Chapter 1 The History of Buildings

The development of building knowledge

In order to understand the construction of buildings it is necessary to determine the age of the building and the technologies likely to be included in the construction and design of that period. For this reason, this first chapter briefly explains the construction and features of buildings over the years and this is further developed in chapter three where the construction is discussed in more detail.

Since the beginning of time man has been engaged in building structures and it is remarkable that many of the early structures still exist. The Neolithic period as early as 6500–10 200 BC saw the first structures being made which may have been simple huts and bridges but nevertheless commenced mankind's quest to construct buildings. Buildings continued to develop through the Mesopotamian, Ancient Greek and Ancient Egyptian periods, which ranged from 6000 BC until 146 BC, and some of these structures – such as the pyramids – are a lasting legacy to the ingenuity and understanding of building construction principles. Following this, the period of the Ancient Romans from around 753 BC until 476 AD saw large-scale buildings become more commonplace. As techniques and materials became better understood, more adventurous structures were constructed.

The Medieval period of the 12th century until the 18th century saw timber frame houses being constructed and some of the early timber frame houses of this era still exist, such as the Medieval Merchants House in Southampton, Hampshire. The development of these structures is intrinsically linked to the understanding of materials and the behaviour of structures which carpenters gained over these centuries.

Masons involved in the construction of churches would travel across the east and west, refining techniques and applying them to new and larger structures. One such example is the development of the arch from a circular arch to a gothic pointed arch, which improved its ability to carry loads, thus resulting in larger-scale and more impressive structures. This is evident in the late 16th century when large glass windows became fashionable in churches to provide light, which also had a significant theological meaning.

The understanding of flying buttresses to resist large lateral and horizontal loads meant that vaulted ceilings could be constructed which accommodated large spans. The first example in England was in Durham Cathedral, which was commenced in 1093. Other early examples include the apse of the Basilica of Saint-Remi in Reims dating from 1170.

Although some of the structural principals were understood, many were based on trial and error and then carried through as tried and tested means of developing structures.

Structural Design of Buildings, First Edition. Paul Smith.

Such scholars as Marcus Vitruvius Pollio wrote some of the earliest books on architecture, and his work *De architectura* (known as *Ten Books of Architecture*) is the only surviving book from the classical period. This provided dimensions for columns based on the number and type of column used and the style of temple required. The height of the column was expressed as a multiple of the diameter. This work was not discovered until 1414 in a library in Switzerland, and interestingly there had been no other printed works prior to this time.

During the Renaissance period, in 1450, Leon Battista Alberti published *De re aedificatoria*, which translates as *The Art of Building*. This was one of the first printed books on architecture. Later, Sebastiano Serlio (1475–1554) published *Regole generali d'architettura*, which translates as *General Rules of Architecture*. Then, in 1570, Adrea Palladio published *I quattro libra dell'architettura*, which translates as *Four Books of Architecture*. This final publication carried many of the Renaissance ideas into Europe.

Prior to these publications there were very few books for architects and masons to reference how structures were constructed. Following the Renaissance period (15th–17th centuries), more information became available.

During the years 1100–1200, fire was the major concern and a hazard in built-up cities. The construction of houses during this time was predominantly in timber, and densely populated areas resulted in accommodation being provided by extending existing properties and adding additional storeys.

In 1666 the Great Fire of London transformed building control and regulation in the UK. The following year the London Building Act banned the use of timber and insisted on the use of brick and stone in the construction of houses. In 1694, following another major fire in Warwick, more major cities were prompted to introduce Building Acts based upon that introduced in London. By the 18th century, most cities had a Building Control Authority and had adopted a Building Act.

The Building Act of 1858 meant that plans had to be deposited with the authorities for new buildings and alterations. This makes it easier – after this period – to ascertain the history and construction of properties throughout the UK.

Styles of architecture and building construction

It is remarkable that today we still dwell in houses constructed as far back as Medieval times, and it is at this point that we begin our analysis of the structures of buildings based on the techniques used in the past.

Medieval

The majority of the remaining residential dwellings of this period are of timber frame. Predominantly these were of cruck construction or box frame, where the roof is a separate structure to the walls. Medieval buildings tended to have thick timber members which were irregular in shape, and the timber posts were placed directly onto or inserted into the ground. The floor joists were generally large and laid flat rather than upright, typically these would be 200 mm × 150 mm timbers. Figure 1.1 shows a photograph of a typical cruck frame construction used in a house in Herefordshire.

In their simplest form, Medieval buildings were four-bay cruck frame structures with a large hall occupying at least two of the bays. The open-plan design centred around a large

Figure 1.1: Photograph of typical cruck construction in Herefordshire.

fire, which was the only means of heating. Access was gained through two large doors normally located on opposite sides, which formed cross passages. Of the remaining bays, one would form a parlour which would create some privacy for its occupants and the other would be split as a pantry and buttery for storing food and drink. Over 4000 cruck frame buildings remain in the UK today.

Other forms of construction existed at this time, and stone cottages have been constructed from materials close to hand from a very early period in history. Cob construction is another form of construction with the main component being mud, earth or clay. This form of construction can be traced back to the 14th century and was particularly evident in the south-west and central-southern England.

Tudor (1485–1560)

With the exception of churches, most buildings in the Tudor period were also of timber frame construction with box frame construction being dominant. Houses tended to be one-room deep with a limited span, as the walls did not have sufficient load-bearing capacity to support the heavy roof structure. Some masonry brick construction was used to fill the timber panels and some stone construction for windows and quoins.

Bricks were a luxury product and found only in the homes of the wealthy, and generally in the east and south parts of the country. This was predominantly because the people who knew how to make and use bricks were Flemish immigrants who settled on the east coast.

Most large houses were constructed around a central hall, with wings containing private chambers at one end and kitchens and service rooms at the other. As today, space within the towns and cities was valuable and the timber frame houses were generally

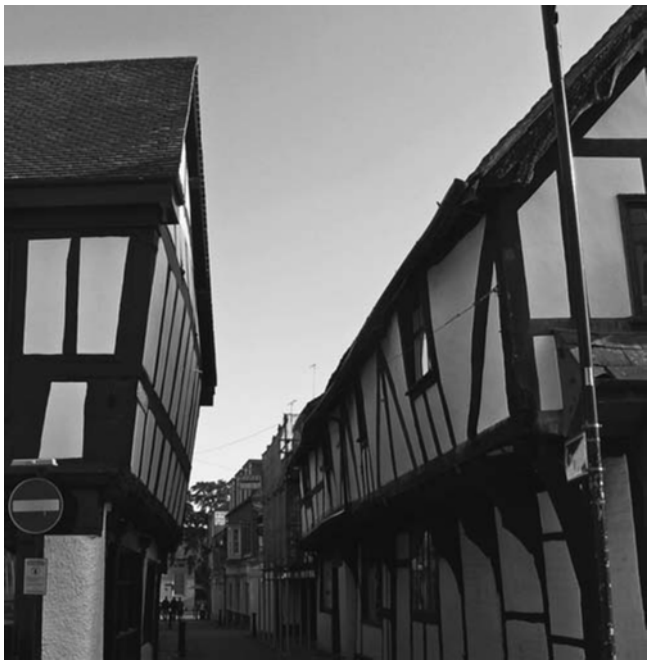

Figure 1.2: Photograph showing the close proximity of timber frame housing in Leominster, increasing the risk of fire.

owned by rich merchants. Plots in the cities tended to be long and narrow, and houses often had a rectangular form with the gable end facing onto the street. The ground floor was used for commercial enterprise, with the living accommodation being above. To gain additional space, jetties were introduced to extend over ground floors and create additional storeys.

The jetties extended the higher storeys forward of the building line into the street, reducing the distance between the facing properties. Consequently, this resulted in an increased fire risk, as fire could travel easily from one building to another. Figure 1.2 is a photograph showing the close proximity of timber frame properties in Leominster, increasing the risk of fire. This was a prominent reason for the spread of the Great Fire of London in 1666.

Initially little consideration was given to external appearance, but towards the end of the Tudor period the finest timber frame houses featured close timber studding, decorative panels and brick panels with diagonal patterns.

Glazing was not generally used in properties at this time, and only the finest properties enjoyed this privilege. Timber frame houses at this time had shutters and mullions rather than glass.

Floorboards above the floor joists were usually left exposed and the joists were chamfered and did not have plastered ceilings. Joists were laid flat and were usually 125 mm × 100 mm in size.

During the Medieval and Tudor periods thatch was the most likely roof covering, and the pitch of the roof had to be steep (generally 45°–60°) to dispel water from the roof. The overhang was deep so that the water was thrown clear of the walls.

Elizabethan and Jacobean (1560–1660)

During the Elizabethan and Jacobean periods, timber frame houses were still the most popular type of building construction but masonry and brick buildings began to appear and transcend down the social scale.

In larger houses the house footprint moved away from a large central hall into smaller rooms; fireplaces reduced in size and chimneys were introduced. These were a status symbol and often tall and topped with decorative chimney pots. The buildings often had an E- or H-shaped floor plan.

Glazing was still only for the privileged, but more modern methods of construction allowed larger areas to be glazed. Windows with patterned glass were being introduced, but more common was a diamond-shaped pane with lead casing.

Buildings became even more decorative, with some containing hidden messages showing allegiance to the Queen by having an E-shaped floor plan or containing the forbidden Trinity Triangle. During this period of religious division Catholic houses often had secret chambers constructed, known as priest holes.

Internally, large fireplaces with decorative mantles and elaborate panelling to the walls further demonstrated the wealth of the owner.

Large columns were introduced to the finest properties, but their proportion did not always match the property. Symmetry became important during this era and properties faced outwards rather than inwards towards courtyards.

Bricks were becoming more popular and ranged in size from 210 mm to 250 mm in length and 100 mm to 120 mm in depth, with a height of 40 mm to 50 mm. An example of a Jacobean property can be seen in the photograph in Figure 1.3.

Figure 1.3: Photograph of a Jacobean house of brick construction.

The commoner houses were still constructed using a timber frame with steeply pitched roofs having thatching or slate tiles. Cruck frame and box frame were still the main methods of construction. Jetties were becoming more common to achieve second storeys in market towns and cities, with the beams becoming more decorative and the introduction of carved finishes. Doors and windows were tall and narrow.

Restoration (1660–1714)

The Restoration period brought about great change to architectural style and building construction. Initially with the restoration of Charles II to the throne, many exiled royalists returned home to reclaim their lands and with them came the European influence on architectural style. In addition during this period was the Great Fire of London, the aftermath of which brought sweeping changes with the introduction of the Building Act of London – legislation controlling the structure and materials used in new houses. This began the new era of Building Control.

New properties were now constructed using mainly masonry and, although some timber frame structures were still being constructed, masonry became more prevalent. There were rapid developments, with properties becoming wider through the introduction of a second room at the rear. Thus, properties became two rooms deep. Quoins became fashionable, and these were highlighted on properties. Steep roofs were introduced, and hips were necessary to achieve this style of roof structure. Dormer windows along the roof line of grand and terraced houses also became noticeable during this period. A Restoration-style property can be seen in the photograph in Figure 1.4.

Figure 1.4: Photograph of a Restoration-period house in Herefordshire.

The brick bond changed from English to Flemish, and lintels were typically brick with stone keystones.

By the end of the 17th century window styles also changed, from casement windows to sash windows. There was a desire to maintain the flat façade of the building and not break the front line when the windows were opened. Single mullions were also popular, with the transom set slightly above the centre – thus the top part of the window was smaller than the bottom.

Although available in the 13th century, clay tiles became widespread during the 17th century (mainly due to the need to protect properties from fire, thus replacing thatch).

Window tax

In 1696 a property tax was introduced on all properties in England and Wales. The window tax was introduced in Scotland in 1748, which was some time after the Union in 1707. Those properties having more than ten windows were subject to an additional tax depending on the number of windows. Interestingly, in Scotland this was later reduced to seven windows.

This additional property tax was known as the window tax, and at the time windows were in-filled or properties were being built with in-filled windows with the intention of the windows being glazed or re-glazed at a later date (on anticipation of the tax being lifted). The in-filled windows meant that the tax was not payable, but the legislation contained no definition of a window and the smallest opening could be included as a window. The tax was repealed in England, Wales and Scotland in 1851 following the argument that the tax was a tax on health and a tax on light and air. Consequently, properties with in-filled windows are likely to have been constructed before 1851.

Georgian (1714–1790)

During the Georgian period houses became much more substantial and focused on symmetry and larger rooms. The architecture was based on Greek and Roman architecture, constructed using uniform stone or brick with Corinthian, Doric and Ionic capitals on columns. The architecture was elegant and based on ancient worlds and temples, with smaller houses using the same approach on a reduced scale. A photograph of a large Georgian-period Grade II listed building can be seen in Figure 1.5.

Two-up, two-down properties were introduced in urban areas, with most terraces being constructed of brick with sloping shallow-pitched slate roofs hidden behind parapets. New regulations on fire introduced standards for compartmentalisation of terraced houses. Party walls were built to prevent the spread of fire and carry the weight of the chimney.

The Building Act 1774 tried to reduce the risk of fire by improving the quality of construction, and houses were rated based on their value and floor area; each category had its own set of structural requirements in terms of foundations, external and party walls.

Windows were predominantly sash windows with thin wooden glazing bars. On the ground floor the windows were kept smaller to ensure the stability of the building, on the first floor the windows were tall and elegant but these reduced in height on successive floors, with the top-floor windows being almost square. Front doors traditionally contained six panels.

Terraced houses also had basements with the front door approached at road level, but later in this period the basement protruded above ground level and formed a half

Figure 1.5: Photograph of a Grade II listed Georgian property.

basement. Thus, the elevated front door was approached via steps, sometimes spanning the void between the basement and the road.

Wall construction was achieved by using thin mortar joints, and darker mortars were covered with lime putty to lighten the colour to match the surrounding brickwork.

As the population grew in rural areas, huge numbers of stone cottages were constructed. These were usually of one or two bays and single storey, with an end chimney.

Regency (1790–1830)

The Regency period saw the introduction of stucco, which is render made to look like stone. Elegant buildings became the fashion and towns such as Brighton and Cheltenham displayed fashionably elegant houses. Figure 1.6 is a photograph of a typical terraced property of this era, taken in Malvern.

At this time cement was also used in mortars, which meant that taller, more robust structures could be constructed in masonry. The half basement was still used during this period, and rear extensions accommodating servants became popular. Gothic style began to replace the Greek and Roman styles of the Georgian period.

Bow windows became fashionable on the finest houses of the wealthy. For terraced properties the first floor accommodated French doors leading to balconies comprised of decorative ironwork. Sash windows were set further back and small timber strips were used, often reinforced with metal strips.

Roof lines became much shallower with the introduction of lightweight Welsh slate, and this was used in abundance. Roof valleys became popular which were hidden behind the parapets, and Mansard roofs were also used to achieve low pitches. In the suburbs detached and semi-detached houses, known as villas, were also being constructed.

Figure 1.6: Photograph of a typical Regency-period terrace in Malvern.

In 1833, at the end of the Regency period, John Claudius Loudon published a book which contained over 2000 designs for houses: the *Encyclopaedia of Cottage, Farm and Villa Architecture and Furniture*. This demonstrates the wide variety of house designs available at the time.

Victorian (1830–1900)

Following this came the Victorian era and the Industrial Revolution, which led to many advances in the use of materials and the construction of buildings. The improvements in iron production led to the economic production of pig and wrought iron. Structural-grade iron was now achievable, and this meant that structures began to appear constructed using iron. The introduction of the railways also meant that bridge engineering and huge retaining structures had to be constructed, increasing our understanding of the materials used and the structures' behaviour.

The quality and availability of materials improved as goods could be transported all over the country by rail. Towards the end of the Victorian era machine-made bricks became widely available, although these were still expensive and as such were only used to construct the façade of buildings.

Britain's population doubled during this time and towns expanded dramatically. Owing to work places being predominantly the mills, collieries and factories, housing was concentrated around these, leading to the densely populated terraced houses known as back-to-back terraces, which can still be seen today.

Middle-class terraced houses were of substantial construction and contained quite a number of rooms, sufficient to accommodate servants. The basement area was usually given over to the kitchen, larder and scullery, with the servants' quarters being accommodated in the attic. These properties also had the benefit of a garden.

The Gothic style was prevalent at this time, but houses were also influenced by other styles of architecture. Buildings were often asymmetrical, with steep-pitched roofs and

Figure 1.7: Photograph of the Cotford Hotel in Malvern.

forward-facing gables. Decorative brickwork was commonplace, and this was complemented by ornate bargeboards. Figure 1.7 is a photograph of the Cotford Hotel in Malvern, which demonstrates the Gothic-style architecture with steep-pitched roofs and ornate bargeboards. The walls are constructed using Malvern stone with ribbon pointing, which is characteristic of this area.

Doors typically had four panels as opposed to the previous six-panel Georgian style. In terraces, doors were often recessed and set in pairs rather than along the same side of the row.

With improvements made in the manufacture of glass windows, increased size and number with larger panes and, by the end of the era, coloured glass was a common decorative feature.

During the Industrial Revolution stone cottages became commonplace and were used for industrial and rural workers alike. Generally constructed using rubble stone walls and lime mortar, the accommodation typically comprised two-up, two-down properties and was used across the country. This method of construction has changed little over time and this type of construction can be found in the south west, Derbyshire, Yorkshire and any area where stone is readily available.

The use of damp-proof courses was introduced by the Victorians, but it was later when they became used throughout the UK. Early damp-proof courses included asphalt, bitumen, tar, three courses of engineering brick or even such materials as lead and copper.

Post-1900

Before the 1900s, local materials were used in the construction of buildings. Walls were of solid brick in towns and cottages were of stone construction with walls some 450–500 mm thick. In later years many of the walls have been rendered in an attempt to improve protection against the infiltration of damp. Parking was not a consideration at this time, since people did not own cars, and consequently properties in the countryside could be constructed in locations some distance from main highways.

At the turn of the century balconies became fashionable in town houses and looked towards the street. Between 1900 and the 1920s the quality of building materials improved. Decorative brickwork panels using coloured bricks such as buff and blue were seen over window openings, and at eaves and first-floor level. Porches and hallways from the entrance comprised decorative tiles. It was not uncommon for the density of housing to be 20 to 30 houses per acre, particularly in terraced rows in cities and towns. Figure 1.8 is a photograph of a typical semi-detached house of this period.

During the 1920s the cavity wall was used more extensively, but it should be noted that cavity walls had been in use since the 1870s in the west of England and parts of Ireland in an attempt to prevent the penetration of damp. The density of housing was reduced to six to ten houses per acre, and larger gardens were provided as minimum distance rules on the close proximity of back-to-back housing were introduced.

The accommodation became more spacious and the concept of housing estates began to become established. During this era social housing was introduced, and this new concept meant that large, spacious estates began to grow.

1930s housing saw the widespread implementation of the cavity wall and hipped roofs, with large overhangs over fashionable bay windows that extended over both storeys.

Figure 1.8: Photograph of a typical brick semi-detached house of the 1900–1920s era.

Figure 1.9: Photograph showing a typical 1930s property.

The gables extended over the bay windows and could be mock Tudor or tiled with timber framing. Another characteristic of this period was the recessed front door, usually with windows either side and approached through a brick arch. Housing estates became more densely populated than in the 1920s. Figure 1.9 is a photograph of a typical 1930s property.

In the 1940s the construction of houses was halted as a result of the war. During the war the housing stock was reduced considerably as a result of bomb damage, particularly in the major cities. This led to a post-war housing shortage and to cope with demand approximately 156 000 prefabricated houses were constructed, which were low cost and could be built rapidly. Figure 1.10 shows a photograph of a Cornish dwelling which was a particular type of prefabricated concrete house.

These prefabricated houses were only intended as a short-term solution but still endure today. Chapter 3 explains this type of housing in more detail, and how it has been adapted to overcome problems with corrosion of the concrete. In addition, flats and maisonettes became popular, which were low-rise constructions up to four storeys in height.

During the 1950s metal-casement Crittal windows became fashionable, and large overhanging cantilevered porches supported on metal posts became characteristic of the period. The London Brick Company mass produced bricks, and walls were constructed without decorative panels as in the 1900–1920s period. Social changes meant that open-plan estates evolved, which removed the concept of front boundaries thus

Figure 1.10: Photograph of a Cornish dwelling which was a particular type of prefabricated concrete house.

leading to open-plan gardens. Transport policies at the time favoured the increased use of the motor car rather than trains, and this led to more garages being constructed.

Bungalows also became fashionable during this period, and this trend continued into the next decade.

During the 1950s timber was in short supply after the war, and the TRADA truss was introduced to complement a cut roof by supporting a 50 mm × 150 mm purlin at mid-span. This reduced the size of the timber rafters and negated the need for a wall extending into the roof space to support the purlin. Typically, the TRADA trusses were spaced at between 1.8 m and 2.4 m, but were soon superseded by the complete trussed roof as seen in modern houses. Typically, TRADA trusses are Fink trusses with double-tie and rafter members laid side by side. A photograph of a typical TRADA truss can be seen in Figure 1.11.

During the 1950s roofing materials also saw a change, with the increased use of concrete tiles.

The decade of the 1960s saw the development of town planning and led to a new approach to inner-city development, with high-rise tower blocks being constructed to increase the density of housing – for example Park Hill, later known as the Hyde Park Estate, in Sheffield. One of the tower blocks in this development has 19 storeys and contains 1160 dwellings.

Even the bungalow was developed to have additional rooms in the roof space, effectively increasing the accommodation on the same floor area. Bungalows grew in popularity and were constructed with dormer windows and rooms in the roof. These are still evident on housing estates across the country. In some cases these dormers have been added

Figure 1.11: Photograph of a TRADA truss.

retrospectively or widened. Chapter 17 explains some of the issues to examine in these circumstances. A typical 1960s bungalow can be seen in the photograph in Figure 1.12.

The trussed roof, introduced during the 1960s, was becoming popular and this removed the need for labour-intensive cut roof construction. A series of single Fink trusses was placed at approximately 600 mm centres along the length of the roof, making the so-called trussed roof.

Between the 1930s and the 1960s clinker or aggregate blockwork was used for the internal leaf of cavity walls. These blocks were cheaper to manufacture than bricks and were larger in size, so larger areas could be constructed in less time.

Figure 1.12: Photograph of a typical 1960s bungalow.

In the 1970s most estates became more densely populated, often using a mix of different standardised housing types to give the impression of individuality. Garages were replaced with off-road parking or car ports, and gardens became enclosed. Larger double-glazed aluminium windows were introduced and became fashionable. The early skylight, such as Velux™ windows, was also introduced to roof structures. The increased use of natural gas as a heating fuel meant that new houses of this period were being connected to mains gas supplies, hence the requirement for the chimney was now obsolete.

Until this time most cavities were 50 mm in width and the introduction of insulation in the cavity was being implemented in recognition of the need to insulate houses.

By the 1980s estates became even more densely populated in an attempt to meet housing shortages. Open-plan gardens took on a revival and estates accommodated a number of similar property types but with a range of styles to give the appearance of variety, but ensuring that mass construction could be undertaken. Figure 1.13 shows a photograph of a typical 1980s house using brick with a rendered gable.

During this time calcium silicate bricks became more popular, but these were more prone to reversible and irreversible moisture movements than their clay brick counterparts. Consequently, walls experienced contractions in the brick material. For this reason BS 5628 Part 3 recommends that movement joints be placed at intervals of not more than 7.5 m–9.0 m in calcium silicate blocks (as opposed to 15.0 m in clay bricks). Where this criterion has not been introduced, many of the houses have experienced vertical cracking due to the natural formation of the movement joints. Figure 1.14 is a photograph showing a typical 1980s house using calcium silicate bricks.

Figure 1.13: A typical 1980s house on a residential estate using clay bricks with a rendered gable.

All walls were constructed using cavity wall insulation, since this was enshrined in the Building Regulations. Although first introduced in the 1970s, by the 1980s the use of Thermalite lightweight blocks had become widespread to improve the thermal qualities of walls. Cavity widths increased to 75 mm to ensure the additional thicknesses of insulation could be accommodated. Flues began to appear on roofs to accommodate solid-fuel burners.

During the 1990s larger estates were being constructed, creating densely populated areas of housing. Decorative brickwork became fashionable, but this was in an attempt to disguise the similarity of properties through subtle differences in their appearance. The introduction of extractor fans to bathrooms and kitchens, and trickle vents to windows, was used to improve ventilation to properties.

In the 21st century the use of sustainable materials, the development of timber frame houses and the introduction of structurally insulated panels (SIPs) have become widespread. The use of renewable energy sources and green technologies has also become commonplace. There have been a number of changes to the Building Regulations in the last two decades, with particular emphasis on sustainable development. Figure 1.15 shows a photograph of SIPs being used in construction.

Figure 1.14: A typical 1980s house on a residential estate using calcium silicate bricks.

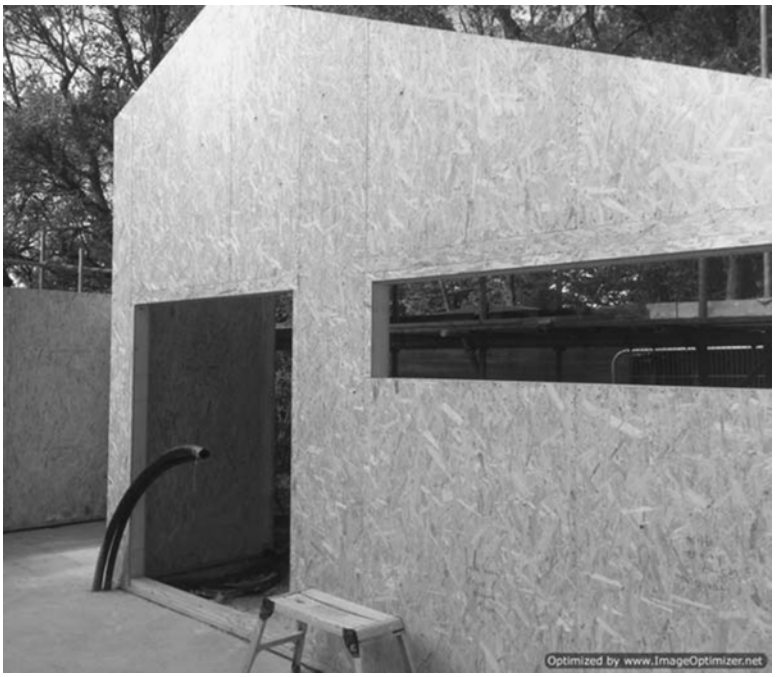

Figure 1.15: A photograph of SIPs being used in construction.

In summary, the 20th century saw advances in technology and improvements in the thermal qualities of houses. This resulted in construction methods changing, and the increased use of non-breathable construction was more evident than the traditional breathable construction. The difference is explained further in Chapter 3. Cavities in walls had been used as early as the Roman period, but traditional houses were of solid brick until 1911. By 1920 the use of cavity walls had become widespread. Since the 21st century, the cavity width has increased to 90 mm to 100 mm to improve the thermal qualities of housing.