6 Building technology in construction

Introduction

Today's construction industry requires technicians who understand modern construction methods, have an appreciation of traditional materials and a knowledge of plant and equipment that will be required to put these components together.

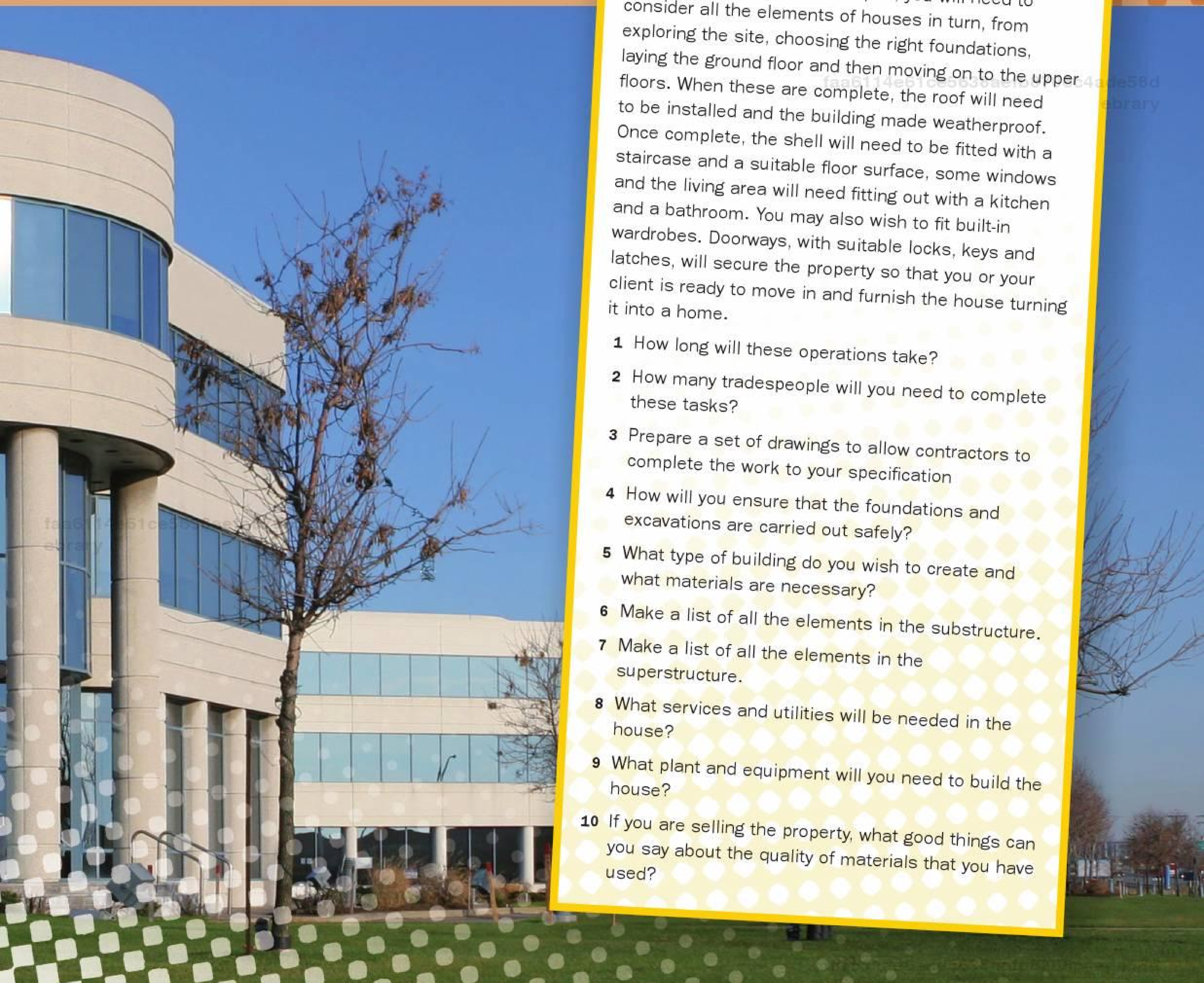
Buildings have evolved over time from simple shelters to the complex and sophisticated structures that we see around us today. Combinations of traditional materials such as brick, mortar and timber form the basis of most buildings, but the increased use of modern materials such as structural glass, plastics and prefabricated components is found in abundance as buildings become more efficient, integrate greater building services systems and other features to make them a more appropriate place to live and work. The challenge for the constructors of future buildings is to combine sustainable building technology with the ability to deliver high-quality buildings for society. The need to plan and organise this work, including the use of skilled labour, is necessary if constructors are to meet this challenge.

How you will be assessed

This unit is internally assessed by your tutor. A variety of activities is included in this unit to help you understand all aspects of building technology used in the construction industry.

After completing this unit you should be able to achieve the following outcomes:

1. Understand common forms of low-rise construction currently used for domestic and commercial buildings
2. Be able to describe, illustrate and evaluate the requirements and techniques used in the construction of substructures for low-rise domestic and commercial buildings
3. Be able to describe, illustrate and evaluate the techniques used in the construction of superstructures for low-rise domestic and commercial buildings
4. Understand the implications of environmental issues and legislative constraints on building construction and the infrastructure required to support typical construction processes



Thinking points

Designing and building houses requires understanding of building technology and the ability to translate these details into the finished product. Imagine that you have acquired your site, and you intend to build a pair of semi-detached houses on the plot. What will you do first? How can you bring all the elements together at the right time?

As you work through this chapter, you will need to consider all the elements of houses in turn, from exploring the site, choosing the right foundations, laying the ground floor and then moving on to the upper floors. When these are complete, the roof will need to be installed and the building made weatherproof. Once complete, the shell will need to be fitted with a staircase and a suitable floor surface, some windows and the living area will need fitting out with a kitchen and a bathroom. You may also wish to fit built-in wardrobes. Doorways, with suitable locks, keys and latches, will secure the property so that you or your client is ready to move in and furnish the house turning it into a home.

1. How long will these operations take?
2. How many tradespeople will you need to complete these tasks?
3. Prepare a set of drawings to allow contractors to complete the work to your specification
4. How will you ensure that the foundations and excavations are carried out safely?
5. What type of building do you wish to create and what materials are necessary?
6. Make a list of all the elements in the substructure.
7. Make a list of all the elements in the superstructure.
8. What services and utilities will be needed in the house?
9. What plant and equipment will you need to build the house?
10. If you are selling the property, what good things can you say about the quality of materials that you have used?

6.1 Understanding common forms of low-rise construction currently used for domestic and commercial buildings

Building uses

Creating a safe enclosure was the first requirement of humankind in the development of housing. Since then, our requirements have included many more things to improve our standard of living and our built environment.

Houses and flats

Houses are typically small structures of one or two storeys with simple components such as bricks, mortar, timber to make floors, roofs, windows and so on. Plastic resins and other synthetic materials have become available in recent years and have made houses significantly more efficient in **thermal performance** and noise exclusion. Improvements in the comfort features of houses, such as integrated kitchens, built-in bedroom furniture and building services, have meant that our houses have become increasingly sophisticated structures, which have to comply with legislation and regulations that place high standards of performance on both the quality of the finished product and also the workmanship of the assembly of these components.

Key Term

Thermal performance The ability of a material to retain heat in the structure.

Theory into practice

Working with a partner, list how many different types of buildings you can think of. Explain how these differ from each other.

Flats and apartments group together individual dwellings in a common structure, making the construction and assembly of these units more economic than if one unit only was occupying the land.

Warehouses and light industrial units

Warehouses and light industrial units are commercial buildings and do not list comfort as their main criterion. More likely, they are **open-span buildings** with steel frames and clad with aluminium or functional materials that allow space to be enclosed both economically and safely.

Key Term

Open-span buildings These are typically built using a skeleton frame, which allows an open-plan floor area that can be divided later into smaller spaces. This clear floor space is particularly well suited to offices where the final floor plan can be changed to suit any client who wishes to move into the building.

Retail

Retail outlets such as shops and commercial buildings can be purpose built or adapted from existing buildings. Newly built premises often take the form of large open-span, **portal frame** buildings which provide a large floor space such as those used in supermarkets and low-rise department stores. Smaller shops and retail outlets modified from larger-type houses need special works to adapt them from a residential property into a building

Key Term

Portal frame A structural frame that forms the building with lightweight cladding to provide weather resistance and to create an enclosure.

A portal frame

that meets the requirements of employment and more frequent visitors that a retail outlet will have. The requirements for fire resistance, noise reduction and ventilation are stricter for commercial buildings than they are for domestic dwellings, and any modification will need to take account of these if the adaptation is to be successful.

Theory into practice

Working with a partner, list all the things that you would need to change in order to convert a house into a small retail shop. What difference, if any, will it make to the types of commodity the shop sells?

Offices

Offices also use large open-span buildings, with many employers choosing to create smaller working spaces based on the functional requirements of the work that will be undertaken there, for example secure areas for accounts or transactions requiring the storage or exchange of money, or the creation of small private units where individual discussion can take place and privacy is required for clients. Small office buildings can be built in much the same way as housing, although should the requirement be for more than four storeys or for larger spans, then a more robust method of construction will be necessary, perhaps including the use of structural steel rather than bricks, mortar and timber.

Forms of construction

Traditional building

Traditionally, houses have used bricks and mortar to build **monolithic walls** which support the roof, floors and all other components. The established and traditional method of building houses is to take material to the site and to build the property to design plans **in situ**.

Key Terms

Monolithic walls Single structural elements that form the basis of the building. Typically, walls and floors are monolithic because they support loads in one direction.

In situ Building each component on site.

Prefabricated construction including timber frame

Timber-framed houses have been built in the UK for over 300 years, but they represent a modern method of working. Rather than building each component in situ as builders would do with more traditional methods, modern construction techniques have enabled timber panels to be crafted in workshops and then taken to site for assembly. This development, along with the use of modern materials and the increased use of insulation to comply with legislation on heat loss, has made homes more efficient. The reduction in on-site time has made timber-framed housing more attractive to builders who can offer better homes at lower prices.

The use of timber-framed panels has also changed the function of some of the elements of the structure. Some items that were at one time load bearing are now no longer used to support other parts of the structure.

Load bearing and non-load bearing

Timber-framed buildings use timber panels, typically made from a 100 mm × 50 mm softwood carcass with plywood or other sheet materials nailed to it to give it strength. The timber panels are load bearing as they support the roof, while any **cladding**, such as brickwork, acts only as a decorative facing. Internally, the partitions simply divide the interior into useable space and provide privacy. They do not support the structure and are therefore non-load bearing. The partitions may need special fixings and fittings if they are to be used to support other items such as cabinets or other wall-mounted items.

Key Term

Cladding The lightweight material that forms the enclosure of the building. Cladding is usually lightweight because it does not have to carry the structure.

Single-storey buildings

In commercial premises used as retail outlets or small industrial buildings, the main structure is frequently made from a frame of structural steel. This frame provides the anchor points for rails or cross rails – known as purlins – that support aluminium sheeting which has been formed and shaped into a corrugated profile that adds to its strength. Again, this type of cladding uses significant amounts of insulation material to enable the building to comply with relevant heat loss legislation and it provides some stiffening of the frame to wind forces but is mainly considered to be non-load bearing. In most portal frame buildings, the first two metres of the walls are made from traditional masonry (brickwork/blockwork) walls, which provides additional security at low level.

Low-rise buildings

Buildings that increase in height will need additional bracing and strengthening as they get taller. Commercial buildings of up to three storeys are typically made from structural steel in standard sections that provide an open-plan area which can be split further into smaller spaces by the occupier and tailored to their needs using demountable partitions and non-load bearing elements.

Detached housing

Speculative housing in the UK involves house builders constructing houses and domestic units for sale to a buoyant market that at present shows no signs of slowing down. House building across the country cannot keep up with demand and as such many designs for detached houses have been simplified and standardised to National House-Building Council (NHBC) standards. The rising standards have led to an increased number of features being incorporated into most detached houses, including en-suite bathrooms, home offices, fire and intruder alarms.

Remember!

The NHBC (National House-Building Council) is the industry body responsible for setting and maintaining construction standards for new homes in the UK.

Terraced housing

In Victorian times, terraced housing provided volume housing at cheap prices and the ability to accommodate large numbers of people in a given area. This was at a time of significant migration from rural England to the industrial cities. Modern designs use a similar format of structural walls coupled with roofing systems that stretch across multiple properties with appropriate fire and privacy breaks to create individual dwellings.

Roofs

Pitched roofs

Roofs can take many forms ranging from flat, monopitch, gabled, hipped or accommodating multiple pitches and features. Traditionally, roofs have been built by carpenters on site using large sections of timber with the features being created as work proceeds. More recently, the use of trussed rafters has meant that the roof is crafted using a series of manufactured triangles of frames to create the roof in pieces that are then assembled in situ. The use of trussed rafters has resulted in improvements in the standard of workmanship and thermal performance, and the use of smaller, more economic sections of timber has made roofing more affordable.

Flat roofs

Flat roofs are cheaper than pitched roofs. The cheapness of their construction has led to them being used for smaller contracts, especially small extensions to existing domestic dwellings. Flat roofs, incorrectly constructed, suffer from a great deal of condensation. For bigger projects, the use of large sheet materials or rolled aluminium profiled sheeting with correctly positioned **vapour checks** has been much more successful.

Key Term

Vapour checks Impermeable barriers or membranes used to prevent moisture passing through the structure.

Theory into practice

Draw a traditional pitched roof with a hip section and a dormer window. Identify the components of the roof, using the correct terminology for each part.

Short-span and medium-span roofs

Short-span roofs can be made from timber, whereas longer-span requirements will need stronger members made from either steel or concrete. Short- and medium-span roofs are cheaper to construct.

Remember!

The span of a roof is dependent on the roof loadings and the use of the building, for example if clear, uninterrupted areas are required with no columns. This may be required within a warehouse where large fork-lift trucks operate. Generally, the wider the span, the deeper the beams required to carry the load.

Implications of different forms of construction

Traditionally built buildings are labour intensive and require most of their construction to be built on site.

This makes the process expensive and difficult to monitor for quality control. Various tradespeople are required such as a ground working crew, a bricklaying gang, several joiners or carpenters, roof tilers/slaters, plasterers and then the services engineers, such as plumbers and electricians, to fit out the interior services. It also requires that materials are delivered to site which then have to be stored ready for use.

Prefabrication

In recent times, there has been a shift towards prefabrication of single or multiple components which has increased the speed of erection on site for the completed units and has also resulted in improved performance based on the high quality of materials and workmanship. A high level of quality control can be maintained in workshop conditions and the completed components taken to site for assembly.

Remember!

Prefabrication involves manufacturing and constructing components such as kitchen units, staircases and window frames in a factory. The components are then taken to the site where they are assembled. Using prefabricated components reduces the amount of time spent on site compared with the traditional method of constructing everything on site from scratch.

Thinking points

In 2003, Forest Bank Prison was built near Manchester. The use of prefabricated cells allowed the prison to be built in reduced contract time since all the cells were designed to be constructed off site, prepared with all the necessary fittings and taken to site for assembly on a prepared base. Later, when all the cells were bolted together, services were connected and secure doors were fitted.

The success of prefabrication within the construction process depends on the following:

- *A well-designed construction site layout.* This typically relies on the construction site manager having a detailed knowledge of the operations and the layout of the construction site to ensure that each component is integrated at the appropriate time.
- *Correct sequencing of the construction works.* This relies on the designer and the construction site manager working together to ensure that the correct plant and components are delivered to the site in the right sequence.
- *Use of prefabricated components wherever possible.* Careful consideration of the structure and the design brief will enable the designer to identify all components of the project that are suitable for prefabrication. The construction site manager should be consulted as they are also likely to have detailed information on the practicalities of delivering large items to site and whether it will be feasible to assemble and install large items on site.
- *Use of plant at all stages of construction.* Wherever possible, skilled craftspersons should use machinery to help them assemble and install components correctly. The reduction or elimination of as much physical labour as possible is a key feature in improving the economic viability of prefabricated housing and building projects.

Remember!

Using prefabricated components improves the quality of the finished product and also speeds up work on site.

Advantages and disadvantages of prefabrication

Kitchen cabinets, door frames, bedroom furniture and many other components are now frequently made off site and taken to the building project for installation and assembly rather than being built in situ. This

A prefabricated house

prefabrication of components has not been restricted to non-load bearing elements, and for offices or other steel frame buildings standard forms of structural steel sections can be cut, bent and shaped to specifications obtained from the design drawings and specifications, then taken to site and placed on prepared slabs and linkages to assemble the building in sequence from the ground upwards.

While there has been a significant improvement in the standard of workmanship and the speed at which buildings using prefabricated components can be built, there are some limitations to the use of prefabricated elements. Not all components are likely to be built off site and there will always be a need for some minor alterations as work proceeds. This is especially true of instances where the design has been agreed in advance. If the design needs to be changed, then it may be easier to make any alterations required on site while work is taking place. Only if the contractor can contact and communicate changes to the workshops and other subcontractors can these changes be made if the project relies on prefabricated elements.

Where the whole building is completely prefabricated, that is, taken to site fully assembled and lifted in position using a crane onto a prepared base, variations are possible, although care must be taken to ensure that the designers are consulted to check that the removal of or amendment to any component does not adversely affect the structural integrity of the building.

Portal frames

A portal frame is a shape that looks like a **portal**. It has a low pitched roof member that is attached to a column at either end. Portal frames can be constructed from several different materials: timber, steel or reinforced concrete. Generally, modern portal frames are constructed from steelwork that enables a high strength-to-weight ratio, which gives a large economical span. Concrete portal frames are generally pre-cast within a factory environment that ensures consistent quality. They are then assembled on site, like the steel portal frame, using a mobile crane. Timber portals are constructed using **Glulam** construction and stainless steel fixings. With all three methods, cladding rails hold the portals together along with eaves beams. Portal frames have the following advantages:

- large spans can be achieved
- speedily erected
- factory-produced quality
- easily extended and adapted
- good height-to-strength ratio
- enable lighter foundations than traditional construction of brick and block
- aesthetic when timber used
- enable recycling when the building comes to the end of its life.

Key Terms

Portal A large gateway or doorway.

Glulam A process of gluing timber strips together to form a solid beam within a mould.

Their disadvantages and limitations include the following:

- require some form of coating to prevent rust
- require fire protection coating
- expensive to bend
- external coatings have to be maintained.

Concrete frames

Concrete forms of construction are generally divided into two forms:

- in situ
- pre-cast.

In situ concrete frames consisting of beams and columns require some form of formwork in which mixed concrete is poured and held until it has set and attained enough strength to have the formwork shuttering removed. Pre-cast concrete is similar to that previously described and may require some of the beam-to-column connections to be cast on site or bolted to form a rigid structure.

The advantages of concrete frames:

- in-built fire protection
- can be moulded into any shape
- high strength in compression
- do not require a secondary finish
- faster construction period using pre-cast
- variety of surface finishes can be achieved.

Their disadvantages or limitations:

- require support initially
- crainage required
- poor strength on tension
- require highly skilled workforce to assemble.

Steel frames

Once again, these are a series of beams and columns and may be composite in design, which means they can contain concrete floors and steel supporting beams, that is, a mixture of the two technologies.

6.2 The requirements and techniques used in the construction of substructures for low-rise domestic and commercial buildings

The choice and selection of the building type will rely largely on the functional requirements of the building and the use to which it is put. In order to determine the suitability of the ground and its capacity to support the building, a thorough and detailed site investigation is necessary so that the foundations and the fabric of the building can be selected.

Subsoil investigation

Site survey and subsoil investigation

The main objective of a site investigation is to examine the ground conditions so that the most appropriate type of foundation can be selected. A typical site investigation begins with a **desk study** and a **walk-over survey** to establish the geology of the site and continues with an examination of the **geotechnical properties** of the ground. We are going to look more closely at a variety of techniques for a direct investigation and the selection of appropriate methods for given locations.

Key Terms

Desk study An investigation of information about a piece of ground undertaken by reviewing existing records.

Walk-over survey Visiting the site enables the surveyor to match the information from the desk study to what they see in the field. Experienced surveyors can get a feel for ground conditions by undertaking a walk-over survey.

Geotechnical properties How soil is likely to perform when imposing loads on it or what will happen when water is removed to allow work to take place.

Remember!

It is very difficult to be precise when investigating the subsoil. It is only an indication of what you may find in excavations.

Recording and interpretation of results

Purpose of the site investigation

Remember!

Site investigation takes place to check whether the proposed structure can be built on the site.

Site investigation involves gathering all the information on ground conditions which might be relevant to the design and construction of a building on a particular site. On a site intended for low-rise development, the desk study is the first stage of investigation. This involves checking existing records such as geological maps of the site, utilities records, local historical archives, etc. The desk study, along with the walk-over survey, will (hopefully) give sufficient information about the ground and groundwater conditions, and the problems that they may pose for the construction and the finished building. The walk-over survey:

- checks the accuracy of desk study information
- obtains any additional information required to ensure that the building can be constructed safely and within budget.

Theory into practice

Where can you find information about soil or site conditions? Use the Internet to see what information is available through utilities companies and the local authority.

There are many cases where a site investigation is specific and tailored to a particular site. Generally, all site investigations should provide the following information:

- classification of soils
- soil profile
- soil parameters.

Classification of soils

Ground investigations classify the soils beneath the site into broad groups. Each group contains soils with similar engineering behaviour. The simplest classification used by geologists is:

- rock
- granular (sands and gravels)
- cohesive soils (clay)
- organic soils (peat)
- fill or made ground.

Broad soil classifications, coupled with simple tests to determine **soil parameters** or to detect the presence of chemicals harmful to construction materials, are normally sufficient for low-rise buildings.

Key Term

Soil parameters How the soil will react to building work and imposing loads. The soil can be expected to carry a certain amount of weight depending on its parameters and its characteristics.

The soil profile

Ground investigations identify the levels of the various soil or rock types on the site by recognising the boundaries between them. This builds up a picture of what the ground looks like under the surface of the earth – this is known as the soil profile. Boundaries between the various soil types are not always distinct – many layers of the earth (strata) change gradually from one to another with no clear point where just one condition exists, which means it is difficult to tell what conditions you will actually find when you dig into the earth.

Soil parameters

Engineering design and calculation may require finding out the soil parameters. In many situations, soil parameters may not be required, for example where conditions are particularly good (such as rock), which in most cases will support buildings very well, or particularly bad (such as peat), which should be excavated away to deeper, better load bearing ground. The parameters of soil found in difficult ground (clays and the like) must be determined since these soils perform variably; hence the need to quantify the load imposed by a building and the ability of the clay to support this load.

Planning and carrying out the site investigation

Desk studies and the walk-over survey are both indirect investigations. They are normally cheaper than direct investigations which involve drilling into the ground, extracting samples and then laboratory testing of samples to determine their properties. These operations require planning if they are to be fully effective. The stages of a full investigation are as follows:

Stage 1: Carry out a detailed desk study and walk-over survey. Identify the probable ground and groundwater conditions. Locate areas on the site that are likely to cause problems such as areas of fill, old hedgerows and trees, mineshafts, low-lying ground, etc.

Stage 2: Make initial designs for the structure and the site. Work out the positioning of the proposed structure so as to avoid as many problems as possible. Design structural forms, for example lightweight construction of timber-framed houses as opposed to dense, heavyweight concrete design, with special regard to anticipated ground hazards such as peat or excessive water conditions. Make preliminary estimates of the type of foundations required; determine the position of critical slopes and retaining walls.

Stage 3: Plan the direct methods required for the site investigation. Identify the depths of investigations required at different locations around the site. **Boreholes** should always penetrate completely through **made ground** or in-filling. Identify suitable in situ and laboratory testing methods for the expected soil conditions. Decide on the number of exploratory holes and the sampling and testing frequency, making allowances for the presence of unforeseen ground or groundwater conditions.

Key Terms

Boreholes Holes sunk into the ground to extract soil samples at differing levels. The information is recorded as the holes are drilled so that the design engineer discovers at what depth each soil is found.

Made ground Any ground that has been artificially made from material placed from previous works, for example layers of stone compacted and laid to form a level surface ready for construction work.

Stage 4: Keep records of the investigation. Record the basis of the planned site investigation and the expected ground conditions. The specialist contractor who carries out the work will then know if the ground conditions they encounter are unforeseen, in which case they may have to alter the scope of the field or testing work.

Ground investigation techniques

Many different methods of ground investigation are available for direct site investigations. It is important to select methods which:

- will work in the particular ground conditions expected at the site
- give the information required to resolve any construction problems that might be expected
- give information that will allow the structural design calculations to be resolved
- are sufficiently economical given the financial constraints of the construction process.

Let's look at some of the methods available for site investigation.

Exploratory holes

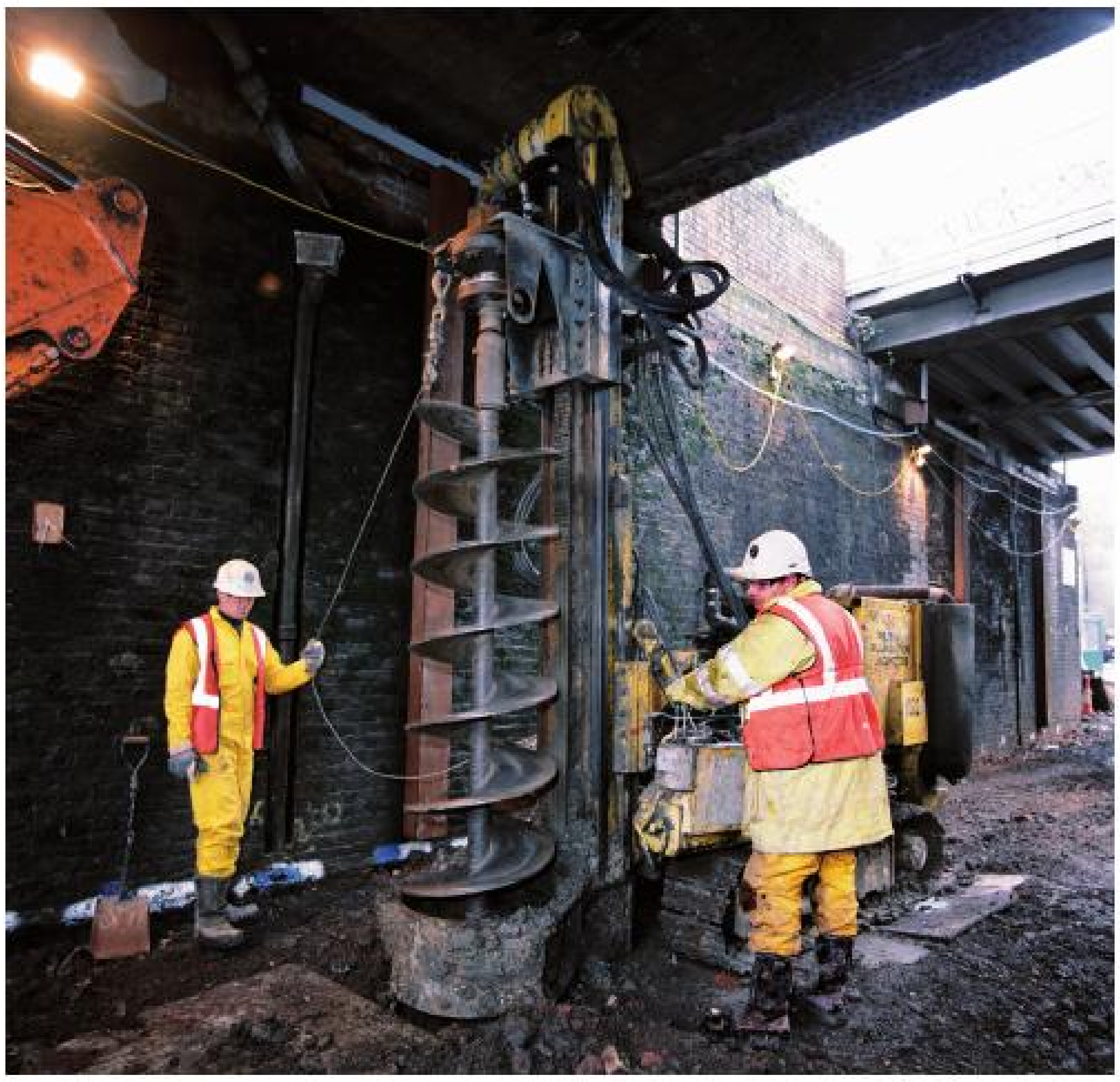
There are a number of techniques involving the excavation of or drilling into the earth.

Trial pits. These are extremely valuable if the depth of the investigation is limited to approximately 5 metres or less. This is the depth that can be conveniently excavated in most soil types using a back-actor or 360-degree slew hydraulic excavator. Trial pits are particularly useful in the investigation of sites intended for low-rise construction because the foundation types for this type of structure are generally 0.4– 0.5 metres wide and 1–3 metres deep, so the depth of the investigation is 3–5 metres. Routine trial pit records are normally kept as a 'log' with the soil profile recorded as the hole is dug. Trial pit excavations are relatively cheap and offer quick results, but care needs to be taken with exposed excavations, as some pits may need shoring with timber supports or hydraulic earth props. Open excavations are dangerous and should be clearly marked or cordoned off to prevent anyone falling into them.

Theory into practice

List the equipment you would need to complete the work on excavations on site.

Auger holes. These are normally made by hand turning an auger drill into the ground. Some light power tools may also be used. Auger holes, unlike trial pits, do not allow the soil to be examined in situ. Typical auger holes are 75–150 mm in diameter. Samples of the soil are collected at the surface when the earth is displaced by the helical auger flight (which is a technical term for a large spiral drill), the information is recorded and the descriptions collated to allow an engineer to produce a cross-section drawing which represents the conditions below ground.



Ground investigation techniques

Window sampler. This is a steel tube, usually about 1 metre long with a series of 'windows' cut in the wall of the tube through which to view or take specimens of the soil sampled. It is driven into the ground by a lightweight percussion hammer, then extracted using hydraulic jacks. Samplers come in a range of diameters allowing the largest diameter to be driven first, then a sample from the bottom of the hole taken with a sampler of smaller diameter. Next, a sampler with a smaller diameter than the first is driven: this process continues with the use of smaller diameter samplers until an adequate depth is investigated. The results are recorded as an ongoing process up to a depth of approximately 8 metres.

Boreholes. In the UK, 150 mm or 200 mm boreholes are normally made using light percussion equipment. This type of equipment is portable and is often towed behind a four-wheeled drive vehicle.

In clay soils, the borehole is made by dropping a hollow tube – a claycutter – into a hole so that the clay becomes lodged in its base. The claycutter and its contents are then lifted carefully to the surface.

In granular soils, a hollow tube with a flap valve is surged or pressed in the ground using water pressure creating a water/soil mixture. Soil drops out of this mixture and is collected. Material taken from the drilling tools is usually retained as small 'disturbed' samples which can affect the results of the soil analysis. In some cases, the strength of the soil will have changed because it has been remoulded into the sample from the water/soil mixture; it may also have removed small particles from the soil; it may have increased the water content of the soil sample. Ideally, undisturbed samples are better since they show what the soil is actually like. However, disturbed samples can be analysed in a laboratory, which is more costly but more accurate in determining the soil's load bearing capability.

In cohesive soils, samples are taken at intervals of 1.0–1.5 metres by driving a sample tube into the bottom of the hole. These undisturbed samples are often taken to a laboratory for analysis. On site, the supervisor records data which is relevant to the sampling such as weather conditions, ground conditions, etc.

The main advantage of light percussion drilling is its ability to make deeper holes in a wide range of ground conditions such as is necessary for civil engineering projects, medium-rise construction and low-rise construction built on poor bearing ground, although the drawbacks include the fact that it is considerably more expensive than shallow trial pits and auger holes.

Depths, numbers and locations of exploratory holes

Borehole depth depends on the **stress distribution** under the foundation. Boreholes should penetrate all deposits unsuitable for foundation purposes such as unconsolidated fill or material that needs further compacting such as peat, organic silt and very soft, **compressible clay**. Depth requirements should be reconsidered when the results of the first borings are

Key Terms

Stress distribution How the foundation distributes the load of the building. A very wide, flat foundation will support more load than a narrow strip foundation.

Compressible clay Clay that can be compressed or compacted to increase its strength or load bearing capacity.

available. It is often possible to reduce the depth of subsequent borings or to confine detailed and special exploration to particular strata.

The maximum number of boreholes will depend on the complexity of the local geology and the planned construction project – it may change as information becomes available from the early investigations. The location of boreholes depends on the nature of the site. Additional boreholes should be drilled at problem areas and at locations near the site of the proposed structure. Where practicable, they should be located along **grid lines** at regular intervals to enable **section drawings** to be produced.

Key Terms

Grid lines An imaginary series of lines running north–south and east–west allows designers and engineers to plot exactly key positions on site.

Section drawings A profile of the ground using the information from the boreholes next to one another – that way engineers can predict what happens to the ground between each borehole.

Remember!

The cost of the site investigation is around 0.5–1 per cent of the **capital cost** of the construction contract. It is considered good practice to invest adequately at this stage of the construction.

Key Term

Capital cost The total cost of all the equipment and necessary expense required to complete the works.

Radon gas

Radon is a radioactive gas that occurs naturally and is found in most locations in the UK, although there are areas where it occurs more frequently and with higher concentrations such as Cornwall or South Wales. Radon gas has no taste, smell or colour. Radon gas comes from the decay of uranium that is found in small quantities in all soil and rocks. Concentration levels of radon gas can build up in enclosed spaces such as excavations during construction work. Environmental health officers are appointed by the local authority to determine safe levels of radon gas in existing properties; the Health & Safety Executive has the task of monitoring how contractors deal with radon gas during construction work. Contractors have a duty of care under the Health and Safety at Work Act to provide a safe and healthy place of work.

Building Regulations require that buildings and buildings extensions (workplaces and dwellings) constructed after 2000 in radon-affected areas have protective measures installed during construction. To prevent the build up of radon gas, barriers are built into the structure. This barrier must cover the total area of the foundation of the building.

Remember!

Building Regulations are appropriate for England and Wales. Separate documents exist for Scotland and Northern Ireland. Find out what these documents are called.

Groundwater conditions

Groundwater is found below the ground in the spaces and cracks between soil, sand and rock. The general level of water in the ground is known as the water table – the level of the water table is of interest to builders since their operations will be affected by its presence in the works that they will undertake. Digging into the ground can cause groundwater to fill up any trenches and excavations. It will also affect the building, so construction companies have to plan how to remove or deal with the water during construction.

Groundwater conditions are significant because they can affect construction in a number of ways:

- A high **water table** can lead to extra costs – from de-watering techniques (using either a temporary or a permanent solution), increased support for trenches and excavations, ground stabilisation requirements, etc. – and make construction more difficult.

Key Term

Water table The level of water found in the ground during excavations.

- The presence of chemicals in groundwater, such as acids and sulphates, can lead to damage if foundation concrete and other materials used in the substructure are not of an appropriate quality.
- A high groundwater table implies that **pore-water pressure** in the soil is high, which usually means that the soil is weaker. As well as influencing foundations, high pore-water pressures will adversely affect the stability of slopes and the pressures on **retaining structures**.

Key Terms

Pore-water pressure The pressure that water exerts on the ground as it moves through the fissures and cracks in the ground.

Retaining structures e.g. walls and buildings that hold back or support the earth.

Theory into practice

What are the implications for health, safety and welfare of personnel working on site in excavations where water is present? What can be done to minimise risks?

Impact on foundation design

Foundation design is complex and the following factors need to be considered fully in order to select the correct foundation:

- *Loading* – the imposed load from the building including the deadweight of the structure and any live loads exerted from wind forces.
- *Water table* – the presence of water in the ground will need to be taken into account. The usual choice is to remove the water found in excavations either as a temporary solution or to install land drains and remove the water on a permanent basis.
- *Contamination* – water and nitrates in the ground combine and produce acid that erodes concrete over a period of time. Sulphate resistant concrete is specified for these purposes but care is required both in its handling and its placement to ensure that it reaches its compressive strength in good time.
- *Bearing capacity of the soil* – following a thorough site investigation, it should be accurately determined how much force the soil will support. The bearing capacity of the soil can be enhanced or improved with ground stabilisation techniques or further excavated to lower levels of earth that will support the load with better bearing capacity.
- *Cost* – the respective costs of these options should be explored by the design engineer who must take account of the excavations, the plant and equipment necessary balanced against the need to locate suitable bearing strata.

Foundation design

Foundations spread the load of a building over an area of the ground to avoid any settlement and also support the building. The **safe loading** of the building will need to be determined by calculation and by assessing the capability of the soil to carry the load. Reference tables in the 'Building Regulations Document A 1/2 Minimum Width of Strip Foundations' allow designers to select foundations of known dimensions and performance matched to the soil characteristics.

Key Term

Safe loading The solution calculated from the soil's ability to carry a load plus a factor of safety.

Remember!

Foundations carry the weight of the building, transferring the load safely to the ground below. They spread the weight of the building, and hence the load, to an acceptable level of force exerted on the ground.

Principles of design and factors affecting choice of foundations

The selection of a foundation for a particular project depends upon:

- the type of building structure
- soil conditions
- external or site constraints, e.g. the size and shape of the site layout
- type of foundations available (see Figure 6.1).

Type of building structure

Low-rise buildings, such as most houses or domestic dwellings, up to about four storeys with load bearing walls, generally allow line loads from walls to be distributed to the earth below via strip foundations.

Theory into practice

Which types of foundation are most suited to a portal frame, low-rise flats and a simple detached house? Which of these foundations are suitable for more than one application?

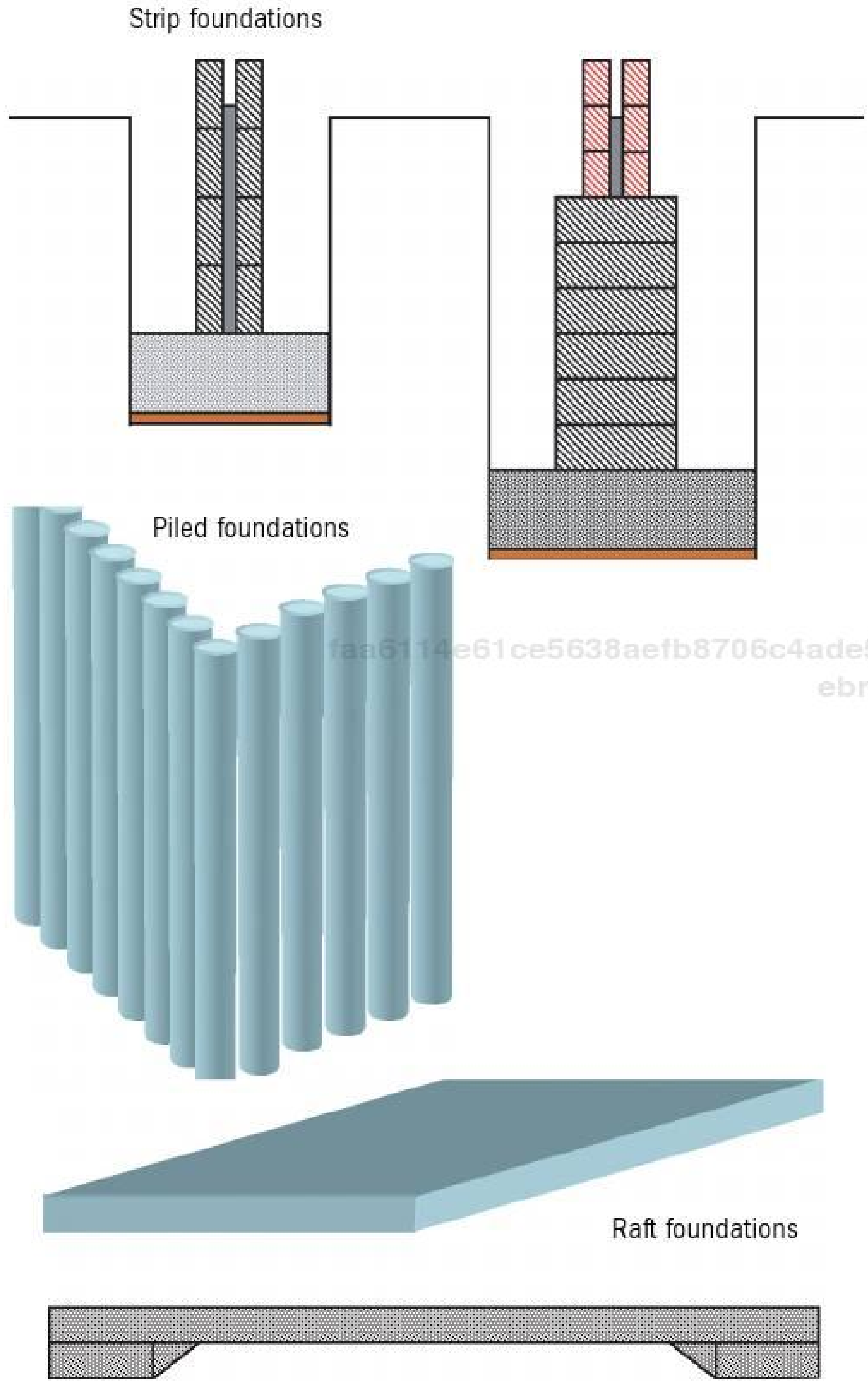


Figure 6.1 Strip, raft and short bored piled foundations

Heavyweight buildings and those with a requirement for open plan spaces, such as offices, result in heavier loads that are usually delivered to the foundations in isolated points via columns from a structural framework.

Soil conditions

The two main characteristics that affect the choice of foundation are the maximum loads that can be carried without failure and excessive **settlement**. Normally, the settlement characteristics of a soil relate to spread foundations such as strip, raft and pad foundations whereas the actual strength of the soil is more important with piles.

Key Term

Settlement The way that soil reacts to having a load placed upon it – usually the soil 'sinks' a little due to the extra weight placed upon it, although this settlement should not affect the building a great deal.

Poor soils

Poor soils such as peat, silts, soft alluvial soil and filled ground have very poor load bearing and settlement characteristics and are suitable for buildings that can readily accept large amounts of movement. In most cases, these types of soil prove unsuitable for bearing loads. Poor cohesive soils such as clays are very sensitive to changes in moisture content. In many cases, the excavation of these unsuitable soils and the siting of foundations on better load bearing ground at a lower level will prove to be the most satisfactory solution. There is also a range of techniques that can be employed to 'stabilise' the ground and improve the load bearing capacity.

Cohesive and non-cohesive soils

Cohesive soils are weak compared with sands and gravel but have reasonable bearing capacities. However, they are prone to some long-term settlement and, with this in mind, foundations should be of an appropriate size. As with poor soils, cohesive soils are sensitive to changes in the moisture content and are prone to swelling and shrinkage when the water content of the soil is altered.

Non-cohesive soils such as sand and gravel are generally stronger and have a higher bearing capacity and low **compressibility** compared with cohesive soils. Settlement usually occurs instantaneously during the construction of the building. This type of soil may prove acceptable to any of the foundation types selected, for example strip foundations, piled foundations and raft foundations.

Key Term

Compressibility The ability of soil to compress and withstand a load imposed upon it.

Rock

This is generally the strongest material on which to put a foundation and its safe bearing capacity is not usually a major consideration. Some rocks such as chalk are the exception to the rule – this type of rock will behave more like weak soil especially when the moisture content is high.

Contaminated soils

These soils may prove problematic for the work taking place on the foundation and the other substructure works. For these conditions, a more detailed investigation is normally made in order to determine the extent of the contamination and the concentration. The primary concern is to health, but some aggressive contaminants can cause damage to buried services and structures. The site investigation results are used to determine the extent and the severity of the contamination. Only after these are known should the overall strategy for the site be decided: heavily contaminated sites may be costly and impractical to clean up but may prove suitable for light industrial use. Typical examples of contaminated land are:

- landfill sites
- gasworks sites
- sewage farms and works
- scrap yards
- industrial areas.

The two most common approaches to the problems associated with contaminated ground are either removal or capping. Removal of the soil is costly and disposal to licensed tips awkward because of the nature of the material. However, this is a positive and permanent way of approaching the problem. Capping involves the sealing of the material by a layer of clean material of approximately one metre deep. This effectively places the contaminated soil in a zone that is not readily accessible.

Theory into practice

Use the Internet to find out how you could dispose of contaminated ground or materials. What legislative controls are in place to ensure safety when disposing of contaminated materials?

Although consideration must be given to the effects of placing material in such proportions, capping is usually the most economical and common form of treatment.

Foundations on poor ground

Poor ground with insufficient strength can be considered in one of two ways:

- to excavate it away until ground of good bearing capacity is found
- to improve it so that it can accept the load of the building.

Ground improvement increases the density of the soil and enhances its bearing capacity. This allows the construction of lightly loaded spread foundations at high level. A specialist subcontractor with the necessary plant, equipment and expertise usually carries out this kind of work. These techniques normally employ large pieces of machinery that can have an effect on the site and its constraints. The nature of making adjustments to the ground conditions can make these techniques suitable for isolated or relatively exposed sites where there is little risk of damage to adjacent buildings.

Vibro-compaction of poor soils

This technique has been employed for more than 30 years. A large vibrating poker is vibrated into the ground on a grid pattern of approximately 2–3-metre centres. Vibration rearranges the particles of the soil to make them more dense. Sand is then pumped in through the poker as it is extracted to fill the void. The treated soil is then suitable for light-use spread foundations such as strips and rafts. The foundation must be designed to accept local soft spots that have been missed by the treatment.

Vibro-replacement of poor soils

This is similar in concept to vibro-compaction but more suitable for poor cohesive soils such as peat and silt. The technique requires that stone columns are formed through the poor soil on a grid pattern of 1–3-metre grids over the site. The columns are formed using a poker similar to the vibro-compaction treatment or a suitable piling rig to drill holes in the earth. The installation of stones compresses the ground, increasing its density and also acting as a weak column transferring the load to a lower level of the ground that can support the load more effectively.

Dynamic compaction of poor granular soils

Over the past 20 years, dynamic compaction has been used for the compaction of poor soils on remote sites. The technique uses a large crane to drop weights of approximately 20 tonnes from a height of approximately 25 metres on a grid pattern across the site. Most sites need about three to five passes before a satisfactory density is achieved. There are problems with the use of this method, most notably the restriction on the site conditions: it can only be considered where the dropping of a 20-tonne weight will have little or no effect on neighbours, hence dynamic compaction may prove to be unsuitable for some sites with neighbours close by.

Piling

Piling is used in situations when the ground is unsuitable for heavy load and in particular where the loading of the building is transmitted by a framework in such a way that the total load is concentrated on a few points.

Piles are employed usually where, because of soil conditions, economic or constructional considerations, it is desirable to transmit the load of the building to strata beyond the depth of the practical reach of spread foundations. There may be a high water-table level where spread foundations could be employed but where piling may provide a cheaper answer than lowering the water table. Piled foundations may also provide a satisfactory solution where a site is restricted and spread foundations or their excavation may cause problems to adjacent buildings.

Piles can also act in tension to resist uplift, which might be caused by wind loads, or buoyancy conditions from a fluctuating water-table level. Piles are designed to take vertical loads but can accommodate some horizontal movement – where this horizontal movement is expected to be of a sizeable nature, raking piles are usually used.

Piles can be either replacement or displacement. Replacement piles remove the earth and place another material – typically concrete – in the hole created by the boring tool. Displacement piles are driven by a machine by dropping a hammer a ‘set’ number of blows.

The following are the main types of pile:

- Bearing piles – transmit the building load directly to solid strata.

- Friction piles – rely on shape and frictional resistance to the ground. They are used where safe bearing strata cannot be reached.
- Consolidated piles – used in a situation where the ground is weak or waterlogged, the aim being to strengthen the overall nature of the ground rather than to provide a specific point support.
- Sheet piles – used to contain earth and prevent movement that would result in a weakening of the natural foundation. They are more frequently used for temporary works but can be permanent.

The method of driving and sinking the piles depends on site conditions, space and height available, proximity of buildings, avoidance of vibration, number of piles required, etc (see Figure 6.2).

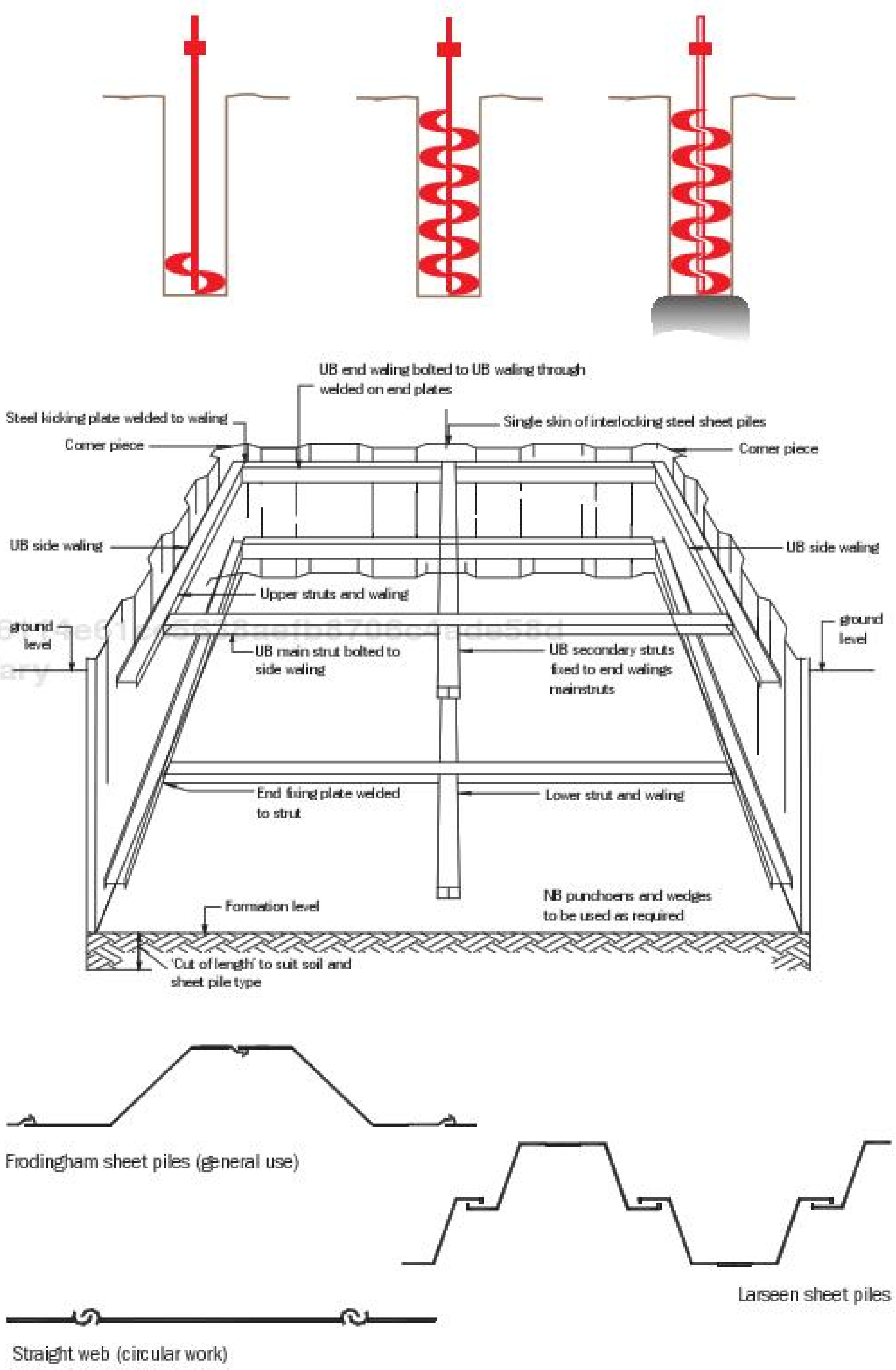


Figure 6.2 Types of piles

Materials used for piling

Timber

Timber is a suitable material, but the length and sectional area are limited. Timber piles are frequently used adjacent to water forming piers, jetties and landing points. They are prone to rotting if alternately wet and dry conditions exist.

> **Remember!**
>
> Timber piles are quite rare nowadays. They are used for small projects, usually on piers or jetties, adjacent to water courses.

Steel

Piles from steel generally consist of two types: bearing and sheet. Sheet piles will be considered in more detail later. Load bearing piles are usually single or multiple, universal beam or column, which provides a good profile for the required friction in the ground. The use of multiple sections also creates stiffness and rigidity in the section used. Steel is a material that is flexible and versatile – it can be cut and welded fairly easily on site.

Concrete

Concrete piles driven in one section are suitable for unrestricted sites where long piles do not pose handling problems. They require minimum site work in that, once driven, the pile is ready apart from stripping of the top to expose and integrate the reinforcement to the main structure.

These piles are generally cheaper than a cast in situ and control on quality is very good. Protection to the head of the pile may be necessary to allow the pile to be driven, but this is more for practical purposes than appearance since the top of the pile is cut away. Some disadvantages do exist – the pile could be deflected by obstructions too long to be driven.

Pre-cast piling such as this requires an extensive site investigation in order to determine the subsoil conditions to avoid problems such as those mentioned above.

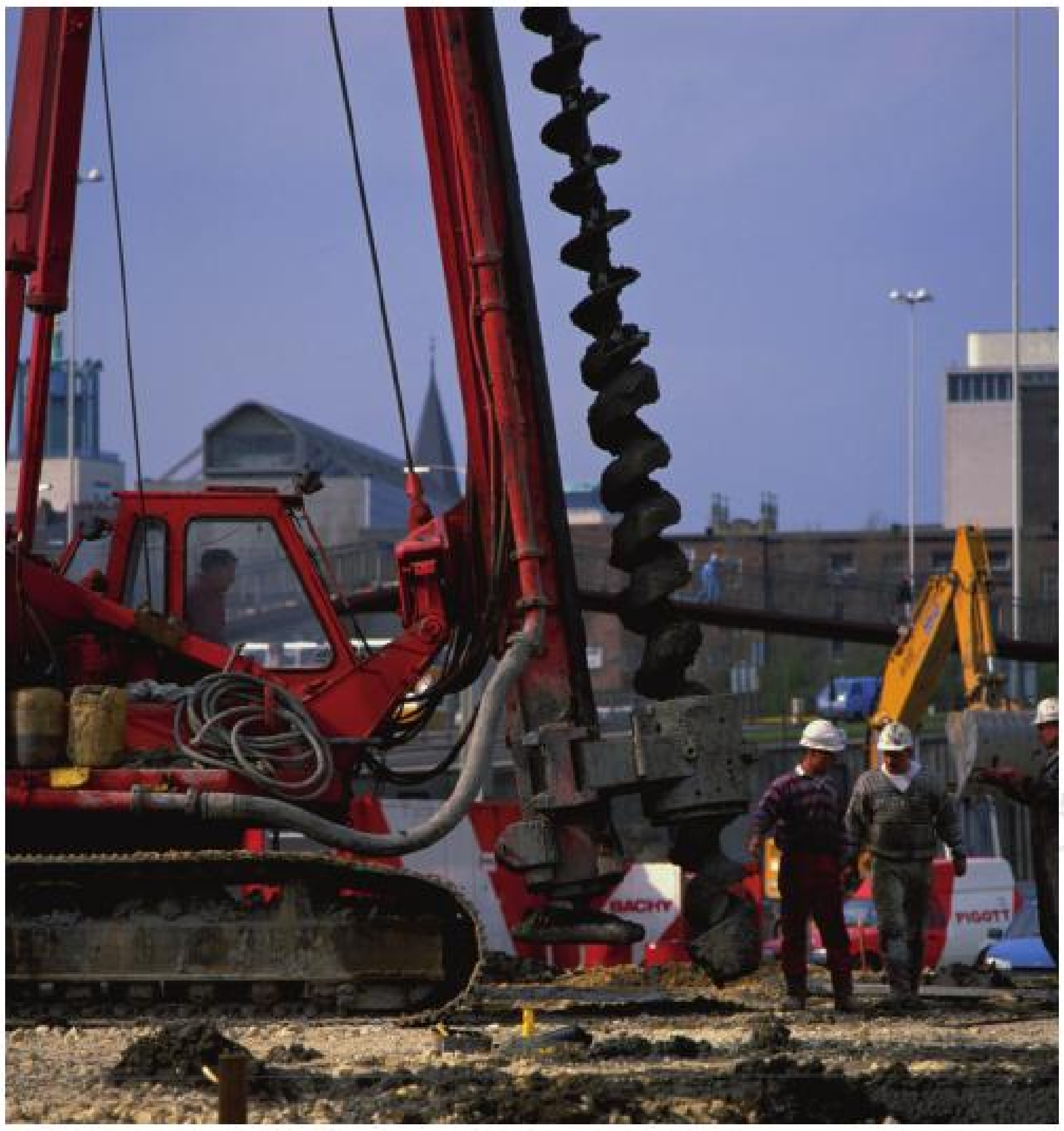
Piles can also be driven using short lengths that are easier to manipulate on site and transport. They consist of concrete shells, which are driven by a steam hammer transmitted to a special concrete or steel shoe. When driven, there exists a watertight concrete tube in the ground and the main reinforcement is inserted into this – the whole is then concreted. The advantage of this method is that using prepared casings, the ground can be fairly unstable such as running sand, made up ground, gravels, etc. Pre-cast piles are hollow inside and are guided into the casings using a steel mandrel. A cage of reinforcement steel is prefabricated and lowered into the pile. The casings are then withdrawn by a hoist.

In situ piles

Using a sealed tube and mandrel, the tube is sunk by a piling rig to the correct depth. The concrete and reinforcement is then introduced. The concrete assumes the ground profile, but care must be taken to ensure that the level of concrete is above the bottom of the sleeve since the earth pressure can cause 'necking' or 'waisting' at low levels. An alternative is to drive the pile with a steel cylinder weight complete with a semi-dry concrete mix in the bottom of the pile. When the pile reaches the required set, the plug is forced out, concrete and reinforcement is introduced to form the completed pile.

In situ excavated piles

A single flight auger drill on the end of a Kelly bar is used to bore a hole into the earth. Extending the Kelly bar can increase the depth. The spoil is removed by retracting the drill to the surface. This method is generally slow and is restricted to depths of up to about 13 metres. Using a continuous fight auger, the earth is removed, which gives a belated indication of the subsoil conditions. The use of a lining in cohesionless soils may be necessary to prevent collapse of the pile into the vacant hole. Some piles may have an added advantage of being hollow through which the concrete is pumped under pressure as the drill is retracted. This creates two major positive features: first, the need for a lining is removed; second, the concrete is forced into the surrounding subsoil which provides a good frictional interface.



A piling rig with auger drill

Piles can also be under-reamed to provide increased base for end bearing piles. However, under-reaming is a slow process requiring a stop in the drilling to change the tool for the actual under-reaming operation. In some clay soils it may prove more profitable to use a deeper, straight-sided shaft. Consideration should be given to arranging the piles into a pattern that might include clusters of piles grouped together with a pile cap.

Structural requirements, effects of and precautions against subsoil shrinkage, ground heave and differential settlement

Subsoil shrinkage

Foundations, whether they are piled, raft, strip or pads, should be sufficiently deep and robust to withstand the effects of being in the ground. Acid and sulphate resistant concrete should be used in all foundations to prevent acidic attack and corrosion through nitrates and other impurities found in the ground.

The effect of water in the ground should not be underestimated. If the level of water rises due to increased amounts of rainfall, any building of lightweight construction has the potential to 'float' or be lifted by the rising level of water. This movement, which is likely to represent differential forces on the building at various points, will lead to cracking and possible failure or rupture of the building components. The stability of the ground should be considered, bearing in mind that any temporary excess amount of water in the ground may well subside in times of dryness. A prolonged lack of water on the ground could lead to ground shrinkage and cracking. Foundations that are subject to ground conditions such as this may also crack, move and deform if they are not designed with sufficient density to resist these forces in the ground.

Ground heave

Ground heave due to the water level freezing in very cold conditions needs to be considered. Again, the effect of water freezing in the ground will result in an expansion of the ground conditions which could lead to differential movement in the building.

The effect of water freezing in the ground can also 'crush' elements of the building that are not sufficiently protected. As a consequence, compressible materials are placed in the excavations and foundations to enable the ground to take up this differential movement without affecting the structure.

Differential settlement

Buildings will exert differing levels of point loads on the earth at their foundations that sometimes leads to differential settlement. These loads will result in a twisting and buckling of some of the structural elements of a building as it settles more or less in each part of the building. Naturally, the foundations will have to be robust enough to deal with these movements and, in addition, the inclusion of flexible joints and opportunities for the building to accept these movements will need to be incorporated into the design.

Excavations

Excavations up to 5 metres depth

Most buildings up to three storeys high will have foundations of less than 5 metres deep. Excavations in excess of 5 metres deep are specialist operations with specific health and safety requirements for the contractor. There are significant dangers in excavating earth and working in the ground which will need to be considered in the foundation design and the method of constructing the foundations.

Earthwork support

In order to place the foundations at a suitable level, earth is excavated to load bearing strata. Building control officers from the local authority are usually involved in determining the suitability of the depth of foundations and can advise builders on local ground conditions that have frequently been exposed through site investigation and soil analysis.

Excavations in the ground can be very dangerous. Safety of those operatives working in trenches must be paramount when designing suitable foundations and therefore, wherever possible, the depth of a trench should be kept to a minimum. To protect other people in the area, trenches should be cordoned off and clearly marked with suitable warning signs.

Thinking points

Earthwork support is essential if personnel are to work safely in excavations. In 2005, there were several casualties and deaths in construction resulting from earthwork collapse during excavations.

Water elimination

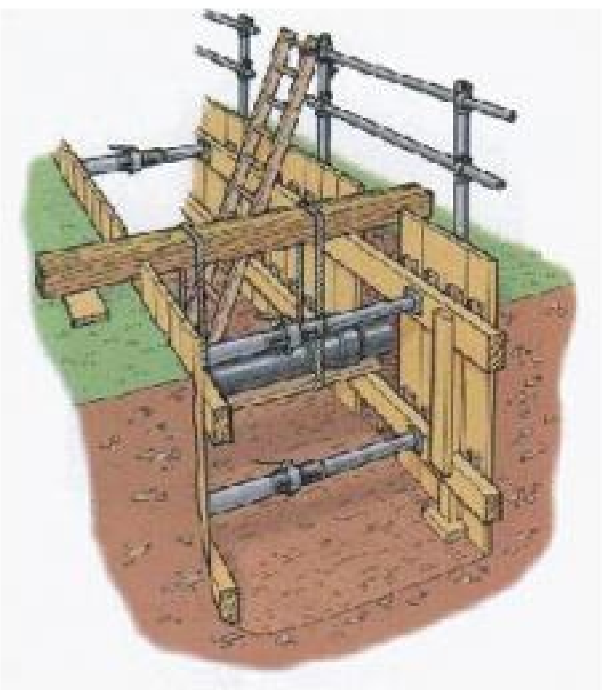
Water exclusion may also be necessary using temporary pumping and removal to enable the work to proceed safely. As we have seen, fluctuations in the water table found in the ground can have a detrimental effect on the foundation and other building components, and rising, falling or continuous variation in the water level can have a disastrous effect on the ongoing construction works.

Temporary supports and health and safety issues

As earth is excavated, the ground becomes more unstable. Therefore, it is necessary to support all surrounding ground to prevent any sudden or unplanned collapse of the surrounding ground. Timber shores or planks were used until very recently to support the ground while the excavated material was carted away and the foundation concrete poured. Modern methods of supporting the ground include sheet piling or purpose-made 'boxes' of steel braced with hydraulic or mechanical jacks that enable operatives to work safely while there is any danger of the earth crumbling or capsizing into the trench.

Excavation and earth moving plant

Hand excavation in all but very small and shallow excavations has now been replaced by the use of mechanical excavators. Before an excavation takes place, the area should be examined both visually and from any available drawings to see if there are any signs of underground services. Additionally, the use of cable avoidance tools (CAT) scanners that send ultra-sonic rays through the ground can detect underground services prior to the excavation. In any event, mechanical diggers and plant should not operate within 500 mm of any services, which means that most excavations near to services should be finished off by hand excavation when they become close to services.



▲ An earthwork support prevents the trench from collapsing

Foundation construction and design

Domestic foundations are commonly formed from either 600 mm wide concrete strip or 450 mm wide concrete trench fill foundations excavated to 1 metre below final external ground level. However, there are several alternative foundation methods such as in situ rafts or a number of types of piled foundations, such as pre-cast concrete, shell, continuous flight auger, all of which support the load bearing walls and ground floors of a building. For the first time, the Building Regulations 'Approved Document A – Structure: 2004 edition' requires minimum depths for strip foundations; these are 750 mm in clay and 450 mm in others. In practice, foundations are usually 1 metre or so deep.

The main requirement of the Building Regulations for foundations is set out via 'Approved Document A' regarding loading and ground movement in relation to domestic buildings no higher than a specified height that takes into account the topography, altitude and the basic wind speed at a given site. In practice, this height is usually no more than three storeys. The main requirement is that foundations are designed and constructed so that all the loads that are applied to a building, such as from wind, snow and occupiers, as well as the self weight of the building's construction, for example roof, intermediate floors, walls and ground floors, if suspended, are safely transmitted to the ground without impairing the building's safety.

Prior to construction, the ground substratum should be checked to ensure it has adequate bearing strength to support the foundations and is free of possible conditions that may affect its integrity. These may include swelling, shrinkage, slippage or subsidence that could be caused by geological conditions or other factors such as mining, landfill or moisture take-up from tree roots. If some of these conditions exist, it may be possible to overcome them by the use of specialist foundation techniques of rafts or piling with suspended floors, as necessary, in conjunction with ground stabilisation such as grouting of old mine workings or vibration compaction of filled or made-up ground where, due to economic, speed and safety factors, deep conventional foundations would not be viable.

Construction techniques used for strip, pad, raft and pile foundations

Foundations should be constructed in sufficient depth of ground and with appropriate materials to ensure that they adequately support the building. 'Approved Document A – Structure' of the Building Regulations contains guidance about the design and construction of plain in situ strip foundations for domestic construction up to three storeys in height.

The design is based upon a number of assumptions:

- The concrete mix is ST2, GEN 1 or a ratio of 50 kg Portland cement, 200 kg fine aggregate and 400 kg coarse aggregate.
- The concrete mix in soils that contain aggressive elements/chemicals such as sulphates should be designed accordingly.
- The ground and level that the foundations are formed at has no major strength variation, e.g. rock and clay, that may cause uneven settlement problems.

The total load applied to strip foundations does not exceed 70 kilo-Newtons (kN) per metre length and the width of the foundation is based upon Table 10 in 'Approved Document A'.

The Building Regulations require that, where the proposed foundation design or conditions do not fall into the above guidance, they are designed upon proper structural principles with necessary calculations to prove the adequacy and the stability of the design.

The Approved Document guidance regarding the design and construction of strip foundations requires the following points to be adopted:

1. That walls are positioned centrally on foundations.
2. That the foundation concrete has a minimum thickness equal to the foundation projection on either side of the wall or a minimum of 150 mm.
3. At the ends of walls or around projections such as chimney breast/piers that there is a foundation under them and that the projection is maintained.
4. That foundation bottoms are level and that changes in foundation levels are accommodated by steps not exceeding the foundation concrete thickness.
5. At foundation steps that the concrete is continuous and overlaps the lower section by twice the height of the step.

For the first time, the 2004 Building Regulations provide minimum foundation depths. These are 0.45 metre for all strip foundations (to prevent risk of frost) and 0.75 metre in clay soils. The Regulations acknowledge that these depths may need to be increased to suit local circumstances. Prior to this, 'Approved Document A' did not give a specific minimum depth but required it to be at a depth where the ground is not subject to movement. This has been (and still is) generally interpreted by most local authority building control surveyors as 1 metre below finished external ground level in average soil conditions. However, foundations may need to be deeper below the zone of influence from trees, as well as provided with other precautionary measures such as clay board to avoid damage by ground movement. Conversely, it would be pointless to excavate a foundation trench to 1 metre depth if solid rock is encountered, as this would not be subject to heave or subsidence.

Environmental issues

Foundations and drains

The Building Regulations 'Approved Document H – Drainage and waste disposal: 2002 edition' requires that precautions are taken for drains passing under buildings or within their zone of influence (see below). This is because damage to the drains could cause them to leak or block and cause local settlement of the building's substructure.

1. Where foundations are excavated alongside existing drains, etc. they should be excavated to a level below the influence of existing or proposed drain level.
2. Conversely, if drains are excavated below a foundation zone of influence or within a metre, the drainage trench should be filled with concrete up to the foundation's level of influence.
3. Where drains pass through the building's substructure and foundations, an allowance should be made for the settlement of the building or drains. This is usually achieved in two ways, either by building the pipe solidly into the wall with flexible

joints and rocker pipes either side, or lintelling over the pipe leaving at least 50 mm gap around the pipe and filling the gap with a flexible inert material such as mineral wool or sheeting covering the opening over with rigid flexible material. Also, the pipe should be bedded and surrounded with a minimum thickness of 100 mm granular material such as pea gravel.

Where building near public sewers, foundations should be constructed and positioned not to influence or damage the sewer. They should be at least 3 metres away from the sewer if the pipe is 225 mm, or the pipe is 3 or more metres deep. The purpose of this is to provide working space around the sewer. Smaller adopted sewers may be built over with the agreement of the water authority, but this should not exceed a 6-metre length or cover any access points.

Rafts and pad foundations

Key Terms

Raft foundation A slab that supports the building over a large area.

Pad foundation A mini raft similar in function to a raft but not connected to other pads that support structural members.

In the 1940s and 1950s, **raft foundations** were quite common, particularly beneath the thousands of prefabricated, pre-cast concrete or steel buildings erected during the years following the Second World War. Most of these houses were built on good quality farmland where the soil was generally of modest to high bearing capacity. Rafts (or foundation slabs as they were sometimes called) were often used because they were relatively cheap, easy to construct and did not require extensive excavation (trenches were often dug by hand).

In modern construction rafts tend to be used:

- where the soil has low load bearing capacity and varying compressibility – this might include loose sand, soft clays, fill and alluvial soils (soils comprising particles suspended in water and deposited over a flood plain or river bed)
- where pad or strip foundations would cover more than 50 per cent of the ground area below the building
- where differential movements are expected
- where subsidence due to mining is a possibility.

Flat slab rafts offer a number of advantages over strip foundations:

- No trenching is required.
- They are simple and quick to build.
- There is less interference with subsoil water movement.
- There are no risks to people working in trenches. Detailing needs careful thought, for example they may be subject to frost attack around the edges, the edges themselves are exposed, and there is the risk of cold bridging around the perimeter. They are generally suitable for good soils of consistent bearing capacity.

Flat slab rafts (that is, no perimeter or internal beams) have been recommended in some mining areas. These rafts will flex if ground movement is considerable, so the superstructure needs to be designed accordingly.

In the UK, rafts have to be designed on a one-by-one basis, in other words there are no 'deemed to satisfy' provisions in the Building Regulations as there are with strip foundations. In practice, engineers are advised to consider local practice with regard to raft design. Shallow rigid rafts for one-, two- and three-storey housing can be cheaper than piles. On poor ground, the raft must be stiff enough to prevent excessive differential settlement. This usually requires perimeter and internal ground beams to help stiffness and minimise distortion of the superstructure. Some overall settlement of the house will inevitably occur, but differential settlement should be kept within acceptable limits.

On filled sites, depending on the fill depth, rafts can be a cost-effective alternative to piling. They can also be used on sloping sites as an alternative to stepped strip foundations. A well-compacted (in shallow layers), graded granular fill can form a suitable base. Designing the fill and the raft is obviously specialist work and many speculative house builders would probably prefer 'tried and tested' stepped strip foundations.

Assessment practice

List three methods of investigating the earth prior to starting construction work on a commercial building. Describe the process of subsoil investigation and explain the significance of this information to the building contractor. **P1**

Describe how foundations spread the load of a building over the ground. Produce a sequence of operations to create a strip foundation of 900 mm deep. What equipment would you need and how would this differ from short-bored piles as a foundation for a commercial building? **P2**

You have been asked to plan the substructure of a single detached house which is to be built on an area known to suffer from mining subsidence. What type of foundation – raft, strip or piled – do you think is best suited for this and what materials will you need to produce the foundation? **M1**

Try to think of all the factors involved in the use of materials used in foundations and substructures. Make a table of alternative materials that could be used and evaluate their performance in use and their environmental impact. **D1**

Superstructure design and construction

Principles of design, factors affecting choice and construction techniques

The superstructure, or the building shell, is the part of the building that sits on top of the substructure and forms the outer envelope of the building. The superstructure includes all the walls, the roof, the floors and the doors and windows which will enable the building to become a weather-tight structure.

Walls

Walls are traditionally made from bricks, although nowadays house builders more frequently use timber-framed buildings.

The UK, like most EU member states, now has its own National Annex, published as part of BS EN 771-1:2003 to provide informative guidance to specifiers/users. Each **National Annex** is not a formal part of the Standard and will certainly vary from one EU member state to another. For example, BS EN 771-1 distinguishes between high density (HD) and low density (LD) clay masonry units. The UK National Annex provides guidance on the fact that all clay bricks currently produced and traded within the UK are of HD classification. This annex provides specification guidance on other aspects of HD type clay brick such as:

- dimensions and tolerance
- configuration and format
- density
- compressive strength
- freeze/thaw resistance
- active soluble salts content
- durability designations
- water absorption
- reaction to fire
- bond strength
- clay engineering and DPC bricks.

Key Term

National Annex A document that supplements the British Standards specifications that ensures materials meet quality requirements. These documents apply to all members of the European Union (EU).

Concrete blocks have been in common use since the 1930s. Early blocks were often made from local aggregates, most of which are no longer available. The aggregates were often industrial waste products such as breeze and clinker. Blocks can be used in either leaf (or both leaves) of a cavity wall. The nature of the blocks will depend, to some extent, on the nature of the insulation. Insulation is typically in the form of cavity boards and a thermal drylining. Blocks are also used for internal load bearing walls and partitions.

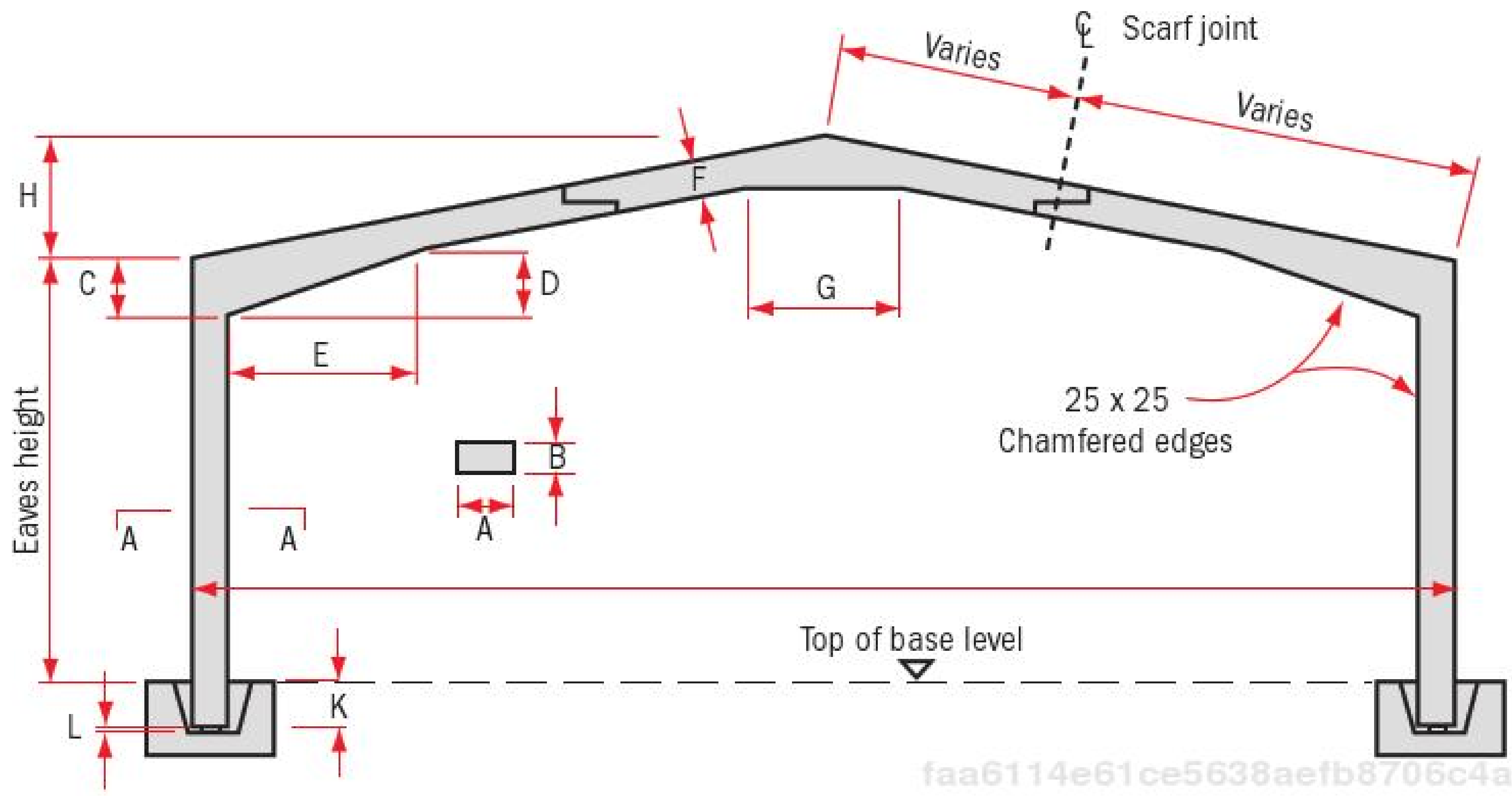
Theory into practice

Using the Internet to source bricks and blocks, investigate how many colours, shapes, sizes and finishes are available from a range of manufacturers.

Blocks used to form internal leaves of external walls are frequently made from aerated concrete. They form the internal leaf of a cavity wall and will be finished by plasterboard fixed with plaster dabs. Most blocks can also be plastered. Aerated blocks can be used for lightweight partitions and load bearing internal walls. They have been available for about 40 years and have replaced earlier lightweight blocks made from a variety of lightweight aggregates.

For commercial buildings, where larger open span areas are required, portal frames are common (see Figure 6.3).

Figure 6.3 A portal frame



This allows the use of brick and profiled aluminium sheeting for the cladding and enclosure of the structural elements.

For domestic dwellings, brickwork walls are usually constructed with a cavity to ensure that they comply with Building Regulations and offer an adequate resistance to the passage of heat energy and therefore are energy efficient. Successive legislation has adopted more stringent measures to make new buildings as efficient as possible with additional insulation and a range of different materials used to promote sustainable building projects. Cavities also reduce or eliminate any excessive amount of moisture or damp from entering the property from the outside.

Since building in a cavity means that the external walls are usually comprised of two separate but connected 'skins' of brick or blockwork construction, the inner leaf of the wall can be built using materials that are usually high in energy efficiency. In some cases, the inner leaf acts as an anchor for plasterboards or other materials that finish off the wall and provide a smooth finish ready for decoration.

Within the construction, a barrier to the entry of moisture usually takes the form of a damp-proof course, a thin layer of pitch polymer plastic that prevents any moisture from getting to an area that is required to be moisture free. It is very important that these barriers are built in at the correct position and in no way bridged or broken so that moisture cannot pass to the superstructure from the ground. In normal conditions, the damp-proof course is set no more than 150 mm above ground level (see Figure 6.4).

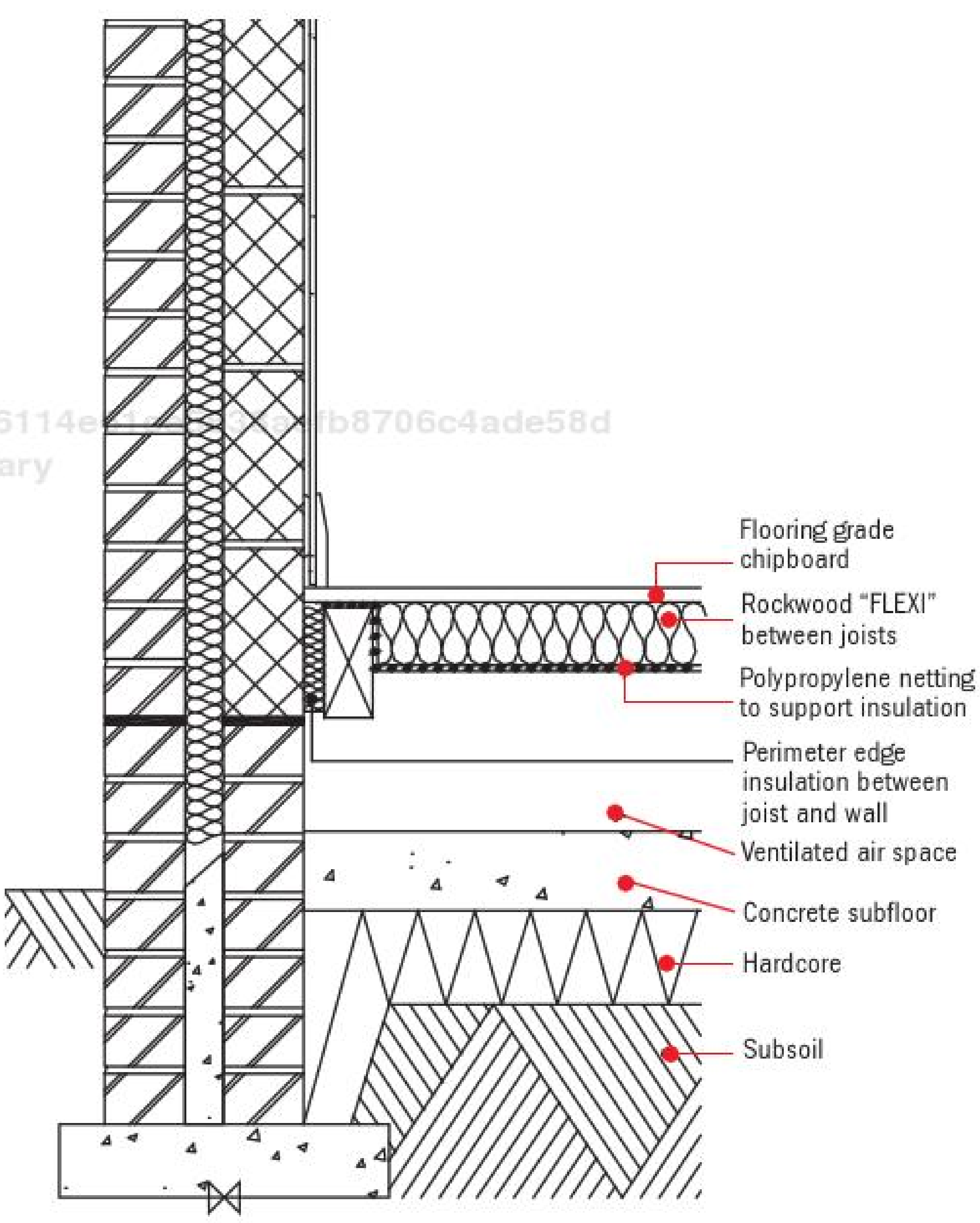


Figure 6.4 Damp-proof course

Timber-framed housing construction

Timber frame is a method of constructing houses and low-rise buildings using structural timber, typically prefabricated in a factory and assembled on site. These panels are taken to site and assembled in sequence according to manufacturers' instructions. The prefabrication of panels in workshop conditions improves quality control and timber-framed houses are renowned for their energy efficiency.

Theory into practice

Compare the advantages of building in traditional materials with materials used in timber-framed housing.

Most timber-framed houses in the UK use platform framing methods whereby each storey is assembled, and each subsequent floor forms the platform for the next storey (see Figure 6.5). External walls are usually constructed from 100 mm × 50 mm softwood studs nailed together to form a frame. Wind bracing using 18 mm plywood or other sheet materials is fixed to one side; the void between the inside plasterboard finish is filled with glass fibre insulation. A suitable cladding is then applied, either brickwork or in some cases a lightweight cladding system to provide an external finish and keep out the weather. Due to the likelihood of condensation forming inside the walls, a moisture barrier or vapour check is essential. This barrier usually takes the form of polythene sheet or foil backing to the plasterboard.

Remember!

The most common form of cladding in the UK is brickwork – one reason why timber-framed houses can be difficult to spot.

Modern timber-frame houses can provide very high levels of thermal insulation. The wall insulation is contained within the panels. If the panels are 90 mm thick, typical **U-value** is 0.35W/m2K; 140 mm panels

Key Term

U-value The overall coefficient of heat transmission which indicates the heat flow through materials – the higher the figure, the greater the heat loss. (See also Unit 4.)

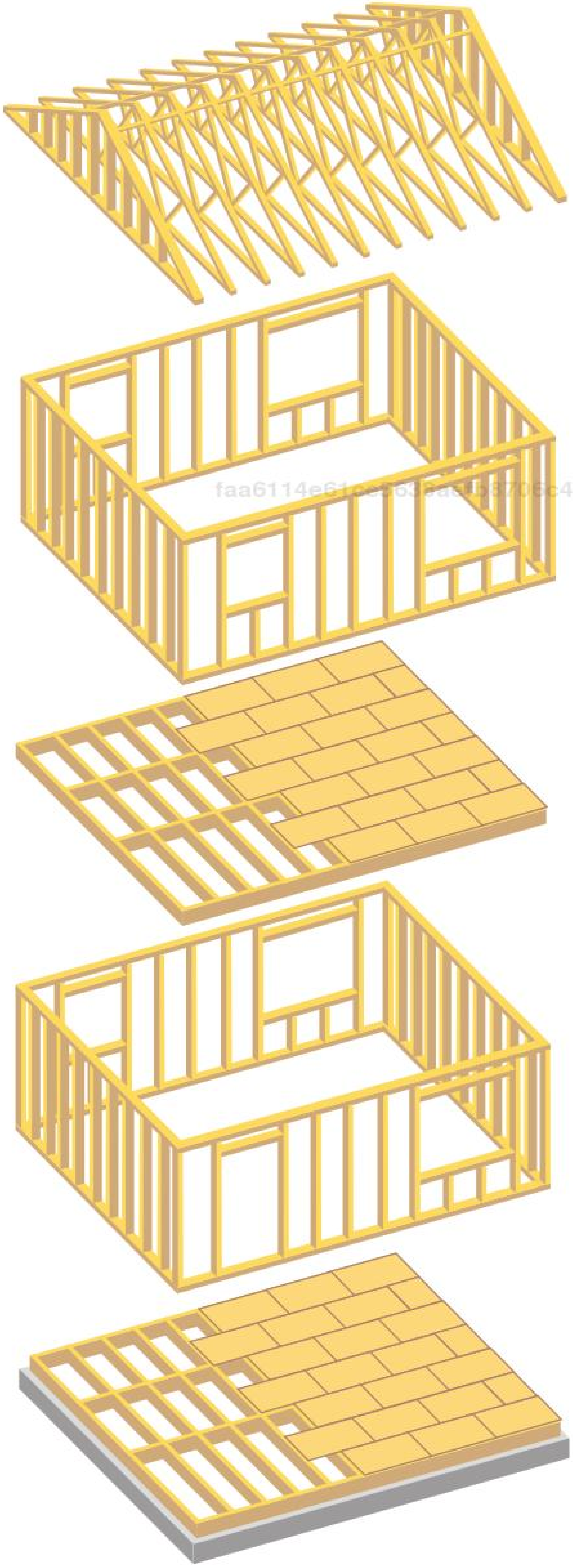


Figure 6.5 A timber-framed house

will provide a level of about 0.25W/m2K. The internal lining usually comprises a layer of plasterboard with some form of vapour check behind. The purpose of the vapour check is to prevent moist air migrating through the panel and condensing on the cold side of the insulation.

Most timber-frame systems are factory made. The panels are made on large jigs, usually by hand, although in some plants automation is replacing the need for operatives. A waterproof breather paper covers the outer face of the panels partly to protect them during transport and site erection, and partly to prevent water crossing the cavity and wetting the panel once the building is complete. It is the timber-frame structure which carries all the building loads; the brick facing is merely a cladding.

Floors

The upper floors of timber-framed houses are supported by the wall panels. No load is carried by the brick outer leaf. The load bearing wall panels usually comprise the external panels, load bearing partitions and the party wall panels. The floor itself is no different from a timber floor in a brick/block house. It comprises a series of joists supporting some form of boarding. Boarding is normally in the form of chipboard, strand board or ply. In some cases, the timber floor is prefabricated (assembled into panels) in the factory, in others the timbers are pre-cut to length but not assembled.

The floor gives its name to the most common form of timber-frame system – the platform frame. The joists sit on top of the head binder. The construction varies depending on whether the joists are parallel or at right angles to the panels. In the former, two header joists sit on the lower-storey panels. The inner header joist is slightly offset to provide a fixing for the plasterboard ceiling. Where the joists are at right angles to the panels, a header joist is required to provide additional support for the upper panels and to provide a fire barrier to prevent smoke and fire (in the cavity) entering the floor void.

Most timber-suspended ground floors have now given way to concrete slabs that form the base of typical housing and domestic properties in the UK. Ground-floor slab construction is regulated to ensure that the

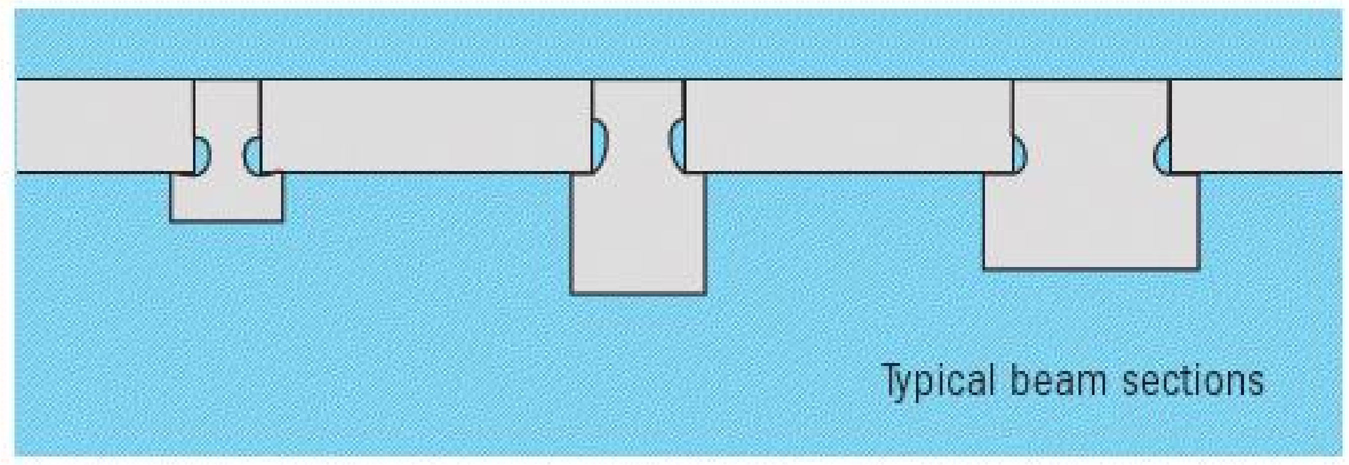


Figure 6.6 Beam and block floor systems

maximum heat loss permissible through this structure does not exceed the amounts shown in the Building Regulations. To ensure that the floor complies with this requirement, insulation is built into the slab.

Suspended floors consisting of concrete beams with blocks to infill the separating space have become very popular, and again insulation is required to ensure compliance. Typical beam sections and their size and interval are determined by the span and the space that they can carry safe working loads.

Beam and block floor systems combine pre-cast concrete beams and infill blocks to produce high performance yet economic ground and intermediate floors in housing and other building types. Both lightweight and dense aggregate concrete blocks complying with British Standards can be used for beam and block floor construction with the following advantages:

- Simplicity – exactly the same blocks may be used for both walls and floors.
- Cost saving – long spans are readily achieved without intermediate support.
- Performance – requirements for thermal, acoustic and fire resistance are easily achieved.
- Reliability – eliminates effects of ground heave or shrinkage.
- Versatility – beam and block systems may be used for ground and intermediate floors.
- Working platforms – once installed, the floor may be used as a working platform.

Roofs

Roofs need to be weatherproof and provide shelter from the elements. They also need to have the qualities of strength, durability, fire resistance, heat retention and a pleasing appearance. Most roofs on domestic dwellings are of pitched construction, although a significant number of flat roofs exist for smaller properties and extensions to existing homes. For industrial or commercial buildings that require a large uninterrupted span, the roofing system forms a major part of the structure such as in the case of a portal frame building.

Insulation and ventilation of roofs

The roof construction has to limit the loss of heat from a building and in domestic construction this is usually achieved by incorporating a suitable thickness of insulation into the roof construction. However, if the roof construction is a cold construction where the insulation is either or both between or under the rafters/ceiling joist, the construction must be ventilated to prevent condensation in the roof and the possibility of moisture damage or rot.

Alternatively, a vapour permeable felt fixed in accordance with both the felt and tile manufacturers' recommendations is an acceptable alternative to ventilation in a cold roof construction. If, however, a warm roof construction where a continuous layer of insulation is provided above the rafters is used with a suitable felt and cladding/covering, ventilation does not have to be provided within the roof construction as condensation and associated damage should occur on the outside face of the felt and not damage the roof

Whichever type of roof construction method is used, the Building Regulations specify a maximum U-value that the construction has to achieve to reduce the heat loss from the roof, which is the part of a building where most heat is lost. There are various ways to meet Building Regulations U-values. The elemental method takes each element of the building and then finds the overall heat loss for these elements added together. The permitted U-values using the elemental method to prove compliance are as follows and vary depending upon the type of roof and insulation position:

- Pitched roof with insulation between rafters: 0.2 W/m2K
- Pitched roof with integral insulation: 0.25 W/m2K (e.g. insulation over rafters as warm roof)
- Pitched roof with insulation between joists: 0.16 W/m2K (e.g. insulation between ceiling joists)
- Flat roof: 0.25 W/m2K
- Insulated sloping ceilings for loft conversions: 0.30 W/m2K
- Metal framed roof lights: 2.2 W/m2K
- Other framed roof lights: 2.0 W/m2K.

However, if the target U-value is used to show compliance with the Building Regulations, a higher (poorer) general U-value of 0.35 W/m2K is permitted for roofs. It is usually easier to increase the level of insulation in roofs using these methods to allow lower levels of insulation to be used elsewhere in the building.

The Building Regulations, through 'Approved Document C – Site preparation and resistance to contaminants and moisture: 2004 edition' and BS 5250:2002 'Code of practice for control of condensation in buildings', require that cold roofs are ventilated to limit condensation build-up and associated long-term problems of rot, dampness and mould growth which can both damage the fabric of the building and the occupants' health. The amount of ventilation required depends upon the design/form of the roof and is expressed in the form of equivalents of continuous gaps which means that the amount of air passing through a gap needs to be quantified and assessed as adequate for an enclosed space. These gaps might take the form of spaces between eaves or soffit casings in the structure. However, ventilation can be provided by other means such as ventilation tiles or air bricks provided they are equally and adequately positioned within the roof construction.

Pitched roofs may consist of rafters and purlins alone, with the purlins supported on posts, masonry walls or primary trusses. They may also consist of an arrangement in which the lower ends of each pair of rafters are tied or trussed together.

The most common form of roof construction, particularly in today's housing, is trussed rafters which have a tie between the lower ends of each pair of rafters and some form of cross bracing between (see Figure 6.7). They are normally designed and made by a specialist manufacturer using computer-controlled design and fabrication. The members are usually 38 mm or 35 mm wide and are all in line with each other because the joints are made with punched metal plates. Proprietary trussed rafters are used extensively in domestic construction because they are quick and easy to erect.

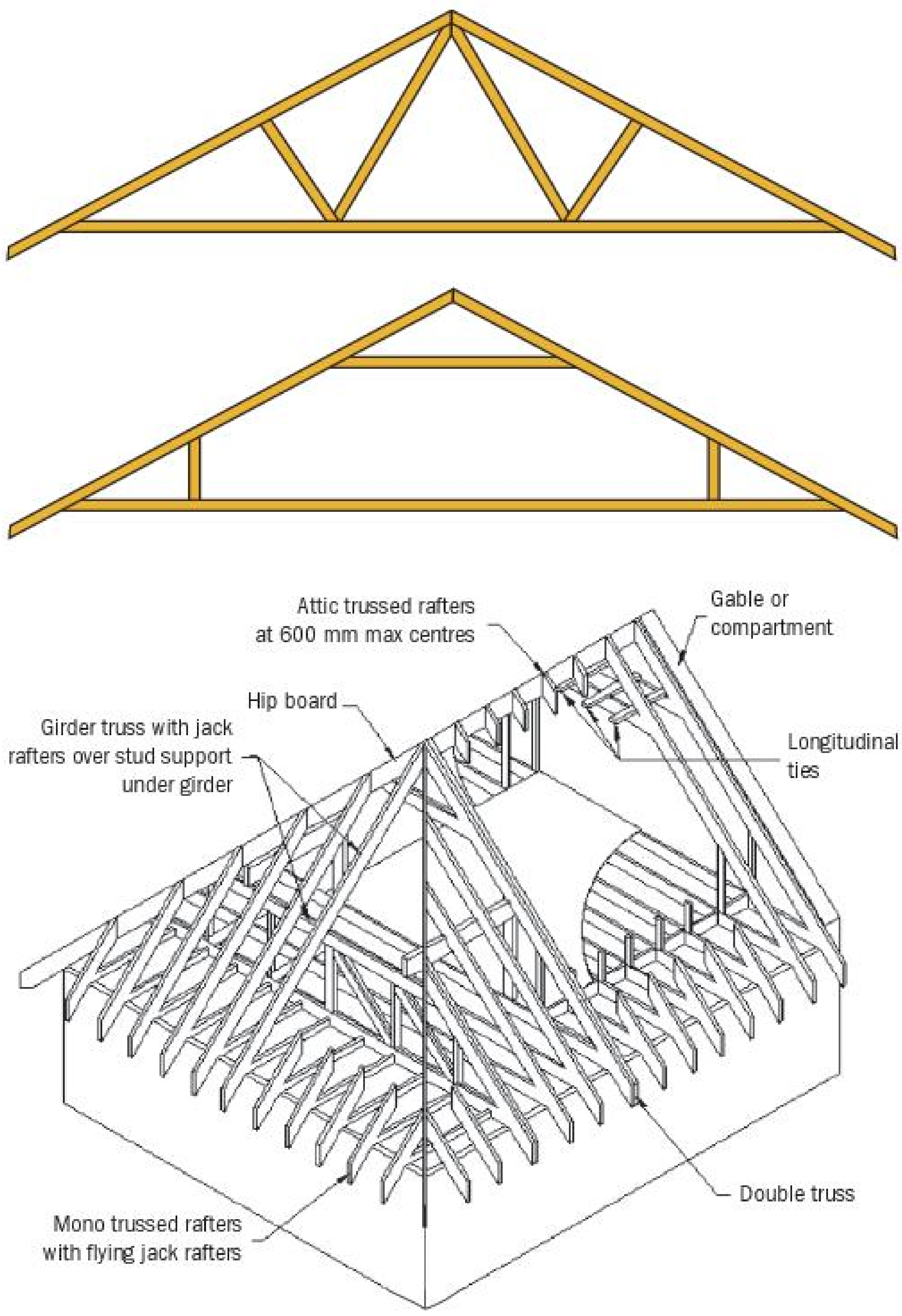


Figure 6.7 Trussed rafters

Trussed rafter roofs are designed in accordance with BS 5268-3:2006 'Structural use of timber: Code of practice for trussed rafter roofs'. Many manufacturers have their own software to calculate appropriate truss designs in accordance with this Standard. They will need to know:

- height and location of building (to determine wind conditions)
- profile, span, spacing and pitch of trussed rafters
- overhang at eaves and verges
- method and position of support
- nature of roof coverings and ceiling materials
- size and position of water tanks and loft hatches.

Under Building Regulations, pre-treatment of roofing timbers is required in certain parts of the country (in the south east, for example, to protect against House Longhorn Beetle). This usually requires some form of pressure impregnation. The chemicals are designed to guard against rot as well as insect attack. Some developers treat the timbers as a matter of course, although there are increasing environmental concerns regarding some of the material used.

Prefabricated trussed rafters can also be designed to accommodate rooms in the roof – called attic trusses. Prefabricated roof panels are increasingly being used as an alternative to roof trusses, particularly in association with timber-frame buildings. They can provide unobstructed roof spaces for occupation. The panels are similar to timber-frame wall panels and enable a weatherproof structure to be achieved rapidly on site.

Trussed rafters are sometimes purpose designed by an architect or engineer for an individual project and constructed by a carpenter on site or in a workshop. The members in these are usually lapped at joints and fixed with nails, bolts or timber-connectors. More traditional forms of roof include the use of primary trusses and site constructed, or 'cut' roofs using an arrangement of rafters and purlins. Primary trusses are designed to support purlins which in turn support rafters. They are of heavier construction than trussed rafters and are spaced at intervals which are normally a multiple of the rafter spacing, for example 1800 mm or 2400 mm. Purlin-supported rafters need no tie members. The rafters are notched or 'birdsmouthed' over the purlins or otherwise fixed to avoid displacement and to keep all loads vertical. The purlins are fixed to posts, walls or primary trusses and all or any of these supports are designed and built to remain in a state of equilibrium. The main reason to use purlin-supported rafter structures is usually either to allow the roof space to be used or for it to be seen.

Remember!

Trussed rafter roofs are made from smaller sections than traditional roofs. The truss derives its strength from the way each member is tied together. It is not usually possible to cut out any members or make alterations.

Position of insulation

There is a choice of insulation position in pitched roofs:

- at rafter level, either between the rafters or above and between the rafters
- at ceiling level.

Insulation between the rafters can be designed in two ways:

- 'breathing' roof with vapour permeable underlay as tiling underlay
- ventilated design (see Figures 6.8 and 6.9).

With breathing roof design, insulation fully fills the rafter space without an airspace between the insulation and tiling underlay, which must be vapour permeable. If a thin layer of insulation is installed, it is recommended that an insulation/plasterboard laminate is used as the internal lining to prevent thermal bridging. This is not necessary where rafters are at least 140 mm deep and fully filled with insulation.

A combined airtight/vapour control layer should be placed on the warm side of the insulation. This not only makes the ceiling convection tight but also restricts the amount of water vapour passing through the ceiling. Where cables and piped services are to be installed, the plasterboard lining may be battened out to provide a suitable duct. The services should be routed on the inside of the vapour control layer to avoid any puncturing.

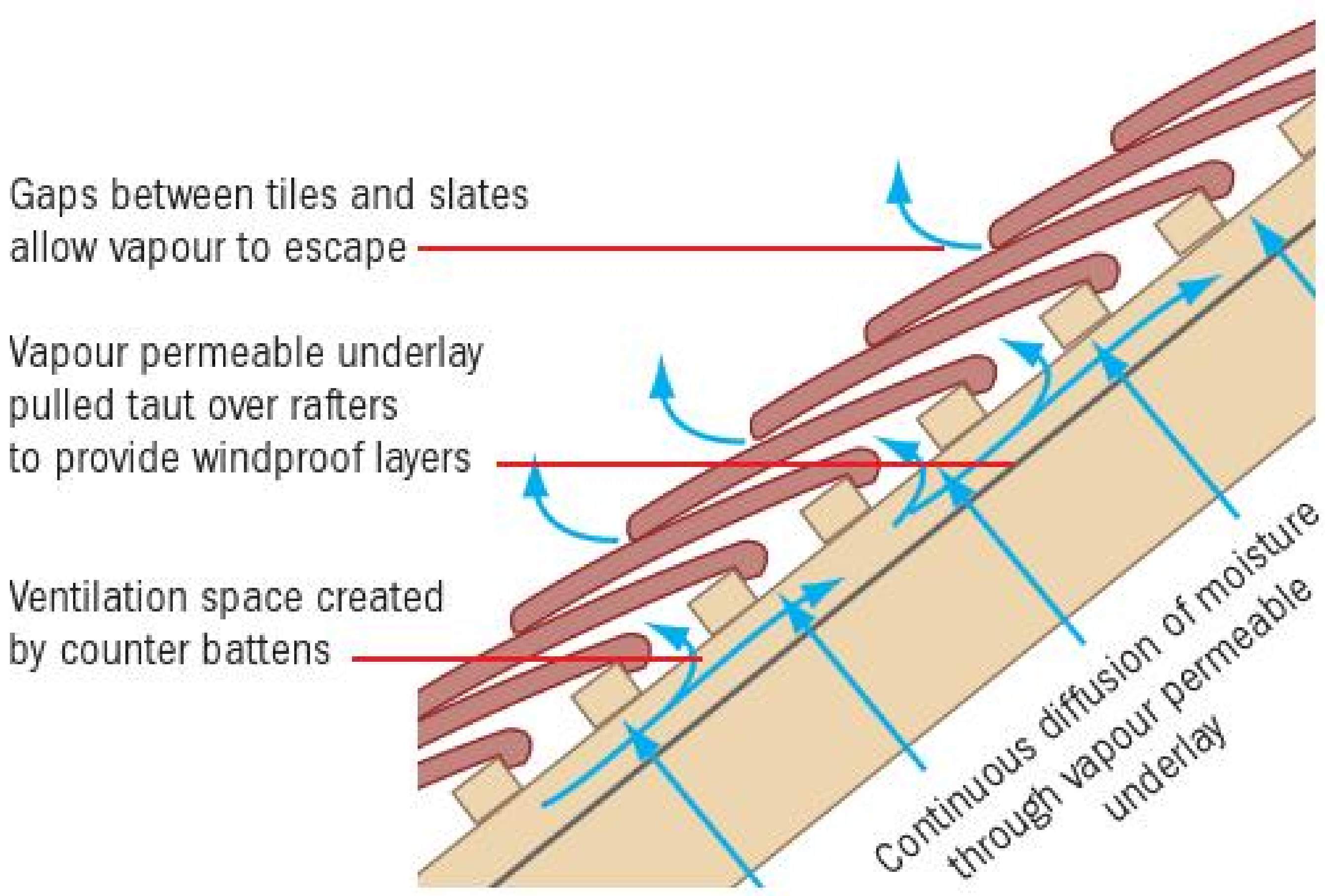


Figure 6.8 Section through roof members showing tiles and vapour barrier

With the ventilated design, there is 50 mm ventilated airspace between the top of the insulation and the tiling underlay. Should the rafter depth be insufficient to accommodate both the required thickness of insulation and the 50 mm ventilated airspace, an insulated dry lining is recommended. This has the added benefit of minimising thermal bridging. Ventilation openings should be provided at each and every roof void at both low and high level. At the eaves, ventilation openings should be equivalent to a 25 mm continuous gap. At the ridge, the ventilation opening should be the equivalent of a 5 mm continuous gap each side of the ridge.

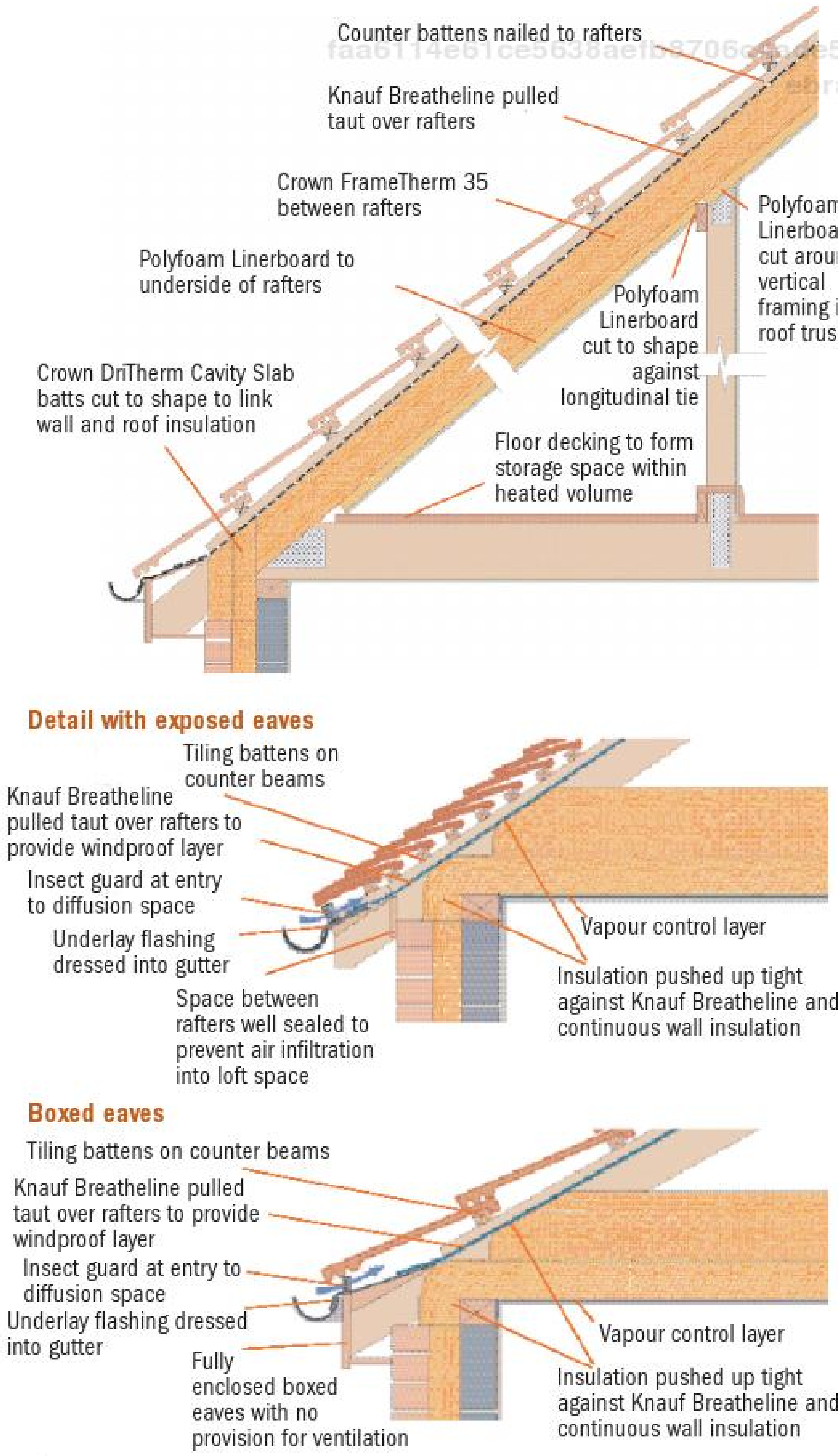


Figure 6.9 Roof eaves

Remember!

Ventilation is very important in roof spaces. It ensures that the roof members stay healthy for a long time.

Stairs

Stairs are used to gain access to and egress (exit) from the upper floors of a building. They are traditionally manufactured from timber and must conform to the Building Regulations, which set a standard for the height of a step and the width of a step so that your body gets used to walking up and down stairs which are similar and safe all the time. Modern methods of construction have enabled prefabricated concrete stairs to be manufactured and lowered into place. These require finishing with a floor finish.

Windows

Windows were traditionally manufactured from timber. This material has to be treated by applying a painting system to the timber frames. Once this barrier is broken, then the timber can degrade and swell with moisture. With the introduction of the modern upvc technology, warmer and draught-sealed, high quality windows have substantially replaced the manufacture of timber windows. However, timber-engineered, high performance windows are making inroads into the current upvc market as an environmentally friendly product.

Doors

Doors are essential for maintaining the security of a home or commercial premises. There are many different types available, including:

- traditional timber-panelled, external doors
- plywood, flush internal doors
- part-glazed doors
- roller-shutter doors
- upvc French and patio doors
- fire doors which are fire rated.

These are just a few of the wide variety of applications that a door can provide.

Finishes

Factors affecting the choice of finishes

Many factors affect the choice of finishes for a domestic or commercial building design, including the following:

- Cost – the budget for a project has to be maintained and often finishes of a lower quality are seen as a cost saving.
- Use – a school corridor will require harder wearing finishes than a library corridor.
- Cleanliness – finishes used in a hospital operating theatre must be capable of being sterilised.
- Aesthetics – the attractiveness of a finish to the eye is often an essential item.
- Fashion – finishes may be chosen because they are the current fashion, e.g. block paving of a driveway.
- Fire resistance – often finishes have to resist the spread of fire and flame.
- Sound resistance – the denser a material, the more effective it is at sound reduction.
- Health and safety – such as non-slip finishes.
- Function – a shower's finishes have to be waterproof.
- Colour – you would not use red finishes in a prison cell, for example, as it promotes anger.

Types of finishes

Early plastering

Plastering is an ancient craft. Originally, the materials and techniques used were dependent on the geology of the locality, the materials to hand and the technology available to the local artisan.

In earliest times, buildings or structures were plastered to render (hence rendering) them windproof and weathertight. Simple mud daubs on basic interwoven wattle structures are among the earliest means of walling, even in localities with a ready supply of building stones or fellable timber. Early stone walls, often laid dry for lack of mortar, were rendered both flat and weathertight with basic plaster. Even timber buildings, such as log cabins in the past and in many parts of the world still today, were weatherproofed with layers of plasters as crude as clay reinforced with straw.

As early societies developed and the first cities came into being, people recognised the decorative potential of plaster work as well as its hygienic, fire and weatherproofing qualities. A flat, hard surface was easy to clean, did not harbour dirt, was comfortable to the touch and pleasing to the eye. It could be painted and decorated and also provide the substrate for three-dimensional decorative relief. It slowed the spread of fire, especially in timber buildings, and helped deaden sound as the needs for privacy and comfort became increasingly important.

Gypsum plasters

Gypsum is the basis of plaster as we know it today. It is a naturally occurring mineral – hydrated calcium sulphate – and is sometimes known as alabaster when found in its soft, translucent form. When burnt at relatively low temperatures (less than 200ºC), some or all the water of hydration is driven off and a highly reactive powder remains. This powder, in its hemihydrate form, is known as plaster of Paris and reacts vigorously with water to set hard and quickly. With few exceptions, the plasters of today are based on gypsum.

Lime plasters

Limestone was much more commonly available and the vast majority of ancient plasters and mortars were based on lime and its various byproducts. Limestone is the mineral calcium carbonate when found in its purest form. Chalk is one of the purest forms of naturally occurring limestone and is nearly 100 per cent pure calcium carbonate. Many impurities exist in most limestones, mainly of a clay-like nature, and these impurities can be very important in the properties that they give to the finished plaster.

Cement plasters

Plasters based on cement rather than lime have been common for more than 100 years. They were mostly used for external renders, often gauged with lime to produce a more workable mix. Cement-based renders need to be used with care; strong mixes (with a high proportion of cement) are likely to shrink and may part from the background.

Plasterboard

Plasterboard has been available since the 1920s, although its early use was mainly confined to ceilings where it proved a cost-effective and quick alternative to traditional lath and plaster. Nowadays, it is available in a wide range of grades and sizes and is used for a variety of purposes, including ceiling linings, wall linings and proprietary partition systems. It can also be used to improve thermal insulation, sound insulation, fire protection and to provide vapour control layers. Early plasterboards were always intended to receive one or two coats of plaster, but in modern construction most plasterboard is self finished. Manufacturers produce their own specific products, many with trade names.

Plasterboard comprises a core of gypsum plaster (with added aggregates) with thick paper linings bonded either side. Their lightweight and low thermal capacity means that they will warm up quickly and will help reduce the risk of surface condensation. Plasterboard linings are not suitable for areas of high humidity or areas which are permanently damp.

Wallboard and vapour control wallboard

Wallboard, despite its name, is used for a variety of applications, including drylining walls, lining ceilings and on stud partitions. Typical thicknesses include 9.5 mm, 12.5 mm 15 mm and 19 mm. Wallboard is available in a range of sizes, for example 1800 mm × 900 mm, 2400 mm × 900 mm, 2400 mm × 1200 mm, 3000 mm × 1200mm, and can have tapered or square edges (on the long sides). The tapered edges are designed for direct decoration or skimming, and the square edges for skimming or textured (Artex) finishing.

Vapour control wallboard is the same as wallboard except that the inner face is covered with a thin vapour control membrane. Vapour control wallboard is used where there is a risk of condensation.

Thermal boards and moisture resistant boards

A thermal board is a wallboard with insulation bonded to the inner face. The insulation can be of various types, including polystyrene and phenolic foam. Thermal boards often contain an integral vapour control layer to minimise the risk of condensation.

Moisture resistant boards are usually 2100 mm × 1200 mm with a thickness of 9.5 mm or 12.5 mm. They can be used for external soffits or as a base for wall tiling around showers, etc.

Drylining

When plasterboard is used as a wall finish in place of wet plaster, it is referred to as drylining. In modern construction there are two main approaches: bonding the boards to adhesive dabs, or securing the boards to metal channels which themselves have been bonded to the background. British Gypsum and Lafarge, currently the two major manufacturers, offer both systems. They differ in detail but are broadly the same in terms of principle.

Theory into practice

If dry lining is quicker and cheaper than more traditional methods of plaster finishes, find out how many contractors can do this work. Use the Internet to list specialist contractors in your area.

The use of adhesive dab is the simpler of the two systems. It comprises a series of adhesive dabs applied by trowel to the wall and typically 50 mm to 75 mm wide and 250 mm long. Three 'columns' of dabs are normally required per board (9.5 mm board 1200 mm wide usually requires four), with horizontal dabs between the columns at ceiling level, and a continuous band of adhesive at skirting level. When the dabs are in position the board (cut 15 mm short of wall to ceiling height) can be pressed and tapped into position, tight against the ceiling. It is temporarily supported at floor level by off-cuts of board. An insulated reveal board is available where there are risks of **cold bridging**.

Key Term

Cold bridging This occurs when the insulation layer within a wall or roof is interrupted by another material or is reduced in thickness. The thinner area of insulation leads to greater heat loss through that part of the wall or roof and provides a reduced internal surface temperature. When the warm, moist air inside the property comes into contact with the cooler surface, it is chilled and less able to carry moisture. This results in surface condensation or pattern staining of décor.

The procedure for thermal laminate board (a plasterboard with an inner layer of insulation) is similar, although two plug fixings are required, 15 mm in from the board edge and at mid height. These are required to ensure that the plasterboard is not distorted in the event of a fire.

In the second system, the boards are fixed to a series of metal channels bonded on dabs to the background. The channels are fixed at 600 mm centres (vertically) with top and bottom channels running horizontally. The boards themselves are fixed to the channels with special screws, typically at 300 mm centres. The boards must be well fitted to ensure there is no flow of air behind the boards. Failure to do this will reduce their thermal performance. Additional sealant can be provided around the edges of junctions, that is, around window reveals, external angles, etc. In long runs of drylining, Building Regulations require the provision of vertical cavity barriers to limit the spread of fire. This can be formed using a continuous vertical line of dabs running down the centre of a board.

Case study

Modern requirements increasingly call for new build units of high quality and technical input, both traditionally and on a design and build basis. Ideally, you will have built up several years' experience and accomplished many successful projects, having constructed hundreds of new build units over many years to tender for appropriate contracts and seek out further work.

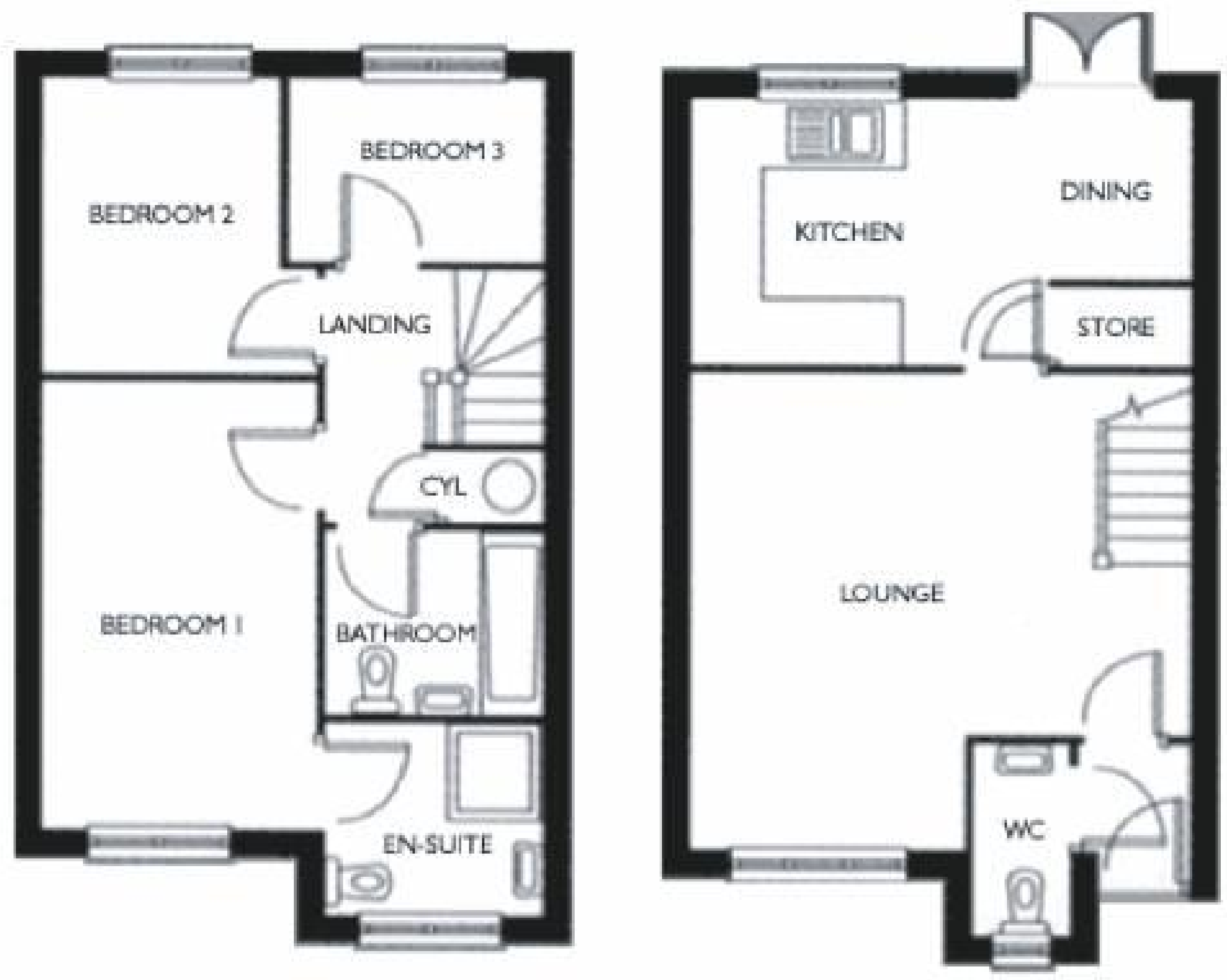
You will need up-to-date knowledge of Building Regulations, Scheme Development Standards, National House Building Council (NHBC) standards, etc. Imagine you have secured the contract to build a development of 44 new units. Think about the possibilities of creating a good place to live and a lasting legacy of your work that you can be proud of for many years to come.

3-bedroom, semi-detached

A large three-bedroomed semi-detached house which offers spacious family accommodation. The 'Beverley-Hills' incorporates a dining kitchen, WC and generously proportioned lounge with open-plan staircase to the ground floor. The first floor houses three bedrooms which includes an ensuite to the master bedroom.

Dimensions

Room	mm
Kitchen/Dining room	4451 × 2752
Lounge	4451 × 4833
Bedroom 1	4290 × 2423
Bedroom 2	2912 × 2183
Bedroom 3	2525 × 1812
Ensuite	2285 × 1675



1 What kind of investigation is necessary to find out about the land that the building will sit on? How will you know that the foundation is strong enough to support the house and the loads imposed on it?

2 Having decided what type and size of foundation, how will you communicate your thoughts and decisions to the builders. Can you draw to a suitable scale all the components in the substructure so that the builder can clearly see how the building goes together?

3 What type of superstructure will you use and how will you explain to potential buyers that this type of house is safe, warm and uses good materials, particularly if they are of sustainable construction and do not cause problems for the environment?

4 What drawings and specifications are required to explain how the superstructure goes together?

5 What plant and equipment will you need to build the elements of the houses that need special equipment and tackle, e.g. the fixing of the roofs? How will you gain access to high-level work and how will you ensure that any operative working there will be safe in their work?

Assessment practice

Produce a section drawing of the most suitable foundations for each of the following:

a a single detached house made of timber-frame construction

b a portal frame building made from structural steel sections and clad with lightweight aluminium sheeting. **P3**

Describe how the design of a commercial building superstructure differs from a domestic building superstructure. Explain what methods are used to create these two forms of building. **P4**

Make a list of all the materials you can think of that are used in the superstructure of a detached house and a portal frame building. Explain the main characteristics of each material and why you consider them suitable for use. **M2**

Consider one element of the superstructure of a house such as an external wall. List all the components that make up this element and identify how these materials are used. Evaluate the use of these materials and explain how their use impacts on the environment. **D2**

6.4 Implications of environmental issues and legislative constraints on building construction and the infrastructure required to support typical construction processes

Environmental issues

Environmental impact resulting from materials and methods used in construction

Sustainability is about balancing society with the environment. The construction industry uses natural products such as timber, clay, iron and other minerals. It creates our physical environment and contributes to the economy and the gross domestic product – nearly 2 million people work in the industry every day. The construction industry has to consider how its activities contribute to global warming and how we replace those materials taken from our planet.

Remember!

Sustainable construction is not an option – all buildings will need to comply with legislation in the future.

There are three main threats to environmental sustainability:

- Global warming (climate change by emissions of gases).
- Resource depletion such as extracting minerals from the ground and how quickly we use up those resources.
- Pollution in the atmosphere due to how construction activities take place.

The most immediate of these threats is global warming, which can lead to climate change and a long-term rise in sea levels which could bring about flooding and damage to buildings in low-lying areas.

Extraction and manufacture

The extraction and use of fossil fuels is the primary source of carbon dioxide (CO_2). It also causes the majority of eco-toxic pollution, and is the prime resource depletion issue in the UK as the economy is largely dependent on fossil fuels. Action to cut fossil fuel use not only helps prevent climate change, but also reduces resource depletion and pollution. Reducing CO_2 emissions is therefore by far the most significant issue in buildings. Designers and constructors of buildings have a duty to produce homes, offices and buildings that are energy efficient, reduce heat loss through the walls, roof and other parts of the structure by the inclusion of increased dimensions of insulating material, and to build in the provision to run energy saving appliances that display the 'Energy Saving' logo and are approved by the Energy Saving Trust, such as washers, dryers, dishwashers, boilers, etc. which operate at lower temperatures. Lighting and illumination can also be included in energy efficient lighting schemes that use low-energy light bulbs in preference to standard bulbs. Contractors during the construction process need to be aware of the tolerances of waste materials and that by operating efficiently they can contribute to overall savings and reduce costs that high levels of waste bring.

Construction methods

Heavyweight traditional construction

Heavyweight or dense construction is preferred by many since this form of construction tends to store heat in the thick walls and materials. However, in summer heavyweight buildings tend to be cooler based on the idea that it takes a long time for any heat to penetrate or dissipate from heavyweight construction, hence it takes longer to heat up or for the building to dissipate its heat.

This effect is known as thermal mass. It tends to take longer and hence more energy to heat these buildings to a satisfactory level, but they will stay warmer for longer periods due to their dense constructional form.

Lightweight construction

Timber-framed housing provides a lightweight constructional form, quickly erected with excellent thermal performance. The increased use of prefabricated designs has also improved quality control and led to higher standards. In some cases, these efficiencies have been passed through the supply chain with this form of construction being the preferred option for those that need low-cost homes and social housing projects.

Construction activities and how homes and offices are used also impacts on sustainability issues. Designers have a responsibility to consider how water is used, how we generate and deal with waste products and the use of materials that add to pollution in the environment. Higher standards and awareness of sustainability issues will bring about improved performance in energy use, lower costs and generally increase the quality of life.

The Code for Sustainable Homes has been issued by the Department for Communities and Local Government, which should promote changes in the way that designers tackle sustainability issues in new developments. The UK government states that this will become a national standard to be used by designers and constructors of buildings to develop better homes and buildings as well as making clients and homeowners aware of sustainability issues around the home.

Theory into practice

Use the Internet to find out whether major contractors operating in your area have a 'Sustainable Construction' policy. How do they differ from one another?

Developing an awareness of sustainable issues and relating these issues to construction should lead to a reduction in CO_2 emissions, better management of water disposal and an emphasis on recycling materials that would otherwise have been lost. Homeowners can be assured that changes made to the design and construction of a new building comply and promote sustainability and hence be aware of the improved standard and performance of the building. It is highly likely that contractors who comply with new codes of practice will use this fact in their advertising and promotional literature to demonstrate this improved performance and show the benefits of lower energy consumption and water efficiency.

Recycling and waste implications

In order to conserve the Earth's finite resources, we have to be aware of the long-term implications of manufacturing materials. Materials need to contain an element of recycling in their manufacture and within their eventual demolition when the life of the building is exceeded. Concrete can be crushed and the reinforcing bars recycled into steel making, while the crushed concrete becomes hardcore fill for levelling sites. This can also be done with brickwork, but bricks can also be cleaned and reused for new house construction with any damaged ones recycled as hardcore. Steelwork from buildings and any metals can be reshaped into new products during steel making processes.

Embedded energy

This is the amount of energy that has been used in the manufacture of a material. It is therefore far better to specify and select materials that have a low embedded energy, which should also include the transport costs of getting the material to its final point of use. Cement-based products such as pre-cast concrete and building blocks contain high levels of embedded energy from the manufacture of the cement.

CO_2 emissions

This is the greenhouse gas that is associated with the current trend in global warming. Releasing CO_2 into the atmosphere increases the average temperature of the world which has consequences for weather patterns and the rise in sea levels. Using timber-based products will help CO_2 emissions in that when the tree is growing it absorbs CO_2 and gives off oxygen as a waste product through photosynthesis. During the processing of timber very little CO_2 is released into the air making this a very sustainable product; its waste can also be reused and turned into engineered timber.

Noise

This is a form of pollution that can cause environmental disturbance to residents living near construction sites that produce a high level of noise. Where cutting and processing of materials is carried out onsite, noise suppression systems should be used where available.

Case study

A new home being built today will have to meet any level of the Code for Sustainable Homes. For Level 1 this means that the home will have to be 10 per cent more energy efficient than one built to the 2006 Building Regulations standards. This could be achieved by:

- improving the thermal efficiency of the walls, windows and roof, e.g. by using more insulation or better glass
- reducing air permeability, that is, by improving the control of the fresh air into a home, and the stale air out of a home (a certain amount of air ventilation is needed in a home for health reasons)
- installing a high efficiency condensing boiler
- carefully designing the fabric of the home to reduce thermal bridging (thermal bridging allows heat to escape easily between the inner walls and the outer walls of a home)

The home will have to be designed to use no more than about 120 litres of water per person per day. This could be achieved by fitting a number of items such as:

- 6/4 dual flush WC
- flow reducing/aerating taps throughout
- 6–9 litres per minute shower (note that an average electric shower is about 6–7 litres per minute)
- 18 litres maximum volume dishwasher
- 60 litres maximum volume washing machine.

Other minimum requirements are required for:

- surface water management – this may mean the provision of soakaways and areas of porous paving
- materials – this means a minimum number of materials meeting at least a 'D' grade in the Building Research Establishment's 'Green Guide' (the scale goes from A+ to E)
- waste management – this means having a site waste management plan in place during the home's construction, and adequate space for waste storage during its use.

But to get to Level 1 you need a further 33.3 points. So the builder/developer must do other things to obtain the other points such as:

- providing accessible drying space (so that tumble dryers need not be used)
- providing more energy efficient lighting (taking into account the needs of disabled people with visual impairments)
- providing cycle storage
- providing a room that can be easily set up as a home office
- reducing the amount of water than runs off the site into the storm drains
- using environmentally friendly materials
- providing recycling capacity either inside or outside the home.

1. Identify which of these elements are included in the current Building Regulations.
2. Use the internet to obtain the price of a selection of items such as a condensing boiler, a dual flush WC, aerating taps and fittings for the bathroom and kitchen.
3. What other items can be built into the design to encourage recycling of waste products?

Remember!

Noise pollution from a construction site is temporary environmental disturbance which will eventually leave the environment.

Pollution

Pollution and wastage must be controlled as these can damage the environment. Chemicals especially should be limited in use during the construction process. Care should be taken in what wastage is taken to landfill and all waste should be sorted into recycling skips. For example, some plasterboard manufacturers supply waste skips for recycling offcuts of their products.

Legislative constraints

Building Regulations

The Building Regulations apply in England and Wales and exist principally to ensure the health and safety of people in and around buildings. They also provide for access to and around buildings and energy conservation.

A detailed explanation of the Building Regulations, the Building Control system and how they might affect individual building projects is provided on the Planning Portal found at www.planningportal.gov.uk. The regulations apply to most new buildings and many alterations of existing buildings, whether domestic, commercial or industrial.

Building Regulations promote the following:

- Standards for most aspects of a building's construction, including its structure, fire safety, sound insulation, drainage, ventilation and electrical safety. Electrical safety was added in January 2005 to reduce the number of deaths, injuries and fires caused by faulty electrical installations.
- Energy efficiency in buildings. The changes to the regulations on energy conservation came into effect on 6 April 2006 and will save a million tonnes of carbon per year by 2010 and help to combat climate change.
- The needs of all people, including those with disabilities, in accessing and moving around buildings. They set standards for buildings to be accessible and hazard-free wherever possible

Health and Safety at Work Act 1974

The Health and Safety at Work Act provides the legal framework to promote, stimulate and encourage high standards of health and safety in places of work. It protects employees and the public from work activities. Everyone has a duty to comply with the Act, including employers, employees, trainees, the self-employed, manufacturers, suppliers, designers, importers of work equipment.

The Act places a general duty to 'ensure so far as is reasonably practicable the health, safety and welfare at work of all their employees'. Employers must comply with the Act. They must:

- provide and maintain safety equipment and safe systems of work
- ensure materials used are properly stored, handled, used and transported
- provide information, training, instruction and supervision, and ensure staff are aware of instructions provided by manufacturers and suppliers of equipment
- provide a safe place of employment
- provide a safe working environment
- provide a written safety policy/risk assessment
- look after the health and safety of others, e.g. members of the public or visitors to the site
- talk to safety representatives.

An employer is forbidden to charge an employee for any measures which they are required to provide in the interests of health and safety, for example personal protective equipment used during the construction process.

Employees have specific responsibilities too. They must:

- take care of their own health and safety and that of other people
- cooperate with their employer

- not interfere with anything provided in the interest of health and safety.

It is the responsibility of the Health & Safety Executive (HSE) to carry out inspections of construction sites. The powers of an inspector include:

- rights of entry at reasonable times, etc. without appointments
- the right to investigate and examine
- the right to dismantle equipment and take substances/equipment
- the right to see documents and take copies
- the right to assistance (from colleagues or the police)
- the right to ask questions under caution
- the right to seize articles/substances in cases of imminent danger.

The HSE can visit any site and report on whether there is an infringement of the Health and Safety at Work Act. It does this by producing **legal notices** that are issued to **improve**, to **prohibit** something from continuing or to bring about a prosecution. Both employers and employees may face prosecution.

Key Terms

Legal notices Written document requiring a person to do/stop doing something.

Improvement Identifying what is wrong and how to put it right within a set time.

Prohibition Banning the use of equipment/unsafe practices immediately.

The Construction (Health, Safety and Welfare) Regulations 1996

These regulations cover most aspects of site safety and welfare, including the following:

- Safe places of work – excavations, tunnels, work at ground level and at height, access to and from work area.
- Preventing falls – physical precautions or equipment to check a fall and prevent falls through fragile materials; scaffolding and supervision by a competent person; safe use of ladders.
- Preventing falling objects – and/or provide covered walkways.
- Work on structures – prevent collapse of structures; plan demolition and dismantling and supervise such work by a competent person; take precautions with explosives.
- Excavations – prevent collapse and risk from underground cables and services.
- Preventing drowning – rescue equipment must be immediately available.
- Traffic routes, vehicles, gates and doors – make these safe and provide safe access and egress onto and from construction sites.
- Prevention and control of emergencies – procedures for evacuating sites, fire-fighting equipment, emergency exits.
- Welfare facilities – provide sanitary and washing facilities; provide rest facilities; provide facilities to store and change clothing.
- Site-wide issues – including fresh air, protection from bad weather, lighting, cleanliness on sites, marking of the perimeter of the site and maintenance of equipment in safe and sound condition.
- Training, inspections and reports – all work should be carried out by people with the training, technical knowledge and experience to do so safely, or should be supervised by those with such qualifications. Before work at height, on excavations, cofferdams or caissons begins, they must be inspected by a competent person, and a written report made.

Town and country planning legislation

Towns and development need to be planned appropriately. Planning is necessary to ensure that the buildings and environment that we create is fit for purpose and does not interfere with other properties around a given site. Local authorities are responsible, through their planning committees to decide whether a new building or an alteration to an existing building is suitable. These alterations could be an extension to a house or the complete adaptation of a large building into an office building.

Planning permission is not always required. Internal alterations or work which does not change the appearance of the outside of a property does not require planning permission. In other instances, such as extending or altering the physical shape and size of a building, planning permission will be needed.

Some properties have special terms and conditions when they were built. Examples of this are the requirement for or restriction on the erection of fences around the front gardens which will require permission to make any changes to the original terms and conditions. It is not required, generally speaking, for changes to the inside of buildings, or for small alterations to the outside such as the installation of telephone connections and burglar alarm boxes.

Dividing a home into flats, or creating a separate home within an existing building will also need planning permission as would the alteration of a domestic building into a workshop or office building.

Plant

Construction plant

There is a huge range of construction plant available today to assist in the construction of modern domestic and commercial buildings. Here we shall have a look at the major pieces of plant that you would expect to see when visiting a complex, active construction site.

Scaffolding

This consists of scaffold metal tubing and timber scaffold boards (see Figure 6.10). All is tested to achieve a British Standard under current UK health and safety legislation. For health and safety reasons, scaffolding must be erected by a qualified and competent person and cannot be adapted, moved or dismantled by any unqualified individual. Scaffolding is a complex structural system of many components such as:

- standards – the vertical tubes
- boards – the element you walk on
- ledgers – a horizontal tube
- putlogs and transoms – a tube that is built into the construction as work proceeds or acts independently

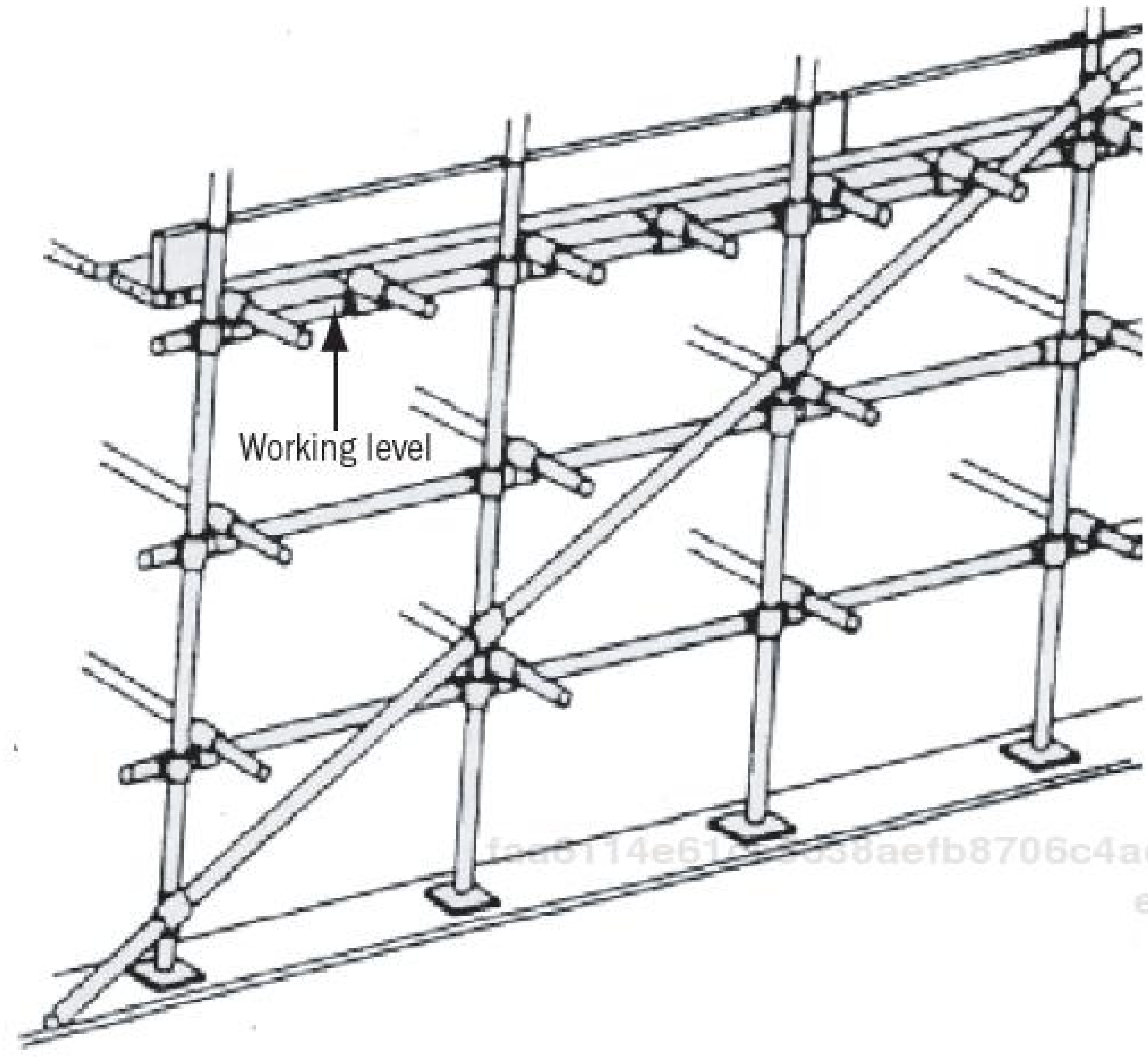


Figure 6.10 Typical scaffolding system

- guard rails – two rails that prevent falling
- toe boards – a vertical board to prevent objects falling off the scaffolding
- bracing – diagonal bracing that secures the structure against collapse.

You should refer to the HSE's publications on scaffolding for detailed requirements. Scaffolding must be inspected by a competent person and the Construction (Health, Safety and Welfare) Regulations should be referred to for the frequency of inspections and the records to be kept.

Trench support systems

These are used to support the sides of excavations and can take many forms including:

- steel sheet piling which is driven in and propped
- hydraulic props between timber shores
- steel hydraulic trench boxes.

Forklift trucks

On construction sites, these are rough-terrain forklift trucks that have large off-road tyres in order to cope with site conditions. Modern forklifts have telescopic booms that can be used to reach onto scaffolding platforms to deposit materials. An access platform with a roll-over guard rail system has to be provided at these points. This type of plant is ideal for the unloading and distribution of materials in any 360-degree location, both vertically and horizontally.

Dumper trucks

These are available in a variety of weight and volume capacities. They are steered hydraulically and can have tipper facilities incorporated into the front and rear hoppers. They are ideal rough-terrain vehicles and can manoeuvre over any rough ground. These machines are used for moving loose, bulky materials, for example drainage bedding.

Cement mixers and silos

These range from a full batching plant that can produce concrete down to a small bag mixer. Cement silos and mortar producing plants should be used on larger construction sites where economies of scale can be obtained by purchasing raw materials in bulk.

Excavators

There are two types of excavator:

- 360-degree excavators
- Backhoe excavators which can only move 180 degrees.

The most common excavator is the JCB 3CX which is very versatile and can have many attachments incorporated onto its hydraulics. Excavators have two movable forms: wheeled and tracked. They are used mainly in demolition and earth excavation and removal but can also be used to lift materials if certified to do so.

Cranes

Crainage varies widely from small 15-tonne lifting cranes to large tower cranes. Their use is limited by the reach that is required and the amount that has to be lifted by the crane. A specialist hirer would provide all the necessary documentation and they must be used with a certified **banksperson**.

Key Term

Banksperson A competent person who supervises the lifting operations of the crane.

Small plant and tools

There are many small plant and tools that are regularly used on construction sites, including:

- cartridge guns – these fire a nail fixing
- 110v drills – for creating holes of various diameters
- generators – small petrol generators to produce independent power
- petrol-driven saws – used to cut materials using a rotating disc.

Materials

Supply of building materials for both traditional and modern projects

Many materials are supplied in construction and these are sourced either:

- direct in bulk from the manufacturer
- from a distributor such as a builder's merchant where smaller lots can be purchased.

When purchasing materials always select the 'crane off load option'. This is an attachment that goes on the delivery wagon which is, in effect, a crane. This enables easy off loading of large heavy materials onto the correct location. Where possible, materials should always be on pallets to prevent damage and wrapped from the weather.

Prefabricated components and system building

For more on these topics, see pages 228–29.

Assessment practice

You have been appointed to a design team that specialises in small design and build contracts. There are two projects available for you to work on which will require you to create detailed drawings of the superstructure. Produce a series of drawings that show how each of the elements of the building will fit together:

a A pair of semi-detached, three-bedroom homes with integral garage made using timber-framed construction with brick cladding to the exterior face. The upper floor is to have a family bathroom and an ensuite to the master bedroom.

b A small office/retail outlet made of traditional brick/block construction comprising two floors. The lower floor is to be used as a retail outlet and the upper floor is intended for use as office space. **P5**

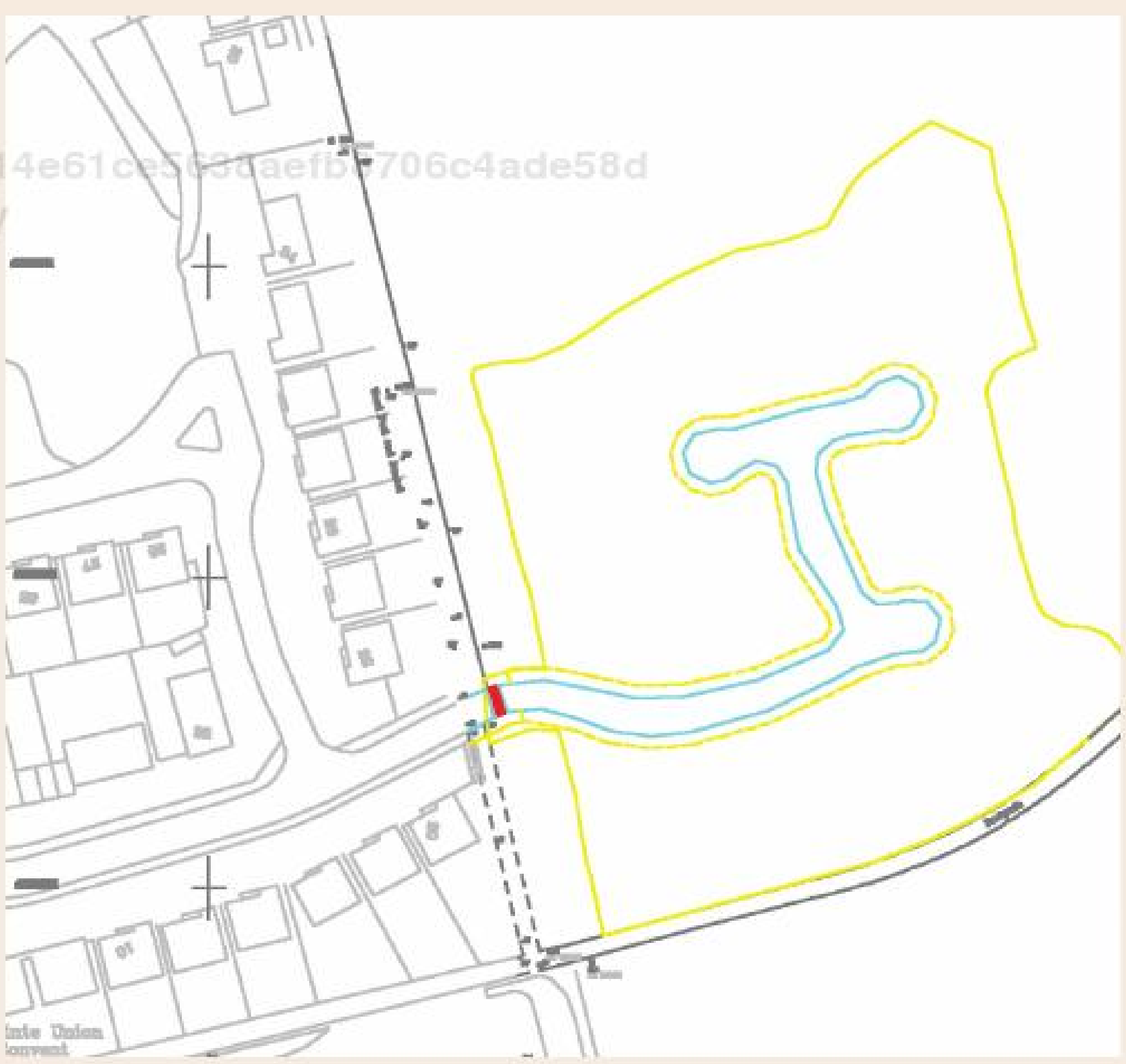
For the pair of semi-detached houses in P5, consider the plant and equipment needed to complete the installation of the roof. Make a list of all the resources required to undertake this work. Justify why you will need to use this type of equipment. **M3**

End of unit assessment

Preparation for assessment

Brief

As a small property developer, you have won the contract to build 14 units, comprising seven pairs of semi-detached properties and a small single-storey community centre on the parcel of land shown in the drawing below The client will need to assure themselves that you have considered all available options and will produce a high-quality plan that the builders will be able to follow accurately. This will mean producing clear and concise drawings, along with being able to justify and explain the details contained in the drawings. Environmental issues will also need to be considered along with an evaluation of the performance of the materials you have selected for the construction of the buildings.



▲ Location plan

Explain the procedure involved in your subsoil investigation and how you will use this information in order to design the substructure. **P1**

Explain the principles of suitable foundation design and describe the methods used to construct different types of foundation that you could use for this building. **P2**

Produce a series of detail drawings showing the construction of your foundation for the houses and how they differ from the community centre. **P3**

Explain the principles that you have adopted in the selection of the superstructure design. Describe the methods used to construct all elements of this superstructure. **P4**

Produce a series of detail drawings showing the techniques used to construct all elements of the superstructure for the houses and how this differs for the community centre. **P5**

Explain and justify the selection of your materials and techniques used in the construction of the substructure for the houses and how these differ from the materials used in the community centre. **M1**

Explain and justify the selection of your materials and techniques used in the construction of the superstructure for the houses and how they differ from the community centre. **M2**

Identify and justify the plant and equipment requirements, including safety equipment, for the construction of the roof of one of the houses. **M3**

Evaluate the performance in use, and environmental implications of, alternative materials and techniques used in the construction of:

- **a** the substructures to the houses
- **b** the substructure to the community centre
- **c** the external walls of the houses. **D1** **D2**

Grading tips

You will need to justify your selections. **M1 M2**

You will need to identify plant and equipment requirements for at least one complex component of a building such as a roof. Then you will need to justify this selection in terms of cost, equipment, suitability and availability of the equipment to complete the construction of the element that you choose. **M3**

You will need to evaluate your selections if you are to achieve a distinction grade. **D1 D2**

Knowledge check

1 Identify and compare three different types of method used for soil investigations.

2 List six factors of ground conditions that would affect the type and size of foundation design.

3 Explain the principles involved in correct foundation design.

4 Sketch and annotate four different types of foundation suitable for low-rise domestic buildings.

5 Describe with the aid of appropriate well-annotated sketches and drawings, the process associated with the construction of a timber-framed house. The process should include:

- a site clearance
- b site set up and organisation
- c material storage
- d plant positioning
- e access and safety onsite
- f excavation and plant needed
- g water elimination
- h temporary support.

6 Draw a cross-section through a concrete pot and beam floor showing the structural components and the position of the insulation.

7 Compare the properties of steel and timber. Relate the properties to their performance when used as structural members.

8 Draw a vertical section through a timber-framed house showing all the key components and how the house is constructed.

9 Illustrate how the following elements can be integrated into the structure of a timber-framed house:

- a Upper floors
- b Window frames
- c Door frames
- d Stairs

10 Draw to a suitable scale a section through a portal frame building showing the structural frame and a suitable form of cladding.

11 Identify and describe three internal and three external finishes.

12 List four common forms for cladding used for timber-frame domestic housing. Identify the merits and disadvantages of each form.

13 List the plant and equipment necessary to fix a pitched timber roof on a low-rise domestic dwelling

14 Evaluate the impact of raw materials used in the building of the substructure of a domestic dwelling. Explain how building contractors can contribute to the development of sustainable construction.

15 Analyse and evaluate the performance of lightweight construction. Explain how this differs from heavyweight construction and what the implications are for global warming by selecting suitable materials for the construction of buildings.

Grading criteria: Unit 6		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 explain the procedures involved in subsoil investigation and how the information obtained is used in the design of substructures **Assessment practice pages 246, 267** **P2** explain the principles of foundation design and describe the methods used to construct different types of foundation **Assessment practice pages 246, 267**	**M1** explain and justify the selection of suitable materials and techniques for use in the construction of substructures for low-rise domestic and commercial buildings, for two different tutor-specified scenarios **Assessment practice pages 246, 267**	**D1** evaluate the performance in use, and environmental implications of, alternative materials and techniques used in the construction of substructures to low-rise domestic and commercial buildings **Assessment practice pages 246, 267**
P3 produce detailed drawings showing foundation construction for a low-rise domestic building and for a low-rise commercial building **Assessment practice pages 258, 267** **P4** explain the principles of superstructure design and describe the methods used to construct all elements of a superstructure **Assessment practice pages 258, 267**	**M2** explain and justify the selection of materials and techniques used in the construction of superstructures for low-rise domestic and commercial buildings **Assessment practice pages 258, 267**	**D2** evaluate the performance in use, and environmental implications of, alternative materials and techniques used in the construction of a tutor-specified element of a superstructure, e.g. the external wall **Assessment practice pages 258, 267**
P5 produce detailed drawings showing the techniques used to construct all elements of superstructure for low-rise domestic and commercial buildings **Assessment practice pages 266, 267**	**M3** identify and justify the plant and equipment requirements, including safety equipment, for the construction of a complex tutor-specified element of superstructure, e.g. a roof **Assessment practice pages 266, 267**	