ENGLISH EDITION

The house-building experience

From plot to move-in

A practical guide to the whole journey

13 chapters · 2 appendices · 86 illustrations

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CHAPTER

Groundworks and foundations

The foundation is the link between the house and the ground

A foundation is more than a piece of concrete at the bottom of a house. Its job is to carry the loads from the structure and transfer them to the ground without unacceptable settlement, movement or cracking. At the same time, it is in contact with ground moisture, service pipes and the surrounding landscaping. Decisions about what lies beneath the house therefore need to be made together, before those elements become inaccessible.

A few minutes before the concrete is poured, every pipe, joint and piece of reinforcement is still visible. A few hours later, all that remains is a smooth grey surface. In construction, the moment just before things disappear is often more important than a photograph of the finished element.

By the end of this chapter, you will be able to

- distinguish between the ground, the load-bearing foundation and the floor slab;
- understand why the foundation type and reinforcement are specified by the design;
- recognise the role of compaction, service penetrations, earthing and concrete placement;
- distinguish between waterproofing, a capillary break and drainage.

A project begins with information about the ground

A level surface may conceal made ground, clay, sand, rock, groundwater or layers with differing bearing capacities. Geotechnical information helps the structural engineer choose a foundation system and prepare the ground. A neighbour's house can offer a useful clue, but the decision should be based on information about your own site.

A surveyor transfers the position of the proposed house onto the ground. This process is called setting out. Before excavation begins, check the building lines, distances from the boundaries, levels and where the excavated soil can be stored safely.

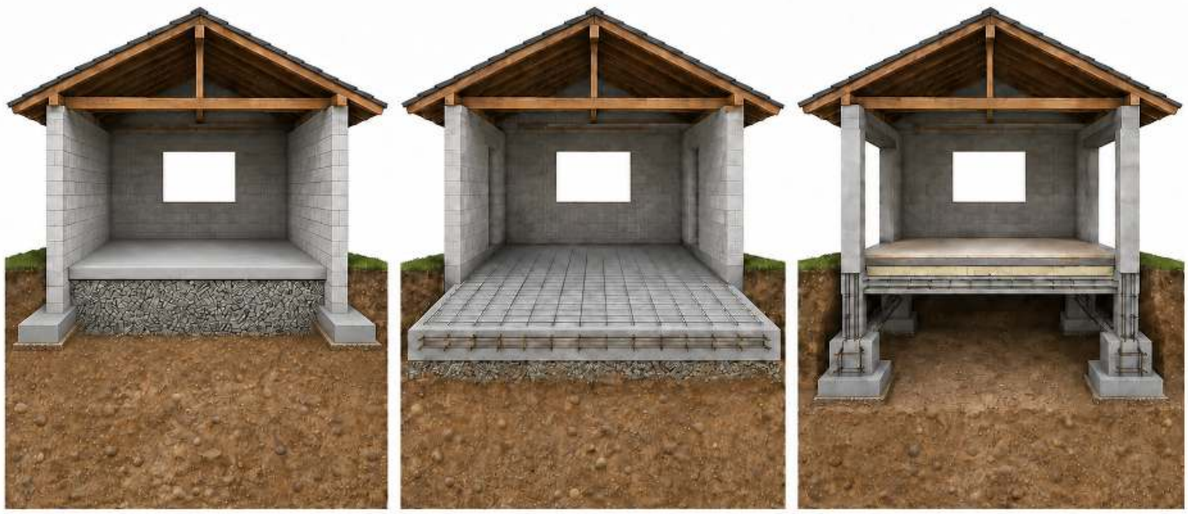
Some common foundation systems

With strip foundations, load-bearing walls rest on continuous strips of concrete. In a house without a basement, the space between the strips is usually not an empty void: it is prepared and filled with specified, compacted stone material, above which a separate floor slab and floor build-up are formed. With a raft foundation, a larger reinforced concrete slab spreads the load across almost the entire footprint of the house. Other options include pad foundations, ground beams, piles and combinations of these systems.

The term “dead slab” is often used informally for a concrete base within the foundation that is not load-bearing or carries relatively little load. The term is imprecise, so always check the drawing to see whether it refers to a load-bearing raft foundation, blinding concrete or a floor slab. Two elements can look similar while serving completely different purposes.

Do not choose a system based on the price of concrete or the quantity of reinforcement alone. A comparison must include excavation, formwork, reinforcement, concrete, thermal and waterproofing measures, floor layers, time and the risks posed by the specific ground conditions.

Figure 24. Three different ways of transferring a house’s load to the ground



On the left, load-bearing walls rest on strip foundations, with compacted stone material between the strips supporting a separate floor slab, sometimes informally called a “dead” slab. In the centre, a load-bearing raft foundation distributes the load across the whole footprint. On the right, columns transfer loads to individual pad foundations linked by ground beams. The illustration shows the basic differences; it does not select a system or specify dimensions or reinforcement.

Venice: a city that uses timber to stand in water

Beneath many historic buildings in Venice are timber piles driven into the ground, along with horizontal timber foundation elements. At first, this sounds unusual: we try to protect timber from moisture, yet here it forms part of the foundations in the middle of a lagoon. [216]

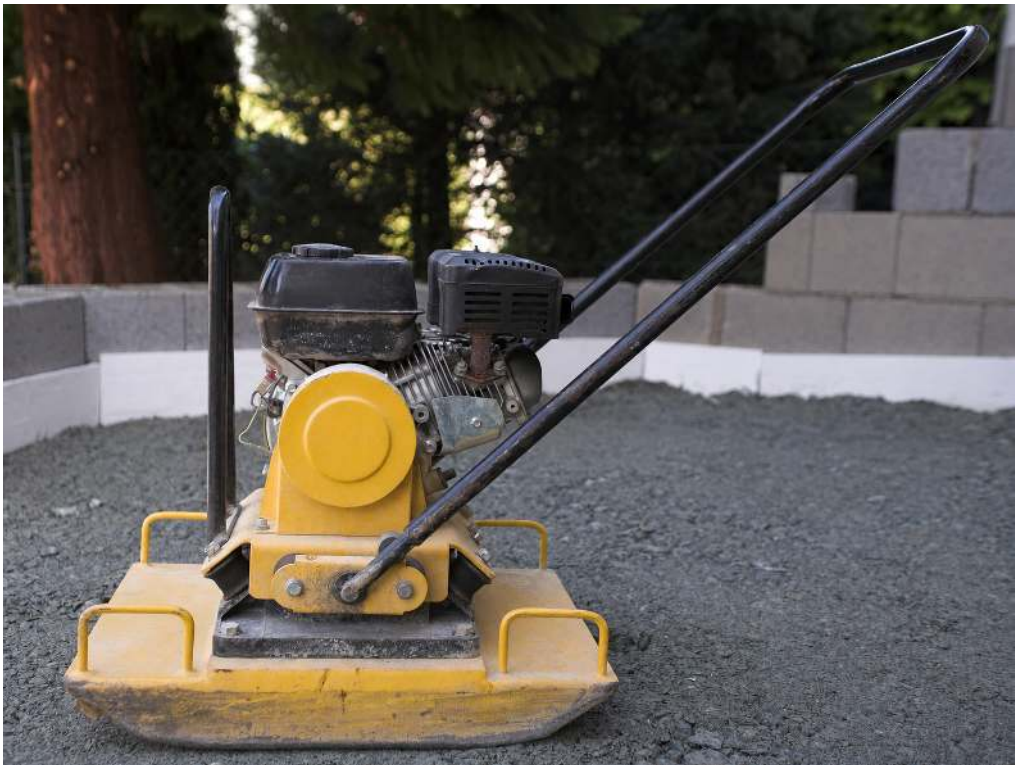
The key lies in the conditions. In permanently waterlogged ground, the limited availability of oxygen can slow some forms of biological decay. This does not turn timber into stone or make it everlasting, however. Research by Italy’s CNR has also found substantial decay in timber piles, varying from place to place. In the cases studied, the system’s load-bearing capacity could be maintained through the combined action of the timber and the compacted ground around it, despite the weakened timber. [216] [217]

Venice illustrates why foundations cannot be considered separately from the ground and water. Their load-bearing capacity depends on how they interact. When building a new house, it is more useful to understand the conditions on your own site than to copy a foundation system that has worked for centuries elsewhere.

What lies beneath the concrete

The excavated formation should be protected from softening and unnecessary traffic. The design may require some of the ground to be replaced and layers of stone aggregate to be laid. These layers are placed to controlled depths and compacted using suitable equipment. On site, a vibrating plate compactor or similar machine is sometimes nicknamed a “frog”. The achieved level of compaction should be checked using the method specified in the design or by the geotechnical supervisor.

Figure 25. A vibrating plate compactor, often nicknamed a “frog” on site



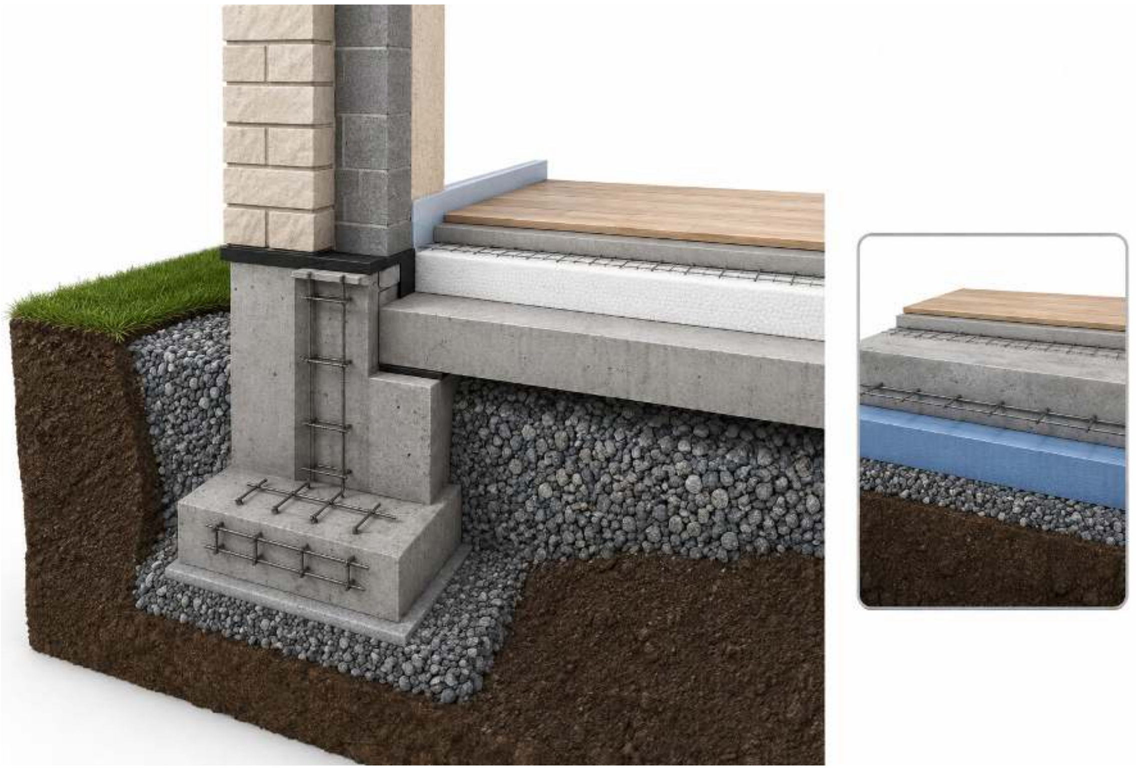
The engine drives a heavy base plate, which uses vibration to help compact the stone layer. [73]

Beneath a floor slab or raft foundation, the build-up may include compacted stone, blinding concrete, thermal insulation and membranes to resist moisture or the ingress of ground gases. There is no universal sequence. Continuity is crucial: a membrane with a hole around a pipe is no longer an unbroken barrier. [56] [57]

The design may also specify high-compressive-strength XPS beneath the foundation slab. XPS is extruded polystyrene, a rigid insulation material that resists moisture and higher compressive loads than many conventional insulation boards. This solution must form part of a designed foundation system. Do not buy just any ‘rigid polystyrene’ and add it beneath the foundation on site without a design. [60]

Above the structural or ground-bearing slab, and beneath the screed, there is usually a layer of thermal or acoustic floor insulation. This is often suitable EPS (expanded polystyrene), but its type and compressive properties must be declared for floor use. The screed must not rest on a soft façade board chosen simply because it looks similar. [61]

Figure 26. The structural foundation and the finished floor are not a single layer of concrete



The main section shows the ground, compacted stone, blinding concrete, strip foundation, a capillary break beneath the wall, a separate floor slab, and floor insulation beneath the screed and floor finish. The inset shows one possible designed arrangement, with high-compressive-strength XPS beneath the foundation slab. The actual sequence and properties are determined by the structural, moisture-protection and thermal-design specifications.

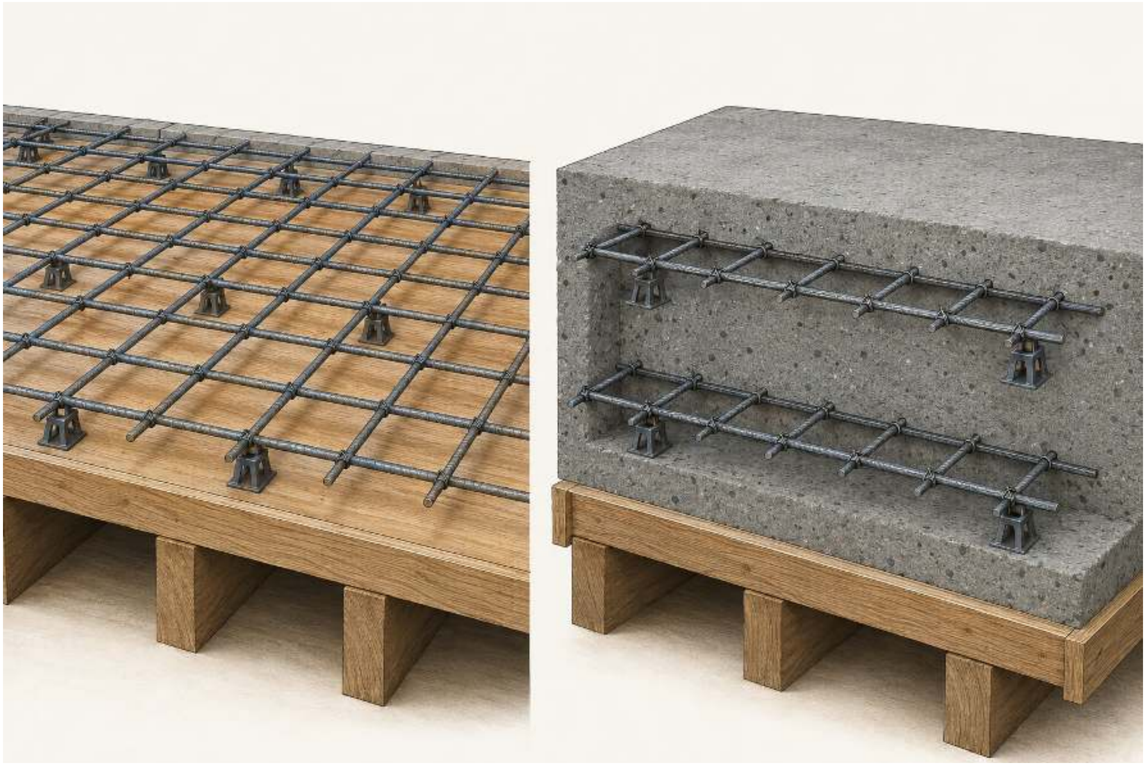
Reinforcement is not decoration in concrete

Concrete performs well under compressive stress, while steel reinforcement helps an element resist tensile stress and control cracking. The bar diameter, number, spacing, laps, anchorage and position are specified in the structural design. There is no safe number of ‘layers of rebar’ to recommend without knowing the dimensions, loads and ground conditions. [190]

A Q-mesh is a factory-welded mesh of steel bars arranged in two perpendicular directions. The letter and number in its commercial designation identify a particular mesh type, but the meaning of the designation and the available sizes should be checked against the current product declaration for the local market. The term Q-mesh alone is therefore not enough information for an order, nor is it a substitute for a reinforcement drawing. [69]

A thinner or simpler element may be designed with one mesh, while a thicker or more demanding slab may have reinforcement in both the top and bottom zones. The decision does not depend on concrete thickness alone. It is also affected by spans, supports, loads, openings and how the slab transfers forces. Where two meshes are specified, they must be kept at the two designed levels, supported by spacers and chairs and secured with tying wire. Two meshes that have fallen on top of each other do not provide two effective reinforcement zones. [190]

Figure 27. Q-mesh and two designed levels of reinforcement



On the left, a welded steel mesh is raised above the formwork on spacers. On the right, a conceptual section shows bottom and top reinforcement within a thicker slab. The exact mesh type, position, laps and concrete cover should always be taken from the reinforcement drawing.

Before the concrete is poured, check that the reinforcement is not resting directly on the ground, that it has the specified concrete cover, that openings and service penetrations are in the right places, and that everything will remain stable during the pour. These errors are difficult to put right afterwards. [190]

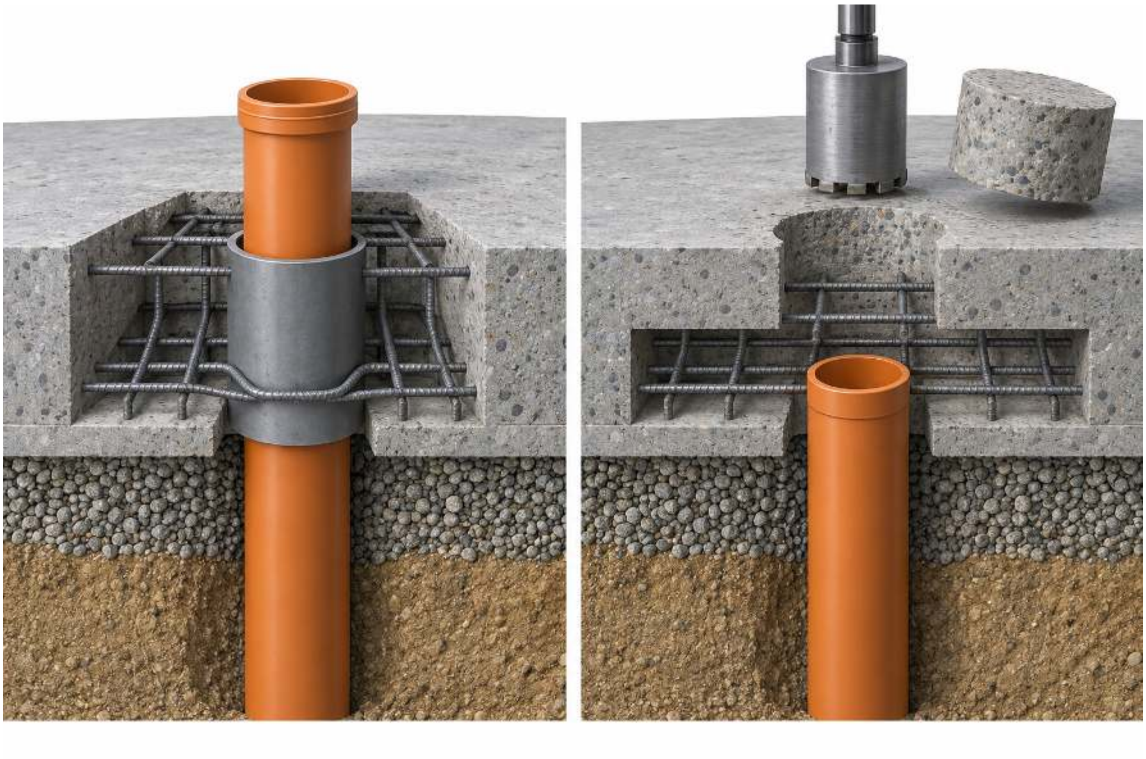
Drainage, water and electrical service penetrations must be planned before concreting

Drainage, water supplies, protective conduits for electrical cables and other services often pass through or beneath the foundation assembly. Before concreting, prepare a coordinated plan showing the position, diameter and height of all required penetrations, and coordinate it with the structural and services designs. A spare protective conduit may be inexpensive; drilling through a structural element or excavating again later is not.

Large plastic drainage pipes are not the same as small water pipes or electrical cables. A drain must have its specified diameter and a continuous fall, so its position cannot simply be shifted by a few centimetres once the concrete has been poured. Any route through a foundation, beam or slab must therefore be shown on the drawings, with a suitable sleeve or another designed detail, before concreting. A pipe must not be routed arbitrarily through the reinforcement or reduce the structural section without the structural designer's approval. [49] [221]

Smaller services can sometimes be routed later through a service zone or a shallow chase in a wall, but that is no reason to defer larger penetrations. A simple rule to remember: the larger and more rigid the pipe, and the more its route depends on a fall, the earlier the decision must be made.

Figure 28. Large drainage penetrations must be set out before concreting



On the left, a large drainage pipe is positioned in a coordinated opening before concreting. On the right, the same decision has been left until the slab is complete, when a new route requires scanning, approval from the structural engineer, and specialist drilling or further excavation. Required openings and protective conduits for water supplies and electrical services should be planned before concreting, along with the drainage. This is a schematic illustration; the diameter, fall, position and sealing are determined by the structural and services designs.

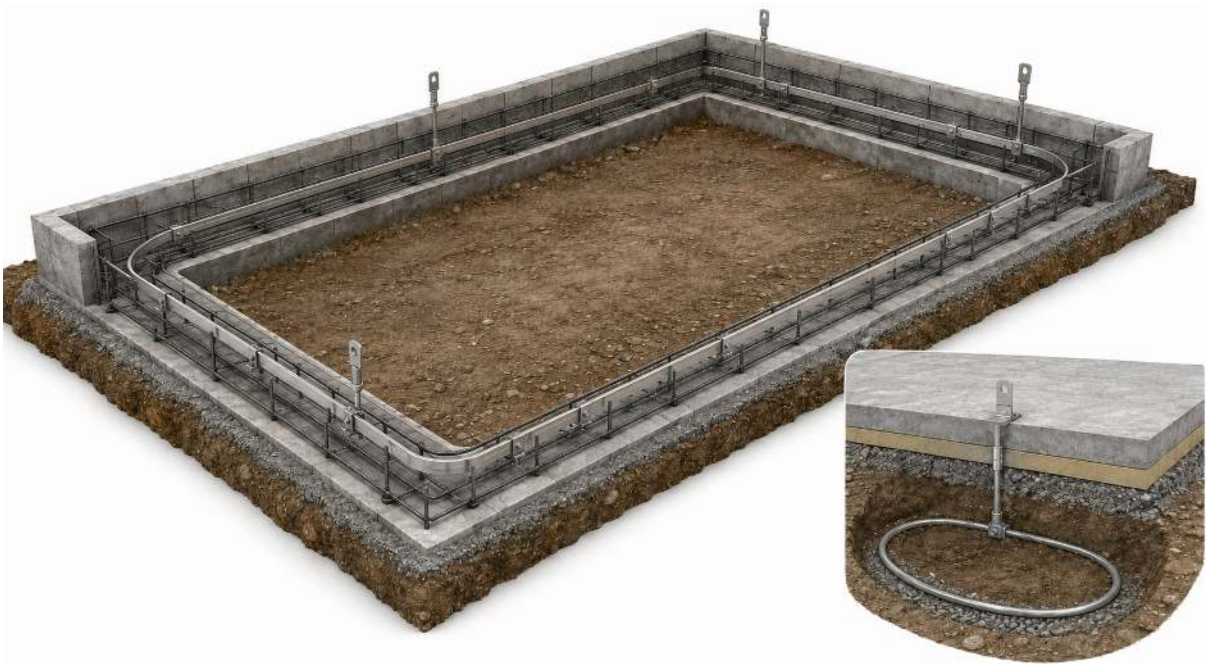
A foundation earth electrode is a conductive metal element cast into the concrete foundation and connected into a continuous circuit as specified in the electrical design. It helps protect people and the electrical installation by connecting the house to earth and the equipotential bonding system. It is not the same as the visible part of a lightning-protection system on the roof, although an external lightning-protection system may use the same designed earthing system. [62]

Its importance becomes clearest when a fault occurs. If a damaged conductor brings a dangerous voltage to a metal casing, the protective system must provide the fault current with its intended path so that the protective device disconnects the supply quickly. Equipotential bonding reduces dangerous voltage differences between metal parts that someone might touch at the same time. The effectiveness of the protection is confirmed by the designed installation and the required electrical tests. Without these, there is a risk of fatal electric shock, overheating or fire. [62]

Where foundations are separated from the ground by thermal insulation or another layer with high electrical resistance, a corrosion-resistant ring earth electrode may be needed in the ground outside the concrete, together with an additional equipotential bonding conductor in the structure. That is why the advice to “always leave four tails and extend two of them by ten metres” is not a safe rule of thumb. The number and position of connections, their materials and joints, and their relationship to the lightning-protection system must be determined by a suitably qualified electrical designer, taking account of the structure and local requirements. [62]

One thing applies in every case: the system should be designed, connected, inspected, tested and photographed before the concrete is poured. Adding a continuous conductor to a completed foundation later is difficult and expensive.

Figure 29. Foundation and ring earth electrodes depend on the foundation design



The main illustration shows a continuous metal conductor connected to the reinforcement in the strip foundations, with several planned connection points. The separate cross-section shows a ring conductor in the ground beneath a thermally insulated raft foundation. The image explains two basic options, but does not specify the material, number of connections, spacing or joints.

Placing fresh concrete

Fresh concrete should be delivered, placed, compacted and cured in accordance with the mix design and site conditions. Compaction helps the fresh mix fill the formwork, surround the reinforcement and release large air pockets trapped accidentally. Inadequate compaction can leave pockets of aggregate and honeycombed voids, reducing strength and increasing permeability. [65] [66]

The most common tool is an internal or poker vibrator: a power unit drives a cylindrical vibrating head through a flexible hose, and the head is inserted into the fresh concrete in a controlled manner. Rapid vibrations temporarily reduce friction between the aggregate particles. The mix then settles more readily under gravity, filling corners and the spaces between bars, while large trapped air bubbles rise to the surface. [67] [68]

An external vibrator transmits vibration through the formwork when an internal head cannot reach part of an element safely or effectively. A vibrating beam works from the surface, helping to compact and level suitable slabs at the same time. These are not three interchangeable names for the same tool. The method, head size, spacing and immersion time depend on the mix, the element’s geometry, reinforcement density and the concreting plan. [67]

A vibrator is not a shovel for pushing a heap of concrete to the other end of the formwork. Doing so can separate the constituents and leave an uneven element. But longer vibration is not automatically better. In a sensitive or poorly proportioned mix, excessive vibration can cause segregation—the separation of constituents: coarser aggregate settles towards the bottom, while finer particles, cement paste and some of the water collect at the surface. The section is then no longer uniform. This is not the literal extraction of dry cement from the concrete, and a well-proportioned ordinary concrete mix of suitable consistency does not separate easily because of a little extra compaction. [192] [193]

At a given point, compaction is complete when the mix has settled, large trapped bubbles have stopped rising and the surface is uniformly damp. Too little vibration can still leave large voids, so do not skimp by missing areas. No single duration works for every mix and element; the contractor adjusts the method to suit the concrete, formwork and reinforcement. Self-compacting concrete is designed to fill the formwork with little or no additional vibration, so follow the specific instructions for it. [66] [193]

Figure 30. A vibrator helps fresh concrete fill the formwork and release large trapped air pockets

On the left, a poker vibrator's vibrating head is shown inserted vertically into fresh concrete, with a small trail of bubbles rising to the surface. The section on the right deliberately shows honeycombed voids caused by poor filling and compaction. The illustration explains the principle; the position, depth and duration of insertion depend on the concrete design, the element's geometry and the responsible contractor.

After it has been placed, concrete needs protection against losing water too quickly, extreme temperatures and premature loading. A surface that looks hard does not mean the element has reached its design properties. [68]

Three different ways of keeping water out

Waterproofing is a continuous layer that prevents water from passing through the structure. Bituminous roofing felt is just one product group; membranes and mineral and polymer coatings are also available for different substrates and exposure conditions.

What builders mean by 'roofing felt'

The name roofing felt comes from the older flexible strips, made with a fibrous carrier impregnated with tar or bitumen. Today's products are generally factory-made bituminous membranes with a reinforcing carrier and a range of surface finishes. Bitumen is now mostly obtained by refining crude oil, but that does not mean all black rolls are the same. [63] [71] [72]

How was water kept at bay before bituminous felt?

Perhaps you are wondering how people built before factory-made bituminous membranes. The answer is not some lost ‘felt’ from the age of the old cathedrals. Medieval cathedrals and other traditional masonry buildings generally did not have today’s continuous horizontal damp-proof course: a layer running through the full thickness of the wall. Their thick stone walls and lime mortar—a binder made from lime, sand and water—could absorb some moisture and release it gradually through evaporation. That is why the roof, gutters, drainage beside the wall and vapour-permeable lime joints were integral to keeping water at bay, not mere finishing details. [72] [121]

Metal played an important part in historic construction, chiefly in the form of lead roofing, flashing or sheet-metal protection where the roof and wall direct rainwater. However, this does not mean that a metal sheet was laid beneath every wall in an old cathedral. Such a claim would require a verified drawing or finding from that particular building. Horizontal damp-proof courses only began to be used more widely and systematically in the second half of the 19th century. Depending on the building and region, they were made from lead sheet, slate, dense brick or a bituminous layer. [72]

This was a small but important step in the history of construction. Before modern membrane systems, builders first tried to keep water away from the wall: they raised the base above the surrounding ground, extended the roof beyond the façade and carried water away from the foundations through gutters. Lime mortar and plaster did not form an impervious shell; instead, they allowed the wall to dry after rain. Once horizontal damp-proof courses began to be installed, lead sheet was one durable material that could be laid in a bed joint—the horizontal joint between two courses of masonry—to interrupt moisture’s path upwards. Slate and other denser materials were also used, followed later by bituminous products. [72] [121]

Imagine a thin grey strip of lead hidden in the wall: almost invisible, yet interrupting the route water would take through pores towards higher courses of brick or stone. It follows the same building principle as a modern membrane, but it is not the same product, and should not be assumed to exist in every old building. Historic churches, especially those built before the 20th century, often have no horizontal damp-proof course at all, so their damp problems need to be understood in terms of the whole system of roof, ground, drainage and wall joints. [72]

This shows a change in approach. An old wall generally sought to accommodate and safely release small amounts of moisture; a modern wall is designed to intercept water at a particular layer and direct it away. The bituminous membrane in the next image belongs to this second approach: it is not a decorative black strip, but part of a continuous barrier that interrupts capillary rise before the first course of masonry.

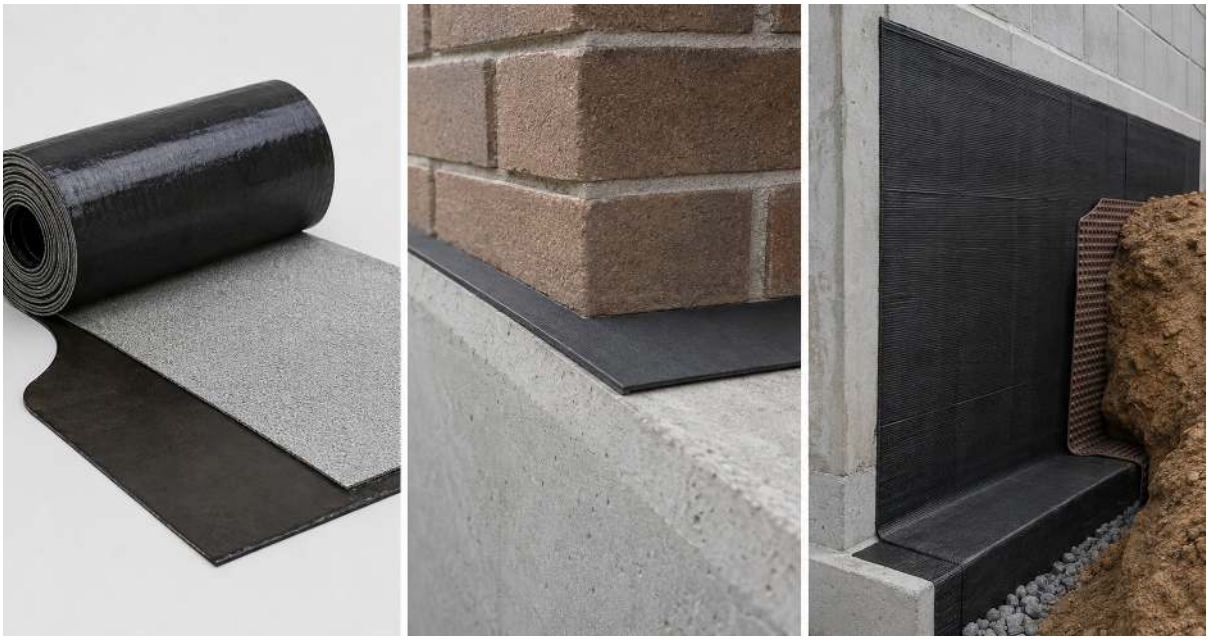
One membrane may be specified as a damp-proof course beneath the first course of a wall, another for horizontal waterproofing beneath a floor, and a third for a basement wall or roof. They differ in reinforcement, thickness, flexibility, bonding method, resistance and permitted exposure. Beneath floor insulation or a screed, a membrane may form part of the designed build-up, but its position depends on water, vapour, the substrate and its junction with the wall waterproofing. [63] [64] [94]

Where required by the technical data sheet for the selected bituminous membrane, first treat the cleaned, sound substrate with a compatible bituminous primer. On site, you may hear the trade or regional names Resitol and Bitulit. A primer of this kind penetrates the surface, binds residual dust and improves the bond between the membrane and concrete, masonry or cement mortar. It is not a waterproofing layer in its own right. For example, the Resitol technical data sheet says the primer must dry completely before subsequent layers are applied and warns that the solvent-based product may be flammable. [70]

Do not apply just any black coating beneath just any black roll. Self-adhesive, torch-applied and mechanically fixed membranes may require different preparation. The substrate, primer, membrane, drying time and bonding method must form a compatible system, in accordance with current technical and safety instructions. [63] [70]

A damp-proof layer may also be needed beneath a timber wall plate on masonry or concrete, but do not assume that any roll of bituminous felt will be suitable. The design must address moisture, timber anchorage and continuity with the other layers.

Figure 31. A black roll can serve several different purposes



On the left is the construction of a flexible bituminous membrane. In the centre is a narrow strip serving as a damp-proof course between a concrete support and the first course of masonry. On the right is a continuous membrane on a basement wall and foundation, before protection and backfilling. For each application, choose a product with the precise specification and installation method required.

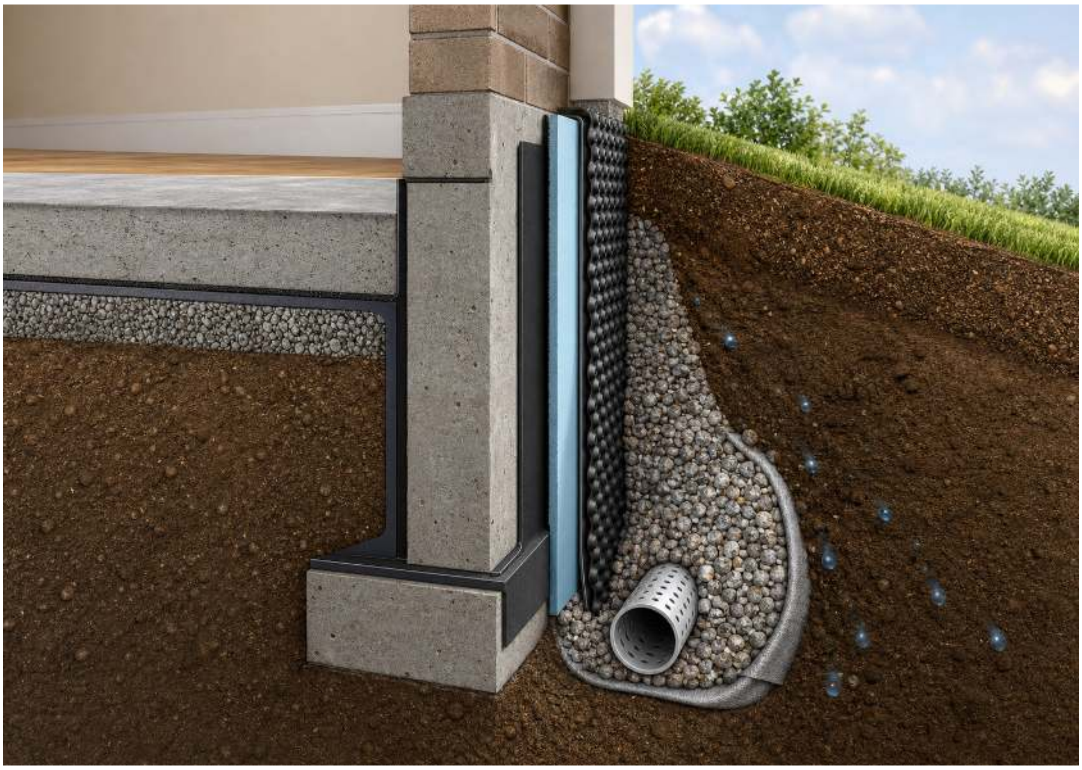
A capillary break stops moisture being drawn through tiny pores in materials. It is particularly important between the ground and the floor build-up, and between the foundation and the wall. [55] [56] [64]

Drainage collects and carries water away before it can build up against a structure. A perforated pipe laid in permeable material, wrapped in a suitable filter and provided with an effective outlet is often called a French drain. A pipe with nowhere for the water to go is not a drainage system. [21]

Drainage should be designed according to the water conditions, soil permeability, slope, presence of a basement and possible outlet—not by applying a single general formula or simply judging that the ground is stony. Water freezing in the soil can create forces that cause movement, but these are addressed through the foundation design, depth, drainage and thermal conditions, not with one universal pipe.

A dimpled membrane protects or separates certain layers against a backfilled wall. Waterproofing must be provided by a separately designed system. Before backfilling, photograph every joint, penetration, membrane termination and drainage route. [21]

Figure 32. Waterproofing, protection and drainage have different roles



A continuous membrane protects the floor and wall from water, external thermal insulation reduces the thermal bridge, and a dimpled membrane protects the vulnerable layer during backfilling. At the bottom, a perforated drainage pipe sits in permeable stone aggregate wrapped in filter geotextile. The finished ground slopes away from the house. Drainage is useful only if the water has a safe outlet.

A basement is the toughest test of a water-management plan

In a house without a basement, a small defect near the foundations may remain outside the heated rooms. In a basement, the same buried wall is at once a structural element, the boundary of usable space and a surface you cannot reach from outside without excavating again. What looks today like a neat black coating will tomorrow be hidden beneath tonnes of earth. The practical lesson is simple: inspect the protection while it is still accessible.

A basement is not a concrete box to be coated only on the inside if it starts leaking. First, roof and surface water should be directed away from the house through gutters, ground grading and a safe discharge route. The designed water and damp-proofing system must then connect continuously between the basement slab, the outside face of the wall, construction joints and every pipe or