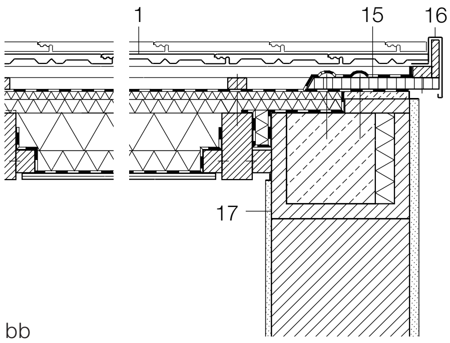
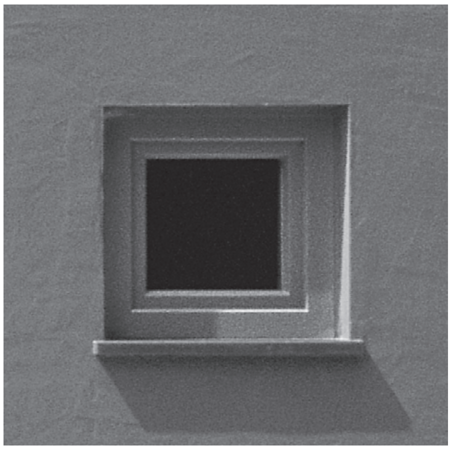






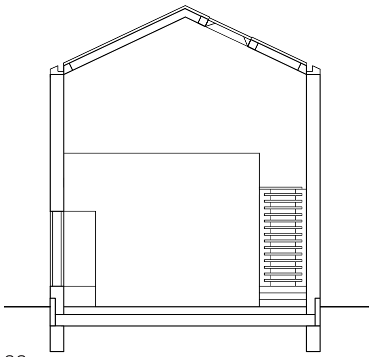
Ground floor plan • Section
scale 1:250
Section • Verge detail
scale 1:20

1 Roof construction:
natural-colour concrete roof tiles
battens and counter battens
roofing felt, open to diffusion
22 + 40 mm wood fibre insulation
80 x 176 mm rafters with
100 + 60 mm thermal insulation between
vapour barrier
16 mm spruce boards
2 240 x 300 mm reinforced concrete ring beam
3 Lightweight clay toothed blocks, 8-0,8-12 DF
4 3-coat lime render
5 Heat-absorbing glass (2 panes of toughened safety glass)
6 Perforated sheet titanium-zinc
7 60 x 160 mm wall plate
8 Steel angle, 90 x 90 x 7 mm both sides of rafter
9 8 mm toughened safety glass
10 25 x 25 x 3 mm stainless steel angle
11 Wood/Aluminium window
12 Louvre blind
13 Prefabricated clay lintel
14 Drainage channel
15 24 mm veneer plywood
16 Titanium-zinc verge flashing
17 Clay channel

Studio house in Eichstätt

Diezinger & Kramer, Eichstätt

On the edge of the old quarter of the town, a compact, rendered studio house has been erected to replace a ruined artisan's house dating from the 16th century while retaining the contours of the old building. With its distinct, modern stance, the new house is not intimidated by the confines of its surroundings and introduces a striking urban highlight. The diagonal entrance elevation, like the old building, and the freely arranged openings animate the envelope with its rigid contours. The white, brightly lit interior contrasts with the rendered external walls with their coat of dark grey paint. This two-storey house has a total of about 75 m² of floor space. The ground floor has a small display area and a larger room for receptions and similar events (but also suitable as guest accommodation). Upstairs is the sculptor's studio. The bathroom, in red-painted wood, is a stark contrast to the white of the rest of the interior surfaces. The two levels are linked by the small display area next to the entrance, extending right up to the underside of the roof. Passers-by can see into this area through the "display window" which is finished flush with the render and continues around the corner of the building. Despite its small size, the display area forms a link between interior and exterior, and acts as a focal point for the internal layout. All the fixed lights are positioned flush with the render. There are no frames around the panes of glass; the glass is held in place by clips between the panes. The top-hung Velux-type roof windows open outwards.
🕮 DETAIL 7/8 2002



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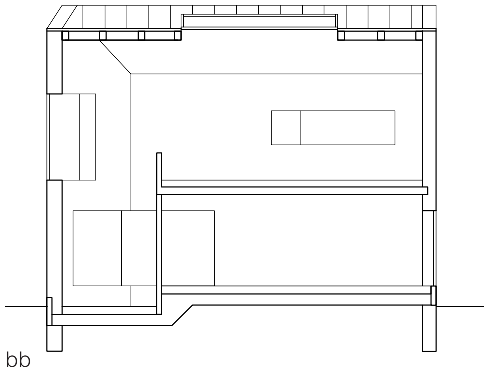

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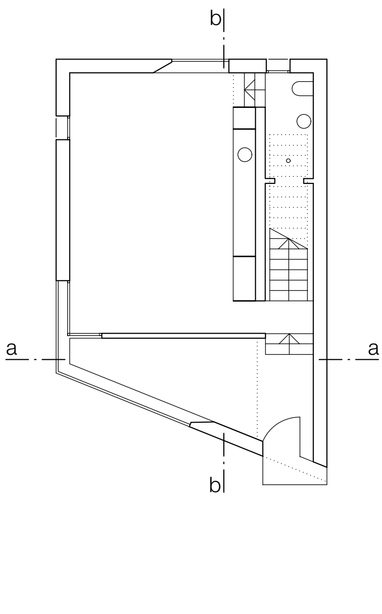
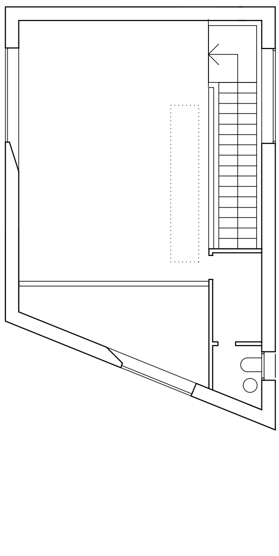
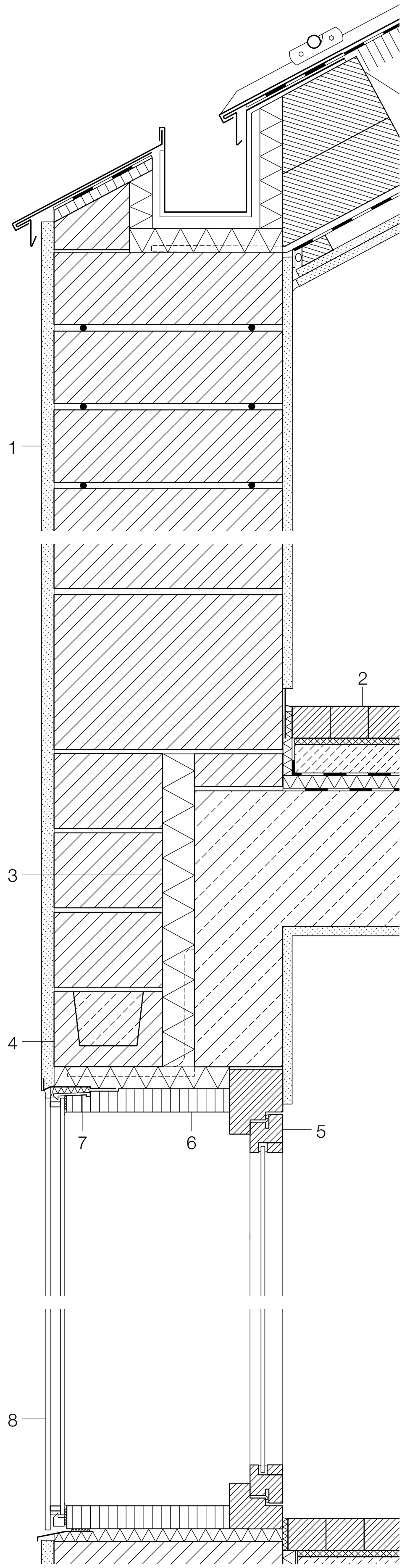




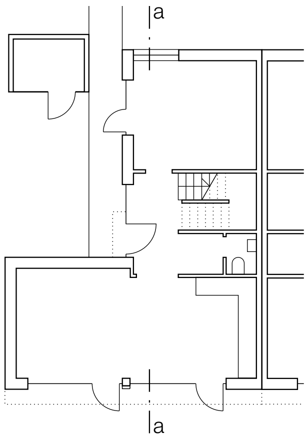
Sections • Plans
scale 1:200
Section
scale 1:20

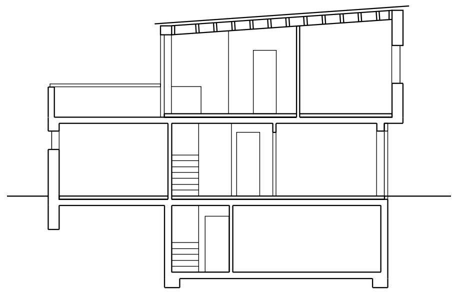


1 Wall construction:
25 mm painted mineral render
365 mm vertically perforated clay masonry
galvanised reinforcement to top 3 courses
2× Ø 8 mm bars per bed joint
15 mm lime-gypsum plaster
2 Floor construction:
60 mm end-grain wood-block flooring
10 mm hot-rolled asphalt
45 mm cement screed on PE sheeting
20 mm impact sound insulation on
PE sheeting
220 mm reinforced concrete floor slab
3 50 mm mineral fibre thermal insulation to side of 140 mm reinforced concrete beam
4 Clay channel lintel on galvanised steel angles, 200 x 200 x 16 mm
5 Wooden window with single glazing
6 36 mm white-faced plywood
7 Glazing clip between panes
8 Double glazing: 6 mm float glass + 16 mm cavity + 8 mm toughened safety glass, edge seal enamelled for UV protection

Housing development in Neu-Ulm

G. A. S.-Sahner, Stuttgart
Georg Sahner





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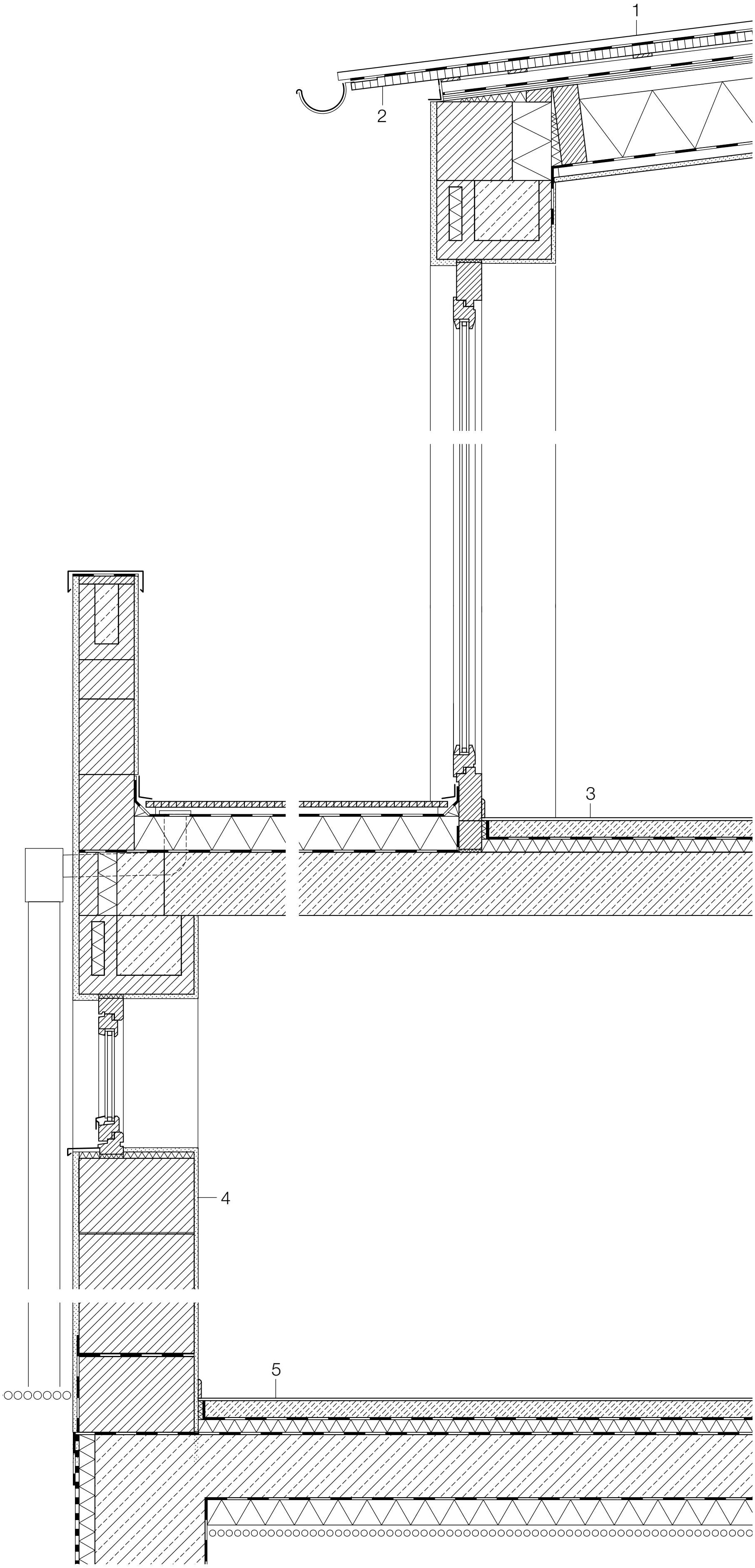
Not far from the town of Neu-Ulm, adjoining an area of farmland, there is a small residential district with a core of 20 system houses. With their associated storage sheds, the small entrance yards to these L-plan houses form an important private area. At first sight it is not obvious that all the houses here have an identical ground floor layout and belong to the same system. The picture is too diverse – due to the different roof shapes but, principally, the various grouping options. The basic idea is to build houses with a modular structure. Starting with a minimum unit size, which encompasses two rooms, the stairs and the central utilities block with kitchen, bathroom and WC, the houses can be extended by adding individual rooms. The largest variation has seven rooms spread over three floors.
The sizes of the rooms and the layouts are similar so that highly diverse occupancies are possible. Further variations are possible by including basements and attaching different roof modules.
The concept also allows for the use of the most diverse building materials in order to suit the local suppliers and availability of materials. The group of houses in Neu-Ulm was built using clay masonry.
🕮 DETAIL 4/2001

Ground floor • Section
scale 1:250
Section
scale 1:20



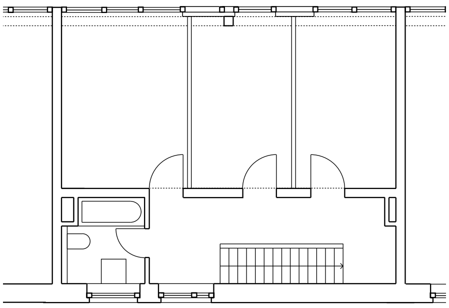
1 Roof construction:
18 x 76 mm corrugated aluminium sheeting
50 x 40 mm battens and counter battens
roofing felt
24 mm rough-sawn spruce boards
80 x 220 mm spruce rafters
200 mm mineral fibre insulation between rafters
vapour barrier
48 x 28 mm spruce battens
12.5 m plasterboard
2 3-ply core plywood, 25 mm spruce
3 Upper floor construction:
carpet or PVC floor covering
50 mm screed on polyethylene separating layer
50 mm thermal and impact sound insulation
200 mm precast concrete flooring units
4 365 mm gauged clay masonry units (λ_R = 0.11 W/mK)
5 Ground floor construction without basement:
carpet or PVC floor covering
50 mm screed on polyethylene separating layer
50 mm thermal and impact sound insulation
waterproofing
200 mm in situ concrete ground slab
polyethylene separating layer
80 mm perimeter insulation

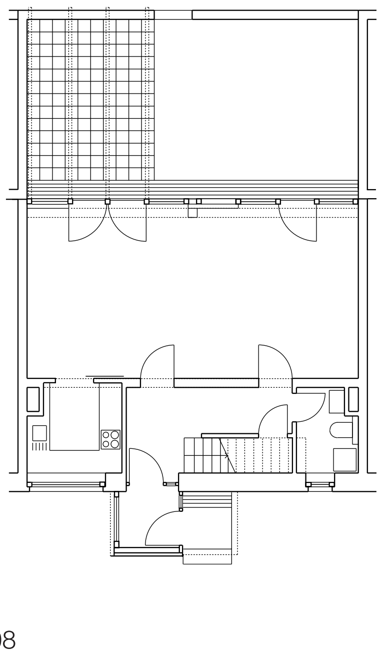
Housing complex in Waldkraiburg

-

Andreas Meck, Munich

This complex is the first phase of what is intended to be a larger development. Situated alongside a busy road, it is designed to act as a noise barrier for the plots further from the road. Access is via two staircases and there are 11 apartments plus a café. The eight maisonettes are arranged in two groups of four on two levels, meaning that the entrances are at ground floor level and second floor level. On the road side the ancillary rooms serve as a buffer for the living accommodation and bedrooms, which face away from the road. Every apartment has its own garden or rooftop terrace.
The arrangement of the access to the maisonette entrances at ground floor level nearest to the road helps to preserve privacy: a paved pathway between grassed areas leads to the two steps up to a covered landing in front of the entrance door. From here we pass through a lobby, which projects from the main line of the facade, into the hallway which leads to the various rooms. Access to the upper floor is via a single flight of stairs.
The entrances to the upper maisonettes are situated along the covered walkway, with only a narrow opening on the side facing the road. This opening allows the afternoon sun to shine through on to the larch wood benches next to the doors. These extend the private sphere and encourage social contact between the tenants.
🕮 DETAIL 4/1997

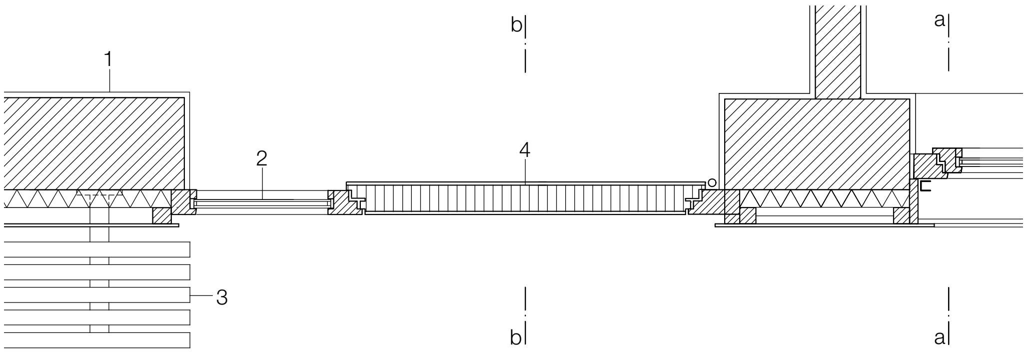




Ground floor • 1st floor
scale 1:200

Horizontal section • Vertical section
scale 1:20

1 Wall construction:
15 mm plaster
240 mm vertically perforated clay masonry
40 mm mineral wool thermal insulation between counter battens
50 mm battens/ventilation cavity
8 mm fibre cement sheets
2 Double glazing in wooden frames, outer pane of wired glass
3 Bench of 40 x 40 mm larch wood strips on ⊤ 50 steel section brackets welded to end plates
4 Wooden double-skin door, painted
5 Rooftop terrace/covered walkway construction
300 x 300 x 50 mm paving flags in 50 mm chippings
waterproofing on separating layer
160 (80) mm thermal insulation
vapour barrier
reinforced concrete slab
6 Precast concrete coping
7 Rendered vertically perforated clay masonry, 240 mm
8 Roller shutter box
9 Linoleum floor covering on floating screed



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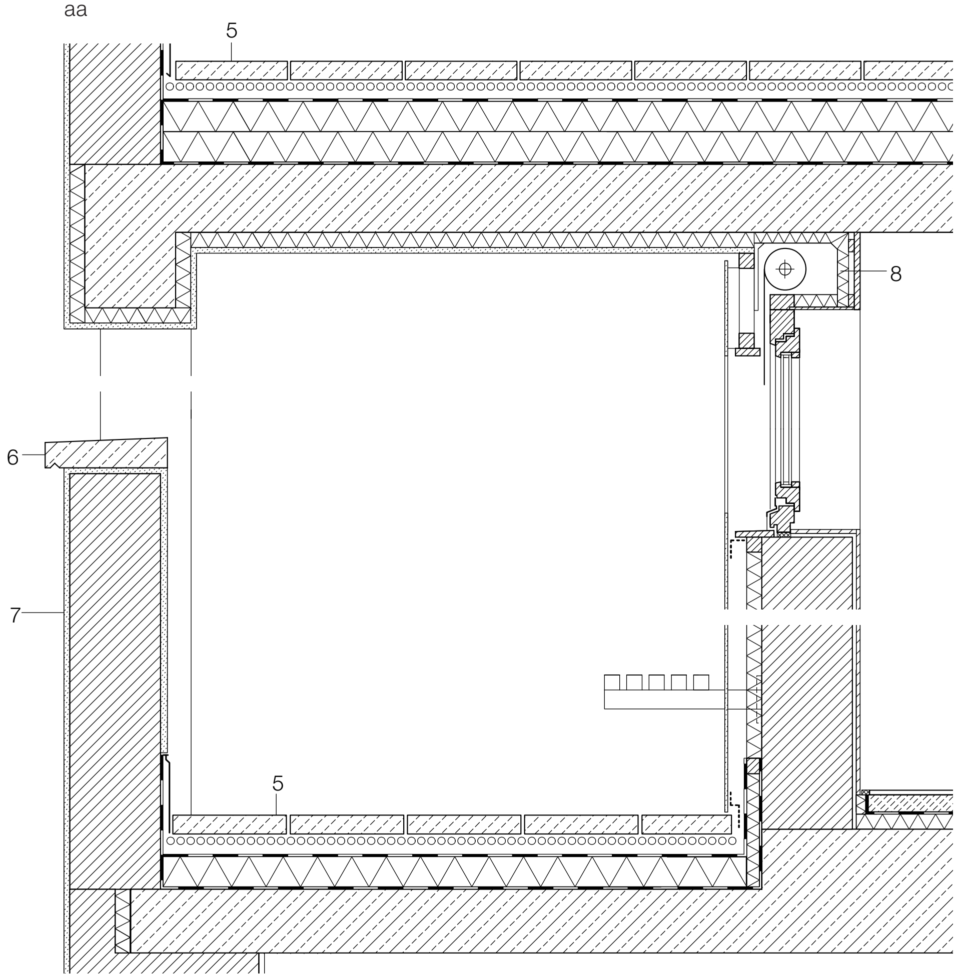

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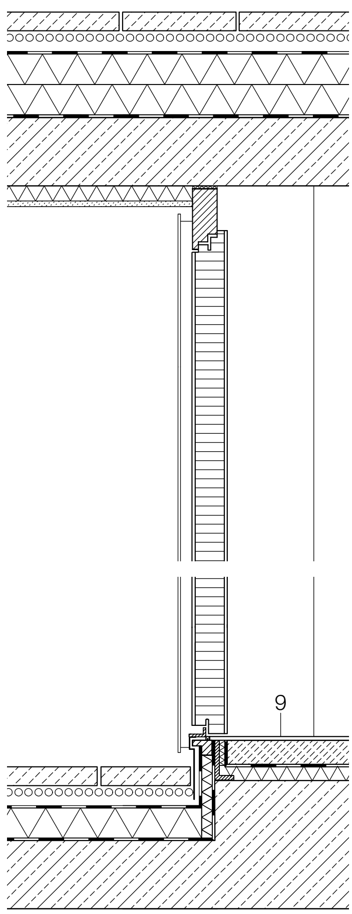
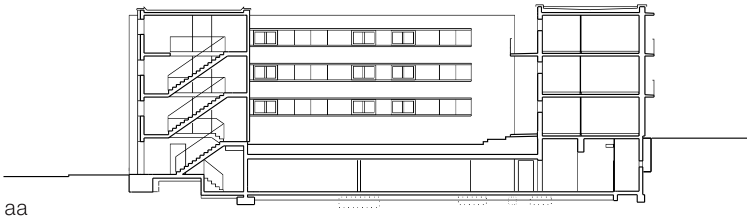


Housing complex in Ludwigsburg

Hartwig N. Schneider
with Gabriele Mayer, Stuttgart

These 60 publicly assisted rented apartments for different occupancies – singles, single-parent families, couples and families – were erected in a quiet urban location between the city centre and the suburbs, among low-density developments from the 1950s. Clearly arranged around three semi-private courtyards, this development complements the open design of the surroundings while providing a high density (plot ratio 1.2) through a differentiated concept of accommodation and open spaces. All the apartments, with one, two and three rooms (plus bathroom and kitchen), sometimes on two floors, are well lit from two sides. The living rooms lead on to loggias with sliding windows in the rendered facades. Sliding glass shutters with an enamelled inside face provide privacy for the bedrooms. The tree-lined courtyards face the road and are accessed from there via open staircases; covered passageways link them to the gardens on the south side. Located beneath the courtyards are two naturally ventilated underground parking areas.
The envelope was built in lightweight clay masonry and finished with pigmented mineral render, the surface of which changes with the weather. To contrast with this some parts of the facade make use of untreated timber cladding. On the south elevation sliding wooden shutters and narrow balconies of coloured precast concrete elements define the appearance. Wooden windows with heat-absorbing glass were installed but in some more exposed areas wood/aluminium windows were employed. 🕮 DETAIL 1/1999



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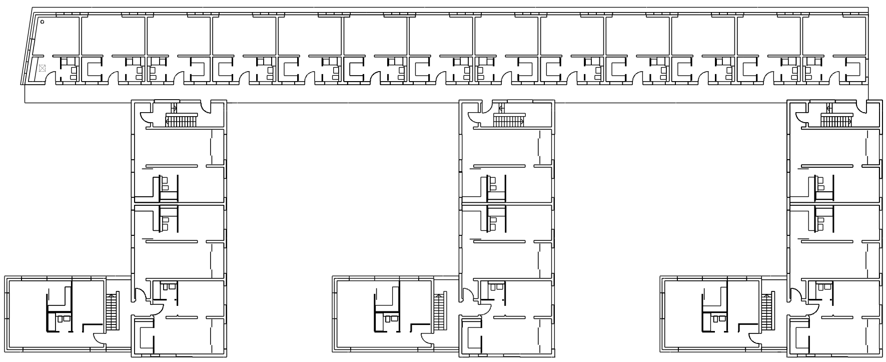
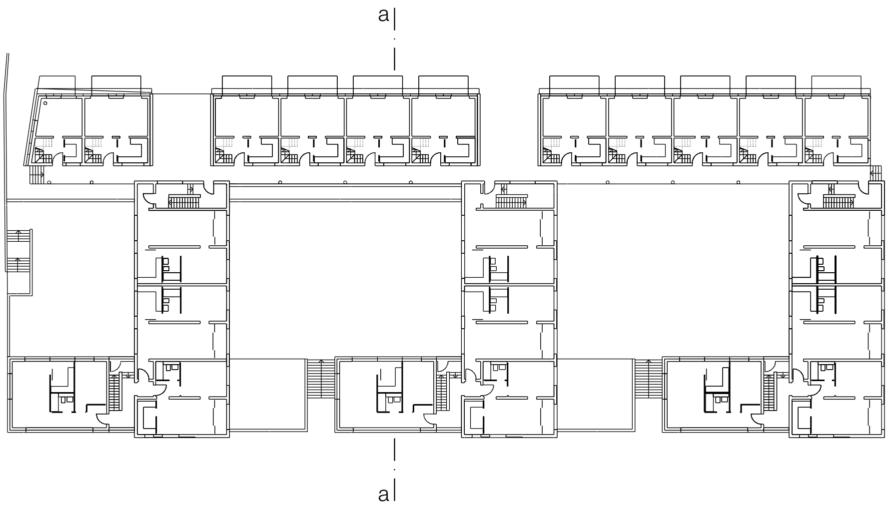
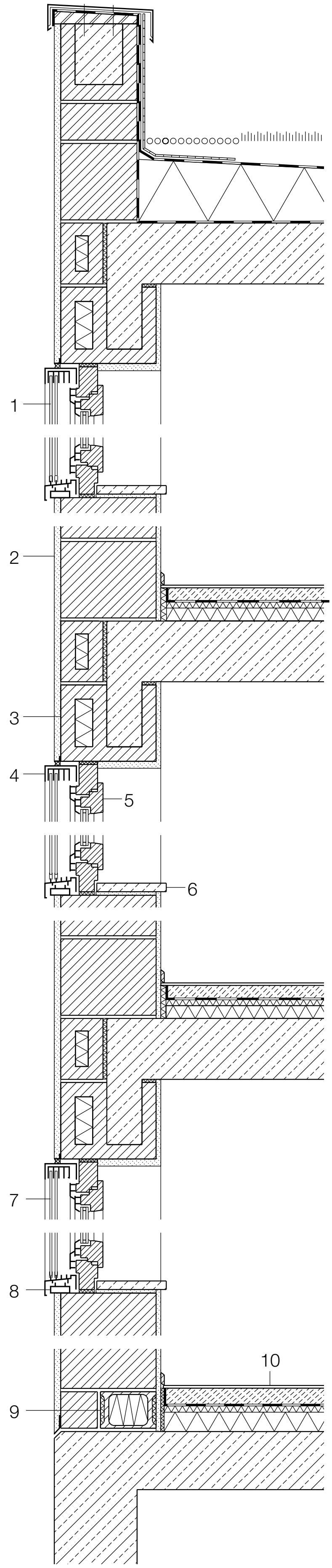
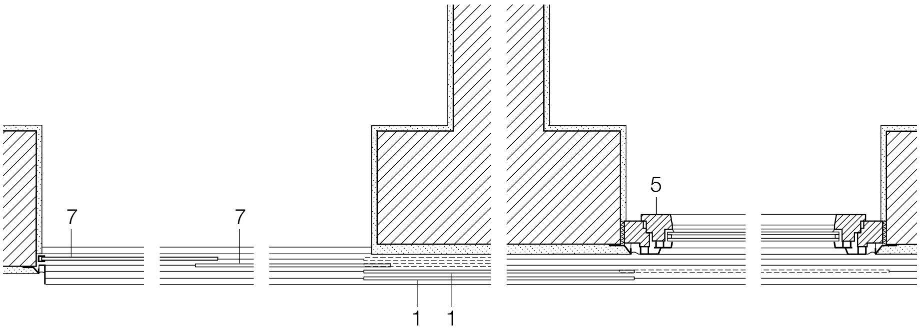






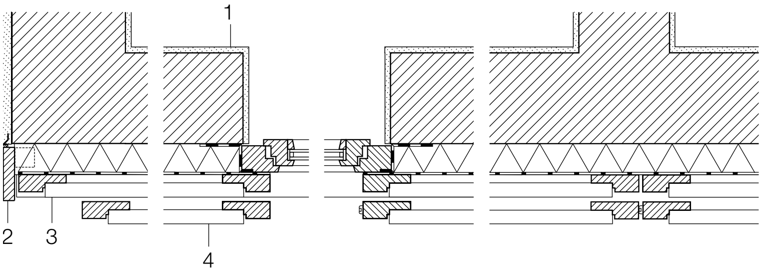


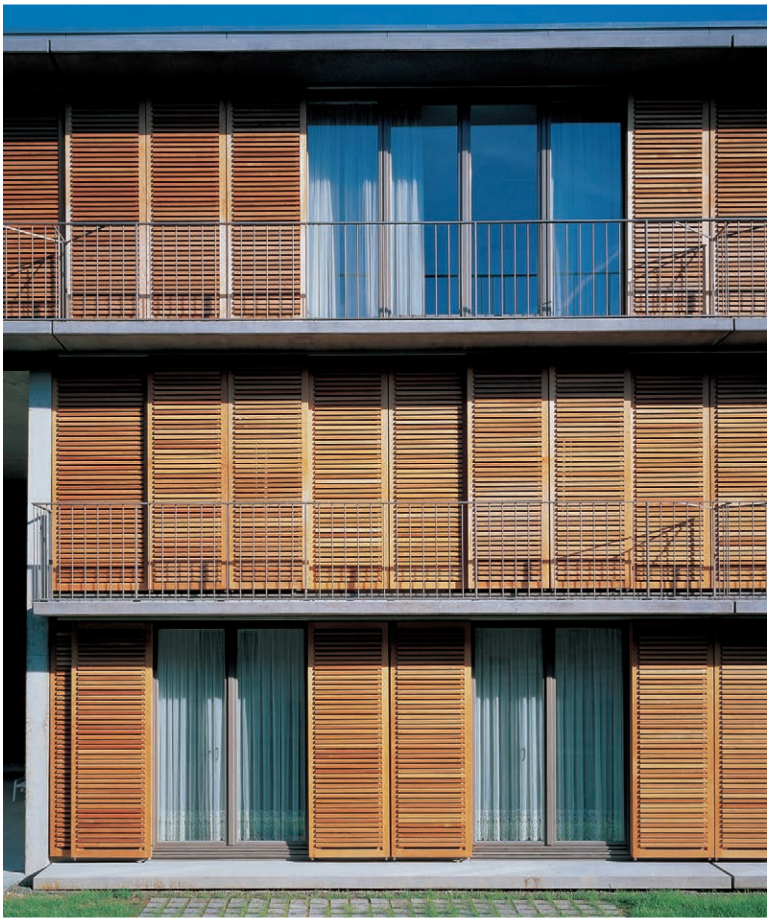
Section • Plans
scale 1:500
Section through west elevation
Horizontal section through sliding glazing and render
scale 1:20

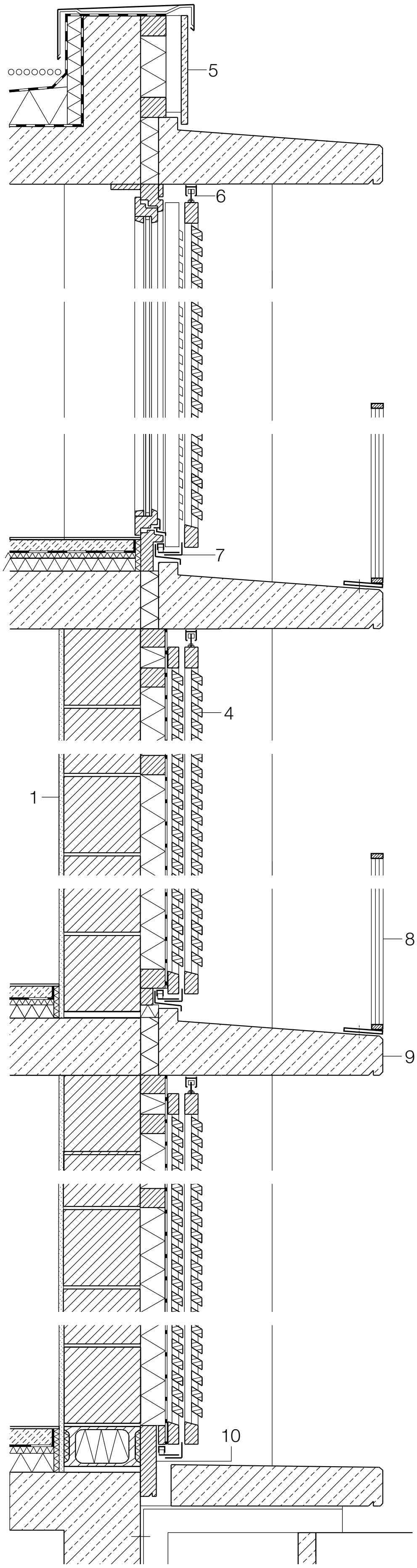
1 8 mm toughened safety glass, inside face enamelled
2 Wall construction:
 20 mm mineral render
 300 mm HLz lightweight clay masonry
 15 mm plaster
3 300 mm lightweight clay channel
4 100 x 50 x 5 mm aluminium channel
5 Wood/Aluminium window
6 Reconstituted stone window board
7 8 mm toughened safety glass
8 60 x 20 x 3 mm steel hollow section, galvanised
9 Loadbearing thermal insulation element
10 Floor construction:
 5 mm floor covering
 0.2 mm polyethylene separating layer
 20 mm impact sound insulation
 60 mm thermal insulation
 180 mm reinforced concrete floor slab

1 Wall construction:
15 mm plaster
240 mm HLz clay masonry
80 mm mineral wool
protective covering (non-woven fabric)
58 mm prefabricated cedar wood cladding
2 140 x 30 mm timber closing piece
3 Fixed cedar wood cladding
4 Cedar wood sliding shutter
5 Parapet cladding, 14 mm wood-cement fibreboard
6 Upper track for sliding shutters
7 Lower track
8 Balustrade of galvanised, colour-coated steel sections
9 Precast concrete element, coloured
10 220 x 48 mm timber closing piece

Horizontal section • Vertical section
scale 1:20







Appendix

The brick and block formats used in this book, their designations and the statutory instruments mentioned correspond to German standards.

Standards

DIN 105: Clay bricks

DIN 1045: Structural use of concrete

DIN 1053: Masonry

DIN 4095: Planning, design and installation of drainage systems protecting structures against water in the ground

DIN 4108: Thermal insulation and energy economy in buildings

DIN 4109: Sound insulation in buildings

DIN 4226: Aggregates for concrete

DIN 18195: Waterproofing of buildings and structures

DIN 18530: Solid structural decks for roofs

DIN 18550: Plaster

References

Masonry Construction Manual
Günter Pfeifer, Rolf Ramcke, Joachim Achtziger, Konrad Zilch
2001

Der Mauerziegel
Franz Hart, Ernst Bogenberger
1964

Baukonstruktion für Architekten
Franz Hart
1959

Die Kunst der Wölbung
Franz Hart
1965

Rissschäden an Mauerwerk
Werner Pfefferkorn
1994

Schadenfreies Bauen mit Mauerwerk
Peter Schubert
2002

Information supplied by the clay industry:
Ziegellexikon
1999
Aussenputz auf Ziegelmauerwerk
2002

Trade associations

Bayerischer Ziegelindustrie-Verband e.V.
Bavariaring 35
D-80336 München
Tel: +49 (0) 89 746616-0
Fax: +49 (0) 89 746616-30
bzv@ziegel.com
www.ziegel.com

Fachverband Ziegelindustrie Südwest e.V.
Friedrich-Ebert-Str. 11-13
Industriehaus
D-67433 Neustadt a. d. Weinstrasse
Tel: +49 (0) 6321 852-0
Fax: +49 (0) 6321 852-290
vse@verband-steine-erden.de
www.verband-steine-erden.de

Fachverband Ziegelindustrie Nord e.V.
Bahnhofsplatz 2a
D-26122 Oldenburg
Tel: +49 (0) 441 210260
Fax: +49 (0) 441 2102620
fachverband@ziegel-industrie.de
www.ziegel-industrie.de

Fachverband Ziegelindustrie Nordwest
Am Zehnthof 197–203
D-45307 Essen
Tel: +49 (0) 201 5921306
Fax: +49 (0) 201 5921359
info.zz@t-online.de
www.ziegel-zentrum.de

Bundesverband der Deutschen Ziegelindustrie e.V.
Schaumburg-Lippe-Straße 4
D-53113 Bonn
Tel: +49 (0) 228 91493-0
Fax: +49 (0) 228 91493-28
info@ziegel.de
www.ziegel.de

Massiv mein Haus e.V.
Falkensteinstr. 9
D-86316 Friedberg
Tel: +49 (0) 821 7849773
Fax: +49 (0) 821 784447
info@massiv-mein-haus.de
www.massiv-mein-haus.de

Wienerberger Werk Eisenberg
Jenaer Straße 56
07607 Eisenberg/Thüringen
Tel: +49 (0) 36691 71-100
Fax: +49 (0) 36691 71-115
info@wzi.de

Wienerberger Werk Zwickau
Bürgerschachtstraße 6a
08056 Zwickau
Tel: +49 (0) 375 27535-0
Fax: +49 (0) 375 27535-99
info@wzi.de

Wienerberger Werk Hainichen
Frankenberger Straße 60
09661 Hainichen
Tel: +49 (0) 37207 45-0
Fax: +49 (0) 37207 45-29
info@wzi.de

Wienerberger Lager Brück
Paul-Ruoff-Straße 2
14811 Brück
Tel: +49 (0) 33844 610
Fax: +49 (0) 33844 61125
info@wzi.de

Wienerberger Werk
Bad Freienwalde
Eberswalder Straße 107
16259 Bad Freienwalde
Tel: +49 (0) 3344 417-0
Fax: +49 (0) 3344 417-119
info@wzi.de

Wienerberger Werk Gransee
Strelitzer Straße
16775 Gransee
Tel: +49 (0) 3306 7983-0
Fax: +49 (0) 3306 7983-83
info@wzi.de

Wienerberger Werk Jeddeloh
Jeddeloher Damm 26
26188 Edewecht
OT Jeddeloh 1
Tel: +49 (0) 4405 7020
Fax: +49 (0) 4405 8496
info@wzi.de

Wienerberger Werk Sittensen
27419 Sittensen OT Tiste
Tel: +49 (0) 4282 2041
Fax: +49 (0) 4282 2044
info@wzi.de

Wienerberger Ziegelindustrie GmbH
Oldenburger Allee 26
30659 Hannover-Lahe
Tel: +49 (0) 511 61070-0
Fax: +49 (0) 511 614403
info@wzi.de

Ton- und Ziegelwerke
Werner Flörke KG
Niedermehner Str. 36
32351 Stemwede
Tel: +49 (0) 5773 202
Fax: +49 (0) 5773 317

Otto Bergmann GmbH
Im Roten Lith 3 (Werk 1)
32689 Kalletal-Hohenhausen
Tel: +49 (0) 5264 6482-0
Fax: +49 (0) 5264 6482-64
Info@Bergmann-Ziegel.de

Otto Bergmann GmbH
Heinrich-Spier-Str. 11 (Werk 2)
32839 Steinheim-Bergheim
Tel: +49 (0) 5233 9558-0
Fax: +49 (0) 5233 9558-28

August Lücking GmbH & Co. KG
Postfach 2409
33050 Paderborn
Tel: +49 (0) 5251 1340-0
Fax: +49 (0) 5251 1340-20
MeckBo@aol.com

Pasel & Lohmann GmbH
Salzkottener Str. 35/36
33178 Borchen-Alfen
Tel: +49 (0) 5258 6001
Fax: +49 (0) 5258 6588
pasel-lohmann.alfen@t-online.de

Wienerberger Werk Rietberg
33397 Rietberg OT Westerwiehe
Tel: +49 (0) 5244 9039-0
Fax: +49 (0) 5244 9039-17
info@wzi.de

August Lücking GmbH & Co. KG
Eggestr. 2
34414 Warburg-Bonenburg
Tel: +49 (0) 5642 6007-0
Fax: +49 (0) 5642 6007-22

Wienerberger Lager Volkmarsen
Steinweg 65
34471 Volkmarsen
Tel: +49 (0) 5693 9896-0
Fax: +49 (0) 5693 6350
info@wzi.de

Heinrich Abhau GmbH
Lispenhäuser Straße 1
36199 Rotenburg a. d. Fulda
Tel: +49 (0) 6623 9248-0
Fax: +49 (0) 6623 9248-21

Julius Zange GmbH & Co.KG
Schlitzer Straße 40
36272 Niederaula
Tel: +49 (0) 6625 9151-0
Fax: +49 (0) 6625 9151-79
mail@zange-ziegel.de

Ziegelwerk Schenklengsfeld
GmbH & Co. Baukeramik KG
Ringbergstraße 10
36277 Schenklengsfeld
Tel: +49 (0) 6629 332
Fax: +49 (0) 6629 7861

Wienerberger Werk Wefensleben
Zechenhäuser Weg
39365 Wefensleben
Tel: +49 (0) 3 9400 9612-0
Fax: +49 (0) 3 9400 2081
info@wzi.de

Wienerberger Lager Lauterbach
Ziegelei 1
36367 Wartenberg/Angersbach
Tel: +49 (0) 6641 9644-0
Fax: +49 (0) 6641 9644-11
info@wzi.de

Ziegelwerk Friedland GmbH
Heimkehrerstraße 12
37133 Friedland
Tel: +49 (0) 5504 8080
Fax: +49 (0) 5504 80827
friedland-ziegel@t-online.de

Wilhelm Alten Ziegelei
Ziegelweg 1
37586 Dassel-Wellersen
Tel: +49 (0) 5562 252
Fax: +49 (0) 5562 6610
altenzieglei@t-online.de

Ziegelwerk Buch GmbH
Hansastraße 1
37671 Höxter
Tel: +49 (0) 5271 2248
Fax: +49 (0) 5271 38184
info@ziegelwerk-buch.de

Janinhoff GmbH & Co. KG
Thierstraße 130
48163 Münster
Tel: +49 (0) 251 981680
Fax: +49 (0) 251 9816830
jaco@Janinhoff.de

Wienerberger Werk Buldern
Rödder 59
48249 Dülmen-Buldern
Tel: +49 (0) 2590 9455-0
Fax: +49 (0) 2590 4185
info@wzi.de

Eifeler Ziegel- und Klinkerwerke
Peter Koos GmbH & Co. KG
54675 Utscheid- Neuhaus
Tel: +49 (0) 6522 717
Fax: +49 (0) 6575 1300

Adolf Hüning GmbH & Co. KG
Hauptstraße 1
59399 Olfen
Tel: +49 (0) 2595 9642-0
Fax: +49 (0) 2595 9642-22
webmaster@huening-ziegel.de

JUWÖ-Porotonwerke
Ernst Jungk & Sohn GmbH
Ziegelhüttenstraße 42
55597 Wöllstein
Tel: +49 (0) 6703 910-0
Fax: +49 (0) 6073 910-159
poroton@juwoe.de

Keraform Spezialziegel
Homburger Straße 97
61118 Bad Vilbel
Tel: +49 (0) 6101 5448-48
Fax: +49 (0) 6101 5448-40
info@keraform.de

Ziegelwerk
Franz Wenzel
Offenbacher Landstraße 105
63512 Hainburg
Tel: +49 (0) 6182 9506-0
Fax: +49 (0) 6182 9506-20
ziegelwerk-wenzel@t-online.de

Adolf Zeller GmbH & Co.
Poroton-Ziegelwerke KG
Märkerstr. 44
63755 Alzenau
Tel: +49 (0) 6023 97760
Fax: +49 (0) 6023 30157
info@zellerporoton.de

Ziegelwerk U. Grün
Hahner Straße 80
64354 Reinheim
Tel: +49 (0) 6162 3415
Fax: +49 (0) 6162 3316
info@klimaton.de

Trost Mauerziegel
An der B3
69254 Malsch
Tel: +49 (0) 7253 208-0
Fax: +49 (0) 7253 208-16
info@trost-online.com

Hess Ziegelwerke
Ameisenbühl 40
71332 Waiblingen
Tel: +49 (0) 7151 51034
Fax: +49 (0) 7151 18949
ziegelwerke_hess@freenet.de

Neuschwander GmbH
Neippergerstraße 41
74336 Brackenheim
Tel: +49 (0) 7135 96109-0
Fax: +49 (0) 7135 96109-3
info@neuschwandner.de

Ziegelwerk Schmid
Erligheimer Straße 45
74357 Bönnigheim
Tel: +49 (0) 7143 8744-0
Fax: +49 (0) 7143 8744-50
info@ziegelwerk-schmid.de

Wienerberger Werk Mühlacker
Ziegeleistraße 12
75417 Mühlacker
Tel: +49 (0) 7041 8706-0
Fax: +49 (0) 7041 8706-55
info@wzi.de

Ceraline GmbH
Weisweiler Straße 6
79771 Klettgau-Erzingen
Tel: +49 (0) 7742 9240-0
Fax: +49 (0) 7742 9240-40
erzinger-ziegelwerke@t-online.de

Ziegelsysteme Michael Kellerer
Ziegeleistraße 13
82282 Oberweikertshofen
Tel: +49 (0) 8145 923-0
Fax: +49 (0) 8145 5422

Ziegelwerke
Leipfinger-Bader KG
Puttenhausen (Werk 2)
Äußere Freisinger Str. 31
84048 Mainburg
Tel: +49 (0) 8751 9021
Fax: +49 (0) 8751 4571

Schlagmann Baustoffwerke
Grafentraubach 505
84082 Laberweinting
Tel: +49 (0) 8772 9686-0
Fax: +49 (0) 8772 9686-10
info@schlagmann.de

Erlus Baustoffe AG
Hauptstr. 106
84088 Neufahrn/NB
Tel: +49 (0) 8773 18-0
Fax: +49 (0) 8773 18-113

GIMA Girnghuber GmbH & Co. KG
Ludwig-Girnghuber-Str. 1
84163 Marklkofen
Tel: +49 (0) 8732 24-0
Fax: +49 (0) 8732 24-200

Schlagmann Baustoffwerke
Lanhofen 100
84367 Tann
Tel: +49 (0) 8572 17-0
Fax: +49 (0) 8572 8114
info@schlagmann.de

Schlagmann Baustoffwerke
Lengdorfer Straße 4
84424 Isen
Tel: +49 (0) 8083 5399-0
Fax: +49 (0) 8083 1563
info@schlagmann.de

Ziegelwerk Aubenham
Adam Holzner KG
Aubenham 3
84564 Oberbergkirchen
Tel: +49 (0) 8637 841
Fax: +49 (0) 8637 454

Ziegelwerke Leipfinger-Bader KG
Vatersdorf 10 (Werk 1)
84712 Buch a. Erlbach
Tel: +49 (0) 8762 733-0
Fax: +49 (0) 8762 733-110
info@leipfinger.de

Ziegelwerk Gerhard Turber
Riedenburger Str. 25
85104 Pförring
Tel: +49 (0) 8403 9294-0
Fax: +49 (0) 8403 9294-25

Ziegelwerk Ignaz Schiele
Wittenfelder Straße 15
85111 Adelschlag
Tel: +49 (0) 8424 8922-0
Fax: +49 (0) 8424 8922-22
info@schiele-unipor.de

Hörl & Hartmann
Ziegeltechnik GmbH
Pellheimer Str. 17
85221 Dachau
Tel: +49 (0) 8131 555-0
Fax: +49 (0) 8131 555-222
info@hoerl-hartmann.de

Ziegelwerk-Deckensysteme
Wöhrl GmbH
Berghaselbach 5
85395 Wolfersdorf
Tel: +49 (0) 8168 9062-0
Fax: +49 (0) 8168 9062-23
info@woehrl-ziegel.de

Ziegelwerk Anton Hanrieder OHG
Harland 19 1/2
85406 Zolling
Tel: +49 (0) 8167 950284
Fax: +49 (0) 8167 9036
Hanrieder.Harland@t-online.de

Ziegelwerk
Franz X. Hanrieder OHG
Kratzerimbach 3
85406 Zolling
Tel: +49 (0) 8167 950233
Fax: +49 (0) 8167 9317

Hörl Ziegel-Technik
Ziegeleistraße 24
86368 Gersthofen
Tel: +49 (0) 821 4789-0
Fax: +49 (0) 821 4789-299
Info@hoerl-hartmann.de

Schlagmann Baustoffwerke
Ziegeleistraße 31
86551 Aichach
Tel: +49 (0) 8251 8881-0
Fax: +49 (0) 8251 8881-10
info@schlagmann.de

Ziegelwerk Stengel GmbH
Ingolstädter Str. 101
86633 Neuburg-Ried
Tel: +49 (0) 8431 8319
Fax: +49 (0) 8431 41128

Creaton AG
Dillinger Str. 60
86637 Wertingen
Tel: +49 (0) 8272 86-0
Fax: +49 (0) 8272 86-500

Rapis-Ziegel
Markt Wald GmbH
Lechfelder Str. 20
86830 Schwabmünchen
Tel: +49 (0) 8232 4074
Fax: +49 (0) 8232 3321
Rapis@t-online.de

Ziegelwerk Klosterbeuren
Ludwig Leinsing GmbH & Co.
Ziegeleistraße 12
87727 Babenhausen
Tel: +49 (0) 8333 9222-0
Fax: +49 (0) 8333 4405
info@zwk.de

Ziegelwerk Arnach
J. Schmid GmbH & Co. KG
Ziegeleistraße 1
88410 Bad Wurzach-Arnach
Tel: +49 (0) 7564 308-0
Fax: +49 (0) 7564 308-90
zwa-info@t-online.de

Georg Rimmele KG
J.G. Scheerle KG
Pfullendorfer Straße 10–12
88512 Mengen
Tel: +49 (0) 7572 8275
Fax: +49 (0) 7572 6764

Ott Ziegel
Pfullendorf GmbH & Co. KG
Überlinger Straße 70
88630 Pfullendorf
Tel: +49 (0) 7552 9216-0
Fax: +49 (0) 7552 9216-22
unipor@gmx.de

Ziegelwerk Ott
Ziegeleistraße 20
88662 Überlingen-Deisendorf
Tel: +49 (0) 7551 62214
Fax: +49 (0) 7551 4947

THERMOPOR
Ziegel-Kontor Ulm GmbH
Olgastraße 94
89073 Ulm
Tel: +49 (0) 731 966940
Fax: +49 (0) 731 63053

Ziegelwerk Bellenberg
Wiest GmbH & Co. KG
Tiefenbacher Str. 1
89297 Bellenberg
Tel: +49 (0) 7306 9650-0
Fax: +49 (0) 7306 9650-77
service@bellenberger-ziegel.de

Ziegelwerk Gundelfingen GmbH
Äußere Haunsheimer Str. 2
89423 Gundelfingen
Tel: +49 (0) 9073 9599-0
Fax: +49 (0) 9073 9599-60

Georg Rimmele KG
Riedlinger Straße 49
89584 Ehingen
Tel: +49 (0) 7391 5008-0
Fax: +49 (0) 7391 5008-33
info@rimmele.de

Walther Dachziegel GmbH
Lohmühle 3–5
90579 Langenzenn
Tel: +49 (0) 9101 708-0
Fax: +49 (0) 9101 708-38

Wienerberger Werk Spardorf
Buckenhofer Straße 1
91080 Spardorf
Tel: +49 (0) 9131 509-0
Fax: +49 (0) 9131 509-50
info@wzi.de

Dehn-Ziegel GmbH & Co. KG
Am Hutsberg 1
91413 Neustadt a. d. Aisch
Tel: +49 (0) 9161 8998-0
Fax: +49 (0) 9161 8998-22
dehn-ziegel-NEA@t-online.de

Ansbacher Ziegelei
Naglerstraße 40
91522 Ansbach
Tel: +49 (0) 981 96955-0
Fax: +49 (0) 981 96955-15
Service@ansbacher-ziegel.de

Schlagmann Baustoffwerke
Ziegeleistraße 5
92444 Rötz
Tel: +49 (0) 9976 20011-0
Fax: +49 (0) 9976 20011-504
info@schlagmann.de

Ziegelwerk Sittling
Köglmaier OHG
Sittling 23 1/2
93333 Neustadt a. d. Donau
Tel: +49 (0) 9445 2834
Fax: +49 (0) 9445 2598

Jungmeier GmbH & Co. KG
Landshuter Str. 130
94315 Straubing
Tel: +49 (0) 9421 5007-0
Fax: +49 (0) 9421 5007-400

Dehn-Ziegel GmbH & Co. KG
Culmer Straße 14
95490 Mistelgau
Tel: +49 (0) 9279 998-0
Fax: +49 (0) 9279 998-66
dehn-ziegel-MGAU@t-online.de

Ziegelwerk Waldsassen AG
HART-KERAMIK
Mitterteicherstraße 6
95652 Waldsassen
Tel: +49 (0) 9632 848-0
Fax: +49 (0) 9632 848-48
info@hart-keramik.de

Ziegelwerk Waldsassen AG
HART-KERAMIK
Am Bergwerk 12
95706 Schirnding
Tel: +49 (0) 9233 7714-0
Fax: +49 (0) 9233 7714-14

Ziegelwerk Englert GmbH
Krautheimer Straße 8
97509 Zeilitzheim
Tel: +49 (0) 9381 2433
Fax: +49 (0) 9381 4740

Wienerberger Werk
Bad Neustadt
Besengaustraße 19
97616 Bad Neustadt
Tel: +49 (0) 9771 61340
Fax: +49 (0) 9771 2952
info@wzi.de

ZU Bayerische Ziegelunion
Zur Ziegelei 16
97753 Karlsstadt-Wiesenfeld
Tel: +49 (0) 9359 9710-0
Fax: +49 (0) 9359 971018
info@bayerische-ziegelunion.de

Wienerberger Werk
Erfurt-Gispersleben
Zur Alten Ziegelei
99091 Erfurt-Gispersleben
Tel: +49 (0) 361 74018-0
Fax: +49 (0) 361 74018-99
info@wzi.de

Wienerberger Werk Bollstedt
Am Silberrasenweg 1
99998 Bollstedt
Tel: +49 (0) 3601 8816-0
Fax: +49 (0) 3601 8816-14
info@wzi.de

Subject index

Index of persons

page 97
Housing complex in Munich
Architect:
Christof Wallner, Munich
Associates:
Bettina Görgner, Corinna Müller
Structural engineer:
Joachim Eiermann, Munich

page 98
Semi-detached house in Munich
Client:
Brigitte Püls, Munich
Architects:
Andreas Meck, Munich
Brigitte Püls, Munich
Detailed design:
Stephan Köppel, Munich
Structural engineers:
Hans-Ludwig Hausdorfer,
Markt Schwaben

page 100
Houses in Munich
Clients:
Norbert und Klaus Weigl
Architects:
Thomas Hammer and
Doris Schmid-Hammer, Munich
Associates:
Timo Jeskanen,
Manfred Weihermann
Structural engineers:
Behringer und Müller, Munich

page 102
House in Hallertau
Architect:
Walter Stolz, Rosenheim
Associates:
Georg Trengler
Elisabeth Mehrl (colour scheme)
Structural engineers:
Bauer Ingenieure, Landshut

page 104
Studio house in Eichstätt
Client:
Mr and Mrs Lang, Eichstätt
Architects:
Diezinger & Kramer, Eichstätt

page 106
Housing development in Neu-Ulm
Client:
NUWOG/Helmut Mildner,
Neu-Ulm
Architect:
G.A.S.-Sahner, Stuttgart
Georg Sahner
Structural engineers:
Ing. Büro Müller, Kirchberg/Iller

page 108
Housing complex in Waldkraiburg
Architect:
Andreas Meck, Munich
Associates:
Egbert Ackermann,
Christoph Engler
Structural engineer:
Franz Mitter-Mang, Unterreit

page 110
Housing complex in Ludwigsburg
Client:
Wohnungsbau Ludwigsburg GmbH
Architect:
Hartwig N. Schneider with
Gabriele Mayer, Stuttgart
Project architects:
Andreas Gabriel,
Ingo Pelchen
Associates:
Franz Lutz

Index of persons
The names are listed after specifying the respective architect.

Picture credits

pages 7, 108
Franz Wimmer, Munich
pages 95, 97, 98, 99
Michael Heinrich, Munich
pages 100, 101
Henning Koepke, Munich
page 102
Job Roman, Munich
page 103
Gerhard Schlötzer, Bamberg
page 104
Andreas Gabriel, Munich
page 105
Stefan Müller-Naumann, Munich
pages 106, 107
Peter Bonfig, Munich
page 109
Edwin Kunz, Berg
pages 110, 111
Christian Kandzia, Esslingen
page 112
Roland Halbe/Contur, Cologne

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