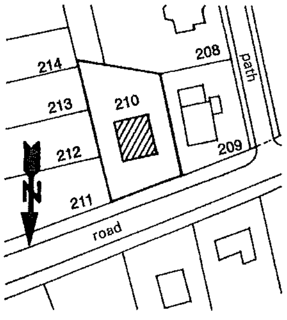
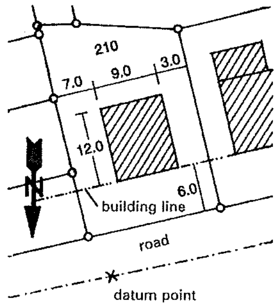
FOUNDATIONS

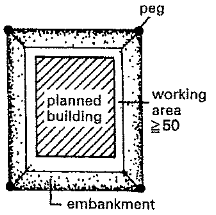
Building Excavations



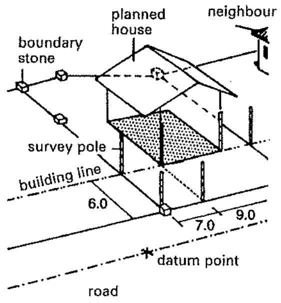
❶ Official site plan



❷ Site plan with building's dimensions



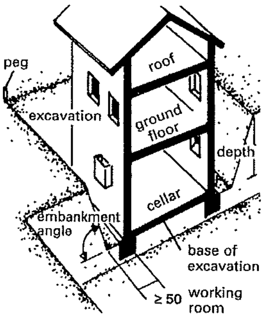
❸ Building (basement) excavation



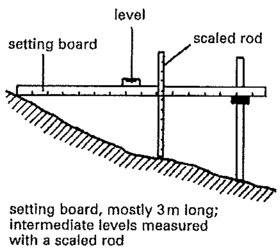
❹ Planned house set out on the lot

Setting out
Before the start of groundworks, the planned building is set out on the plot by a publicly appointed surveyor working from the official site plan in the building permit documents. The intended excavation for the building (basement) is marked out with pegs → ❶ – ❹. To secure the points that have been set out, **profile boards** → ❽ are set up, set back from the planned top of the excavation's batter (sloped bank). After the excavation, **string lines** are stretched between the profiles to mark the corners of the building again. The intersections of the string lines are then plumbed down to mark the external corners of the building.

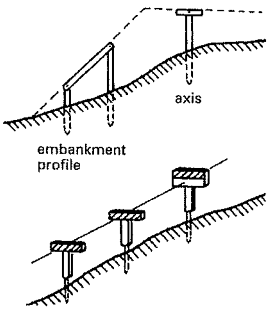
The levels also have to be set out. These are based on benchmarks in the surroundings. **Geometric surveying** measures the difference in height of a horizontally set up **level** from a benchmark with a **levelling staff** held vertically → ❾. Intermediate levels can be obtained with a **long spirit level**, normally a 3 m long light metal rail with built-in bubble, and a **measuring stick** → ❻. **Hydrostatic levelling** uses a **water level**, a flexible hose filled with water. This has glass cylinders at each end calibrated in mm, and can be used to transfer levels between points without visual contact because the water in the tube finds the same level at each end.



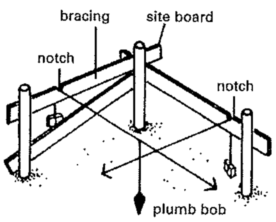
❺ House in the excavation



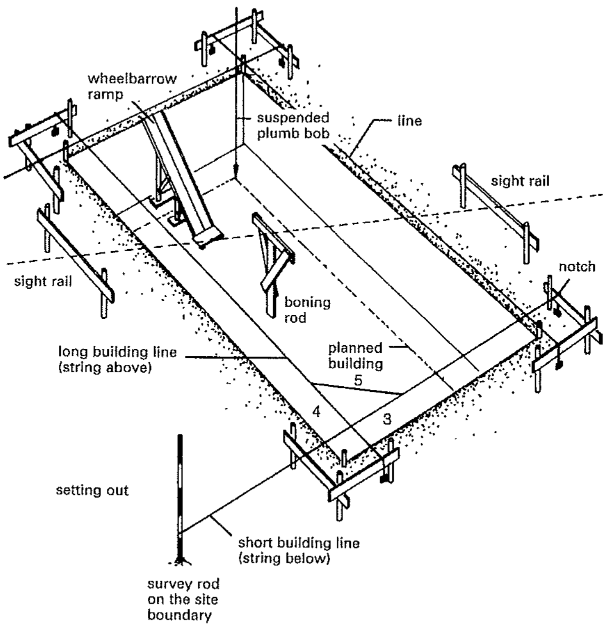
❻ Spirit level



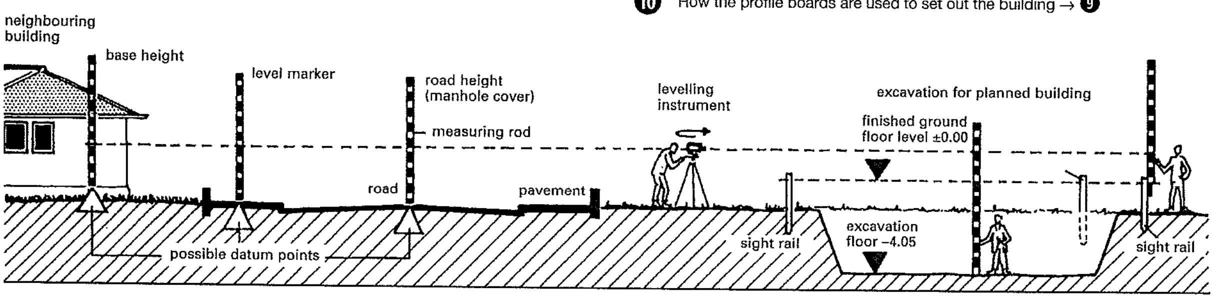
❼ Profile boards



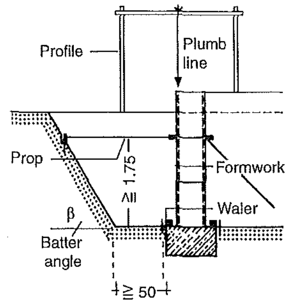
❽ Profile boards



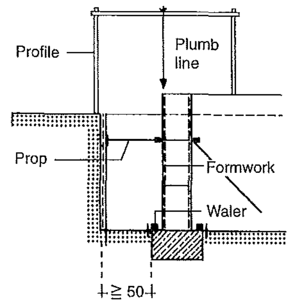
❿ How the profile boards are used to set out the building → ❾



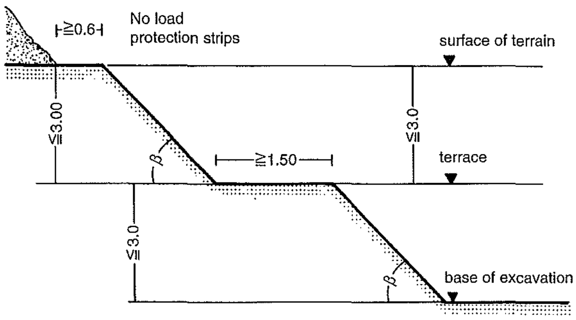
❾ Surveying the building site



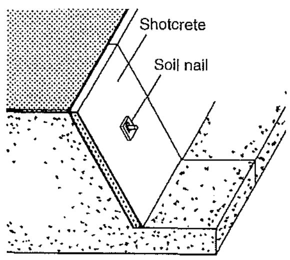
❶ Building excavation with working space and battered side



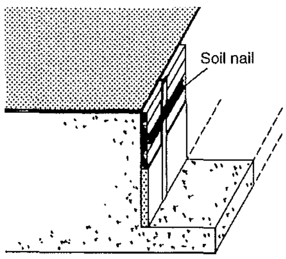
❷ Building excavation with working space and support



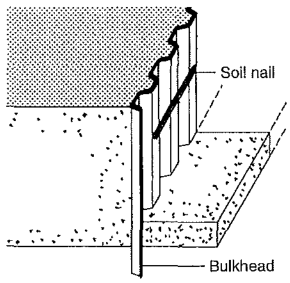
❸ Battered side to building excavation with banks to catch slipping material



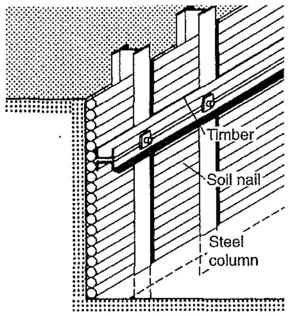
❹ Shotcrete applied to slope



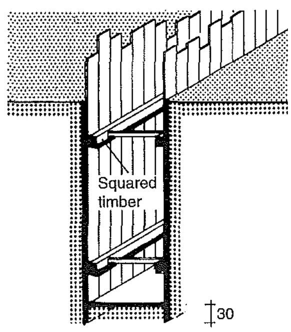
❺ Steel beam support with concrete filling



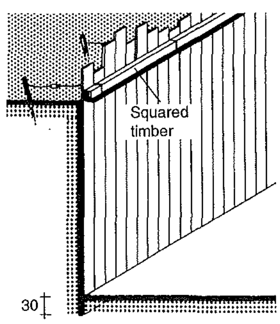
❻ Sheet pile wall with earth anchors



❼ Wall support with round timbers



❽ Vertical support with trench planks



❾ Wall support with thick vertical boards

Incorrect interpretation of the subsoil and groundwater conditions, and the behaviour of the planned foundations, often lead to technically and economically irreparable damage. This applies particularly to lateral displacement of the soil under foundation loading (**load-bearing failure of the ground, slope failure**), where the foundations sink into the soil or are laterally displaced, or **settlement**, through compression of the subsoil under the foundations due to ground pressure and/or loads applied next to the foundations. The results can be deformation or cracking in masonry.

Soil investigation

If there is insufficient local experience about the properties, extent, bedding and thickness of the soil strata on the site, a **soil investigation** performed as early as possible by a geotechnical specialist is essential. The specialist can obtain information through **trial pits** (excavator or hand excavation), drilling **boreholes** (auger/rotary/core drilling), with extraction of samples, and **probing** (number and depth depending on the topography, structure and particular investigation). The **groundwater table** is measured with gauges in boreholes and regular measurement of variations in level.

Soil investigations should provide data for the design and construction of the building without technical or economic problems:

– **Soil samples** are tested for grading, water content, consistency, density, compressibility, shear strength and permeability. – Probing provides continuous information about strength and density for the investigated depth. – **Groundwater samples** can be investigated for aggressiveness towards concrete.– The results of the investigations are provided to the client as a **site investigation report.**

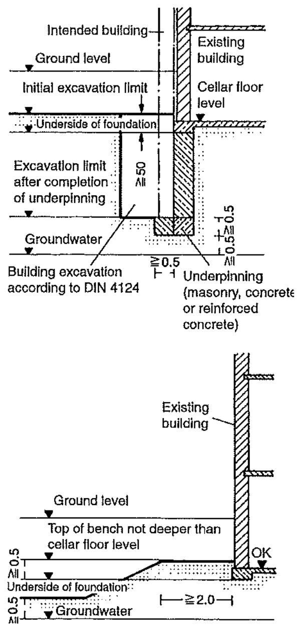
Building excavations

Basement excavations are normally battered (with sloped banks) → ❶. The following **slope angle** β can normally be assumed without verification of the structural safety by calculation:

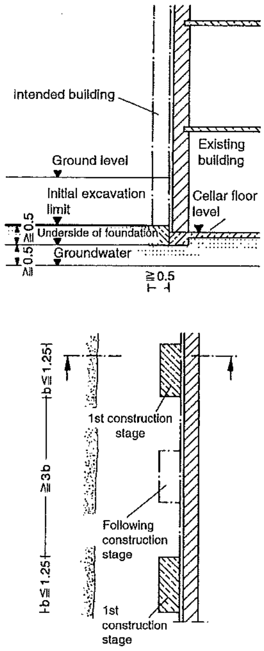
a)	non-cohesive or soft, cohesive soils	β ≦45°
b)	stiff or semi-hard, cohesive soils	β ≦60°
c)	rock	β ≦80°.

In order to provide protection against surface water, frost and drying out, it is recommended to cover batter slopes with **protective foil, shotcrete or similar** and also possibly to keep water away from the top of the batter → ❹. If the excavation is deep, it must be expected that parts of the slope will slide, even if the angle is correct. **Banks** should therefore be provided to break up the slope → ❸. If the ground will not stand up or the space is limited, then the sides must be **supported**. This can be done with thick, vertical planks tied with ground anchors or braced → ❾, steel profiles with a filling of round or squared timber → ❼ or **sheet steel piles** → ❻. Difficult cases, where the support can be integrated as a part of the later foundations, are constructed with **bored piles** or **diaphragm walls** supported with bentonite. A **working space** of ≧50 cm should be provided between the foot of the batter or support construction → ❶ - ❷.

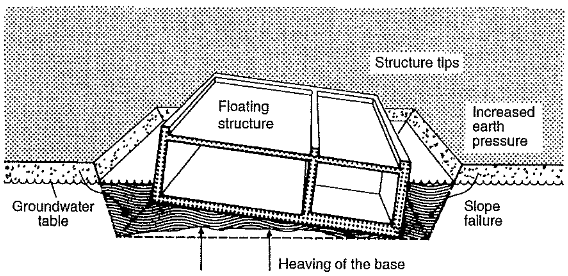
BS 6031
BS EN 14199
BS 22475
DIN 1054
DIN 4123/4



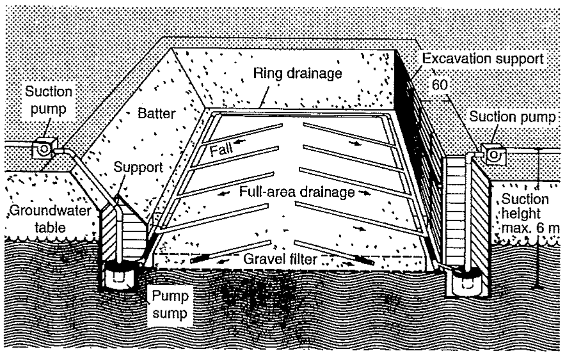
❶ Underpinning existing adjacent structures



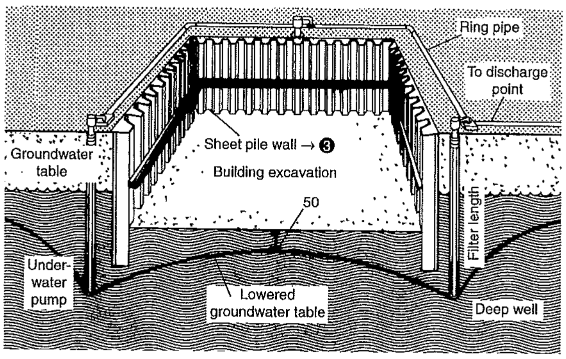
❷ Foundations



❸ Excavation below the water table – buoyancy of the structure



❹ Open dewatering



❺ Groundwater control and lowering

FOUNDATIONS

Building Excavations

Underpinning

If a new building is to be erected directly next to an existing building with the underside of its foundations at a higher level, then the existing foundations have to be underpinned to prevent damage to the existing building through settlement or ground failure.

Excavations, foundations and underpinning work next to existing buildings should therefore be thoroughly and carefully designed, prepared, planned and constructed in accordance with DIN 4123 → ❶ – ❷.

A competent site manager must be present on the site during the underpinning work.

Even work undertaken with careful planning and construction in accordance with this standard cannot rule out **slight deformation** of the existing building, according to condition and type of construction.

Fine cracking and settlement of the underpinned building by up to 5 mm is generally considered unavoidable. It is therefore recommended to perform a survey of the existing building before starting work, with the participation of all involved parties, to determine its condition and survey reference levels and possibly also deflection points.

Groundwater

If the bottom of the excavation is below the water table, then special measures will be required:

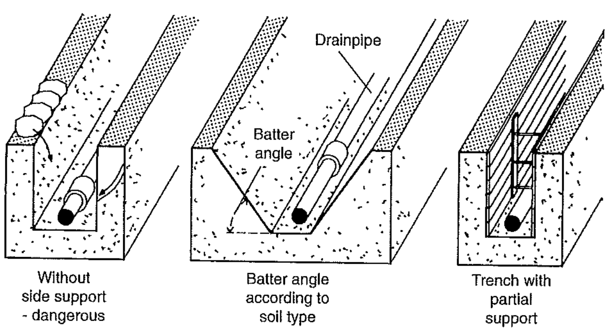
This can be **open dewatering**, with the water being continuously pumped out of sumps in the bottom, trenches and drains → ❹.

If the quantity of water is higher, then **closed dewatering** is necessary → ❺: the groundwater is lowered using underwater pumps (with a safety distance of about 50 cm) under the base of the excavation.

If the excavation is larger or deeper, however, there is a risk that this lowering of the water table could impair the soil conditions near the site (settlement of neighbouring buildings!) or the use of public surface water drains could be forbidden. In this case, the entire area of the bottom of the excavation will have to be **waterproofed.**

To achieve this, the excavation is normally supported with a continuous back-anchored sheet pile or diaphragm wall. Then the excavation is dug down to floor level 'under water' and an **underwater concrete base** designed to be safe from floating is laid (if necessary, from a pontoon). After the concrete has hardened, the water can be pumped out and any leaks grouted. Alternatively, a **soft gel base** can be constructed by grouting the subsoil with sodium silicate plus a chemical hardener additive to produce a nearly waterproof layer.

The actual structure with external walls of **watertight concrete** can be built in the basin produced in this way.



❻ Trenches for drainage

BS 8004
BS 22475
DIN 1054

Foundations can be constructed as spread or shallow foundations (**pad foundations** → ❶, **strip footing** → ❷, **ground-bearing slab or raft** → ❸) or deep foundations (**piled foundations** → ❹ → p. 70).

Spread foundations

Masonry foundations are technically feasible but seldom used today on account of the high cost.

Unreinforced concrete foundations are used for smaller widths and relatively small buildings.

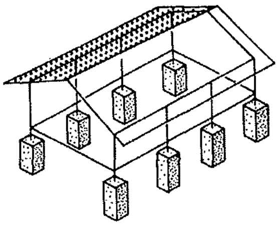
Reinforced concrete foundations are used where the ground pressure is higher or the projection outside the wall is wider → ❼ – ❽ (reinforcement to resist the tension forces → ⓬). Reinforced concrete requires less thickness, weight and excavation depth than unreinforced concrete. The detailing of foundations at expansion joints and next to existing buildings or boundaries is shown in → ❾.

Raft foundations → ❿ are used where the load-bearing capacity of the subsoil is low or where pad foundations or strip footings are insufficient to bear the load.

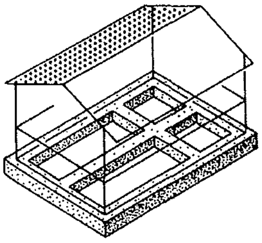
The foundation level must be at a frost-free depth, so that the subsoil under it cannot move due to freezing and thawing. According to DIN 1054, a depth of 0.80 m (for engineered structures 1.0–1.5 m) counts as frost-free.

Improvement in the load-bearing capacity of the subsoil

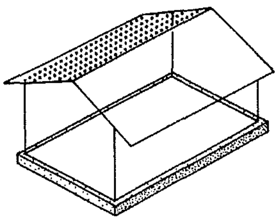
a) **Vibroflotation compaction**: uses vibration to compact a radius of 2.3–3 m; spacing of the vibration cores approx. 1.5 m. Settlement is topped up. The improvement depends on the grading of the soil and its original bedding density.
b) **Vibro stone columns**: columns are formed by vibration of aggregate of various grading without binder.
c) **Stabilisation and compaction of the soil:** Cement grouting cannot be used for soils which are cohesive or aggressive to cement. Grouting with chemicals (silica solution, potassium chloride) produces immediate and permanent petrifaction, but can be used only with soils containing quartz (gravel, loose rock).



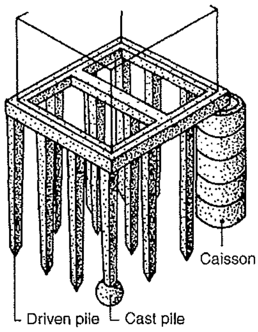
❶ Pad foundations for a lightweight building without cellar



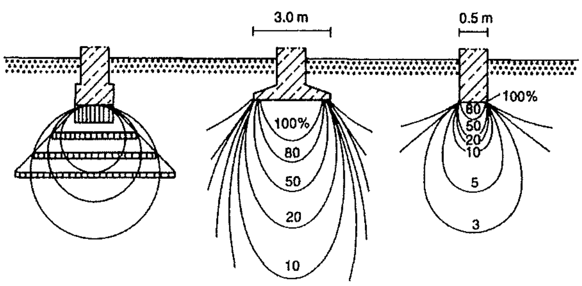
❷ Strip footings are the most commonly used



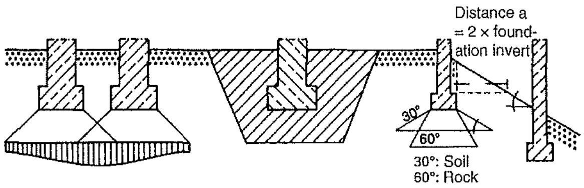
❸ Raft foundation with steel reinforcement



❹ Pile grillage and caisson deep foundations



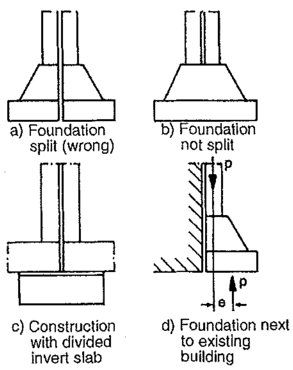
❺ Wide foundations result in greater permissible stresses than narrow foundations for the same ground pressure.



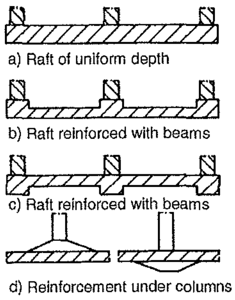
❻ The overlapping of areas loaded by adjacent foundations brings the danger of settlement or cracking, an important fact to remember for new buildings next to existing buildings.

Foundations on sandfill of 0.80 to 1.20 m thickness, compacted in layers of 15 cm and soaked, can distribute loading onto a wider area.

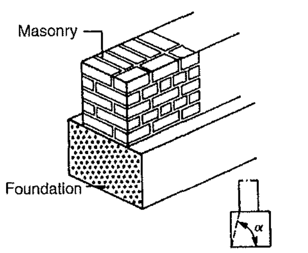
Foundations next to a slope. Pressure distribution lines – angle of slope of the subsoil.



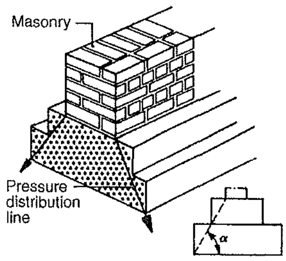
❾ Foundation details at separation and expansion joints



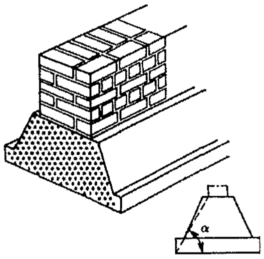
❿ Sections through raft foundations



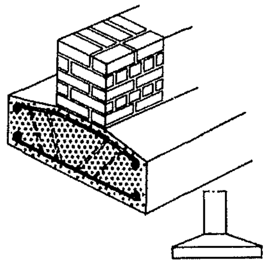
❼ Simple strip footing of lean concrete



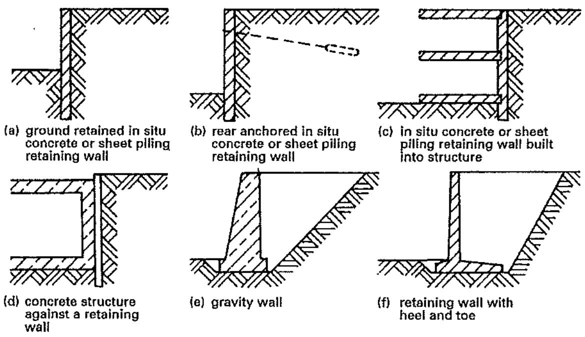
❽ Widened, stepped foundations of unreinforced concrete



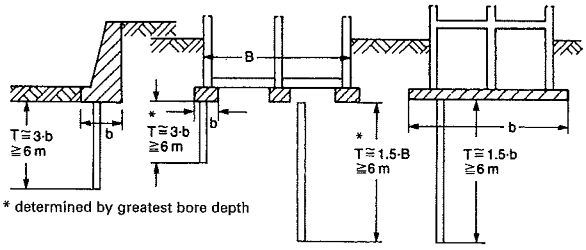
⓫ Widening foundations of unreinforced concrete



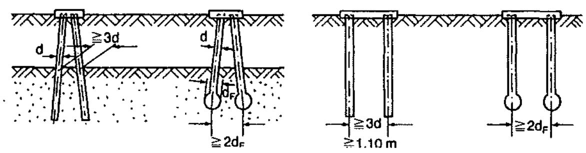
⓬ Still wider strip foundations of reinforced concrete



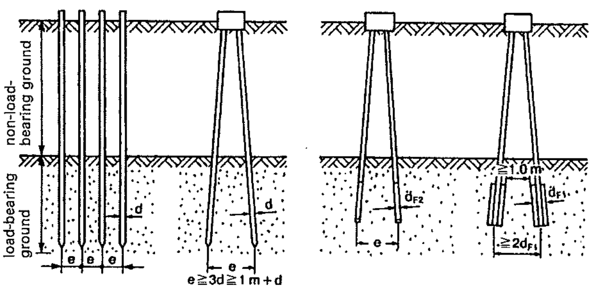
1 Building elements designed to resist active ground pressure



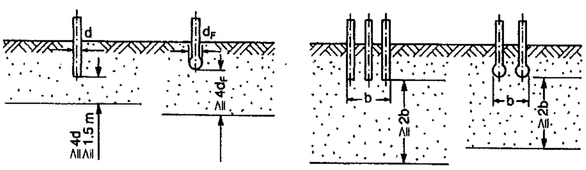
2 Minimum depths for structural boring



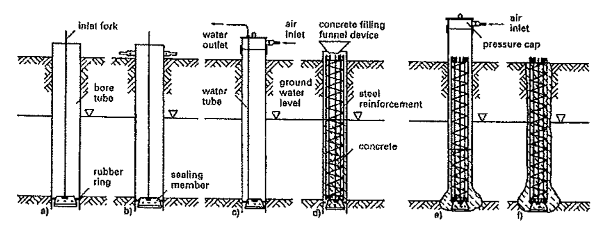
3 Bored piles (principle)



4 Driven piles (principle)



5 Required depth of load-bearing subsoil under bored piles (guideline values)



6 Pressed concrete bored pile (Brechtel system)

Deep foundations

Deep foundations are used where sufficiently load-bearing strata only occur at a great depth under the planned building and thus cannot be reached by shallow foundations.

They are normally constructed of reinforced concrete piles, which transfer the loading from the building through the weak ground to the load-bearing ground below. The design of piled foundations is based on the permissible loading on the ground and the type, properties, extent, density and thickness of the subsoil layers, which have to be established by investigation boreholes and probing if local experience cannot deliver sufficient certainty.

Basic terms

The force in the pile can be transferred to the stable ground by **skin friction, end-bearing** or a combination of both (the type of load transfer depends on the ground conditions and type of pile).

Standing pile foundations: load transfer is through the end of the pile into load-bearing ground, additionally through skin friction.

Hanging pile foundations: the pile ends do not reach load-bearing ground. Weakly load-bearing layers are compacted by the driving of the pile.

Piles are categorised according to the method of load transfer into: **friction piles**, which essentially transfer load into load-bearing layers by skin friction between the pile surface and the ground. **End-bearing piles** mainly transfer load into the ground through pressure under the end, with skin friction being irrelevant. The permissible force on the can be increased considerably by making the end larger (under-reaming).

According to the location of the piles in the ground, they can be **ground piles**, which are underground for their entire length, while **long piles** (free-standing piles) are in the ground only for part of their length and the upper part is free-standing, and therefore at risk of buckling.

According to the method of installation, there are piles which compact, displace or loosen the ground. **Driven piles** (driven with a pile hammer), **pressed piles** (pressed in), **bored piles** (installed in a bored hole), **screwed piles** (turned into the ground) and **jetted piles** (jetted into the ground).

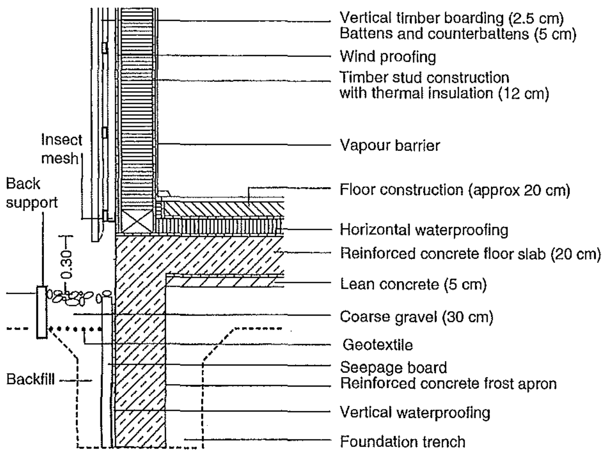
According to the type of loading, they can be: axially loaded piles, **tension piles** (which are loaded in tension and transfer the force in the pile into the ground through skin friction), **compression piles** (which are loaded in compression and transfer load through end pressure and skin friction) and **piles subject to bending** (for example horizontally loaded large-diameter bored piles).

According to the method of production and installation, piles can be:

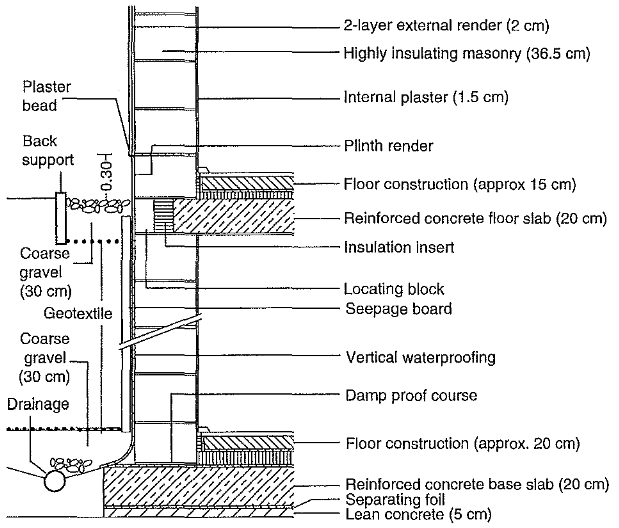
- **precast piles**, in prefabricated lengths or complete, which are delivered to the site and driven into the ground, jetted, vibrated, pressed, screwed or inserted into prepared holes.
- **in-situ piles**, which are concreted in a hole prepared in the ground by boring, driving, pressing or vibrating.
- **mixed foundation piles**, which consist of a combination of locally produced and prefabricated components.

In-situ piles have the advantage that their length can be determined during construction, from the data recorded during driving or from the inspection of the spoil from boring.

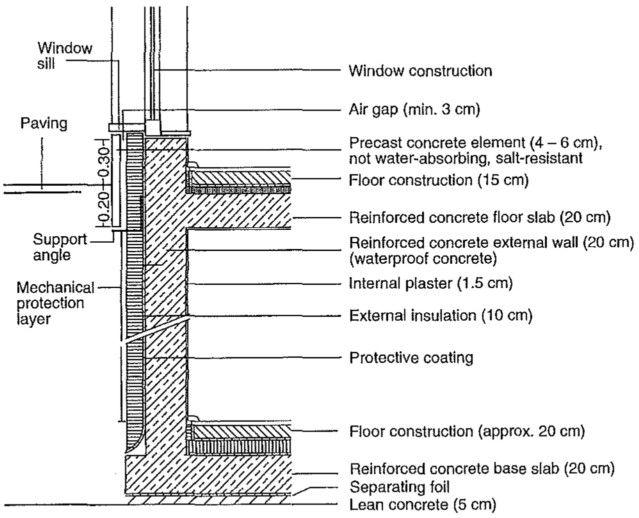
BS 8000-4
BS 8102
BS EN 13967/9
DIN 4095
DIN 18195



1 Plinth detail of a timber-framed building without cellar with open ground transition in strongly permeable soil



2 Plinth detail of a building with masonry cellar walls in weakly permeable or cohesive soil



3 Plinth detail of a building with cellar, ground floor at street level, construction as a waterproof basin

FOUNDATIONS

Tanking, Basement Drainage

Waterproofing

External walls and slabs in contact with the ground must be waterproofed against **damp under external pressure.** External and internal walls in cellars and ground floors without cellars also have to be protected with horizontal waterproofing against **rising damp.**

This occurs as **ground moisture** (capillary, suction and residual water in the ground, which can be carried against gravity by capillary action) or **seepage water,** from precipitation and non-standing, which is not under pressure (e.g. earth-covered cellar roofs under courtyards), as well as **water under pressure** from the outside or occasionally **standing water** (groundwater and floodwater).

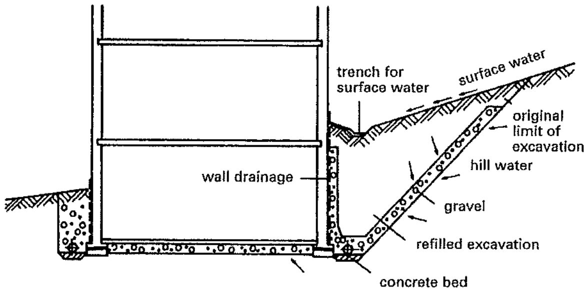
Waterproofing **materials** can be sheet material from the roll based on bitumen, plastic or elastomer, metal bands, mastic asphalt or thick plastic-modified bitumen coatings.

Vertical and horizontal waterproofing layers are to be brought together and sealed so that no moisture bridges remain. They must generally be continued 30 cm above ground level. Protective layers should also be provided in order to protect the waterproofing until the assignment of the various types of waterproofing to the various actions of water is shown in → **4**.

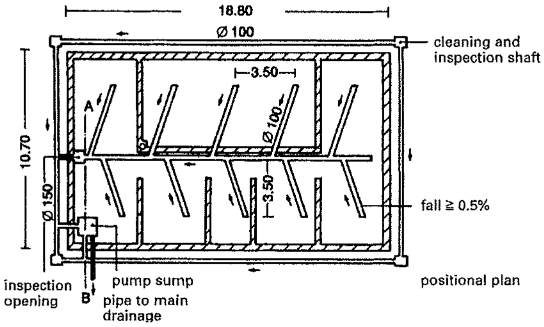
Type of building element	Nature of water	Installation situation	Type of water action
walls and slabs in contact with the ground **above** the estimated water table	capillary water residual water seepage water	very permeable soil $>10^{-4}$ m/s	**ground dampness** and non-standing seepage water
		low permeability soil $\leq 10^{-4}$ m/s **with drainage**	
		low permeability soil $\leq 10^{-4}$ m/s **without drainage** (up to foundation depth of 3 m below ground level)	**standing seepage water**
horizontal and sloping surfaces in the ground	precipitation water seepage water	used roof areas (e.g. covered cellar roof)	**water without pressure**, high loading
walls and slabs in contact with the ground **below** the estimated water table	groundwater flood water	any type of soil, building and construction	**water under pressure** from outside

4 Building elements in contact with the ground: water action, installation situation and type of waterproofing

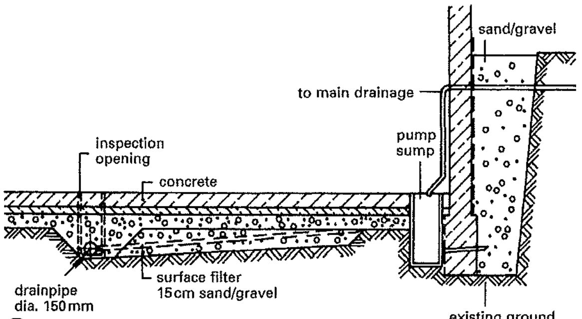
BS 8000-4
BS 8102
BS EN 13967/9
DIN 4095
DIN 18195



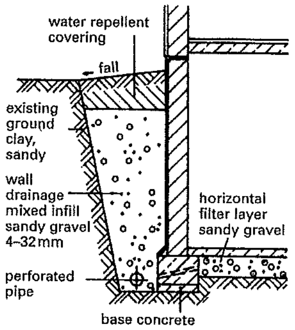
❶ Building walls built against a slope must be well drained



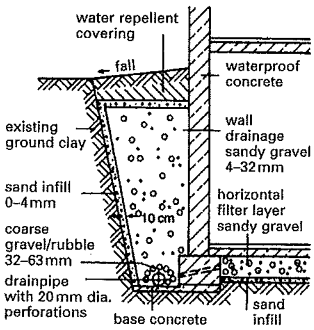
❷ Area drainage with seepage pipes and ring drainage, with a pumped sump



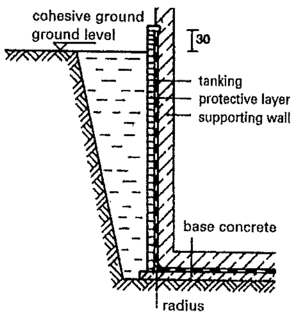
❸ Cross-section A–B → ❷



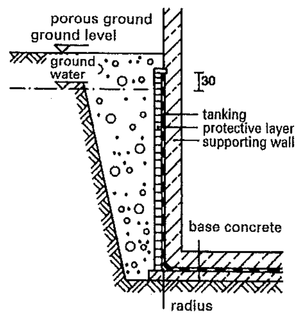
❹ Piped drainage with mixed filter



❺ Piped drainage with staged filter



❻ Basement tanking against water pressure



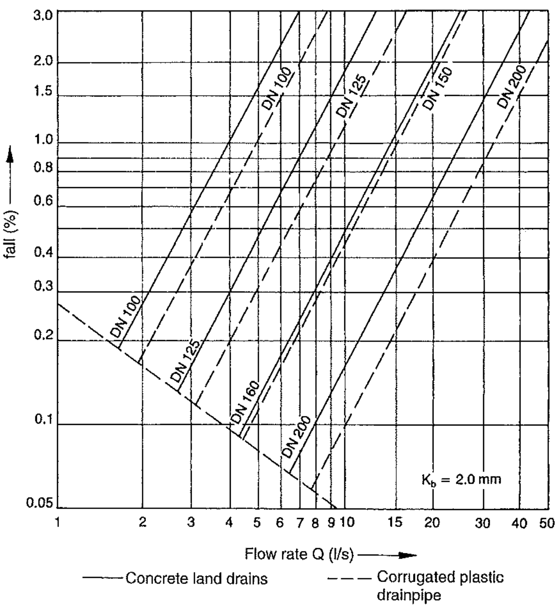
❼ Basement tanking against water pressure

Basement drainage

The ground can be drained through a **drainage layer** and **drainage pipes** in order to prevent the occurrence of water under pressure against an external wall. The entire procedure consists of drainage, inspection and flushing shaft and drainage pipes → ❽.

Drainage pipe, DN 100, fall 0.5. Flushing and control pipe, DN 300. Flushing, control and collector shaft, DN 1000. The required nominal diameter for round drainage pipes and operating roughness k_b = 2 mm can be determined from → ❽. The flow speed in the drainage pipe when full should not be less than v = 0.25 m/s. For areas over 2000 m², full-area drainage should be provided, through drainage pipes. The spacing of the individual drainage pipes should be calculated, and if necessary inspection shafts should also be provided → ❷.

The precondition for effective drainage is that the water runs away into a sewer or stream even at the highest water level in the main drainage channel. The best arrangement is a connection with free fall into an open stream or rainwater sewer, to avoid the need for pumping. If a pump is necessary, it must be protected against water coming back from the sewer or stream by a suitable device like a backflow preventer valve. This device must be accessible and must be maintained. Water from drainage can also be percolated into permeable subsoil, for example in a soakaway.



❽ Design example for circular drainage pipes

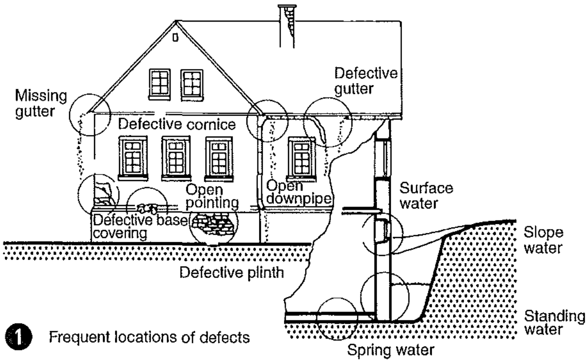
Tanking

If there is water under pressure or it is not possible to divert standing water through the provision of drainage, then the building elements must be constructed of **watertight concrete**, or a **continuous waterproofing layer** capable of resisting water pressure must be applied to the invert and side walls. This can consist of bituminous sheeting, metal waterproofing or plastic foil. It must be resistant to aggressive water and must maintain its effectiveness despite shrinkage, settlement and temperature-related deformation → p. 71. Bentonite waterproofing is also possible.

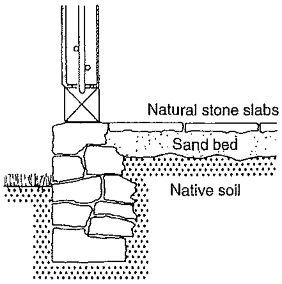
Watertight concrete is today the generally preferred method of resisting water under pressure. If the cellar floor and walls are separated by a construction joint, this must be waterproofed with a suitable waterstop or raised edge. The external surface of the walls is also provided with a protective coating based on bitumen or artificial resin as additional protection → ❻ – ❼.

Most building defects are caused by damp. Rising damp from the ground can be caused by missing or defective damp proofing over the foundations or cellar, missing or silted drainage or defective rainwater goods, resulting in surface water at the transition area between ground and wall.

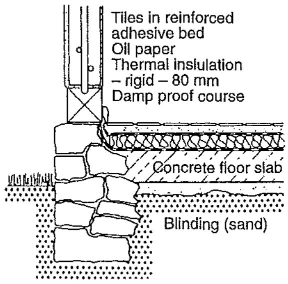
When a repair is undertaken, it also necessary to investigate and remedy the cause of the moisture penetration. Missing or damaged horizontal damp courses are laborious to replace, and the work needs to be carried out very carefully because the capillary transport of moisture must be interrupted. Building elements, which are impossible to waterproof, or only at excessive expense, can be coated using special plaster systems, which enable the damp to evaporate. The efflorescence of mineral salts resulting from evaporation can be absorbed for a long time, but the durability of such remedial plasters is still considerably shorter than plaster on a dry substrate.



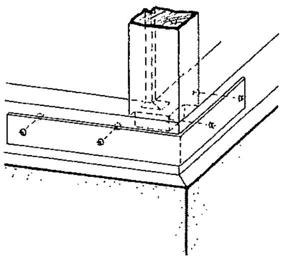
1 Frequent locations of defects



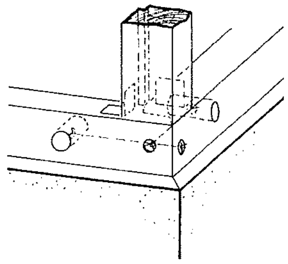
2 Old natural stone flooring of a ground floor without cellar



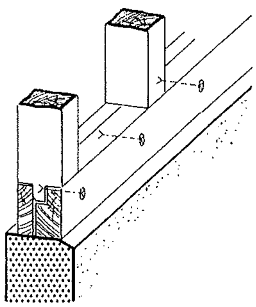
3 Renewal of the floor with thermal insulation and damp-proof layer on a sub-concrete of lime mortar



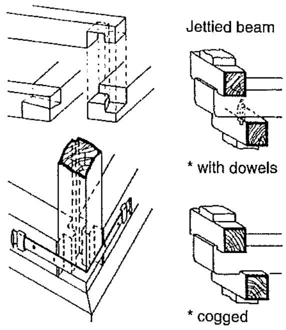
4 Corner reinforcement with a metal angle



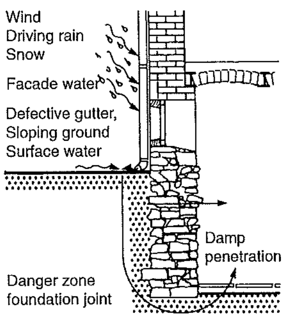
5 Corner of sill beam newly anchored with coach bolts



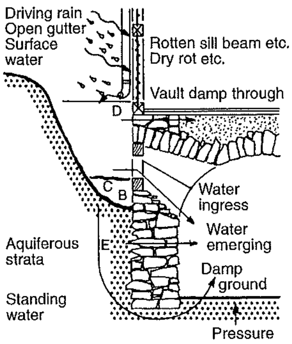
6 Replacement of sill beam in two stages



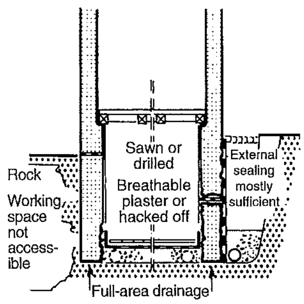
7 Possible corner joints for timber frame sill beams (tension and compressive loading)



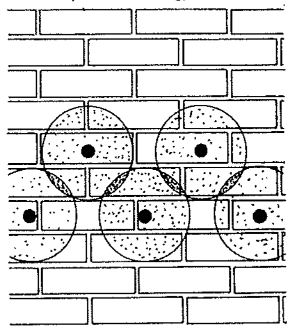
8 Main sources of damage from water without pressure



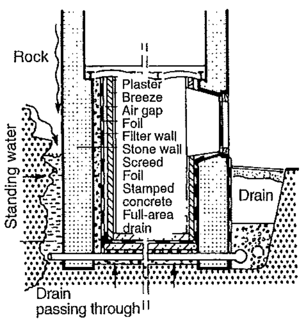
9 Main sources of damage from water under pressure



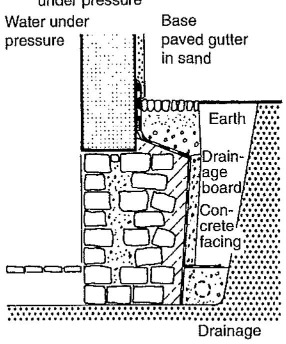
10 Supplementary horizontal isolation and waterproofing of a damp cellar



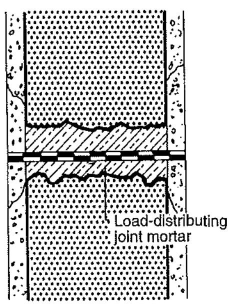
11 Injected damp-proofing



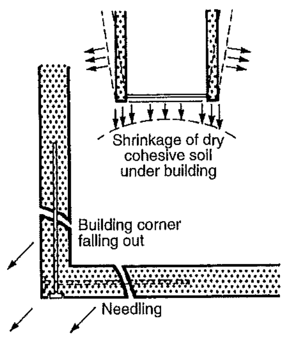
12 Internal waterproofing of partially inaccessible external walls



13 Repair of foundations built in contact with the earth

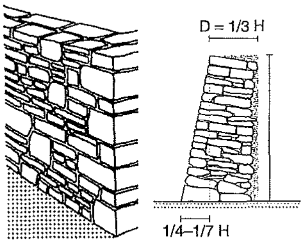


14 Supplementary insertion of horizontal waterproofing (wall separation)

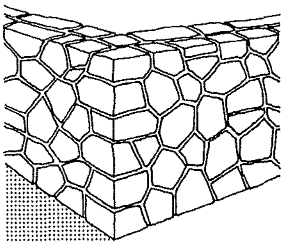


15 Needling of a subsiding house corner

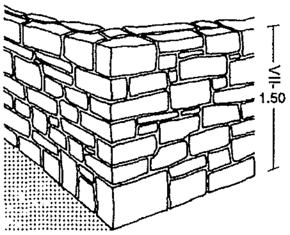
BS EN 771-6
BS EN 1745
BS EN 1996
DIN 1053



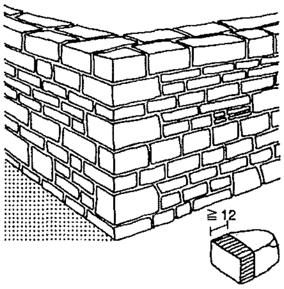
❶ Dry stone walling / section



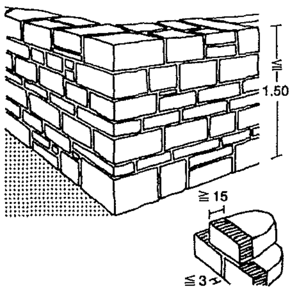
❷ Cyclopean masonry of volcanic stone



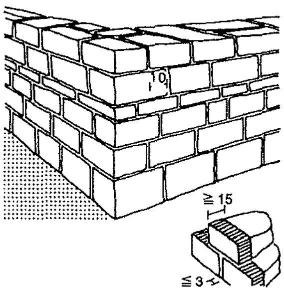
❸ Rubble masonry



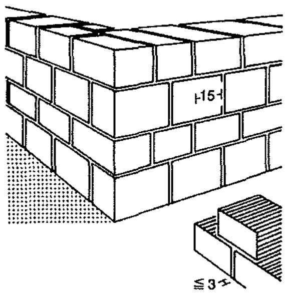
❹ Rubble masonry squared with a hammer into courses



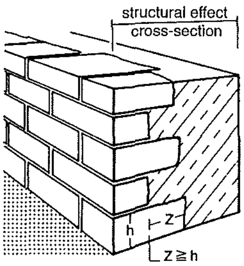
❺ Irregularly coursed masonry



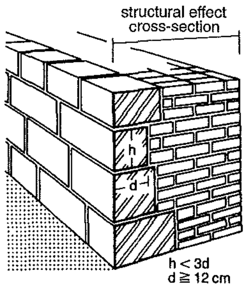
❻ Regularly coursed masonry



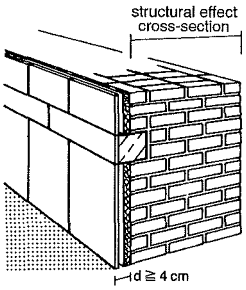
❼ Ashlar masonry



❽ Composite masonry



❾ Composite masonry showing the structurally effective section



❿ Stone cladding without structural contribution

Natural stone walling can be categorised into **rubble, cyclopean, coursed, ashlar and composite.**

Stone, which has a natural plane of cleavage, should be split and laid according to the cleavage, e.g. → ❶, ❸, ❹, which looks better and is also structurally sounder because the loading is then mostly at right angles to the natural bedding.

The size of the individual blocks is of great importance. The block length should not be more than four to five times the block height and should not be less than the height (the stones should be bonded well on all sides). Pure natural stone masonry must be bonded in the entire cross-section in accordance with good trade practice.

There should never be more than three joints meeting at the front or rear surfaces of a block and no vertical joint should pass through more than two courses. For structural reasons, a course should be brought flat and level every ≦1.5 m (spacing of scaffold platforms).

Header and stretcher courses must alternate, or there must be at least one header for every two stretchers in each course. The depth (into the wall) of the headers must be at least 1½ times the course height but at least 30 cm.

The depth (into the wall) of the stretchers must be about equal to the course height. The vertical joints must be covered by ≧10 cm in coursed masonry and ≧15 cm in ashlar masonry → ❺ + ❼, and the largest blocks should be laid at the **corners** → ❶ – ❻. **Face surfaces** should subsequently be fully pointed, first scratching out a depth equal to the joint width. The joints should be about 3 cm thick according to roughness and method of working. Lime or lime-cement mortar should be used, as cement can discolour certain types of stone. In **composite masonry**, the worked stone facing can be integrated into the load-bearing cross-section → ❾. Non-load-bearing **stone cladding** of 2.5–5 cm thickness is fixed to the backing wall with anchors → ❿.

Stone type	Compressive strength (N/mm²)
limestone, travertine, volcanic tuff	20
weak sandstone (with clay binder) and similar	30
dense (strong) limestone and dolomite (incl. marble), basalt lava and similar	50
quartzitic sandstone (with siliceous binder), greywacke and similar	80
granite, syenite, diorite, quartz porphyry, black porphyry, diabase and similar	120

⓫ Minimum compressive strengths of building stone

Grade	Stone strength βst (N/mm²)	Basic values σ_0[1] for mortar group I (MN/m²)	II (MN/m²)	IIa (MN/m²)	III (MN/m²)
N1	≧20	0.2	0.5	0.8	1.2
	≧50	0.3	0.6	0.9	1.4
N2	≧20	0.4	0.9	1.4	1.8
	≧50	0.6	1.1	1.6	2.0
N3	≧20	0.5	1.5	2.0	2.5
	≧50	0.7	2.0	2.5	3.5
	≧100	1.0	2.5	3.0	4.0
N4	≧20	1.2	2.0	2.5	3.0
	≧50	2.0	3.5	4.0	5.0
	≧100	3.0	4.5	5.5	7.0

[1] If joints are more than 40 mm thick, then the basic values σ_0 are to be reduced by 20%.

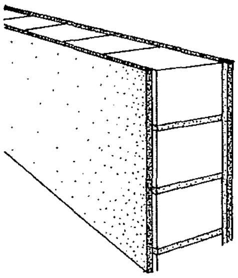
⓬ Basic values σ_0 of the permissible compressive stresses for natural stone masonry with normal mortar

Grade	Basic category	Joint height / block length	Slope of bed joint – tan α	Transfer factor η
N1	rubble masonry	≦0.25	≦0.30	≧0.50
N3	masonry hammered into courses	≦0.20	≦0.15	≧0.65
N3	coursed masonry	≦0.13	≦0.10	≧0.75
N4	ashlar masonry	≦0.07	≦0.05	≧0.85

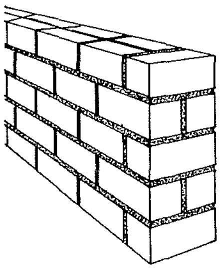
⓭ Guideline values for the grading of natural stone masonry

BS 8103-2
DIN 1053

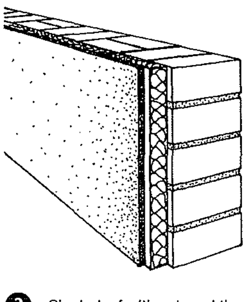
see also:
Building physics
pp. 471 ff.



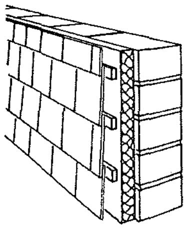
❶ Single-leaf plastered



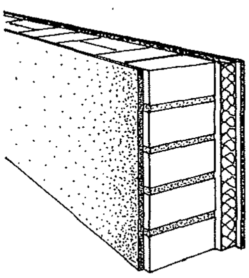
❷ Single-leaf faced



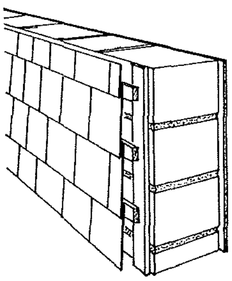
❸ Single-leaf with external thermal insulation



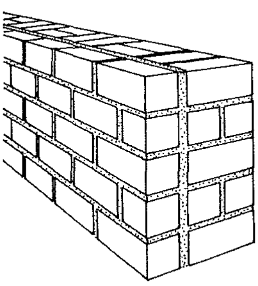
❹ Single-leaf with thermal insulation and weather protection



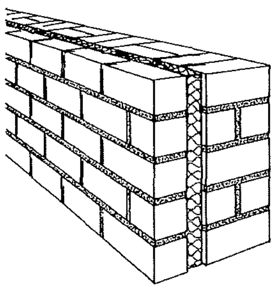
❺ Single-leaf with internal insulation



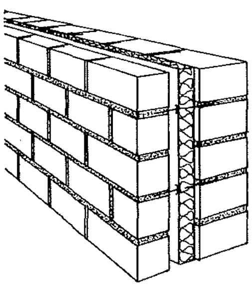
❻ Tiled cladding on masonry with a high thermal insulation value



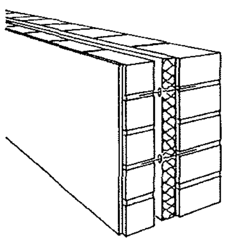
❼ Two-leaf composite masonry with internal plaster layer



❽ Faced cavity wall without air gap



❾ Faced cavity wall with air gap

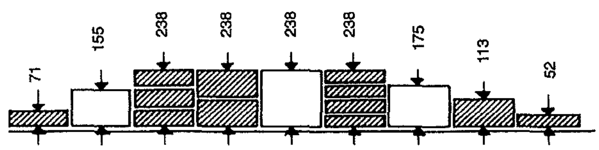


❿ With/without air gap plastered

Building materials
Countless bricks and blocks are available for the production of masonry walls in various forms, sizes and qualities → ⓫.
The dimensions (formats) are normally multiples of the standard format and thin format → ⓬.

Clay bricks and blocks	**Sand-lime blocks**
solid brick	solid and holed blocks
facing solid brick	facing blocks
hard-burnt solid brick	facing blocks
vertically cored block	cored and hollow blocks
facing vertically cored block	plan blocks (for thin mortar laying)
vertically cored hard-burnt block	
ceramic solid hard-burnt block	**granulated slag aggregate concrete blocks**
ceramic vertically cored hard-burnt block	
aerated concrete blocks	**solid aerated concrete blocks**
lightweight hollow concrete blocks	**concrete masonry units**

⓫ Brick and block types



Description		Length (cm)	Width (cm)	Height (cm)
thin format	TF	24	11.5	5.2
normal format	NF	24	11.5	7.1
2 thin format	2 TF	24	11.5	11.3
3 thin format	3 TF	24	17.5	11.3

⓬ DIN brick formats (excerpt)

External wall construction
Single-leaf external walls → ❶ – ❷ are unproblematic regarding building physics, but on account of the high thermal insulation requirements can only be built with materials with high thermal insulation value (e.g. aerated blocks) and special thermally insulated mortars and plasters. If the blocks used are susceptible to frost damage, they have to be rendered or protected in other ways. If the masonry is externally visible, then each course must consist of at least two rows of blocks of the same height with a continuous 20 mm thick longitudinal joint between them, and each course staggered and mortared without voids.

Single-leaf walls with additional insulation layers → ❸ – ❻ (external, internal insulation → Building physics, p. 471 ff.) are therefore a common alternative.

Cavity walls consist of an inner load-bearing wall and an outer non-load-bearing weather protection facing (**minimum thickness 90 mm**). They can be built with an air gap, with air gap and thermal insulation, with cavity-filling insulation and with intermediate plaster layer → ❼ – ❿. The masonry leaves are connected with **ties** of non-rusting steel. The width of the air gap should be min. 40 mm (max. 150 mm). Vertical expansion joints should be provided in the external leaf and there should also be ventilation openings (e.g. open vertical joints) at the top and bottom, with the openings at the bottom also serving to drain water p. 77 → ❸.

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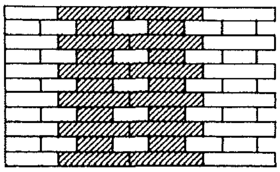
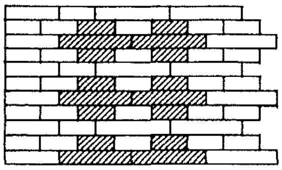
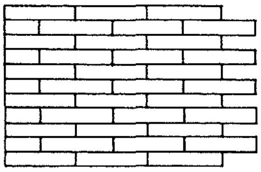


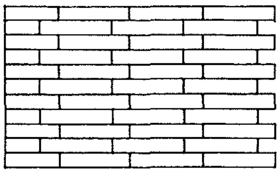
❶ English bond



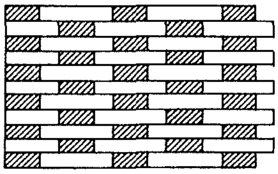
❷ Cross bond



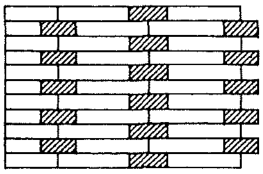
❸ Stretcher bond with ½ brick displacement



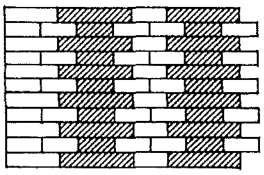
❹ Stretcher bond with ¼ brick displacement



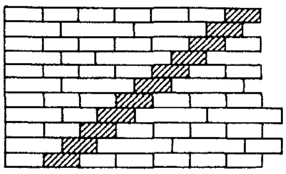
❺ Flemish bond; one header, one stretcher, alternate courses



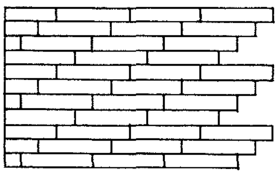
❻ One header, two stretchers, alternate courses



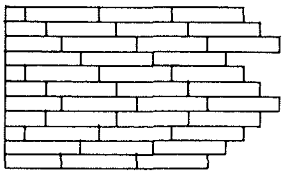
❼ One stretcher and one header course, alternating with header course



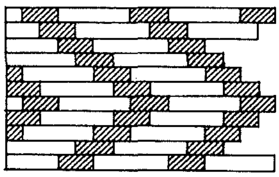
❽ Two stretcher and one header course, alternating with header course



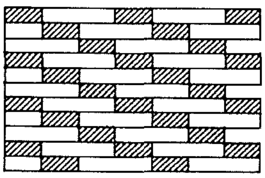
❾ Stretcher bond with ¼ brick displacement, joints rising to the right



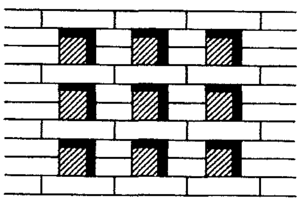
❿ Stretcher bond with ¼ brick displacement, joints rising to the right and left



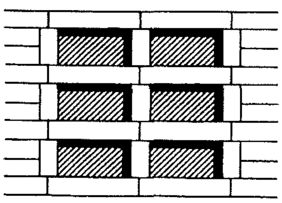
⓫ One header and one stretcher alternating in courses with ¼ brick displacement, joints rising to the right and left



⓬ One header and one stretcher alternating in courses, with ½ brick displacement, joints rising to the left



⓭ Hole coursed into the masonry for light or ventilation (hole ½ × ½ brick)



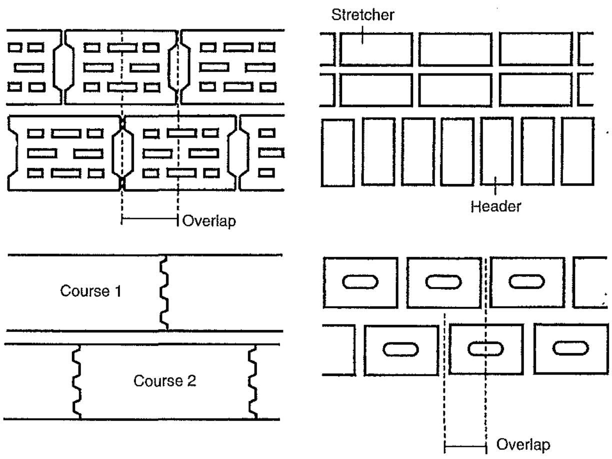
⓮ as → ⓭ (hole ½ × ¾ brick)

Bonding of masonry

In order to evenly transfer the loads acting on masonry and ensure crack-free wall surfaces, bricks and blocks are normally laid in regular courses and bonded. Masonry courses are named, according to their method of integration into the bond, **stretcher, header or soldier courses**:

Stretcher courses lie with their length along the face of the wall. Header courses lie with their end in the face of the wall and are bonded into the masonry by their length.

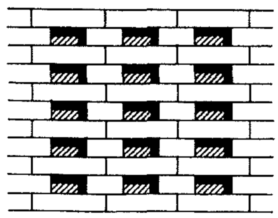
Masonry courses should continue horizontally through all walls in a building. **Vertical joints** in adjacent courses must always be overlapped, i.e. displaced relative to the adjacent course by a certain dimension (at least ¼ brick). In order to reduce the proportion of joints, as many whole bricks as possible should be used (in the currently prevalent single-leaf wall made of large-format blocks, the joints are the thermal weak point and have to be carried out in lightweight or thin mortar, or with the vertical joints toothed → ⓯). The type and dimension of the displacement of the vertical joints in adjacent courses leads to the basic pattern of the various masonry bonds, in addition to the sequence of stretchers and headers.



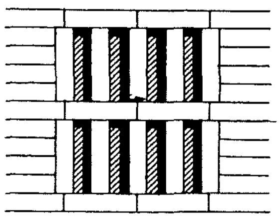
⓯ Modern masonry bonds

Modern masonry bonds are normally laid in **stretcher bond** → ❸ as 'middle bond' with displacement of the vertical joint by ½ brick in the next course or, alternatively, as 'English bond' with displacement of the vertical joint by ⅓ brick in the next course → ❶, or with 'cross bond', alternating stretcher and header courses → ❷.

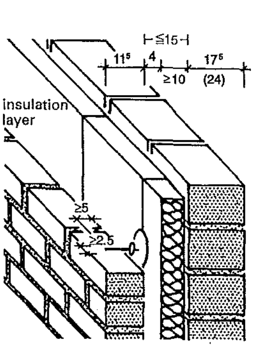
There are many other bonds in classical bricklaying such as 'Flemish bond' → ❺, or one header and three stretchers in each course → ❻ and other decorative bonds.



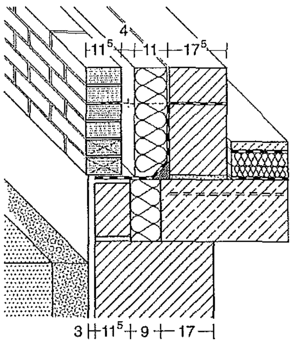
⓰ as → ⓭ (hole ¼ × ½ brick)



⓱ as → ⓭ (hole 1 × ¼ brick)



❶ Two-leaf wall with air gap and insulation



❷ Plinth connection

Building element	Conditions		
	Wall thickness (τ in cm)	Clear wall height (η in cm)	Imposed load (π in kN/m^2)
internal wall	$\geqq 11^5$ $\leqq 24$	$\leqq 275$	$\leqq 5$
	$\geqq 24$	–	
solid external wall	$\geqq 17^5$ $\leqq 24$	$\leqq 275$	
	$\geqq 24$	$\leqq 12\,t$	
load-bearing leaf of a cavity external wall and cavity party wall	$\geqq 11^5$ $\leqq 17^5$	$\leqq 275$	$\leqq 3$
	$\geqq 17^5$ $\leqq 24$		$\leqq 5$
	$\geqq 24$	$\leqq 12\,t$	

❸ Conditions for the application of the simplified calculation procedure for building heights ≦20 m (DIN 1053-1 → refs)

Load-bearing walls

Walls which have to bear more than their self-weight on one storey are called load-bearing walls.

Bracing walls

Masonry can be secured by bracing walls and slabs below and above (three-dimensional cell principle). Bracing walls are building elements which work as deep beams to transfer horizontal loads (e.g. wind loads).

Non-load-bearing walls

Walls which are only loaded by their self-weight and are not used for bracing against buckling are called non-load-bearing.

Cut-outs and chases

Cut-outs and chases can either be chased out mechanically or formed in bond by the bricklayer. Their details can require structural verification under certain circumstances → ❹.

Perimeter tie

Perimeter ties are required for the **transfer of horizontal forces** over all external and transverse walls in buildings with more than two full storeys or more than 18 m length and walls with many or large openings under the floor slab. These are normally made of reinforced concrete and constructed together with columns and massive floor slabs. A simplified verification procedure can be used under certain circumstances for the design of masonry construction → ❸.

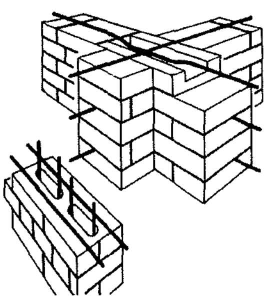
Building components

WALLS
Natural stone masonry
Brick and block masonry
Composite construction
Repair

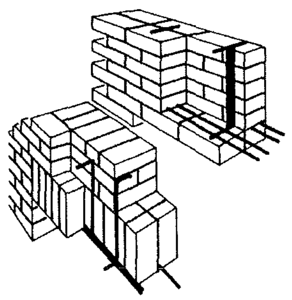
BS 8103-2
DIN 1053

Wall thickness (cm)	Horizontal and inclined chases carried out later (cm)		Vertical chases and cut-outs, carried out later (cm)			Vertical chases and cut-outs in bonded masonry (cm)			
	Chase length								
	Unlimited	$\leqq 1.25$ m	Chase depth	Chase width	Distance of chase or cut-out from openings	Chase width	Residual wall thickness	Minimum distance of chases and cut-outs	
	Chase depth	Chase depth						From openings	To each other
$\geqq 11^5$	–	–	$\leqq 1$	$\leqq 10$		–	–	$\geqq 2$ x chase width or $\geqq 24$	$\geqq$chase width
$\geqq 17^5$	–	$\leqq 2^5$	$\leqq 3$	$\leqq 10$		$\leqq 26$	$\geqq 11^5$		
$\geqq 24$	$\leqq 1^5$	$\leqq 2^5$	$\leqq 3$	$\leqq 15$	$\geqq 11^5$	$\leqq 38^5$	$\geqq 11^5$		
$\geqq 30$	$\leqq 2$	$\leqq 3$	$\leqq 3$	$\leqq 20$		$\leqq 38^5$	$\geqq 17^5$		
$\geqq 36^5$	$\leqq 2$	$\leqq 3$	$\leqq 3$	$\leqq 20$		$\leqq 38^5$	$\geqq 24$		

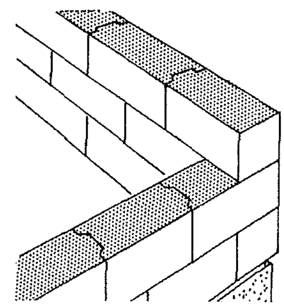
❹ Permissible size of chases and cut-outs in load-bearing walls (DIN 1053-1 → refs)



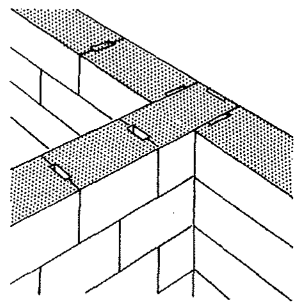
❺ Crossing of reinforced aerated concrete blockwork



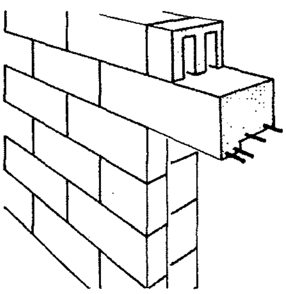
❻ Reinforced masonry door and window lintels



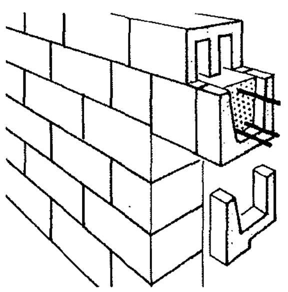
❼ Glued aerated concrete blockwork, 1 mm joints



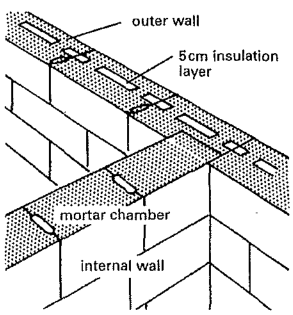
❽ Vertically cored clay bricks and blocks laid or with poured mortar



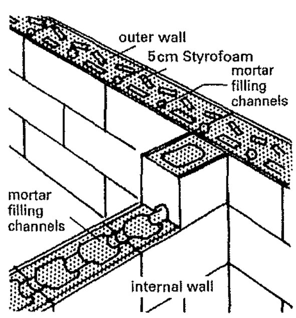
❾ Masonry of aerated concrete (hollow blocks) with reinforced pumice concrete lintel



❿ Masonry of hollow blocks with cast trough lintel

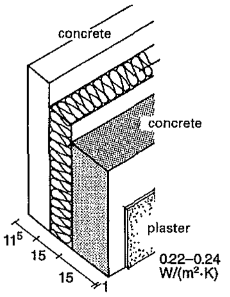


⓫ Blocks with 5 cm insulation layer and mortar pockets

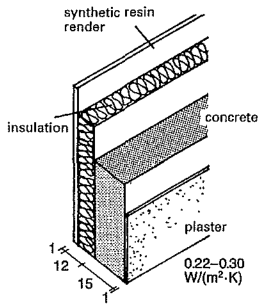


⓬ Assembly blocks with insulation and cavities for mortar filling

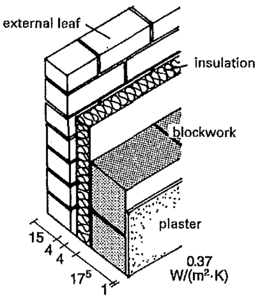
see also: Glass pp. 104 ff.
Building physics pp. 471 ff.



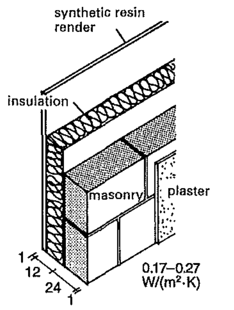
1 Two-layer concrete



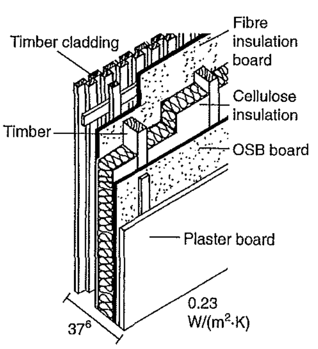
2 Concrete with external thermal insulation system



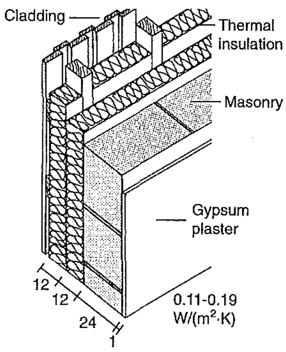
3 Two leaves of aerated concrete



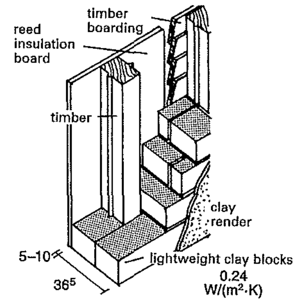
4 Masonry with external thermal insulation system



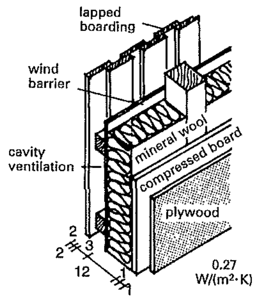
5 Low-energy wall (Heckmann Ökohaus)



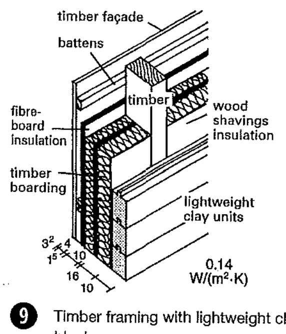
6 Masonry with external cladding



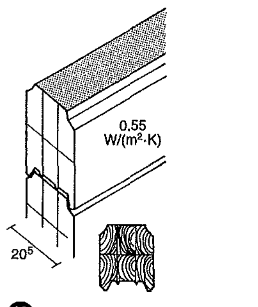
7 Stud framing with lightweight clay elements



8 Timber framing (insulation between the posts)



9 Timber framing with lightweight clay blocks



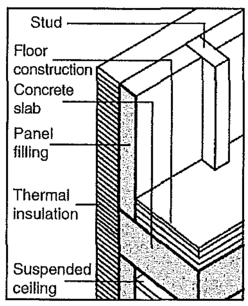
10 Laminated timber sections for log house construction

Reinforced concrete walls → 1 – 2

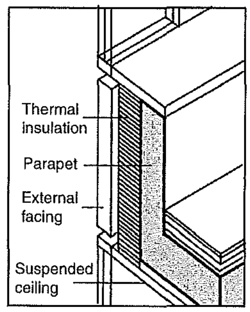
Reinforced concrete walls can be concreted on site or pre-cast. **Solid concrete walls** can be used as external walls only with an additional thermal insulation layer. This can be as an external thermal insulation system → 1 or as a multi-leaf construction (analogous to p. 75) with core insulation and possibly back-ventilation. **Two-layer reinforced concrete walls** → 1 with core insulation are used particularly as large-format external wall elements.

Timber-framed walls → 5 – 10

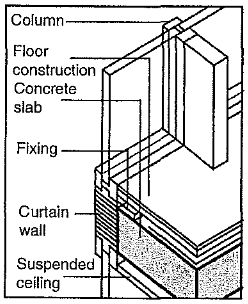
The oldest form of timber walling is **log cabin construction** with the round logs or beams laid on top of one another and cogged at the corners → 10. Timber-framed walling (with the panels filled in with various materials) is economical and the most common method, with vertical loads being transferred through the studs. A variant of timber framing is the erection of framed panels, which are prefabricated with thermal insulation. When timber-framed walls are to be used, provide sufficient roof overhang and design cladding in the splash area to be easily replaced.



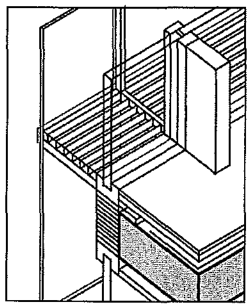
11 Framed construction with non-load-bearing masonry panels



12 Curtain wall with back-ventilated façade



13 Curtain wall of multi-layer façade elements

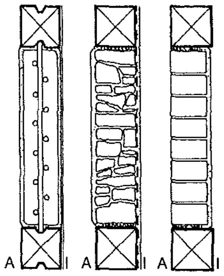


14 Curtain wall as double façade

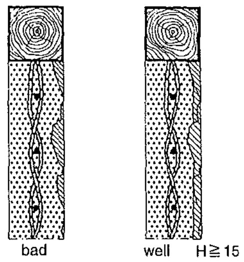
Non-load-bearing external walls

Light and often prefabricated panels are frequently used for non-load-bearing external walls (e.g. for framed buildings) → 11. The advantage is the low loading on the edges of the slabs, rapid assembly and simpler replacement later.

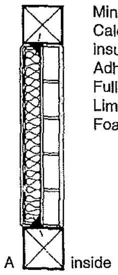
Curtain walls → 12 – 14 can be made of light, prefabricated metal-glass construction in the form of **façade panels** of metal or plastic, **multi-layer façade elements** complete with windows and parapets or **pre-cast concrete elements.** The most common elements are fixed to the slabs (or framed columns) with fixing brackets or anchors and can be combined to form any size of wall.



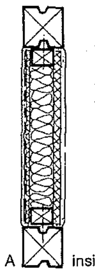
❶ Panel infilling (left to right) of loam on stakes (wattle and daub), with rubble masonry and with hard-burnt bricks



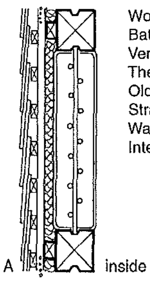
❷ Avoidance of dragged transitions when repairing loam infilling



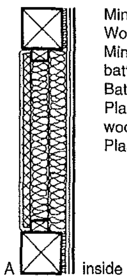
❸ New infilling of mineral insulation panels and brick: timber framing visible on both sides



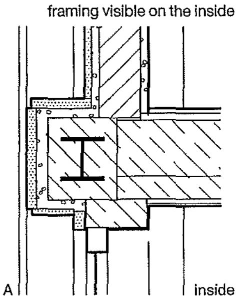
❹ Lightweight infilling (no thermal storage possible!): timber framing visible on both sides



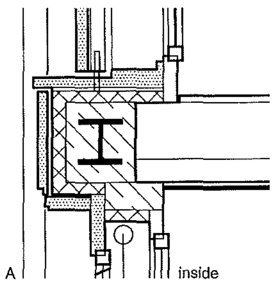
❺ External insulation with highly diffusible material behind ventilated cladding = constructional timber protection: timber framing visible on the inside



❻ New infilling with good thermal insulation: timber framing clad on the inside without damp barrier!

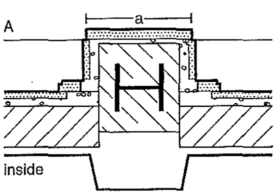


The original structure of natural stone tiles on a concrete base and masonry parapet was solid. To preserve the external view and insert large-scale French windows affecting the inside view, the windows and parapet were replaced with casement windows with natural stone parapet elements.

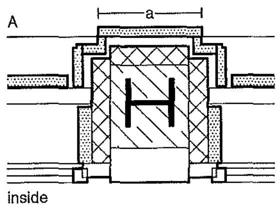


The design used natural stone slabs on self-supporting sub-structure and upgraded with interjacent thermal insulation, without changing much the proportions of the profile.

Arch.: Kister Scheithauer Gross, Cologne



❼ Existing situation: natural stone cladding to concrete structure



❽ Improvement in thermal insulation while mostly preserving the outline and proportions which determine the façade

External walls

Defects to external walls are caused by natural weathering, poor maintenance and often also incorrectly carried out repairs and modernisation attempts. When modernisation or conversion work is undertaken, walls have to be upgraded to meet current energy and structural requirements.

Timber framing

A main characteristic of timber-framed houses is the separation of the load-bearing timber construction from the non-load-bearing panels between (the panels should always be fitted so they receive no loading). Timber construction was originally carried out without metal fixings and can normally be repaired without the use of steel or iron parts (water condensation on metal parts can damage the timber, which in Germany is often softwood). The original infilling of the panels is usually facing brick or a clay daub → ❶ – ❷. The timber functions and the appearance of joints at the contact between timber and panel is unavoidable. Triangular strips or grooves in the timber are used to fix the panel infilling and prevent draughts. Constructional timber protection (wide roof overhang, full-surface render or ventilated cladding) can avoid damage due to water penetrating from outside. Waterproof paints and permanently elastic mastic also stop water from infiltrating but are one of the main causes of damage to timber framing!

Loam panels should always be preserved and damaged ones repaired. There is still no other panel infilling material available that is as good as loam → ❶ + ❺ in terms of good trade practice, building physics and building biology. It also counters fungal and insect attack. Brick infilling has a stiffening effect, which acts against the structural principles of timber framing, and lightweight infilling has no thermal storage capacity.

Natural stone and stucco façades

The energy performance of solid walls with structured façades of natural stone or stucco is often improved by internal insulation → p. 55 ❼. When natural stone cladding is replaced, insulation can be installed behind the stone façade. The stone facing panels must be fixed to an independent support structure while maintaining the outline and proportions of the façade. If the expense of insulation to EnEV standards is too high (i.e. economically unreasonable), an exemption from certain requirements can be agreed with the responsible authority. When installing external insulation, attention should be paid to whether the extra projection infringes any boundary or building line → ❼ + ❽.

Aim	Element	Measure according to	Residential buildings and zones in other buildings with temperatures >19 °C	Zones of non-residential buildings with indoor temperatures from 12 to <19 °C
			max. of heat transmission coefficients U_{max} (W/m² × K)	
1	external walls	No. 1 a to d	0.24	0.35
4a	ceilings, roofs and roof pitches	No. 4.1	0.24	0.35
4b	flat roofs	No. 4.2	0.20	0.35
5a	roofs and walls next to unheated rooms or earth	No. 5 a, b, d and e	0.30	no requirement
5b	floor construction	No. 5 c	0.50	no requirement
5c	slabs with outside air below	No. 5 a to e	0.24	0.35

❾ Maximum heat transmission coefficients with new installation, replacement or conversion of building elements, in existing buildings, EnEV 2009 (windows and doors → p. 99)

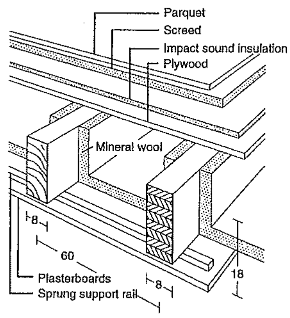
Building components

FLOOR SLABS
Slab construction
Refurbishment
Concrete repair
Floors

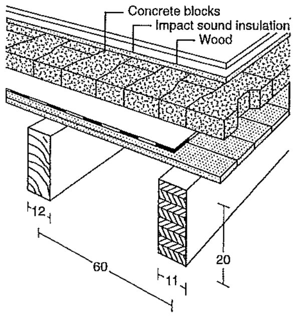
BS EN 1168
BS EN 12058
DIN 1045
DIN 1055

see also: Building physics pp. 471 ff.
Fire protection pp. 511 ff.

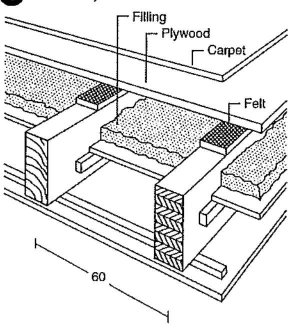
Floor slabs separate storeys and have to fulfil sound insulation and fire protection requirements in addition to their structural function. In addition to the main building materials (natural/artificial stone, concrete, steel, timber and lightweight concrete), slabs can be divided by their structural system into **vaulted** (subject to compression) and **flat** (subject to bending).
They can be built as **slab** or **joist/beam** constructions:
Slabs are flat structures loaded at right angles to their plane and spanning in one or two directions with linear or point loading. Common forms are solid reinforced concrete slabs → ❾ – ⓫, as in-situ, pre-cast or partially prefabricated elements; hollow pot slabs → ❺ with structurally connected clay pots forming cavities; pre-stressed concrete cored planks → ❻, made out of welded single elements; and composite slabs → ⓮.
Joist constructions consist of single beams, mostly loaded in bending.
In addition to timber joist floors → ❶ – ❹, solid beam slabs → ❼ – ❽, ⓭, and steel joist slabs → ⓯ can also be used.
For large spans and loads, there are double-T slabs → ⓬ and ribbed slabs, structurally optimised mixed constructions.



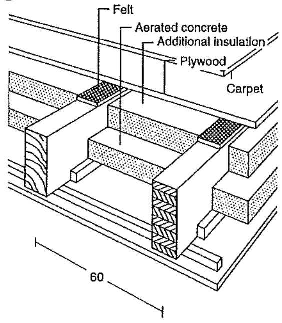
❶ Timber joist floor



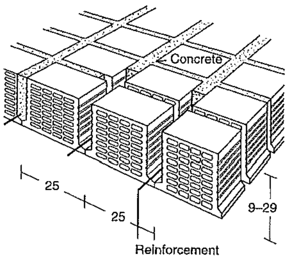
❷ Timber joist floor, exposed below



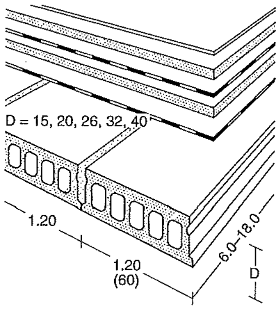
❸ Timber joist floor with filling



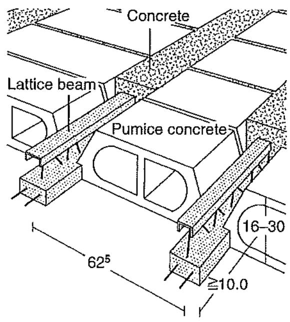
❹ Timber joist floor with aerated concrete and additional insulation (refurbishment)



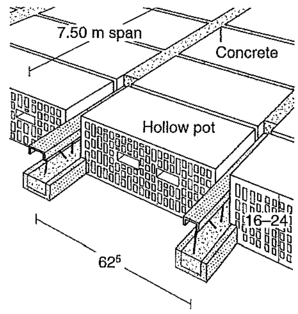
❺ Hollow pot slab, fully mortared



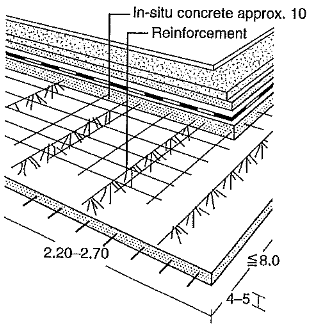
❻ Pre-stressed concrete core slabs



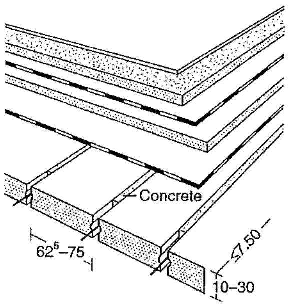
❼ Slab with prefabricated component and filling material



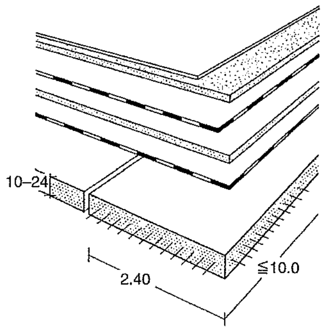
❽ Brick slab with beam elements



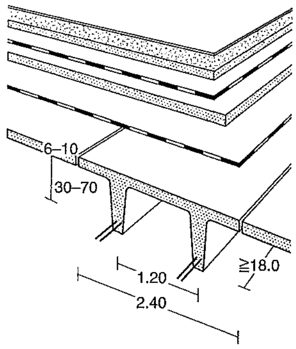
❾ Reinforced concrete composite floor slab



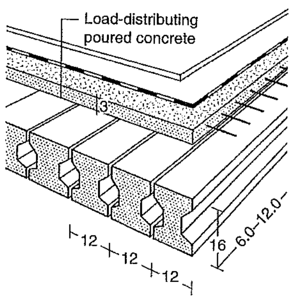
❿ Aerated concrete floor slab



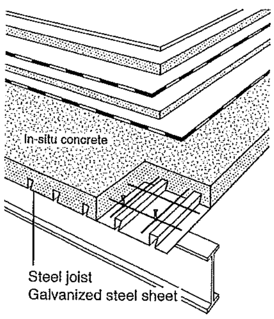
⓫ Solid reinforced concrete slab



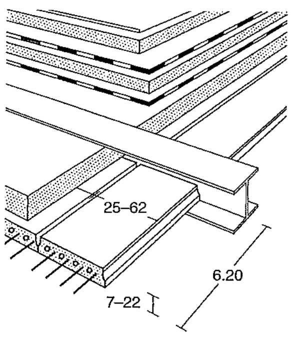
⓬ Double-T slab



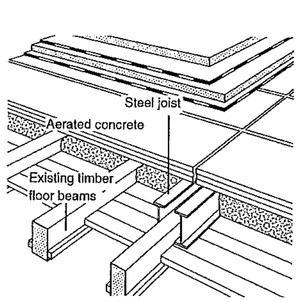
⓭ Reinforced concrete beam slab



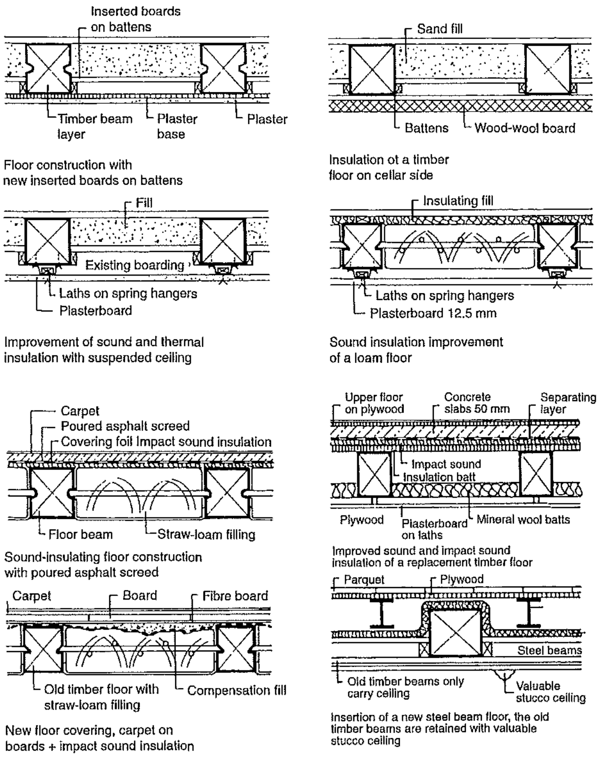
⓮ Composite slab



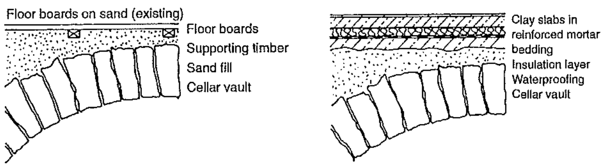
⓯ Steel joist floor with panel filling



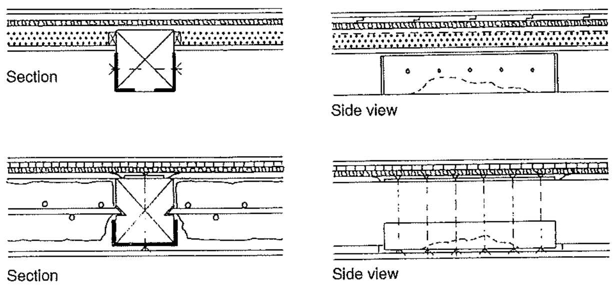
⓰ Old and new floor



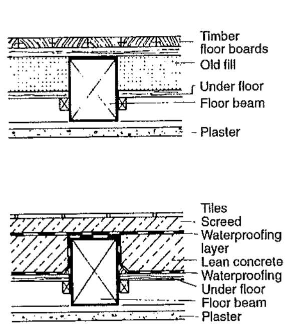
❶ Various methods of upgrading timber joist floors



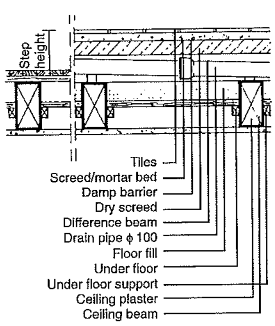
❷ Replacement of a boarded floor laid in sand



❸ Strengthening weak parts of joists in the span



❹ Conventional ways of waterproofing timber joist floors in old buildings



❺ Distortion of drain pipe under a new floor

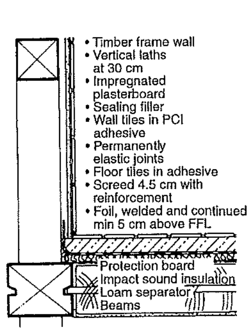
Floor slabs

Load-bearing floor joists in old buildings used to be designed empirically by the carpenter. The loads were mostly carried on transverse joists spanning one or more longitudinal support beams. In an old building book from 1900, a ratio of joist height to width of 5:7 is given as a guideline for the determination of joist size. The rule: half the room depth in decimetres = the joist height in cm. Because of this sizing, old timber joist floors often sag considerably, though this does not compromise structural safety as long as the permissible stresses are not exceeded.

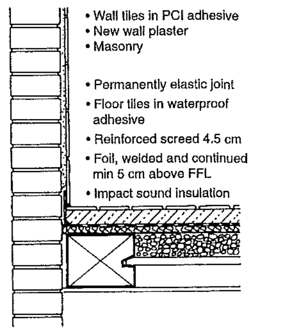
Refurbishment possibilities → ❶. Strengthen the timber joist by adding a second. Improve the load distribution by inserting additional floor joists or a steel beam → ❶. Shorten the span by inserting one or more additional support beams or a load-bearing cross wall. Alterations to the load-bearing structure should always be preceded by a precise survey of load-transferring and bracing functions. In order to guarantee the load transfers, all connections must be in firm contact.

Improvement in sound insulation can normally be achieved only through an increase in the weight of the floor, so the floor will probably have to be strengthened as well. Impact sound can be reduced by separating the walking surface from the structure and by using soft floor coverings → ❶.

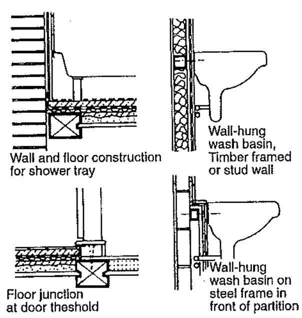
If new building standards are to be achieved, it will normally be necessary to change the entire floor structure → p. 55. The installation of wet rooms above timber joist floors requires particular attention because it will scarcely be possible to check for penetration of water and damp damaging the structure → ❹ – ❾.



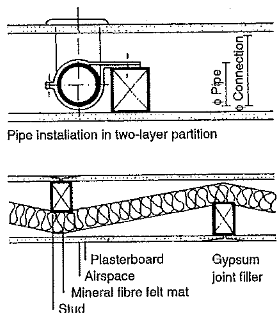
❻ Floor and wall details for wet rooms in a timber-framed building



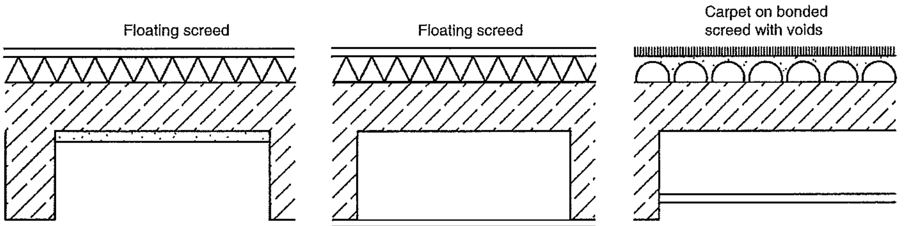
❼ Floor and wall details for wet rooms in a masonry building with timber joist floors



❽ Important details in wet rooms



❾ Sound-insulating double-leaf wall construction

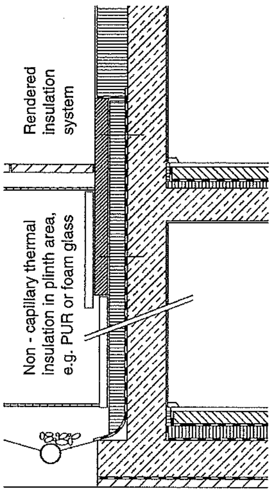


Shotcrete (approx. 3 cm) increases the cover to the reinforcement and thus improves fire and airborne sound insulation

Suspended ceilings must either provide the entire fire rating (here F90) or they may not be considered. Advantage: the impact sound insulation is also improved

Suspended F90 ceiling between the ribsin low rooms. If bonded screed is used, impact sound insulation can be improved by carpeting

1 Upgrading of concrete slabs in refurbishment or conversion of buildings



2 Improvement of an external wall with composite insulation system

Evaluation criterion	Testing method/equipment
presence of voids	hammering with hammer or steel rod, drag chain method
surface tension strength	Herlon device, Schenk-Trebel device etc.
compressive strength (non-destructive)	Schmidt hammer
crack widths	measuring magnifying glass, crack width ruler
alteration of crack widths	crack marks, dial gauge, inductive transducer
carbonisation	phenolphthalein test on freshly exposed substrate
presence of chlorides	spraying of silver nitrate (qualitative), Quantab process (semi-quantitative)
concrete cover of reinforcement	electromagnetic meters
corrosion activity	potential field measurement
degree of rusting of reinforcement	calliper

3 Methods of testing concrete quality (Kind-Barkansas → refs)

Environmental class	Example of environmental conditions	Concrete reinforcement (mm)			Pre-tensioning reinforcement (mm)		
		General	Slabs	C40/50	General	Slabs	C40/50
1	interior of residential and office buildings (only applies if no worse conditions were present for a significant time during construction)	15	15	15	25	25	25
2 2a	– rooms with high humidity (e.g. laundries) – external building elements – building elements in non-aggressive ground or water	20	15	15	30	25	25
2b	– external building elements exposed to frost – building elements in non-aggressive ground or water with frost – interior building elements with high humidity and frost risk	25	20	20	35	30	30
3	– external building elements exposed to frost and defrosting agents	40	35	35	50	45	45
4 also with frost	– building elements in splash zone or dipping into seawater, a part exposed to air – building elements in salty air (directly on coast)	40	35	35	50	45	45
5 5a	weakly chemically aggressive environment (gaseous, liquid, solid), aggressive industrial atmosphere	25	20	20	35	30	30
5b	moderately chemically aggressive environment (gaseous, liquid, solid)	30	25	25	40	35	35
5c	strongly chemically aggressive environment (gaseous, liquid, solid)	40	35	35	50	45	50

4 Minimum cover to reinforcement (Association of German Cement Industry → refs)

Old	B 15	B 20	B 25	B 30	–	B 40	–	B 50	–	B 60
New	C12/15	C16/20	C20/25	C25/30	C30/37	–	C35/45	C40/50	C45/55	C50/60

5 New descriptions of concrete strength (Association of German Cement Industry → refs)

Requirements

The existing condition must be surveyed and damage analysed before starting the repair of concrete buildings. The following points are particularly important:

Surfaces: damage through insufficient cover to the reinforcement. The cause may be the low requirements of earlier guidelines and, often, inappropriate construction. Carbonisation (conversion of alkaline concrete into acid through environmental effects) can lead to corrosion of the reinforcement, which results in spalling of the concrete surface.

Joints: elastic joints should be replaced after max. 10 years. If this is not done, damage can be caused to the structure by penetrating water (e.g. frost damage).

Building elements: if the walls or slabs are too thin for the fire protection and sound insulation requirements, then additional measures are necessary.

Building materials for concrete replacement:

- cement concrete and cement mortar (CC)
- plastic-modified cement concrete and cement mortar (PCC)
- reaction resin concrete and reaction resin mortar (PC). Mortar and concrete with artificial resin additives are not suitable for the improvement of fire protection requirements!

The surfaces must be cleaned and have the surface strength specified for the relevant treatment. Large areas of concrete surface can be removed and the reinforcement derusted by using high-pressure water jetting. If it is possible to provide sufficient thickness of concrete cover, then no further rust protection is necessary for the reinforcement. If only a thinner cover is possible, then the reinforcement must be protected against rust. In this case, the requirements for derusting are higher.

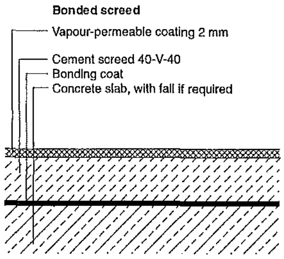
Building components

FLOOR SLABS

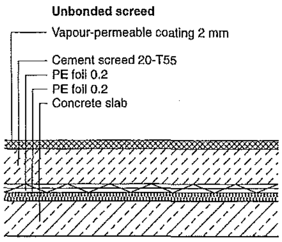
Slab construction
Refurbishment
Concrete repair
Floors

BS 8204
BS EN 13813
DIN 18560

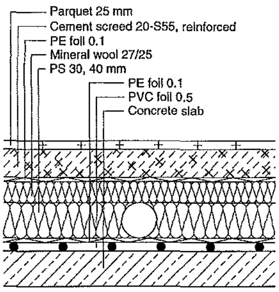
see also: Building physics pp. 471 ff.
Fire protection pp. 511 ff.
Heating pp. 532 ff.



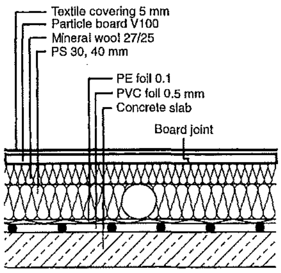
❶ Bonded screed (for industrial flooring), construction height approx. 4 cm, traffic load 10 KN/m²



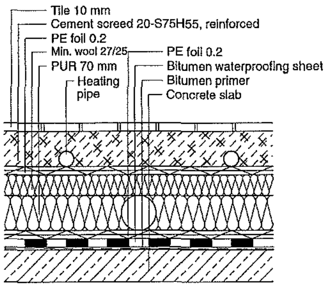
❷ Floor construction for subsidiary rooms in basement: construction height approx. 6 cm, traffic load 2 KN/m²



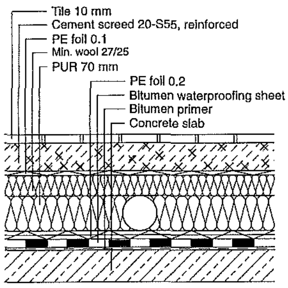
❸ Floor construction for slabs between living rooms: construction height approx. 14.5 cm, traffic load 2 KN/m²



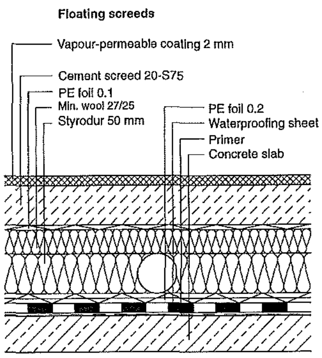
❹ as → ❸ but as dry screed: construction height approx. 10.5 cm, traffic load 2 KN/m²



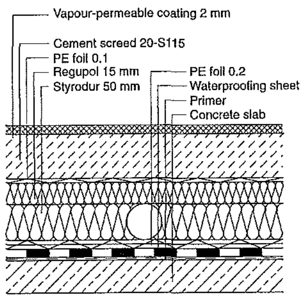
❺ Floor construction (underfloor heating) for living rooms above cold areas: construction height approx. 19 cm, traffic load 2 KN/m²



❻ as → ❺ but without underfloor heating: construction height approx. 17 cm, traffic load 2 KN/m²



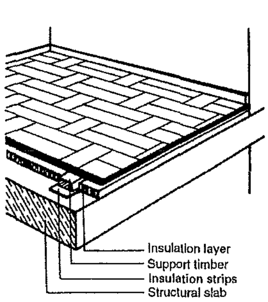
❼ Floor construction for above-ground office space: construction height approx. 16 cm, traffic load 5 KN/m²



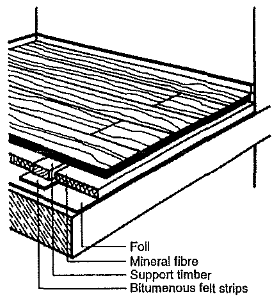
❽ as → ❼ but for higher loading: construction height approx. 19 cm, traffic load 10 KN/m²

Floor construction

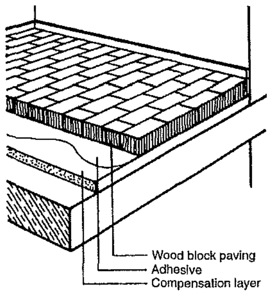
Floors are normally built up in many layers, consisting of covering, screed (if necessary, with substructure), separation, waterproofing and insulation layers. The nature, arrangement and thickness of these layers is determined by the requirements for thermal insulation, sound insulation and waterproofing (against water penetrating from above). Screeds can be constructed as **bonded screed** → ❶, **unbonded screed** → ❷ or **floating screed** → ❼. Screed can be based on cement, anhydrite or flowing anhydrite, or poured asphalt. The load-bearing capacity of screed depends on the thickness and quality of the material as well as the load-bearing capacity of other layers (e.g. insulation). The requirements for expansion joints also have to be observed.



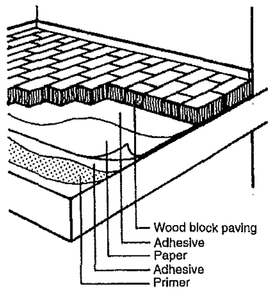
❾ Prefabricated parquet blocks on support timbers



❿ Tongue and groove boards on support timbers



⓫ Wood-block paving (rustic type) laid tight with surface treatment (living areas)



⓬ Wood-block paving (heavy duty) laid tight on flat-floated base concrete (industrial building)

Prefabricated screed (dry screed) is becoming more common as construction schedules become shorter. This can be made of mechanically fixed, engineered wood boards (e.g. resin-bonded boards), gypsum fibre board or gypsum plasterboard. It is laid floating on insulation or dry leveller fill → ❹ or on flooring sleepers.

Parquet and wood-block paving

Parquet is available in the form of parquet blocks, mosaic parquet blocks, made-up panels and parquet strip → ❾ – ❿. The surface layer consists of oak, or another parquet timber, in various grades.

Timber species for floorboards: softwood spruce/fir; for tongued and grooved floorboards: Nordic spruce/fir, American red pine and pitch pine.

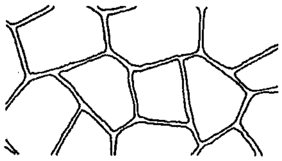
Wood-block paving is also available as end-on paving (square or round and laid on a sub-floor) → ⓫ – ⓬.

Floor coverings

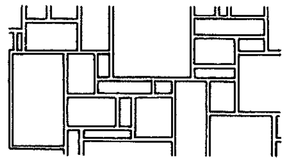
Natural stone slabs: Limestone, slate and sandstone slabs can be laid either with the natural roughness from splitting, or half or fully sanded → ❶ – ❷. Sawn slabs such as limestone (marble), sandstone and all volcanic stone types can have any surface treatment specified. The slabs are laid in a mortar bed or glued to screed.

Mosaic flooring consists of various materials such as glass, ceramic or natural stone and is laid in a mortar bed or glued → ❸ – ❽.

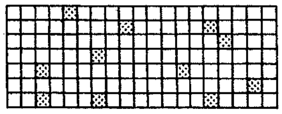
Ceramic floor tiles: stoneware and mosaic floor tiles are made of clay; they are sintered during the firing process so that they absorb almost no water.
They are therefore frost-resistant, acid-resistant to a certain degree and suffer little mechanical wear; but they are not resistant to oil → ❾ – ⓬.



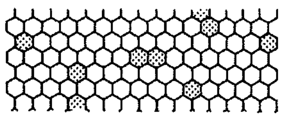
❶ Irregular laying of natural stone (crazy paving)



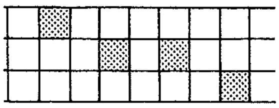
❷ Natural stone slabs in Roman bonding



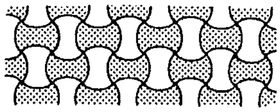
❸ Small mosaic squares 20/20, 33/33 mm



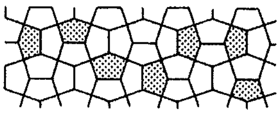
❹ Small mosaic hexagons 25/39, 50/60 mm



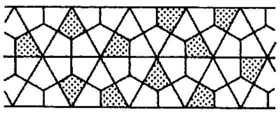
❺ Mosaic squares 50/50, 69/69, 75/75 mm



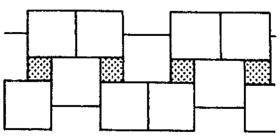
❻ Small mosaic, circular cut-out 35/35, 48/48 mm



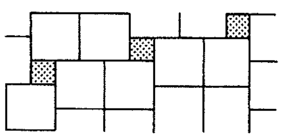
❼ Small mosaic, five-sided 45/32 mm



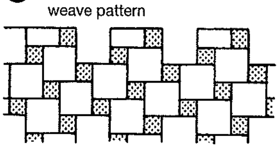
❽ Small mosaic in Essen pattern 57/80 mm



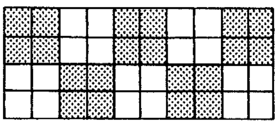
❾ Squares with smaller inserts, weave pattern



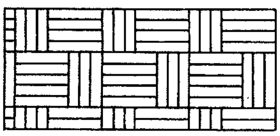
❿ Squares with smaller inserts 100/100, 50/50 mm



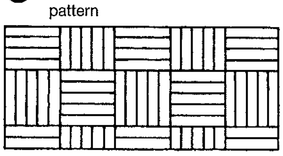
⓫ Squares with smaller inserts, displaced pattern



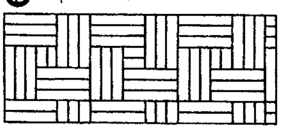
⓬ Squares with double chessboard pattern



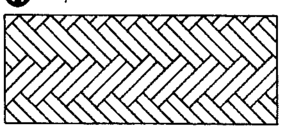
⓭ Open basket



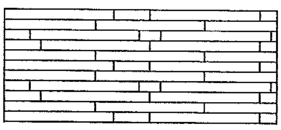
⓮ Square basket



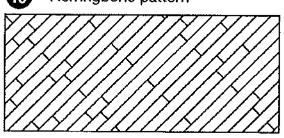
⓯ Open basket



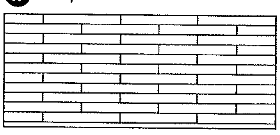
⓰ Herringbone pattern



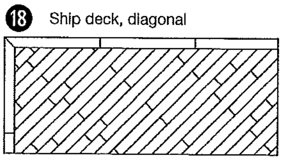
⓱ Ship deck



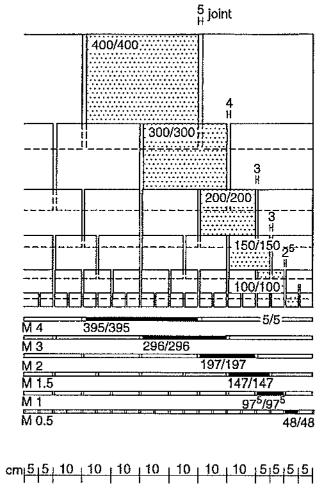
⓲ Ship deck, diagonal



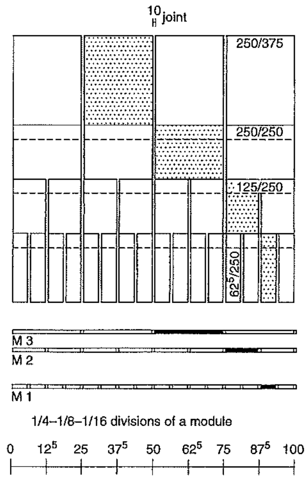
⓳ English



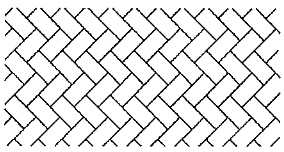
⓴ Ship deck with frieze



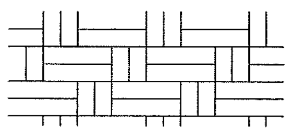
㉑ Modular system for stoneware



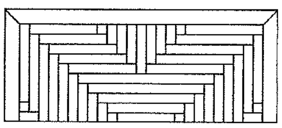
㉒ Modular system for split tiles



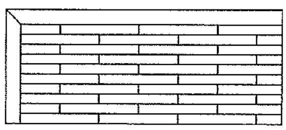
㉓ Herringbone



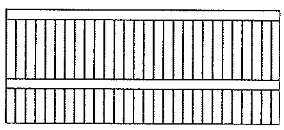
㉔ Weave pattern



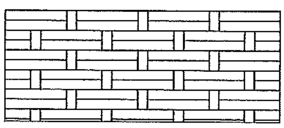
㉕ Herringbone with frieze



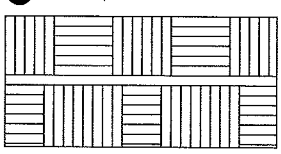
㉖ English with frieze



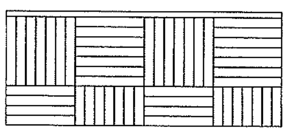
㉗ Ladder pattern



㉘ Burgundy pattern



㉙ Cube with strip pattern

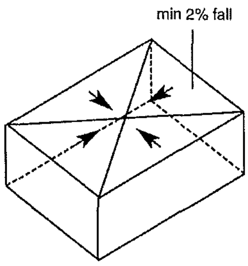


㉚ Cube pattern

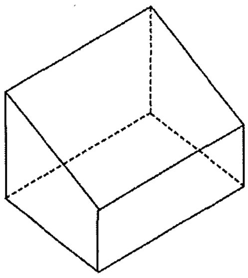
Roof shape and **roof pitch**: the selection of roofing material and the detailing of the **roof edges** at the verge and eaves have a decisive influence on the appearance of buildings. 1 – 16 show the basic forms of roofs and roof projections.

Roof covering	Pitch range	Usually
accessible paved roof	2–4°	3–4°
wood cement roof	2.5–4°	3–4°
felt roof, gravel covered	3–30°	4–10°
felt roof, double	4–50°	6–12°
zinc roof, double standing seams	3–90°	5–30°
felt roof, single	8–15°	10–12°
steel sheeting roof	12–18°	15°
interlocking tile roof, 4 sides	18–50°	22–45°
shingle roof (canopy 90°)	18–21°	19–20°
interlocking tile roof, normal	20–33°	22°
zinc and steel corrugated roof	18–35°	25°
fibre cement corrugated roof	5–90°	30°
artificial slate roof	20–90°	25–45°
slate roof, double decked	25–90°	30–50°
slate roof, normal	30–90°	45°
glass roof	30–45°	33°
clay tiles, double decked	30–60° y	45°
clay tiles on battens	35–60°	45°
clay tiles, pantiled	40–60°	45°
clay tiles, split stone	45–50°	45°
thatch	45–80°	60–70°

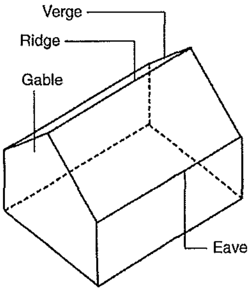
17 Roof pitches for various roof coverings



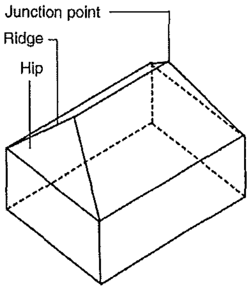
1 Flat roof



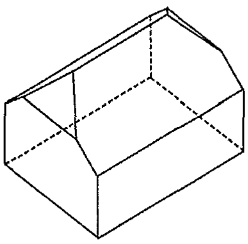
2 Single-pitch (monopitch) roof



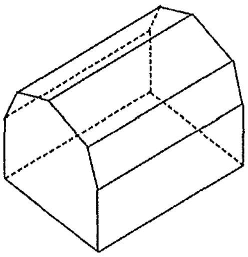
3 Gabled roof



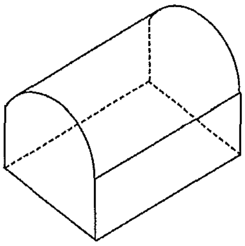
4 Hipped roof



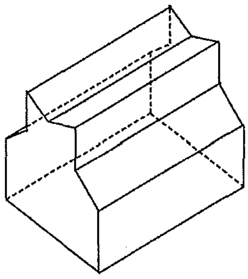
5 Half-hipped roof



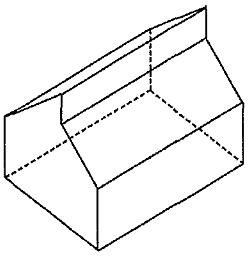
6 Mansard roof



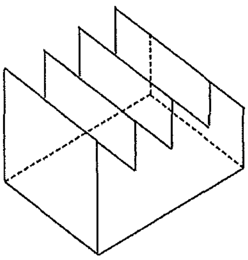
7 Barrel roof



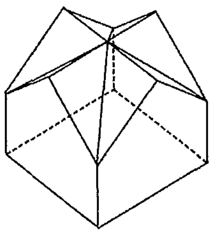
8 Compound roof with central gutter



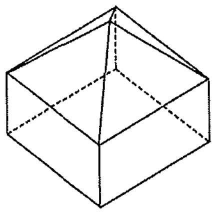
9 Two single pitches



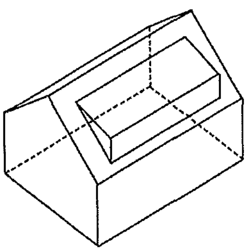
10 Northlight or saw-tooth roof



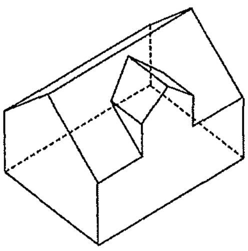
11 Four gables



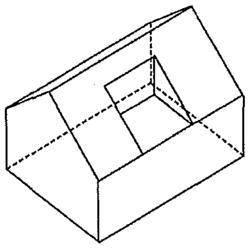
12 Square hipped roof



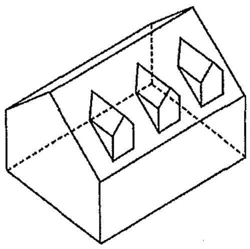
13 Wide dormer with sloping roof



14 Gabled dormer window



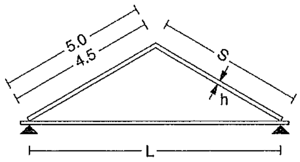
15 Roof cut-out



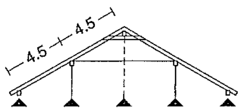
16 Single pitched-roof dormers

ROOFS

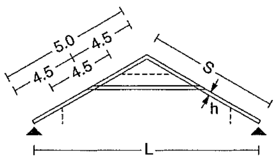
Pitched Roofs



❶ Couple roof

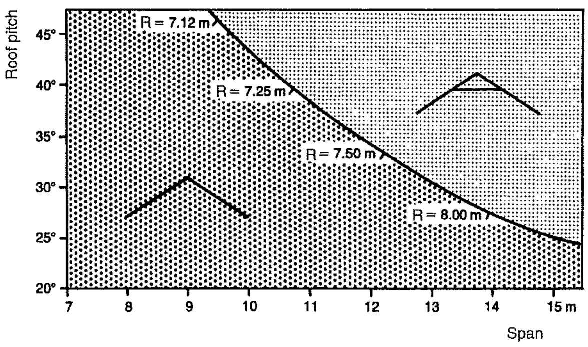


❷ Purlin roof

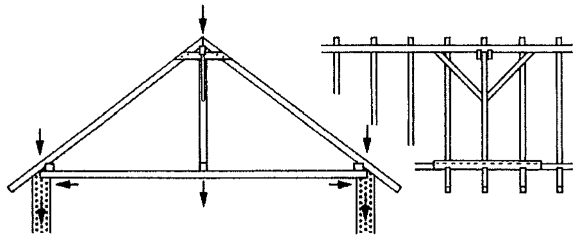


❸ Collar roof

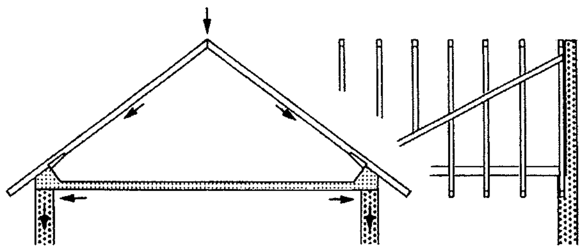
Roof pitch in degrees	Span L in m	Height of building element h
15–40	10–20	$h^2 \frac{1}{25} \times S$
30–60	10–20	$h^2 \frac{1}{30} \times S$



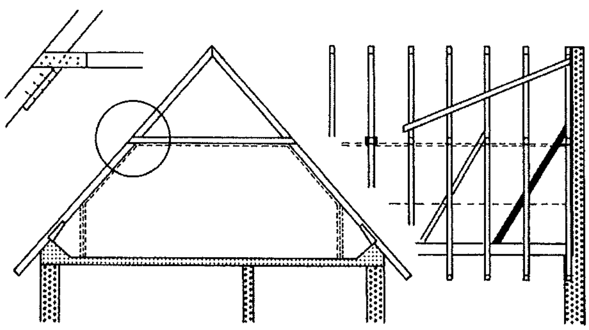
❹ Couple or collar roof: economic limits, slope vs span. R = rafter length



❺ Strutless purlin roof with centre hanger



❻ Couple roof



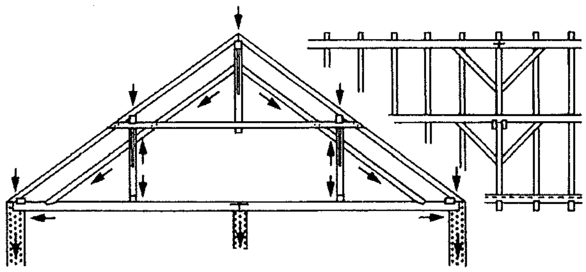
❼ Collar roof with loft conversion

The roof forms the upper edge of a building and protects it from rain and atmospheric influences (wind, cold, heat). A roof consists of a supporting structure (**roof frame, roof truss**) and **roof covering.** The design of the roof truss depends on material (timber, steel, reinforced concrete), roof pitch, loading (self-weight, traffic load, wind and snow load), etc. Roof trusses for pitched roofs are traditionally divided into **purlin roofs** and **couple roofs.** These vary according to the structural function of the members → ❶ – ❸.

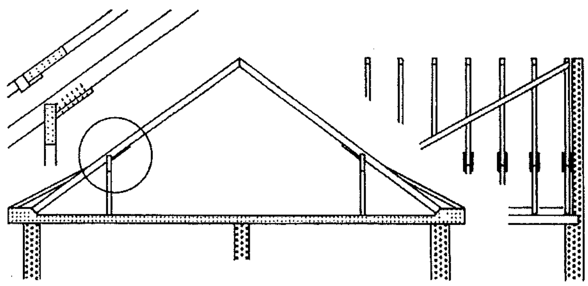
Purlin roof

The purlin roof is the simplest form of roof construction. The rafters are supported by cross-beams called **purlins**, which are either mounted directly onto the masonry (monopitch principle) or form load-bundling support beams as part of a roof truss, supported by various arrangements of **posts.** Purlin trusses in relatively narrow houses mostly have a single row of posts in the centre of the roof, but wider roofs have two rows of posts or more → ❷.

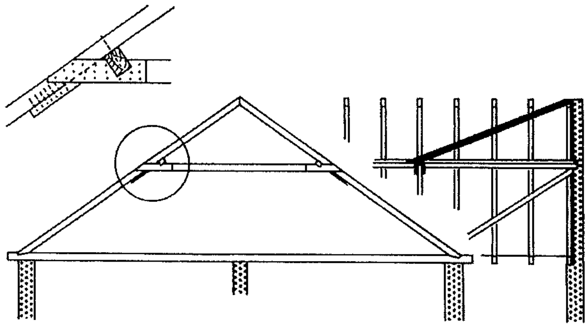
There are various further forms of construction for wider span roofs, like 'strutted purlin' → ❽ and 'centre hanger' → ❺.



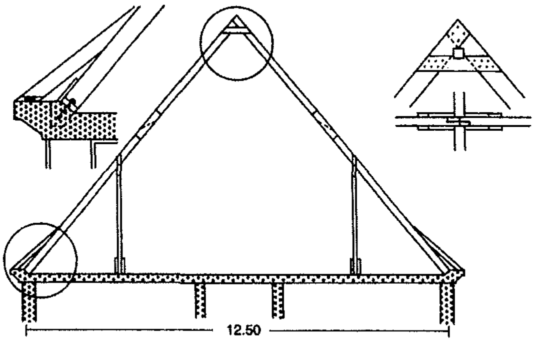
❽ Strutted purlin roof



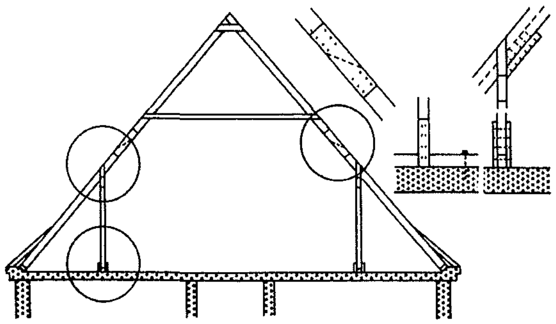
❾ Couple roof with hangers



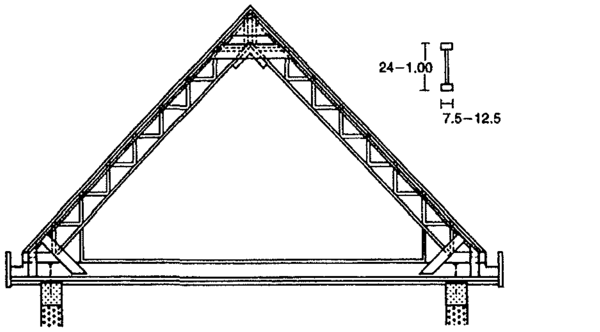
❿ Collar roof with purlins



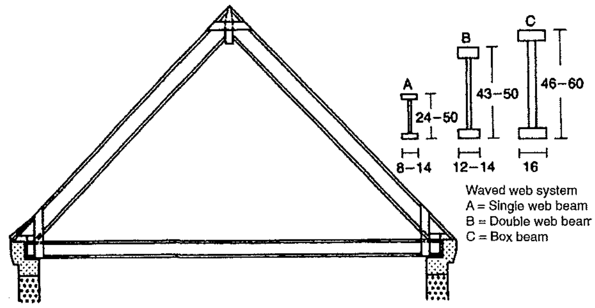
❶ Couple roof with hangers and jointed rafters



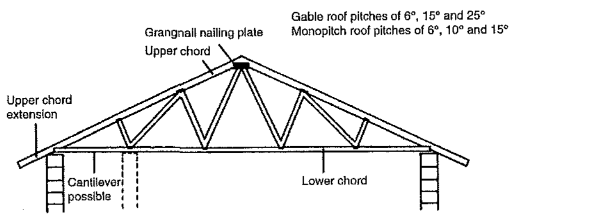
❷ Couple roof with jointed rafters, stiffened at three points



❸ Couple roof in timber framing with lifetime-guaranteed glued joints and 45° inclined struts as twin supports; span ≦25 m



❹ Couple roof with composite, corrugated web beams (waved web system); ratio of profile height to span 1:15–1:20

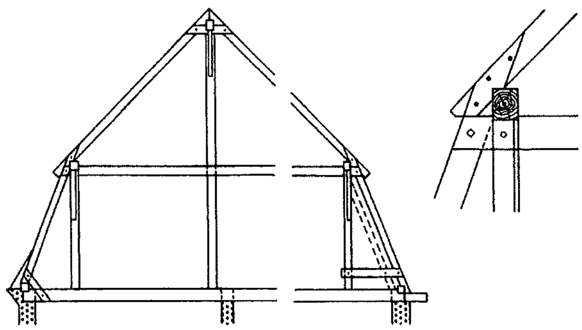


❺ Euro prefabricated truss and gang-nail system: depending on octametre sizes, for flat roof, single-pitch and two-pitch roofs

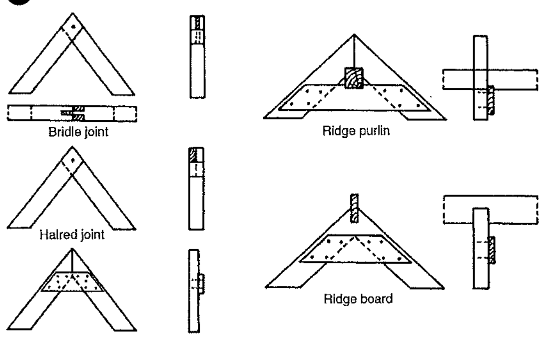
Couple roof

The couple roof is a structural system in which **two rafters and a ceiling joist** (or the corresponding strips of a solid ceiling slab) form a **rigid triangle** → p. 86 ❶.

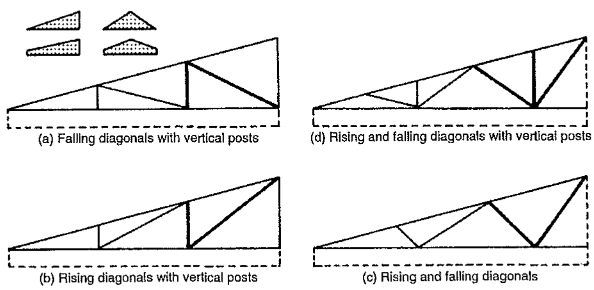
The weight of the roof is transferred to the external walls without loading the ceiling. This makes possible large roof spaces without posts. The necessary joint to transfer tension at the junction of rafter and ceiling joist traditionally leads to the characteristic change of roof pitch in couple roofs, which is constructed with a sprocket fixed at the top to the rafter and at the bottom to the projecting end of the ceiling joist → p. 86 ❾ (modern couple roofs with upstands at the edge of the solid ceiling slab 'rafter shoes') can be constructed without this change of pitch → p. 86 ❻). Very wide buildings (with rafter lengths of more than 4.5 m) lead to uneconomical rafter sections; and in these cases they are braced with a collar → p. 86 ❼. **Collar roofs** are suitable for buildings up to 12 m wide (rafter length up to 8 m, collar up to 4 m). Much larger widths are possible with modern structures (e.g. latticed beam → ❸, composite, corrugated web beam – waved web system → ❹) or with gang-nail trusses → ❺.



❻ Mansard roof



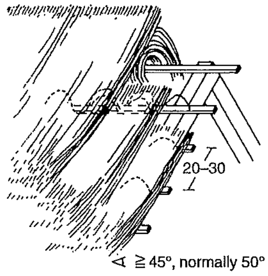
❼ Butt joint with fishplate



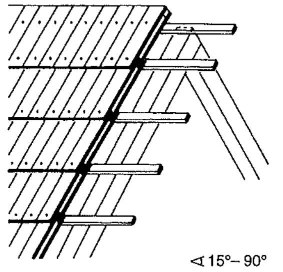
❽ Timber truss forms and bracing

Building components

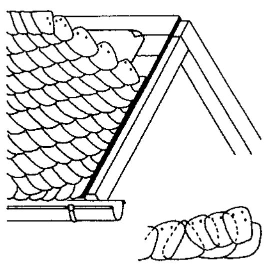
ROOFS
Roof shapes
Pitched roofs
Flat roofs



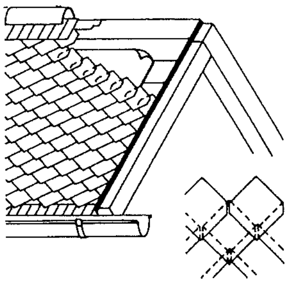
❶ Reed thatch, load 0.70 KN/m²



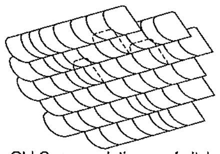
❷ Wood shingle roof, load 0.25 KN/m²



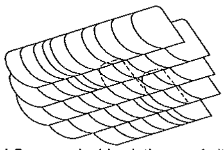
❸ 'Old German' slate roof, load 0.45–0.50 KN/m² → ❺ – ❽



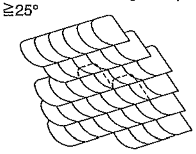
❹ English slating with fibre cement slates, load 0.45–0.50 KN/m²



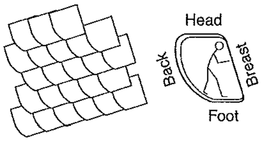
Old German slating, roof pitch ≧25°



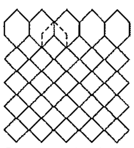
Old German double slating, roof pitch ≧22°



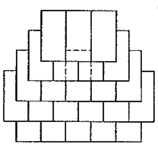
❺ ≧25° fish scale slating



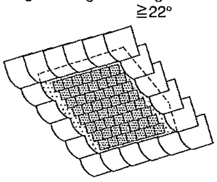
❻ ≧25° curved-cut slating



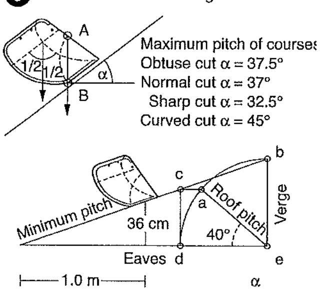
Sharp angle slating ≧30°



English slating ≧22°



❼ Curved-cut slating with solar elements



Roof pitch a–e, any large circle d–b, construct a vertical d–c; connect point a–c parallel to the eaves: c–b gives the minimum pitch of the slating courses.

❽ Minimum angle of truss, e.g. 40°

Roof coverings

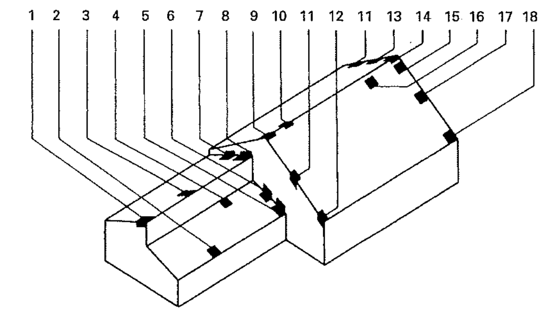
Reed thatching → ❶: 1.2–1.4 m long, on battens, spacing 20–30 cm, fixed with ends upwards in a thickness of ≧28 cm (better 35–40 cm). Lifetime in sunny districts 60–70 years, half that in wet districts.

Wood shingle roof → ❷: of oak, beech, larch, pine or, unusually, spruce. The lifetime of wooden shingles depends on the quality and treatment of the material, the intensity of precipitation and the pitch of the roof. Rule of thumb: degrees of roof slope = years of lifetime. Wooden shingles are suitable for covering all sorts of roof.

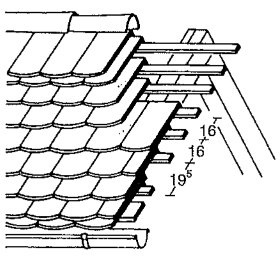
Slate → ❸ – ❽ (at pitches of 15–90°) on ≧24 mm thick boarding made of 12 cm wide planks. Sanded roofing felt (200 gauge) protects against dust and wind. Lap ≧8 cm (better 10 cm). Various types of slating are used for roof and wall covering in Germany: 'exclusive', 'Old German' and 'wild', as well as 'decorative slating' (mostly template slates such as shingle, sharp angle, fish scale, octagonal etc.)

Reasonably priced slating types: rectangular and curved-cut template. Template slating is also suitable for artificial slate.

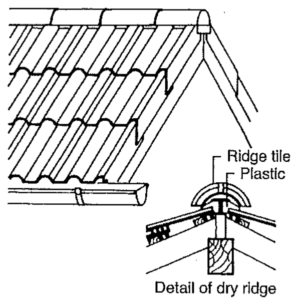
1 mono-pitch: edge tile, corner tile right
2 eaves tile
3 mono-pitch roof tile
4 wall connecting tile
5 eaves: wall connecting, corner tile right
6 wall connecting tile right
7 wall connecting tile left
8 lean-to roof: wall connecting, corner tile left
9 ridge end tile left
10 ridge and hip tile
11 edge tile left
12 eaves edge tile left
13 ridge connecting edge tile, corner tile left
14 ridge starting tile right
15 ridge edge connecting tile corner tile right
16 ridge connecting tile
17 edge tile right
18 eaves edge corner tile right



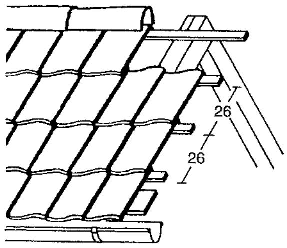
⓫ Special tiles



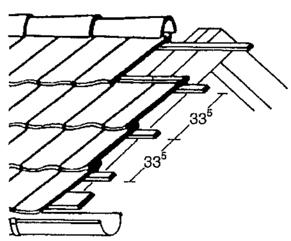
❾ Double-lap tiling ('beaver tail'), heavy roof covering, load 0.60 KN/m², 34–44 tiles/m²



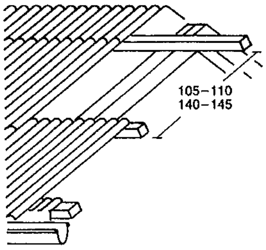
❿ Concrete tiles, 0.60–0.80 KN/m², pitch 18°



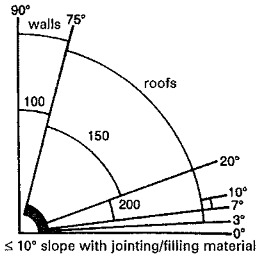
⓬ Pantile roof, lightweight, load 0.50 KN/m²



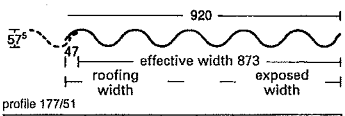
⓭ Interlocking clay tile roof, load 0.55 KN/m²



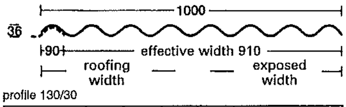
❶ Corrugated cement fibre roofing with shaped pieces for eaves and ridge, load 0.20 kN/m²



❷ Minimum roof pitches → ❶ and lap lengths

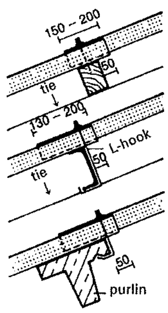


length (mm)	2500	2000	1600	1250	thickness 6.5
width (mm)	920	920	920	920	weight 16–32 kg

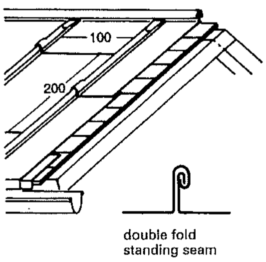


length (mm)	2500	2000	1600	1250	thickness 6.0
width (mm)	1000	1000	1000	1000	weight 15.8–31.5

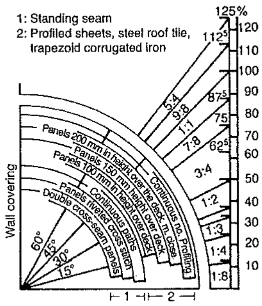
❸ Corrugated cement fibre roofing sheets



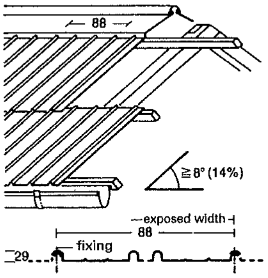
❹ Methods of fixing



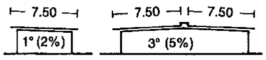
❺ Metal sheet roof with welted joint construction, load 0.25 KN/m²



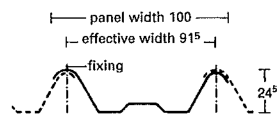
❻ Minimum roof pitch for roof covering of galvanised steel sheet



❼ Steel pantile roofing, load 0.15 kN/m²

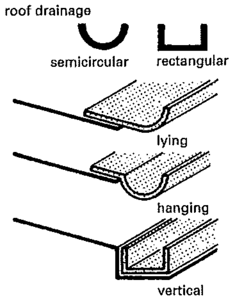


length (mm)	9000	7500	4000	thickness 8.0
width (mm)	1000	1000	1000	weight 19kg/m



❽ Large elements for roof and wall (Canaleta)

roof drainage



❾ Possible shapes and locations of gutter

Zinc sheet DIN 9721 at least 0.7 mm	(Zn)
Gutter brackets: zinc-coated strip steel	(St 2)
Galvanised strip steel DIN 1541 leaded	(St 2)
Gutter bracket: galvanised strip steel	(St 2)
Semi-hard copper sheet DIN 1787	(Cu)
Gutter brackets: flat copper	(Cu)
Aluminum sheet cut in half DIN 1725	(Al)
Gutter brackets: galvanised strip steel	(St 2)

Specification:
(example: semi-circular gutter 333 Zn 0.75 mm; with gutter bracket 333 St Zn)

❿ Materials

Roof coverings (continued)

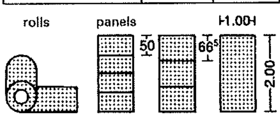
Cement fibre roof → ❶ – ❷ composed of corrugated sheets with purlin spacing of 70–145 cm for 1.6 m sheets, of 1.15 and 1.175 m for 2.50 m sheets; lapped 150 or 200 mm.

Sheet metal roof → ❺ – ❼ of zinc, titanium-zinc, copper, aluminium, galvanised steel sheet etc. Many special shapes available for ridge, eaves, edge etc. Copper sheeting is in commercially produced sizes → ⓬. Copper has the highest elongation at break of any metal sheeting and is therefore suitable for embossing, pressing, stretching and compressing. The typical patina of copper roofing is very popular. Combination with aluminium, titanium-zinc and galvanised steel should be avoided, but with lead and high-grade steel there is no problem. Copper roofs are impermeable to water vapour and thus particularly suitable for cold roofs → p. 90.

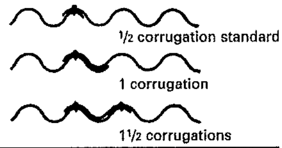
	kN/m²
'beaver-tail' tiles and 'beaver-tail' concrete tiles	
with underlay incl. underlay parts	0.60
clay tiles, single or double lap	0.80
extruded interlocking clay tiles	0.60
interlocking tiles, reform pantiles, interlocking pantiles, flat tiles	0.55
interlocking tiles	0.55
Spanish tiles, concave tiles	0.50
pantiles	0.50
large-format pantiles (up to 10 per m²)	0.50
Spanish tiles without mortaring, 0.70 with mortaring	0.90
metal sheeting, aluminium roof (aluminium 0.7 mm thick) incl. boarding	0.25
copper roof with double seams (copper sheet 0.6 mm thick) incl. boarding	0.30
double standing seam roof of galvanised seamed sheeting (0.63 mm thick) including underlay and boarding	0.30
German slate roof on boarding incl. felt underlay and boarding	
large format (360 mm × 280 mm)	0.50
small format (about 200 mm × 150 mm)	0.45
English slate roof incl. battens	
on battens with double lap	0.45
on boarding and underlay incl. boarding	0.55
Old German slate roof on underlay and boarding	0.50
with double lap	0.60
steel pantile roof (galvanised steel sheets)	
on battens incl. battens	0.15
on boarding incl. underlay and boarding	0.30
corrugated steel roof (galvanised steel sheets) incl. fixings	0.25
zinc roof with cover strips of zinc sheet incl. boarding	0.30

⓫ Loads per 1 m² pitched roof surface (without rafters, purlins or trusses, but including battens). If mortar-pointed, add 0.1 kN/m².

supplied form	rolls	panels
length (m)	30–40	2.0
max. width (m)	0.6 (0.66)	1.0
thickness (mm)	0.1–2.0	0.2–2.0
specific wt (kg/dm³)	8.93	8.93



⓬ Form and dimensions of rolled copper material for strip and sheet roofing



roof depth eaves/ridge	profile ht 18–25mm	26–50mm
up to 6m	10° (17.4%)	5° (8.7%)
6–10m	13° (22.5%)	8° (13.9%)
10–15m	15° (25.9%)	10° (17.4%)
over 15m	17° (29.2%)	12° (20.8%)

8–10°	200mm with sealing of overlap
10–15°	150mm without sealing of overlap
over 15°	100mm without sealing of overlap

⓭ Corrugated sheet metal roofing, minimum roof pitch, side laps

Roof area to be drained with semi-circular gutters (m²)	Guideline size of gutters (mm ∅)	Cut lengths for metal gutters (mm)
up to 25	70	200
25–40	80	200 (10-part)
40–60	90	250 (8-part)
60–90	125	285 (7-part)
90–125	150	333 (6-part)
125–175	400 (5-part)	400 (5-part)
175–275	200	500 (4-part)

Gutters should generally be installed on a slope as greater flow speed helps prevent blocking, corrosion and freezing. Guttering supports normally consist of galvanised steel strips, width 20–50 mm and thickness 4–6 mm.

⓮ Guideline sizes for gutters

Roof area to be drained with round downpipes (m²)	Guideline size of downpipe (mm ∅)	Cut lengths for metal pipes (mm)
up to 20	50	167 (12-part)
20–50	60	200 (10-part)
50–90	70	250 (8-part)
60–100	80	285 (7-part)
90–120	100	333 (6-part)
100–180	125	400 (5-part)
180–250	150	500 (4-part)
250–375	175	
325–500	200	

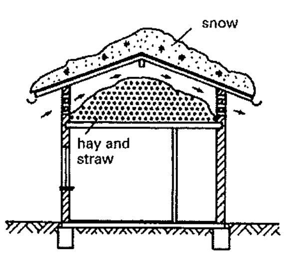
Fixing with pipe clips (corrosion-protected), whose inner diameter is that of the downpipe. Minimum distance of downpipe from the wall 20 mm. Pipe clip spacing 2 m.

⓯ Guideline sizes for downpipes

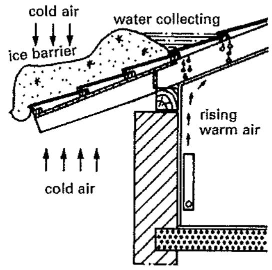
Building components

ROOFS
Roof shapes
Pitched roofs
Flat roofs

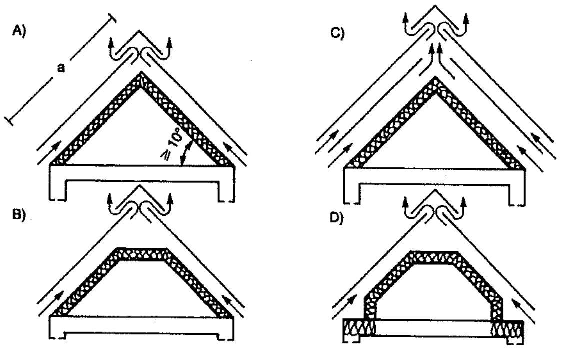
see also: Building physics pp. 465 ff.



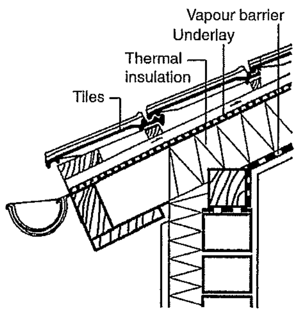
❶ Cross-section through an Alpine farmhouse with hay loft



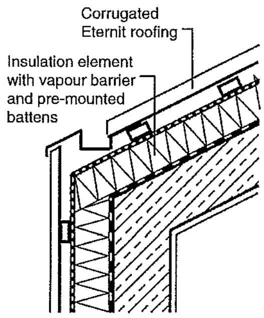
❷ Ice blockage problem



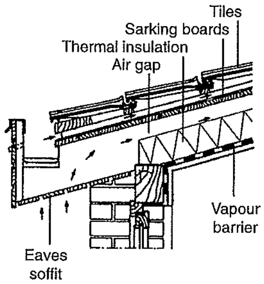
❸ Arrangement of thermal insulation in roof spaces (cold roofs)



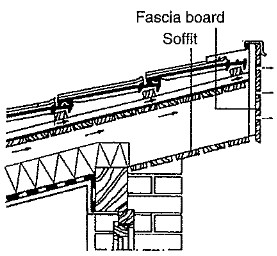
❹ Normal warm roof



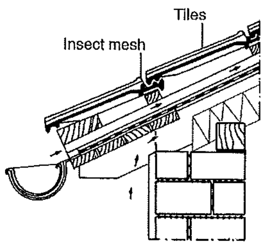
❺ Concrete roof with warm roof construction



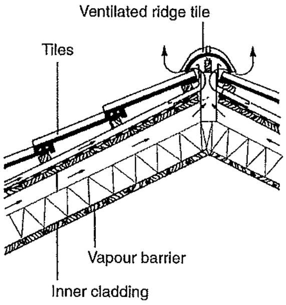
❻ Cold roof: eaves detail, eaves soffit with ventilation slots



❼ Cold roof (monopitch): ridge detail, fascia board with ventilation slots



❽ Cold roof: eaves detail with exposed rafters



❾ Cold roof: ridge detail

Roof spaces

Spaces under pitched roofs were formerly used as naturally ventilated 'hay lofts' for the storage of the harvest. The rooms below were protected from cold by the stored produce → ❶. Today, roof spaces are converted into habitable rooms. The roof construction must comply with additional building physics requirements.

Building methods

Thermally insulated roofs can be divided into **ventilated** and **non-ventilated** construction. In addition to the ventilation space between roof covering and underlay (or lower layer of roof), which is required in both cases, ventilated roof construction has an additional ventilation gap between underlay and thermal insulation, to remove spray and condensate.

Ventilated roofs require additional rafter depth and work properly only with a correctly installed vapour barrier and functioning roof ventilation. Therefore the building industry commonly prefers **unventilated roof construction.**

Standard build-up of layers

Roof coverings, battens → pp. 88–89

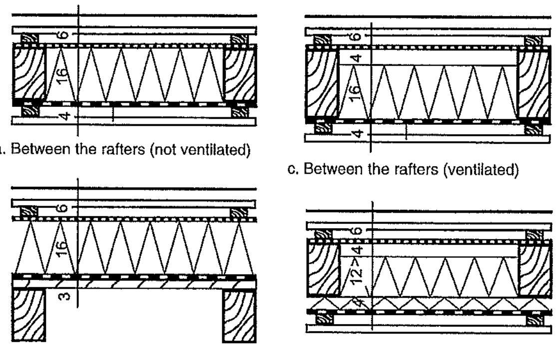
Underlay of plastic mesh-reinforced foil or vapour-permeable plastic sheeting serves to carry away any spray water or snow penetrating under the roof covering.

Roof boarding of tongue and groove boards with applied waterproofing (e.g. welded bitumen sheeting) is installed instead of underlay in conditions of severe exposure.

The **air gap** in ventilated roof construction serves as an additional ventilation layer (e.g. to remove condensation). The necessary ventilation cross-sections depend on the roof pitch.

Thermal insulation is generally in the form of mineral wool roll material and is installed between and under the rafters or as prefabricated insulation elements, sometimes with interlocking, vapour barrier on the room side and battens fixed to the rafters → ❿.

The **vapour barrier** is under the thermal insulation to prevent condensation inside the roof construction. When the vapour barrier is installed, it is important that all air flow between interior and roof construction is prevented. Any penetration points, laps and junctions with building elements must be carefully sealed.
Inner cladding is normally plasterboard on support construction (pay attention to the possibility of cracks!).

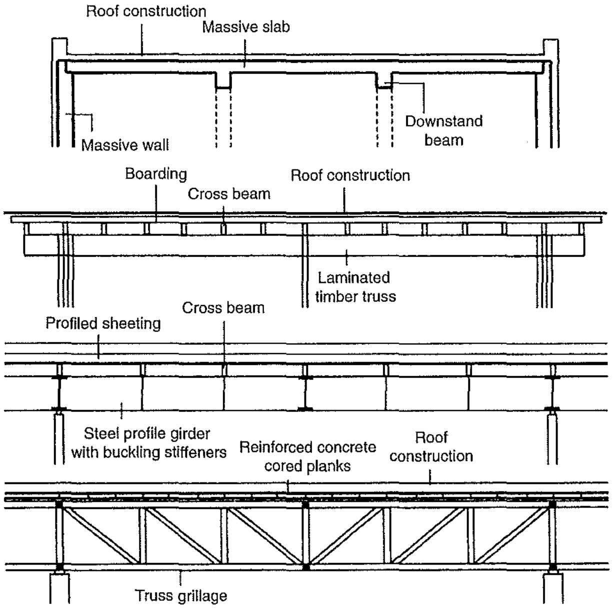


a. Between the rafters (not ventilated)
c. Between the rafters (ventilated)
b. On the rafters (not ventilated)
d. Between/under the rafters (ventilated)

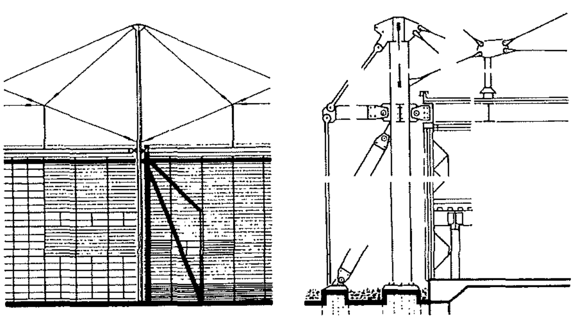
❿ Location of thermal insulation for pitched roofs converted for storage

Building components

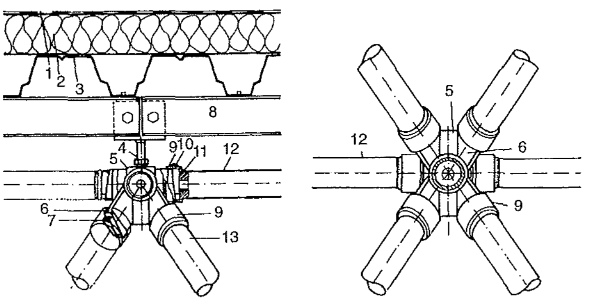
ROOFS
Roof shapes
Pitched roofs
Flat roofs



❶ Flat roof structures (selection): slabs, trusses, beam grillages

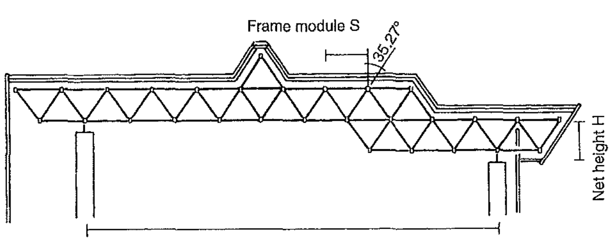


❷ Guyed structure: Fleetguard factory, Quimper Arch.: Rogers & Partner



1 Root covering 2 Insulation 3 Steel profiled sheeting 4 Raising piece
5 Centre piece 6 Wedge connection 7 Wedge 8 Purlin, rail
9 Cage ring 10 Grooved dowel pin 11 Wedge cheek 12 Horizontal tube
13 Diagonal tube

❸ Upper and middle nodes of space frames (KEBA tube nodes)



❹ Space frame with KEBA tube node connections (example), details → ❸

Flat roofs are defined as roofs with a slope of up to 5%. Flat roofs without slope are possible as a special construction in exceptional cases. Flat roofs should generally have a minimum slope of 2%. On account of unavoidable flatness tolerances and deflection of the construction, however, it is recommended to construct flat roofs with a minimum slope of 5% (3°).

Construction
There are many different structural types for flat roofs. The basic difference is between **planar** and **linear** structural systems:

Planar structures are based on flat elements spanning one or two axes, with point or linear supports and loaded at right angles to their plane (e.g. floor slabs, roof slabs, beam grillages, space frames).

Linear structures are systems comprising parallel-laid beam elements (e.g. full-web steel beams, trussed beams, cable-trussed beams) and intermediate components not laid in the direction of the beam (e.g. cross-beams with boarding) to transfer the roof loading.

Both structural types are differentiated into various degrees of resolution of the structural elements, in addition to the material:

Slabs → ❶
Flat roofs are mostly constructed as flat solid reinforced concrete slabs. These are fire-resistant, not susceptible to damp and form a stable structural system in combination with solid walls.Their disadvantage lies in their high dead weight, wet installation and poor thermal and sound insulation. Movement resulting from thermal expansion, creep or shrinkage must be compensated with additional insulation layers and appropriately detailed bearings and joints.

Truss structures → ❶ – ❷
Trusses are linear structures. Commercially available truss beams can be made of timber, steel or pre-cast reinforced concrete with intermediate elements of various materials. Longer spans may involve: truss beams of squared timber or with steel struts, laminated timber beams, box beams of plywood or laminated timber, specially produced full-web girders with high web plates and bracing against buckling, and castellated or lattice beams. Additional guying and cable trussing can reduce the cross-section of the beams, effecting light and delicate structures.

Beam grillages → ❶ – ❷
Beam grillages are planar structures made of wide-span beams laid in both directions and crossing in a plane. They are normally composed of prefabricated components (e.g. of laminated timber beams with node plates or steel trusses) and are particularly suitable for roofing over industrial sheds etc. If there are fire protection requirements, then additional measures must be undertaken to protect the structure.

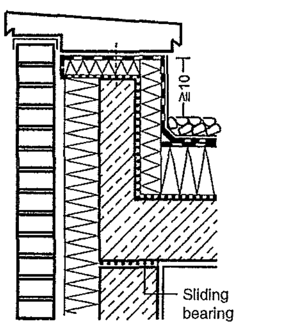
Space frames→ ❸ – ❹
The space frame is a further development of the beam grillage. Steel rods are connected with spherical nodes to form stiff three-dimensional structures which require no additional stiffening.

ROOFS
Roof shapes
Pitched roofs
Flat roofs

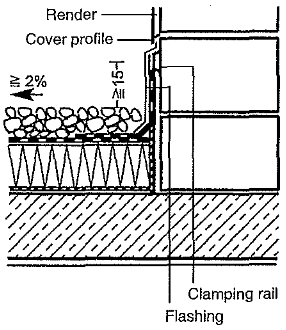
BS 8298
BS EN 12730
DIN 18531

Flat Roof Guidelines, Central Association of German Roofers

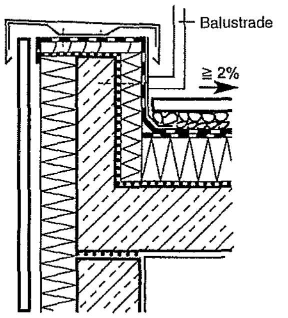
see also: Building physics pp. 471 ff.



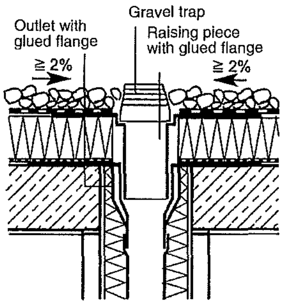
1 Parapet with artificial stone coping



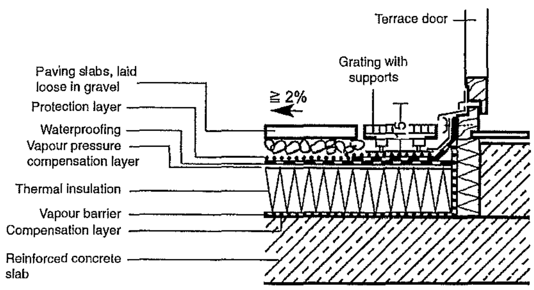
2 Wall connection



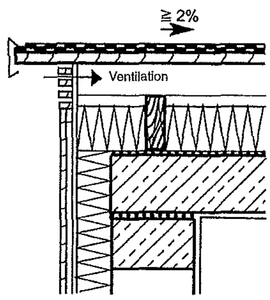
3 Roof edge detail (terrace)



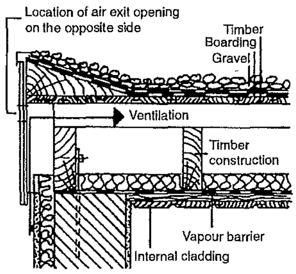
4 Drain detail with sealing connection



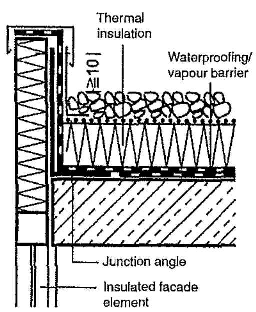
5 Terrace connection with extended grating



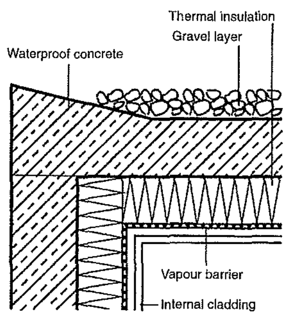
6 Cold roof above reinforced concrete slab



7 Cold roof in timber construction



8 Upside-down roof



9 Watertight concrete roof with internal insulation

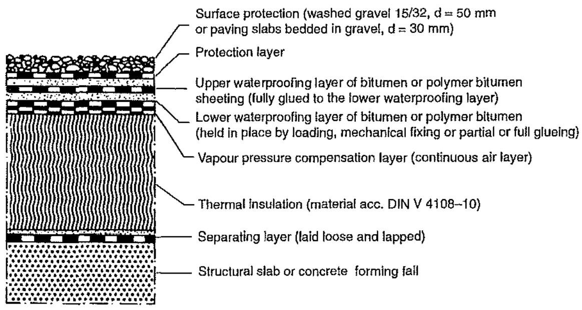
ROOFS

There are two methods of building a flat roof from the building physics perspective:

Non-ventilated, single-layer construction ('warm roof'), in which the load-bearing structure, vapour barrier, thermal insulation and waterproofing (including intermediate layers) form a composite element.

This can either be the conventional construction → 10, or an **'upside-down roof'** → 8 (waterproofing and vapour barrier are applied as one layer directly onto the load-bearing construction and the closed-cell insulation is loosely laid on top and secured with a gravel layer), or a combination of both construction types (e.g. a '**plus roof**'), or with **internal insulation** → 9.

Ventilated two-layer construction ('cold roof'), where there is a ventilation layer between the waterproofing (and its sub-structure) and the thermal insulation → 6 – 7. The advantage of this arrangement (evaporation of condensation) is, however, effective only if the through-ventilation is fully functional and a defect-free vapour barrier is installed on the inner side of the construction. Otherwise, the waterproofing acts as a **wrongly positioned vapour barrier,** which can cause the roof construction to become damp!



10 Standard construction of a warm roof with heavy surface protection and multi-layer waterproofing

Standard construction (warm roof) → 10
Surface protection can either be heavy (gravel layer – depth ≧5 cm, slabs laid in a bed of stone chips, or an extensive green roof) or lightweight (pre-applied gravel covering of bitumen sheeting) to prevent the formation of bubbles, temperature shocks, mechanical stress to the waterproofing or UV damage.

Protection layers (e.g. PVC protective sheeting, synthetic fleece, rubber granulate protection mats, protection against penetrating roots), waterproofing with many layers of bitumen sheeting and polymer-bitumen sheeting (fully glued to each other) or a single layer of plastic or elastomer waterproofing membrane. The waterproofing can be held in place by a superimposed load, mechanical fixing, or full or partial gluing.

Vapour pressure compensation layer: ribbed felt or holed bitumen sheeting, to prevent bubble formation resulting from evaporated residual dampness or the construction layers above.
Insulation is provided by thermal insulation boards (cork, rigid foam, fibre insulation or foam glass), laid without joints or with all-round interlock edges.

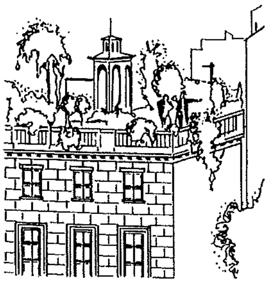
Separation/compensation layer: mostly loosely laid.
Load-bearing construction on a slope → p. 91, with sliding bearings on account of thermal expansion (consequent formation of a sliding joint over the load-bearing walls and separation of internal wall and slab. Glue Styrofoam strips to the underside of the slab in advance)

Roof planting

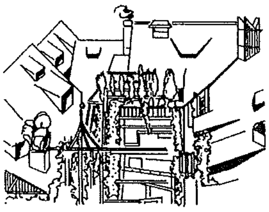
The Babylonians were constructing roof gardens and green roofs as long ago as the 6th century BC. In Berlin around 1890, farmhouses were covered with a layer of soil for fire protection purposes, causing plants to grow. In the 20th century, during the classic modernist period and with the introduction of flat roofs, the almost forgotten green roof was rediscovered.

Properties of planted roofs

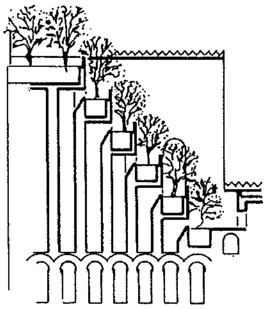
1. Insulation, due to the air layer within the plants and the growing layer (corresponding to soil) with its roots, and also through warmth from microbial processes
2. Sound insulation and thermal storage capacity
3. Improvement of the air in built-up areas
4. Improvement of the microclimate
5. Positive effect on urban rainwater drainage and landscape water cycle
6. Building physics advantages: UV radiation and severe temperature variations are prevented by the protective growing and plant layer.
7. Dust retention
8. Design element/improved quality of life
9. Reclamation of green areas



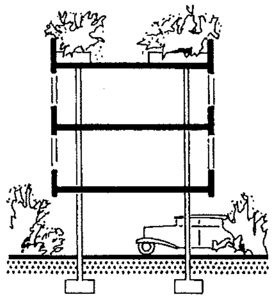
❶ Roof gardens on rented housing: 'Pointer towards a new architecture'



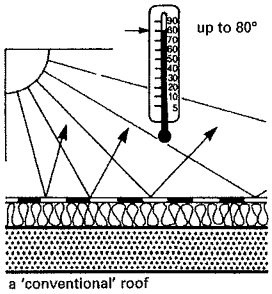
❷ Roof garden in the form of a collection of plant containers on balconies and roof terraces



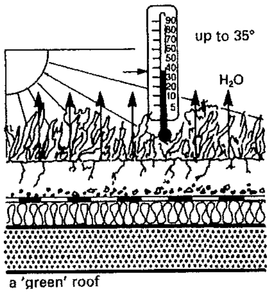
❸ The Hanging Gardens of Semiramis in Babylon (6th century BC)



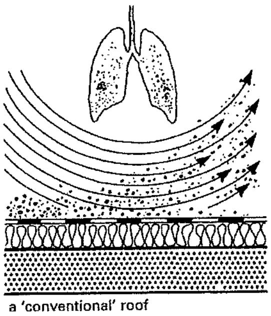
❹ Lost green areas can be regained by planting roofs



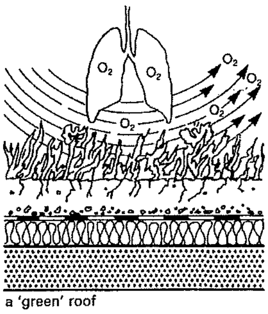
❺ Overheated, dry urban air → ❻



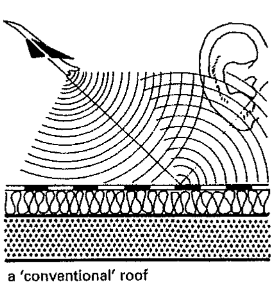
❻ Cooler and moister air through the energy consumption of plant transpiration



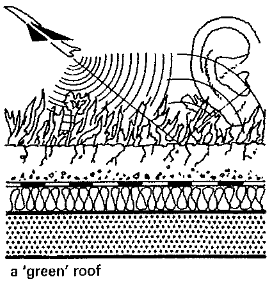
❼ Dust production and circulation → ❽



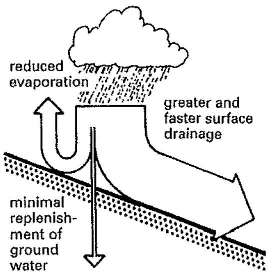
❽ Improvement of urban air through the filtering and binding of dust and the oxygen production of the plants



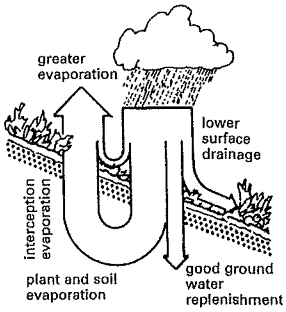
❾ Sound reflections from 'hard surfaces' → ❿



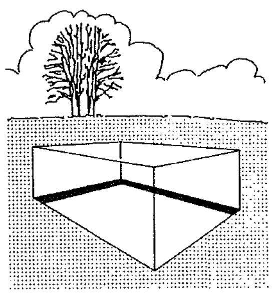
❿ Sound absorption by soft plant surfaces



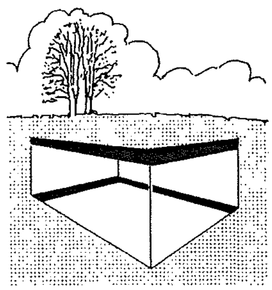
⓫ Distribution of rainwater run-off – paving → ⓬



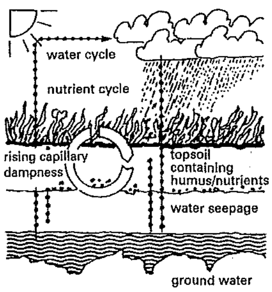
⓬ Distribution of rainwater run-off – unbuilt areas



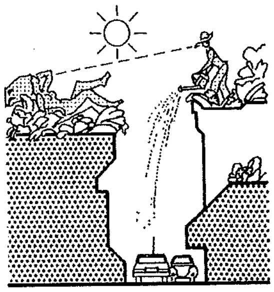
⓭ The building of every house causes the loss of open landscape → ⓮



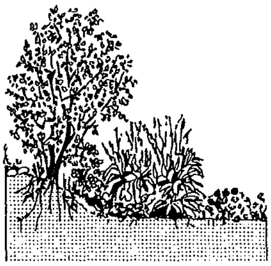
⓮ A large part of the lost green areas could be reclaimed by planting roofs



⓯ Natural water and nutrient cycle

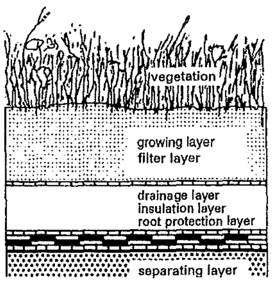


⓰ Mental and physical value of green areas

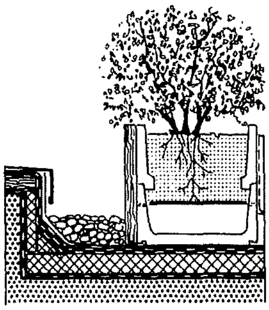


1 Intensive planting

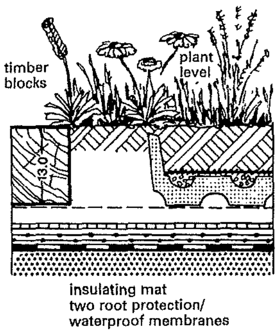
2 Extensive planting



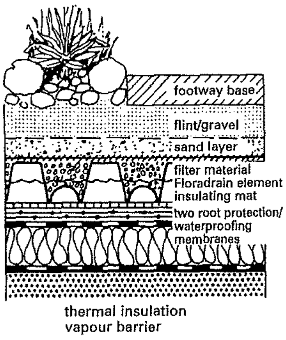
3 Layer structure of a green roof



4 Plant containers form an edging for the green area



5 Zinco Floraterra roof greening system



6 Zinco Floradrain roof greening system

Slopes for roof planting

The pitch of gabled roofs should not exceed 25° and flat roofs should have a maximum slope of 2–3%.

Types of roof planting

Intensive: The roof becomes a residential garden with features like pergolas and loggias. Constant care and maintenance are required. Plants: lawn, shrubs, bushes, trees

Extensive: The planting is onto thin soil and requires the minimum of care. Plants: moss, grass, herbs, shrubs, bushes

Mobile greening: Plants in containers can be used for the greening of roof terraces, parapets and balconies.

Watering

Natural watering with rainwater: Water is backed up in the drainage and growing layers.

Dammed watering: Rainwater is backed up in the drainage layer and mechanically refilled when required.

Drip irrigation: Drip irrigation hoses in the drainage or growing layers keep the plants watered through dry periods.

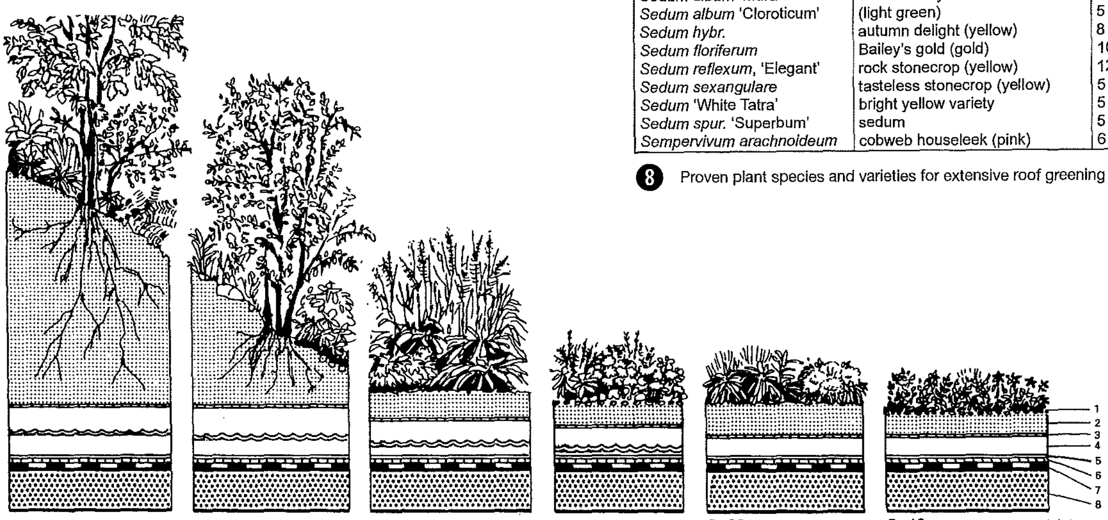
Sprinkler: Sprinkler equipment above the growing layer.

Plant feeding

Fertiliser can be applied to the growing layer or as an additive to artificial watering.

Botanical name	English name (colour of flowers)	Height	Month of flowering
Saxifrage aizoon	encrusted saxifrage (white-pink)	5 cm	VI
Sedum acre	biting stonecrop (yellow)	8 cm	VI–VII
Sedum album	white stonecrop (white)	5 cm	VI–VII
Sedum album 'Coral Carpet'	white variety	5 cm	VI
Sedum album 'Laconicum'	white variety	10 cm	VI
Sedum album 'Micranthum'	white variety	5 cm	VI–VII
Sedum album 'Murale'	white variety	8 cm	VI–VII
Sedum album 'Cloroticum'	(light green)	5 cm	VI–VII
Sedum hybr.	autumn delight (yellow)	8 cm	VI–VII
Sedum floriferum	Bailey's gold (gold)	10 cm	VIII–IX
Sedum reflexum, 'Elegant'	rock stonecrop (yellow)	12 cm	VI–VII
Sedum sexangulare	tasteless stonecrop (yellow)	5 cm	VI
Sedum 'White Tatra'	bright yellow variety	5 cm	VI
Sedum spur. 'Superbum'	sedum	5 cm	VI–VII
Sempervivum arachnoideum	cobweb houseleek (pink)	6 cm	VI–VII

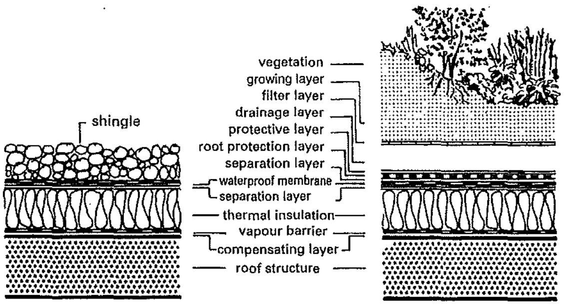
8 Proven plant species and varieties for extensive roof greening (selection)



growth height > 250cm	up to 250cm	5–25 cm	5–20 cm	5–20 cm	5–10 cm
build-up height fm 35cm	19–35 cm	14 cm	12 cm	12 cm	10 cm
surface loading 3.7 kN/m²	1.9–3.7 kN/m²	1.4 kN/m²	1.1 kN/m²	1.15 kN/m²	0.9 kN/m²
water supply 170 l/m²	80–170 l/m²	60 l/m²	45 l/m²	40 l/m²	30 l/m²
mulch layer – cm	– cm	– cm	1 cm	– cm	1 cm
soil mixture 23cm	7–23 cm	5 cm	4 cm	7 cm	4 cm
drainage layer 12cm	12 cm	9 cm	7 cm	5 cm	5 cm
watering, by hand or automatic	by hand or automatic	by hand or automatic	by hand	by hand	by hand

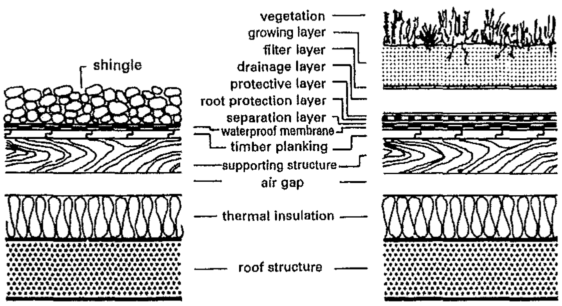
1 mulch layer
2 soil mixture
3 filter mat
4 drainage layer
5 root protection membrane
6 separation and protection layers
7 roof sealing
8 supporting construction

7 Various types of roof greening



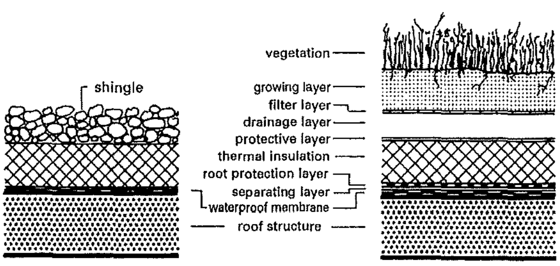
1 Warm roof → 2

2 Warm roof with greening



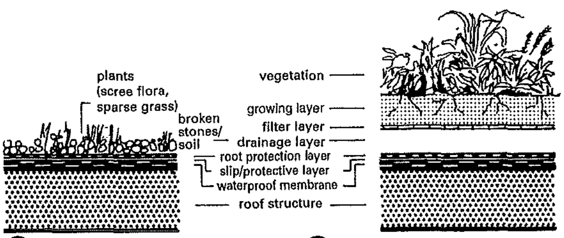
3 Cold roof → 4

4 Cold roof with greening



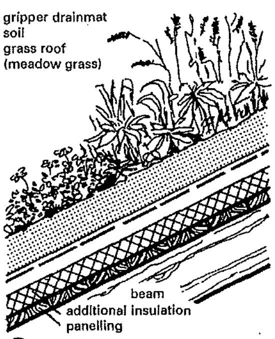
5 Upside-down roof → 6

6 Upside-down roof with greening

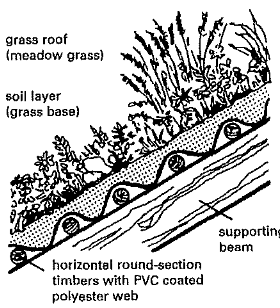


7 Greening of existing roof with the least expense

8 Greening of existing roof (if constructionally and structurally possible)



9 Greening on a sloping roof



10 Greening of a steeply pitched roof

Planted roof: construction layers

Growing layer: expanded clay and expanded slate are used. These offer structural stability, soil ventilation, water storage and soil modelling. Functions: nutrient storage, soil reaction (pH value), ventilation, water storage.

Filter layer: consisting of filter material, it hinders silting in the drainage layer.

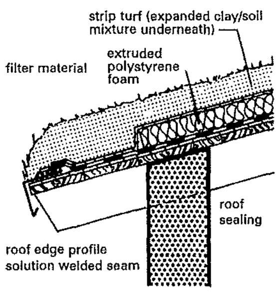
Drainage layer: prevents the plants from becoming waterlogged. Material: woven mats, plastic boards, protective building materials.

Protection layer: protects during the building phase and against point loading.

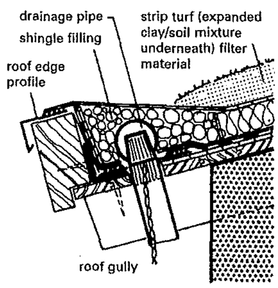
Root protection layer: the roots are retained in PVC/ECB and EPDM sheeting.

Separation layer: separates the load-bearing construction from the roof greening.

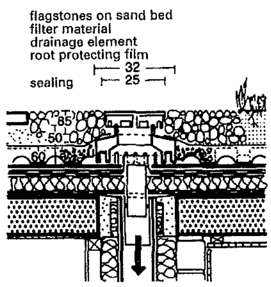
Examples → 1 – 8 show common layer structures for roof greening. Before planting, check that the roof is in perfect condition and that each layer can fulfil its function. Carefully inspect the technical condition of the roof surface. Pitched roofs can also be greened → 9 – 12, but this demands yet more extensive constructional preparations to prevent slippage and soil drying out.



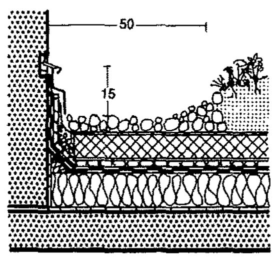
11 Eaves detail of a greened pitched roof



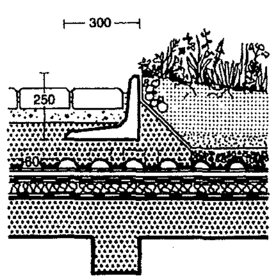
12 Eaves detail → 11



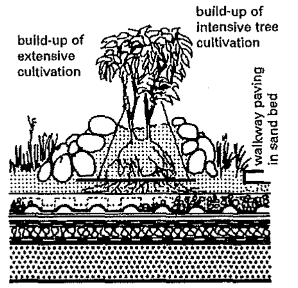
13 Drainage inspection shaft



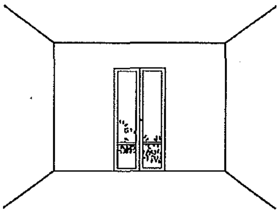
14 Wall connection with shingle safety strip



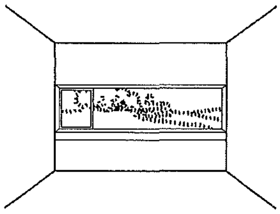
15 Transition from roadway to intensive roof greening



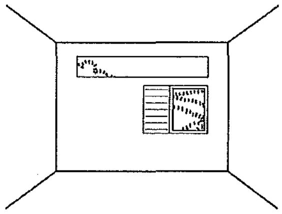
16 Transition from pathway to intensive or extensive roof greening



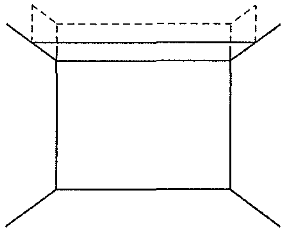
❶ Vertical window, floor-level underfloor heating or radiators at the side



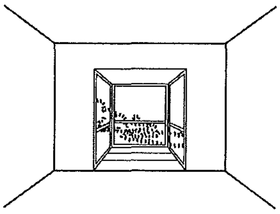
❷ Horizontal window with single opening light at the side, enclosed window sill for heating/media duct



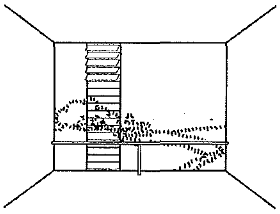
❸ Window composition: upper window brings light deep into the room, small window provides view out and ventilation



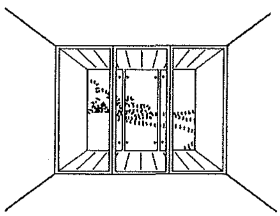
❹ Rooflight for scattered light on a wall



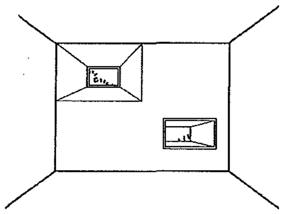
❺ Bay window, plastic projection



❻ Full-length fixed glazing with parapet handrail and ventilation flaps with sound insulation boxes

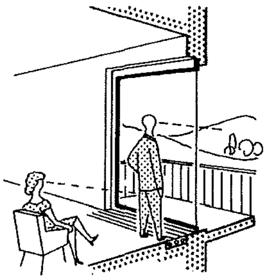


❼ Double glazing with accessible space between (façade as second skin; conservatory glazing)

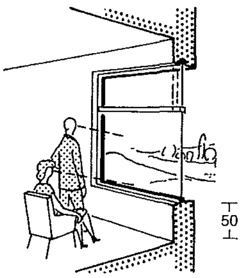


❽ Plastically modulated wall with window flush with outer or inner face

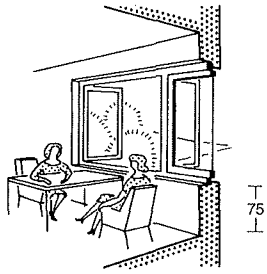
ELEVATION



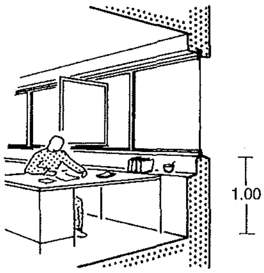
❾ A scenic view and projecting building elements



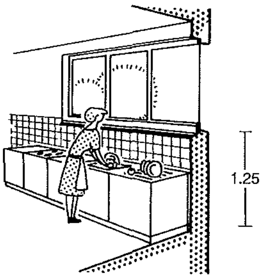
❿ Room with a view



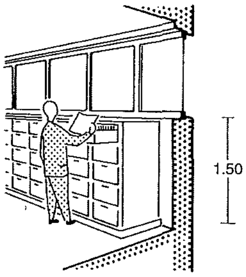
⓫ Normal window height (table height)



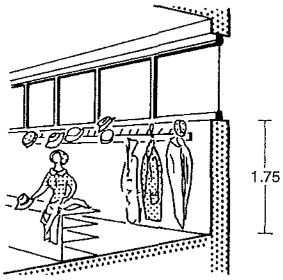
⓬ Office



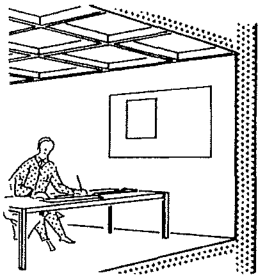
⓭ Kitchen



⓮ Office (filing cabinet)

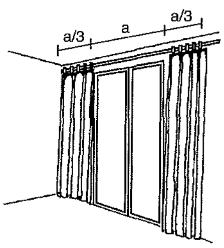


⓯ Coat rack

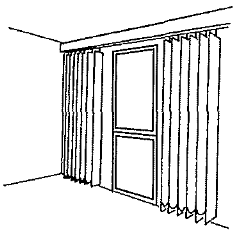


⓰ Rooflight, e.g. drawing office

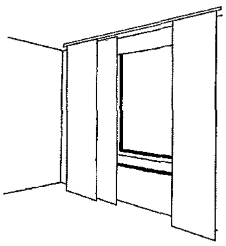
VISUAL PROTECTION



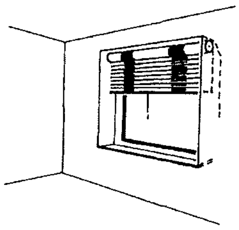
⓱ Sufficient space in the corners for curtains



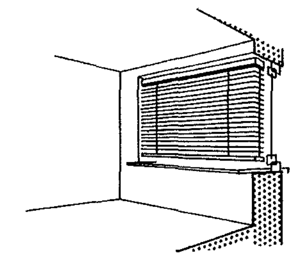
⓲ Vertically hung panel blinds



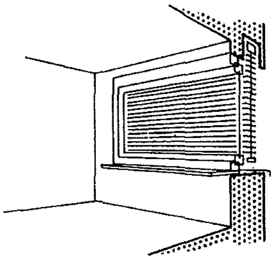
⓳ Sliding cloth panels



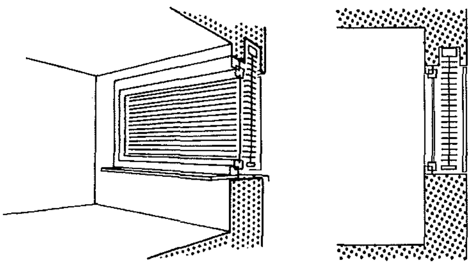
⓴ Venetian blinds of cloth or plastic (darken the interior)



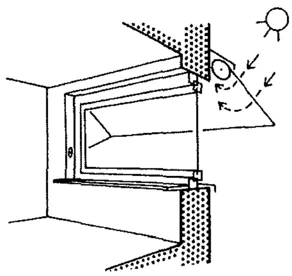
❶ Internal venetian blind, heat builds up behind the window (only glare protection)



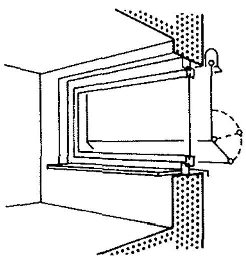
❷ External louvred blind



❸ External louvred blind with impact pane (shields external sun protection)

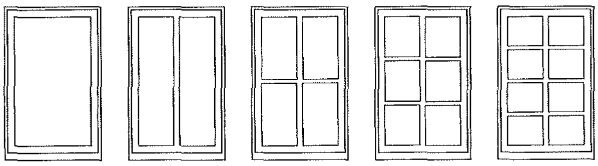


❹ Awnings stop sunshine and warmth. Distance from wall prevents heat build-up



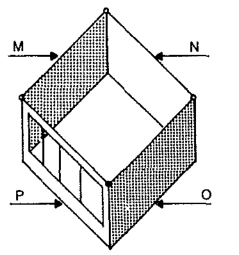
❺ Markisolette – partly angled sun blind

WINDOW SIZES



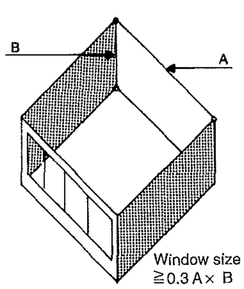
For a 1.5 m wall opening, 1 m^2 glass area remains = 66%	For a 1.5 m wall opening, 0.92 m^2 glass area remains = 61%	For a 1.5 m wall opening, 0.89 m^2 glass opening remains = 59%	For a 1.5 m wall opening, 0.87 m^2 glass area remains = 58%	For a 1.5 m wall opening, 0.84 m^2 glass area remains = 56%

❻ Example of reduction in glass area with glazing bars



Glass area= 1/10 of the floor area
Window width= 1/10 (M + N + O + P)

❼ Window sizes in industrial building



❽ Window sizes for rooms over 3.5 m high

The window, as an element built into the wall, has essential functions apart from just closing the opening. It controls the level of natural lighting, the supply and extraction of air to and from the room, and the view out for connection with the world. These functions can also be fulfilled by separate elements: overhead lights, ventilation flaps and shop windows, respectively.
The size and location of windows in rooms, in addition to the requirements under building regulations and the rules for daylight in interiors (see Daylight → pp. 488 ff.), are determined above all by architectural considerations. Their external impact has a decisive influence on the appearance of the façade. Important factors are: the location in the wall, with internal windows emphasising the wall depth and external windows allowing the wall to present as a surface; the proportions of width to height; the ratio of construction thickness to glass area (visible frame, casements and possibly glazing bar widths); and the relationship to other façade elements (which is often neglected when replacing windows).
In the interior, windows are responsible for light direction, which is essential for the architectural effect of a room. Most decisive is the location on plan, which may have to be supplemented by sun shading equipment or light directing glass. The type of opening determines the functional quality as a ventilation element. How far do the casements open into the room? Is the window sill still usable when the window is open? (Tilted windows are not sufficient for through ventilation! They ensure only the slow cooling of a room.) There may also be specific requirements for fire protection or for resistance against break-in or damage. Resistance classes → pp. 107, 118. If the window serves as an escape route, it must have a clear opening of at least 0.9 × 1.2 m and a sill height of max. 1.2 m above floor level.
In the Netherlands, regulations stipulate the sizes of windows in relation to the angle of incidence of the light.

Refurbishment

If windows are replaced by those with better thermal insulation, then the installation demands particular attention. There is a danger with improved windows that condensation may occur at other less well-insulated locations (window reveals, outside corners of rooms), which can lead to mould formation! In order not to impair the appearance of the façade and the entrance of light, the dimensions of the panes should not be altered (pay attention to frames, casements and glazing bar width → ❻).

Residential construction

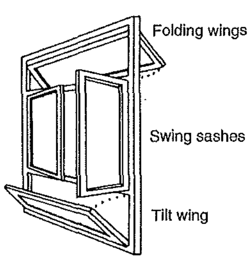
The minimum requirement for structural window apertures in occupied rooms is specified in the state building regulations and is 1/8 or 1/10 of the plan area of the room. Further design constraints are the distance from buildings opposite (shadow formation) and the requirements of the energy saving regulation EnEV. In order to optimise the energy balance, the criteria for workrooms can be applied.

Workrooms

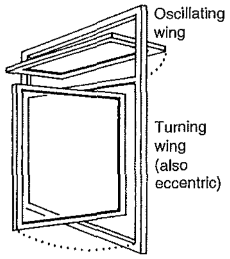
The required window area can be roughly worked out using the following rules. The total width of all visual connections to the outside must be at least 1/10 of the total width of all walls, according to workplace guidelines → ❼. Possible visual connection to the outside should be at eye level (window sill heights of 0.85 –1.25 m) → p. 96 ❾ – ⓰. For workrooms more than 3.5 m high, the glass area of the window must be at least 30% of the outside wall area → ❽. For rooms with dimensions corresponding to those of residential rooms, the minimum height of the glass area is 1.3 m.
With the increasing use of existing sources of energy, the optimisation of thermal losses and gains and the control of light through windows merit a separate design prepared by experts.

see also: Daylight pp. 488 ff. (Directing sunlight p. 499, Sun shading p. 500)

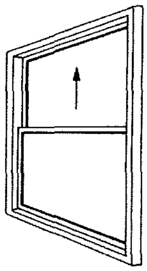
OPENING TYPES



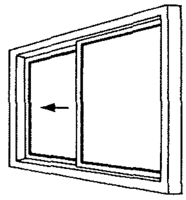
❶ Casement (outward and inward)



❷ Centre pivot-hung casement

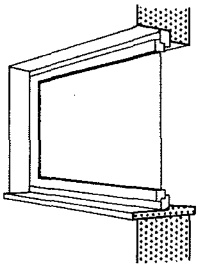


❸ Vertically sliding window

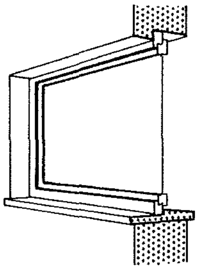


❹ Sliding window

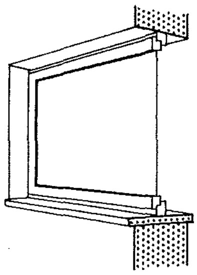
REBATE TYPES



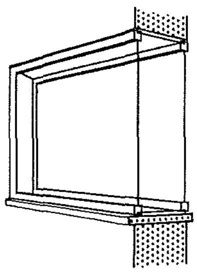
❺ Opening inward with frame behind recessed jamb



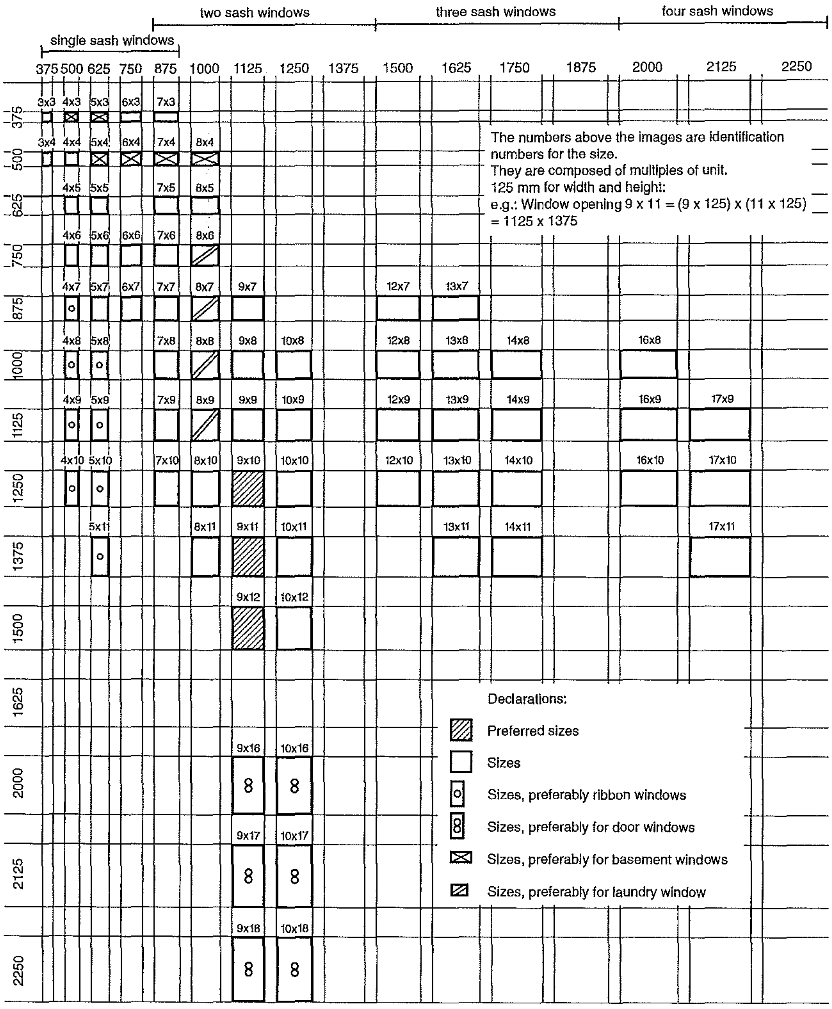
❻ Opening outward with frame behind recessed jamb



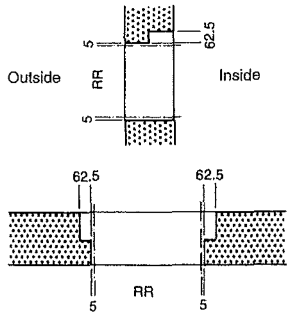
❼ Plain jamb with rebated frame



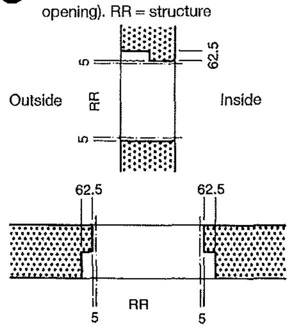
❽ Plain jamb with wrap-around window frame



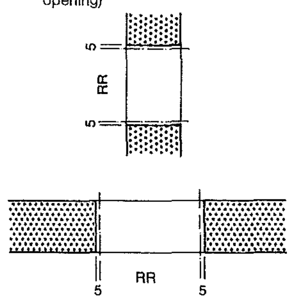
❾ Guideline sizes for structural window openings



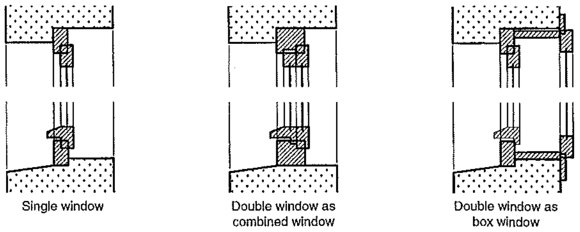
❿ Meeting type 1 (rebated inward opening). RR = structure



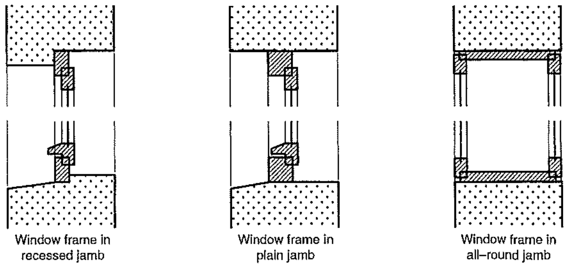
⓫ Meeting type 2 (rebated outward opening)



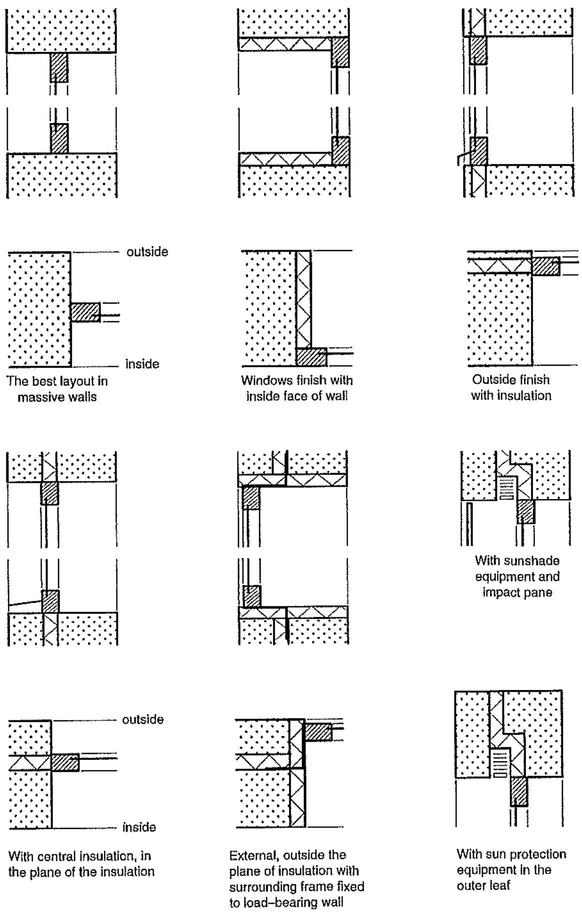
⓬ Meeting type 3 (no rebate)



❶ Window forms according to type of casement



❷ Window forms according to type of frame (left: outside, right: inside)



❸ Location of window in the wall (left: outside, right: inside)

Row	No. full storeys in building	Joint permeability class
1	up to 2	2
2	more than 2	3

❹ Joint permeability classes in external windows, French windows and roof windows

Various forms of window according to type of casement → ❶ and type of frame → ❷ are shown opposite. The stringent requirements for windows (thermal and sound insulation) result in a multitude of window types and constructions. The location of the window in the wall is a significant design feature of the façade. The arrangement of the insulation and any sun protection are also important → ❸. An impact pane (external, no closing function) serves, like double façade systems, as wind protection for the sun protection system and enables natural ventilation in strong wind and rain. A staggered layout of window and insulation planes should be avoided if possible, because it leads to expensive and defect-prone insulation and weatherproofing construction. The permissible dimensional tolerances for window and door openings up to 3 m long are max. 12 mm and, for elements up to 6 m, max. 16 mm.

External windows and French windows of heated rooms must be constructed with at least insulating or double glazing. The thermal transmittance (U-value) of windows in new buildings must, according to EnEV 2009, be determined together with a survey of the whole building. Solar gains are included in the calculation → p. 474 ff. For new installations, replacement and renewal in existing buildings, the values according to → ❺ are to be observed. In addition, windows, French windows and roof windows have to comply with requirements for airtightness and minimum air change → ❹.

Building components

WINDOWS
Arrangement
Requirements
Design types
Thermal insulation
Sound insulation
Cleaning buildings
Roof windows
Rooflights

EnEV 2009

see also: Glass pp. 107 ff., Building physics pp. 471 ff., Daylight pp. 488 ff.

Row	Building element	Residential buildings and zones of non-residential buildings with interior temperatures >19°C	Zones of non-residential buildings with interior temperatures 12–19°C
		Highest value of thermal transmittance U_{max} 1) in W/(m² × K)	
2a	external windows, French windows	1.30 2)	1.90 2)
2b	roof windows	1.40 2)	1.90 2)
2c	glazing	1.10 3)	no req'ment
2d	curtain walls	1.40 4)	1.90 4)
2e	curtain walls	1.90 4)	no req'ment
2f	glass roofs	2.00 3)	2.70 3)
3a	external windows, French windows, roof windows with special glazing	2.00 2)	2.80 2)
3b	special glazing	1.60 3)	no req'ment
3c	curtain walls with special glazing	2.3 4)	3.0 4)

1) Thermal transmittance of the building element, taking into account the new and existing building layers.
2) Design value of the thermal transmittance of the window; this is to be taken from the technical product specification or according to the known energy characteristics of the product according to building regulations. This applies particularly to energy characteristics from European technical approvals and from the regulations according to the building rules and based on decisions contained in general approvals under the building regulations.
3) As 2) but regarding the glazing.
4) Thermal transmittance of the curtain walling; this is to be determined in accordance with the generally recognised data relating to the technology.

❺ The maximum values approach for single building elements is applicable only to new buildings, and replacement or renewal in existing buildings, EnEV 2009

Building components

WINDOWS
Arrangement
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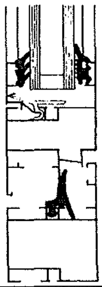
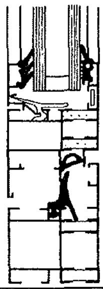
Design types
Thermal insulation
Sound insulation
Cleaning buildings
Roof windows
Rooflights

BS EN ISO 140
BS 8233
BS EN ISO 15186
DIN 4109

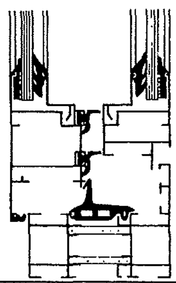
see also: Glass p. 107



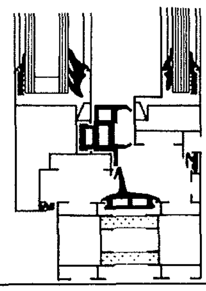
❶ Aluminium window with flush casements



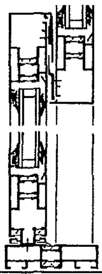
❷ Aluminium window with thermally separated profiles, up to 37 dB



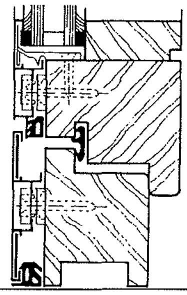
❸ Universal aluminium window, sun protection possible between panes, up to 47 dB



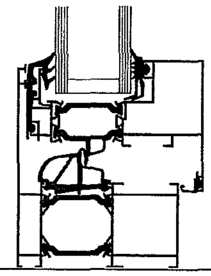
❹ Aluminium combined window, thermally insulated, up to 47 dB



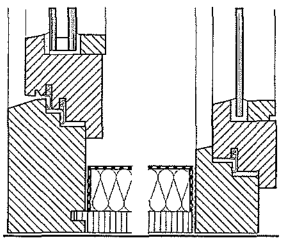
❺ Aluminium sliding window, thermally insulated, up to 35 dB



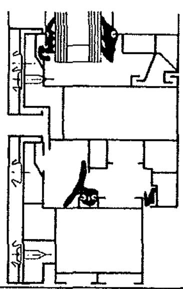
❻ Aluminium/wood window with composite construction, up to 40 dB



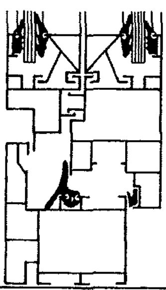
❼ Aluminium window with thermally separated profiles; narrow casement is covered by frame, up to 40 dB



❽ Wooden box-type window with sound-absorbing surround, up to 45 dB



❾ Plastic window with aluminium frame facing, up to 42 dB



❿ Plastic combined window, sun protection possible between panes, up to 45 dB

In order to improve the sound insulation of windows, a number of glass layers are installed behind each other. To reduce the reciprocal effect of resonance, different glass thicknesses are combined (e.g. 4/8 mm; 6/12 mm). The greater the distance between the panes, the better is the sound insulation. Further improvements can be gained from the separation of the frame and the sound-absorbing construction of the resulting wrap-around window surround. Box-type windows, even with only single glazing, have better sound insulation values than double-glazed windows.

If the requirements for sound insulation are very high, then suitably sound-insulated ventilation equipment must also be provided, because the sound insulation is only effective with the windows closed.

Road type	Distance from window to centre of road (m)	Traffic load in daytime, both directions (vehicles/h)	Noise level range
residential road		<10	0
residential road	<35		0
(2-lane)	26–35	10–50	I
	≦10		III
residential feeder road	>100		0
	36–100		I
(2-lane)	26–35	50–200	II
	11–25		III
	≦10		IV
rural road	101–300		
in village[1]	101–300		I
(2-lane)	36–100		II
residential feeder road	11–35	200–1000	III
	≦10		IV
(2-lane)			
urban road	101–300		III
main road	36–100	1000–3000	IV
industrial areas	>35		V
4- to 6-lane main roads	101–300		IV
motorway slip roads and motorways	≦100	3000–5000	V

1) Outside built-up areas and for roads in industrial and commercial areas, the next noise level range applies

⓫ How loud is it?

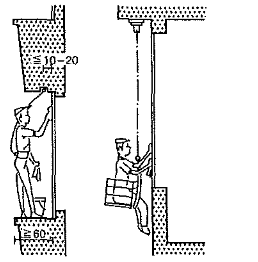
relevant noise level range	average outdoor noise level (dB)	necessary window sound insulation value R_W (dB) in occupied rooms of dwellings [1]
0	≦50	25 (30)
I	51–55	25 (30)
II	56–60	30 (35)
III	61–65	35 (40)
IV	66–70	40 (45)
V	>70	45 (50)

1) Values in brackets apply for external walls and must also be used for windows if they comprise more than 60% of external wall area.

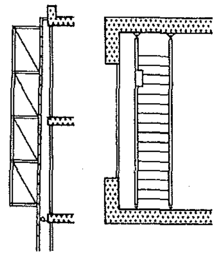
⓬ Selection of the correct sound insulation

Sound insulation class	Sound insulation value (dB)	Orientation notes on construction features of windows and ventilation systems
6	50	box-type window with separated frames in reveals and special sealing, wide spacing of panes and thick glazing
5	45–49	box-type window with special sealing, wide spacing of panes and thick glazing; combined window with decoupled casement frames, special sealing, spacing of panes over about 100 mm and thick glazing
4	40–44	box-type windows with additional sealing and centre-seal glazing; combined window with special sealing, spacing of panes over about 60 mm and thick glazing
3	35–39	box-type window without additional sealing and with centre-seal glass; combined window with additional sealing, normal spacing of panes and thick glazing; double-glazed unit in heavy multi-pane construction; 12 mm glass, non-opening or in sealed window.
2	30–34	combined window with additional sealing and centre-seal glazing; thick double-glazed unit, non-opening or in sealed window; 6 mm glass, non-opening or in sealed window
1	25–29	combined window with additional sealing and centre-seal glazing; thin double-glazed unit in window with additional sealing
0	20–24	unsealed single- or double-glazed window

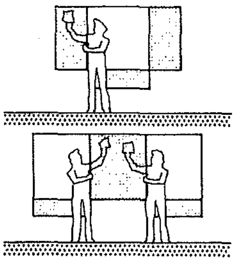
⓭ Sound insulation classes of windows (excerpt from VDI guideline 2719)



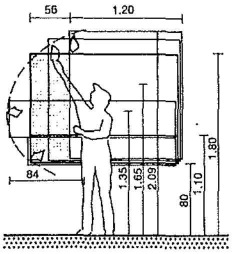
❶ Mobile safety cradle and safety belt



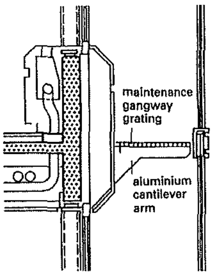
❷ Parallel travel safety ladders (for three or four storeys)



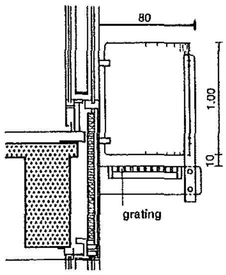
❸ Cleaning of adjacent windows



❹ Shading shows acceptable cleaning surface area



❺ Maintenance gangway



❻ Cleaning platform

Façade hoists and mobile equipment

Safety belts with straps, safety cables or safety equipment for working at height should be used as a protection against falls → ❶

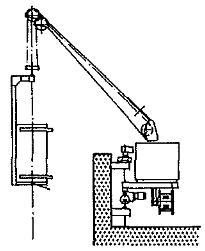
Façade hoists and mobile equipment (allowing access to fixed glazing) for cleaning windows and façades → ❽ – ⓫ are available to carry out maintenance and repair work (thus saving the cost of scaffolding). If fitted at the right time, they can also be used to carry out minor building work (such as fixing blinds, installing windows etc.). With slight modifications, façade hoists and access equipment can be used as rescue apparatus in the event of a fire. The options available include mobile suspended ladders mounted on rails, trackless roof gantry equipment with a cradle, and a rail-mounted roof gantry with a cradle and attached to the roof deck or the balustrade, with curves and points.

Suspended light metal ladder equipment (for façade access) → ❷ consists of a suspended mobile ladder on rails. The width of the ladder is 724 mm or 840 mm, and the total overall length is 25 m maximum, depending on the shape of the building. The maximum safe working load (S.W.L.) is 200 kg (i.e. two men and the apparatus itself). Alternatives are available, such as maintenance gangways → ❺ and cleaning balconies → ❻.

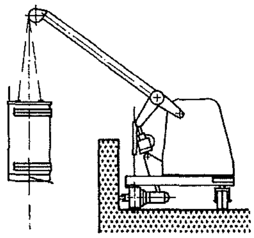
Type of building	External windows	Roof windows
offices	every 3 months*	every 12 months
public offices	2 weeks	3 months
shops	outside, weekly inside, every 2 weeks	6 months
shops (high street)	outside, daily inside, every week	3 months
hospitals	3 months	6 months
schools	3–4 months	12 months
hotels (first class)	2 weeks	3 months
factories (precision work)	4 weeks	3 months
factories (heavy industry)	2 months	6 months
private houses	4–6 weeks	–

* ground floor windows must be cleaned more frequently

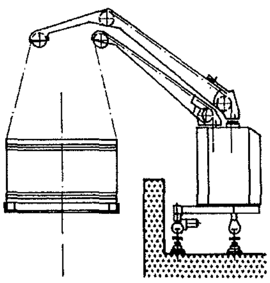
❼ Intervals of time for window cleaning



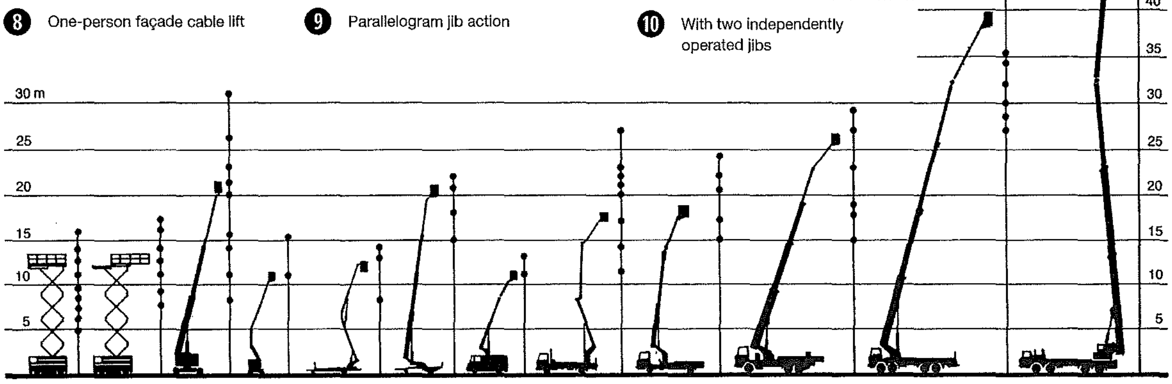
❽ One-person façade cable lift



❾ Parallelogram jib action



❿ With two independently operated jibs



⓫ Work platform hoists

Gardemann system

Building components

WINDOWS
Arrangement
Requirements
Opening types
Thermal protection
Noise protection
Cleaning buildings
Loft windows
Rooflights

see also: Dormer windows p. 85

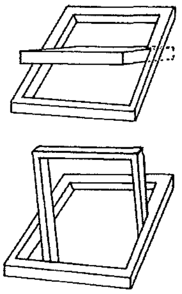
WINDOWS

Loft Windows

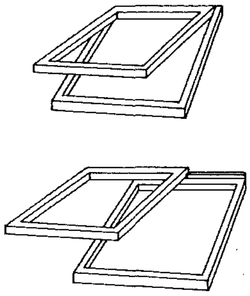
The required quality of living is decisive for the determination of window size in inhabited loft spaces. Building regulations require a minimum window area of ⅛ of the floor area for living rooms → ⓫. Large windows make these rooms more comfortable. The window widths in secondary rooms can be chosen according to the distance between the rafters.

Generously wide windows in living rooms can be achieved through the installation of rafter trimmers and additional rafters. Steeper roofs need shorter windows, while flatter roofs require longer windows.

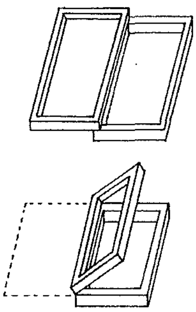
Loft windows can be joined using flashing → ❹ and can be arranged horizontally or vertically in rows or window groups.



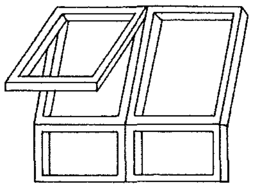
❶ Pivoting window



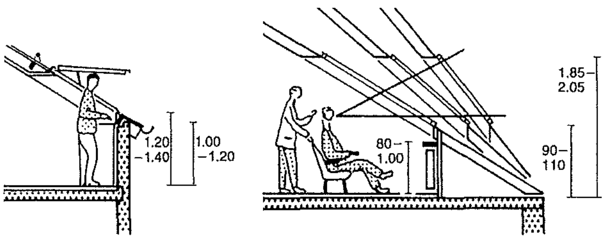
❷ Top-hung window, sliding



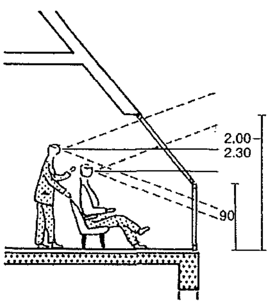
❸ Sliding window, casement door



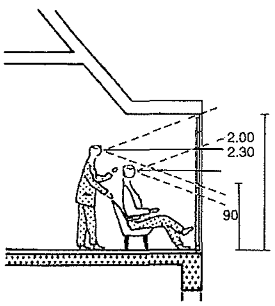
❹ Top-hung window with vertical unit



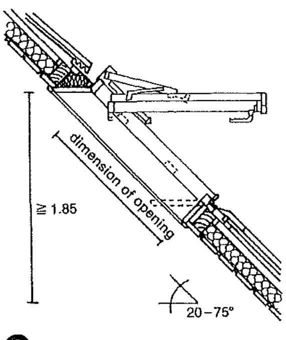
❺ Installation heights for loft windows



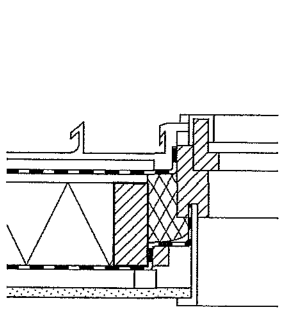
❻ With additional vertical window



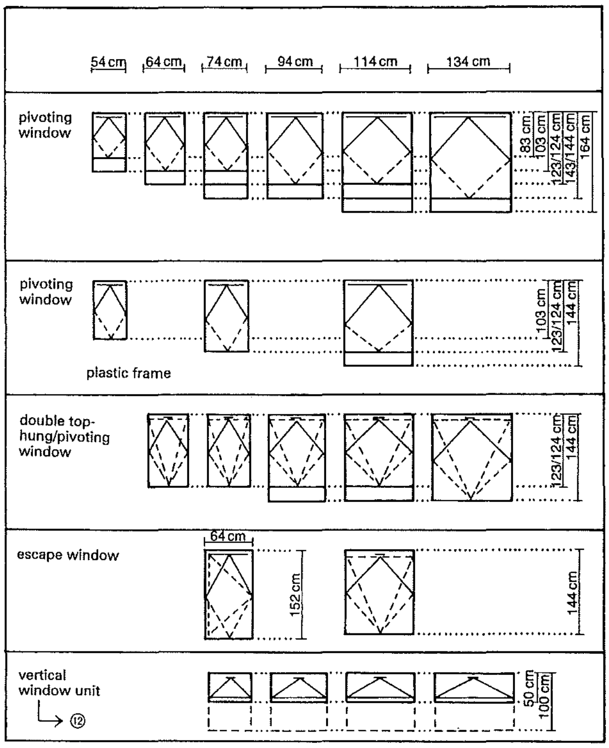
❼ As dormer window; see p. 85



❽ Installation variant, vertical section



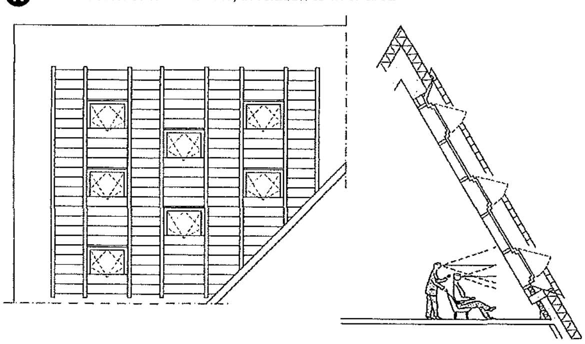
❾ Horizontal section



❿ Window sizes

window size	54/83	54/103	64/103	74/103	74/123	74/144	144/123	114/144	134/144
surface area of light admitted (m²)	0.21	0.28	0.36	0.44	0.55	0.66	0.93	1.12	1.36
floor area (m²)	2	2–3	3–4	4–5	6–7	9	11	13 m²	

⓫ Calculation of window size, in relation to floor area

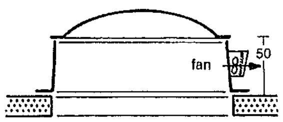


⓬ Glass façade with integrated loft windows and external perforated metal screen
Arch.: Kister Scheithauer Gross

with solid or ventilated curb

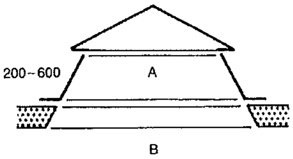
60 × 60	1.20 × 2.40	1.80 × 2.40
80 × 80	1.25 × 2.50	1.80 × 2.70
90 × 90	1.50 × 1.50	1.80 × 3.00
1.00 × 1.00	1.50 × 1.80	2.20 × 2.20
1.00 × 2.00	1.50 × 2.40	2.50 × 2.50
1.20 × 1.20	1.80 × 1.80	
1.20 × 1.80		
round domes: 60, 90, 100, 120, 150, 180, 220, 250cm dia.		

❶ 'Normal' dome rooflight



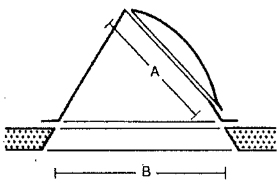
50 × 1.00	1.00 × 1.00	1.20 × 1.50
50 × 1.50	1.00 × 1.50	1,20 × 2.40
60 × 60	1.00 × 2.00	1.50 × 1.50
60 × 90	1.00 × 2.50	1.50 × 3.00
90 × 90	1.00 × 3.00	1.80 × 2.70

❷ Dome rooflight with high curb



A	B	A	B
40	60 × 60	1.6	1.80 × 1.80
70	90 × 90	1.7	2.00 × 2.00
80	1.00 × 1.00	2.20	2.00 × 2.20
1.00	1.20 × 1.20	2.30	2.50 × 2.50
1.30	1.50 × 1.50	2.40	2.70 × 2.70

❸ Pyramid rooflight



A = rooflight area	B = roof opening
72 × 1.20 × 1.08	1.25 × 1.25
72 × 2.45 × 2.30	1.25 × 2.50
75 × 1.16 × 76	1.50 × 1.50

❹ North light dome

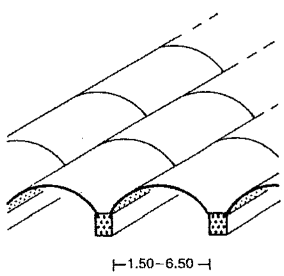
Domes, skylights, coffers, smoke vents and louvres, as fixed or movable units, can be used for lighting and ventilation, and for clearing smoke from rooms, halls, stair wells etc.

By positioning dome rooflights facing north sunshine and glare are avoided → ❹. Glare from low sun can be avoided by the use of a high curb → ❶ Dome rooflights used for ventilation should face into the prevailing wind in order to utilise the extraction capacity of the wind. The inlet aperture should be 20% smaller than the outlet aperture. Forced ventilation, with an air flow of 150–1000 m^3/h, can be achieved by fitting a fan into the curb of a skylight → ❷. Dome rooflights can also be used for access to the roof.

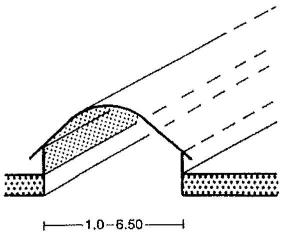
Attention should be given to the aerodynamic extraction surfaces of smoke exhaust systems. Orientating each extraction unit at an angle of 90° from the adjacent one will allow for wind coming from all directions. Position to leeward/windward if pairs of extraction fans are to be mounted in line with or against the direction of the prevailing wind.

Smoke extraction vents are required for stairwells more than four complete storeys high. Variable skylight aperture widths up to 5.50 m are available, as is a special version up to 7.50 m wide which does not need extra support.

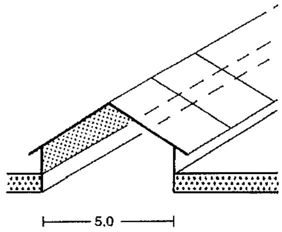
Skylight systems offer diffused room lighting which is free from glare → ⓫. North-facing saw-tooth skylights with spun glass fibre inlays guarantee all the climatically important advantages of a full workshop space → ⓭.



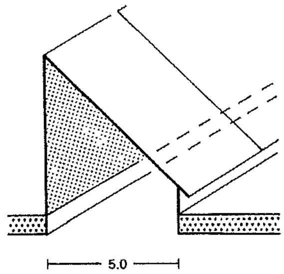
❺ Continuous multiple barrel skylights



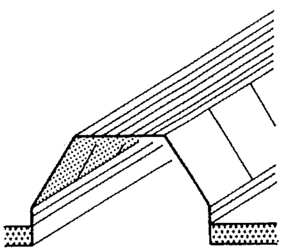
❻ Continuous barrel skylight



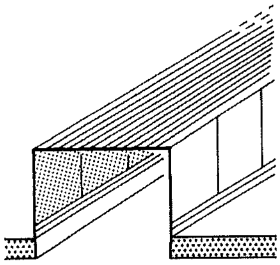
❼ Continuous double-pitched skylight



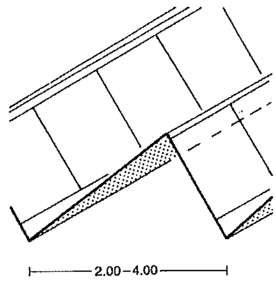
❽ Continuous single-pitched skylight



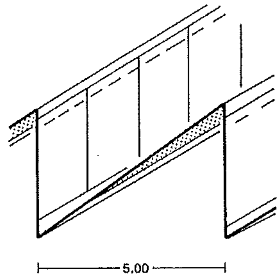
❾ Monitor rooflight with inclined panes



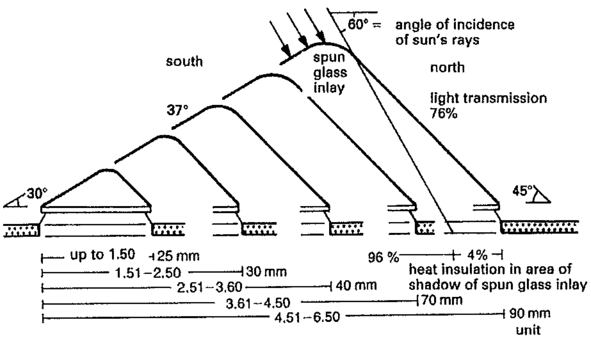
❿ Monitor rooflight with vertical panes



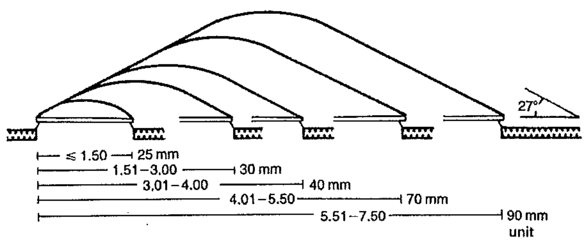
⓫ 60° saw-tooth north light



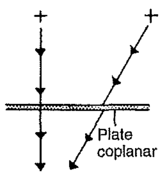
⓬ 90° vertical saw-tooth north light



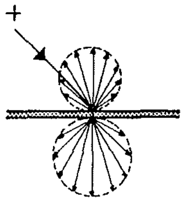
⓭ Saw-tooth glass fibre-reinforced polyester skylight



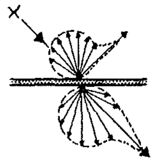
⓮ Double-skinned rooflight units



❶ Directional transmittance of clear glasses with the refraction of slanting rays



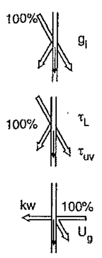
❷ Dispersed transmittance of opal milk glasses, alabaster etc.



❸ Mixed transmittance of ornamental glasses, silk, light opal glasses etc.

Material	Dispersion	Thickness (mm)	Reflection (%)	Transmittance (%)	Absorbance (%)
clear glass	none	2–4	6–8	90–92	2–4
mirror glass	none	6–8	8	88	4
wire glass	none	6–8	9	74	17
raw glass	none	4–6	8	88	4
ornamental glass	slight	3.2–5.9	7–24	57–90	3–21
clear glass, externally opaque	slight	1.75–3.1	7–20	63–87	4–17
clear glass, internally opaque	slight	1.75–3.1	6–16	77–89	3–11
porcelain	good	3.0	72–77	2–8	20–21
marble, polished	good	7.3–10	30–71	3–8	24–65
marble, soaked	good	3–5	27–54	12–40	11–49
alabaster	good	11.2–	49–67	17–30	14–21
cardboard, lightly soaked	good	13.4	69	8	23
parchment, undyed	good		48	42	10
parchment, light yellow soaked	good		37	41	22
parchment, dark yellow	good		36	14	50
silk, white	nearly good		28–38	61–71	1
silk, coloured	nearly good	1.1–2.8	5–24	13–54	27–80
laminate, tinted	good		32–39	20–36	26–48

❹ Light properties of transparent materials
Reflectivities → p. 498 ❷, p. 507 ❼



g The overall energy transmittance g refers to the wave length range from 300 mm to 2500 mm. It is the sum of the radiation allowed to pass directly through and the inward secondary heat output (radiation and convection).

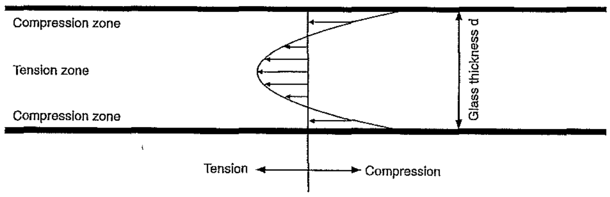
τ_L The statement of the light transmittance τ_L refers to the wavelength range of visible light from 380 mm to 780 mm and is weighted with the brightness sensitivity of the human eye.

τ_{UV} The UV transmittance τ_{UV} for ultraviolet radiation is given for the wavelength range from 280 mm to 380 mm.

U_g The thermal transmittance U_g (DIN EN 673) of glazing is a measure of how much energy is lost per second and per m² with a temperature difference of 1 kelvin. The lower this value is, the less heat is lost. Coatings, gas filling and the width of the space between the panes decisively influence the thermal transmittance of glazing.

R_a The colour rendering index R_a describes the colour rendering of glazing. An Ra value of more than 90 denotes very good colour rendering.

❺ Technical data relating to light and energy



The pane is heated to about 680°C. Blowing with cold air cools the outer layers more quickly so they harden. Under further cooling, the hardened edge zones prevent the core zone from contracting. The outer zones are compressed while a tension stress is caused in the middle.

If bending forces now act on the pane, this first has to relieve the existing compression stresses before the material has to accept tension stresses. This measure can increase the bending strength from about 24 N/mm² of normal float glass to 120 N/mm².

❻ Properties of pre-stressed panes of toughened or partially toughened glass

Transparent, translucent building materials

For the determination of size, colour, window dimensions and lighting of rooms, knowledge of the visual transmittance, dispersion and reflection characteristics of glass materials are important for their artistic and economic effect.

Light-reflecting materials are able to demonstrate directional, completely dispersed or incompletely dispersed reflection and transparent materials directional → ❶, dispersed → ❷ and mixed transmittance → ❸.

Note that frosted glasses, which are internally opaque (which is preferable because they become less dirty), absorb less light than externally opaque glasses.

Manufacture

Glass is drawn in a mechanical process and leaves the drawing machine in a condition ready for use without further processing. The glass is clear and translucent, colourless and of uniform thickness. The surface is flat on both sides and fire-polished. The basic composition of float glasses varies slightly due to the origin of the raw materials used. This has practically no effect on the physical properties. Colour values and visual and energy (heat) transmittance can be exceptions. Tinted glasses are made with the addition of various metallic oxides. The possible spectrum of colours is very limited. A greater variety of colours and patterns can be produced by enamel, which is applied to the surface using a screen-printing process. These can only be applied to toughened safety glass.

Glass panes which are inclined at more than 10° from the vertical are considered as roofing glass on account of the additional loadings (self-weight, snow, wind and climatic loads) and are subject to the 'Technical regulations for the use of glazing with linear support' (TRLV) of the DIBt (German Institute for Construction Technology).

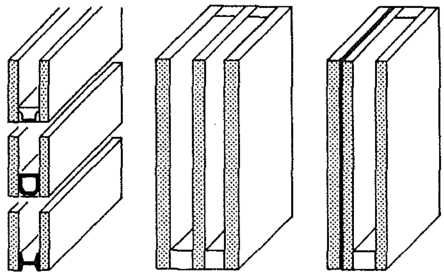
Properties

Glass is physically a super-cooled liquid. It is a brittle material, which can bear high compression stresses, but the tension strength is only about 1/10 of the compressive strength. If the limits of elasticity are exceeded by mechanical or thermal stresses, it breaks. Normal glass then breaks into jagged pieces of various sizes, which can be dangerous.

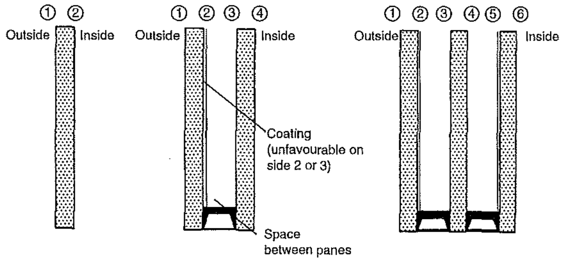
Different processes can be used to adapt the properties of glass for the most varied requirements.

Tempering of the sheets produces a basic stress in the glass, which increases its tension and bending strength → ❻. If the glass breaks, this pre-stress causes it to shatter into blunt fragments (**toughened safety glass**). Coatings can be applied to change the transmittance or the reflection of defined wavelengths (e.g. thermally insulated glazing).

Two or more panes can be combined with an intermediate layer to fulfil the most varied functions. Tear-resistant foils can prevent glass splinters falling out (**laminated glass** → p. 106 ❹), and many layers make glazing resistant to breaking. Printed intermediate layers offer a range of colourful and graphic design possibilities. Special fillings can hinder the transmittance of unwanted thermal radiation (fire protection glazing → p. 111).



1 Insulated glazing can consist of two or three panes. The specific properties can be influenced by a multitude of combinations of coatings and composite glasses.



2 Description of the pane surfaces for the numbering of the position of coatings

Type of glass	Glass thickness, outer (mm)	Visual transmittance T_L (%)	Light reflection to the outside R_{LA} (%)	Overall energy (heat) transmittance (%)
float glass	4	80	13	61
outer	6	79	13	59
THERMOPLUS→S3	8	78	12	57
at pos. 3	10	77	12	56

3 Light and energy values of insulated glazing with various thicknesses of the external pane and coating of the inner pane (position 3)
Inner pane: clear float glass pane with a thickness of 4 mm. (EnEV → refs)

Type of glass	Glass thickness, outer (mm)	Visual transmittance T_L (%)	Light reflection to the outside R_{LA} (%)	Overall energy (heat) transmittance (%)
float glass®	4	80	14	59
outer	6	79	14	57
THERMOPLUS® S3	8	78	14	56
at pos. 2	10	78	14	55

4 Light and energy values of insulated glazing with various thicknesses of the coated outer pane (pos. 2)
Inner pane – clear float glass pane with a thickness of 4 mm. (EnEV → refs)

Glass type	Visible transmittance	Overall energy transmittance	U_g-value (W/m²K) acc. DIN EN 673 Space between panes			Light reflection		UV transmittance	Absorption	General colour rendition
	T_L(%)	g (%)	12 mm	14 mm	16 mm	outside	inside	T_{UV} (%)	A_{Ea} (%)	R_A
blue 50/27	50	28	1.2	1.1	1.1	19	19	6	39	95
70/35	70	37	1.2	1.1	1.1	16	17	11	29	97
66/33	66	36	1.2	1.1	1.1	16	18	11	32	94
brilliant 50/25	50	27	1.2	1.1	1.1	19	20	7	42	92
40/22	40	23	1.2	1.1	1.1	20	22	7	44	91
30/17	30	19	1.2	1.1	1.1	26	17	6	47	88
neutral 70/40	71	43	1.3	1.2	1.1	10	11	18	31	95
silver 50/30	50	32	1.2	1.1	1.1	39	33	17	28	94

5 Infrastop® – solar control insulating glass with argon filling. Construction layers 6 (16) 4 mm. Technical and physical data under vertical radiation. (EnEV → refs)

Simple double glazing

Double-glazed units normally consist of two panes. These are connected at the edge with an air-tight and gas-tight spacer.

A considerable improvement in the coefficient of thermal conductivity (U-value) has been achieved through special coating of the panes. Such thermally insulating and solar control glazing has, since the introduction in Germany of the Insulation Regulations in 1995 and the Energy Saving Regulations (EnEV) in 2002, replaced uncoated glazing on account of its improved coefficients of thermal conductivity. Only in isolated cases does the calculation according to EnEV permit the use of normal double-glazed units.

Current types of glass with their optical features and the current construction physics properties and maximum sizes can be taken from the information provided by the glass industry. The combination with any kind of wire glass or tinted cast glass causes stress in the glass in direct sunshine and can lead to breakages, and so should be avoided. In addition, the glass dimensions and the selection of the construction of the double glazing should take into account all current standards, the technical regulations for the use of glazing with linear support and secured against falling out, glazing guidelines and workplace regulations. Only products with general technical approval should be used.

Thermally insulating double-glazed units

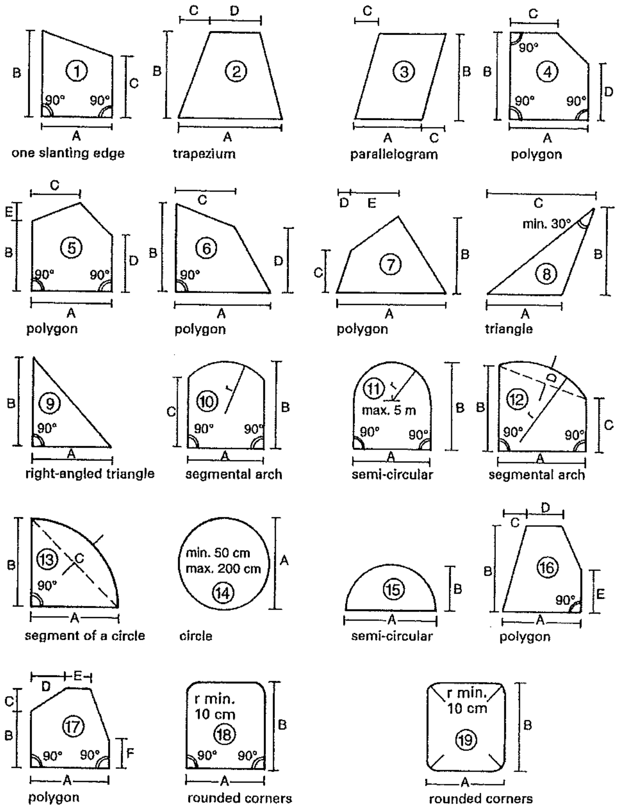
Thermally insulating double-glazed units are neutral in appearance and transparency, so that they look similar to simple double-glazed units. The low coefficients of thermal conductivity (U_g-value) are achieved through a coating of precious metal in position 3. Because the coatings applied to thermal insulation glass show low emissivity, this is often described as low-E glazing. Filling with inert gas can produce a further improvement of the coefficient of thermal conductivity. These units have high visual and overall energy (heat) transmittance in order to make the greatest possible part of the solar radiation available for passive energy gain. If the thermal insulation coating is applied to position 2, then the overall energy passing through is reduced. The visual impression can show slight differences, particularly if units are directly next to each other.

Solar control glass

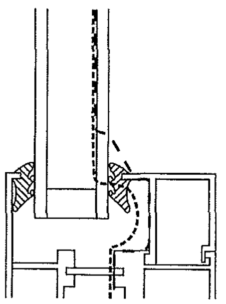
Solar control glass is characterised by high visual transmittance at the same time as low overall energy transmittance. The passive energy gain from incoming solar radiation is low. This is made possible by a wafer-thin coating based on precious metal, which is applied in the protection of the space between the panes. In addition to its good solar control properties, solar control glass fulfils all current requirements for high-quality insulated glazing. Solar control units are normally labelled with a pair of values, which show firstly the visual transmittance and secondly the overall energy transmittance as percentages. Solar control units can be delivered with various grades of colour and reflection as seen from outside.

In order to select the optimal coloration of glass, sample panes should be requested from the manufacturer of the solar control glass. Absolute conformity of colour in the external elevation is not practically possible to produce, particularly when replacements are ordered. The mirror image of highly reflecting glazing can be distorted by imperfections in flatness.

The view of colour from inside to outside is insignificantly falsified. If the view is compared directly with the view through an open window, a slight toning will be recognised. This toning can be more apparent for some types of solar control glass.



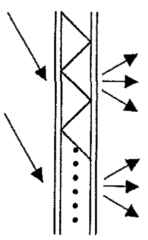
❶ Delivery shapes of model panes (examples)



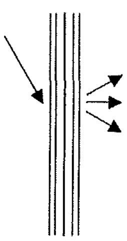
The illustration shows schematically the isotherms, that is lines of equal temperature, for thermal insulation glass with thermally optimised edge bonding in comparison to a conventional spacer of aluminium or steel.

It can be clearly seen that the isotherms with the improved spacers lie closer to the bottom of the glass, which shows that the glass is warmer on the room side so that less condensation will be created at the edge of the double-glazed unit, or none at all.

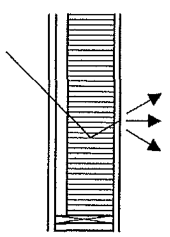
❷ Heat flow at the glass-frame transition for highly insulated windows (EnEV → refs)



❸ Grid, fabric, spotted foils, blinds **Glazing units with inserts**



❹ With transparent, translucent, tinted foils; stuck onto glass **Laminated safety glass**



❺ Capillary system between panes, diffusing, low U_g-values **Transparent thermal insulation**

Model panes are described with sketches and dimensioned according to the system in → ❶. For acute angles of less than 30°, at the top a blunt edge of at least 10 mm is required. Smaller panes (≦60 cm edge length) should be avoided because these have a higher risk of breakage and the edge seal can tend to leak due to the reduced elasticity of the panes.

Thermally improved spacers

The Energy Saving Regulations (EnEV) and more stringent standards and guidelines have resulted in the increased significance of thermally improved spacers. The thermal properties of the spacers may be taken into account in the new verification process under EnEV. This improvement is, however, not reflected in the U_g-value, but ψ is additionally applied as lengthwise heat transmittance and is thus reflected in the official verification.

This improved thermal insulation in the critical transition from glass to window frame results in higher surface temperatures on the room side than with the use of conventional aluminium spacers. This results in less or even no condensation, which always forms at the coldest point under unfavourable conditions, like for example high air humidity → ❷. For windows with wooden frames, the harmful effects of damp and the danger of mould are reduced.

Light deflection and solar control in the space between the panes

Various light deflection systems can be installed in the space between the panes of insulated glazing → ❸. Rigid light control elements use reflection and dispersion to allow diffused light into the room and shield direct sunlight according to the position of the sun, or direct it deep into the room. Sunshading blinds, which can either be rotated or completely raised, are protected from dirt by the location between the panes. They can be operated manually or electrically. The panes of glass at each side must be of toughened glass, because increased stresses could be caused by the heat. The width of the space between the panes varies from 20 to 27 mm according to construction.

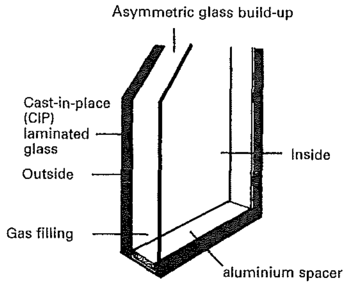
Thermal insulation between the panes

Transparent thermal insulation → ❺ enables high thermal insulation values at the same time as high heat transmission (heat trap). These systems diffuse the light passing through to varying extents. Glass or plastic tubes can be used, installed at right angles to the glass surface. They reflect the light further into the inside of the room and hinder air movement when the gap between the panes is large. Units with more panes, or filled with foam particles, reflect more light externally. Transparent thermal insulation elements need effective shading in summer. They are mostly used for heat-storage walls.

Self-cleaning coating on the weather side

Various glass manufacturers offer self-cleaning coatings in position 1 (→ p. 105) of insulated glazing. This coating results in a slight alteration of the colour and also a slight influence on the visual and energy values compared to standard. The coatings can be applied to thermal insulation and solar control glazing and also on façade panels; it will be necessary to request further information from the manufacturer. The manufacturer's cleaning instructions are to be observed absolutely.

1. Weight of glass: the heavier the glass pane, normally the higher the acoustic insulation
2. The more elastic the pane (e.g. resin-filled cast-in-place), normally the higher the acoustic insulation
3. The thicknesses of the inner and outer panes must be different; the greater the difference, normally the higher the acoustic insulation



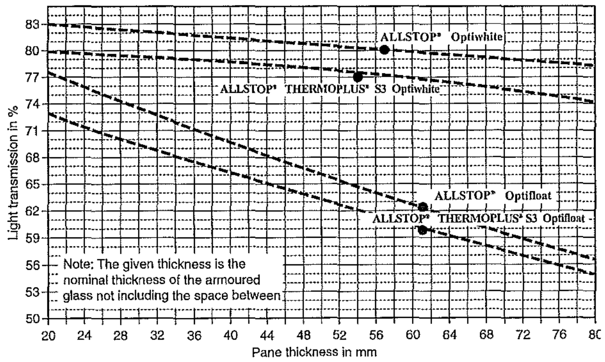
❶ Improvement of the sound reduction properties of insulated glazing

C	– motorway traffic – rail traffic with medium or high speed – jet aircraft, short distance away – factories emitting mostly medium or high frequency noise
C_{tr}	– urban road traffic – rail traffic at low speed – propeller aircraft – jet aircraft, far away – disco music – factories emitting mostly low and medium frequency noise

❷ Adaptation terms C and C_{tr} for the sound reduction value R_w for particular noise types. C 100–5000 or C_{tr} 100–5000 describe an extended frequency spectrum.

Type	R_w (dB)	C	C_{tr}	C 100–5000	C_{tr} 100–5000	Configuration (mm)	Thickness (mm)	Weight (kg/m2)
28/37	37	–2	–5	–1	–5	8(16)4	28	30
30/38	38	–2	–6	–1	–6	10(16)4	30	35
28/38 V	38	–2	–6	–1	–6	4(16)8 VSG	28	30
30/38 X	38	–2	–6	–1	–6	4(16)10 VSG	30	35
30/38 V	38	–3	–7	–2	–7	6(16)8 VSG	30	35
29/39 L	39	–1	–5	0	–5	4(16)8,8 L	29	30
32/40 V	40	–2	–6	–1	–6	6(16)10 VSG	32	40
31/41 L	41	–3	–7	–2	–7	6(16)8,8 L	31	35
33/42 L	42	–3	–7	–2	–1	6(16)8,8 L	33	40
33/43 L	43	–3	–7	–2	–7	8(16)9,1 L	33	40

❸ Sound reduction and adaptation terms for Phonstop® glasses. U_g-values of Phonstop® TH-SN 1.2 W/m²K and Phonstop® TH S3 1.1 W/m²k (EnEV→ refs)



❹ Comparison of light transmittance values of armoured glass with and without white glass → (EnEV→ refs)

Attack-resistant glazing, DIN 52290-3, DIN 52290-4	DIN EN 356	Break-in-resistant windows, doors, DIN V ENV 1627	According to the security guidelines of VdS Loss Prevention	Health and safety regulations
A1	P2A	–	–	–
A2	P3A	–	–	P3A
A3	P4A	WK 2	EH01	–
–	P5A	WK 3	EH02	–
B1	P6B	WK 3–4	EH1*	–
B2	P7B	WK 5	EH2*	P7B
B3	P8B	WK 6	EH3*	–

*Certification by VdS is required.

❺ Comparison table of security classes according to insurance regulations. This table is only an overview: it must be possible to fulfil and verify the required values.

Noise reduction

All thermal insulation and solar control units can also fulfil noise control functions, but need additional measures. These additional measures can influence the visual transmittance, the g-value and the U_g-value. These altered values have to be taken into account in the verification under EnEV.

As examples, these additional measures are possible, according to the required level of noise reduction: poured resin or heavy glass fillings, composite glass with noise reduction foil etc. The noise reduction values or sound transmission class for all glass combinations are listed in the individual manufacturers' handbooks and should be taken into account in the design. Only products with the required test certificates should be used. For sound reduction classes of windows → p. 100 ⓭ and p. 386. In addition to the evaluated sound reduction value R_w, spectrum adaptation terms can be given, which are used to modify the R_w-value to the subjective response of the ear to certain noise types → ❷.

Security glazing

These requirements on glazing units lead to thick glass, which causes a green coloration. This can be reduced by white glass. Combination with thermal insulation and solar control glazing is also possible.

Break-in resistance (private areas)

This is security glass for private clients, intended to dissuade an opportunist criminal, through to high-quality break-in resistant glazing according to the security guidelines of VdS Loss Prevention. These requirements can be met by a composite secure glazing unit consisting of at least two panes with a high-strength plastic foil.

Resistance against manual attack (commercial use)

In these cases, the security effect can be provided only by a multi-layer configuration with the use of various glass thicknesses and plastic foil inserts.

If the security glazing is to be used and recognised by insurance companies, VdS Loss Prevention's guidelines are to be complied with, the break-in resistance classes being categorised as EH1, EH2 or EH3.

Bullet-proof glass

The following 'BR' resistance classes are defined according to European standards:

Class BR 1:	.22 rifle
Class BR 2 (C1):	9 mm pistol
Class BR 3 (C2):	.357 Magnum pistol
Class BR 4 (C3):	.44 Magnum pistol
Class BR 5:	5.56 × 45 rifle
Class BR 6 (C4):	7.62 rifle × 51 standard ammunition
Class BR 7 (C5):	7.62 rifle × 51 hard-core ammunition
Class SG 1:	shotgun calibre 12/70 (1 hit)
Class SG 2:	shotgun calibre 12/70 (3 hits)

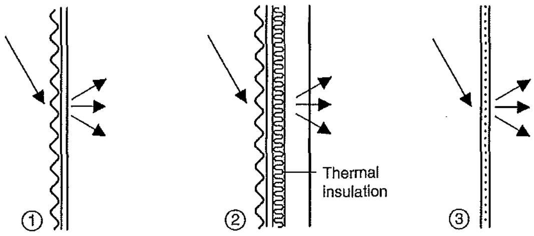
These glasses can be produced with the grading 'splinter-free' (on the inside).

Glazing for counters in banks etc. should comply with the regulations of Accident Insurance for Administration. The technical solutions from Accident Insurance Information (BGI) do not exclude other solutions, which are just as safe.

Explosion resistance

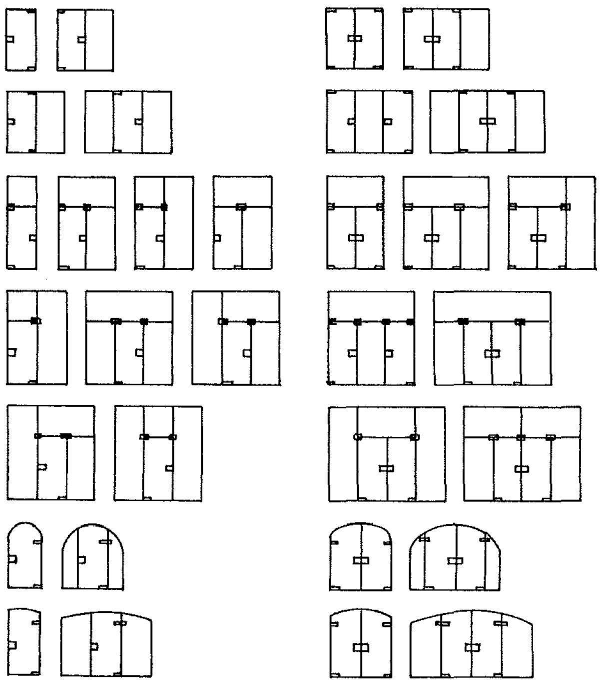
Glazing was tested with maximum dimensions of 900 × 1100 mm and fixed all round in a retaining construction. This must be installed in accordance with the test certificate or the window unit should be tested.

BS EN 356
BS EN 1063
BS EN 1279
BS EN 12758
DIN EN 356
DIN EN ISO 717
DIN EN 1063
DIN EN 13123



① Cast glass ornamental surface etc.
② Cast glass profile
③ Cast glass with amorphous structures, rough surface, transparent, translucent

1 Light dispersion and light modifying effects of cast glasses



2 Single leaf Double door elements

DELODUR®	Glass thickness (mm)	Maximum size (cm × cm)	Thickness tolerance (mm)
blank, grey, bronze, optiwhite	10 12	244 × 510 244 × 510	0.3 0.3
green	8 10	244 × 510 244 × 510	0.3 0.3
structure 200 master glasses	8 10	194 × 425 194 × 425	0.5 0.5
bamboo, chinchilla blank/bronze	8	175 × 425	0.5

3 Whole glass door elements (fanlights and side elements) – maximum sizes of toughened panes that can be produced (EnEV → refs)

	Size in 1/1 G (mm × mm)	Size in 2/2 G (mm × mm)	Size in 3/3 G (mm × mm)
outside door size standard	709 × 1972 709 × 2097	834 × 1972 834 × 2097	959 × 1972 959 × 2097
lining rebate size	716 × 1983 716 × 2108	841 × 1983 841 × 2108	966 × 1983 966 × 2108
structural size	750 × 2000 750 × 2125	875 × 2000 875 × 2125	1000 × 2000 1000 × 2125

4 Glass doors: dimensions (EnEV → refs)

OPTICALLY VARIABLE GLASS

Double-glazed units whose transmission properties can be altered are differentiated into switching and switchable units. Switching units are conditioned during production so that they react automatically to certain influences (e.g. thermotropic units). The visual transmittance of switchable layers can be altered at any time by changing the gas layer in between the panes or by applying a voltage.

Thermotropic units

These composite units react with alterations of temperature by changing from clear (transparent) to opaque (diffuse). This is achieved with a mixture of two components with different refraction properties, which align their structures differently according to temperature, altering the refraction of the layer. The alteration is reversible.

Electrochromatic units

The transmittance of these units can be altered by applying a voltage to the reactive layer. For internal use, this can be achieved with the use of liquid crystals in the space between the panes (LC foils function reliably only between –40°C and +40°C). Other systems make use of the property of some materials to alter their visual transmittance and coloration with the absorption or release of ions (by applying a voltage). These units are suitable for external glazing.

CAST GLASS

Properties

Cast glass is produced mechanically by rolling certain surface structures. It is not clear to look through. Cast glass is used for applications where obscure glass is required (bathroom, WC) and as a design element. Ornamental glass is available as white and tinted, raw white glass, and white and tinted ornamental wired glass. Wired glasses are no longer classified as safety glass, with exceptions when used in overhead glazing.

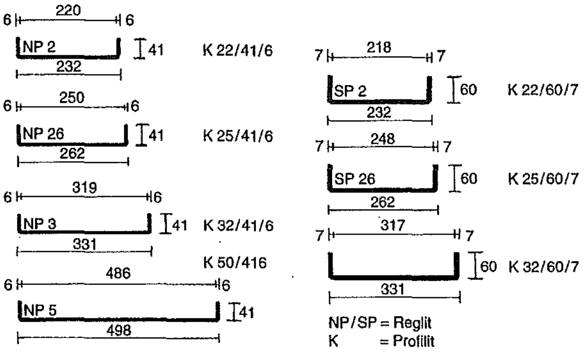
Most cast glasses can be further processed to make toughened glass, laminated safety glass and thermally insulated glazing units. The structure is normally faced to the outside in order to ensure a proper edge joint. If the glass is only lightly structured, the structured side can be faced inwards in order to simplify cleaning. Tinted cast glass cannot be used in combination with tinted classes like float glass, toughened glass or laminated safety glass, nor with coated glass with thermal insulation or solar control functions.

GLASS DOORS

Whole glass doors

The dimensions of doors correspond to the dimensions of metal door linings → **4**. They can be installed in all the metal door linings produced to DIN 18111 standard. The doors are made of toughened glass panes. If violently smashed, the glass crumbles into a network of small fragments, which more or less stay loosely together. The normal glass thicknesses of 10 or 12 mm comply with the structural requirements. Structured cast glass and printable toughened float glass panes are available. Printable laminated safety glass panes can also be supplied (the composite glass foil is printed).

Whole glass door elements consist of one or more glass doors, the side elements and the fanlight. Further possibilities are sliding, folding, segmented arch, and round arch door elements. Various tints and glass structures are available, and standard or special sizes.



❶ Profiled glass – cross-sections

Height above ground level clear opening	up to 8 m	up to 20 m	up to 100 m	up to 8 m	up to 20 m	up to 100 m	up to 8 m	up to 20 m	up to 100 m
	I			II			III		
glass type → ❶	L*	L*	L*	L*	L*	L*	L*	L*	L*
NP 2 K 22/41/6	2.67	2.11	1.80	3.19	2.52	2.15	3.77	2.98	2.55
NP 26 K 25/41/6	2.53	2.00	1.70	3.02	2.39	2.03	3.57	2.82	2.41
NP 3 K 32/41/6	2.27	1.80	1.53	2.72	2.15	1.83	3.21	2.54	2.17
NP 5 K 50/41/6	1.88	1.49	1.27	2.25	1.78	1.52	2.66	2.11	1.80
SP 2 K 22/60/7	4.22	3.33	2.84	5.04	3.98	3.40	5.96	4.71	4.02
SP 26 K 25/60/7	3.99	3.16	2.69	4.77	3.77	3.22	5.65	4.46	3.81
K 32/60/7	3.59	2.84	2.42	4.29	3.39	2.89	5.08	4.02	3.43

❷ Sheltered buildings (0.8–1.25 × g)

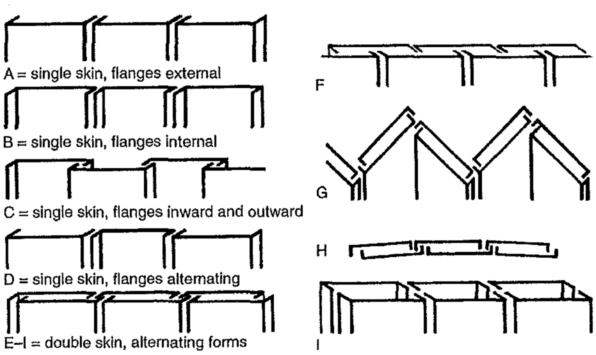
	h/a = 0.25; – (1.5 × q)						H/a = 0.5; – (1.7 × q)					
Height above ground level clear opening	up to 8 m	up to 20 m	up to 100 m	up to 8 m	up to 20 m	up to 100 m	up to 8 m	up to 20 m	up to 100 m	up to 8 m	up to 20 m	up to 100 m
glass type → ❶	L*	L*	L*	L*	L*	L*	L*	L*	L*	L*	L*	L*
NP 2 K 22/41/6	2.18	1.72	1.47	3.08	2.44	2.08	2.05	1.62	1.38	2.90	2.29	1.95
NP 26 K 25/41/6	2.06	1.63	1.39	2.92	2.31	1.97	1.94	1.53	1.31	2.74	2.17	1.85
NP 3 K 32/41/6	1.85	1.47	1.25	2.62	2.07	1.77	1.74	1.38	1.17	2.46	1.95	1.66
NP 5 K 50/41/6	1.54	1.22	1.04	2.17	1.72	1.47	1.44	1.14	0.97	2.04	1.61	1.38
SP 2 K 22/60/7	3.44	2.72	2.32	4.87	3.85	3.28	3.23	2.56	2.18	4.57	3.62	3.08
SP 26 K 25/60/7	3.26	2.58	2.20	4.61	3.64	3.11	3.06	2.42	2.06	4.33	3.42	2.92
K 32/60/7	2.93	2.32	1.98	4.15	3.28	2.80	2.76	2.18	1.86	3.90	3.08	2.63

L* = length of glass sheets in metres

❸ Exposed buildings

light transmittance:	single skin	up to 86%
	double skin	up to 75%
noise reduction	single skin²	up to 29 dB
	double skin	up to 41 dB
	triple skin	up to 55 dB
thermal insulation	single skin	k = 5.6 W/m²K
	double skin	NP U_g = 2.8 W/m²K
		SP U_g = 2.7 W/m²K

❹ Physical data



❺ Installation possibilities

Profiled glass is a cast glass produced with a U-shaped profile. It is translucent with an ornamentation on the outside surface of the profile, and conforms to the properties of cast glass. It has low maintenance requirements. It is suitable for lift shafts and roof glazing. Rooms using this glass for fenestration are rendered glare free. Heat-absorbing glasses Reglit and Profilit 'Plus 1.7' are coated with metallic oxides and attain a U_g-value of 1.8 W/m²K.

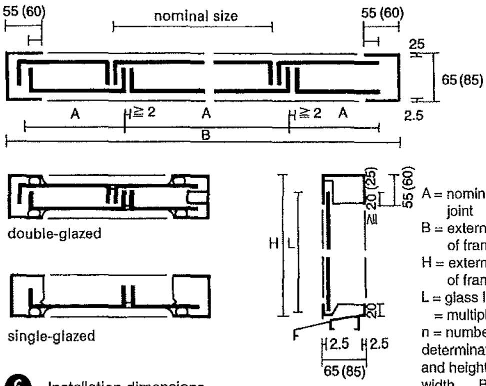
Solar control glass (Type R, "Bernstein'; Type P, 'Antisol'), which reflects and/or absorbs ultra-violet and infra-red radiation, can be used to protect delicate goods from UV radiation. The transmission of radiant energy into the room is reduced, as is the convection from the glazing, whilst the light transmission is maintained.

For glazing subject to impacts, e.g. in of sports halls (ball throwing safety), Reglit SP2 or Profilit K22/60/7 without wire reinforcement should be used.

Regulit and Profilit are allowed as fire-glass with a fire resistance class of G30. Normal and special profiles are also available with longitudinal wires.

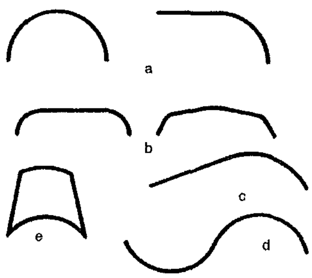
Building components

GLASS
Basics
Insulated glazing
Security and noise control glass
Optically variable glass
Cast glass
Profiled glass
Glass blocks
Fire protection glass
Curtain walling



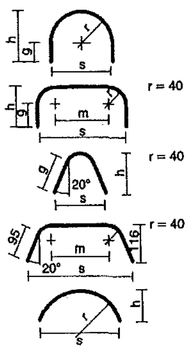
A = nominal dimension + joint
B = external dimension of frame
H = external dimension of frame (height)
L = glass length = multiple of 25 mm
n = number of widths
determination of width and height: overall
width B = n × A + 5 cm
height H = L + 4 cm

❻ Installation dimensions



a) circular curves with and without straight extensions
b) double-sided curves with regular or variable curvature diameter
c) conical curves
d) S-shaped curves
e) U-shaped or similar curves with and without straight extensions

❼ Curved forms



s	r	g	h	Unfolded
80–300	40–50	0–100	40–190	126–501

s	m	g	h	Unfolded
100–340	20–260	0–100	40–140	126–501

s	g	h		Unfolded
80–200	7–183	33–200		126–501

s	m			Unfolded
160–340	20–200			126–501

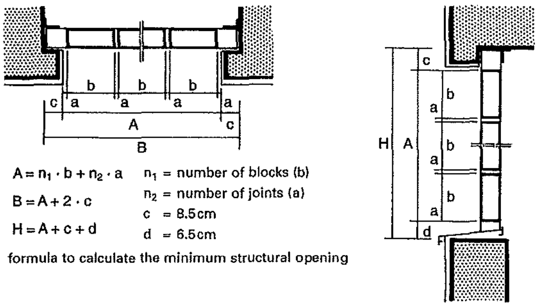
s	h	R		Unfolded
140–300	60–100	71–163		126–501

❽ Sample configurations of the possibilities of bending ornamental glass (dimensions in mm)

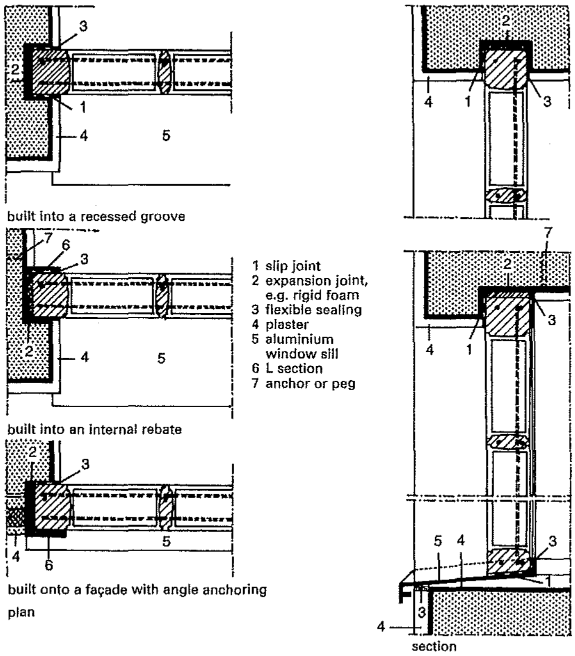
Building components

GLASS
Basics
Insulated glazing
Security and noise control glass
Optically variable glass
Cast glass
Profiled glass
Glass blocks
Fire protection glass
Curtain walling

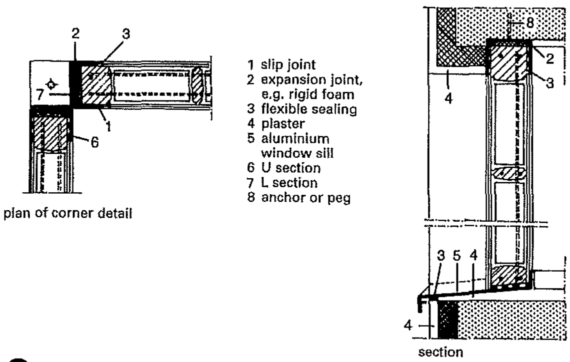
BS EN 1051
ISO 21690
DIN EN 1051
DIN 4102-3,
DIN 4242



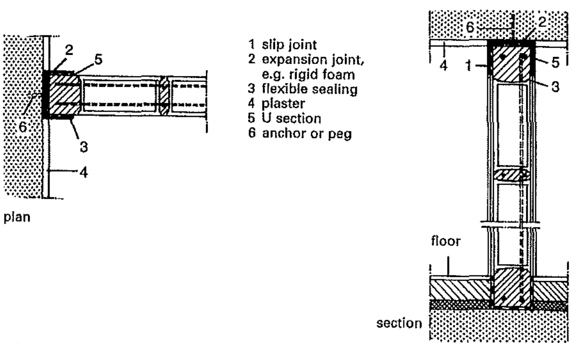
❶ Standard dimensions for glass block walls



❷ Examples of glass block wall construction

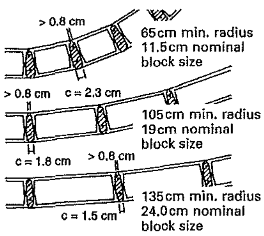


❸ Installation with U-profiles and external thermal insulation



❹ Interior wall junction using U-profiles

Glass blocks are hollow units which consist of two sections melted and pressed together, thereby creating a sealed air cavity. Both surfaces can be made smooth and transparent, or very ornamental and almost opaque. Glass blocks can be obtained in different sizes, coated on the inside or outside, uncoated, or made of coloured glass. They can be used internally and externally, e.g. transparent screen walls and room dividers (also in gymnastic or sports halls), windows, lighting strips, balcony parapets and terrace walls. Glass blocks are fire-resistant up to G60, G120 or F60 when used as a cavity wall with a maximum uninterrupted area of 3.5 m², and can be built either vertically or horizontally. They are used as building elements, but cannot be load-bearing. Their properties: good sound and thermal insulation; high light transmittance (up to 82%); transparent, translucent, diffusing and low-glare according to decor; increased impact resistance. The thermal insulation of a glass block wall: with cement mortar U_g-value = 3.2 W/m²K, with lightweight mortar U_g = 2.9 W/m² K, with special bricks up to U_g = 1.5 W/m² K.



smallest radius R with glass thickness 8cm joints must be <1.0cm wide			
glass block nominal size	11.5cm	19.0cm	24.0cm
joint width c = 1.5cm	200.0cm	295.0cm	370.0cm
joint width c = 1.8cm	95.0cm	180.0cm	215.0cm
joint width c = 2.3cm	65.0cm	105.0cm	135.0cm

❺ Minimum radii of glass block walls

	Dimensions mm	Weight kg	Stock m²	Stock carton	Stock range
	115 × 115 × 60	1.0	64	10	1.000
	146 × 146 × 98 6″ × 6″ × 8″	1.8	42	8	512
	190 × 190 × 50	2.0	25	14	504
	190 × 190 × 80	2.3	25	10	360
	190 × 190 × 100	2.8	25	8	288
	197 × 197 × 98 8″ × 8″ × 4″	3.0	25	8	288
	240 × 115 × 80	2.1	32	10	500
	240 × 240 × 80	3.9	16	5	250
	300 × 300 × 100	7.0	10	4	128

❻ Dimensions of glass blocks

Unreinforced glass block walls

Glass block walls that meet the requirements of → ❼ may be built without reinforcement and without specific structural verification. Take note of DIN 4242 with regard to the structural reinforcement of the edge strip.

Arrangement of joints	Thickness (mm)	Wall dimensions		
		Shorter side (m)	Longer side (m)	Wind load (kN/m²)
Continuous	≧80	≦1.5	≧1.5	≦0.8
Overlapped (bonded)		≦6.0		

❼ Permissible limits for unreinforced glass block walls

Glass brick format (mm)	Airborne sound insulation margin	Weighted sound reduction R'_w
190 × 190 × 80	–12 dB	40 dB
240 × 240 × 80	–10 dB	42 dB
240 × 115 × 80	–7 dB	45 dB
300 × 300 × 100	–11 dB	41 dB
double-glazed wall, 240 × 240 × 80	–2 dB	50 dB

❶ Sound insulation of glass block walls

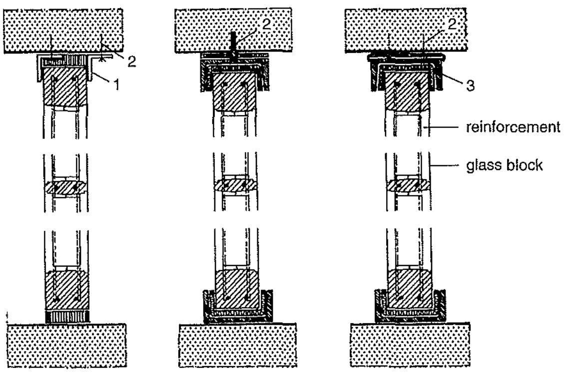
Sound insulation class	R_w	Achievable with glass brick windows with wall structure:
6	50 dB	double skin
5	45–49 dB	single skin
4	40–44 dB	single skin
3	35–39 dB	single skin
2	30–34 dB	single skin
1	25–29 dB	single skin
0	25 dB	single skin

❷ Sound insulation classes, VDI guideline 2719 for windows

Room type	Guideline values for permissible external noise level	
	Average noise level*	Average maximum level
1. domestic living rooms, guest rooms in hotels, wards in hospitals and sanatoria	daytime 30–40 dB (A) night time 20–30 dB (A)	daytime 40–50 dB (A) night time 30–40 dB (A)
2. school rooms, single private offices, scientific work rooms, libraries, conference and lecture rooms, doctors' surgeries and operating theatres, churches, auditoriums	30–40 dB (A)	40–50 dB (A)
3. multiple-use offices	35–45 dB (A)	45–55 dB (A)
4. open-plan offices, inns and restaurants, shops, halls	40–50 dB (A)	50–60 dB (A)
5. entrance, waiting and departure halls	45–55 dB (A)	55–55 dB (A)
6. opera houses, theatres, cinemas	25 dB (A)	35 dB (A)
7. recording studios	observe special requirements	

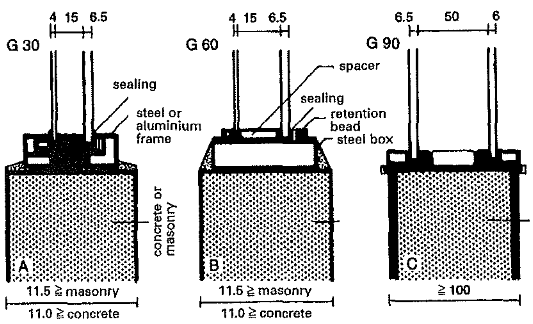
*equivalent maximum permitted constant level

❸ Permitted maximum sound levels for different categories of room, VDI guideline 2719



1 angle steel, 50 × 55 mm
length >100 mm, at least four per glazed area
2 allowable fire-resistant pegs and steel screws M 10
3 flat steel strips to fix the glass block wall (welded)

❹ Installation details: fire-resistant glazing with glass blocks



❺ Glazing with fire resistance class 'G'

Sound reduction

Because of its weight, a glass block wall has particularly good sound insulation properties:
1.00 kN/m² for 80 mm glass blocks
1.25 kN/m² for 100 mm glass blocks
1.42 kN/m² for special BSH glass blocks.
To be effective, the surrounding building elements must have at least the same sound reduction characteristics. Glass block construction is the ideal solution in all cases where good reduction is required. In areas where a high level of sound reduction is necessary, economical solutions can be achieved by using glass block walls to provide the daylight, while keeping ventilation openings and windows. These can serve as secondary escape routes if they conform to the minimum allowable size.

DIN 4109 should be complied with. The weighted sound reduction measurement R'_w is determined according to DIN 52210 → ❶:
R_w = airborne sound insulation margin + 52 dB
Single-skin glass block construction fulfils the requirements of sound insulation class 5 → ❷.

Glass blocks with steel reinforcement

The fire-resistant glazing of glass blocks can, like all other glass block walls, be built with and without U-profiles, and all the possible connections are in principle identical. Because of the strong linear expansion in case of fire and the release of smoke, glass block walls are bedded all round with mineral fibre. → ❹. Fire resistance classes up to G 120 or F 60 can be achieved, depending on the construction and the manufacturer.

FIRE PROTECTION GLASS

Normal glass is of limited suitability for fire protection. In case of fire, the action of heat on one side can cause float glass panes to burst very quickly and large broken pieces to fall out, which can result in the fire spreading. The required fire resistance classes for exposed glazing will be laid down in the building permission. The following fire resistance classes are defined:
G30, G60, G90, G120, G180
F30, F60, F90, F120, F180
T30, T60, T90, T120, T180

Fire resistance classes 'G' and 'F'

'G glasses' must prevent flames or combustion gases passing through for a certain duration of fire (e.g. G30 = 30 minutes). There must be an official technical approval for all 'G glazing', including the installation details. Heat radiation may, however, be transmitted by this glazing, which restricts the possible applications. Such glazing is not permissible for emergency exits.

There are three possibilities for construction of G glazing:
Wired glass with spot-welded mesh
Elaborate special toughened glass combinations in composite isolated glazing
Pre-stressed borosilicate glass, like Pyran.

F glazing has to prevent the transmission of heat radiation, in addition to stopping smoke and fire. This is achieved by using special composite glass panes with a gel layer, which foam or can absorb energy through evaporation effects and can thus prevent radiated heat passing through the pane. The pane and also its connection to the framed construction and adjacent construction elements all have to possess technical approval valid under building regulations.

Construction fire protection can be evaluated only in combination with the adjacent building elements (Fire Protection chapter → p. 511 ff.)

Building components

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Basics
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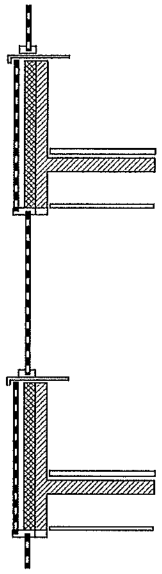
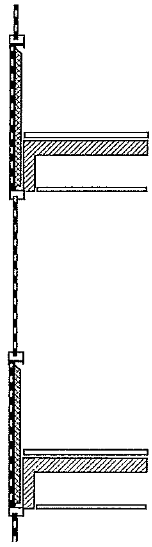
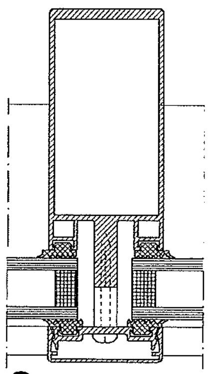
Fire protection glass
Curtain walling



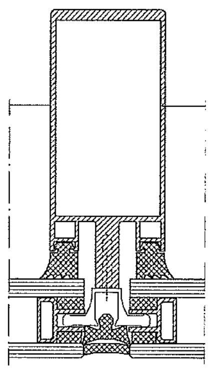
1 Cold façade with rear ventilation and glass parapet cladding (EnEV → refs)



2 Warm façade without ventilation but with glass parapet cladding (EnEV → refs)



3 Curtain wall construction with glass held in place by cover strip



4 Flush glass curtain wall

Radar damping
Radar reflection damping is a requirement of German Air Traffic Control (DFS), applying to the façades of all larger buildings in the vicinity of airports. The purpose is to suppress the reflection of radar signals, which can occur from large façade surfaces, because these reflected signals can lead to false information on the radar screens of air traffic controllers and thus endanger air traffic.

Special coatings can be used to achieve high damping through absorption and phase-delayed overlaying (interference) of the radar signal hitting and being reflected from the insulated glazing. Because of the particular requirements for insulated glazing, the glass structure must be specifically calculated for every application. Light and energy values are determined in each case by the glass structure. The level of radar damping required depends on many factors, including the size of the building and its distance from and orientation to the radar equipment.

A radar report is generally to be commissioned for each building from an accredited institute in order to determine the required radar damping. The glass manufacturers develop a glass structure and this is then discussed with the institute. All other façade surfaces have to be investigated for this report as well, in order to take the necessary measures into account for construction.

Cold façades
A cold façade is a single skin curtain walling construction with a ventilated cavity at the rear, width approx. 40 cm, and single- or double-glazed external cladding panels. Sufficient and controlled heat dissipation must be guaranteed. The façade panels can be fixed all round, on two sides or at points according to official standards and guidelines. Technical approval is required for panels fixed at points, or a special-case approval has to be applied for.

The façade panels can be fully colour-coated on the back or partially printed by the screen-printing process. Special coatings are available from the various manufacturers in order to achieve colour matching with solar control glass. Samples are necessary to ensure a correct colour match. All visible edges must be finely ground and polished and non-visible edges must be ground.

Warm façade without ventilation at rear
The warm façade can consist of post and rail curtain walling or storey-height curtain walling elements. In both cases, the non-transparent parts or parapets have a glass panel. The construction of the external panel can be, for example, an external façade panel with the necessary thermal insulation behind it, thickness in accordance with EnEV, and an internal layer, which is sealed against diffusion of water vapour, e.g. aluminium sheet.

Mixed forms can be constructed, if an additional glass layer is set in front of the warm curtain wall in order to create a two-dimensional appearance (see below). If the panel remains the layer that drains water, then this is still a warm façade.

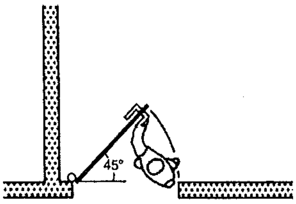
Flush glass curtain wall
This structural glazing façade is characterised by a uniform flat appearance. A full-surface glass appearance is possible only if the panes are glued to metal frames. The system used must possess technical approval or special case approval. The structural sealing must be carried out with a material (e.g. Dow Corning GmbH Technical Approval No. Z-70. 1–75) that possesses general technical approval valid under building regulations.

In Germany, all façades over 8 m in height must have an additional mechanical fixing of the panes. All insulated glazing must have a UV-resistant edge seal.

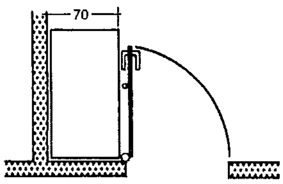
Curtain walling with fire-resistant glass
F fire-resistant glazing has only limited practicality for external use, because the foaming fire-protection layer cannot be heated over 50–60 °C. This is only possible to guarantee for façades subject to direct sunshine if effective sun shading is provided and guaranteed.

Sun screens
Sun screens are normally used as additional external transparent sun shading layers. They consist of metallic oxide-coated toughened glass panes. When installing sun screens, the coating should always be on the weather side. Sun screens can, according to official standards and guidelines, be fixed all round, on two sides or at points. Technical approval is required for panels fixed at points, or a special-case approval must be applied for.

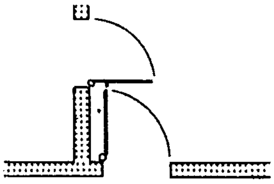
DOORS
Arrangement



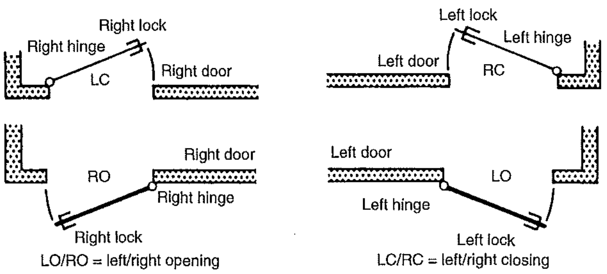
❶ Generally appropriate arrangement



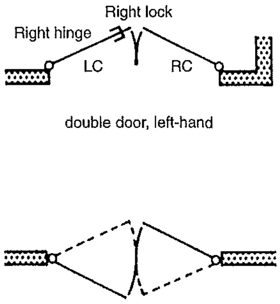
❷ Good door arrangement for use of room



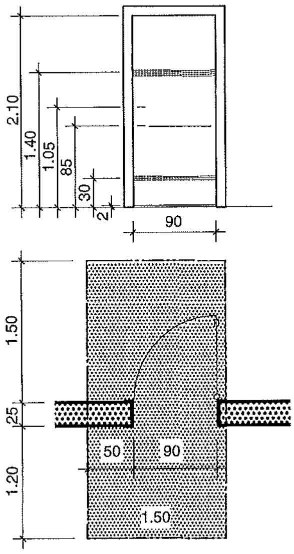
❸ Arrangement of two corner doors, opening into the same room



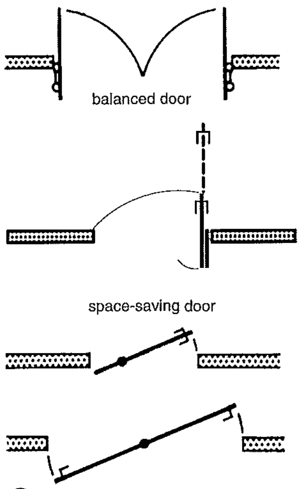
❹ Door descriptions according to occupation of room and hinge direction. If the door is looked at from the hinge side, the direction of the hinges determines the descriptions of hinge and lock.



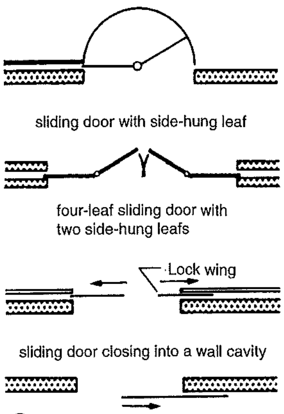
❺ Double swing door, single or double leaf; walk through on the right



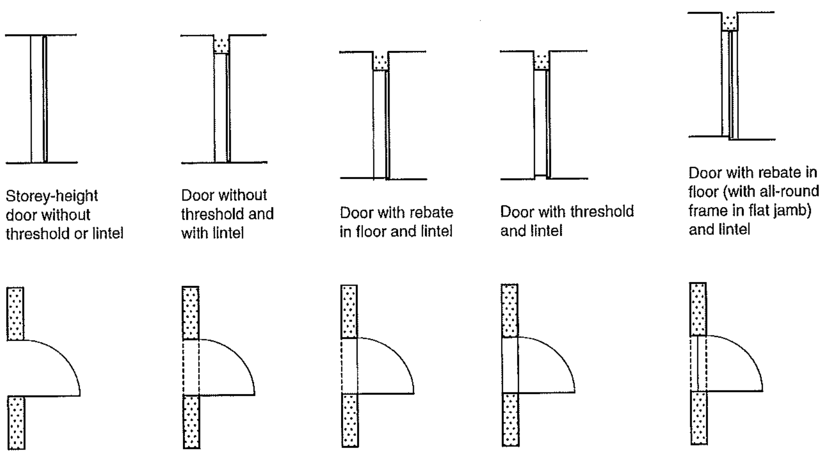
❻ Minimum dimensions for disability-friendly building and marked heights for glass doors



❼ Centre-hung doors – single-leaf, eccentrically hung (bottom); centrally hung 'butterfly' door, for passing on the right (top).



❽ Sliding door, sliding in front of wall



❾ Depiction of lintel and threshold on plan (in this case at 1:100). Height differences in the floor are shown by a continuous line and lintels with a dashed line.

Doors must be sensibly arranged inside a building, because unfavourably distributed or unnecessary doors impair the use of rooms, or cause difficulties, and can lead to the loss of storage places → ❶ + ❷.

Categories: Inward-opening doors, which open into the room; outward-opening doors, which open out of the room; doors normally open into the room. Description of types of door according to location and purpose: opening direction, style detail, door lining, construction of door, type of rotation and opening.

Internal doors: Room doors, entry doors of flats, cellar doors, doors for bathroom, WC and subsidiary rooms.

External doors: House front door, back door or yard door, balcony and patio doors.

Special types like centre-hung doors and balanced doors → ❼ require very little strength to open, but the ironmongery is elaborate and the danger of accident at the hinge side has to be taken into account. These are suitable for through-doors in corridors, entrance lobbies, etc.

The width of a door depends on the intended use and the type of room to be accessed. **Minimum clear width for walking through** is 55 cm. In residential buildings, the clear opening width of doors is:

single-leaf doors

room doors	approx. 80 cm
bath, WC	approx. 70 cm
entrance doors to flats	min. 90 cm
front doors	up to 115 cm

double doors

room doors	approx 170 cm
front doors	140–225 cm

clear opening height of internal doors

minimum	210 cm
better	210-225 cm

Sliding doors and revolving doors are not permissible at emergency exits, which they can block in circumstances of danger.

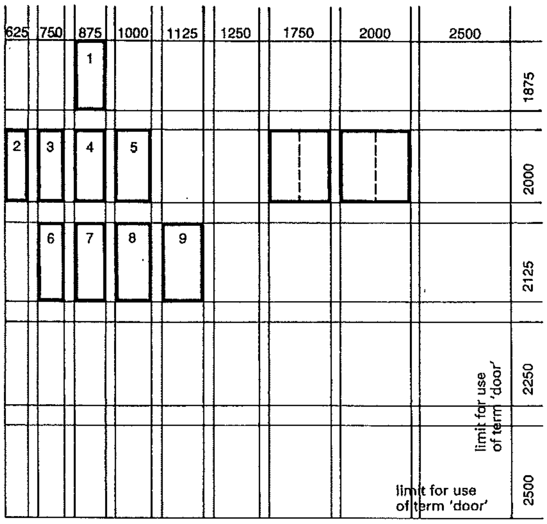
BS 6375
DIN 107

see also: Construction drawing symbols p. 10

Building components

DOORS
Arrangement
Construction details
Special doors
Garage/industrial doors
Locking systems
Security of buildings and grounds

BS 4787
BS 6375
BS 8213
BS EN 14220/1
BS EN 14351
DIN 4172
DIN 18100
DIN 18111



Preferred sizes shown in thick outline

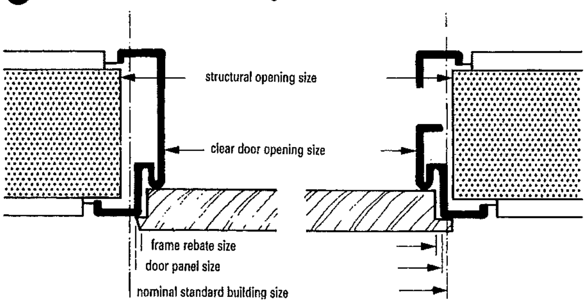
Structural openings for these preferred sizes are, as a rule, for double doors

The standards give the exact measurements concerning frames and door panels for those sizes which are indicated with a number → (8)

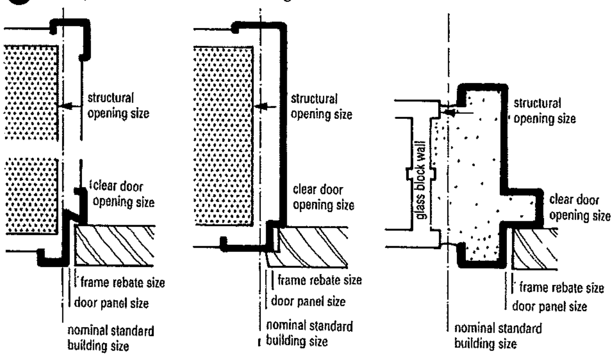
❶ Modular wall openings → ❷

Var.	Standard modular building dimensions		Door dimensions				Lining dimensions	
	Wall openings for door		Outside door panel width		Door panel rebate width, tolerance		Clear opening width, tolerance	Clear opening height, tolerance
					±1	+2 0	±1	0 −2
1	875	1875	860	1860	834	1847	841	1858
2	625	2000	610	1985	584	1972	591	1983
3	750	2000	735	1985	709	1972	716	1983
4	875	2000	860	1985	834	1972	841	1983
5	1000	2000	985	1985	959	1972	966	1983
6	750	2125	735	2110	709	2097	716	2108
7	875	2125	860	2110	834	2097	841	2108
8	1000	2125	985	2110	959	2097	966	2108
9	1125	2125	1110	2110	1084	2097	1091	2108

❷ Rebated doors and rebated linings



❸ One-piece steel rebated door linings



❹ Architrave frame

One-piece lining

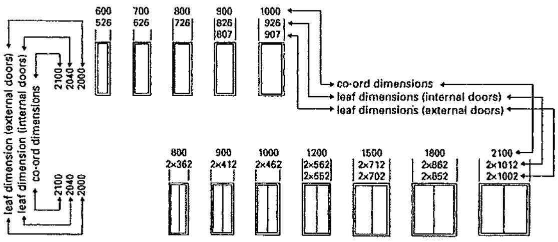
Shadow joint lining

Standard dimensions

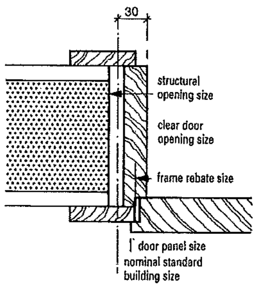
Dimensions of wall openings for doors → ❶ are **standard modular dimensions.** If, in exceptional cases, different dimensions are required then their modular dimensions should be whole multiples of 125 mm (100 mm according to British Standards). A wall opening with 875 mm width and 2000 mm height (modular dimensions) can be described as: wall opening DIN 18100 – 875 × 2000. In order to determine the door width, the frame detail has to be taken into account in the calculation of the structural opening, because some variants offer interesting creative possibilities of reducing the clear opening width by more than standard cased doors on account of the thickness of their construction → ❻ – ⓫.

Frame construction

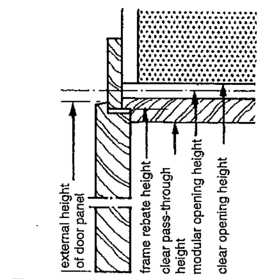
In the specification of a classic frame construction, in addition to the consideration of the differing constructional thicknesses (difference between structural opening and clear pass-through dimension), the different variants of **rebated frame (UK) or rebated door and frame (German)** have to be taken into account, together with the location of the door in the wall. For plain doors in rebated frames → ❿, the quality of construction is important, because inaccuracies in the frame or in hanging the door will immediately be clearly visible. The joint between frame and wall surface can only remain in order in the long term if a shadow joint is specified, because otherwise the transition from wall to door frame will become disarranged with the first redecoration at the latest. Architraves can only solve this problem until the first redecoration.



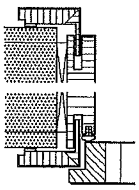
❺ Sizes of internal and external doors, UK, BS 4787-1



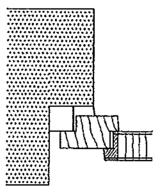
❻ Width of a door with lining and architraves



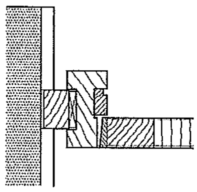
❼ Height of a door with lining and architraves



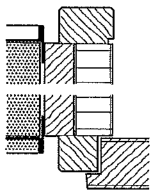
❽ Door lining



❾ Door with recessed frame



❿ Jamb-mounted frame with plain door panel

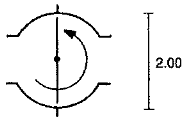


⓫ Steel door lining with integrated plaster beads

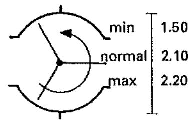
DOORS

Special Doors

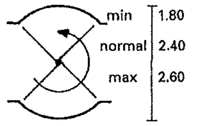
Revolving doors are made in several different designs → ❶ – ❻. Some are adjustable, e.g. when the number of users is large, particularly in the summer, the panels can be folded into the middle to allow people to go in on one side and out on the other simultaneously. Some designs have panels which can be pushed to the side if traffic is only in one direction (e.g. when business closes for the day) → ❹ – ❺. Actuating devices for **automatic doors** can be controlled by radar control, electric contact mats → ❼ – ❽ or pneumatic floor contacts. Unidirectional or reflecting light barriers controlling automatic sliding doors, with six panels up to 8 m wide, are ideal for installation on emergency exits in office blocks, public buildings, and supermarkets. Air curtain doors → ⓳ can be shut off at night by a raised door → ❾.
Folding doors can act as room dividers, guided from the side → ❿. Concertina doors are centrally hung → ⓫ for closing off wide openings. A revolving movement can be combined with a sliding movement. Harmonica doors can be made of plywood, artificial leather or fabric → ⓬. **Telescopic doors** have several panels joined by engagers. Externally guided telescopic doors with external guides are single-skinned→ ⓭; those with internal guides are double-skinned → ⓮.
Sliding partitions → ⓯ + ⓲ make good room dividers (sound insulation) but cannot be installed without tools. Provide room for the relatively bulky partition package in the design!
Folding partitions folded from above → ⓱ or horizontally upwards → ⓰ enable large rooms to be partitioned.



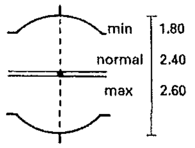
❶ Two-panel revolving door



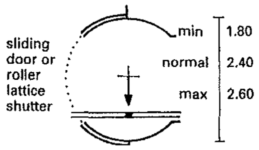
❷ Three panels



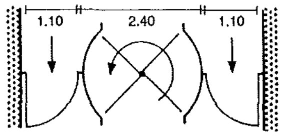
❸ Four panels



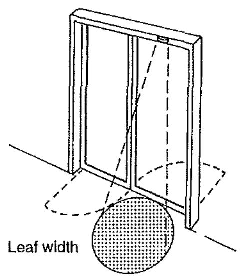
❹ Four panels, folded flat



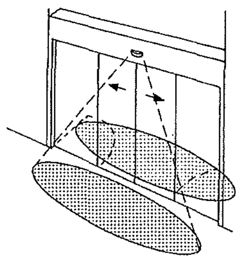
❺ Door assembly pushed to side



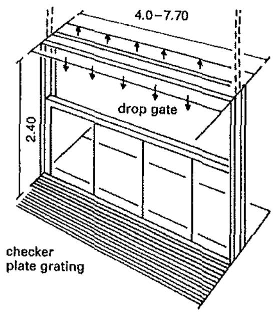
❻ Revolving door with additional emergency exits



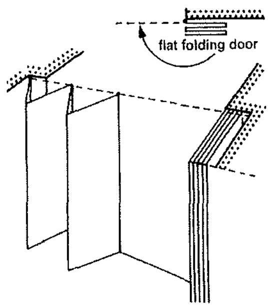
❼ Automatic hinged doors



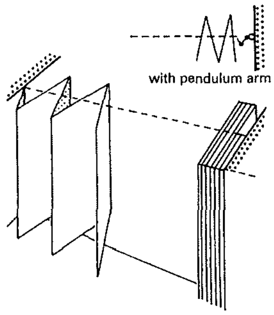
❽ Automatic sliding doors



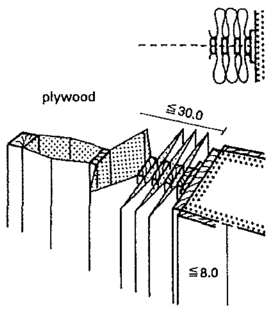
❾ Drop gate installation →⓳



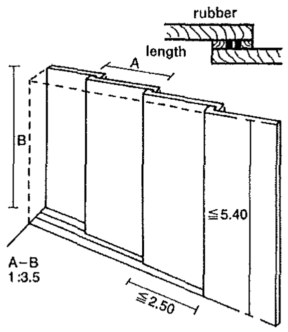
❿ Folding door with side guides



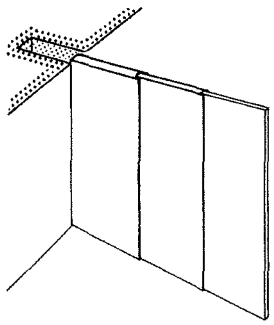
⓫ Folding door with central guides (harmonica door)



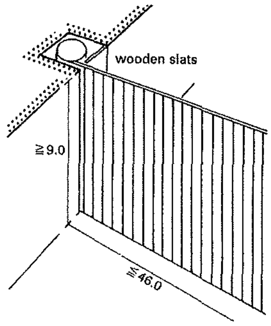
⓬ Accordion door made of wooden panels or flexible material



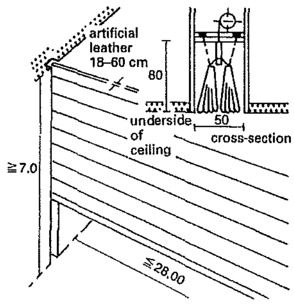
⓭ Telescopic door



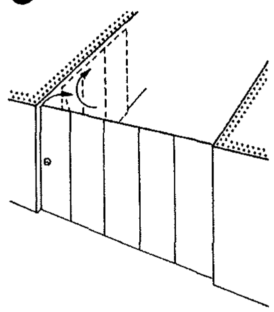
⓮ Telescopic door



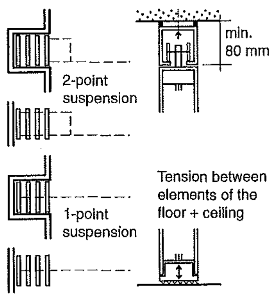
⓯ Roller partition



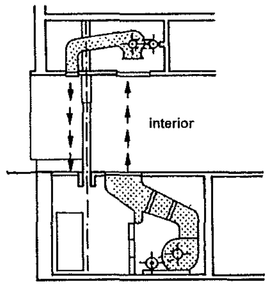
⓰ Partition curtain → p. 341 ❺ – ❽



⓱ Corner sliding door, articulated sliding gate



⓲ Variable sliding doors



⓳ Air curtain system → ❾

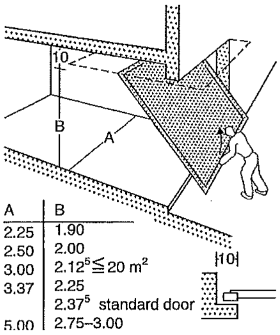
see also: Fire protection pp. 511 ff.

DOORS

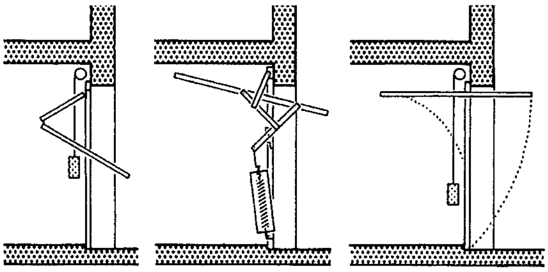
Garage/Industrial Doors

Up and over doors → ❶ can be used for garages and similar: sliding and/or folding doors, with a spring counterbalance or a counterbalance weight. They may be single skin, double skin, solid, partially glazed, fully glazed, constructed of wood, plastic, aluminium, or galvanised steel. The largest drive-though dimensions are 4.82 × 1.96 m. Max. panel size is approx. 10 m². Installation is possible under a round or segmental arch. Operation is by door gear with radio control. Also available are doors folding upwards → ❸, sectional doors → ❹, telescopic lifting doors → ❺ and roller doors → ❻ made of aluminium, plus large single and multi-skin doors for use in industrial buildings, transport and workshops: max. 18 m wide and 6 m high.

Doors can be operated by: pull switches, light beams, induction or wireless remote control contact pads. There are rapid-opening drive-through doors, flexible PVC doors → ⓭, with single layer, wear- and impact-resistant clear PVC; PVC is also used as strip curtain → ⓮. Single and double panel T30–T90 fire doors → ⓯ and sliding fire-protection doors → ⓰ can be fitted. Movable fire-resistant wall closures such as sliding, lifting or hinged doors must function independently of the electricity network and close automatically in the case of fire (Fischer-Riegel mechanism).

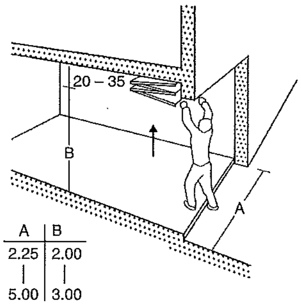


❶ Up and over door

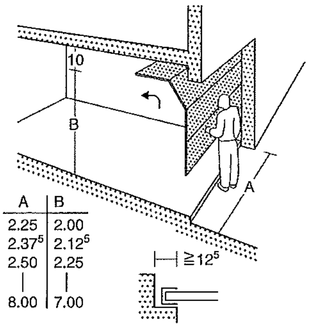


a) lifting and folding door
b) up and over door with spring balance mechanism without roof guide rails
c) up and over door with counterweight

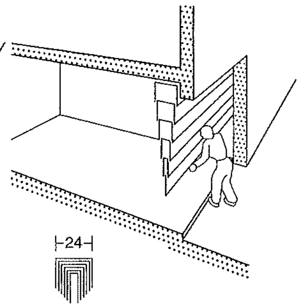
❷ Variants → ❶



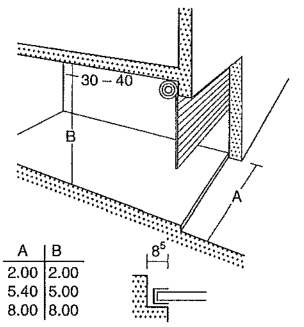
❸ Upward-folding door



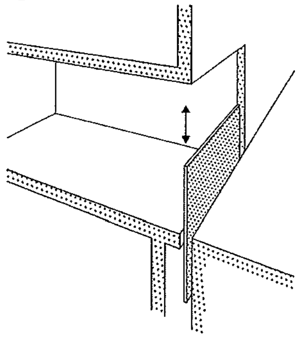
❹ Sectional door



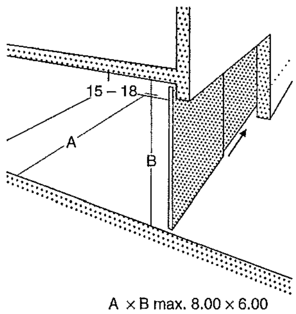
❺ Telescopic lifting door



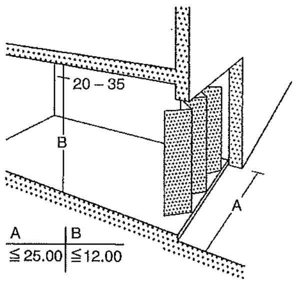
❻ Roller door, shutter (steel and aluminium)



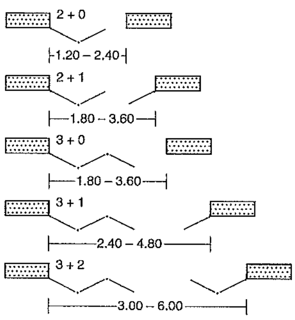
❼ Drop door



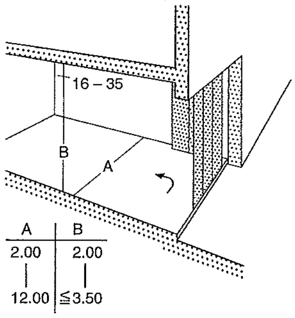
❽ Sliding door
steel sliding door T30–T90
T30: 5.00 × 4.00; T90: 8.50 × 3.50



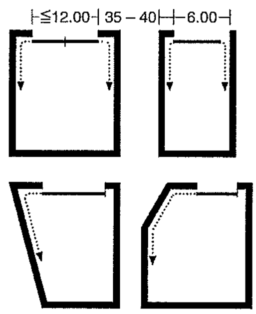
❾ Folding door → ❿



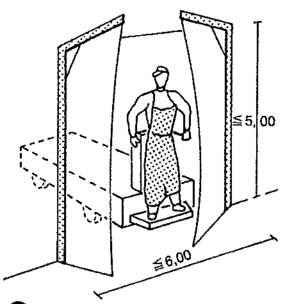
❿ Folding doors → ❾



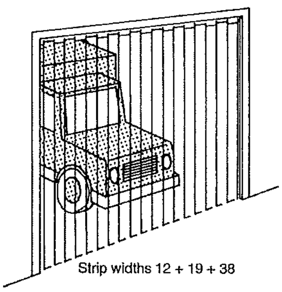
⓫ Sideways-opening sectional door



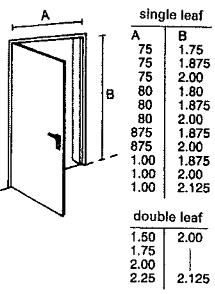
⓬ Possible building layout → ⓫



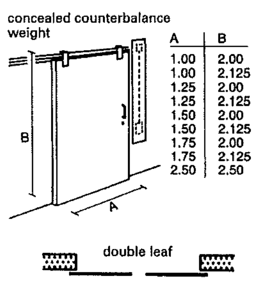
⓭ Flexible rubber door



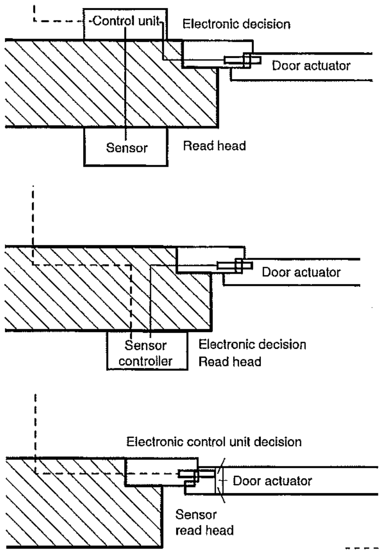
⓮ Strip curtain



⓯ Fire doors T30–T90



⓰ Sliding fire doors T30–T90



for high security requirements, sensor and control must be separated (control unit in secure area). It must not be possible to operate the control by manipulating the sensor (e.g. short circuit).

when the access control is situated in a supervised area, sensor and control can be located in one building element.

mechatronic lock cylinders contain sensor and control unit, with the task of the actuator being undertaken by the mechanical key or a turning knob.

----- possible connection to central monitoring system

❶ Arrangement of the components of electronic locking systems, depending on the security requirements. The systems can be operated either independently (offline) or in connection with a central monitoring system (online).

means of identification

electronic identification
Identification information is read by a sensor from the memory of the identification medium and evaluated by a control system. The following systems vary according to the type of transfer:

with contact	
Passive	magnetic strips – cheap, but can be copied easily (small storage capacity, unencrypted data) chip cards + encryption of the data is possible larger storage capacity than with magnetic cards
Active	chip with battery in the key. Data are transmitted on contact + mechatronic cylinder locks can operate without their own battery

without contact	
Passive	identification medium uses the transmission energy of the querying transmitter for the answer (e.g. RFID chips) + no independent power supply necessary – results in a small range of max. 1 m
Active	infra-red and radio transmitters – independent power supply necessary + range >1 m

biometric identification
Individual characteristics of each person are recorded by a sensor for identification and compared with a database. On account of the complexity of the recognition system, real identification and verification are differentiated.

Identification	the user is recognised through stored biometric data – high computing time, because all reference data have to be compared

Verification	user identifies themselves through a password or an identification medium. The identity of the person is checked against biometric data stored in a database + double system offers high security rapid access to comparative biometric data

❷ Keys are increasingly being supplemented or replaced by electronic and biometric identification methods

Mechanical locking systems

Cylinder locks offer great security, because unlocking using tools is almost impossible. Cylinders can be supplied as required with extensions by multiples of 5 mm on either side to match the particular door thickness.

Locking systems

When a locking system is designed and ordered, a diagram is produced with the associated security certificate. Replacement keys can be delivered only on production of this certificate.

Central locking systems

One key locks the entrance door to a flat and all general and also central doors, e.g. yard, cellar, or front door. Suitable for blocks of flats or houses on estates.

Hierarchical master key locking system

Master keys can lock many cylinders across the entire system. The system can reflect the structure of access rights in a company. Each cylinder has its own key pattern and can be locked only by its own key and by any master keys also intended to open it. For sensitive locations which should be considered in the building design see → ❸

Electronic access control systems

The main disadvantages of mechanical locking systems are the impossibility of altering the lock hierarchy and the inconvenience which results if a master key is lost (replacement of cylinders is expensive). With electronic access systems, right of access can be assigned or deleted at short notice without having to replace building components. Mechatronic cylinders also permit the upgrading of an existing locking systems without wiring it. Elaborate electronic access control systems can make possible the networking of personal identification, access rights according to area and time, and also the recording of working time → ❶ + ❷.

Code locks are also used in private buildings to permit access to anyone who knows the number combination. Entitled people like postmen, tradesmen, suppliers etc. can obtain access without problems.

Emergency exits and panic doors

Since 2004, there have been various requirements for the construction of ironmongery for emergency exits and panic doors. These doors must be tested, approved and labelled as a complete system.

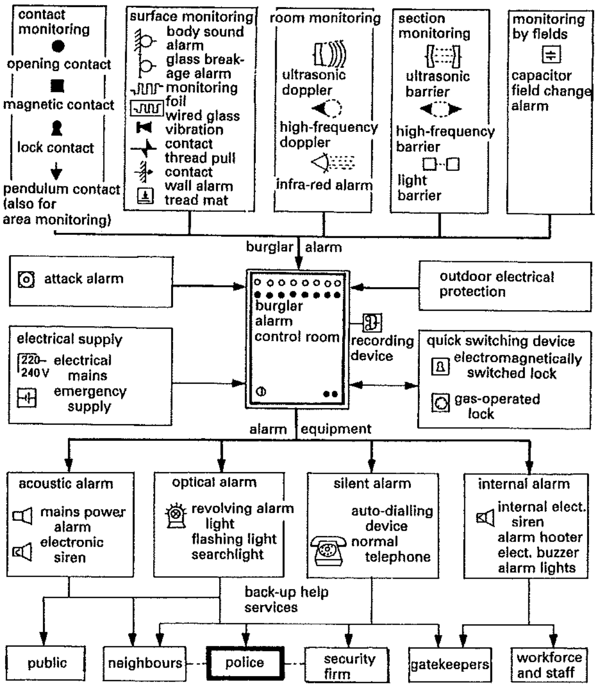
Emergency exits are provided in buildings and areas which are not open to the public and where people familiar with the location understand the function of the escape doors.

Panic doors are used in buildings and areas which are open to the public and in which people familiar with the location do not understand the function of the escape doors.

filing cabinets, bath cubicles, letter boxes, access doors, emergency exits, wardrobes, cool rooms, furniture doors, tube frame doors, roller doors, cupboard doors, desks, drawers, changing cubicles	at risk
lift machinery rooms, lift switches, electrical rooms, garage access doors, up and over garage doors, lattice grille gates, heating room doors, fire-resistant cellar doors, fire-retarding cellar doors, oil filling connections, distribution cabinets	at great risk
office access doors, roof windows, turn and tilt windows, IT rooms, entrance doors, shutters, front doors, lifting doors, cellar windows, fanlights, counters, entrance doors to flats	at very great risk

❸ Risk of break-in according to use

PAS 3621
PAS 10621
BS EN 12209
DIN 18252



❶ Burglar alarm systems – components and function

RC 1	offers basic protection against casual offenders, who only attempt to break in with physical strength – walking in, causing damage etc.
RC 2	resists attempts to break in with simple tools (screwdriver, pliers, wedges etc.). Doors of this class defeat 80% of all attempts to break in.
RC 3	also resists criminals, who use crowbar or professional-quality screwdriver.
RC 4	also resists attempts even if the criminal uses hammer, axe, nail bar and cordless drill.
RC 5–6	security doors of classes RC 5 and 6 resist attack using heavy drills, angle grinders and jig saws for a long period.

❷ Resistance classes (RC) of building components,

Resistance class	Windows	External doors	Roller shutters
RC 1	–	–	ER 1
RC 2	EF 0/1	ET 1	ER 2
RC 3	EF 2	ET 2	ER 3
RC 4	EF 3	ET 3	ER 4
RC 5	–	–	ER 5
RC 6	–	–	ER 6

❸ Correlation table for the old and new security classes. The assignment of building components, which were evaluated according to old resistance classes, to new resistance classes is not permissible.

The term 'security technology' covers all devices used for defence against criminal danger to the body, life, or valuables. In reality, all parts of a building can be penetrated, even those made of steel and reinforced concrete. The need for security should be identified by an in-depth study of vulnerable areas, with an estimate of costs and benefits.

The police will advise on on the choice of security and monitoring system equipment.

Mechanical protection devices are construction measures which provide mechanical resistance to an intruder. These can only be overcome by the use of force, which will leave physical traces behind.

An important consideration is the effectiveness of this resistance. Such measurements are necessary in blocks of flats at the entrance doors, windows and cellar entrances; and in business premises the display windows, entrances, other windows and skylights. Mechanical protection devices include steel grilles, either fixed or as roller grilles over the building's apertures and ventilation openings, secure roller shutters, secure locks, chains and light shafts. Wire and steel thread inserts in glass can retard breaking in and acrylic and polycarbonate window panes offer enhanced protection.

Electrical security devices will automatically set off an alarm if any unauthorised entry to the protected premises or access to monitored rooms is attempted. An important consideration is the time taken from when the alarm is triggered until the arrival of security staff or the police.

1. Burglar and attack alarm systems help to monitor and protect people and property.

They cannot prevent intruders entering premises, but should give the earliest possible warning of such an attempt. Optimum security can therefore only be achieved by mechanical protection and the sensible installation of burglar alarm systems. Surveillance measures include surveillance of external envelope, of each room, and of individual objects, plus case by case security and emergency calls.

Fire alarm systems give an early warning of danger, and enable direct calls for help in case of fire and/or recognise and report fire at an early stage. Fire alarms serve to protect life and property.

2. Open-air surveillance systems monitor areas outside enclosed rooms. They serve to protect a building against events in the vicinity or in the surrounding open area, which normally extends to cover the property boundary. They consist of mechanical and construction, electronic detection and/or organisational/personnel measures. Their purpose is legal definition, deterrence, prevention, delay, early warning, detection of persons, vehicles, observation, identification, sabotage attempts, spying.

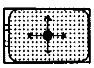
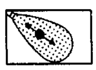
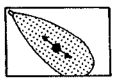
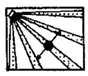
Construction measures may feature building work, fences, ditches, walls, barriers, gates, access control, lighting. Electrical work may includes control centre, detectors, sensors, video/television, access control systems, alarming of next level PO/telemetry exchange/telephone dialler/radio. Organisational measures may concern personnel, observation, supervision, security, security guards, technical personnel, guard dogs, emergency call action plan.

Parts of building and equipment to be protected	Lock contact	Magnetic contact	Surveillance contact	Transitional contact	Glass breakage alarm	Monitoring foil	Glass wired for alarm	Body noise alarm	Vibration contact	Wallpaper alarm and wiring	Tread mat	Trip wire contact	Pendulum alarm	Special types
front doors, external doors	●[2]	●	○											
internal security doors	●[2]	●	●							○				●[4]
room doors[12]	●[3]	●	●							○	○[5]			
internal sliding doors[12]	○[3]	○	●	●						○	○[5]			
up and over garage doors		●	○											●[8]
windows with casements		●	○		●	○	●		○[7]					
glass doors, lifting doors		●	○	○	●	○	●		○[7]		○[5]			
external glass sliding doors		○		●	●	○	●		○[7]		○[5]			
rooflight dome		○										●	○	●[8]
loft windows		●			●		○[9]		○[7]					
glass block walls								○	●					
display windows, large fixed glazing					●	●	●		○[7]					
heavy walls and ceilings								●	●	○				
light walls and ceilings										●				
loft ladder – retractable		○	○							●	○[5]	●	○	
individual objects[12] – sculptures paintings		●												●[10]
internal floor surfaces[12]											●			
safes[12]								●			○[5]			●[11]
cupboards for apparatus[12]		●	●								○[5]			
conduits, ventilation shafts, service installations												●	●	

burglar alarm ● very suitable
○ still suitable

1) various alarms to be used only with reservations (e.g. not on wired, laminated or toughened glass)
2) principally as a security device
3) if there is rapid switching on this door
4) if only the internal security door is to be protected (see also door interlock with alarm)
5) designed for security traps
6) magnetic contact – special type for floor mounting
7) not to be used where it can be touched by hand, if panels are unstable or there are vibration sources nearby
8) there are rooflight domes with built-in alarm protection
9) note reservations concerning the weight of glass
10) individual protection is recommended for very valuable furnishings or those with very valuable contents
11) capacitative field alarms are the recommended protection
12) and/or included in the room surveillance

1 Contact and area surveillance – appropriate use of burglar alarms

Feature		Ultrasound room protection	Ultrasound doppler	High-frequency doppler	Infra-red detector
surveillance characteristics preferred, direction of movement covered					
surveillance range per unit – guidelines for range		ceiling mounted 90–110 m^2, wall mounted approx. 40 m^2 up to 9 m	according to device 30–50 m^2 up to 14 m	according to device 150–200 m^2 up to 25 m	according to device 60– 80 m^2 rooms up to 12 m corridors up to 60 m
surveillance of entire room (over 80% of the room monitored)		guaranteed	not guaranteed	not guaranteed	guaranteed
typical application		– small to large rooms – corridors – surveillance of whole and parts of rooms	– small to large rooms – parts of rooms – motion detection	– long, large rooms – parts of rooms – motion detection in large rooms	– small to large rooms – surveillance of whole rooms or parts of rooms – motion detectors – also fire alarm
permissible ambient temperature	under 0°C	permissible in some cases	permissible in some cases	permissible	permissible
	from 0° to 50°C	permissible	permissible	permissible	permissible
	over 50°C	not permissible	not permissible	permissible	not permissible
are many sensors in one room possible?		no problem	with care	with care	no problem
effects from neighbouring rooms or adjacent road traffic		no problem	no problem	not recommended	no problem
possible causes of false alarms		– loud noises at ultrasound frequency – air heating near sensor – strong air turbulence – unstable walls – moving objects, e.g. small animals	– loud noises at ultrasound frequency – air heating – air turbulence – unstable walls – moving objects, e.g. small animals – disturbing influences near sensor (increased sensitivity)	– ray deflection through reflection from metallic objects – ray passes through walls and windows – unstable walls – moving objects, e.g. small animals, fans – electromagnetic effects	– heat sources with rapid temperature alterations, e.g. light bulbs, electric heating, open fires in working area – direct, strong and changeable or actions on the sensor – moving objects, e.g. small animals

2 Room surveillance – the most important comparative features

Security systems *(continued)*
Symbols → p. 17

3. Goods security systems, also called shop-lifting prevention systems, are electronic systems that serve to prevent theft and the unauthorised and illegal removal of goods from a controlled room or area in normal daily use.

4. Access control systems: electronic access control works together with mechanical elements to permit or refuse access to a building, room or zone through an identity check. This is done by electronically testing the personal identity or by checking the authorisation on site. Combination of an access control with a time recording system is technically possible. → p. 117

5. Remote control systems enable data transmission/exchange between two remote locations over public telephone, mobile phone or Internet. They are used for remote monitoring, measurement, control, diagnosis, regulation and remote querying of information, data and condition of one object in relation to another.

6. Surveillance systems: observation, control, recording of occurrences and events using camera and monitor, manually and/or automatically, inside and outside buildings, any time of day or night and 365 days of the year.

7. Lift emergency system can be used in passenger lifts and goods lifts. Lift emergency systems ensure the safety of the users of lifts and are mainly intended to enable the rescue of trapped people, who have direct voice communication with a constantly manned emergency centre, responsible for rescue.

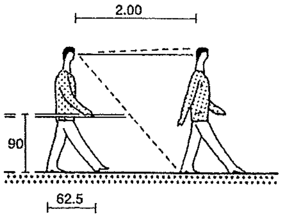
PAS 24
BS 8220
DIN 57100
DIN 57800
DIN 57804

STAIRS

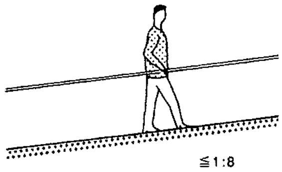
Principles

Various calculations and dimensional requirements for the construction of stairs appear in national building regulations and standards. In the UK, British Standards and the building regulations should be consulted (see Approved Document K). For workplaces, the regulations of the relevant health and safety body are to be observed. According to German standards, residential buildings with no more than two flats must have a usable stair width min. 0.80 m, 17/28 riser to tread ratio, stairs not deemed by building regulations to be legally essential (as fire escape routes) 0.50 m, 21/21 but legally essential stairs 1.00 m, 17/28, high-rise flats 1.25 m width. Stair width in public buildings is calculated according to the required evacuation time → p. 318 (Stadiums).

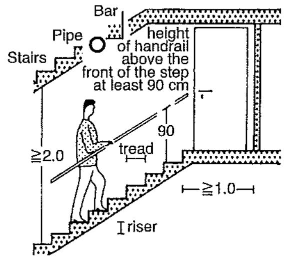
Length of runs on legally essential stairs is ≧3 steps up to ≦18 steps → ❺, landing length = *n* times length of stride + 1 depth of tread (e.g. riser to tread 17/29 = 1 × 63 + 29 = 92 cm or 2 × 63 + 29 = 1.55 m). Doors opening into the stairwell must not obstruct the stair width. The 18-step rule is a 'should' regulation. For stairs intended to be prestigious the requirement to provide landings is mitigated.



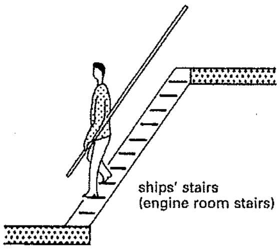
❶ Standard stride of an adult on a horizontal surface



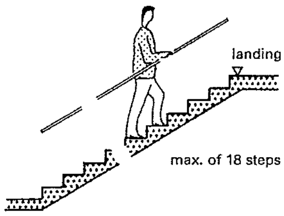
❷ On a slope the stride is reduced: a comfortable slope is 1:10–1:8



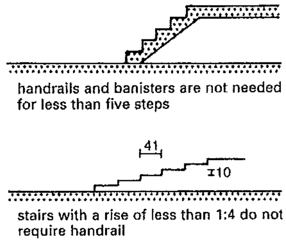
❸ Good standard riser to tread ratio 17/29, stride 2 risers + 1 tread = approx. 62.5 cm



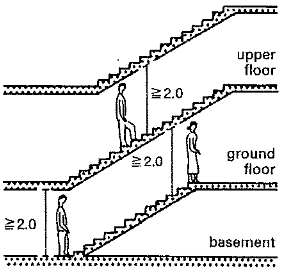
❹ Ladder-type stairs with handrail



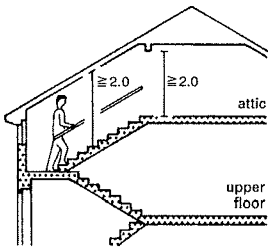
❺ Normal stairs 17/29, landing after max. 18 steps for legally essential stairs. Prestigious-style stairs can climb up to a 4 m storey height without a landing.



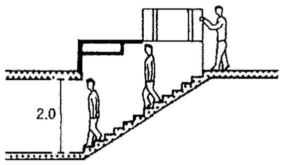
❻ Stairs without a handrail



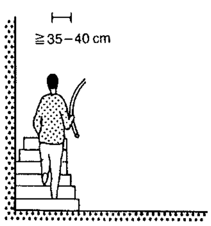
❼ Correctly superimposed stairs save space



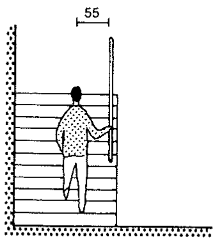
❽ If rafters and beams are arranged in the direction of the stairs, this saves space and expensive trimmers



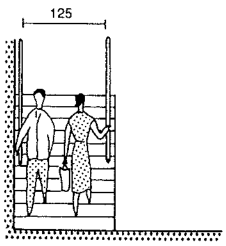
❾ Covered entrances to cellars necks and trapdoors are to be avoided; but the arrangement shown here has advantages and is safe



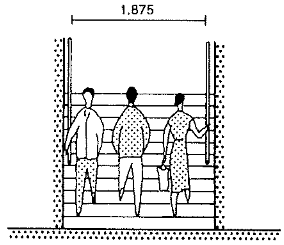
❿ For winding stairs, the distance of the walking line to the inner cheek is 35–40 cm



⓫ For straight stairs, the distance of the walking line to the handrail is 55 cm



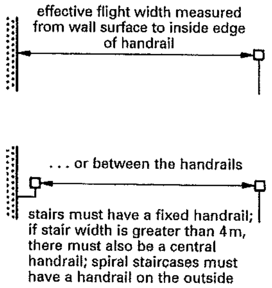
⓬ Stairs on which two people can pass



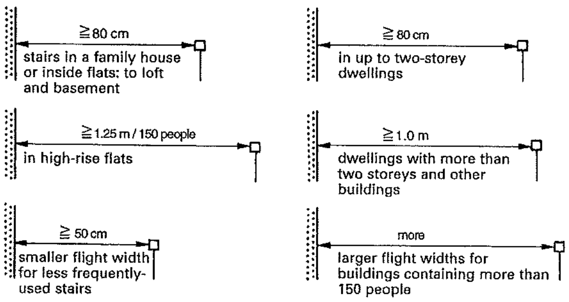
⓭ ≧width for three people

Storey height	Two flight stairs Flat (good) pitch		One, two and three flight plus building stairs Flat (good) pitch	
	No. steps	Riser	No. steps	Riser
a	b	c	f	g
2250	–	–	13	173.0
2500	14	178.5	15	166.6
2625	–	–	15	175.0
2750	16	171.8	–	–
3000	18	166.6	17	176.4

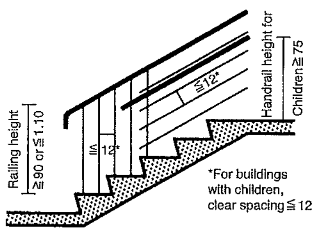
⓮ Storey height and stair risers



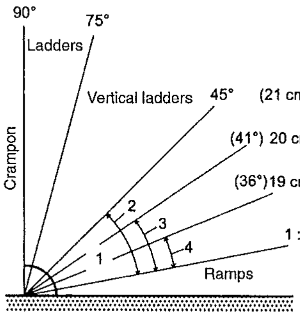
⓯ Stairs: minimum width



⓰ Measurement of usable passing width → p. 121 ❷ – ❸

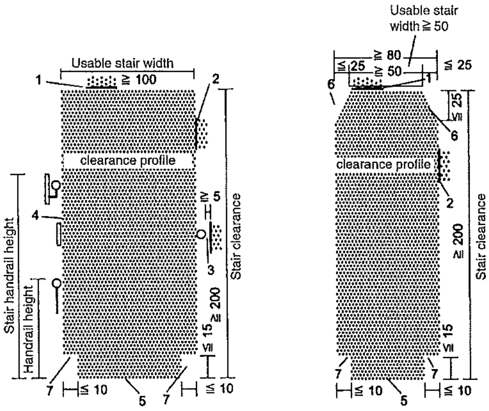


⓱ Handrail heights, hand heights, avoid ladder effect



1 Stairs
2 Cellar and attic stairs, which do not lead to occupied rooms, and stairs which are not required under building regulations (additional stairs) according to Table 3, lines 2, 3 and 5.
3 Stairs required under building regulations, which lead to occupied rooms, for residential buildings with not more than two flats, according to Table 3, line 1.
4 Stairs required under building regulations in other buildings according to Table 3, line 4.

❶ Incline for ramps, stairs and ladders



1 Without limitation of the clear opening section, e.g. the underside of the stair flight above
2 Limitation of the clear opening section at the side, e.g. through the surface of the finished wall (cladding)
3 .... e.g. to the inner edge of a handrail on the wall side; side mounted handrail spaced min. 5 cm from the wall
4 e.g. through the inner edge of a balustrade or handrail on the balustrade side
5 lower edge of the clear opening section
6 Upper edge of the clear opening section, e.g. to a ceiling slope
7 Lower edge (limitation) of the clear opening section e.g. through stair string or continuous skirting at stair pitch

❷ Stairs: clearance profile

Row	Type of building	Type of stairs	Usable stair width (min)	Stair riser (R)[2]	Stair tread (T)[3]
1	residential buildings with not more than two storeys[1]	stairs leading to habitable rooms	80	20	23
2		cellar stairs, which do not lead to habitable rooms	80	21	21
3		loft stairs, which do not lead to habitable rooms	50	21	21
4	other buildings	legally essential stairs	100	19	26
5	all buildings	non-essential (additional) stairs	50	21	21

1. also excludes maisonette flats in buildings with more than two storeys
2. but not <14 cm
3. but not >37 cm = stipulation of the pitch riser/tread
4. for stairs with a tread <26 cm, the overhang (*o*) must be at least so large that a total tread of 26 cm (*t* + *o*) is given
5. for stairs with a tread <24 cm, the overhang must be at least so large that a total tread of 24 cm (*t* + *o*) is given

❸ Stairs in buildings – limits of dimensions (finished dimensions)

Type of building	Max. distance
– high-rise buildings – schools – shops	25 m
– enclosed and underground garages – buildings where people congregate (from exit to stairwell) – hospitals	30 m
– buildings without special status, according to LBO – restaurants and hotels	35 m

❹ Maximum distance of any location in an inhabitable room from a stairwell deemed legally essential by MBO (and observe LBO!)

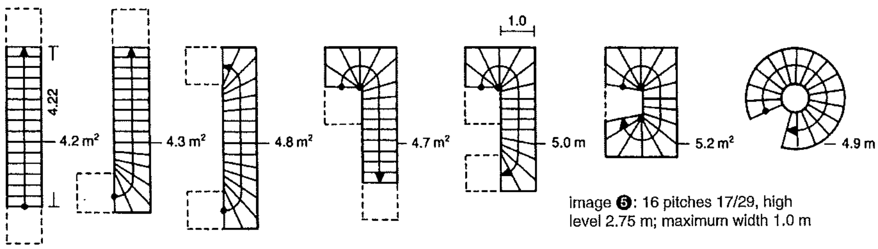
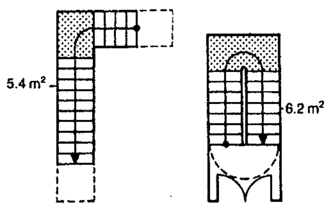
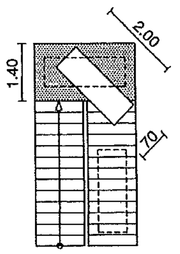


image ❺: 16 pitches 17/29, high level 2.75 m; maximum width 1.0 m

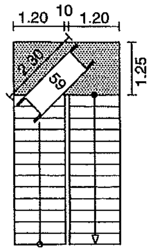
❺ All stairs without landings, whatever the type, cover practically the same surface area; curving of the steps only varies the distance between the bottom and top of the stairs. From the architectural point of view, therefore, only straight or curving stairs should be used. The latter have the advantage that the bottom and top stairs at storey levels lie above one another



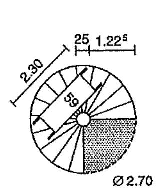
❻ Stairs with landings cover the surface area of single flight stairs + the landing. Stairs with landings are required in legally essential stairways with a storey height of ≧2.75 m. Landing width ≧ stair width.



❼ Minimum space required for furniture transport



❽ For the carrying of stretchers



❾ For a spiral staircase

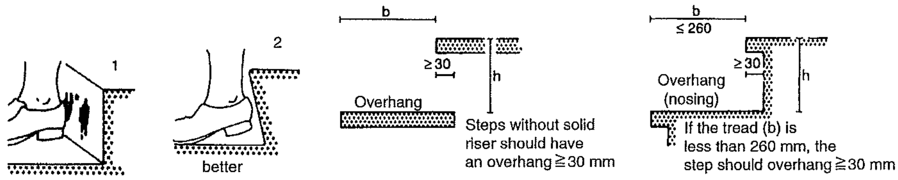
The experience of using stairs and access routes is very varied: from the creative possibilities of the most diverse residential stairs to an elaborate outside staircase, which one can stride up and down. Climbing stairs takes on average seven times the energy input as walking on the flat. From the physiological point of view, the best use of 'climbing effort' is at a stair pitch of 30° and a ratio of riser (*r*) to tread (*t*) of 17/29. The pitch is determined by the stride length of an adult (approx. 59–65 cm). In order to determine a suitable pitch with the lowest energy requirement, this formula applies: $2r + t = 59–65$ cm.

For determining the dimensions and form of stairs, their overall functional and design purpose is just as important as the relationships described above. Not just changing level is important, but how the level is changed. For outside stairs, low steps are preferable, with dimensions of 12 × 41 to 16 × 30 cm. Stairs in offices or emergency stairs should, in contrast, make it possible to change level quickly. All main staircases must be enclosed in a continuous stairwell, which is designed and arranged so that, including its access routes and exit to the open air, it can safely be used for escape. Exit width should be ≦ stair width.

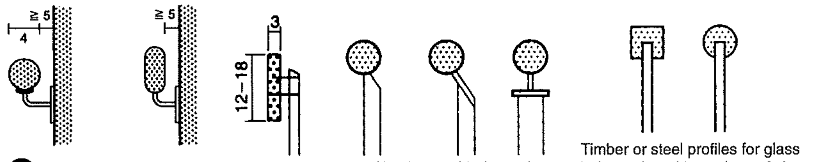
Every location in inhabited rooms and basements must be ≦35 m from the stairwell of at least one legally essential stairway or exit. If a number of stairways are necessary, then they should be arranged so that the escape route is as short as possible. Any openings from stairwells into cellars, uninhabited roof spaces, workshops, shops, storerooms, and similar must be fitted with self-closing doors with a fire resistance rating of 30 minutes.

BS 5395
BS 5578
DIN 18065

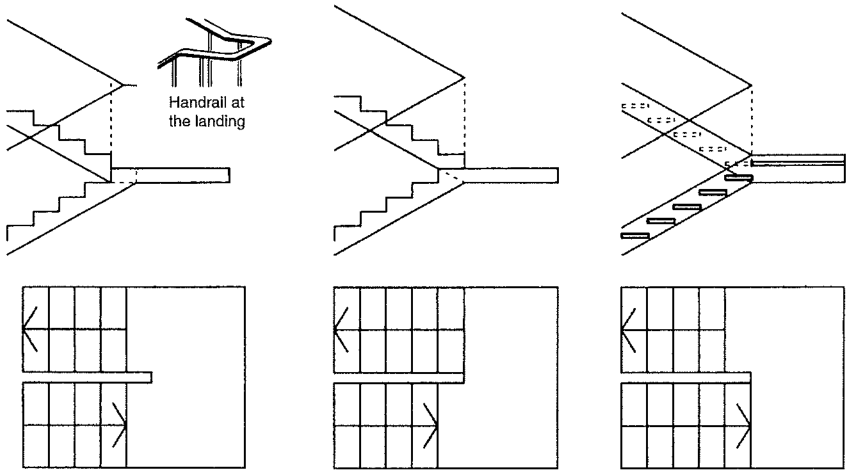
see also: Fire protection pp. 511 ff.



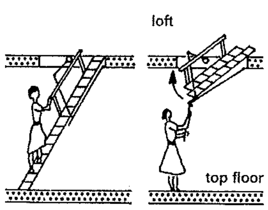
❶ Step profile of a steep flight of stairs. Nosings are not allowed in publicly accessible buildings



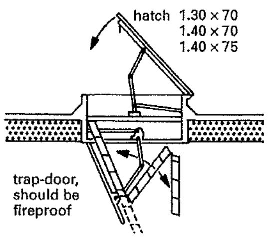
❷ Handrail profiles



❸ Effect of construction principles (steps sit on or are housed in the strings) on the staircase geometry in achieving uniform handrail heights



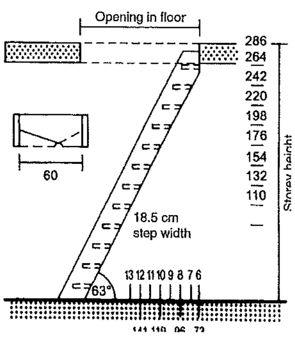
❹ If there is too little space, an aluminium or timber folding loft ladder may suffice



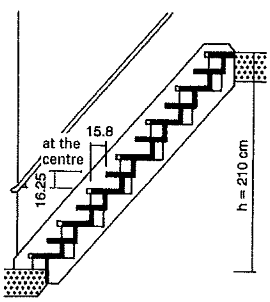
❺ Flat roof access with folding steps

Clear room height	Loft ladder size (cm)
220–280	100 × 60 (70)
220–300	120 × 60 (70)
220–300	130 × 60 (70 + 80)
240–300	140 × 60 (70 + 80)
width of frame: W = 59; 69; 79 cm	
length of frame: L = 120; 130; 140 cm	
height of frame: H = 25 cm	

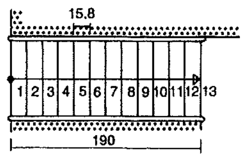
❻ Telescopic loft ladders



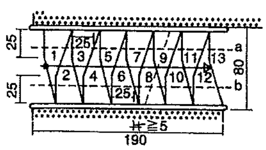
❼ Space-saving stairs with strings



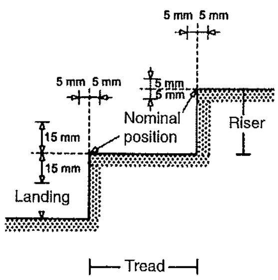
❽ Alternating tread, staggered or samba stairs of wood: section through centre



❾ Normal stairs (tread too short)



❿ Plan of treads with a and b ≧20 cm



⓫ Tolerances in the positions of the steps' leading edges. Tolerances must, however, still comply with the required dimension limits

Step profile

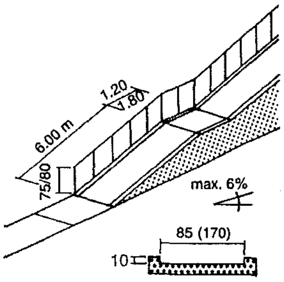
For stairs in buildings subject to disability-friendly building rules, steps may have no nosing! In order to avoid ugly streaks of rubbed-off shoe polish on the risers of vertical stairs → ❶, profiles with an undercut riser are better, and this produces more tread surface. For a tread width <260 mm → ❶ (b), the step is to be undercut ≧30 mm; this also applies to open stairs without risers. A human being requires the most space at handrail height, and considerably less at foot height. The stair width here can be made narrower in favour of a larger stairwell.

Galleries, mezzanines, balconies and circle seating in theatres must have a protective guard rail (height *h*), compulsory from 1 m height difference:

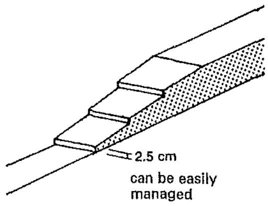
drop <12 m, *h* = 0.90 m
drop <12 m, *h* = 1.00 m for workplaces and if the stairwell is at least 20 cm wide, also for over 12 m *h*.

drop >12 m, *h* = 1.10 m

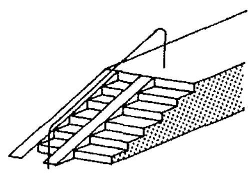
Loft ladders have a pitch of 45–75°. If, however, stairs of such a pitch are required for operational purposes, for example because there is not enough space for a normal flight, then alternating tread (staggered or samba) stairs may be chosen → ❽ + ❿. The risers in an alternating tread staircase should be a few as possible, the riser height anyway ≦20 cm. The treads in this case are measured (staggered) for the tread axes a + b → ❿ of the left and right feet.



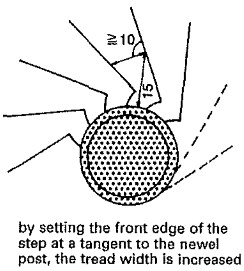
❶ Ramp with handrail and edge kerb



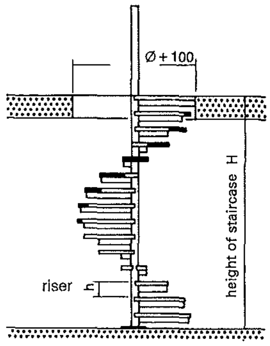
❷ Stepped ramp



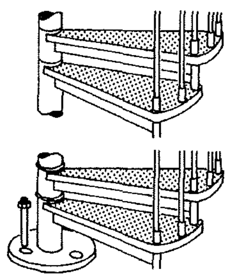
❸ Stair with ramp



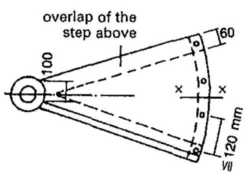
❹ Treads of winding stairs



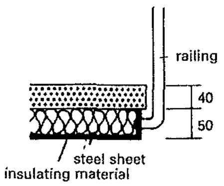
❺ Spiral staircase



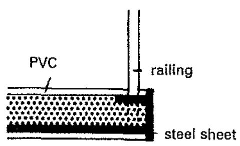
❻ Steps in timber, steel, artificial stone and natural stone



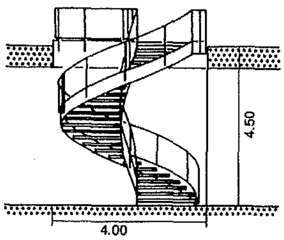
❼ Formation of step



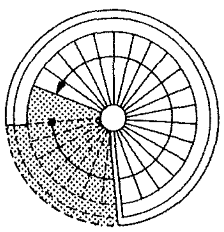
❽ Solid timber step



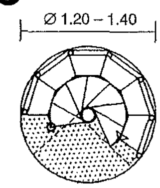
❾ PVC on cement screed



❿ Elevation of winding staircase



⓫ Plan of ❿



Stair suitable as access to non-occupied rooms instead of ladder, if the stair has to be designed with 180° turn due to restricted space

⓬ Space-saving spiral staircase with staggered steps

Pedestrians, wheelchair users and people with prams or push-chairs should be able to move easily from one level to another.

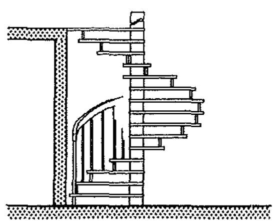
Ramps → ❶ stepped ramp → ❷ stair with ramp → ❸ gradient → ❶.

Winding and spiral staircases
These are permissible for a few family houses as the 'staircase required by building regulations DIN 18065' when there is an approx. 210 cm diameter aperture in the floor (min. 80 cm flight width); for other buildings from approx. 260 cm (min. 1.00 m flight width). Spiral staircases with less then 80 cm of usable flight width are permitted only as 'legally non-essential stairs'. They are suitable for cellars, lofts, subsidiary rooms or if a primary escape route is already provided. Spiral staircases save space and can be constructed with adequate strength with a newel post in the central axis → ❺ – ❻.

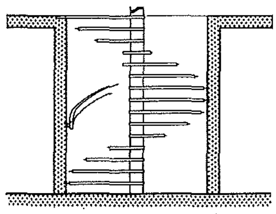
The central axis can also be cleared, which leads to an open spiral staircase with a stairwell → ❿ – ⓫. For spiral staircases, the curve can be chosen freely within the range laid down by regulations. The tread is measured at the walking line. In the curved part of the walking line, the tread is equal to the chord resulting from the intersection of the curved walking line with the leading edge of the step.

use	two-way traffic impossible									two-way traffic possible				two-way traffic easy					
	still passable					easy to pass small furniture can pass through				easy to pass dismantled furniture can pass through				passable with comfort furniture can pass through			for heavy traffic		
secondary rooms																			
basements, lofts																			
home bar, hobby room																			
bedrooms, sauna																			
swimming pool, laboratory																			
workshop, garden																			
gallery, small store																			
sales room																			
maisonette, boutique																			
office rooms, large storeroom																			
consulting/shop room																			
guest bedrooms																			
emergency stairs																			
main/'essential' domestic stairs																			
stairs dia. (nominal dimension)	1200	1250	1300		1500	1550	1600	1650	1700	1750	1800	1850		2050	2100	2150	2200		2400
flight width (mm)	516	541	566		653	678	703	728	753	778	625	650		750	775	800	825		925
	between the newel post and handrail										from 10 cm depth of tread								

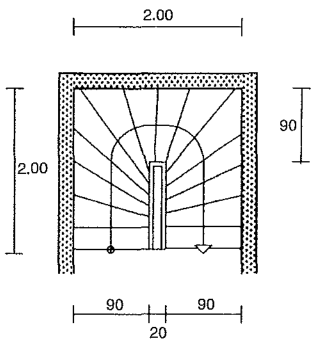
⓭ Determination of the minimum dimensions of spiral staircases of all types according to application



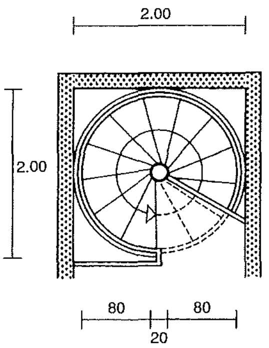
⓮ Free-standing spiral staircase



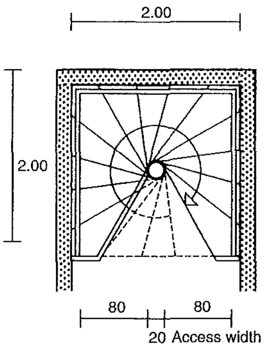
⓯ Wall-supported spiral staircase



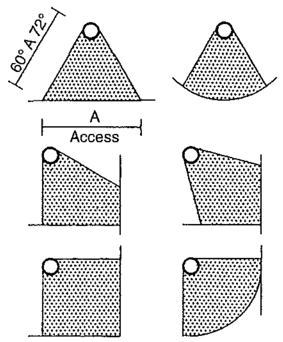
❶ Semi-winding staircase. Usable width 90 cm/tread 26.5 cm



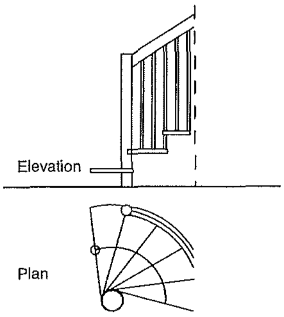
❷ Round spiral staircase. Usable width 80 cm/tread 24 cm



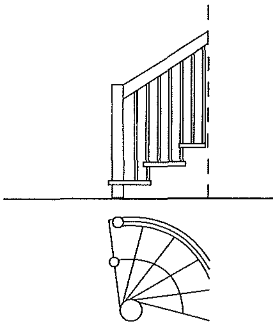
❸ Square shaped spiral staircase



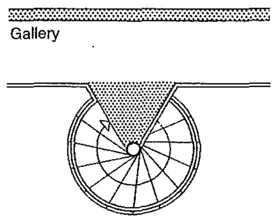
❹ Spiral staircase landing types. Landing access as wide as the steps. Min. landing angle 60–72°



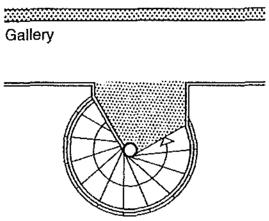
❺ Handrail starts between first and second steps. Comfortable access to the stairs from the side



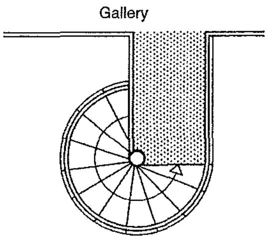
❻ Handrail starts at the leading edge of the first step. Handrail appears optically lower than in → ❺



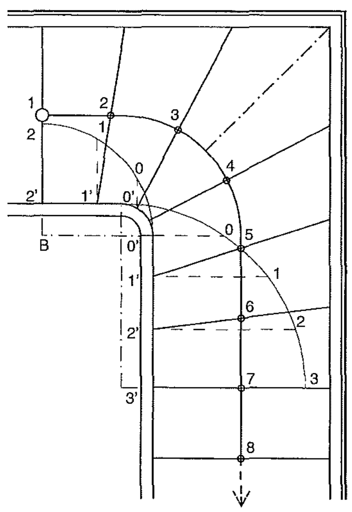
❼ Spiral staircase with ≧60° landing



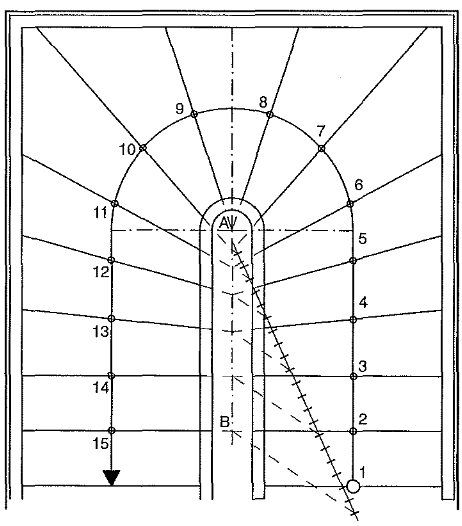
❽ Spiral staircase with obliquely angled landing



❾ Spiral staircase standing free in the room with extended landing



❿ Arc division method for the construction of angled steps, in this case for a 90° turning staircase. Also applicable for a 180° turning staircase



⓫ Proportional division method for the construction of angled steps, in this case for a 180° turning staircase. Also applicable for a 90° turning staircase.

Although spiral staircases appear generous, they should not be installed where every last centimetre of tread is important. Compare → ❶ + ❷, staircases in a 2 × 2 m niche. Spiral staircases work best if they lead to galleries or parapets → ❼ – ❾. The construction is really shown to its full advantage in an open space.

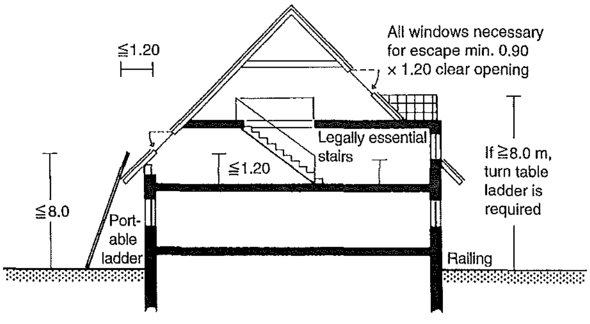
Entrance landings have an angle of at least 60° → ❹. Starting the handrail between the first and second steps works more generously → ❺ – ❻. Spiral staircases are permissible from 190 cm in diameter as the sole connecting stairs inside houses with 80 cm usable walking width → ❷ – ❸. Uniform curving of winding steps can be produced by geometrical construction. In order to achieve a regular curve of the steps, the tolerances can be larger here.

Arc division method → ❿

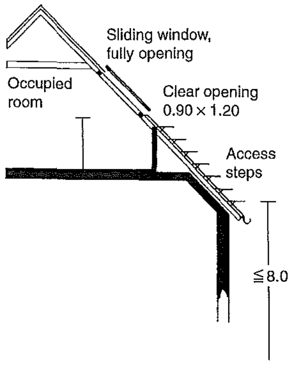
1. Decide the walking line
2. Plot the steps onto the walking line, starting with the corner tread
3. Plot the smallest width of the corner tread and the edges of the tread
4. Intersection B of the last straight step with the staircase's axis is the middle point of a circle tangential to the convexity at A
5. Determine intersection 0' on the circle and point 0
6. Divide the arc between 0 and the last straight step into as many equal lengths as there are steps between these points
7. The division points on the inner cheek provide the connection points of the steps

Proportional division method → ⓫

1. Decide the walking line
2. Plot the steps onto the walking line
3. With an even number of steps and the upper and lower flights of equal lengths: first plot the middle tread symmetrically on the axis of the staircase (in the diagram, treads 8–9). If there is an odd number of steps: first place the middle step on the axis of the stairs
4. Mark the narrowest width of the narrowest step on the inner cheek. Plot from the resulting points from the steps' edge through the walking line point.
5. Extend the edges of the steps to their intersection A
6. Extend the last even step to the axis of the staircase (point B)
7. Divide the line AB in the ratio 1:2:3:4... (as many divisions as curved steps). This line division can be applied to any axis
8. Leading edges of the curved steps go through the points on the walking line and the division points on the axis of the staircase



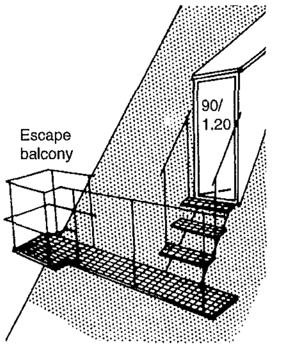
1 Escape routes



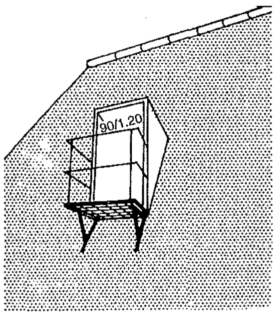
2 Roof window as escape route

Ladder access points must be located so that those in danger can attract the attention of people on public roads. Emergency ladders are items of building equipment which can be used for the rescue of occupants → 1 – 4 + 13. Access ladders, also described as vertical fixed ladders, are required for climbing onto roofs, chimneys, silos, containers, tanks, machines, plant etc. For buildings over 5 m high, access ladders are required to have back protection. Each ladder run has a maximum climbing height of 10 m → 12 – 13. Hoop diameter 0.70 m.

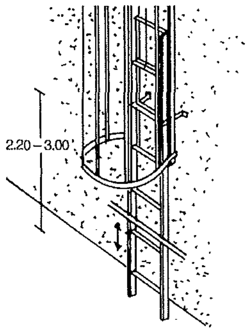
BS 4211
BS 5395
ASTM F21755
DIN 14094
DIN 18065
DIN 18799
DIN 24532



3 Escape route with external platform



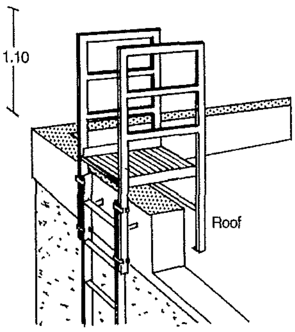
4 Escape balcony/platform



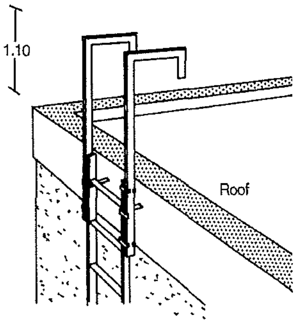
5 Retractable access

Dimensions → 9

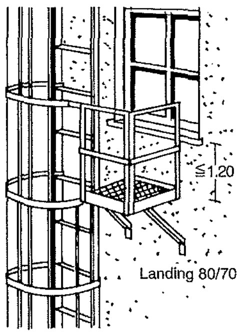
Building height (m) from/to	Back protection (bp)	Pairs of wall fixings
3.0 – 4.0	–	3
4.0 – 5.0	–	3
5.0 – 6.0	BP	4
6.0 – 7.0	BP	4
7.0 – 8.0	BP	5
8.0 – 9.0	BP	5
9.0 – 10.0	BP	6
stepped construction → 10 + 12		
10.0–11.0	BP	8
jumps of 1 m each up to		
19.0–20.0	BP	13



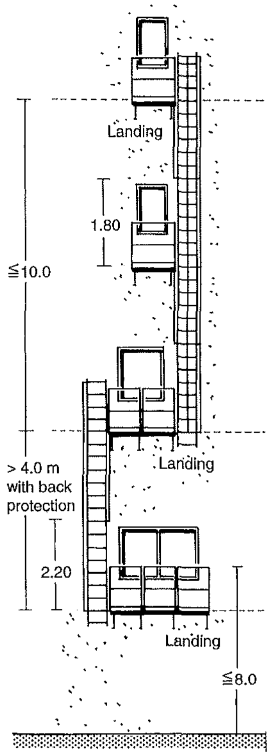
6 Escape with gangway

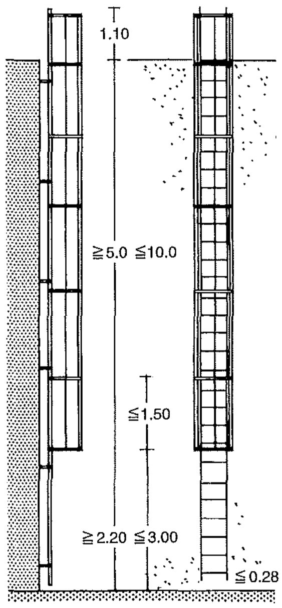


7 Escape ladder extension

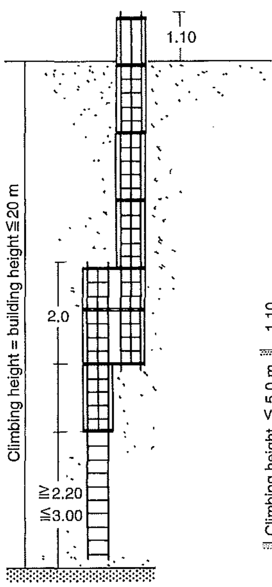


8 Platform with handrail

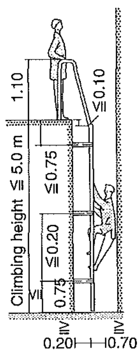




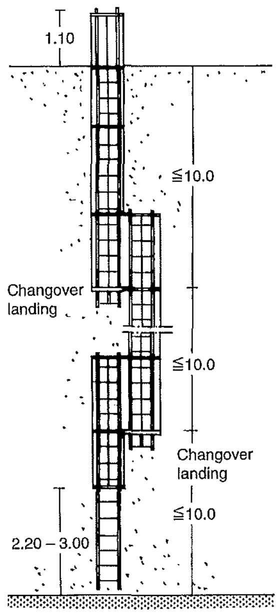
9 Single-run access ladder



10 Stepped access ladder



11 Fixed access ladder

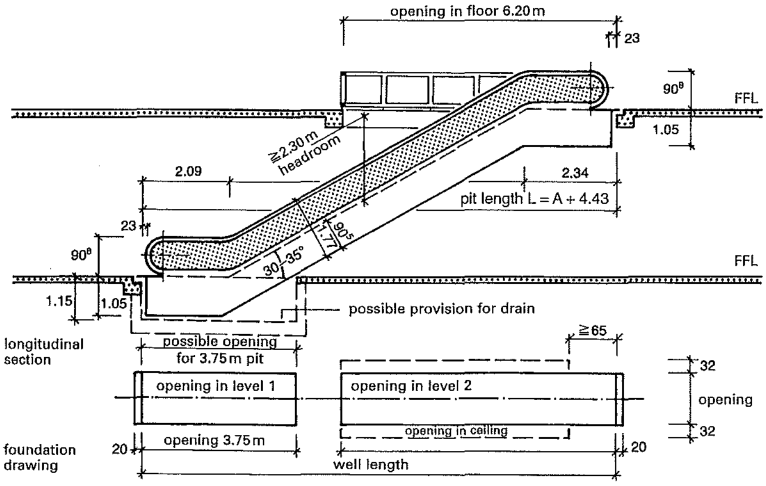


12 Access ladder with transfer platforms

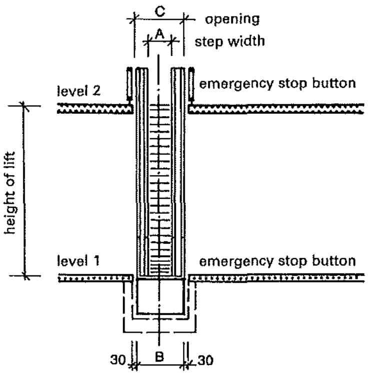
13 Emergency ladder

ESCALATORS

For Shops and Offices



❶ Section through escalator / foundation plan



❷ Width of steps

transportation capacity
$Q = 3600 \times \frac{G_p \times v}{t} \times f$ (people/h)
where
G_p = people per step (1, 1.5, 2)
v = conveyor speed (m/s)
t = tread (m)
f = 0.5–0.8 escalator utilisation factor

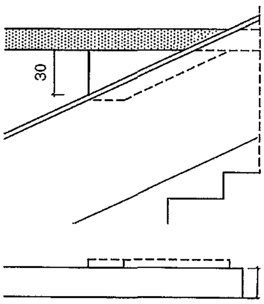
❸ General calculation formula for transport capacity

step width	800	1000
A	80–820	1005–1020
B	1320–1420	1570–1620
C	1480	1680
capacity/h	7000–8000 people	8000–10000 people

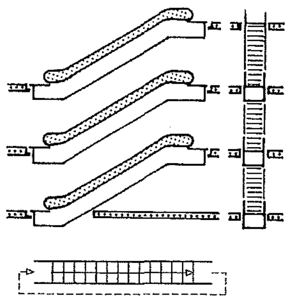
❹ Dimensions and capacities of escalators with 30° and 35° (27°; 18°) pitch. Step width → ❷

speed	travel time for one person	with a width sufficient for	
		1 person	2 people next to each other
0.5 m/sec	~18 sec	4000	8000
0.65 m/sec	~14 sec	5000	1000
		people/h transported	

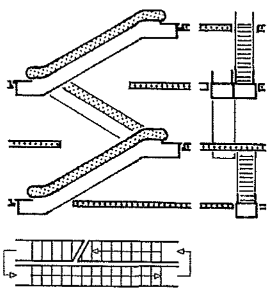
❺ Capacity data



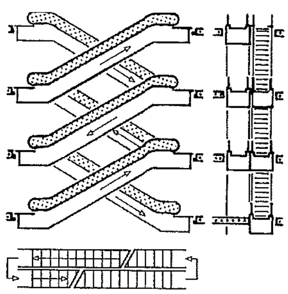
❻ Side guard detail



❼ Single flights parallel



❽ Single flights end-to-end



❾ Double flights crossing

In the UK, construction and operation of escalators is regulated by BS EN 115: 'Safety rules for the construction and installation of escalators and passenger conveyors'. In Germany, construction and operation of escalators follow the 'Guidelines for escalators and moving walkways', ZH1/484, issued by the Association of Commercial Accident Insurers. (The German situation is described below.)

Escalators are utilised for the continuous transport of large numbers of people (they do not count as stairs for the purposes of building regulations) and, for example in department stores, have a pitch of 30 or 35°. The 35° escalator is more economical because it requires less space. For travel heights ≧6 m, the 30° escalator is required . The transportation capacity is about the same for both pitches. When installed as part of transport facilities, a pitch of 27–28° should be used if possible. The pitch is derived from a gradient relationship of 16 × 30 cm, a comfortable size for a step.

For the width of steps, there is a worldwide standard of 60 cm (1 person without hand luggage, no longer permissible in Europe), 80 cm (1–2 people) and 100 cm (2 people) → ❸ – ❺. With a 100 cm step width, people carrying loads have sufficient room for movement. Provide sufficient queuing room at the bottom and top of the escalator, ≧2.50 m deep.

In department stores, offices and administration buildings, trade fair halls and airports, escalator speed is normally no higher than 0.5 m/s. In underground railway stations and public transport facilities, 0.65 m/s is preferred.

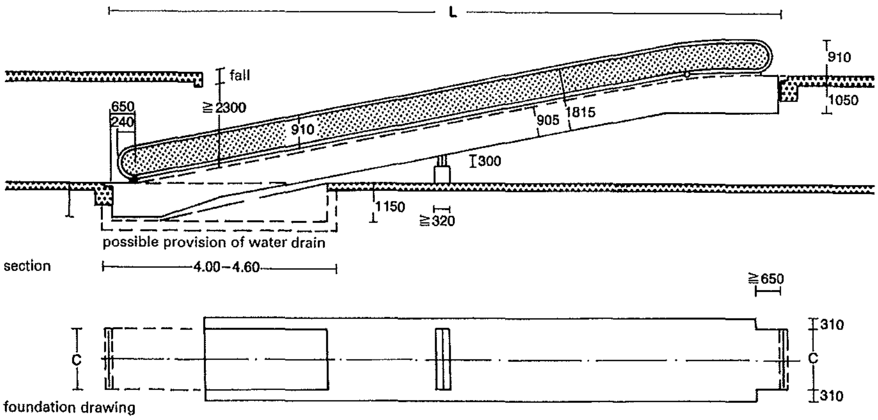
The average distribution of upward traffic in department stores is: fixed stairs 2%, passenger lifts 8%, escalators 90%. Approx. three quarters of downward traffic uses the escalators. Although the average shopping area for each escalator is 1500 m^2 at present, this should be lowered to an optimum of 500–700 m^2.

Escalators in transport facilities. According to Bostrab ('Regulations on the construction and operation of trams'), there are stringent requirements (function, construction, safety) for pitches 27, 18 and 30°. Dimensions and capacities → ❶ – ❷, ❹

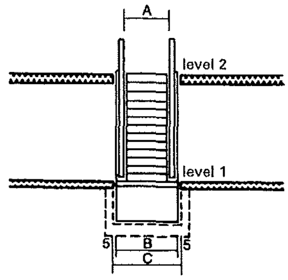
Length on plan → ❶

For 30° pitch = 1.732 × storey height
For 35° pitch = 1.428 × storey height

Example: storey height 4.50 m and 30° pitch (35° is sometimes not permissible abroad), length on plan: 1.732 × 4.5 = 7.794. With the level access and exit areas, this gives a length of approx. 9 m, therefore about 20 people can stand on the escalator at the same time.



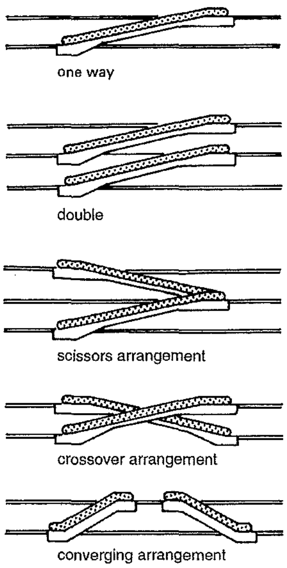
1 Section through moving walkway with foundation plan



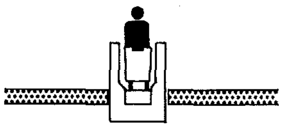
2 Cross-section → **1**

type		80	100
A		800	1000
B		1420	1620
C		1500	1700

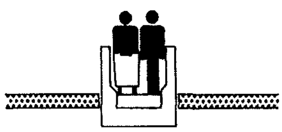
3 Dimensions → **1** – **2**



4 Arrangement 'of moving walkways



5 One person with shopping trolley 80 cm wide



6 Two people, 1 m wide

The hourly capacity of a moving walkway is calculated according to the formula:

$$Q = \frac{K \times w \times v \times 3600}{0.25} \text{ pers./h}$$

where
w = transportation width (m)
v = velocity (m/s)
K = load factor
the load factor varies between 0.5 and 0.9 (average 0.7) according to the use. The 0.25 in the denominator represents a step area of 0.25 m²/person.

MOVING WALKWAYS FOR SHOPS AND OFFICES (ACCORDING TO THE GUIDELINES FOR ESCALATORS AND MOVING WALKWAYS)

Bostrab guidelines, DIN EN 115

Moving walkways, also called conveyors or travelators, are a means of transporting pedestrians on the level or at a slight gradient. The advantage of a moving walkway is that it can also carry prams, wheelchairs, shopping trolleys, bicycles and bulky luggage with little danger. At the design stage, the expected traffic must be established carefully, so that the equipment can provide optimal capacity. The transport capacity depends on the clear width, travel speed and occupation density.

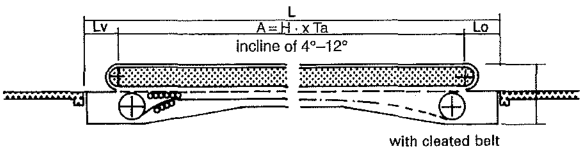
Capacities of 6000–12000 pers/h are possible. Maximum gradient of moving walkways is 12° = 21%. Normal travel speeds are 0.5–0.6 m/s horizontal; installations with gradients up to 4° are slightly faster at 0.75 m/s. Short moving walkways are about 30 m long. Long moving walkways can be built up to a length of 250 m. To enable entry and access at the right time, it is good to design a number of short moving walkways.

The advantage of two-directional moving walkways is that the horizontal return route of the walking surface, → **9** – **10**, requires a lower construction height of 180 mm, in contrast to → **7** – **8**. This makes two-way walkways more suitable for installation in existing buildings.

Values for the cotangent of the moving walkway gradient:
formula = cot × B × transport height

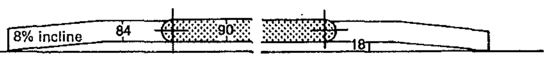
gradient in °	10°	11°	12°
cot B	5.6713	5.1446	4.7046

e.g. transport height 5 m, gradient 12°
average length = 4.7046 × 5 m = (rounded) 23.52 m

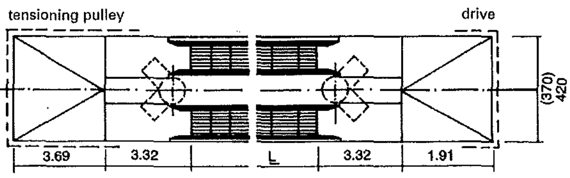


7 Section through moving walkway with rubber conveyor belt with cleated belt

8 Plan → **7**



9 Diagrammatical section of a two-way moving walkway → **10**



10 Plan of a two-way moving walkway with horizontal turnaround → **9**

gradient	10°	11°	12°
d	S × 5.6713 + 15480	S × 5.1446 + 14100	S × 4.7046 + 12950
g	6400	5900	5450
i	H × 5.6713 + 3340	H × 5.1145 + 3150	H × 4.7046 + 2990

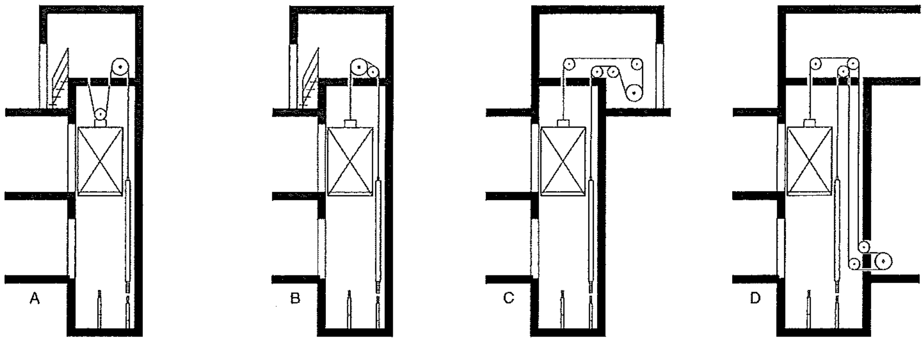
11 Moving walkway with transition curve at top → **1**

horizontal moving walkway	with cleated belt	with conveyor belt (rubber belt)	two-way moving walkway
usable width SW	800 + 1000	750 + 950	2 × 800 + 2 × 1000
external width B	1370 + 1570	1370 + 1570	3700 + 4200
construction	flat construction ≧4° gradient		
length of a section	12–16 m	~10 m	
support spacing	according to structural requirements		
possible practical length L	225 m ≧300 m		
transport capacity	40 m/min	11000 people/h	

12 Dimensions and capacities of horizontal moving walkways → **7** – **8**

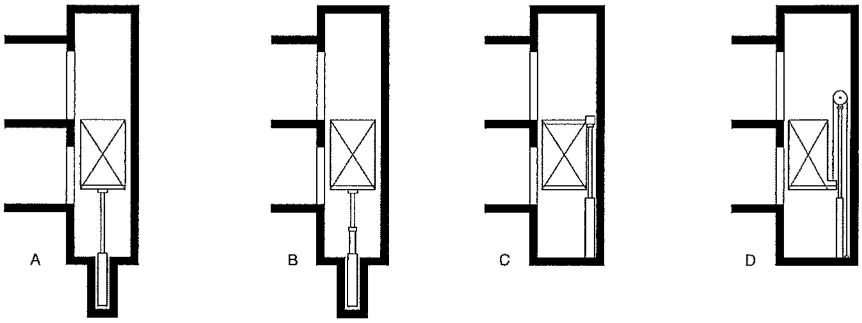
BS EN 81
BS ISO 4190
DD CEN/TS 81
DIN EN 81
DIN 15306
DIN 15309

(In the US lifts are called elevators.)



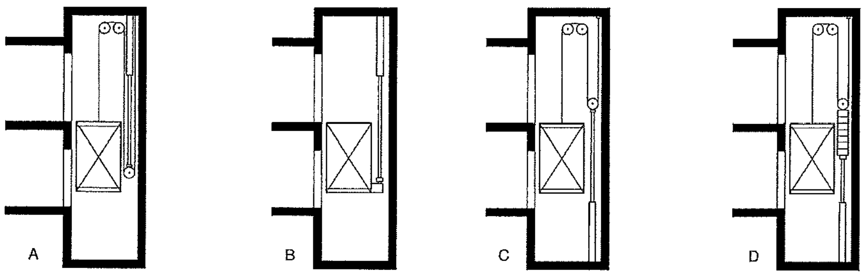
A Drive at top 2:1 — B Top 1:1 — C Top adjacent 1.1 — D Bottom adjacent 1:1

❶ Traction lifts



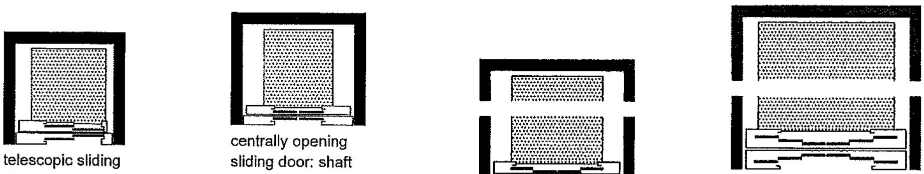
A Direct drive central 1-stage — B Direct central 1-stage telescopic — C Direct adjacent 1-stage — D Indirect adjacent 2:1

❷ Hydraulic lifts



A Push piston hanging 2:1 — B Pull piston hanging 1:1 — C Pull piston indirect 2:1 — D Indirect pull piston with additional weight

❸ Hydraulic lifts, special versions → ❶ – ❷



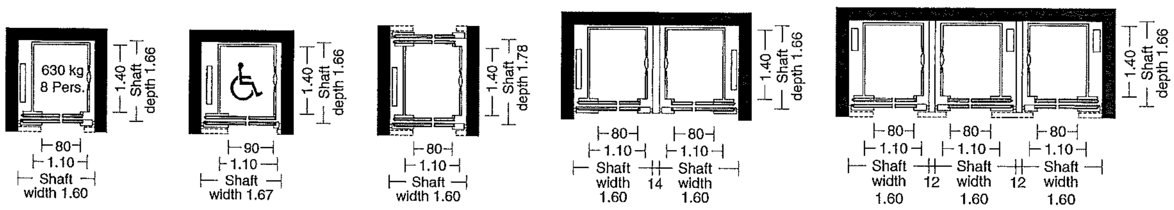
telescopic sliding door opening to one side: shaft width = 1.5 × clear passage width + 27 cm ≧1.60 m

centrally opening sliding door: shaft width = 2 × clear passage width + 20 cm ≧1.80 m suitable for cars, which should be emptied quickly

four-part telescopic sliding door: shaft width depends on the type of drive

six-part telescopic sliding door: suitable for cars with wide openings e.g. in hospitals and commercial buildings

❹ Relationship of door-opening type to shaft width



❺ Plans of lifts → p. 130 ff. — Wheelchair-suitable — Through-loading — Double — Triple

LIFTS

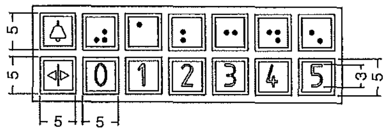
Principles

For all buildings, lifts should normally be positioned at the source of traffic flow. Provide sufficient space for waiting and queuing → p. 130 which must not infringe on stairs. Carefully plan the connection to the traffic routes. There are two different drive systems for lifts:

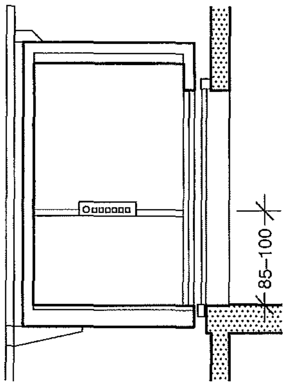
1. Traction sheave drive (for cable lifts) → ❶
2. Hydraulic lifts → ❷ – ❸

Traction lifts: ideally have their drives above the shaft. The empty weight of the car and half the live load are balanced by the counterweight. Placing the drive at the top or at the bottom next to the shaft makes necessary additional pulleys, resulting in higher operating costs. The machinery and control system can be accommodated in a separate machine room or, in the case of lifts without a machine room, placed in the shaft → p. 134.

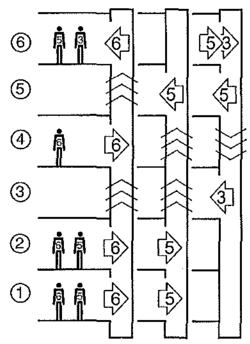
With **hydraulic lifts**, a push cylinder is mostly used → ❷ – ❸. The lifting cylinder can be arranged directly or indirectly. The arrangement of a direct cylinder inside a protective tube under the ground is no longer suitable because of the requirements for the protection of groundwater. The use of a pull cylinder → ❸ B–D can be appropriate in some cases. A pull cylinder in its basic form balances a part of the weight of the car. This has even more effect with additional weights → ❸ D, because the pump motor runs only when the load is lifted by the cylinder, while downward travel is enabled simply by opening the valve, which requires no energy and almost halves the consumption.



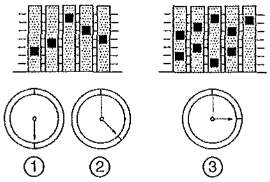
❶ Disability-friendly control panel at a height of 85–100 cm above floor level or car floor level in the central area of the lift car → ❷. Ideally horizontal panels with buttons about 3 x 3 cm, with contrasting and raised labelling and acoustic signals



❷ Disability-friendly control panel

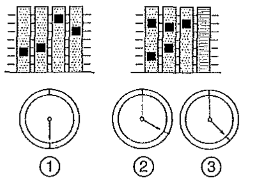


❸ Sensible transport of passengers with a group of three lifts with destination selection control



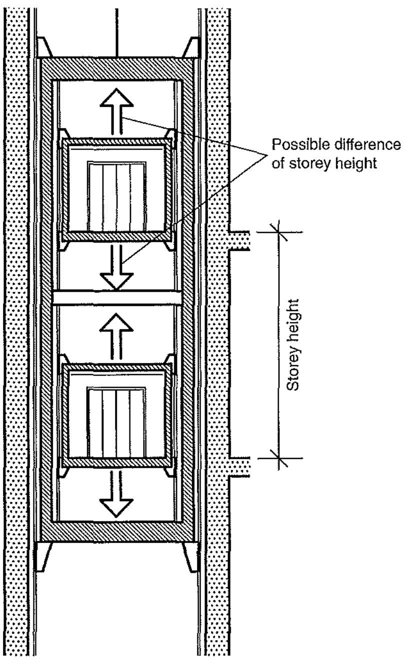
Time to reach the destination
① 5 shafts with conventional control
② 5 shafts with destination selection control
③ 4 shafts with twin lifts

❹ Efficiency of multi-car lifts for the same number of shafts

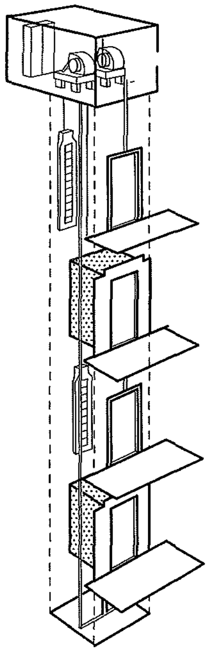


Time to reach the destination
① 4 shafts with conventional control
② 2 shafts with twin lifts
③ 2 shafts with double-decker cars

❺ Efficiency of multi-car lifts with a reduced number of shafts



❻ Double-decker cars with a mechanism to compensate for different storey heights



❼ Multi-car system: two cars in one shaft (Thyssen Krupp TWIN system)

Single-button collective control

This control system saves calls and destination instructions, but travels according to a car call to the highest or lowest destination. Landing calls, however, are taken into account only during downward travel, in order to transport users to the main stop. This simple form of control is mainly suitable for buildings with low lift frequency and one main stop, like residential buildings or multi-storey car parks.

Two-button collective control

This control system, dependent on direction and landing calls, can also give the intended direction. The lift primarily serves car calls, but stops in order to collect further passengers in the travel direction. Two-button collective control systems are particularly suitable where there is frequent traffic at intermediate storeys, as in department stores and office buildings. When there is a group of lifts, the calls and destination instructions of all lifts can be taken into account.

Destination floor control system

With a destination floor control system, the user has to indicate the intended destination at a terminal, and is then allotted a lift by the control system. The car will normally have no selection buttons. For groups of lifts, a destination floor control system enables significant optimisation of the transport capacity. The user does not have to differentiate between express and local lifts, and not all lift access points have to be visible from the waiting area. Special lifts, like double-decker and multi-car lifts, can be integrated into groups of lifts. This control system is suitable above all for high-rise buildings and those where there are different security levels and passenger selection is required, because the control system can also provide access control through identification (card reader, PIN code, etc.), for example among hotel guests, personal areas and areas let to third parties → ❸.

Double-decker lifts

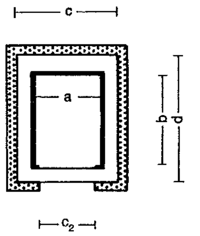
Two cars are fixed one above the other and thus always serve different floors. This increases the transport capacity, particularly of express lifts, for the same shaft size. The access level and the sky lobby have to be constructed at two levels. If individual floors are to be visited, then escalators can be provided at the access level to separate the flow of users into odd and even numbered storey destinations. Double-decker lifts are suitable for transport to panorama and restaurant levels, or as express lifts to a sky lobby in very high buildings → ❻.

Multi-car lifts

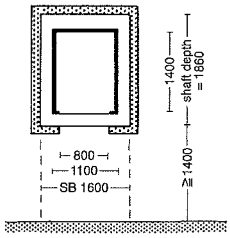
Two or more lifts travel – each equipped with their own traction sheave drive and counterweight – above and below each other in the same guide rails → ❼. A destination selection control system records the intended direction and destination of the user before they enter the lift, and it then assigns the call to one of the cars and ensures that the two cars do not obstruct each other → ❸. This system can achieve 30% more transport capacity for the same number of shafts. Because the cars cannot overtake in one shaft, travel from the lowest to the highest stop is not possible without changing cars. Therefore, multi-car systems should have at least one conventional express lift → ❹ – ❺.

BS EN 81
DD CEN/TS 81
BS ISO 4190
DIN 15306
DIN 15309

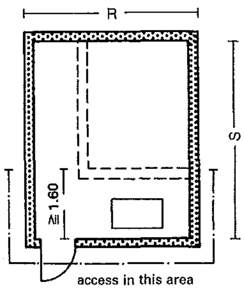
see also: Lifts in high-rise buildings p. 246



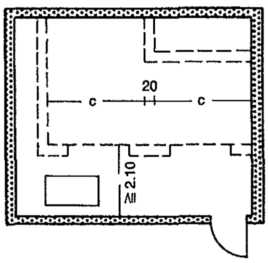
❶ Plan of lift shaft → ❽



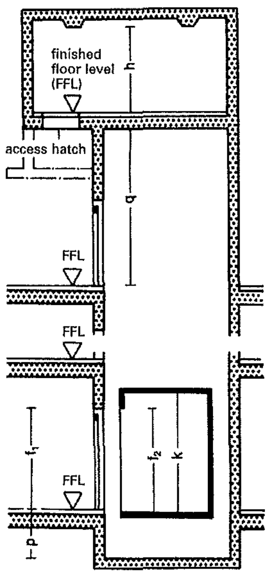
❷ Waiting area in front of lift



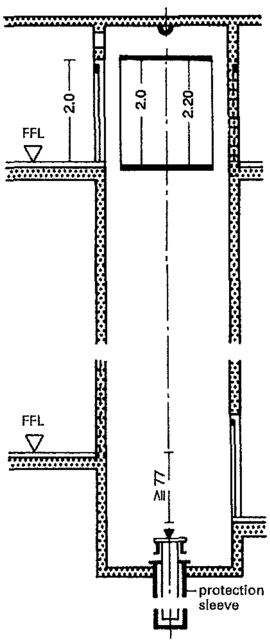
❸ Machine room



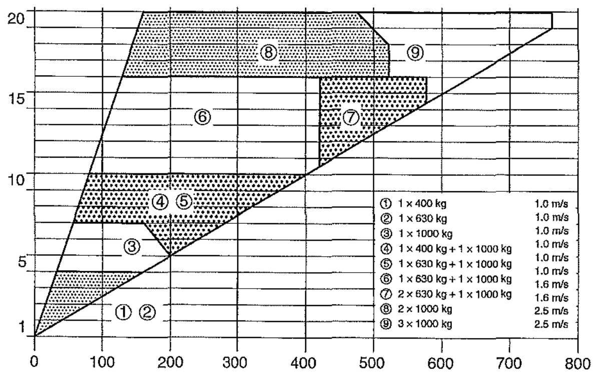
❹ Machine room: set of lifts



❺ Shaft and machine room



❻ Shaft for hydraulic lift



❼ Requirements for transport in normal residential buildings

LIFTS

Passenger Lifts for Residential Buildings

Vertical transport in newbuild multi-storey buildings is mostly provided by lifts. The guidelines given here are based on German standards. In the UK, lift installation is covered by BS 5655, which includes recommendations from CEN and ISO.

The architect normally appoints a specialist engineer for the design of lifts. In larger multi-storey buildings, it is usual to locate the lifts at a central pedestrian circulation point. Goods lifts should be arranged with visible separation from passenger lifts, though their design should take into account that they can also be used by passengers at peak times.

The following load capacities are laid down for passenger lifts in residential buildings:

400 kg (small lift)	for passengers, who may be carrying loads
630 kg (medium lift)	for passengers with prams or wheelchairs
1000 kg (large lift)	suitable for the transport of stretchers, coffins, furniture and wheelchairs → ❽

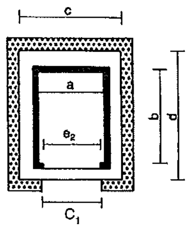
The waiting area (lobby) in front of the lift shaft must be laid out and designed so that:
- lift users entering and leaving the lift do not obstruct each other more than necessary, even if carrying luggage
- the largest items to be transported by the lift (e.g. prams, wheelchairs, stretchers, coffins, furniture) can be loaded and unloaded without risk of injury to people or damage to the building or the lift, and causing the least possible obstruction to other users.

Waiting area in front of a single lift:
- minimum usable depth between shaft door wall and opposing wall, measured in the direction of the depth of the car, should equal the car depth → ❷.
- minimum usable area should equal the product of lift car depth and shaft width.

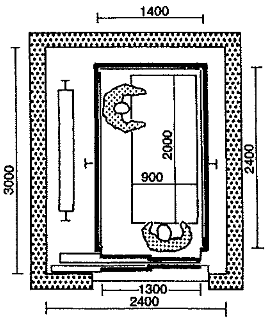
Waiting area in front of adjacent lifts:
- minimum usable depth between shaft door wall and opposing wall, measured in the direction of the depth of the car, should equal the depth of the deepest car.

load capacity	Kg		400			630				1000			
nominal speed	≤m/s		0.63	1.00	1.60	0.63	1.00	1.60	2.50	0.63	1.00	1.60	2.50
shaft	min. shaft width c	mm	1600 + 1800 → ❶										
	min. shaft depth d	mm	1600			2100				2600			
	min. pit depth p	mm	1400	1500	1700	1400	1500	1700	2800	1400	1500	1700	2800
	min. shaft head height q	mm	3700	3800	4000	3700	3800	4000	5000	3700	3800	4000	5000
door	clear shaft door width c_2	mm	800; min. 900										
	clear shaft door height s_2	mm	2000										
machine room	min. area of machinery	m^2	8		10		10	12	14	12	14		15
	min. width of machinery r	mm	2400		2400		2700	2700	3000	2700	2700		3000
	min. depth of machinery s	s mm	3200		3200		3700	3700	3700	4208	4200		4200
	min. height of machinery h	mm	2000		2200		2000	2200	2600	2000	2200		2600
car	clear car width a	mm	1100										
	clear car depth b	mm	950		1400			2100					
	clear car height k	mm	2200										
	clear car access width c_2	mm	800; min. 900										
	clear car access height f_2	mm	2000										
	permissible no. passengers		5		8			13					

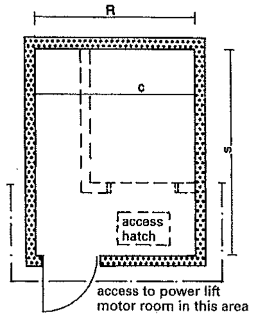
❽ Structural, car and door dimensions → ❶ – ❻



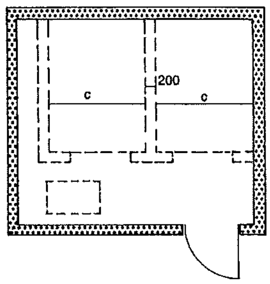
1 Section of lift shaft



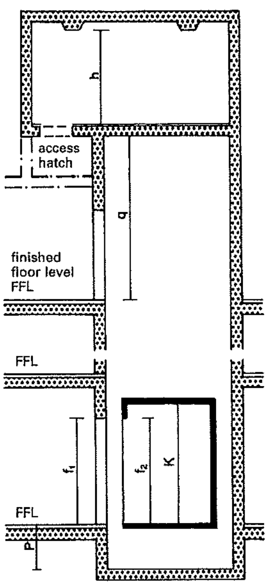
2 Bed lift



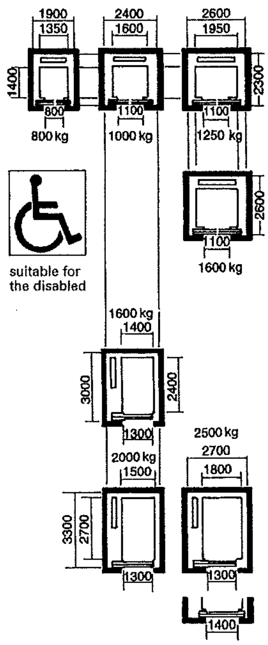
3 Machine room



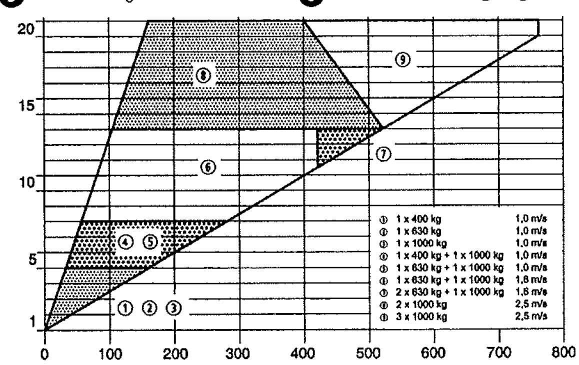
4 Common machine room for set of lifts



5 Shaft for single lift



6 Overview of lifts → 8 – 9



7 Transport capacity requirements for comfortable residential buildings with and without office floors

LIFTS

Passenger Lifts for Offices, Banks, Hotels, Hospitals

The building and its function dictate the basic type of lifts which need to be provided. They serve as a means of vertical transport for passengers and patients. Lifts are mechanical installations which are required to have a long service life (anything from 25 to 40 years). They should therefore be planned in such a way that even after 10 years they are still capable of meeting increased demand. Alterations to installations that have been badly or too cheaply planned can be expensive or even completely impossible. During the planning stage the likely usage should be closely examined. Lift sets normally form part of the main stairwell.

Analysis of use: types and definitions

Turnaround time is a calculated value indicating the time which a lift requires to complete a cycle with a given type of traffic.

Average waiting time is the time between the button being pressed and the arrival of the lift car:

$$= \frac{\text{cycle time (s)}}{\text{number of lifts/set}}$$

Transportation capacity is the maximum achievable carrying capacity (in passengers) within a five minute (300 s) period:

$$= \frac{300\text{ (s)} \times \text{car load (passengers)}}{\text{cycle time (s)} \times \text{no. of lifts}}$$

Transportation capacity expressed as per cent:

$$= \frac{100 \times \text{transportation capacity}}{\text{no. occupants in building}}$$

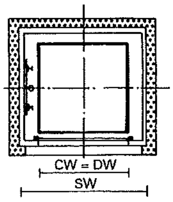
load capacity	kg	800				1000 (1250)				1600			
nominal speed	m/s	0.63	1.0	1.6	2.5	0.63	1.0	1.6	2.5	0.63	1.0	1.6	2.5
min. shaft width	c	1900				2400 (2600)				2600			
min. shaft depth	d	2300				2300 (2600)				2600			
min. shaft pit depth	p	1400	1500	1700	2800	1400	1700		2800	1400	1900	2800	
min. shaft head height	q	3800		4000	5000	4200			5200	4400			5400
shaft door width	c_1	800; min. 900				1100				1100			
shaft door height	f_1	2000				2100				2100			
min. area of machine room	m^2	15			18	20				25			
min. width of machine room	r	2500			2800	3200				3200			
min. depth of machine room	s	3700			4900	4900				5500			
min. height of machine room	h	2200			2800	2400			2800	2800			
car width	a	1350				1500				1950			
car depth	b	1400				1400				1750			
car height	k	2200				2300				2300			
car door width	e_2	800; min. 900				1100				1100			
car door height	f_2	2000				2100				2100			
permissible no. passengers		10				13 (16)				21			

8 Passenger lifts are preferable for more than residential buildings (offices, banks, hotels); lifts enable use with wheelchair

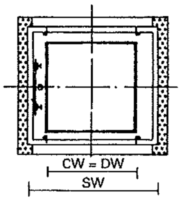
load capacity	kg	1600				2000				2500			
nominal speed	m/s	0.63	1.0	1.6	2.5	0.63	1.0	1.6	2.5	0.63	1.0	1.6	2.5
min. shaft width	c	2400								2700			
min. shaft depth	d	3000				3300							
min. shaft pit depth	p	1800	1700	1900	2800	1600	1700	1900	2800	1800	1900	2100	3000
min. shaft head height	q	4400			5400	4400			5400	4800			5600
shaft door width	c_1	1300								1300 (1400)			
shaft door height	f_1	2100											
min. area of machine room	m^2	26				27				29			
min. width of machine room	r	3200								3500			
min. depth of machine room	s	5500				5800							
min. height of machine room	h	2800											
car width	a	1400				1500				1800			
car depth	b	2400				2700							
car height	k	2300											
car door width	e_2[7]	1300								1300 (1400)			
car door height	f_2	2100											
permissible no.passengers		21				26				33			

Dimensions in mm → 1 – 6

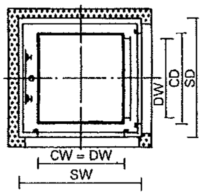
9 Structural dimensions for bed lifts → 1 – 6



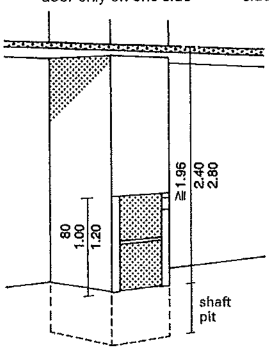
❶ Small goods lift with door only on one side



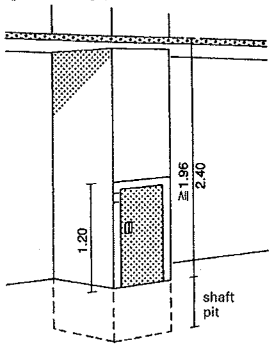
❷ With doors both sides (pass-through)



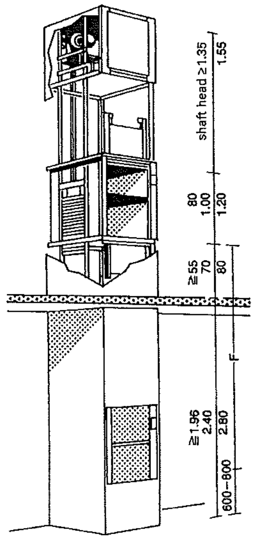
❸ Corner doors



❹ Small goods lift with floor-level sliding doors



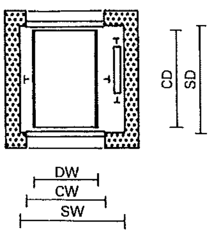
❺ Small goods lift with floor-level hinged door



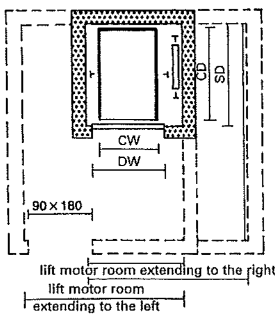
❻ Small goods lift with parapet and vertical sliding door

Loading arrangement		One side access and loading from both sides							Corner access and corner access with loading from both sides				
payload	Q kg				100			300			100		
speed	v m/s				0.45			0.3			0.45		
car width = door width	W = DW	400	500	600	700	800	800	800	500	600	700	800	800
car depth	CD	400	500	600	700	800	1000	1000	500	600	700	800	1000
car height = door height	CH = DH			800			1200	1200			800		1200
door width of the corner doors	DW	–	–	–	–	–	–	–	350	450	550	650	850
shaft width	SW	720	820	920	1020	1120		1120	820	920	1020	1120	1120
shaft depth	SD	580	680	780	880	980	1180	1180	680	780	880	980	1180
shaft head height min.	SHH			1990			2590	2590			2145		2745
machine room door width		500	500	600	700	800	800	800	500	600	700	800	800
machine room door height					600						600		
min. distance between loading points	1.)			1930			2730	2730		1930			2730
min. distance between loading points	2.)				700			450			700		
parapet height min., lowest stop only	B			600			800	800		600			800

❼ Structural dimensions of small goods lifts → ❶ – ❻



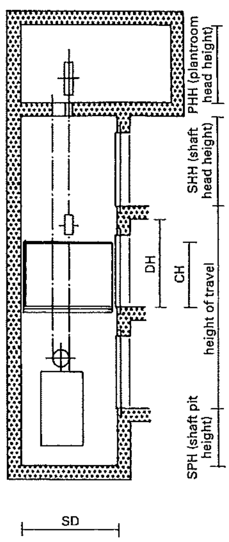
❽ Goods lift with loading from both sides (pass-through doors)



❾ Goods lift with loading only one side, and machine room

load capacity	kg	630	1000	1600	2000	2500	3200
nominal speed	m/s	← 0.40 — 0.63 — 1.00 →					
car dimensions	mm						
CW		1100	1300	1500	1500	1800	2000
CD		1570	1870	2470	2870	2870	3070
CH		2200	2200	2200	2200	2200	2200
door dimensions	mm						
DW		1100	1300	1500	1500	1800	2000
DH		2200	2200	2200	2200	2200	2200
shaft dimensions	mm						
SW		1800	2000	2200	2300	2600	2900
SD		1700	2000	2600	3000	3000	3200
SPH 0.4 and. 0.63	m/s	1200	1300	1300	1300	1300	1400
1.0	m/s	1300	1300	1600	1600	1800	1900
SHH 0.4 and 0.63	m/s	3700	3800	3900	4000	4100	4200
1.0	m/s	3800	3900	4200	4200	4400	4400
PHH		1900	1900	1900	2100	1900	1900

❿ Structural dimensions of traction sheave goods lifts → ❽ – ❾



⓫ Cross-section → ❽ – ❾

Small goods lifts (also called dumb waiters): payload ≦300 kg; car floor area ≦1.0 m²; intended for transporting light goods, documents, food etc.; not for use by passengers. The shaft framework is normally made of steel sections set in the shaft pit or on the floor, and clad on all sides by non-flammable building materials. → ❶ – ❻. Calculation of the transport capacity of goods lifts → ❼. The following formula is used to estimate the time, in seconds, of one transport cycle:

$$T = 2\frac{h}{v} + L_T + H\,(t_1 + t_2) = \ldots s$$

2 = constant factor for round trip
h = height of the lift, v = operating speed (m/s), L_T = loading and unloading time (s), H = number of stops
t_1 = time for acceleration and deceleration (s)
t_2 = time for closing and opening the shaft doors: single doors 6 s, double doors 10 s, vertical sliding doors in small goods lifts about 3 s.

The transportation capacity C can be calculated from the time for one transport cycle, T, according to the formula:

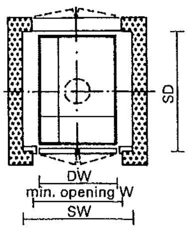
$$C = \frac{60}{\text{time for a cycle (s)}}$$

$$= \frac{60}{T} = \ldots \text{ journeys/min.}$$

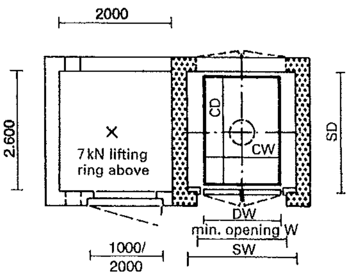
Structural requirements: The machine room must be lockable, have sufficient illumination and be of a size to prevent accidents. Area for the machinery must be ≧1.8 m high. Food lifts in hospitals: lift shafts must have washable smooth internal walls. External press-button control must be provided for calling and despatching the lift to/from each stopping point.

Goods lifts
Goods lifts are those intended
a) to transport goods or
b) passengers who are employed by the operator of the lift.

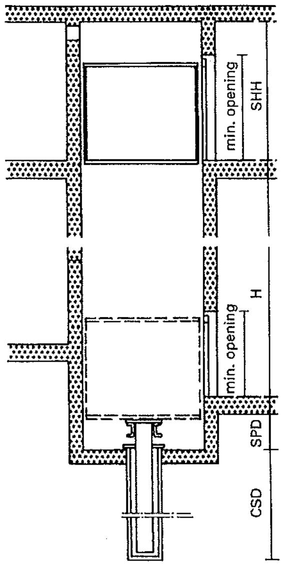
Stopping precision
Goods lifts without travel delay ± 20–40 mm
Passenger and goods lifts with travel delay ± 10–30 mm
Speed: 0.25–0.4 up to 0.63–1.0 m/s.



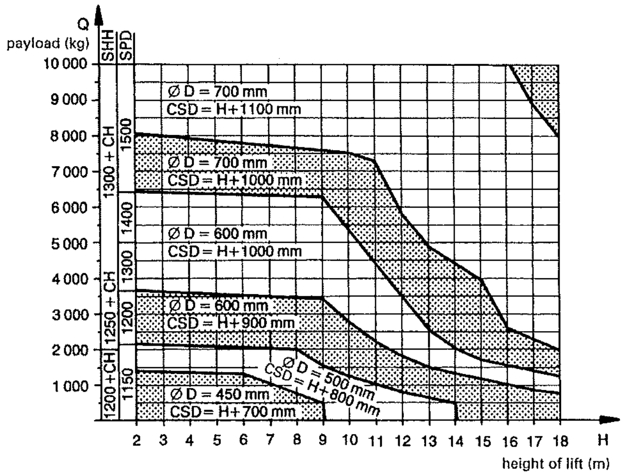
❶ Shaft plan



❷ Shaft plan with machine room for hydraulic lift



❸ Vertical section of shaft



❹ Diagram to determine the shaft head height SHH; shaft pit depth SPD; cylinder shaft depth CSD; cylinders shaft diameter D

Hydraulic lifts meet the demand for transporting heavy loads economically up and down shorter lift heights and are best used for up to 12 m lift height. The machine room can be located remotely from the shaft itself.

Standardised direct-acting push piston lifts can be used to lift payloads of as much as 20 t up to a max. height of 17 m → ❶ – ❸, while indirect-acting push piston lifts in standard operation can lift max. 7 t to a max. 34 m. The operating speed of hydraulic lifts is between 0.2 and 0.8 m/s (considerably slower than traction sheave lifts!). A roof-mounted machine room is not required.

Several variations in hydraulics can be found → ❻ – ❾. The most commonly used is the centrally mounted ram → ❶ – ❸. This requires a bored hole. The ram retraction control, regardless of load, must be kept within ± 3 mm.

Height clearance of the lift doors is min. 50–100 mm greater than for other doors, so that a completely level entry into the lift car is obtained. Double swing doors, or hinged sliding doors, can be fitted – either hand-operated or fully automatic, with a central or side opening.

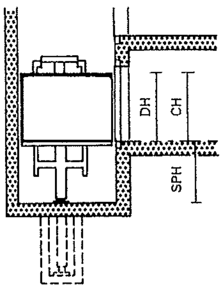
Building components

LIFTS
Principles
Control
Residential buildings
Public buildings
Small goods lifts
Hydraulic lifts
Special lifts

BS EN 81
BS 5655-10
BS 8486-2
PAS 32-2
DIN EN 81
DIN 15306
DIN 15309

Payload	Q ≠ 5000 kg		Q ≠ 10000 kg	
shaft width	SW	=	CW + 500	CW + 550
shaft depth	SD	=	CD + 150 loading from one side CD + 100 loading from both sides	
machine room dimensions approx.	width	=	2000	2200
(other locations of the machine room at up to max. 5 m distance from the shaft are possible, greater distance on request)	depth	=	2600	2800
	height	=	2200	2700

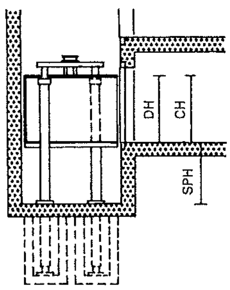
❺ Technical data → ❶ – ❸



❻ Rucksack arrangement 1:1

load capacity kg		630	1000	1600
speed m/s		0.30	0.18	0.23
		0.47	0.28	0.39
lift height max. m		6.0	7.0	7.0
car dimensions mm	W	1100	1300	1500
	D	1500	1700	2200
	H	2200	2200	2200
door dimensions mm	W	1100	1300	1500
	H	2200	2200	2200
shaft dimensions mm	W	1650	1900	2150
	D	1600	1800	2300
	SPH min.	1200	1400	1600
	SHH min.	3200	3200	3200

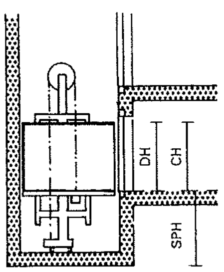
dimensions → ❻



❼ Tandem arrangement 1:1

load capacity kg		1600	2000	2500	3200
speed m/s		0.15	0.18	0.24	0.20
		0.24	0.30	0.38	0.30
lift height max. m		6.0	7.0	7.0	7.0
car dimensions mm	W	1500	1500	1800	2000
	D	2200	2700	2700	3500
	H	2200	2200	2200	2200
door dimensions mm	W	1500	1500	1800	2000
	H	2200	2200	2200	2200
shaft dimensions mm	W	2200	2200	2600	2800
	D	2300	2800	2800	3600
	SPH min.	1300	1300	1300	1300
	SHH min.	3450	3450	3450	3450

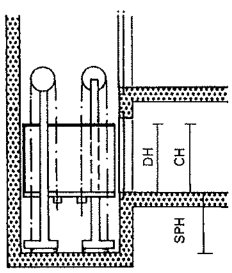
dimensions → ❼



❽ Rucksack arrangement 2:1

load capacity kg		630	1000	1600
speed m/s		0.28	0.30	0.24
		0.46	0.50	0.42
		0.78	0.80	0.62
lift height max. m		13.0	16.0	18.0
car dimensions mm	W	1100	1300	1500
	D	1500	1900	2200
	H	2200	2200	2200
door dimensions mm	W	1100	1300	1500
	H	2200	2200	2200
shaft dimensions mm	W	1650	1900	2150
	D	1600	2000	2300
	SPH min.	1200	1400	1600
	SHH	3200	3200	3200

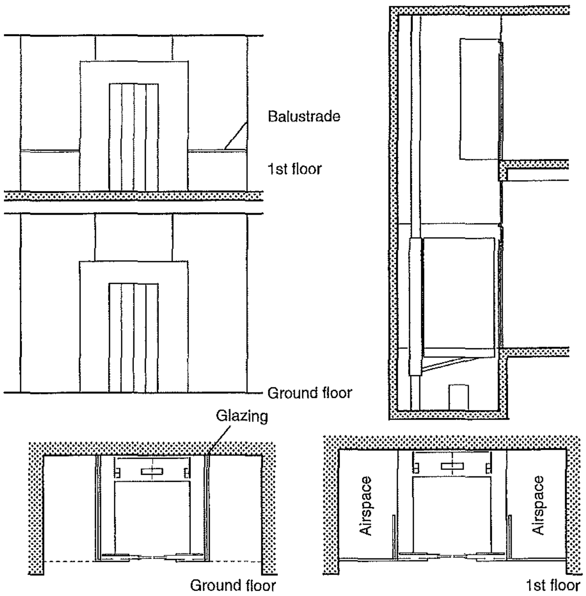
dimensions → ❽



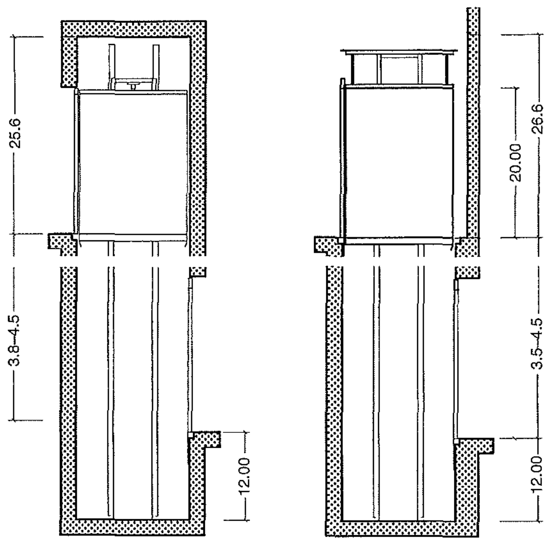
❾ Tandem arrangement 2:1

load capacity kg		1600	2000	2500	3000
speed m/s		0.23	0.19	0.25	0.21
		0.39	0.32	0.39	0.31
		0.61	0.50	0.64	0.51
lift height max. m		13.0	14.0	16.0	18.0
car dimensions mm	W	1500	1500	1800	2000
	D	2200	2700	2700	3500
	H	2200	2200	2200	2200
door dimensions mm	W	1500	1500	1800	2000
	H	2200	2200	2200	2200
shaft dimensions mm	W	2300	2300	2600	2900
	D	2300	2800	2800	3600
	SPH min.	1300	1300	1300	1300
	SPP	3400	3550	3650	3650

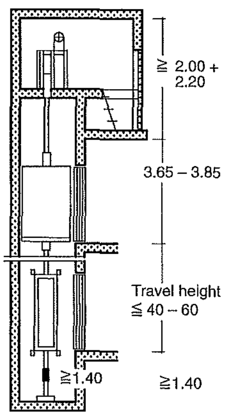
dimensions → ❾



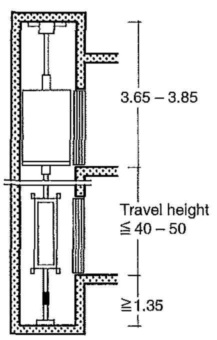
❶ Contact with moving parts must be prevented in glazed lifts: safety barrier around shaft doors min. up to 3.5 m high and on the other sides min. 2.5 m, with the distance to moving parts at least 0.5 m; with greater distances, the height can be reduced.



❷ Load and goods lifts. Because passengers are not allowed to travel, the car does not require doors. This results in a good relationship between shaft cross-section and usable car area.



❸ Traction lift with machine room and pit



❹ Special construction without machine room

Glazed lifts

Glazed lifts offer a view and improve the users' feeling of safety. They can be constructed either with glazed shafts (observing fire resistance requirements) or as shaftless lifts (panoramic lifts) → ❶. These can only be installed near buildings in which, to prevent the spread of fire, no lift shafts are permitted. This makes the inclusion of panoramic lifts into traffic calculations difficult. The glazing must prevent the users touching moving parts with the hand or with objects held in the hand. Glazed lifts are non-standard constructions and require a special prototype approval.

Goods and underfloor lifts (without passenger transport)

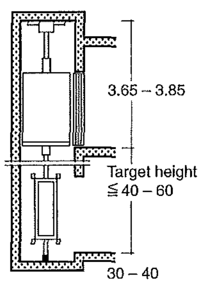
Lifts only intended for loads like rubbish bins or goods deliveries can be installed inside a building or in front of it → ❷. Passenger transport is not permissible with this type of lift. A machine room is not normally necessary.

Underfloor lifts are controlled from the uppermost station. The cover of the lift must be in the field of view of the operator.

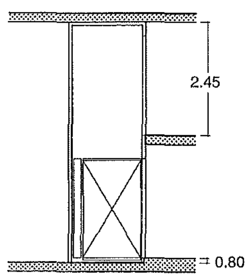
Lifts with reduced shaft dimensions

In refurbishment projects, it is often a major inconvenience to construct the parts of the shaft above and below the working range. For such projects, there are special lifts, which require less pit depth (min. approx. 80 mm) and shaft head heights (min. approx. 2500 mm above the highest stop) → ❸ – ❺. When lifts are installed without machine rooms, special requirements have to be considered for the shaft (ventilation, possible condensation on the ceiling and fire protection measures). These requirements can be taken from the information provided by the particular manufacturer, because such lifts have to undergo a special prototype approval.

Such special constructions also include **lifts for disabled people** → ❻, which may be used only by the specified group. Dead man's controls and similar measures make simple, space-saving installations without pit and car doors permissible. Home stairlifts enable those with impaired mobility to move easily between floors (on straight or curved stairways) and across landings. The requirements for such installations are provided in BS 5776.



❺ Special construction without machine room and with reduced pit depth



❻ Lift for disabled people
These lifts are approved solely for use by those with impaired mobility.