European Building Construction Illustrated

Francis DK Ching
Mark Mulville

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PREFACE

'The realisation of a design intention requires a knowledge of how building materials are assembled in construction and how the resulting construction responds to user needs, contextual fit and environmental forces.'

Francis DK Ching, 2013

First published in 1975, and now just about to go into its fifth edition, *Building Construction Illustrated* is an established classic in the US. Francis DK Ching's clear graphic signature style marks it out as the most accessible visual guide to the basics of building construction. Building on the strengths of Ching's US edition, this first edition of *European Building Construction Illustrated* aims to focus on the construction methods most commonly used in Europe. Some methods used in Europe are similar to those used in North America with simple terminological differences, while others are significantly different in form and application or indeed are governed by regulations that alter the decision-making process, due to impacts on quality, cost and time. It would not be possible to detail the wide variety of construction methods used throughout Europe – which have been heavily influenced by diverse traditions, availability of local materials and climatic conditions – in a single volume. To that end this publication gives an overview of mainstream construction methods in the region while outlining emerging construction methods as driven by the sustainability agenda.

A chapter briefly outlining construction in the Middle East, focusing on the Arab countries bordering the Persian Gulf, has been added. This is a region where the construction industry has been influenced by US and European construction methods and regulatory frameworks. The region is now at the forefront of pushing construction technology to its limits and this in turn is a key driver for innovation in the global construction industry, warranting its consideration if only somewhat succinctly in this case.

The original *Building Construction Illustrated* publications emphasised that 'buildings and sites should be planned and developed in an environmentally sensitive manner, responding to context and climate to reduce their reliance on active environmental control systems and the energy they consume'. This publication maintains this focus, describing and referring to the leading environmental assessment methods of BREEAM® and LEED® while outlining the Passive House Standard, which is of growing importance in the region, and indeed globally. The book takes a 'fabric first' approach to delivering efficient, healthy and comfortable buildings and outlines how thermally efficient and airtight buildings can be delivered.

It would be nearly impossible to cover all building materials and construction techniques, but the information presented herein should be applicable to most residential and commercial construction situations encountered today. Construction techniques continue to adjust to the development of new building materials, products and standards. What does not change are the fundamental principles that underline the approach taken to building elements and the intended function of the systems constructed. This illustrated guide focuses on these principles, which can serve as guidelines when evaluating and applying new information encountered in the planning, design and construction of a building.

Each building element, component or system is described in terms of its end use. The specific form, quality, capability and availability of an element or component will vary with manufacturer and locale. It is therefore important to always follow the manufacturer's recommendation in the use of a material or product and to pay careful attention to the building regulation requirements in effect for the use and location of a planned building. It is the user's responsibility to ascertain the appropriateness of the information contained in this handbook and to judge its fitness for any particular purpose. Seek the expert advice of a professional when needed.

Many of the drawings in this book are by Francis DK Ching and are reproduced from the US fourth edition of *Building Construction Illustrated*. Where relevant to reflect the European content of the book, the original drawings have been adapted or new graphics created, with the aim of maintaining the clarity and style of Ching's original drawing style.

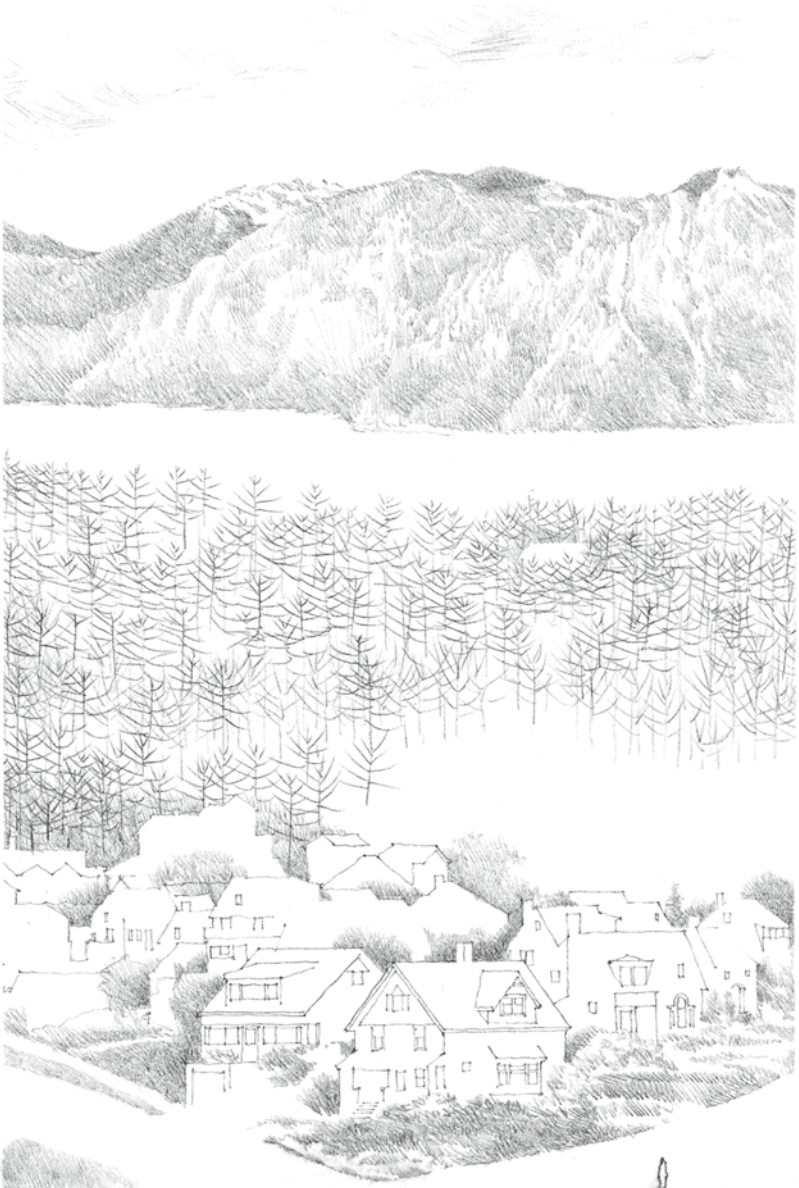
This book would not have been possible without the support, guidance and assistance of a number of people. Thanks must go to Traudel Schwarz-Funke of the University of Sharjah for her expert guidance in the development of the chapter concerning construction in the Middle East. Richard Cooper, Justine Cooper and Anthony Kelly of the University of Greenwich are also owed a debt of gratitude for their support and guidance regarding a number of technical matters throughout the book. Finally thank you to Pat, Cora, Lorna and Yulia for their unending support.

Mark Mulville, 2013

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THE BUILDING SITE

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Buildings do not exist in isolation. They are conceived to house, support and inspire a range of human activities in response to sociocultural, economic and political needs, and are erected in natural and built environments that constrain as well as offer opportunities for development. We should therefore carefully consider the contextual forces that a site presents in planning the design and construction of buildings.

The microclimate, topography and natural habitat of a site all influence design decisions at a very early stage in the design process. To enhance human comfort as well as conserve energy and material resources, responsive and sustainable design respects the indigenous qualities of a place, adapts the form and layout of a building to the landscape, and takes into account the path of the sun, the rush of the wind and the flow of water on a site.

In addition to environmental forces, there exist the regulatory forces of zoning and planning. These regulations take into account existing land-use patterns and prescribe the acceptable uses and activities for a site as well as limit the size and shape of the building mass and where it may be located on the site.

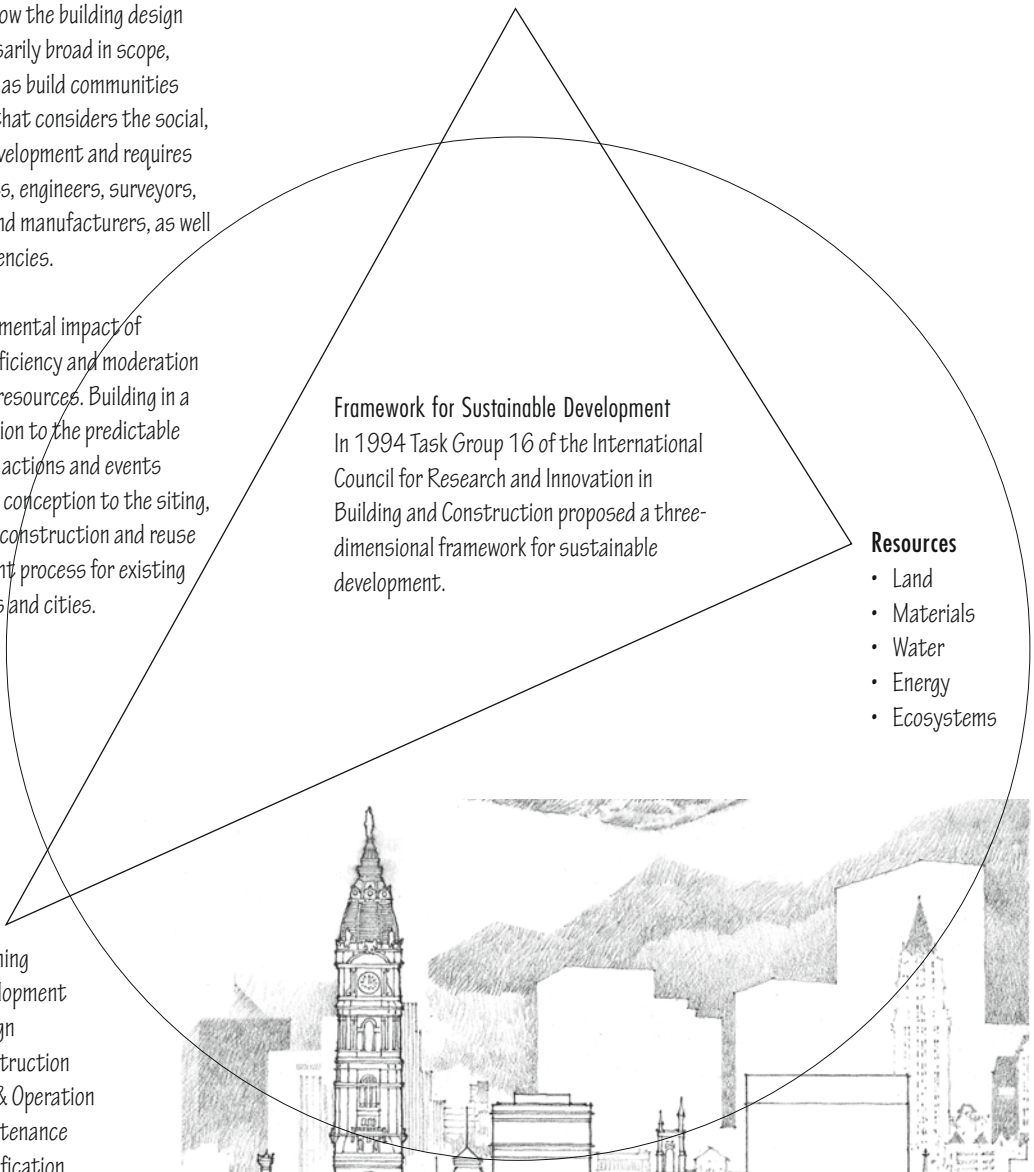
Just as environmental and regulatory factors influence where and how development occurs, the construction, use and maintenance of buildings inevitably place a demand on transport systems, utilities and other services. A fundamental question we face is how much development a site can sustain without exceeding the capacity of these service systems, consuming too much energy, or causing environmental damage.

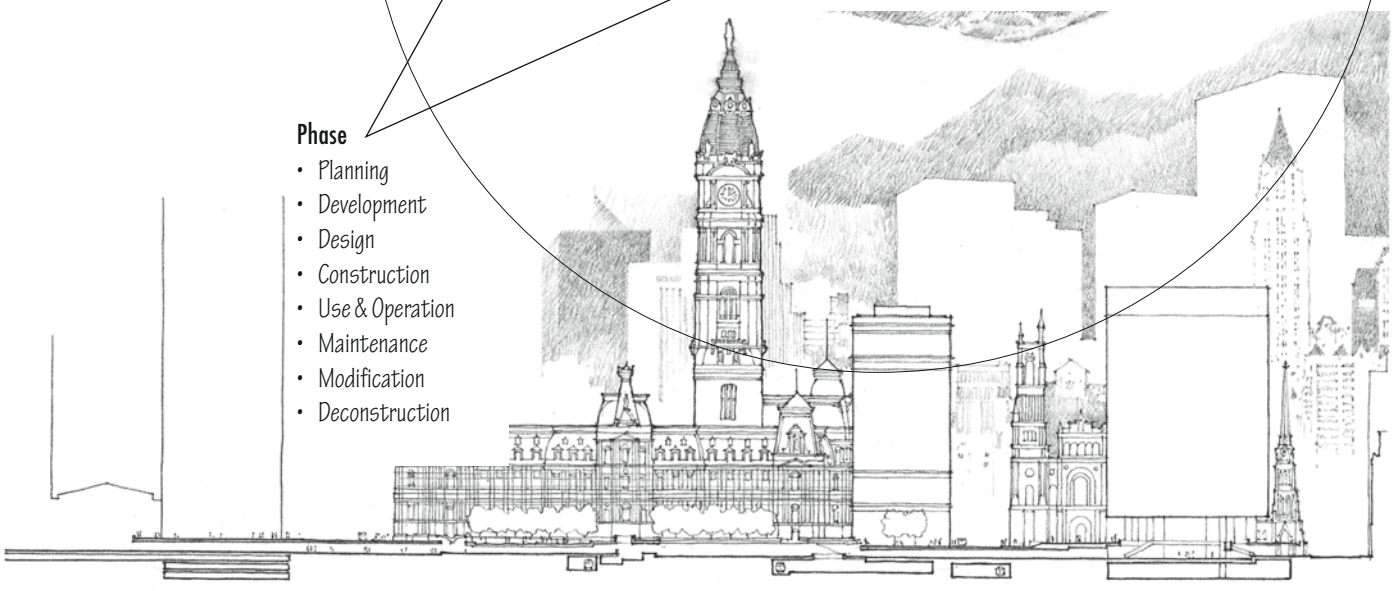
Consideration of these contextual forces on site and building design cannot proceed without a brief discussion of sustainability.

In 1987, the United Nations World Commission on Environment and Development, chaired by Gro Harlem Brundtland, former Prime Minister of Norway, issued a report, *Our Common Future*. Among its findings, the report defined sustainable development as 'a form of development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

Increasing awareness of the environmental challenges presented by climate change and resource depletion has driven sustainability into becoming a significant issue shaping how the building design industry operates. Sustainability is necessarily broad in scope, affecting how we manage resources as well as build communities and the issue calls for a holistic approach that considers the social, economic and environmental impacts of development and requires the full participation of planners, architects, engineers, surveyors, developers, building owners, contractors and manufacturers, as well as governmental and non-governmental agencies.

In seeking to minimise the negative environmental impact of development, sustainability emphasises efficiency and moderation in the use of materials, energy and spatial resources. Building in a sustainable manner requires paying attention to the predictable and comprehensive outcomes of decisions, actions and events throughout the life cycle of a building, from conception to the siting, design, construction, use, maintenance, deconstruction and reuse of new buildings as well as the refurbishment process for existing buildings and the reshaping of communities and cities.





The terms 'green building' and 'sustainable design' are often used interchangeably to describe any building designed in an environmentally sensitive manner. However, sustainability calls for a whole-systems approach to development that encompasses the notion of green building but also addresses broader social, ethical and economic issues, as well as the community context of buildings. As an essential component of sustainability, green building seeks to provide healthy environments in a resource-efficient manner using ecologically based principles.

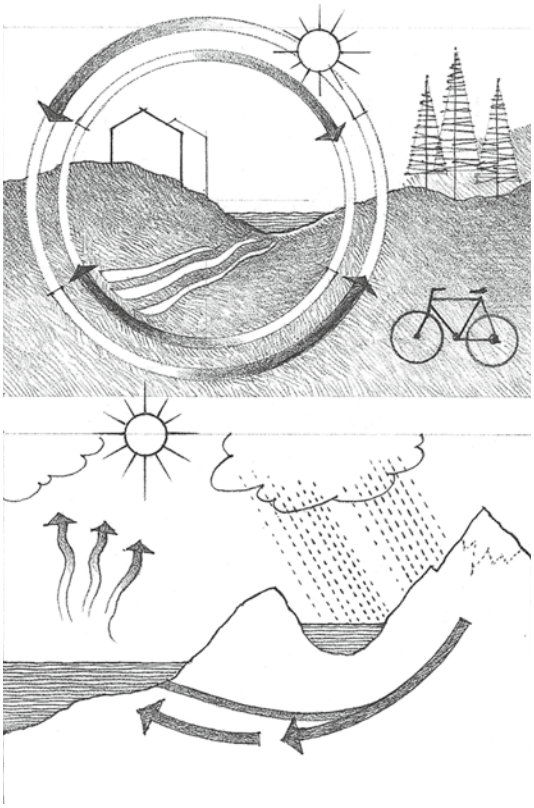
To help drive the green building agenda, the 'sustainability' of buildings is increasingly measured against standards set out within recognised environmental assessment methods. These assessment methods gauge the building's overall performance against a set of measurable criteria. Some such assessment methods or standards focus on specific aspects of sustainability such as environmental impact or energy performance, while others attempt to provide a holistic assessment of the core sustainability issues. The Building Research Establishment Environmental Assessment Method (BREEAM) is one of the longest established and most widely recognised assessment methods in the world. A wide range of similar assessment methods exist within Europe, the European Union's Committee for Standardization is working towards a set of standardised assessment methods for the region building on the European Energy Performance of Buildings Directive (EPBD). The EPBD ensures that the energy use of all domestic and non-domestic buildings within the European Union is assessed when a new building is constructed or an existing building is sold or let, thus allowing for direct comparison of the energy performance between one building and the next.

In the UK the Standard Assessment Procedure (SAP) and Simplified Building Energy Model (SBEM) are used to assess the energy performance of domestic and simple non-domestic building respectively producing Energy Performance Certificates (EPC). In accordance with the requirements of the EPBD, public buildings over 1000 m^2 must have a Display Energy Certificate (DEC), which as such is a reflection on the actual energy usage of the building. This is useful as occupant behaviour and building management which are difficult to predict can have a significant impact upon the energy use of a building.

BREEAM®: Building Research Establishment Environmental Assessment Method, first established by the Building Research Establishment (BRE) in 1990, used globally for a range of largely non-domestic buildings.

LEED®: Leadership in Energy and Environmental Design, developed by the US Green Building Council (USGBC), used globally on a wide range of new-build and refurbishment projects.

Both LEED and BREEAM attempt to assess sustainability in broad terms. They consider a wide range of potential environmental impacts associated with the life cycle of the building including materials and embodied energy, building management and waste reduction. Both methods set out a number of criteria for which credits are available. As the project progresses evidence must be gathered to demonstrate how the building complies with the criteria associated with the credits awarded. See 1.05 & 1.06.



First applied in Germany in the early 1990s, the Passive House Standard aims to achieve low energy, comfortable buildings by focusing on the delivery of a high quality, well designed building fabric and appropriate and correctly configured building systems.

This focus on the performance of the building fabric based on a sound understanding of building physics aims to deliver healthy and comfortable internal environments requiring minimum amounts of heating and/or cooling to maintain this comfort. Depending on where the building is to be located some considerations in relation to resources, climatic conditions and building regulation compliance may need to be accounted for.

The application of Passive House principles has helped to improve European construction standards. This is especially true where they have been applied in regions with milder climates where such high levels of thermal performance have not previously been considered. Care must be taken, however, to ensure that in such well insulated buildings overheating does not become an issue. The Passive House Standard does take account of this overheating risk, but some projects may apply Passive House principles without applying the full standard. See 1.08 & 1.09.

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BREEAM

The BRE and relevant regional partners have developed a range of assessment methodologies covering a broad spectrum of building and project types in many locations, allowing most non-domestic building to be assessed (domestic buildings are assessed using the Code for Sustainable Homes (CfSH)):

- BREEAM New Construction*
  - Shell and Core
  - Fit-Out
  - Major Refurbishment
- BREEAM Data Centres
- BREEAM Bespoke
- BREEAM Communities
- BREEAM In-Use
- BREEAM NL (The Netherlands)
- BREEAM NOR (Norway)
- BREEAM ES (Spain)
- BREEAM SE (Sweden)
- BREEAM International

*BREEAM New Construction addresses nine major areas:

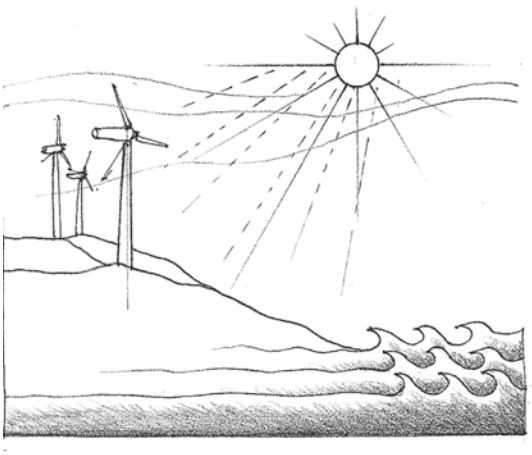
1. Management
2. Health & Wellbeing
3. Energy
4. Transport
5. Water
6. Materials
7. Waste
8. Land Use & Ecology
9. Pollution

To try and challenge the industry to deliver innovative solutions, additional credit can also be awarded for 'innovation', allowing for bespoke solutions to unique or challenging problems.

Under the BREEAM rating system each rating has a number of minimum standards that must be met regardless of the overall percentage score in order for a rating to be achieved. For example, in order to gain an 'outstanding' rating, a minimum of 10 credits must be achieved under the section considering the reduction of CO_2 emissions (ENE 01).

*Source: www.breeam.org

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Each of the nine areas addressed under BREEAM receives an environmental weighting relative to its importance in delivering a sustainable building. The weighting coupled with the number of credits available for each of the criteria dictates the relative importance or impact of the criteria.

*BREEAM Environmental Weightings:

Management	12%
Health & Wellbeing	15%
Energy	19%
Transport	8%
Water	6%
Materials	12.5%
Waste	7.5%
Land Use & Ecology	10%
Pollution	10%

*Possible BREEAM Ratings:

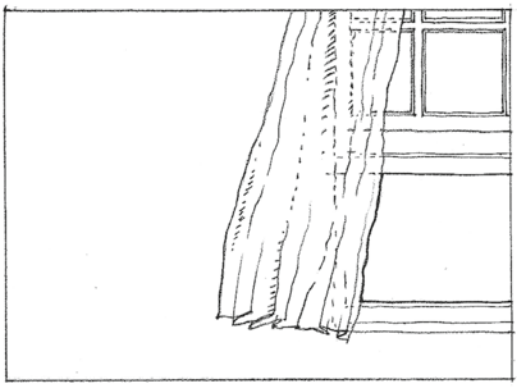
Unclassified	<30%
Pass	30–44%
Good	45–54%
Very Good	55–69%
Excellent	70–84%
Outstanding	85%+

LEED

To aid designers, builders and owners to achieve LEED certification for specific building types and phase of a building life cycle, the US Green Building Council (USGBC) has developed a number of versions of the LEED rating system:

- LEED New Construction and Major Renovations
- LEED Existing Buildings: Operations & Maintenance
- LEED Commercial Interiors
- LEED Core & Shell
- LEED Schools
- LEED Retail
- LEED Healthcare
- LEED Homes
- LEED Neighbourhood Development

The LEED rating system for new construction addresses seven major areas of development.



1. Sustainable Sites

Deals with reducing the pollution associated with construction activity, selecting sites appropriate for development, protecting environmentally sensitive areas and restoring damaged habitats, encouraging alternative modes of transport to reduce the impact of vehicle use, respecting the natural hydrology of a site, and reducing the effects of heat islands.

2. Water Efficiency

Promotes reducing the demand for potable water and the generation of wastewater by using water-conserving fixtures, capturing rainwater or recycled greywater for conveying sewage, and treating wastewater with on-site systems.

3. Energy & Atmosphere

Encourages increasing the efficiency with which buildings and their sites acquire and use energy, increasing renewable, non-polluting energy sources to reduce the environmental and economic impacts associated with fossil fuel energy use, and minimising the emissions that contribute to ozone depletion and global warming.

4. Materials & Resources

Seeks to maximise the use of locally available, rapidly renewable and recycled materials, reduce waste and the demand for virgin materials, retain cultural resources, and minimise the environmental impacts of new buildings.

5. Indoor Environmental Quality

Promotes the enhanced comfort, productivity and wellbeing of building occupants by improving indoor air quality, maximising daylighting of interior spaces, enabling user control of lighting and thermal comfort systems to suit task needs and preferences, and minimising the exposure of building occupants to potentially hazardous particulates and chemical pollutants, such as the volatile organic compounds (VOC) contained in adhesives and coatings and the urea-formaldehyde resins in composite wood products.

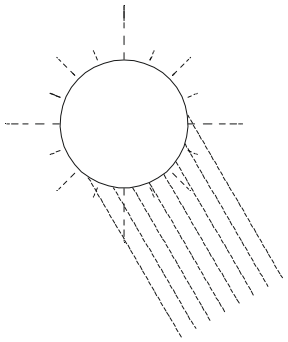
6. Innovation & Design Process

Rewards exceeding the requirements set by the LEED Green Building Rating System and/or demonstrating innovative performance in Green Building categories not specifically addressed by the LEED Green Building Rating System.

7. Regional Priority

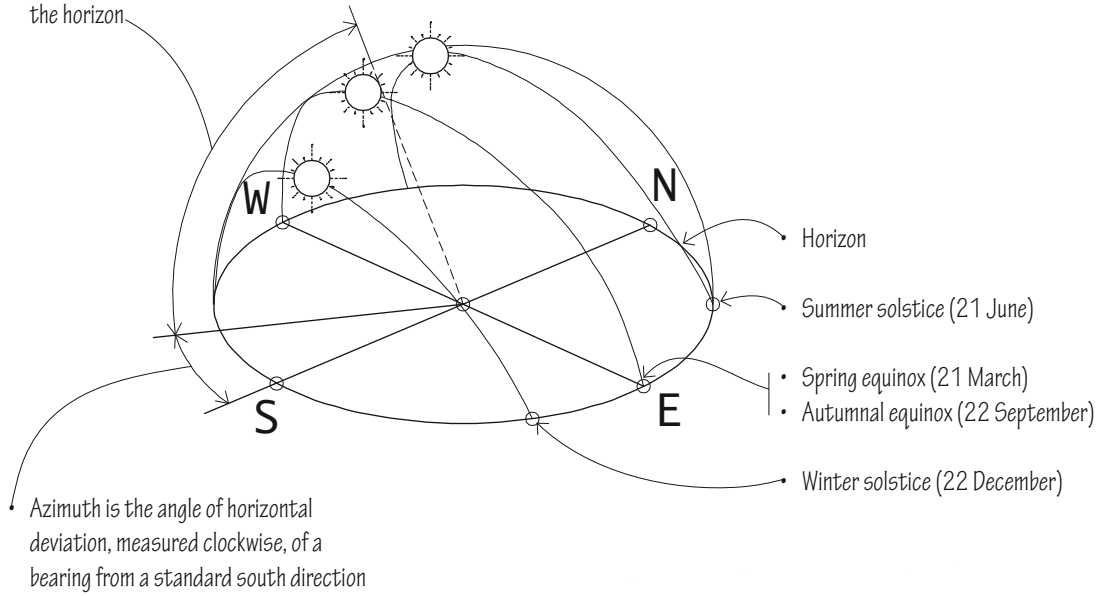
Provides incentives for practices that address geographically specific environmental priorities.

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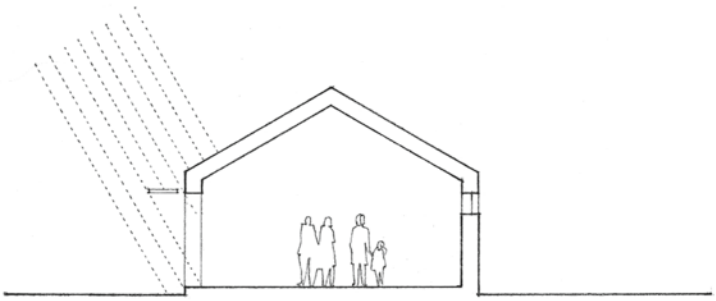


The location, form and orientation of a building and its spaces should take advantage of the thermal, hygienic and psychological benefits of sunlight. Solar radiation, however, may not always be beneficial, depending on the latitude and climate of the site. In planning the design of a building, the objective should be to maintain a balance between underheated periods when solar radiation is beneficial and overheated periods when radiation should be avoided.

The path of the sun through the sky varies with the seasons and the latitude of a building site. The range of solar angles for a specific site should be obtained from the relevant national meteorological office before calculating the potential solar heat gain and shading requirements for a building design.

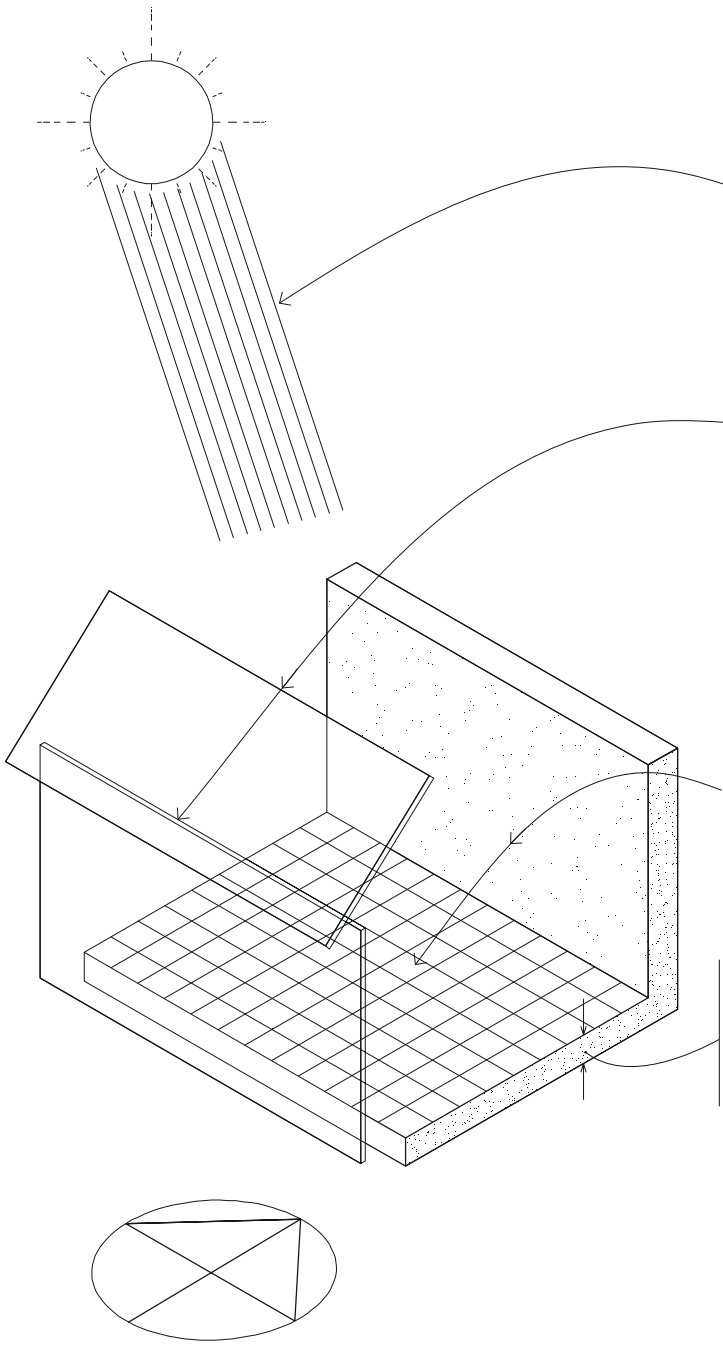


Solar Path Diagram



Representative Solar Angles

North Latitude	Representative City	Altitude at Noon		Azimuth at Sunrise & Sunset	
		22 Dec	21 Mar/22 Sept	22 Dec	21 June
59°	Oslo	6°	30°	40°	143°
53°	Dublin	13°	37°	47°	133°
51°	London	15°	39°	50°	129°
43°	Nice	22°	47°	56°	122°
40°	Madrid	26°	50°	59°	123°



Passive solar heating refers to using solar energy to heat the interior spaces of a building without relying on mechanical devices that require additional energy. Passive solar systems rely instead on the natural heat transfer processes of conduction, convection and radiation for the collection, storage, distribution and control of solar energy.

- The solar constant is the average rate at which radiant energy from the sun is received by the earth, equal to 1353 W/m^2/hr, used in calculating the effects of solar radiation on buildings

There are two essential elements in every passive solar system:

1. South-facing glass or transparent plastic for solar collection
- Area of glazing should be 30–50% of floor area in cold climates and 15–25% of floor area in temperate climates, depending on average outdoor winter temperature and projected heat loss
- Glazing material should be resistant to the degradation caused by the ultraviolet rays of the sun
- Double- or triple-glazing and insulation are required to minimise night-time heat loss

2. Thermal mass for heat collection, storage and distribution, oriented to receive maximum solar exposure
- Thermal storage materials include concrete, brick, stone, tile, rammed earth, sand and water or other liquid. Phase-change materials, such as eutectic salts and paraffins, are also feasible
- Concrete: 305–455 mm
- Brick: 255–355 mm
- Earth: 200–305 mm
- Water: 150 mm or more
- Dark-coloured surfaces absorb more solar radiation than light-coloured surfaces

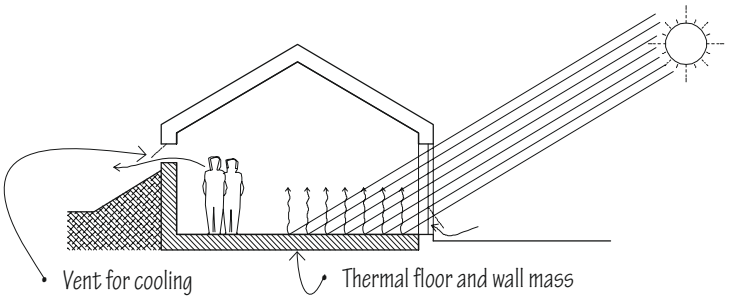
- Vents, dampers, movable insulation panels and shading devices can assist in balancing heat distribution

Based on the relationship between the sun, the interior space and the heat collection system, there are three ways in which passive solar heating can be accomplished: direct gain, indirect gain and isolated gain.

LEED EA Credit 2: On-Site Renewable Energy
LEED EA Credit 6: Green Power
BREEAM ENE 01: Reduction of CO_2 Emissions

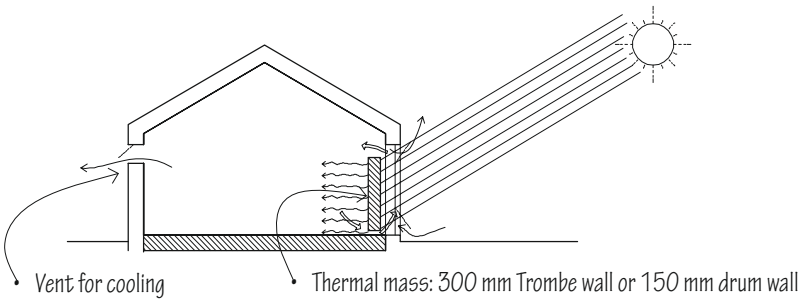
Direct Gain

Direct gain systems collect heat directly within an interior space. The surface area of the storage mass, which is incorporated into the space, should be 50–66% of the total surface area of the space. During the cooling season, operable windows and walls are used for natural or induced ventilation.



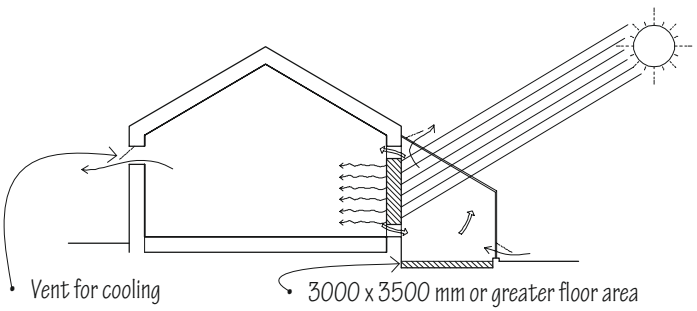
Indirect Gain

Indirect gain systems control heat gain at the exterior skin of a building. The solar radiation first strikes the thermal mass, either a concrete or masonry Trombe wall, or a drum wall of water-filled barrels or tubes, which is located between the sun and the living space. The absorbed solar energy moves through the wall by conduction and then to the space by radiation and convection.



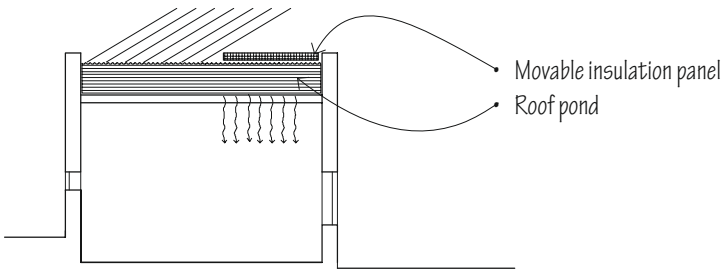
Sunspace

A sun room or solarium is another medium for indirect heat gain. The sunspace, having a floor of high thermal mass, is separated from the main living space by a thermal storage wall from which heat is drawn as needed. For cooling, the sunspace can be vented to the exterior.



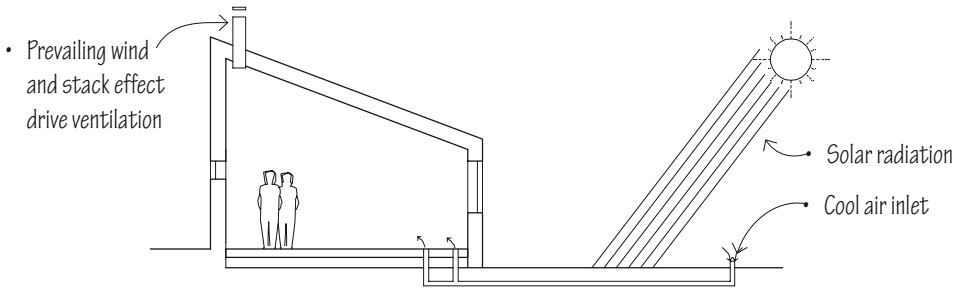
Roof Pond

Another form of indirect gain is a roof pond that serves as a liquid mass for absorbing and storing solar energy. An insulating panel is moved over the roof pond at night, allowing the stored heat to radiate downward into the space. In summer, the process is reversed to allow internal heat absorbed during the day to radiate to the sky at night.



Isolated Gain

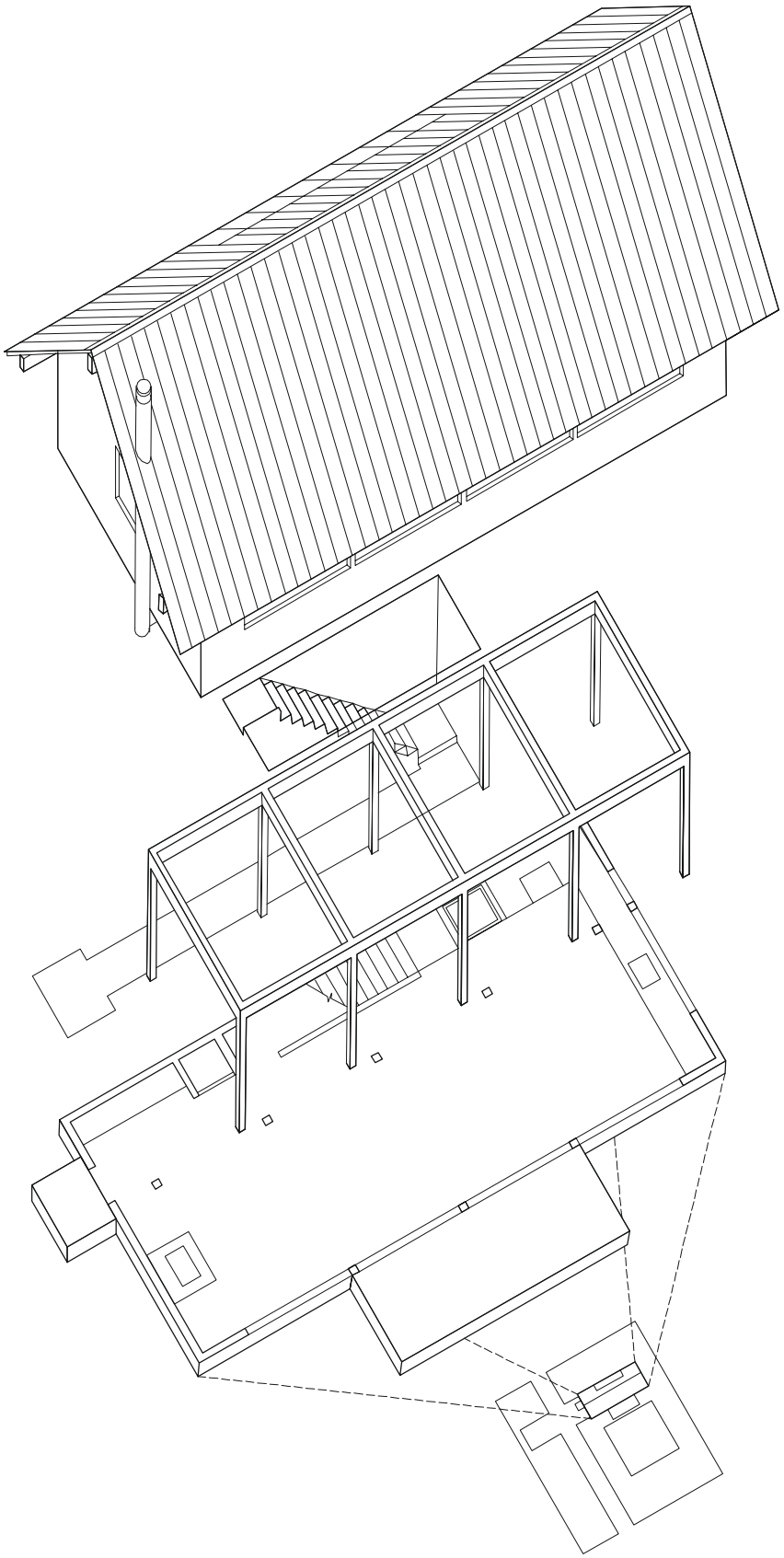
Ground tempered ventilation utilises the relatively constant warmth of the earth at depth in excess of 2 m to pre-heat ventilation air. Ventilation will need to be driven by the stack effect, a solar chimney, the prevailing winds or a combination of these measures.



2

THE BUILDING

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Architecture and building construction are not necessarily one and the same thing. An understanding of the methods for assembling various materials, elements and components is necessary during both the design and the construction of a building. This understanding, however, while it enables one to build architecture, does not guarantee it. A working knowledge of building construction is only one of several critical factors in the execution of architecture. When we speak of architecture as the art of building, we should consider the following conceptual systems of order in addition to the physical ones of construction:

- The definition, scale, proportion and organisation of the interior spaces of a building
- The ordering of human activities by their scale and dimension
- The functional zoning of the spaces of a building according to purpose and use
- Access to and the horizontal and vertical paths of movement through the interior of a building
- The sensible qualities of a building: form, space, light, colour, texture and pattern
- The building as an integrated component within the natural and built environment

Of primary interest to us in this book are the physical systems that define, organise and reinforce the perceptual and conceptual ordering of a building.

A system can be defined as an assembly of interrelated or interdependent parts forming a more complex and unified whole and serving a common purpose. A building can be understood to be the physical embodiment of a number of systems and subsystems that must necessarily be related, coordinated and integrated with each other as well as with the three-dimensional form and spatial organisation of the building as a whole.

Structural System

The structural system of a building is designed and constructed to support and transmit applied gravity and lateral loads safely to the ground without exceeding the allowable stresses in its members.

- The superstructure is the vertical extension of a building above the foundation
- Columns, beams and load-bearing walls support floor and roof structures
- The substructure is the underlying structure forming the foundation of a building

Building Envelope

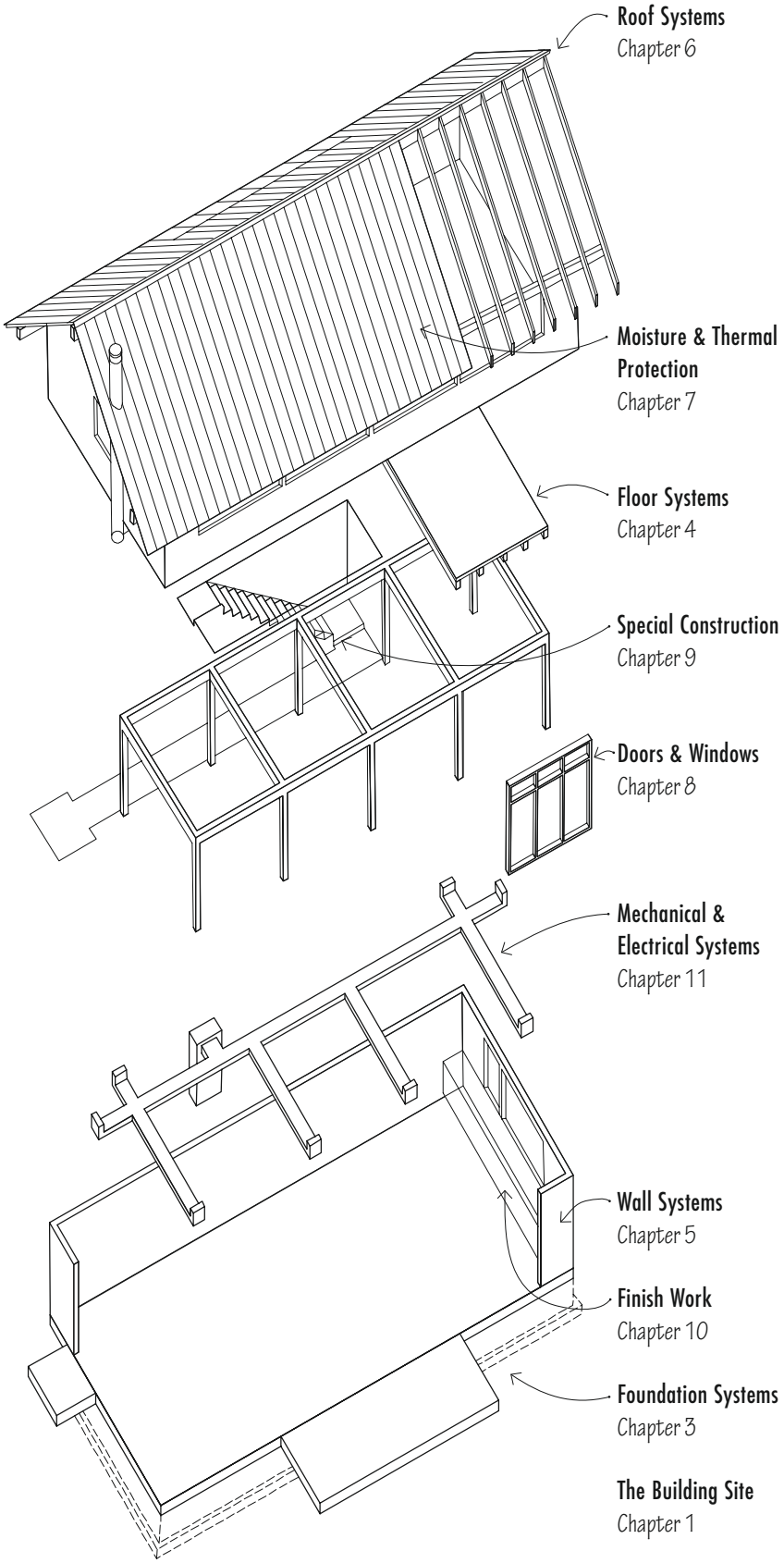
The building envelope is the shell of a building, consisting of the roof, exterior walls, windows and doors.

- The roof and exterior walls shelter interior spaces from inclement weather and control moisture, heat and air flow through the layering of construction assemblies, in effect acting as a filter
- Exterior walls and roofs also dampen noise and provide security and privacy for the occupants of a building
- Doors provide physical access
- Windows provide access to light, air and views
- Interior walls and partitions subdivide the interior of a building into spatial units

Mechanical Systems

The mechanical systems of a building provide essential services to a building.

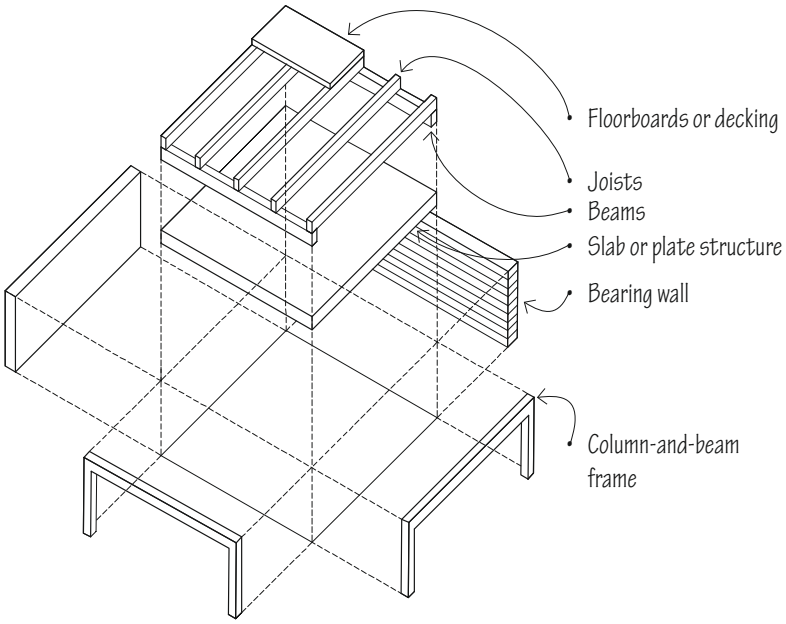
- The water supply system provides potable water for human consumption and sanitation
- The sewage disposal system removes fluid waste and organic matter from a building
- Heating, ventilating and air-conditioning systems condition the interior spaces of a building for the environmental comfort of the occupants
- The electrical system controls, meters and protects the electric power supply to a building, and distributes it in a safe manner for power, lighting, security and communication systems
- Vertical transport systems carry people and goods from one level to another in medium- and high-rise buildings
- Fire-fighting systems detect and extinguish fires
- Structures may also require waste management and recycling systems



2.18 STRUCTURAL UNITS

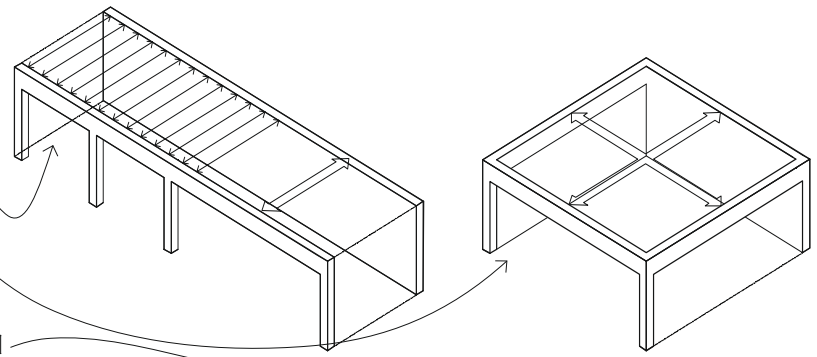
With the principal structural elements of column, beam, slab and load-bearing wall, it is possible to form an elementary structural unit capable of defining and enclosing a volume of space for habitation. This structural unit is the basic building block for the structural system and spatial organisation of a building.

- Horizontal spans may be traversed by reinforced-concrete slabs or by a layered, hierarchical arrangement of beams and joists supporting floorboards or decking
- The vertical support for a structural unit may be provided by load-bearing walls or by a framework of columns and beams

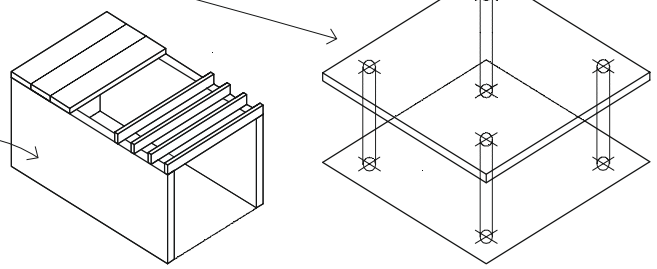


The dimensions and proportions of a structural unit or bay influence the selection of an appropriate spanning system.

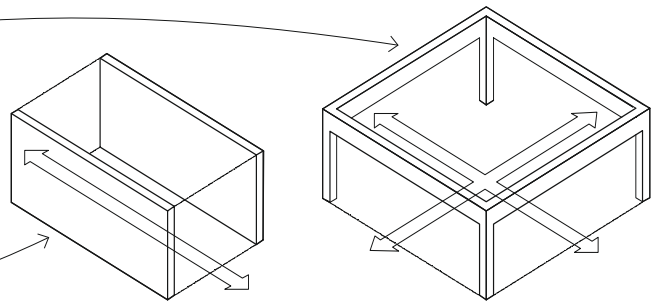
- One-way systems of joists, planks or slabs are more efficient when structural bays are rectangular, that is, when the ratio of the long to the short dimensions is greater than 1.5:1, or when the structural grid generates a linear pattern of spaces
- Two-way systems of beams and slabs are more effective for square or nearly square bays
- A two-way slab supported by four columns defines a horizontal layer of space



- The parallel nature of load-bearing walls leads naturally to the use of one-way spanning systems
- Because load-bearing walls are most effective when supporting a uniformly distributed load, they typically support a series of joists, planks or a one-way slab



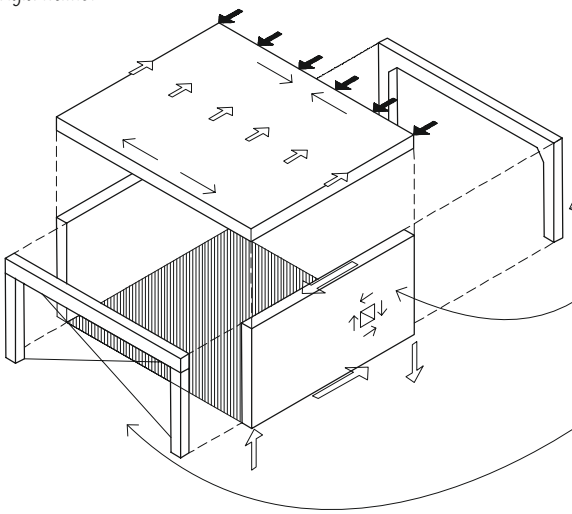
- A linear framework of columns and beams defines a three-dimensional module of space capable of being expanded both horizontally and vertically
- Two load-bearing walls naturally define an axial, bidirectional space. Secondary axes can be developed perpendicular to the primary axis with openings within the load-bearing walls



The structural elements of a building must be sized, configured and joined to form a stable structure under any possible load conditions. Therefore, a structural system must be designed to not only carry vertical gravity loads, but also withstand lateral wind and seismic forces from any direction. The following are the basic mechanisms for ensuring lateral stability.

Horizontal diaphragm

- A rigid floor structure, acting as a flat, deep beam, transfers lateral loads to vertical shear walls, braced frames or rigid frame.



Rigid frame

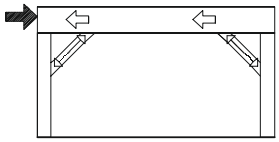
- A steel or reinforced-concrete frame with rigid joints capable of resisting changes in angular relationships

Shear wall

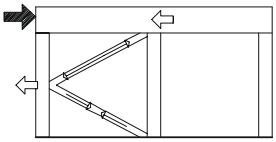
- A wood, concrete or masonry wall capable of resisting changes in shape and transferring lateral loads to the ground foundation

Braced frame

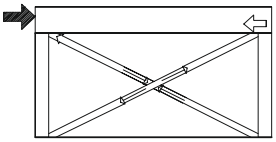
- A timber or steel frame braced with diagonal members



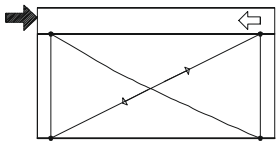
- Knee bracing

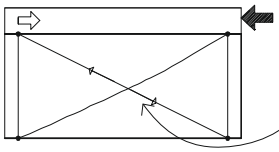


- K-brace



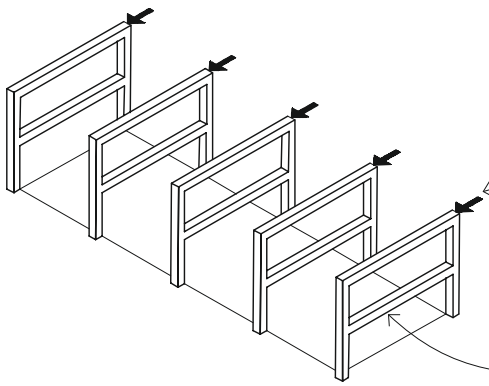
- Cross bracing





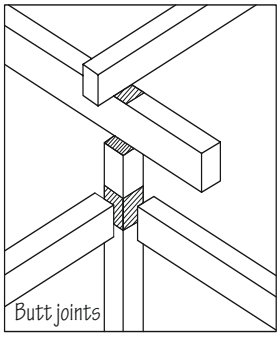
- When using cable bracing, two are necessary to stabilise the structure against lateral forces from either direction. For each direction, one cable will operate effectively in tension while the other would simply buckle. If rigid bracing is used, a certain degree of redundancy is involved because a single member is capable of stabilising the structure

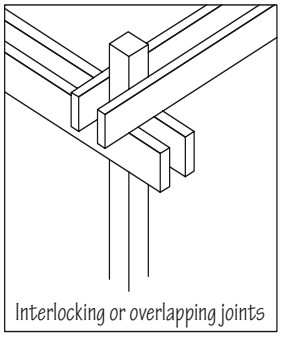
Any of these systems may be used singly or in combination to stabilise a structure. Of the three vertical systems, a rigid frame tends to be the least efficient. However, rigid frames can be useful when employing braced frames or shear walls would form undesired barriers between adjacent spaces.

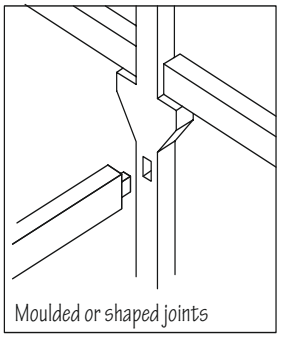


- Lateral forces tend to be more critical in the short direction of rectangular buildings, and more efficient shear walls or braced frames are typically used in this direction. In the long direction, any of the lateral force-resisting elements may be used

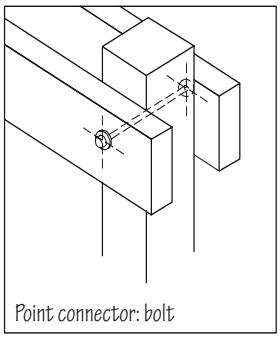
- Braced or rigid frames can be designed to carry vertical and lateral loads transverse to the length of a framed structure

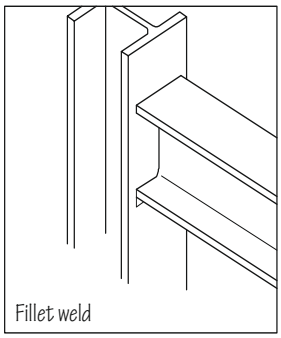

Butt joints

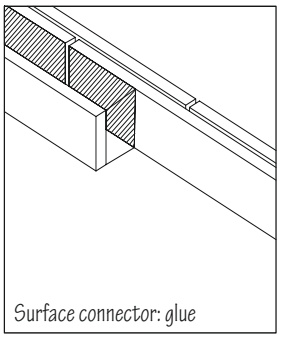

Interlocking or overlapping joints


Moulded or shaped joints

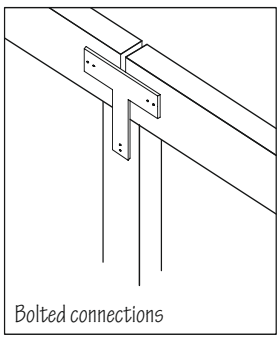
The manner in which forces are transferred from one structural element to the next and how a structural system performs as a whole depend to a great extent on the types of joints and connections used. Structural elements can be joined to each other in three ways. Butt joints allow one of the elements to be continuous and usually require a third mediating element to make the connection. Overlapping joints allow all of the connected elements to bypass each other and be continuous across the joint. The joining elements can also be moulded or shaped to form a structural connection.

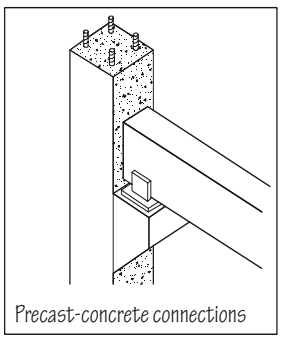

Point connector: bolt

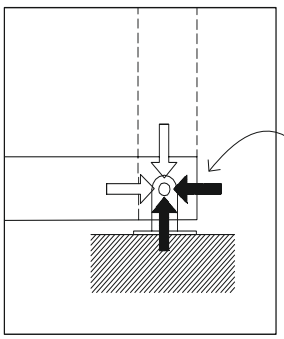

Fillet weld


Surface connector: glue

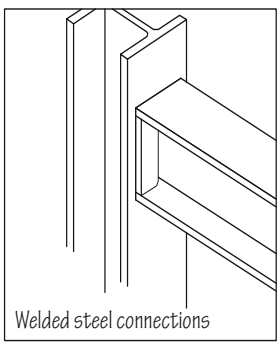
The connectors used to join the structural elements may be in the form of a point, a line or a surface. While linear and surface types of connectors resist rotation, point connectors do not unless a series of them is distributed across a large surface area.

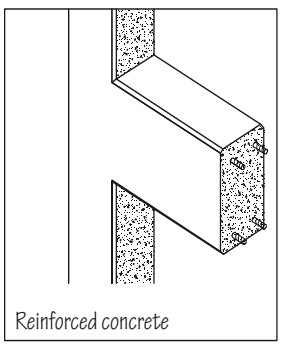

Bolted connections

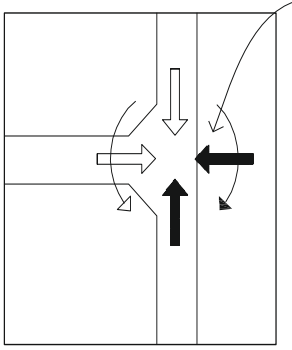

Precast-concrete connections



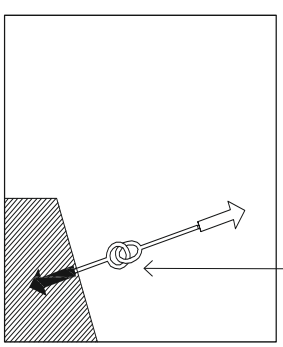
Pinned joints theoretically allow rotation but resist translation in any direction

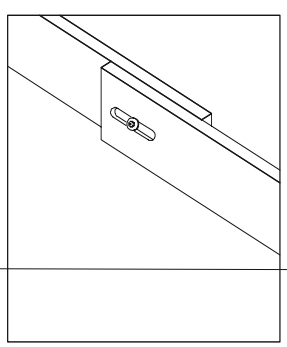

Welded steel connections

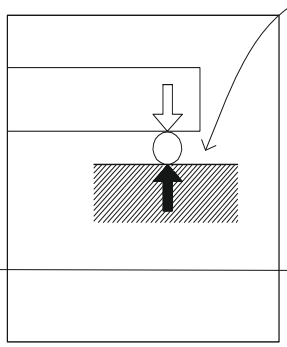

Reinforced concrete



Rigid or fixed joints maintain the angular relationship between the joined elements, restrain rotation and translation in any direction, and provide both force and moment resistance







Roller joints allow rotation but resist translation in a direction perpendicular into or away from their faces. They are not employed in building construction as often as pinned or fixed connections but they are useful when a joint must allow expansion and contraction of a structural element to occur

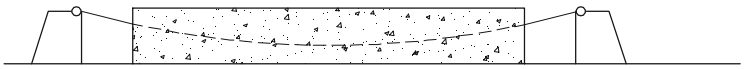
A cable anchorage allows rotation but resists translation only in the direction of the cable

EN Eurocode 3: Design of Steel Structures, Part 1-8, General Design of Joints

- The extremely high-strength steel tendons may be in the form of wire cables, bundled strands or bars



- Unstressed steel tendons, draped inside the beam or slab form, are coated or sheathed to prevent bonding while the concrete is cast. Or a duct is formed in the slab and tendons are passed through and post-tensioned, any voids must be grouted to avoid corrosion of the steel

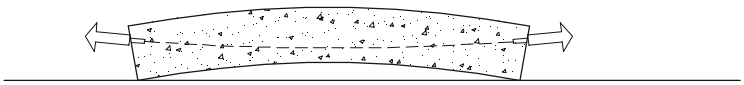


- After the concrete has cured, the tendons are clamped on one end and jacked against the concrete on the other end until the required force is developed

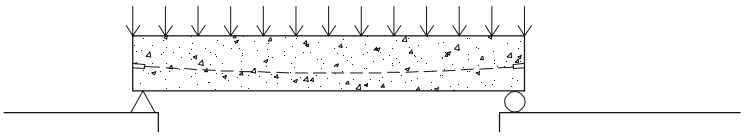
Post-tensioning

Post-tensioning is the prestressing of a concrete member by tensioning the reinforcing tendons after the concrete has set.

- Post-tensioned members tend to shorten over time due to elastic compression, shrinkage and creep. Adjoining elements that would be affected by this movement should be constructed after the post-tensioning process is completed and be isolated from the post-tensioned members with expansion joints



- The tendons are then securely anchored on the jacking end and the jack removed. After the post-tensioning process, the steel tendons may be left unbonded, or they may be bonded to the surrounding concrete by injecting grout into the annular spaces around the sheathed strands

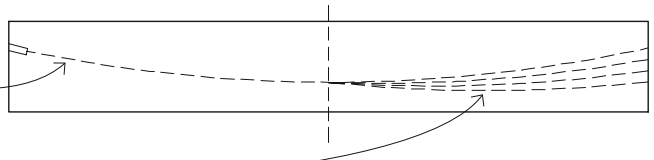


- The deflection of the member under loading tends to equalise its upward curvature

- Load balancing is the concept of prestressing a concrete member with draped tendons, theoretically resulting in a state of zero deflection under a given loading condition



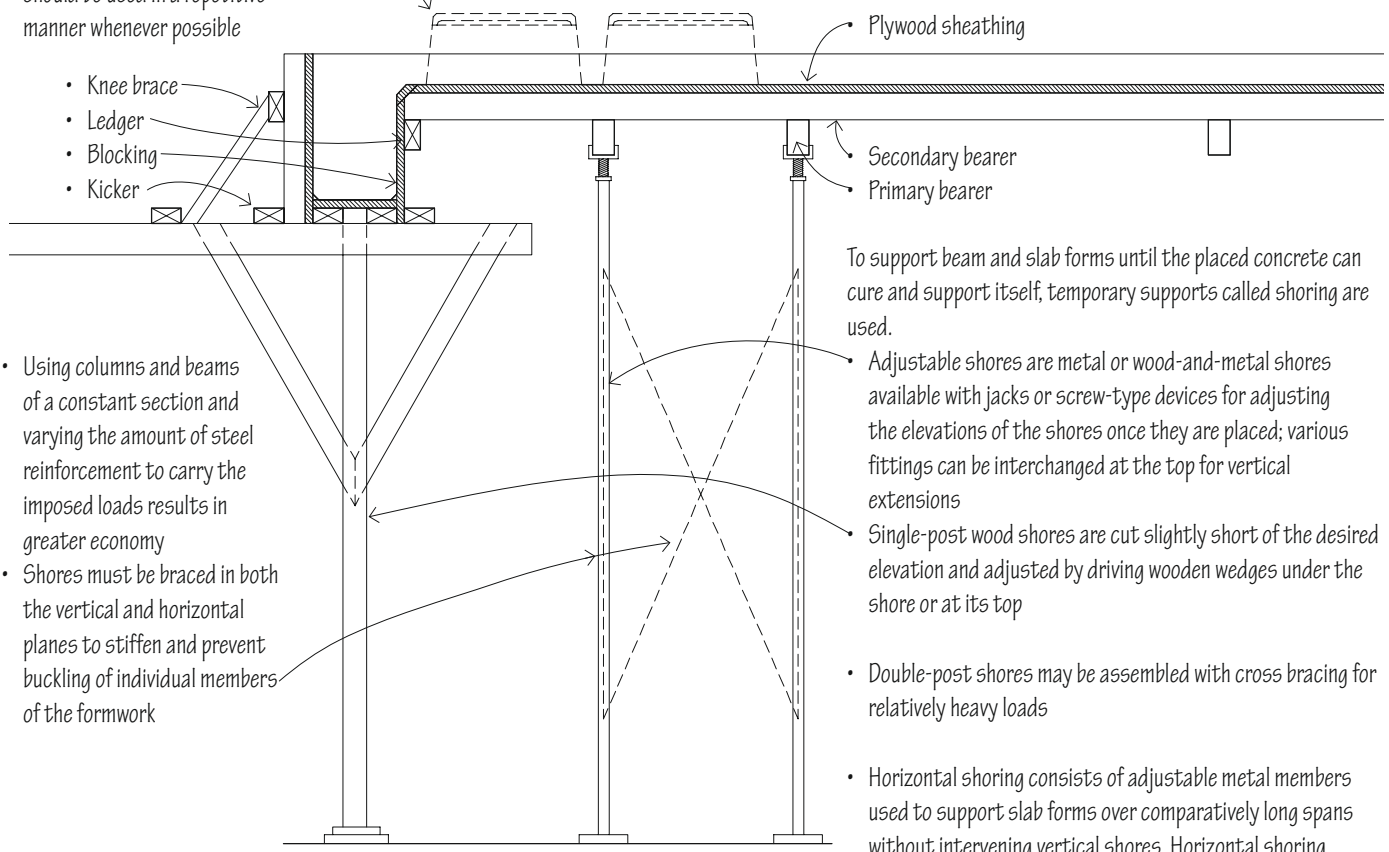
- Draped tendons have a parabolic trajectory that mirrors the moment diagram of a uniformly distributed gravity load. When tensioned, the tendons produce a variable eccentricity that responds to the variation in applied bending moment along the length of the member



- Depressed tendons approximate the curve of a draped tendon with straight-line segments. They are used in the pre-tensioning process because the prestressing force does not allow for draping the tendons. Harped tendons are a series of depressed tendons having varying slopes

Fresh concrete must be shaped and supported by formwork until it cures and can support itself. This formwork is often designed as a separate structural system by an engineer because of the considerable weight and fluid pressure a concrete mass can exert on it.

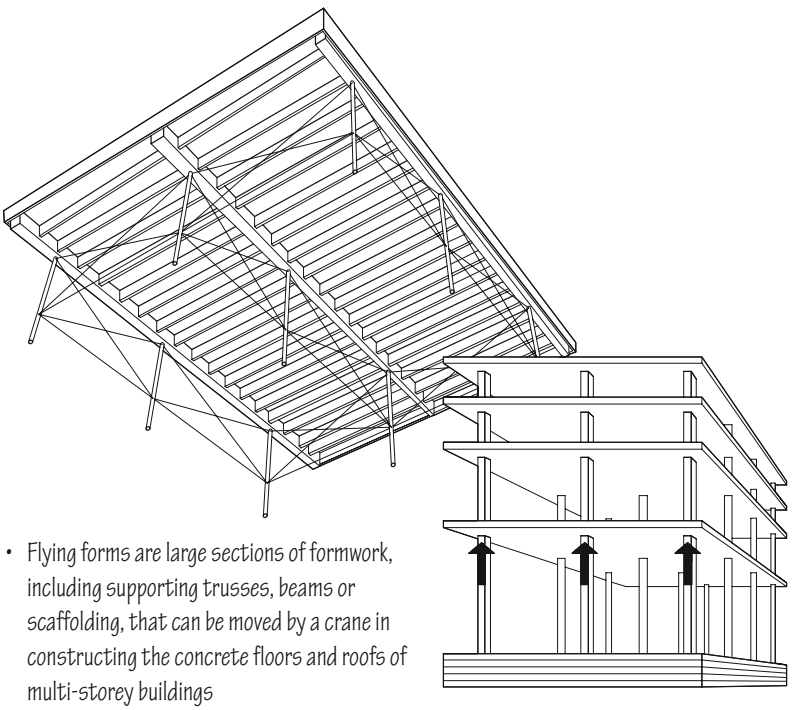
- Proprietary systems are used to form joist and waffle slabs
- For economy, standard forms should be used in a repetitive manner whenever possible



To support beam and slab forms until the placed concrete can cure and support itself, temporary supports called shoring are used.

- Using columns and beams of a constant section and varying the amount of steel reinforcement to carry the imposed loads results in greater economy
- Shores must be braced in both the vertical and horizontal planes to stiffen and prevent buckling of individual members of the formwork

- Adjustable shores are metal or wood-and-metal shores available with jacks or screw-type devices for adjusting the elevations of the shores once they are placed; various fittings can be interchanged at the top for vertical extensions
- Single-post wood shores are cut slightly short of the desired elevation and adjusted by driving wooden wedges under the shore or at its top
- Double-post shores may be assembled with cross bracing for relatively heavy loads
- Horizontal shoring consists of adjustable metal members used to support slab forms over comparatively long spans without intervening vertical shores. Horizontal shoring requires fewer vertical shores, each carrying a comparatively greater load, and leaves open spaces clear for work, but each vertical support carries a greater concentration of load
- After a concrete slab or beam has cured sufficiently to carry its own weight, the original formwork is removed and the slab or beam is reshored until the concrete reaches it full strength
- See 5.07–5.08 for the formwork required for concrete columns and walls



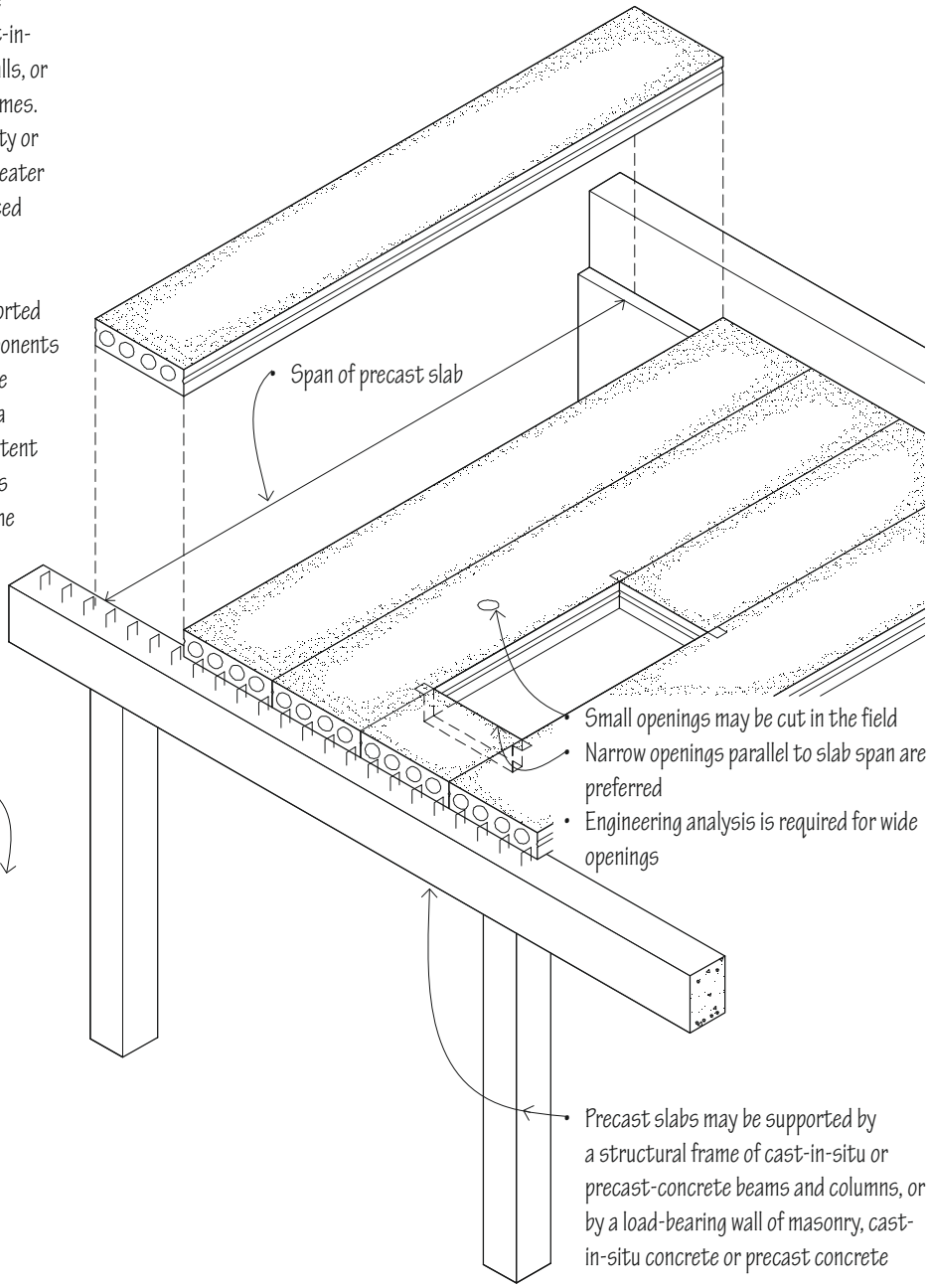
- Flying forms are large sections of formwork, including supporting trusses, beams or scaffolding, that can be moved by a crane in constructing the concrete floors and roofs of multi-storey buildings

- Lift-slab construction is a technique of constructing multi-storey buildings in which all horizontal slabs are cast at ground level and, when cured, are raised into position by hydraulic jacks. The popularity of lift-slab construction has receded in recent years due to safety concerns

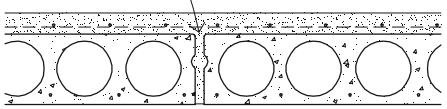
BS EN 5975: 2008 + A1 2011: Code of Practice for Temporary Works Procedures and Permissible Stress Design of Falsework

Precast-concrete slabs, beams and structural tees are one-way spanning units that may be supported by cast-in-situ concrete, precast-concrete or masonry bearing walls, or by steel, cast-in-situ concrete or precast-concrete frames. The precast units are manufactured with normal-density or structural lightweight concrete and prestressed for greater structural efficiency, which results in less depth, reduced weight and longer spans.

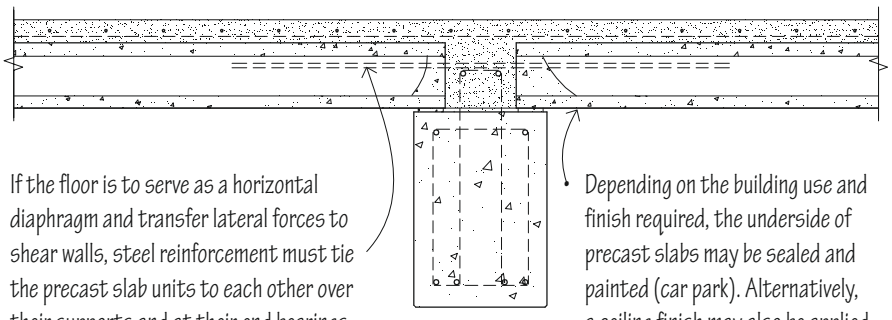
The units are cast and cured in a plant off-site, transported to the construction site, and set in place as rigid components with cranes. The size and proportion of the units may be limited by the means of transportation. Fabrication in a factory environment enables the units to have a consistent quality of strength, durability and finish, and eliminates the need for on-site formwork. The modular nature of the standard-sized units, however, may not be suitable for irregular building shapes.



- A 75–150 mm concrete topping reinforced with steel fabric or reinforcing bars bonds with the precast units to form a composite structural unit
- Grout key



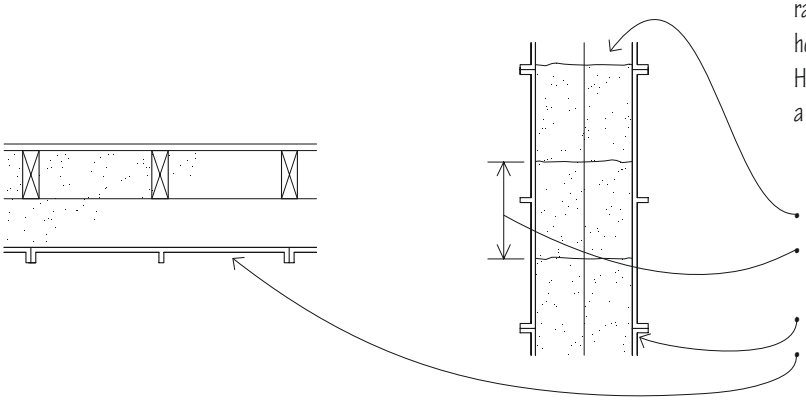
- The topping also conceals any surface irregularities, increases the fire-resistance rating of the slab, and accommodates underfloor conduit for wiring



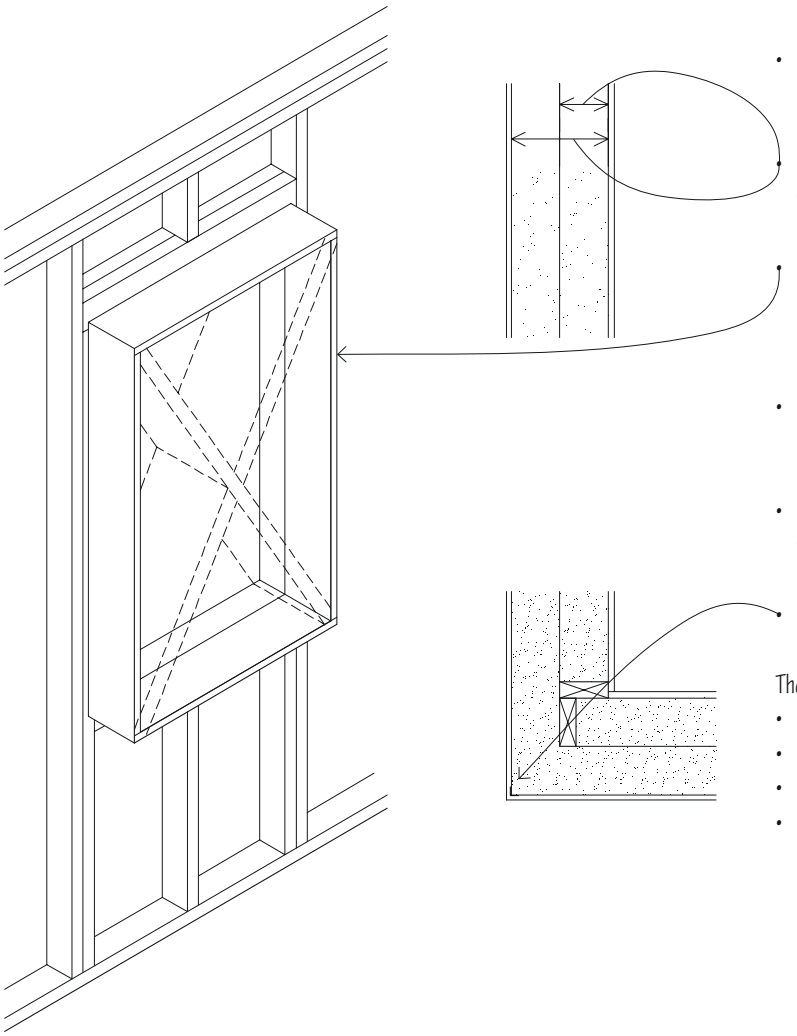
- If the floor is to serve as a horizontal diaphragm and transfer lateral forces to shear walls, steel reinforcement must tie the precast slab units to each other over their supports and at their end bearings

- Depending on the building use and finish required, the underside of precast slabs may be sealed and painted (car park). Alternatively, a ceiling finish may also be applied to the slab or a suspended ceiling installed to conceal services (office)

Hemp shiv used in conjunction with a lime-based binder in the ratio of 5:1, when combined with small amounts of water, forms a hemp lime which can be cast into wall, floor or roof constructions. Hempcrete is non-load-bearing so must be used in conjunction with a structural system such as a timber frame.



- Timber frame construction as load-bearing element
- Built up in layers of 200–300 mm and lightly 'tamped' (over tamping can reduce thermal performance)
- Double temporary shuttering or:
- Permanent internal shuttering and temporary external shuttering



- System becomes self supporting after 24 hours and temporary shuttering can be removed
- Finish with lime-based render to ensure build-up retains its 'breathability'

- Wall thickness ranges from 300 to 500 mm to meet suitable thermal requirements

- Hempcrete is a lightweight material, generally other than permanent shuttering no additional load-bearing elements are required around openings

- Where openings are being formed, temporary propping may be required during the casting process

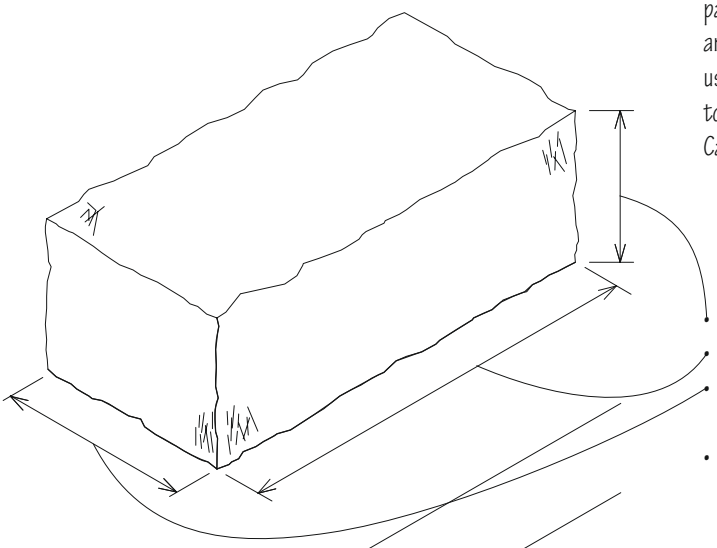
- Building loads should be transferred in the normal way through the supporting structural frame

- Stainless-steel bead to form sharp corner

The advantages of hempcrete include:

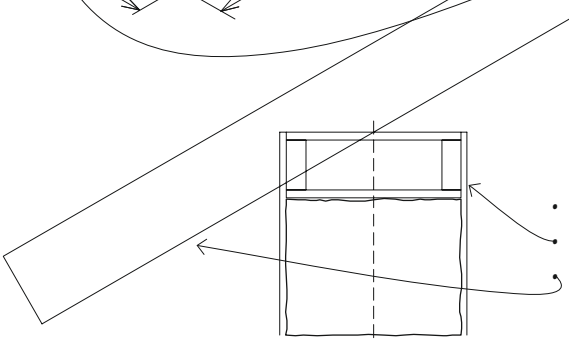
- Increased thermal performance with minimal thermal bridging
- Vapour open construction; see 7.46
- Relatively low-tech and inexpensive solution
- Carbon neutral

As a construction material the use of straw bale provides a low-impact thermally-efficient material which is often available locally. The modular straw bales can be used directly as a construction material for walls or as part of a prefabricated system. In non-load-bearing scenarios straw bales are often used as infill material in a timber frame. Straw bale can also be used in lightly loaded situations up to two storeys in height. It is important to ensure the bales are kept in a state of compression to maintain stability. Careful detailing is required to avoid moisture-related damage.

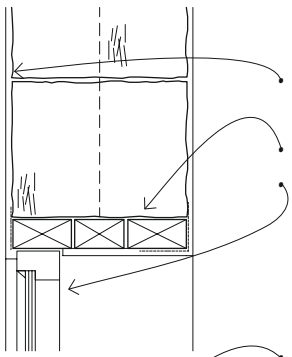


- Typical height 350–400 mm
- Typical length 950–1050 mm
- Typical width 400–500 mm

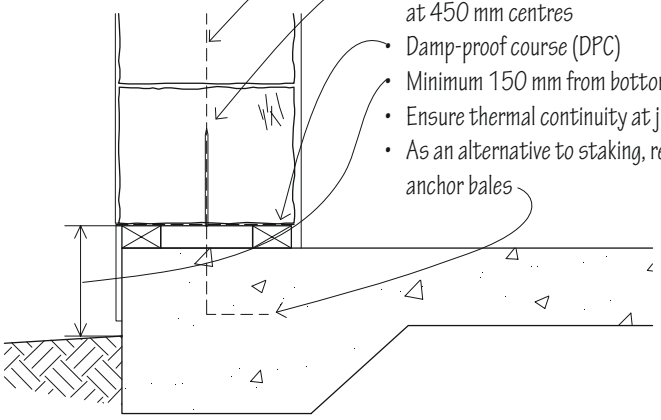
- Ensure bales are tightly bound with a non-degrading material and allowances are made for the likely variation in bale dimensions



- Box beam formed at top of wall to take roof structure
- Alternatively roof structure rests on timber frame in infill construction
- Deep roof overhang to give protection from driven rain



- Lime render or alternative vapour-open finish to minimise the risk of moisture build-up in the construction
- Timber beams to window head
- Window towards the front of the reveal to reduce the risk of water ingress

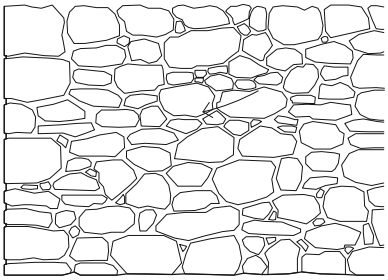


- Hazel stakes driven into wall to improve stability
- Timber stake fixed to slab or rising wall to anchor first course of straw bale at 450 mm centres
- Damp-proof course (DPC)
- Minimum 150 mm from bottom of bale to ground
- Ensure thermal continuity at junction of rising wall and straw bale
- As an alternative to staking, reinforcing bar can be cast into the slab to anchor bales

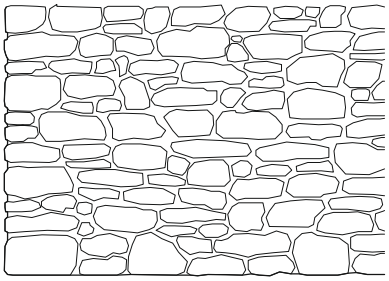
Natural stone is a durable, weather-resistant construction material that may be laid in mortar much like clay and concrete masonry units to make both bearing and non-bearing walls. Some differences result, however, from the irregular shapes and sizes of rubble, the uneven coursing of ashlar masonry, and the varying physical properties of the different types of stone that may be used in the wall construction.

Natural stone may be bonded with mortar and laid up in the traditional manner as a double-faced load-bearing wall. More often, however, stone is used as a facing veneer tied to a concrete or masonry back-up wall. To prevent discoloration of the stone, only non-staining cement and non-corrosive ties, anchors and flashing should be used. Copper, brass and bronze may stain under certain conditions.

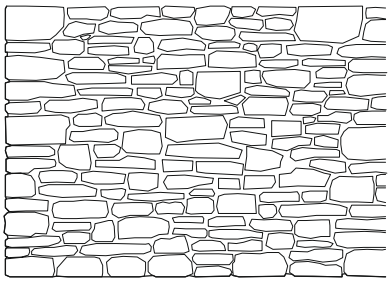
- See 7.27 for stone veneer walls
- See 12.10 for a discussion of stone as a construction material



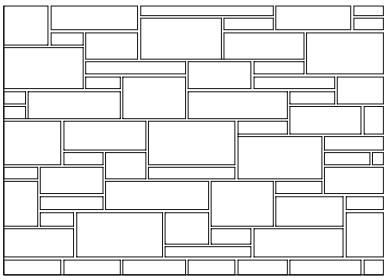
- Random rubble is a masonry wall of broken stones having discontinuous but approximately level beds or courses. The mortar joints are usually held back from the stone faces to emphasise the natural stone shapes



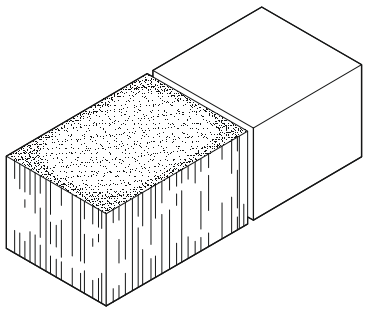
- Coursed rubble is a masonry wall of broken stones having approximately level bed joints and brought at intervals to continuous level courses
- 12–40 mm face joints



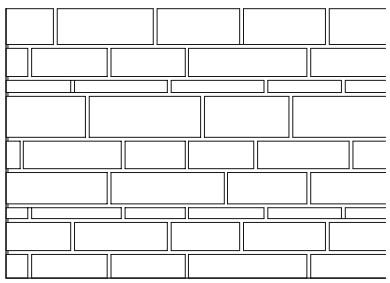
- Squared rubble is a masonry wall built of squared stones of varying sizes and coursed at every third or fourth stone



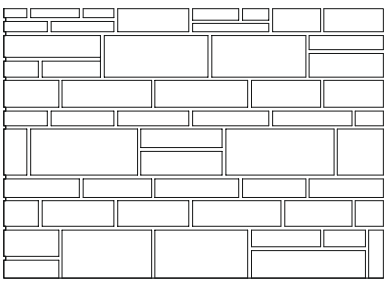
- Random ashlar is built with stones in discontinuous courses



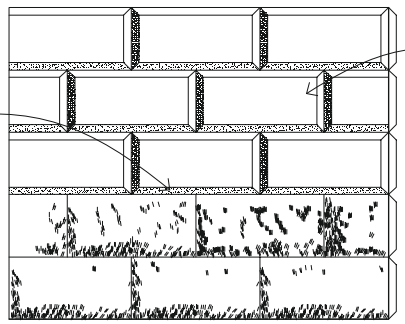
- Ashlar refers to cut building stone finely dressed on all faces adjacent to those of other stones so as to permit very thin mortar joints



- Coursed ashlar is built of stones having the same height within each course, but with each course varying in height

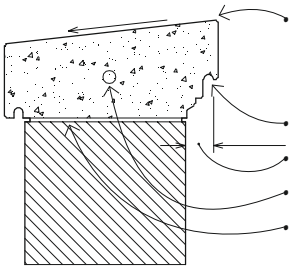


- Broken rangework is ashlar masonry laid in horizontal courses of varying heights, any one of which may be broken at intervals into two or more courses



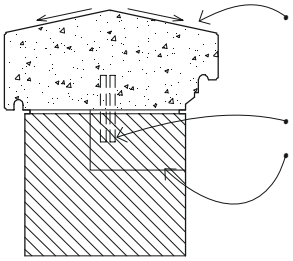
- 10–19 mm face joints

- Rustication is masonry having the visible faces of the dressed stones raised or otherwise contrasted with the horizontal and usually the vertical joints, which may be rabbeted, chamfered or bevelled



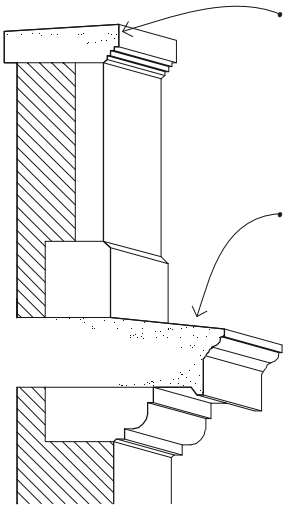
Splayed copings slope only in one direction

Drip on each side
38 mm minimum
Centre dowel
Damp-proof course (DPC)



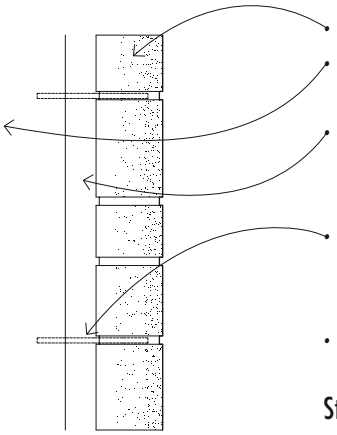
Saddle copings slope to either side of a centre ridge

Two vertical dowels per stone
Stepped DPC



Copestones form a coping, the finishing or protective course to an exterior wall, usually sloped or curved to shed water

Dripstone is a stone moulding used as a drip, as on a cornice over a window or doorway



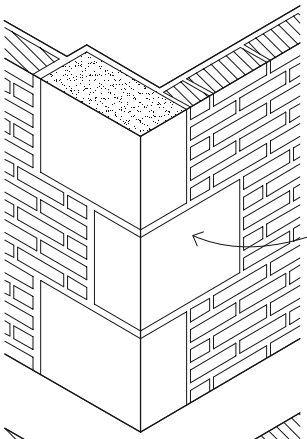
Stone facing; 100 mm minimum
Masonry or reinforced-concrete back-up leaf

The position of the insulation zone in this build-up needs careful consideration

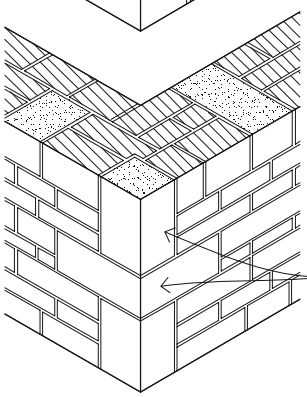
Non-corrosive metal ties or anchors in dovetail slots

- See 7.27 for stone veneer walls

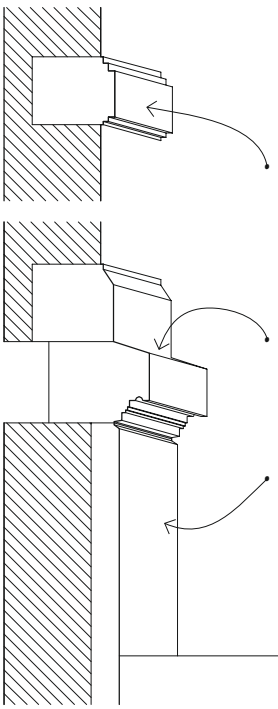
Stone Masonry over a Back-up Wall



Quoin refers to an exterior angle of a masonry wall, or one of the stones or bricks forming such an angle, usually differentiated from adjoining surfaces by material, texture, colour, size or projection



Long-and-short work is an arrangement of rectangular quoins or jambstones set alternately horizontally and vertically

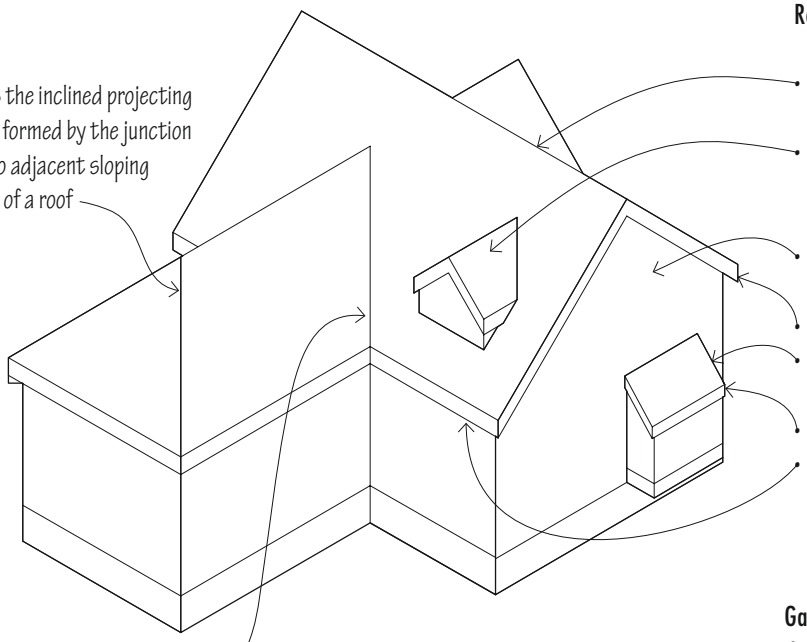


String course is a horizontal masonry course flush with or projecting beyond the face of a building, often moulded to mark a division in the wall. String courses are also known as belt courses

Water table is a projecting string course, moulding, or ledge placed so as to divert rainwater from a building

Plinth is a continuous, usually projecting course of stones forming the base or foundation of a wall

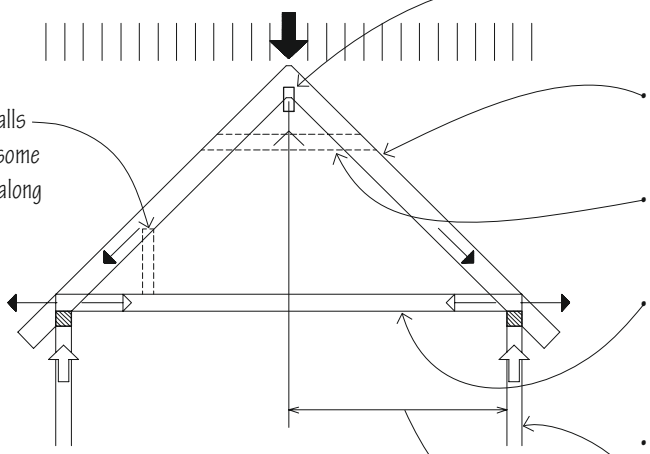
Roof Terminology



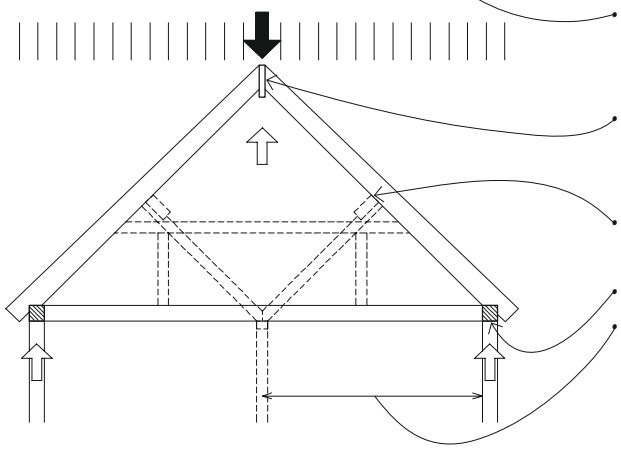
- Hip is the inclined projecting angle formed by the junction of two adjacent sloping sides of a roof
- Valley is an intersection of two inclined roof surfaces towards which rainwater flows
- Ridge is the horizontal line of intersection at the top between two sloping planes of a roof
- Dormers are projecting structures built out from a sloping roof and housing a vertical window or ventilating louvre
- Gable is the triangular portion of wall enclosing the end of a pitched roof from ridge to eaves
- Verge is the inclined, usually projecting edge of a sloping roof
- Lean-to is a roof having a single slope
- Eaves are the overhanging lower edge of a roof
- Soffit is the underside of overhanging roof eaves

Gable Roofs

Gable roofs slope downward in two parts from a central ridge, so as to form a gable at each end.



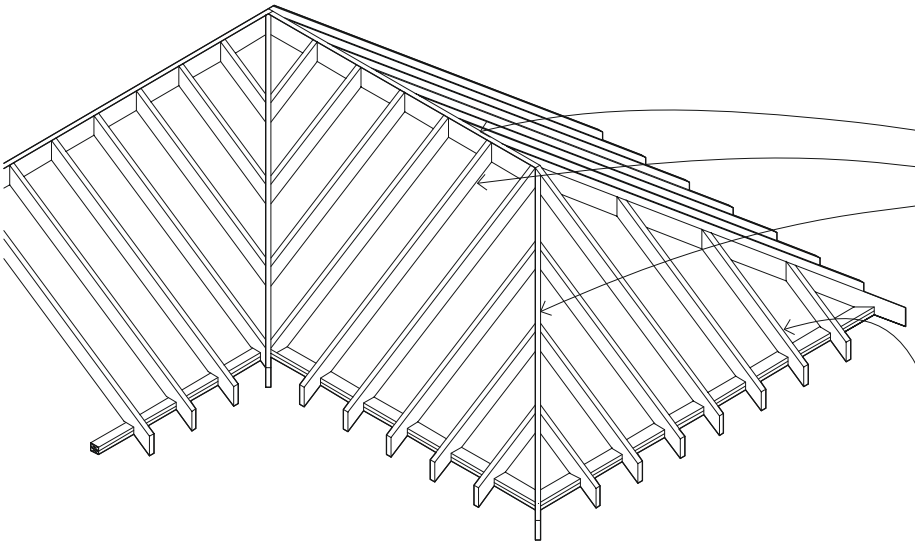
- Knee walls are short walls supporting rafters at some intermediate position along their length
- Ridge beam is a structural horizontal member supporting the upper ends of rafters at the ridge of a roof
- Rafters extend from a wall plate to a ridge board or ridge beam and support the sheathing and covering of a roof
- Collar ties unite two opposing rafters at a point below the ridge, usually in the upper third of the rafter length
- The ties that resist the outward thrust of the rafters may be designed as ceiling joists supporting only attic loads or as floor joists supporting habitable space
- With sufficient headroom, natural light and ventilation, attic space may be habitable
- Load-bearing wall or beam
- Rafter span



- Ridge board is a non-structural horizontal member to which the upper ends of the rafters are aligned and fastened
- A purlin is used to reduce the overall span of the rafters
- Beam or load-bearing wall
- Rafter span

Hipped Roofs

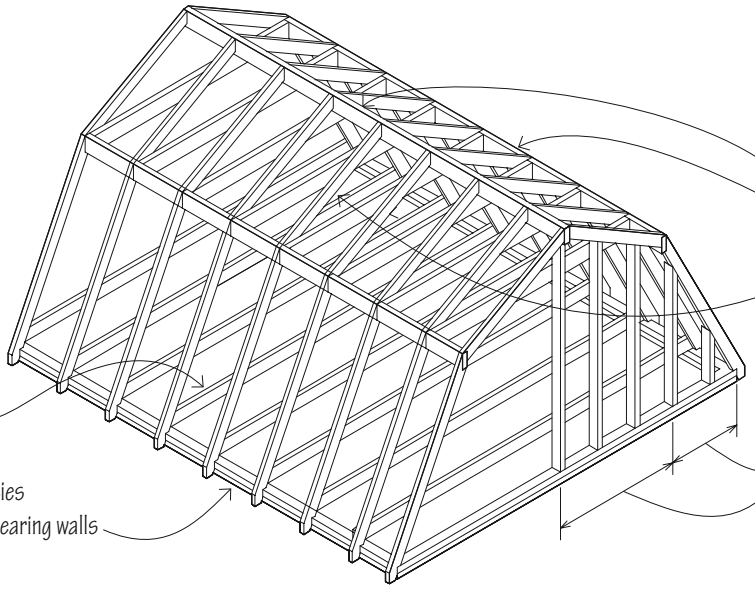
Hipped roofs have sloping ends and sides meeting at an inclined projecting angle.



- Ridge board
- Rafters
- Hip rafters form the junction of the sloping sides of a hip roof
- Jack rafter is any rafter that is shorter than the full length of the roof slope, as one meeting a hip or a valley
- Hip jacks are jack rafters extending from a wall plate to a hip rafter

Mansard Roofs

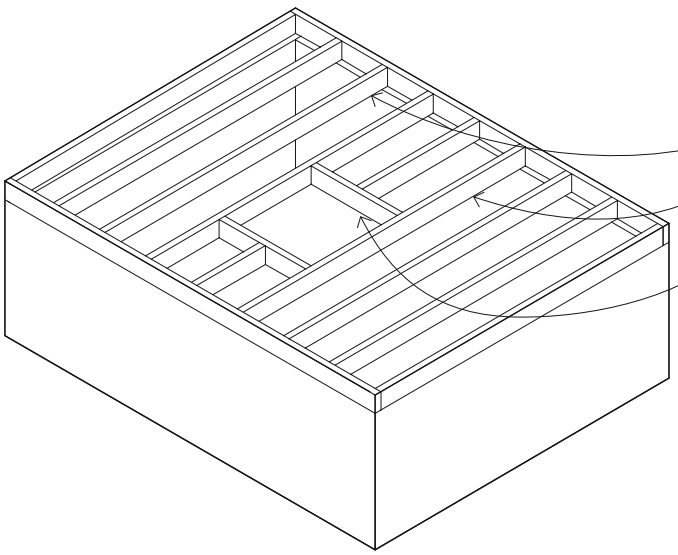
Mansard roofs are divided on each side into a shallower slope above a steeper one.



- Ridge board
- Purlin
- Rafters
- Rafter spans
- Ceiling joists and floor joists serve as rafter ties
- Beams or load-bearing walls

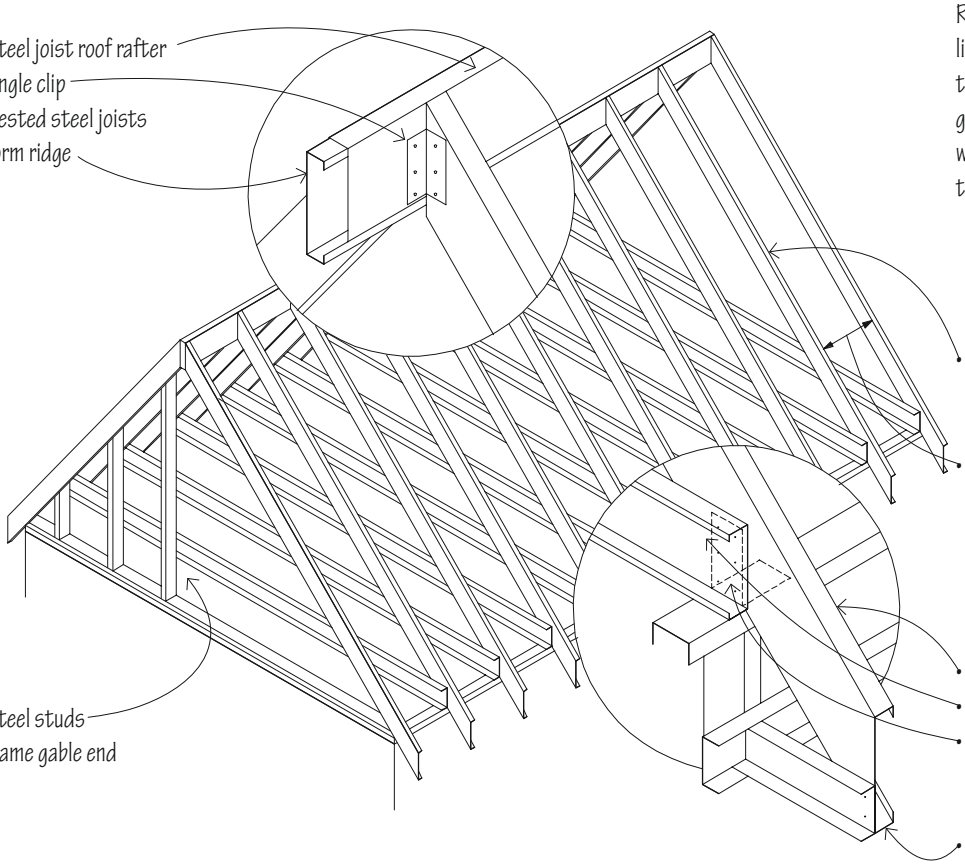
Flat Roofs

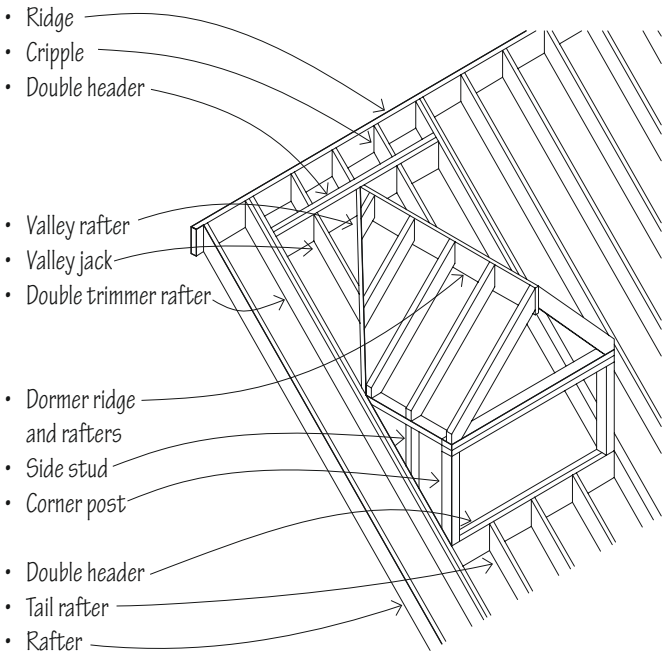
Flat roofs are framed in a manner similar to floor joist framing; see 4.25.



- Roof joists
- Trimmer joist
- Trimming joist to form opening in roof structure
- The required roof slope may be achieved by shortening some of the joist supports and sloping the joists, by tapering the insulating layer of the roof deck or by the use of furring pieces to create a fall

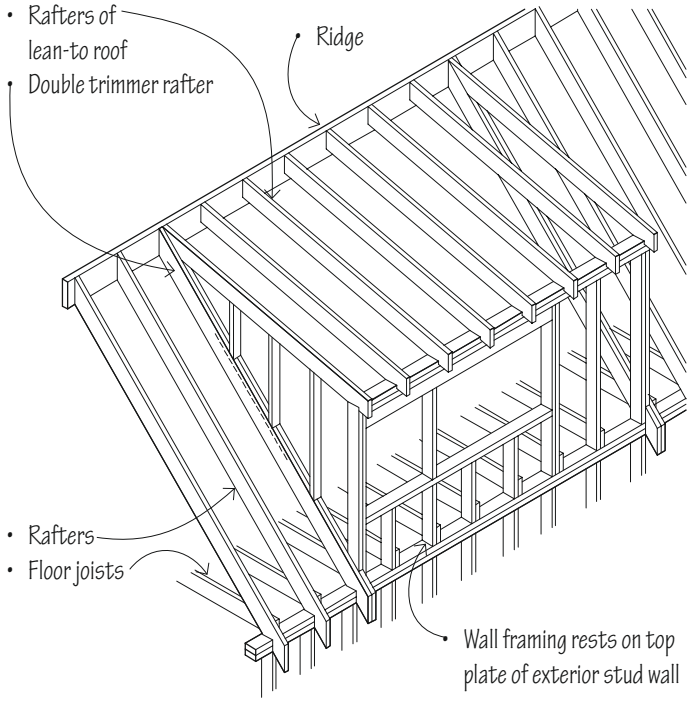
Roofs and ceilings may be constructed with light-gauge steel members in a manner similar to timber light-frame construction. The light-gauge steel members may also be screwed or welded together to form roof trusses similar to those described on 6.24.





• Gable end wall of dormer may also be directly above and be an extension of the exterior wall as illustrated with lean-to dormer

Gable Dormer



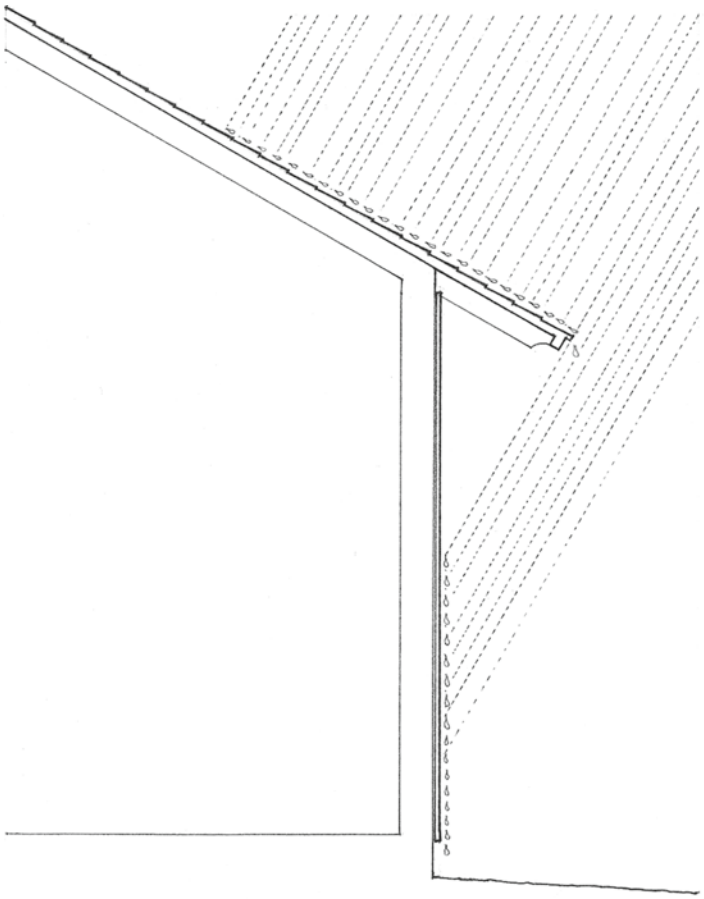
Lean-to Dormer

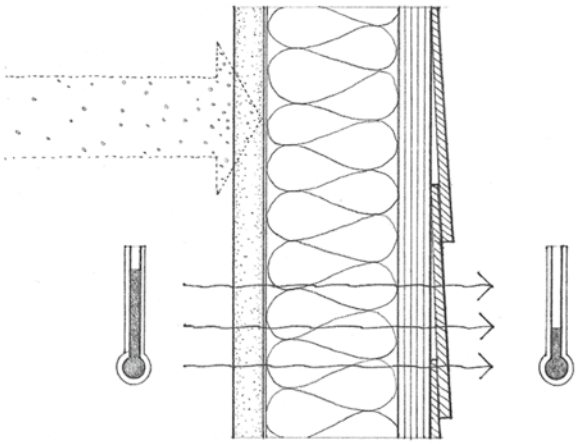
• See 6.16–6.17 for light-frame roof forms and terminology

7

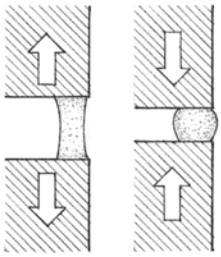
MOISTURE & THERMAL PROTECTION

7.02 Moisture & Thermal Protection
7.03 Slate Roofing
7.04 Tile Roofing
7.05 Green Roofing
7.06 Corrugated-Metal Roofing
7.07 Sheet-Metal Roofing
7.08 Flat Roof Assemblies
7.10 Built-Up Bituminous Roofing Systems
7.11 Single-Ply Roofing Systems
7.13 Roof Drainage
7.14 Flashing
7.15 Roof Flashing
7.17 Flashing Roof Penetrations
7.18 Wall Flashing
7.19 Rainscreen-Wall Systems
7.20 Curtain Walls
7.23 Structural Glazing
7.24 Precast-Concrete Panels
7.25 Masonry Veneer
7.27 Stone Veneer
7.28 Metal Cladding
7.29 Timber-Shingle Cladding
7.30 Horizontal Timber Cladding
7.31 Vertical Timber Cladding
7.32 Render
7.33 Render Details
7.34 External Insulation
7.35 Thermal Insulation
7.36 Thermal Bridging
7.38 Thermal Resistance of Building Materials
7.39 Insulating Materials
7.41 Insulating Roofs & Floors
7.42 Insulating Walls
7.43 Airtightness
7.45 Ventilation
7.46 Moisture Control
7.47 Vapour Barriers
7.48 Radon
7.49 Movement Joints
7.51 Joint Sealants





LEED EA Credit 1: Optimize Energy Performance
BREEAM ENE 01: Reduction of CO_2 Emissions



Roofing materials provide the water-resistant covering for a roof system. They range in form from virtually continuous, impervious membranes to overlapping or interlocking tiles. The type of roofing that may be used depends on the pitch of the roof structure. While a sloping roof easily sheds water, a flat roof must depend on a continuous waterproof membrane to contain the water while it drains or evaporates. A flat roof as well as any well-insulated sloping roof capable of retaining snow may therefore have to be designed to support a greater live load than a moderately- or high-pitched roof. Additional factors to consider in the selection of a roofing material include requirements for installation, maintenance and durability, resistance to wind and fire, and, if visible, the roofing pattern, texture and colour.

To prevent water from leaking into a roof assembly and eventually the interior of a building, flashing must be installed along roof edges, where roofs change slope or abut vertical planes, and where roofs are penetrated by chimneys, vent pipes and skylights. Exterior walls must also be flashed where leakage might occur – at door and window openings and along joints where materials meet in the plane of the wall.

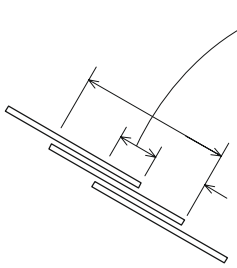
Exterior walls also must provide protection from the weather. While some exterior wall systems, such as solid masonry and concrete load-bearing walls, use their mass as barriers against the penetration of water into the interior of a building, other wall systems, such as cavity walls and curtain walls, utilise an interior drainage system to carry away any moisture that finds its way through the facing or cladding.

Moisture is normally present in the interior spaces of a building in the form of water vapour. When this water vapour reaches a surface cooled by heat loss to the colder outside air, condensation may occur. This condensation may be visible, as on an uninsulated window pane, or it can collect in concealed roof, wall or floor spaces. Means of combating condensation include the correct placement of thermal insulation and vapour barriers, and the ventilation of concealed spaces, such as attics and sub-floors.

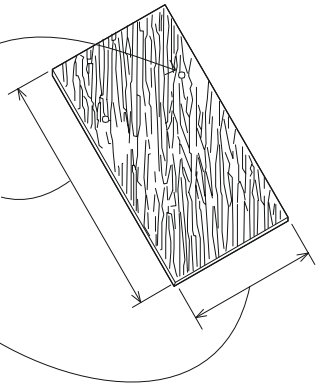
Potential heat loss or gain through the exterior enclosure of a building is an important factor when estimating the amount of mechanical equipment and energy required to maintain the desired level of environmental comfort in the interior spaces. The proper selection of building materials, the correct construction and insulation of the building enclosure and the orientation of a building on its site are the basic means of controlling heat loss and gain.

Building materials expand and contract due to variations within the normal temperature range, as well as exposure to solar radiation and wind. To allow for this movement and help relieve the stresses caused by thermal expansion and contraction, expansion joints should be flexible, weathertight, durable and correctly placed to be effective.

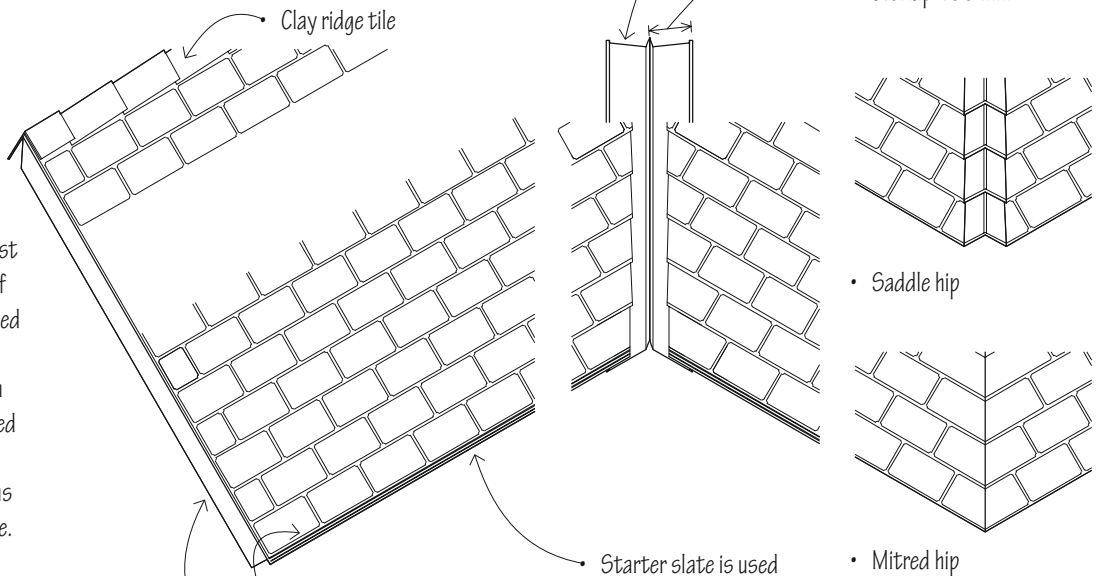
Slate is an extremely durable, fire-resistant and low-maintenance roofing material. Slates are split, trimmed and drilled to receive copper nails. Slates are traditionally laid using a double lap. Typical roof slopes are 22.5–35°.



- Minimum head lap 80–110 mm
- Side lap equals half the slate width



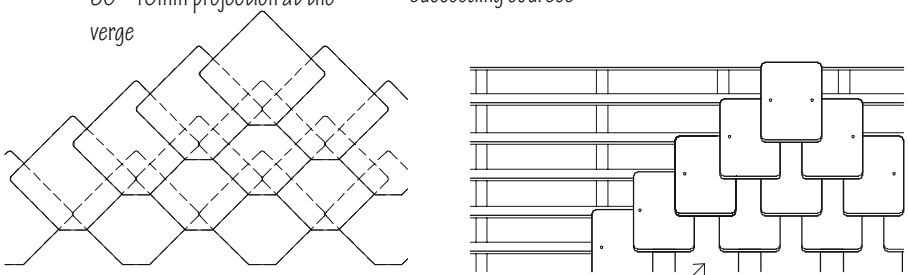
- Two nail holes per slate
- 355–650 mm in length
- Gauge or thickness 4–10 mm
- 250–350 mm wide



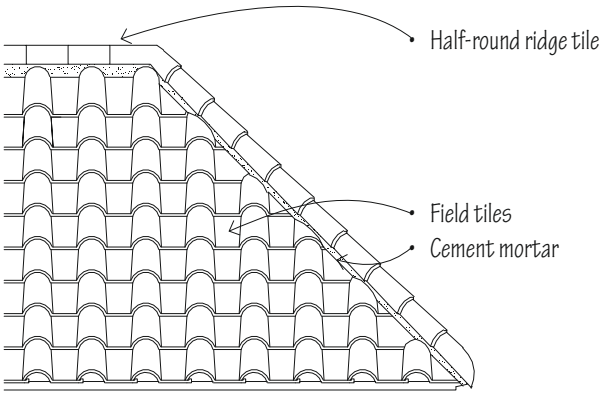
- Code 5 lead flashing
- 280 mm minimum; slate overlap 100 mm
- Clay ridge tile
- Saddle hip
- Mitred hip
- Starter slate is used to give first course the same slope as succeeding courses
- Project 50 mm to form drip at eaves
- 30–40mm projection at the verge

Slate can add a significant dead load to a roof structure, this must be taken into account during roof design. Slates are normally applied over a series of cross battens sitting on the rafters below, with an underlay or sarking sandwiched between. Timber sheeting is now often applied below cross battens to provide a solid working surface.

- Roof underlay traditionally known as sarking can be made from felt, polypropylene, polyethylene and other similar materials. It acts as a weathering layer, offering additional protection to the roof finish during the construction phase. Modern underlay is often vapour open minimising condensation risk



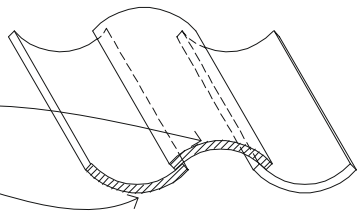
- Open or spaced slating is a method of laying roofing slates with spaces between adjacent tiles in a course



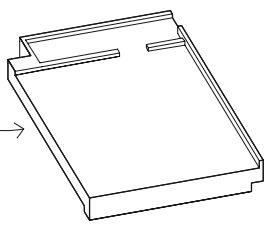
Roofing tiles are clay or concrete units that overlap or interlock to create a strong textural pattern. Like slate, roofing tiles are fire-resistant, durable and require little maintenance. They are also heavy and require roof framing that is strong enough to carry the weight of the tiles. Roofing tiles are normally installed over a solid plywood deck with a roofing underlay and cross battens. Special tile units are used at ridges, hips, verge and eaves.

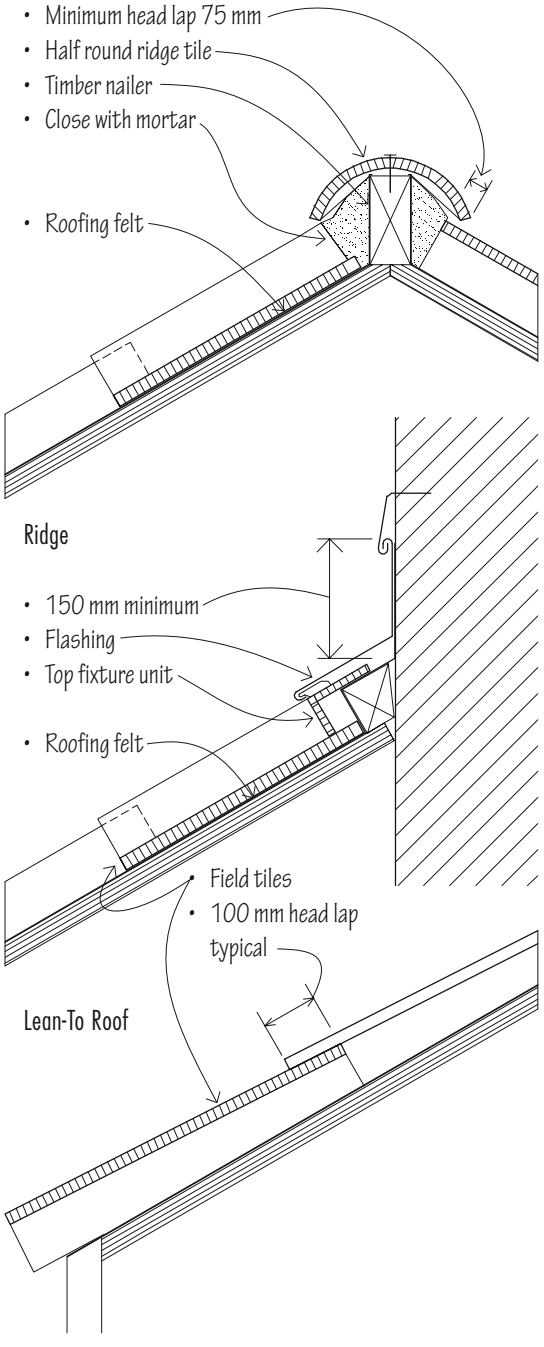
The following are typical types, dimensions and weights of clay tiles. Confirm sizes, weights and installation details with tile manufacturer.

- Traditional Mission or Spanish tiles popular in Mediterranean regions are tapered, semi-cylindrical roofing tiles laid convex side up to overlap flanking, similar tiles laid concave side up
- Imbrex laid convex side up; tegula laid concave side up
- Taper allows tiles to nest into the overlapping tiles



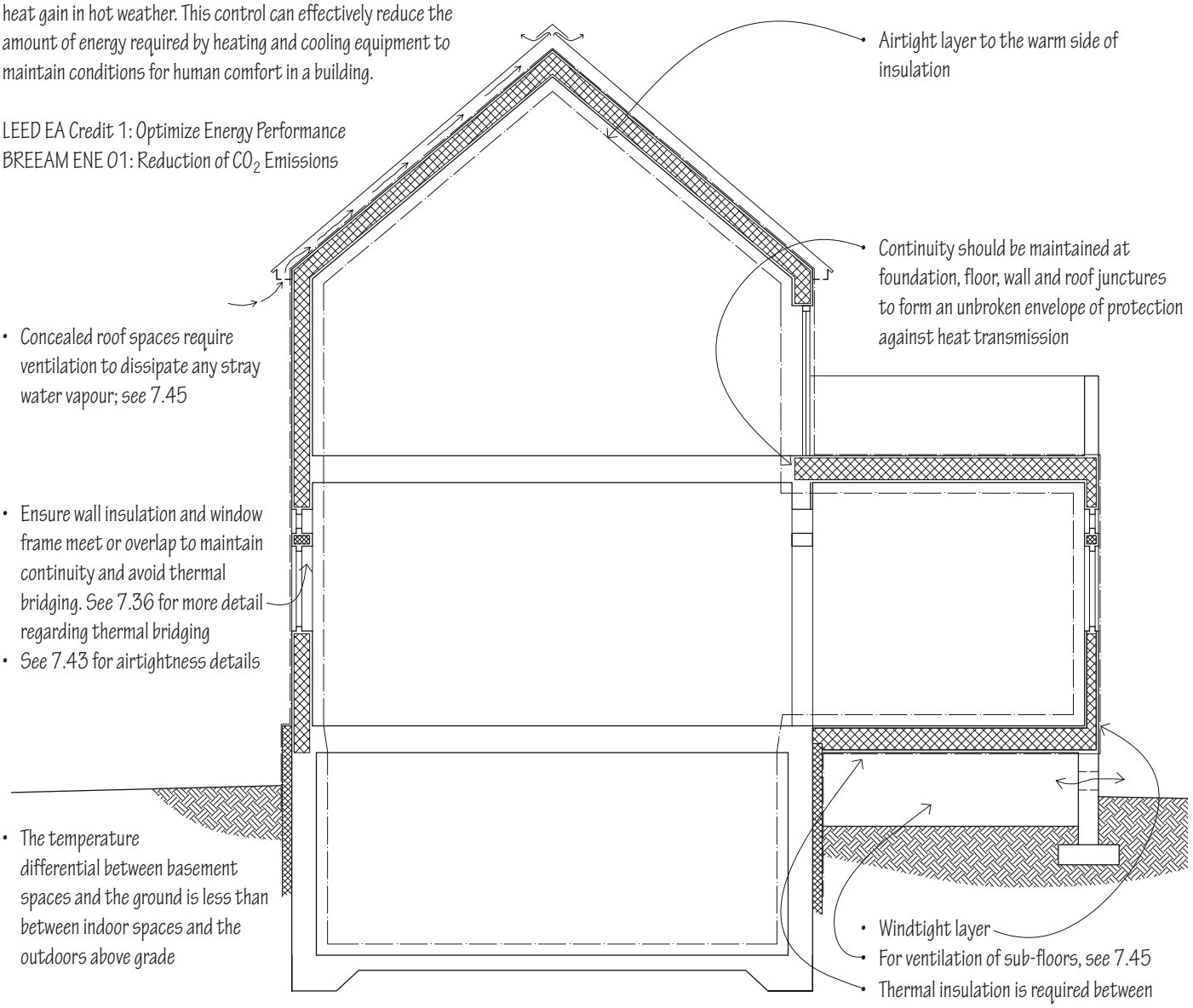
- Interlocking tiles are flat, rectangular single lap roofing tiles having a groove along one edge that fits over a flange in the next tile in the same course
- Minimum recommended slope – 22.5° or manufacturer's minimum recommendation





The primary purpose of thermal insulation is to control the flow or transfer of heat through the exterior assemblies of a building and thereby prevent excessive heat loss in cold seasons and heat gain in hot weather. This control can effectively reduce the amount of energy required by heating and cooling equipment to maintain conditions for human comfort in a building.

LEED EA Credit 1: Optimize Energy Performance
BREEAM ENE 01: Reduction of CO_2 Emissions

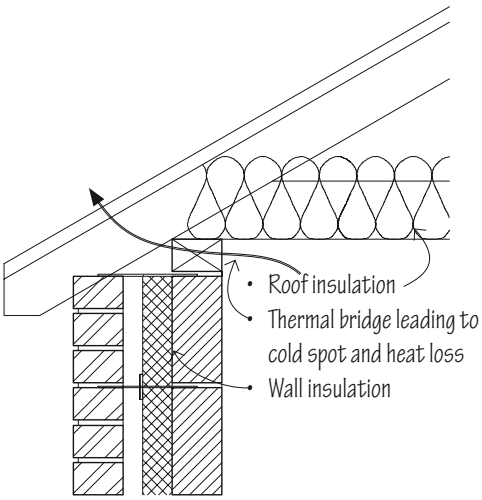


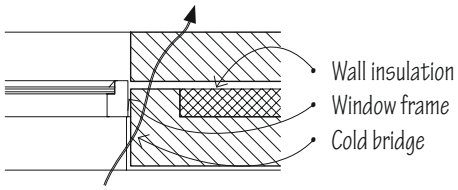
Recommended Minimum U-Values for Building Elements (W/m^2K)

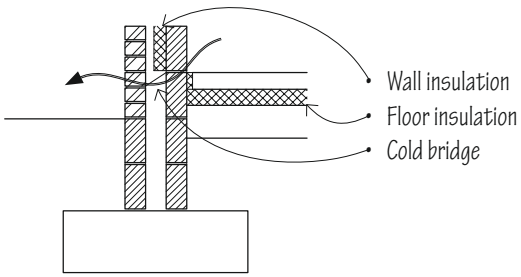
Element	Flat Roof	Pitched Roof	Wall	Floor	Window	Rooflight	Door
Minimum Domestic	0.16	0.13	0.20	0.25	1.80	2.00	2.00
Minimum Commercial	0.25	–	0.30	0.25	2.00	2.20	2.20
Passive House Standard*	0.15	0.08	0.15	0.15	0.80	–	0.80

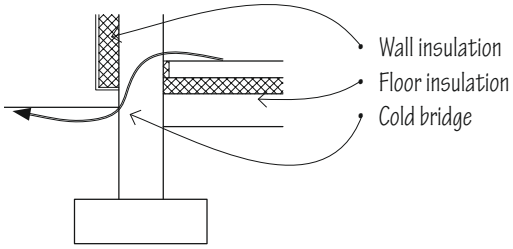
Use these U-values for preliminary design purposes only. Consult local building regulations and/or relevant standards for more specific guidance.
*Passive House Institute (2013)

- For a discussion of the factors that affect human comfort, see 11.03
- For siting factors that also affect potential heat loss or gain, see Chapter 1
- For discussion concerning airtightness, see 7.43
- For discussion regarding thermal bridging, see 7.36

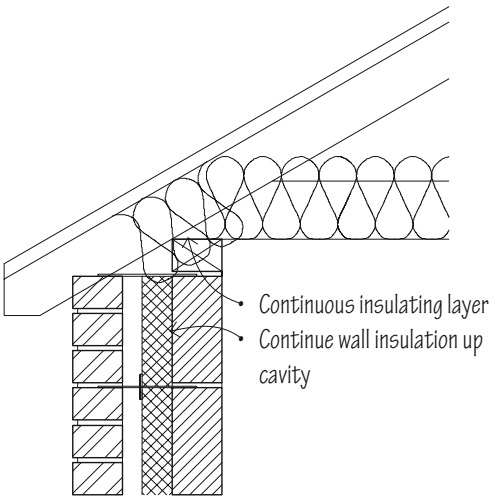


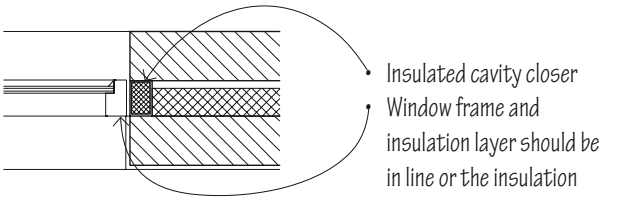


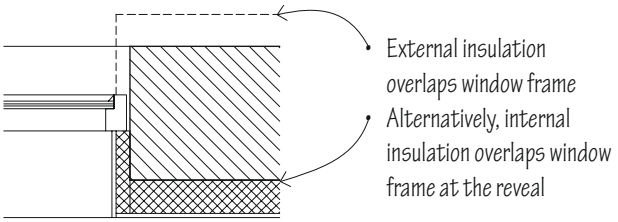


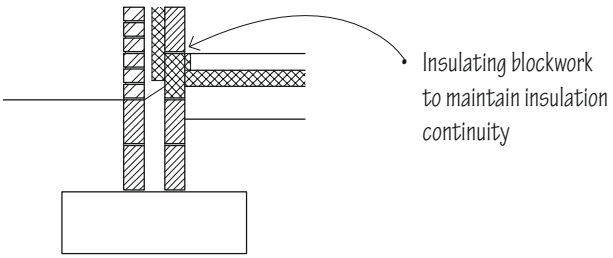


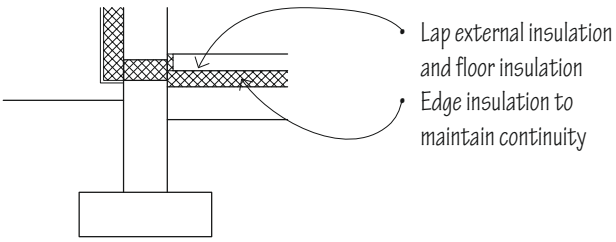
Thermal Bridging Occurrence











Thermal Bridging Solution

Material	Thermal Conductivity (W/mK)
Concrete	
Cast – dense	1.40
Cast – lightweight	0.38
Masonry	
Brickwork – inner leaf	0.62
Brickwork – outer leaf	0.84
Concrete block	
Heavy	1.63
Medium	0.51
Light	0.19
Metal	
Aluminium	200
Brass	132
Copper	394
Lead	35
Steel	50
Timber	
Hard timbers	0.16
Soft timbers	0.12
Plywood	0.13
OSB	0.13
Stone	
Limestone	1.50
Granite	1.70–3.50
Slate	2.00
Sandstone	1.70
Plaster & Gypsum	
Plaster – dense	0.05
Plaster – lightweight	0.16
External render	0.50
Insulation	
Expanded polystyrene	0.035
Extruded polystyrene	0.030
Polyisocyanurate	0.018
Polyurethane	0.030
Sheep's wool	0.040
Mineral wool	0.040
Rockwool	0.045

The tables to the left can be used to estimate the thermal resistance of a construction assembly. For specific k-values of materials consult the product manufacturer.

- k is the thermal conductivity measure of heat flow through a material of 1 m thickness. A material with a lower thermal conductivity will be a better insulator and a high thermal conductivity will be a good conductor and poor insulator. Materials suppliers provide thermal performance information as conductivity

  $k = W/mK$

- R is a measure of thermal resistance of a given material taking into account the thickness of the material. The thickness of a material divided by its conductivity gives its thermal resistance

  $R = W/m^2K$

- R_t is the total thermal resistance for a construction assembly and is simply the sum of the individual R-values of the component materials of an assembly

- U-value (U) is a measure of the thermal transmittance of a building component or assembly. It is expressed as the rate of heat transfer through a unit area of a building component or assembly caused by a difference of one degree between the air temperatures on the two sides of the component or assembly. The U-value for a component or assembly is the reciprocal of its R-value

  $U = 1/R_t$

- Q is the rate of heat flow through a construction assembly and is equal to:

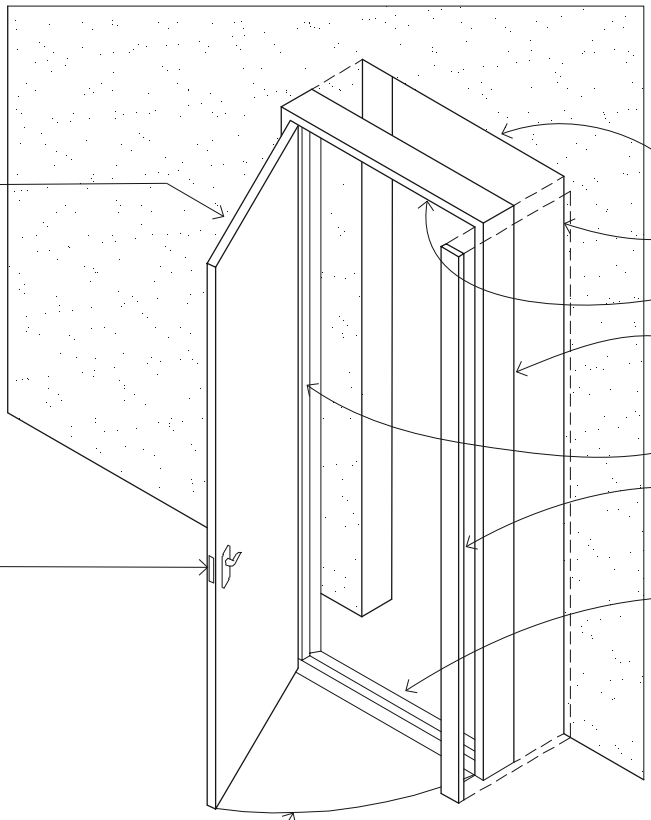
  $U \times A \times (t_i - t_o)$, where:

- U = overall assembly U-value
- A = heat loss area of assembly
- $(t_i - t_o)$ = difference between the inside and outside air temperatures

8

DOORS & WINDOWS

8.02 Doors & Windows
8.03 Doors & Doorways
8.04 Door Operation
8.05 Hollow Metal Doors
8.06 Hollow Metal Door Frames
8.08 Timber Flush Doors
8.09 Timber-Panelled Doors
8.10 Timber Door Frames
8.11 Sliding Glass Doors
8.12 Folding & Pocket Sliding Doors
8.13 Overhead & Roller Shutter Doors
8.14 Glass Entrance Doors
8.15 Shopfronts
8.16 Revolving Doors
8.17 Door Hardware
8.18 Door Hinges
8.19 Door Lock Sets
8.20 Panic Hardware & Closers
8.21 Weatherstripping & Thresholds
8.22 Window Elements
8.23 Window Operation
8.24 Metal Windows
8.25 UPVC & Composite Windows
8.26 Timber Windows
8.28 Glazing Systems
8.30 Glazing Units
8.31 Glazed Curtain Walls
8.34 Skylights
8.35 Skylight Details
8.36 Sunspaces



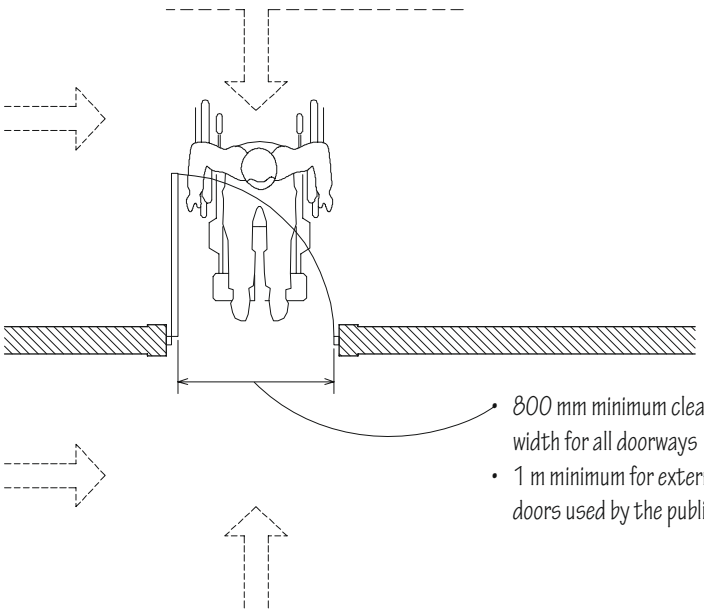
Door Types
- Hollow metal doors and frames; see 8.05–8.07
- Timber doors and frames; see 8.08–8.10

Door Hardware
- Door hardware includes the metal fastenings and fittings required for the operation of a door, such as hinges, lock sets and closers; see 8.17–8.21

Door Operation
- See 8.04

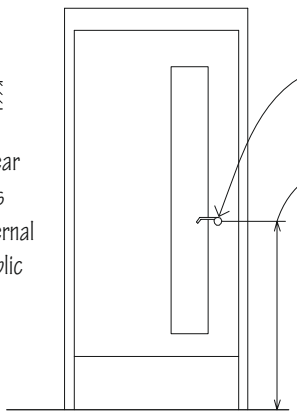
- The detailing of a door frame establishes the appearance of a doorway. Depending on the thickness of the wall construction, a door frame may be set within the structural opening or overlap its edges
- Structural opening is the wall opening into which a door frame is fitted
- Head is the uppermost member of a door frame
- Jamb refers to either of the two side members of a door frame
- Stop is the projecting part of a door frame against which a door closes
- Architrave is the trim that finishes the joint between a door frame and its rough opening
- Threshold is the sill of a doorway, covering the joint between two flooring materials or providing weather protection at an exterior door
- British Standards code of practice 8300 requires a threshold if provided should be no higher than 15 mm and bevelled. Consult local building regulations for specific guidance
- Saddle is a raised piece of flooring between the jambs of a doorway, to which a door fits closely to prevent its binding when opened

Door Frames



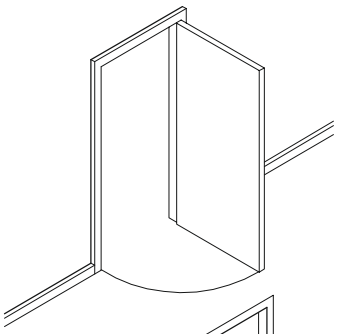
- 800 mm minimum clear width for all doorways
- 1 m minimum for external doors used by the public

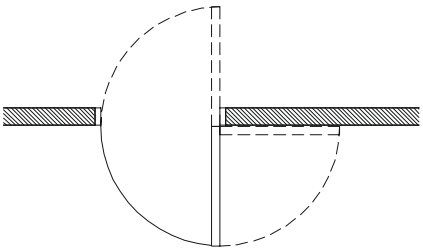
Minimum Clearance at Doorways



- Operating hardware should be easy to grasp with one hand without tight pinching or twisting of the wrist
- 900 mm height to centre of door handle above floor recommended, consult local regulations for maximum and minimum dimensions
- Entrance and lobby doors should incorporate vision panels to prevent accidents

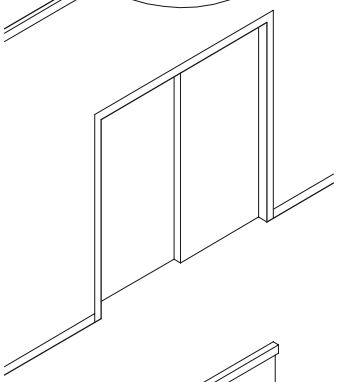
BS 8300:2009 Design of Buildings and their Approaches to Meet the Needs of Disabled People

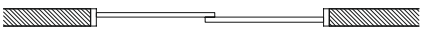




Swinging • Exterior and interior use

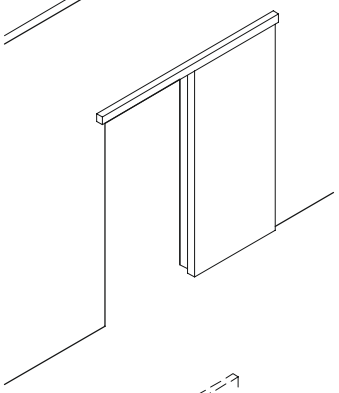
- Door normally turns on hinges about a side jamb when pushed or pulled, but may also be pivoted from head jamb and threshold
- Requires space around doorway for door swing; check clearance required
- Most convenient operation for entry and passage
- Most effective door type for thermal and acoustic insulation and for weather resistance; can be fire-rated





Bypass Sliding • Exterior and interior use

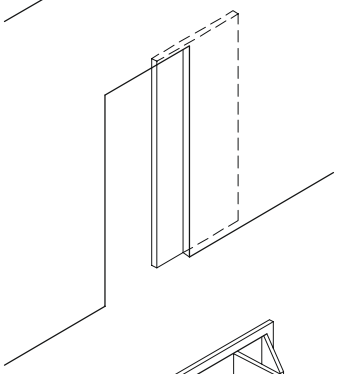
- Doors slide on overhead track and along guides or a track on the floor
- Requires no operating space but is difficult to seal against weather and sound
- Offers access only through 50% of doorway width
- Used on exterior as sliding glass doors
- Used in interiors primarily for visual screening





Surface Sliding • Exterior and interior use

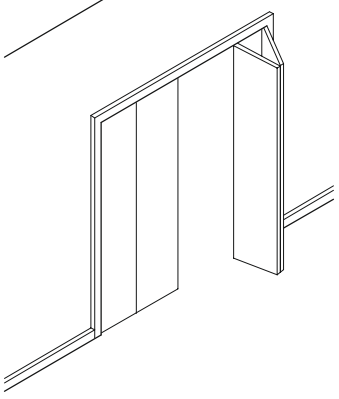
- Similar to a bypass sliding door but provides access through full width of doorway
- No operating space required but is difficult to weatherproof
- Door is surface-hung on an exposed overhead track

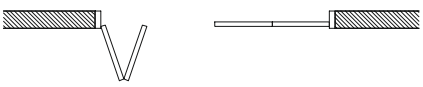




Pocket Sliding • Interior use

- Door slides on an overhead track into and out of a recess within the width of a wall
- Doorway has a finished appearance when fully open
- Often used where a normal door swing would interfere with the use of a space





Folding • Exterior and interior use

- Hinged door panels fold flat against one another when opened
- Bi-fold doors divide into two parts, require little operating space and are used primarily as a visual screen to enclose closet and storage spaces or to create a large opening to an outdoor space
- Accordion doors are multi-leafed doors that are used primarily to subdivide interior spaces. They are hung from an overhead track and open by folding back in the manner of an accordion

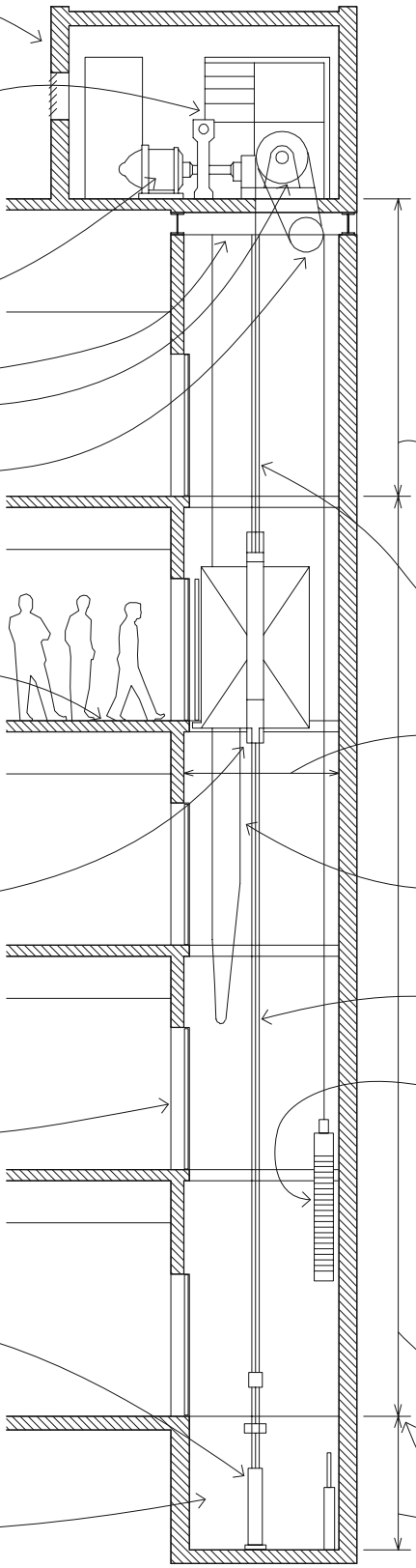
- See 8.16 for revolving doors

Elevators travel vertically to carry passengers, equipment and goods from one level of a building to another. The two most common types are electric elevators and hydraulic elevators.

Electric Elevators

Electric elevators consist of a car that is mounted on guide rails, supported by hoisting cables and driven by electric hoisting machinery in a penthouse. Geared traction elevators are capable of speeds up to 1.75 m/s and are suitable for medium-rise buildings. Gearless traction elevators are available with speeds up to 6 m/s and typically serve high-rise buildings.

- A machine room houses lift machinery located on the rooftop
- A control panel contains switches, buttons and other equipment for regulating the hoisting machinery
- The hoisting machinery for raising and lowering an elevator car consists of a motor-generator set, traction machine, speed governor, brake, driving sheave, and gears, if used
- Heavy steel machine beams support the hoisting machinery for an elevator
- Driving sheave is the hoisting pulley
- Idle sheave tightens and guides the hoisting cables of the elevator system

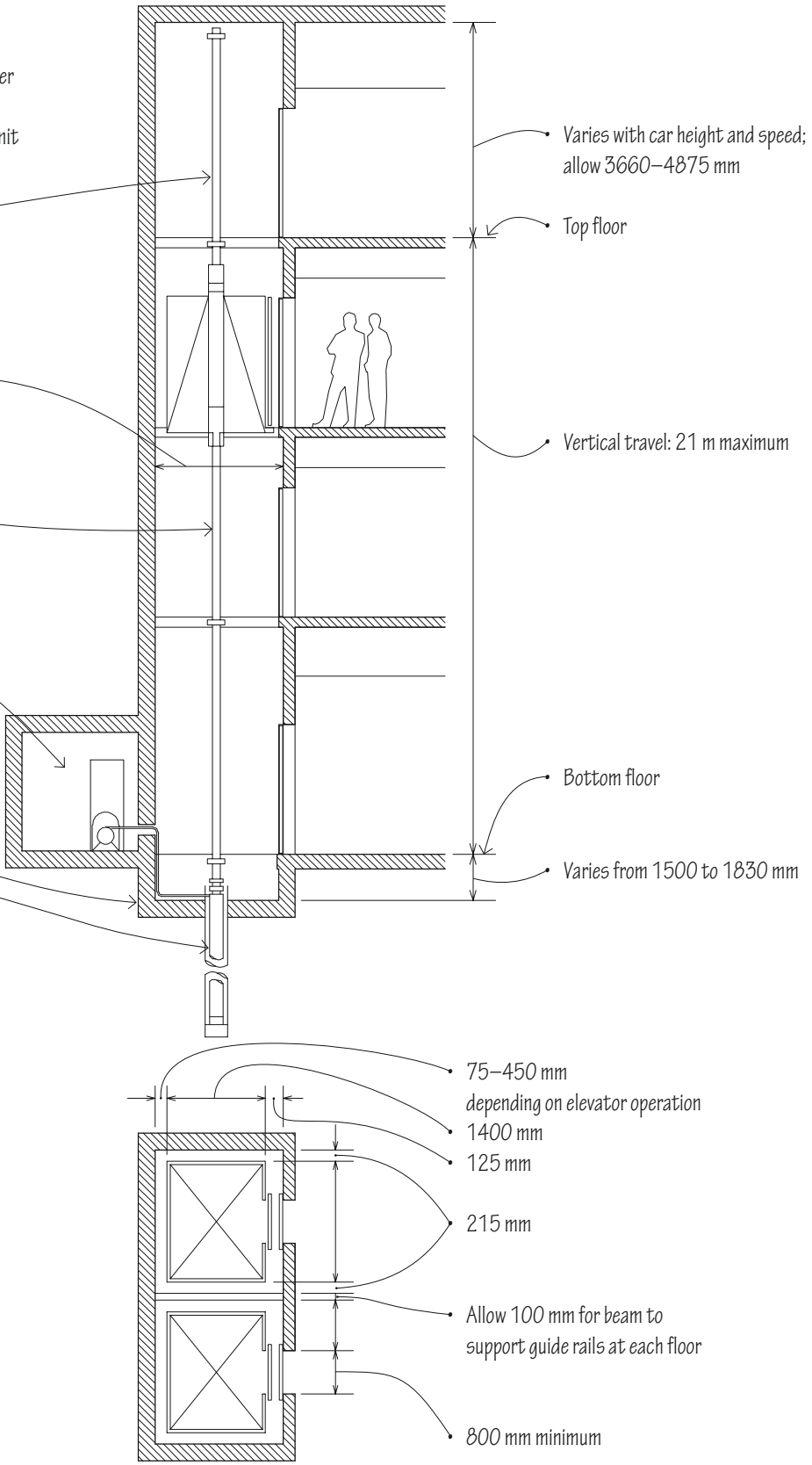


- 4875–6095 mm
- Top floor
- Hoisting cable is one of the wire cables or ropes used for raising and lowering an elevator car
- Landing is the portion of a floor adjacent to an elevator hoistway, used for the receiving and discharge of passengers or goods
- Well is the vertical enclosed space for the travel of one or more elevators
- Elevator car safety is a mechanical device for slowing down and stopping an elevator car in the event of excessive speed or free fall, activated by a governor and clamping the guide rails by a wedging action
- Travelling cable is one of the electric cables connecting an elevator car to a fixed electrical outlet in the hoistway
- Elevator doors between a well and an elevator landing are normally closed except when an elevator car is stopped at the landing; 2100 and 2400 mm heights are typical
- Guide rails are the vertical steel tracks controlling the travel of an elevator car or counterweight; they are secured to each floor with support brackets
- Counterweights are rectangular cast-iron blocks mounted in a steel frame to counterbalance the load placed on the hoisting machine by an elevator car
- Buffer is the piston or spring device that absorbs the impact of a descending elevator car or counterweight at the extreme lower limit of travel
- A limit switch automatically cuts off current to an electric motor when an elevator car has passed a given point
- Rise or travel is the vertical distance covered by an elevator car from the lowest to the highest landings of the hoistway
- Elevator well is the portion of the shaft that extends from the level of the lowest landing to the floor of the hoistway
- Bottom floor
- 1500–3500 mm

Hydraulic Elevators

Hydraulic elevators consist of a car supported by a piston that is moved by or moves against a fluid under pressure. Rooftop housing is not required, but the hydraulic elevator's lower speed and piston length limit its use to buildings up to six storeys in height.

- Guide rail
- Well of fire-resistant construction must extend to the underside of a fire-resistant roof
- Hydraulic piston
- Machine room houses the hoisting machinery, control equipment and sheaves for raising and lowering an elevator car; a location at or near the bottom landing is preferred
- Elevator well
- Piston cylinder well; depth equals rise or travel + 1200–2100 mm
- These dimensional guidelines are for preliminary planning only. Consult the elevator manufacturer for specific sizes, capacities and dimensional and structural support requirements



Elevator Car Dimensions

ISO 4190-1: 2010 Lift Installation

ISO 4190 classifies lifts according to their usage:

- Class I: Transport of persons
- Class II: Persons and goods
- Class III: Healthcare purposes
- Class IV: Transport of goods
- Class V: Service lift
- Class VI: High-speed lifts

10
FINISH WORK

10.02 Finish Work
10.03 Plaster
10.04 Plaster Lath & Accessories
10.05 Plaster Partition Systems
10.06 Plaster Details
10.07 Plaster Over Masonry
10.08 Plaster Ceilings
10.09 Plasterboard
10.10 Plasterboard Application
10.11 Plasterboard Details
10.12 Ceramic Tile
10.13 Ceramic-Tile Application
10.14 Ceramic-Tile Details
10.15 Terrazzo Flooring
10.16 Timber Flooring
10.17 Timber-Flooring Installation
10.18 Stone Flooring
10.19 Resilient Flooring
10.20 Carpeting
10.22 Acoustic Ceiling Tiles
10.23 Suspended Acoustic Ceilings
10.24 Timber Joinery
10.26 Timber Mouldings & Trim
10.28 Timber Panelling
10.29 Plywood Veneer
10.30 Plastic Laminate

Plaster refers to any of various mixtures applied in a pasty form to the surfaces of walls or ceilings in a plastic state and allowed to harden and dry. The most common type of plaster used in construction is gypsum plaster, which is made by mixing calcined gypsum with water, fine sand or lightweight aggregate, and various additives to control its setting and working qualities. Gypsum plaster is a durable, relatively lightweight and fire-resistant material that can be used on any wall or ceiling surface that is not subject to moist or wet conditions. Portland cement plaster, also known as render, is used on exterior walls and in areas subject to wet or moist conditions; see 7.32–7.33.

- Plaster is applied in layers, the number of which depends on the type and strength of base used

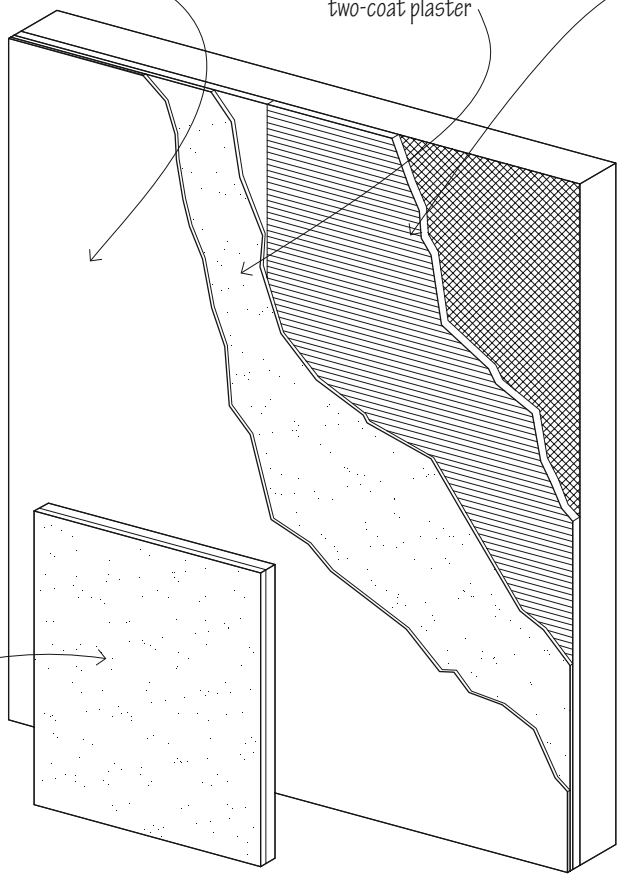
Two-Coat Plaster

- Plaster is applied in two coats, a basecoat followed by a finish coat

Three-Coat Plaster

- Plaster is applied in three successive coats, a scratch coat followed by a brown coat and a finish coat

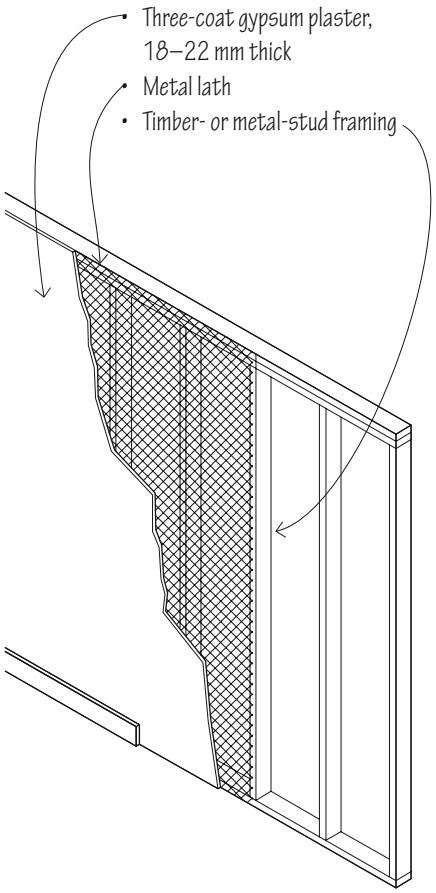
- Finish coat is the final coat of plaster, serving either as a finished surface or as a base for decoration
- Brown coat is a roughly finished, levelling coat of plaster, either the second coat in three-coat plaster or the base coat in two-coat plaster
- Basecoat refers to any plaster coat applied before the finish coat
- Scratch coat is the first coat in three-coat plaster, which must adhere firmly to the base and be raked to provide a better bond for the second or brown coat

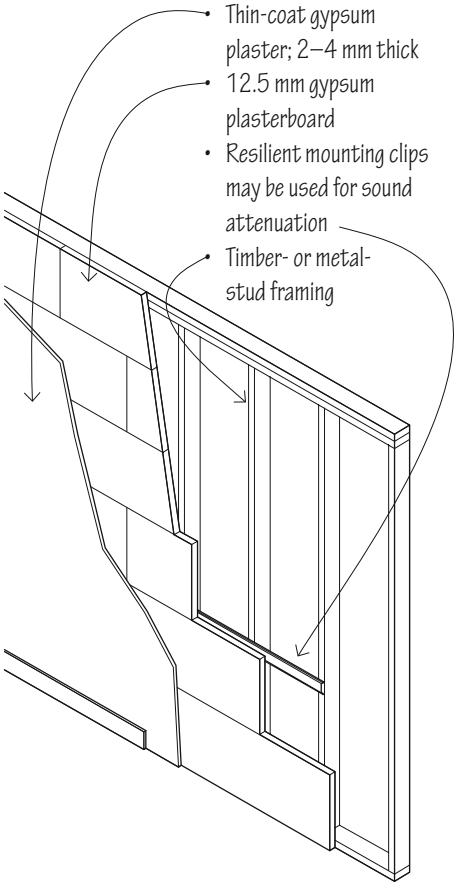


- Hardwall plaster provides a dense finish with high levels of impact resistance
- Gauging plaster is a specially ground gypsum plaster for mixing with lime putty, formulated to control the setting time and counteract shrinkage in a finish coat of plaster
- Thin or skim-coat plaster is a ready-mixed gypsum plaster applied as a very thin, one-coat finish over a plasterboard base
- Acoustic plaster is a low-density plaster containing vermiculite or other porous material to enhance its ability to absorb sound
- Moulding plaster, consisting of very finely ground gypsum and hydrated lime, is used for ornamental plasterwork
- Lime-based plaster is used in renovation projects and traditional buildings. It is a mix of hydraulic lime, sand and water and was traditionally reinforced with horse hair

- The most commonly used plasters come ready-mixed requiring only the addition of water or water and sand depending on the mix. This reduces the preparation time required on-site
- Neat plaster is a gypsum basecoat plaster having no admixture except hair or other fibre, used for on-the-job mixing with aggregates
- Ready-mixed plaster is a mill-prepared plaster mix of calcined gypsum and an aggregate, such as perlite or vermiculite. It requires only the addition of water
- The addition of perlite or vermiculite reduces the weight and increases the thermal and fire resistance of the plaster

- The final appearance of a plaster surface depends on both its texture and its finish. It may be trowelled to produce a smooth, non-porous finish, floated to a sandy, lightly textured finish, or sprayed on for a rougher finish. The finish may be painted; smooth finishes will accept textile or paper wallcoverings



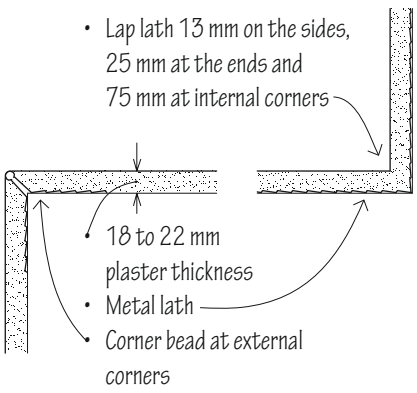


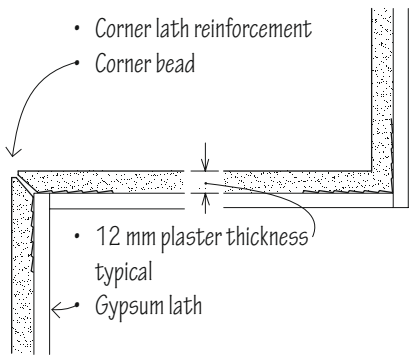
Plaster over Metal Lath

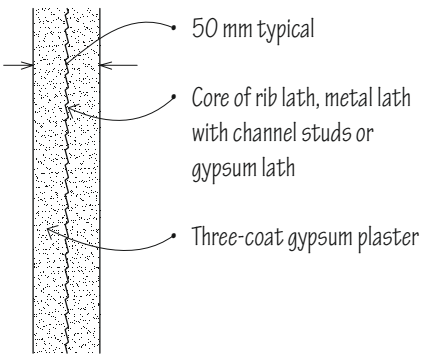
- Three-coat plaster is applied over metal lath
- Timber or metal studs are spaced at 400 or 600 mm centres. The frame should be sturdy, rigid, plane and level; deflection should be limited to $^{1}/_{360}$ of the support spacing
- The long dimension or ribs of the lath are laid across the supports

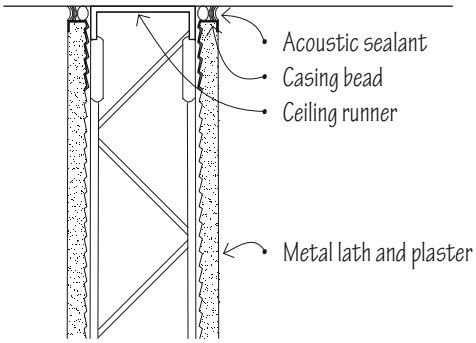
Skim over Plasterboard

- Thin-coat plaster can also be applied as a 2–4 mm thick one-coat finish over a gypsum plasterboard
- Supports may be spaced at 400 or 600 mm centres
- The long dimension of the lath is laid across the supports; ends of lath should bear on a support or be supported by sheet metal clips

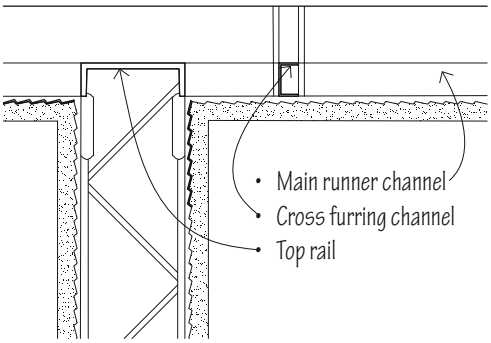




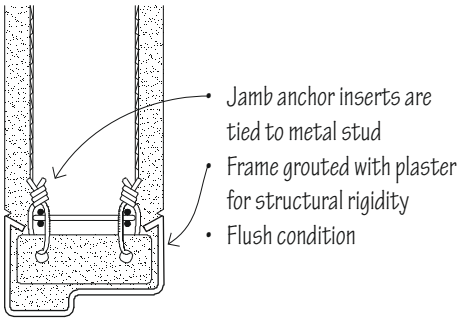




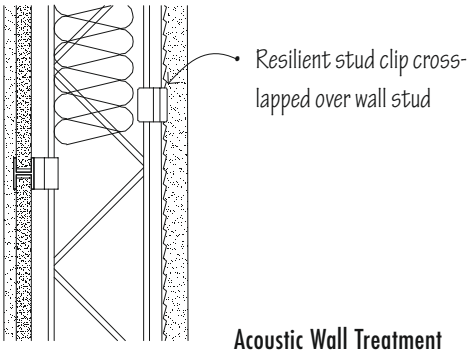
Ceiling Detail



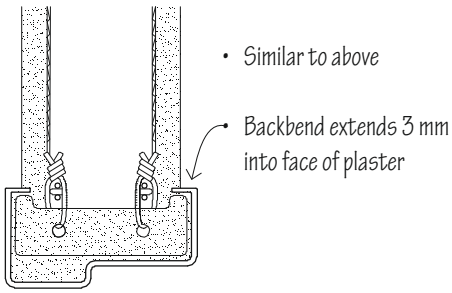
Ceiling Detail



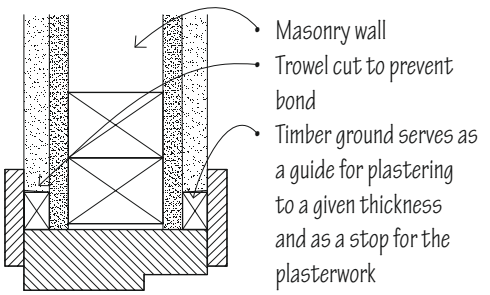
Metal Door Frame



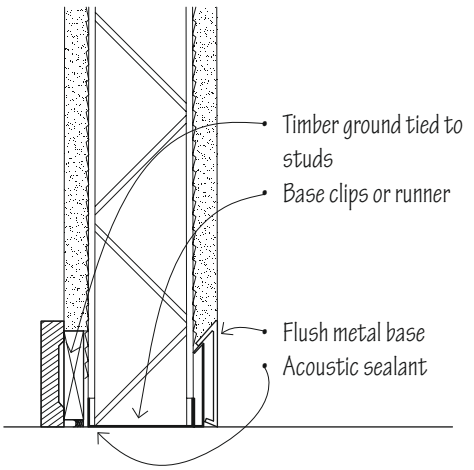
Acoustic Wall Treatment



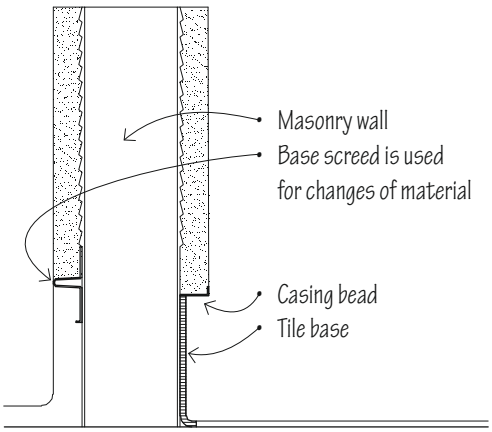
Metal Door Frame

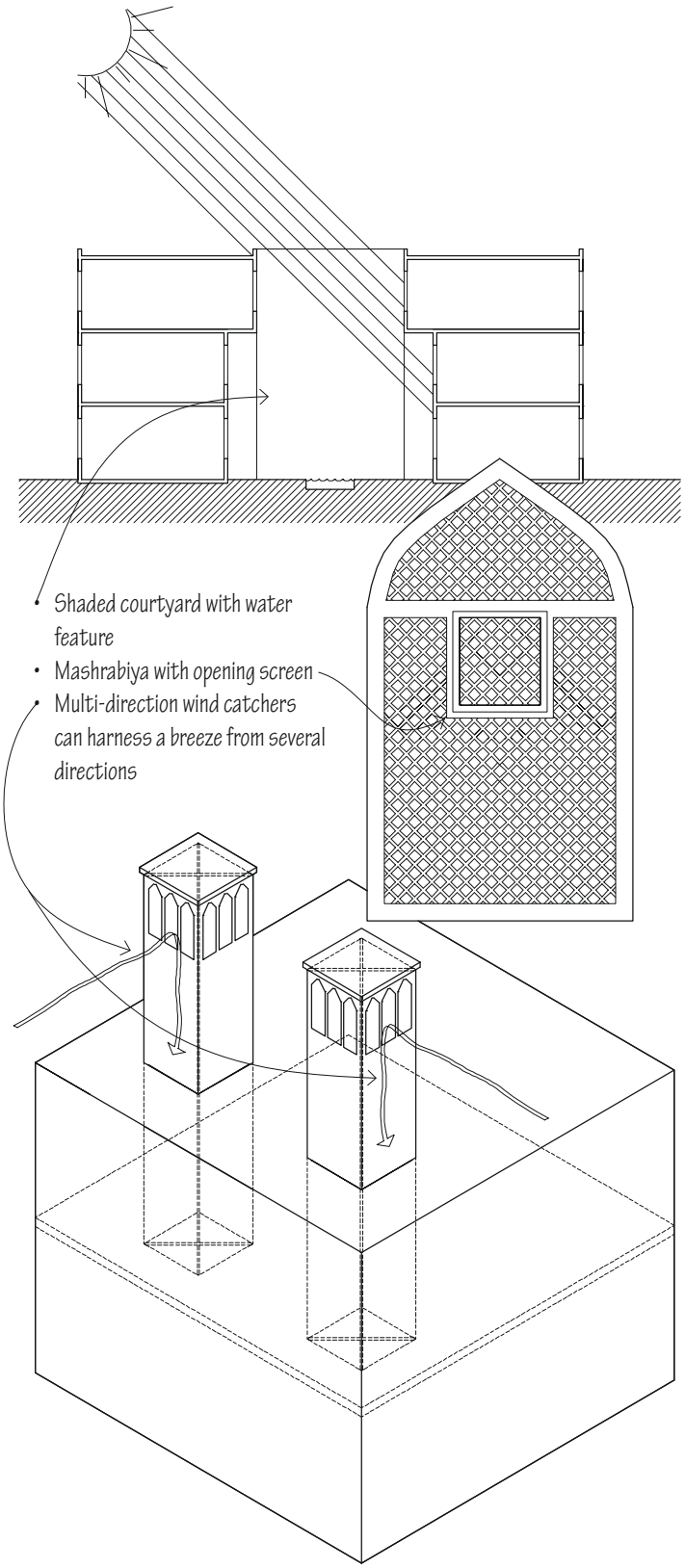


Timber Door Frame



Alternative Base Details





Traditionally, construction methods make use of materials that are available locally and use design strategies handed down through generations, These design strategies are likely to have evolved from necessity to react to the prevailing climatic conditions. Historically, and indeed to this day, in many regions the energy needed to artificially heat or cool a building may not be freely available. As such the building fabric can be viewed as a climatic filter. In cool or temperate climates, it must act to hold heat in, in a compact form. In hot and arid climates like many of those in the Middle East, external heat gains must be excluded from the building and heat in the building stored in thermal mass, again a compact form is often used. In hot and humid climates buildings must allow for high levels of shade and be open in form to allow for high levels of ventilation. A number of traditional design solutions widely used in the Middle East are outlined below.

Building Orientation & Shape
- Compact buildings
- Often with shaded internal courtyards

Earth Buildings
- Widely available construction material
- High levels of thermal mass to absorb heat from the day
- Deep window reveals to minimise solar gains

Evaporative Cooling
- Water features encourage evaporation in dry climates
- Used to cool ventilation air

Shading
- Minimises direct solar gains
- Often in the form of narrow streets between buildings
- Shaded transition zones can be introduced
- Can be combined with a range of design strategies

Courtyards
- Shaded courtyards provide cool ventilation air
- Combined with a water feature can aid evaporative cooling

Mashrabiya
- Screen of timber latticework
- Provides shading while allowing for ventilation
- Sometimes in a projecting bay

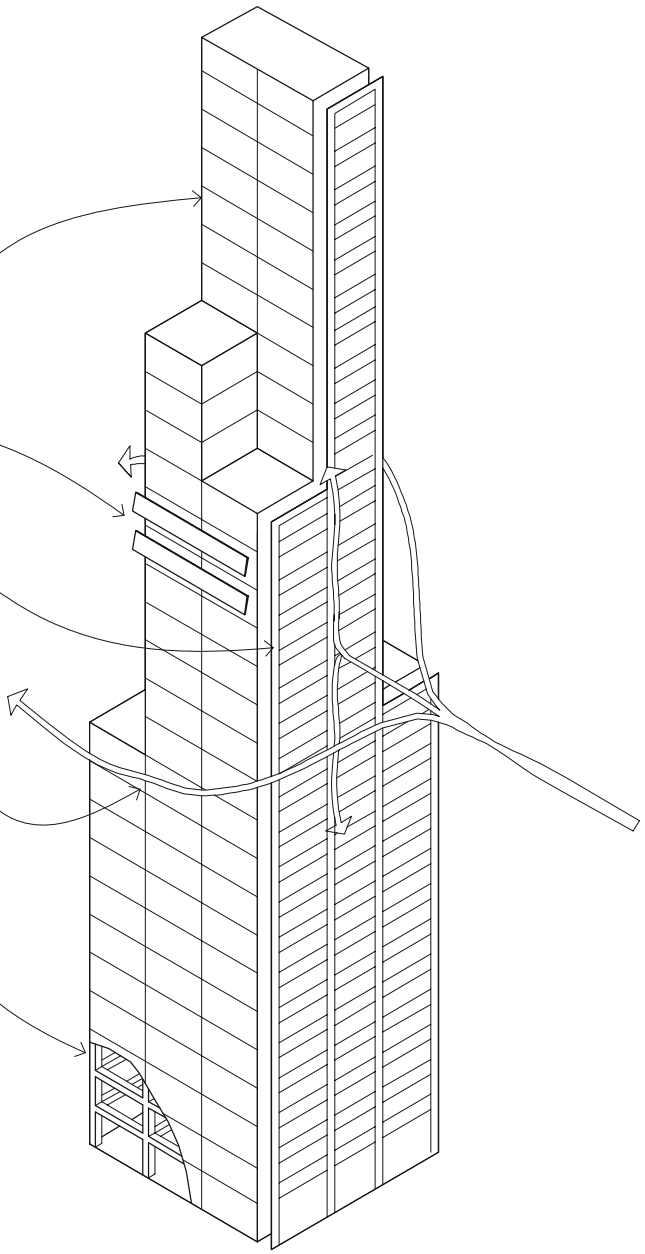
Wind Catchers
- Used to drive natural ventilation
- Draws cool air above ground level into the building
- In regions with a high diurnal range can be used in conjunction with thermally massive construction (earth buildings) to cool the building overnight

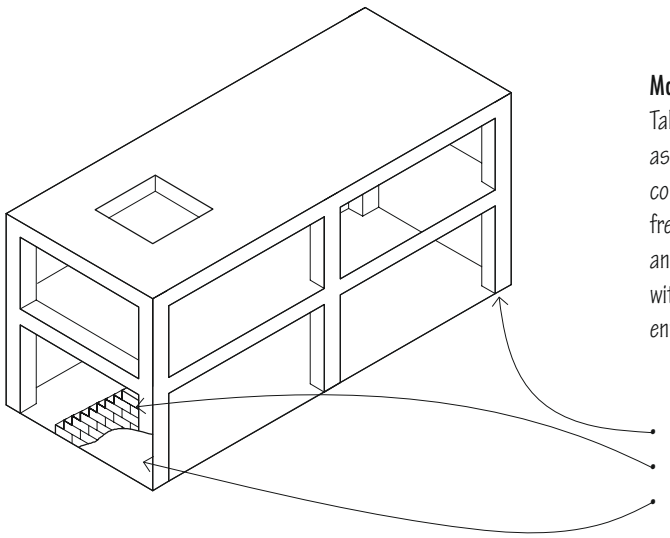
Construction in the Middle East is at the forefront of driving the technical limitations of the industry forward. This is particularly true in relation to tall buildings and increasingly sustainability standards. Additionally, architects and engineers internationally have been using the lessons learnt from traditional construction methods in the Middle East to influence emerging best practice in sustainable design. Methods founded in traditional construction, such as passive and evaporative cooling, wind catchers and thermal mass are now part of many sustainable design strategies.

- Highly glazed buildings can be energy intensive in hot-arid climates
- Building-integrated photovoltaics can be used to provide shading while generating electricity
- A double skin, if correctly configured and engineered, can be used to reduce heat gain, provide integrated shading and to help drive the building's ventilation system
- Tall buildings must be designed to take account of the impacts of high winds
- Concrete frame

Although construction standards generally in the Middle East have been improving and have driven the industry forward, a number of areas still need further development, these include:

- Thermal insulation
- Thermal bridging
- Airtightness
- Flashing details
- Fire regulations and materials

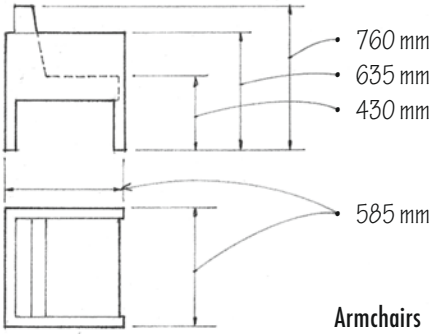




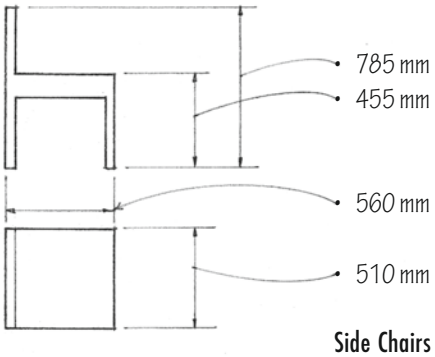
- Concrete frame
- Brick of block infill
- Render

Materials

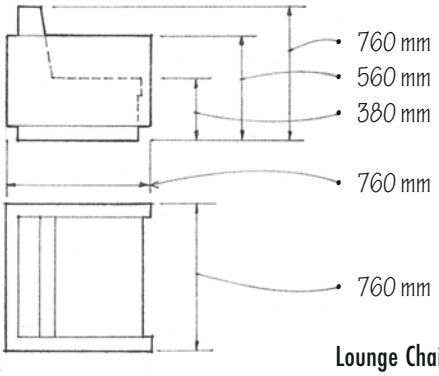
Tall buildings routinely use concrete as the main construction material as it offers availability, durability and workability. In the Middle East, concrete is also often used in low-rise buildings with domestic buildings frequently featuring a concrete frame with infill materials. Concrete is an energy-intensive material to produce, however its durability coupled with its thermal storage capacity can help to justify its use from an environmental perspective.



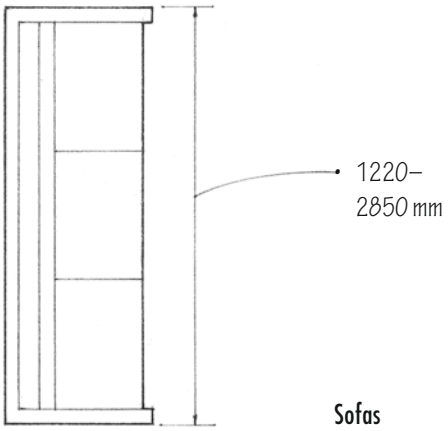
Armchairs



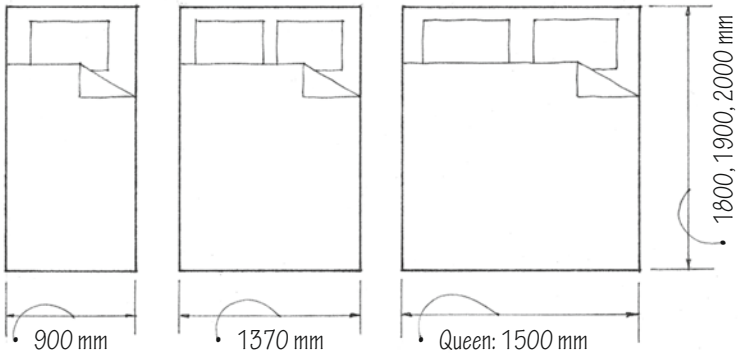
Side Chairs



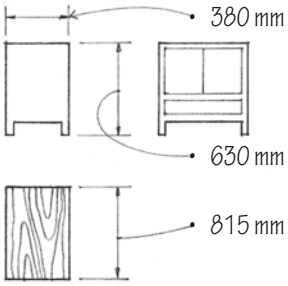
Lounge Chairs



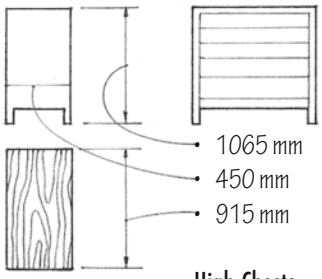
Sofas



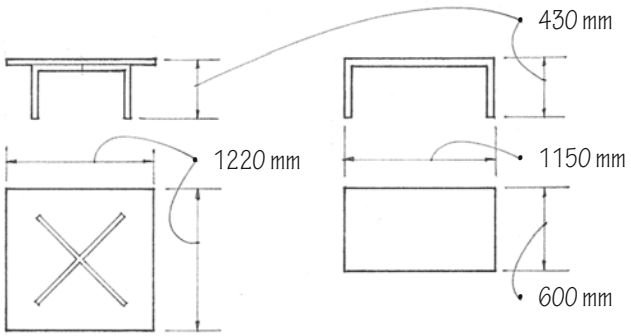
Beds



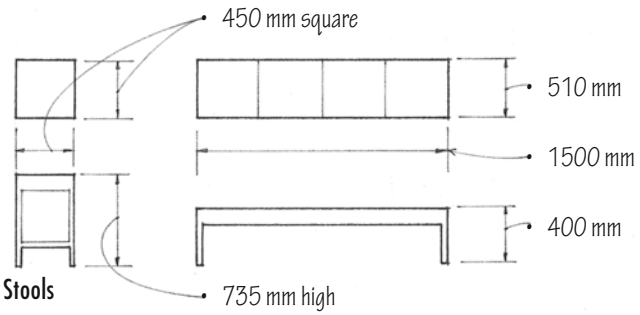
Night Tables



High Chests

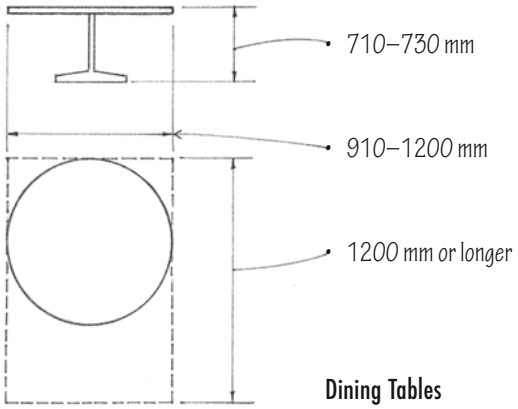


Low Tables



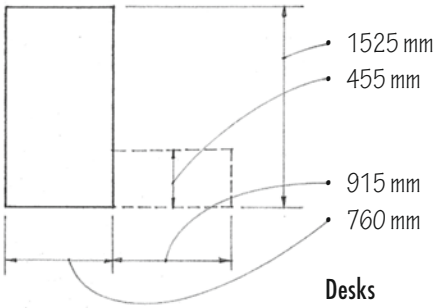
Stools

Benches

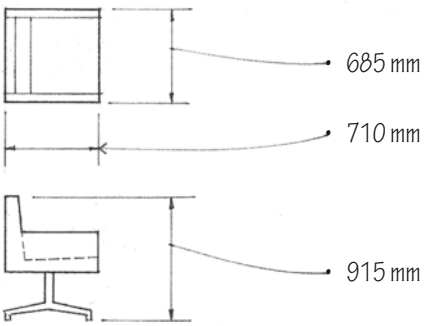


Dining Tables

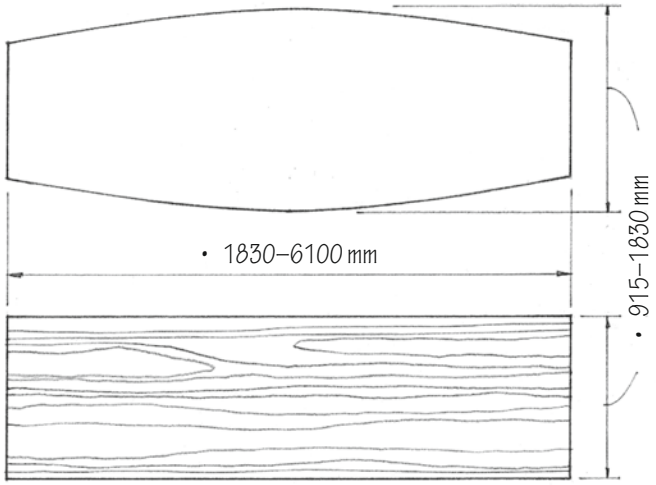




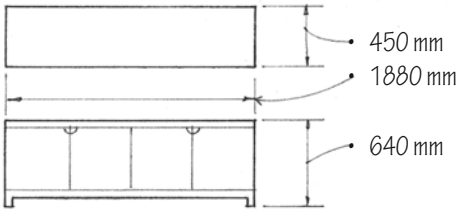
Desks



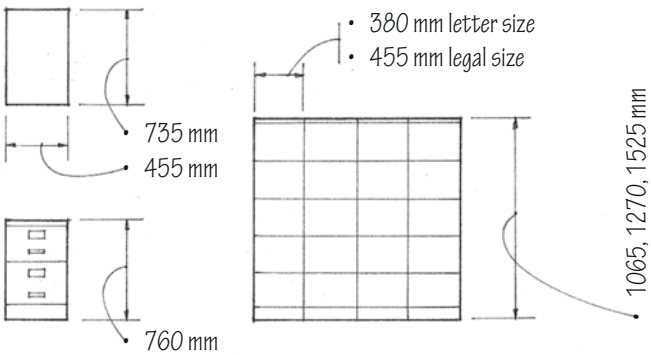
Swivel Chairs



Conference Tables



Sideboards



Filing Cabinets

- All dimensions are typical. Verify with furniture manufacturer
- Furniture may serve as space-defining elements, define circulation paths or be built-in or set as objects in space
- Selection factors include function, comfort, scale, colour and style