

**WOOD FRAME HOUSE CONSTRUCTION PROCESS AND  
PERFORMANCE INVESTIGATION**

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## **WOOD FRAME STRUCTURES FOR SINGLE FAMILY RESIDENCES**

### **SUMMARY**

For decade wooden constructions and structures have been the dominant building systems for Turkey. The vastness of the forest and the availability of quality lumber lead to the development of traditional wood construction methods. Examples of different traditional wood building systems can be found all over Turkey.

With the decreasing number of forest areas and the lack of quality lumber products along with the introduction of cheap and versatile materials, the wood construction nearly stopped in Turkey.

On the other hand in the countries like USA or Canada, wood frame housing is still the main building system for residential dwellings. With the controlled grow of the forest areas and the constant development in technology and material keeps the wood frame housing on a constant movement.

The main building system used in Turkey is Reinforced Concrete but after the tragic earthquake in 1999 alternative building systems are become widely interested. Although the wood building system has been the most popular for a long time, it has nearly come to a halt in the last 30 – 40 years.

This thesis introduces the updated wood framing systems, materials and technologies used in the North American countries as a guideline.

## **MUSTAKIL KONUTLAR ICIN AHSAP CERCEVE STRUKTUR SISTEMLERI**

### **OZET**

Ahsap yapim sistemleri cok uzun surelerce Turkiye de kullanılan en onemli yapim sistemi olmustur. Ormanlik alanlarin yogunlu ve nitelikli agac bulunabilmesi sonucu ulkemizde bircok geleneksel ahşap yapim teknigi gelismistir. Bu yapim sistemlerinin bircok ornekleri Turkiyenin degisik bolgelerinde gorulebilir.

Ancak ormaların azalması ve nitelikli agac bulunmasının zorlaşmasının yanı sıra piyasada daha nitelikli ve ucuz malzemelerin girmesi sonucu Turkiyedeki Ahşap yapim sistemleri durma noktasına gelmiştir.

Ote taraftan kuzey amerika ulkelerinde ahşap cerceve sistemleri halen konutlarda kullanılan ana system olarak guncelligini korumaktadır. Bunu bir bakıma kontrollu orman bakımları, guncel teknolojik gelişmelere borcludur.

Ulkemizde kullanılan en yagın yapim sistemi betonarme yapim teknigidir. Ancak 1999 yilindaki trajik depremden sonra alternative yapim teknilerine olan ilgi artmiştir. Ahşap yapim sistemi bir zamanlar cok populerce kullanilmasına ragmen son 30 40 yilda nerdeyse durma noktasına gelmiştir.

Bu tez ahşap yapim sistemlerini guncel olarak kullanan Kuzey Amerika ulkelerinin guncel ahşap sistemleri tanitmakta. Ilerde ulkemizde olusturulabilecek yeni ve guncel ahşap standartlarına bir on calisma niteligi tasimaktadır.

# **1. INTRODUCTION**

## **1.1 Objective**

For decades wood building systems have been the main building systems for many countries. But because of the decreasing number of forest areas and lack of quality lumber material halted the traditional Turkish wood housing system for nearly 40 years.

With the introduction of new materials and building systems to the market the wooden building systems have been put to shelf and left there. For the last 30 -40 years Reinforced Concrete has been the main building system in Turkey. Even in the rural villages all around Turkey Reinforced concrete systems were preferred over the traditional Wood Systems.

An objective of this thesis is to encourage the modern and rational wooden construction systems to enter the building market of Turkey

After the tragic earthquake in 1999 people started to look for alternative building systems. This lead to the import of light building systems as materials, technologies and design aspects in order to create post-earthquake relief in those areas.

One of the most popular alternative systems is Wood frame housing which is widely used in North American countries for single family residences. With the continuing developments in wood frame technologies and materials this system is updated and current.

To introduce the wood framing system back to Turkey we should have a Wood Frame building standards and material technologies and designs. The traditional systems have to be updated with the introduction of current techniques and materials. Another aim of this thesis is to transfer knowledge and technology regarding wooden construction in North American countries and to create the opportunity for these technologies to be used as a new design tool.

This thesis introduces the basic standards of the North American countries that use wood frame housing. It has been aimed to be used as a reference or a base for future Wood Standards

## **1.2 Scope**

The scope of this thesis is to encourage the revival of wooden construction in Turkey and to improve the technology, knowledge and design regarding this building system. The emergence of the need for light frame housing in Turkey after the earthquake in Marmara region in 1999 has created the need for the existing wood house technology in Turkey to be improved and for the materials and techniques to be standardized.

The scope of this thesis will contain introduction of the framing methods commonly used, framing elements and materials, wall, floor and roof framing methods and alternatives along with common solutions for basic safety and comfort requirements, sheathings as structural elements and exterior finishes, windows and doors, standard framing details for rough-ins and requirements regarding with the building codes, insulation materials and techniques

## **1.3 Procedure**

In the first part of this thesis, the traditional wooden building system in Turkey will be examined and main elements are introduced. Also in this part the ups and downs of these systems are also examined regarding the lateral forces and other forces. This explains us the main down sides of the traditional building systems.

Second part introduces the Canadian Wood Frame Construction. In this part all the main aspects of a wood frame house construction is examined. The main reference for this thesis is National Building Code of Canada – 1997 edition. All the requirements have been derived from this reference.

In the last part of this thesis, a case study, which is conducted in Toronto, Canada, will be discussed in order to introduce the real life applications of the details and systems explained in the second part of the thesis.

## **2. WOOD HOUSE CONSTRUCTION IN TURKEY**

For long time's wooden buildings was the major building type in nearly all regions of Turkey. In the days where the lumbers and forest products were vast and cheap to get, many buildings has been designed and built with wood elements.

### **2.1 Traditional and Other Wooden Structure Types in Turkey**

There is not only one type of wooden construction in Turkey. There are wooden constructions and wooden structured construction. These buildings are the buildings that are being built like a reinforced-concrete building with the vertical and horizontal load bearing elements.[25]

#### **2.1.1 Wooden Structures with Columns and Beams**

The horizontal and vertical elements of this type have been built by small number of big cross sectional elements called “azman”. One downsize of this type of building is that the connection of the horizontal elements with the vertical elements are very hard. This causes problems especially during the lateral forces like earthquakes. The floors in this type of buildings are built with the wooden elements too. The walls are being formed by the filling of the spaces between the vertical elements by bricks or adobe. [24, 25]

#### **2.1.2 “Hımış” Structures**

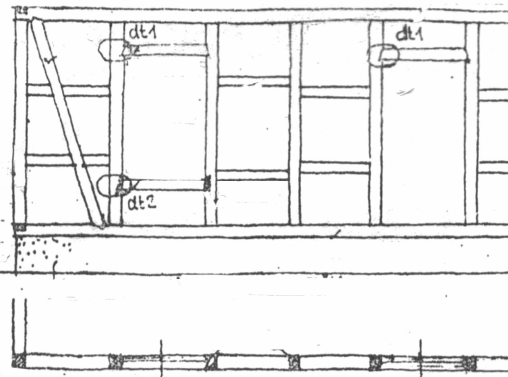


Hımış House in Sivas 150 years



Hımış House in Ayas

This type of buildings is constructed by smaller elements like 2" x 4" (50 x 100 mm) on a dense basis. These dense elements are reinforced by diagonal elements. These diagonal elements sometimes used mono or as dual X shapes. Also in this type of buildings the walls are formed by the filling of the empty space between the wooden



structure elements of stone, brick and/or adobe materials.[24, 25]

In some areas instead of the filling materials long lumbers are used to form the walls. This traditional building system is called "Dizeme" [25]

Figure showing the sturcuture of Himis Building

### 2.1.3 "Bagdadi" Structures



In this type small lumber pieces ½" – 1" (10 – 20 mm) are nailed in and out of wooden structure in every 1" – 2" (20 – 40 mm). These elements reinforce the walls and increase their wall bearing capacities. The cavities between these pieces are filled with tree barks or pebbles for insulation purposes. Then these walls are covered with a stucco type material. The structures works better than the previous types of building on lateral forces. [24, 25]

## 2.2 The Current Situation of Wooden Construction in Turkey

For the last 40 to 50 years not many wooden house has been built in Turkey. We can summarize the reasons for this as below:[24-26]

One of the major reasons is the fact that the wooden construction techniques and systems are not covered in the educational system of Turkey. These building systems are not in the curriculum.

First and one of the major reasons is the decreasing number of the forest and the raising of the cost of lumber used in wooden house construction. Besides this there

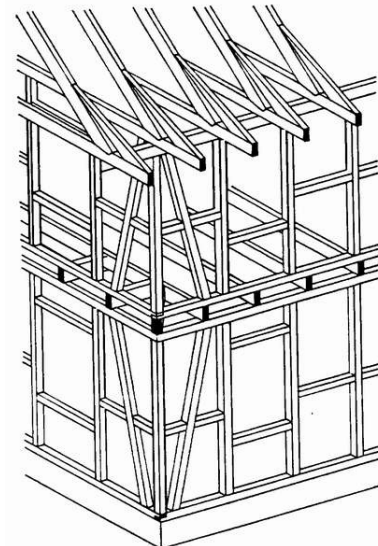
are other less expensive alternative materials available on the market. This does not affect the usage of wood in construction only. There have been a lot of material changes in other fields too.

There has not been a substantial supply of quality lumber. Because of this reason even in the villages surrounded by forest, reinforced concrete structural systems are being preferred.[24-26]

Especially in the big cities the land values increase dramatically. This opens the way to high rise building which are impossible to be built by the wood structure systems.

Besides all the reasons stated above the wood building systems have been abandoned by Turkey. Even if Turkey has the forest and the lumber supplies needed for the wooden construction systems the lack of technology and standardization will lead to an unhealthy construction process.[24-26]

One other major setback for the wooden construction to become wide spread again is the lack of supporting material. In wood construction process special metal pieces, bolts, specialized nails, protective paints and other specialized tools are required. To keep the economical part of the business these materials and pieces have to be manufactured in the country.[26]



### **3. CANADIAN WOOD FRAME CONSTRUCTION**

#### **3.1 Wood Framing**

##### **3.1.1 Types of Framing**

The structural shell of a one or two storey house must be erected before any other work can begin. The shell consists of the foundation, floors, walls and roof. In some cases, interior walls may be load bearing, so they must be erected at the same time as the exterior walls. The shell must be framed and sheathed during construction to obtain its rigidity. Generally, temporary bracings and cross bracings are introduced to allow construction to proceed without accidents and damages. [5]

Before starting the framing of the house, it is important to consider the levels of insulation to be used in the different elements of structural shell, because framing dimensions may have to be increased to accommodate higher levels of insulation. [3, 5]

The platform and balloon methods of framing are two ways of constructing a wood-frame house. Balloon framing was the most common method of wood frame construction method in the latter part of 19th century, and the early part of 20th century. Platform framing has dominated since the late 1940s, and today represents conventional practice in North America. [5, 6]

##### **3.1.1.1 Platform Construction**

The most commonly used method for framing a house is platform construction. The chief advantage of this approach is that the floor system, assembled independently from the walls, provides a platform or working surface upon which walls and partitions may be assembled and erected. Since studs are one storey high, walls can be easily be prefabricated off the site or assembled on the sub floor in sections and erected one storey at a time without using heavy lifting equipment, The bottom and top plates, which are integral part of the wall framing, provide fire stops at the floor and ceiling and also nailing support for wall sheathing and interior finish. [3]

### **3.1.1.2 Balloon Framing**

Balloon framing differs from platform framing in that the studs used for exterior and some interior walls are continuous, passing through the floors and ending at the top plates which support the roof framing. Since the connection between the floor joists and studs in balloon framing do not lend themselves to prefabrication or easy assembly on the site, this method of framing houses is rarely used. However, some of the techniques involved in balloon framing may be used with the platform framing method. For example, ceiling joists may also be supported on a 19 x 89mm (1" x 4") ribbon let into the studs. Floor joist may also be supported in this manner where the level of the floors is offset at an adjoining wall in split-level houses. In some two storey houses, the centre load bearing wall in an otherwise platform framed house is balloon framed to provide convenient passage for heating ducts and pipes. [3, 6, 7]

### **3.1.2 Floor Framing**

In a wood frame house, the floor framing consists of sills, headers, beams and joists, in the interior, load bearing stud walls are used sometimes instead of posts and beams to support the floor joists and center bearing partition. All framing lumber should be well seasoned and have a moisture content not exceeding 19 percent at the time of installation. [6, 7-10]

#### **3.1.2.1 Sill Plates and Anchors**

The sill plate should be leveled carefully. If the top of the foundation is level, the sill plate may be laid directly on the foundation and the junction caulked. Alternatively, the sill plate may be placed on a closed-cell foam gasket or other air-impermeable material of the same width as the sill plate. If the top of the foundation is uneven or not level, the sill plate may be laid in a full bed of mortar. All sill plates must be anchored to the foundation wall with ½" (12.7 mm) minimum diameter bolts or other approved anchors. [5-10]

#### **3.1.2.2 Columns and Beams**

Wood or steel columns are generally used in the basement to support the beams, which in turn support the inner ends of the first floor joists as well as loads from upper floors transferred through walls and posts. [5]

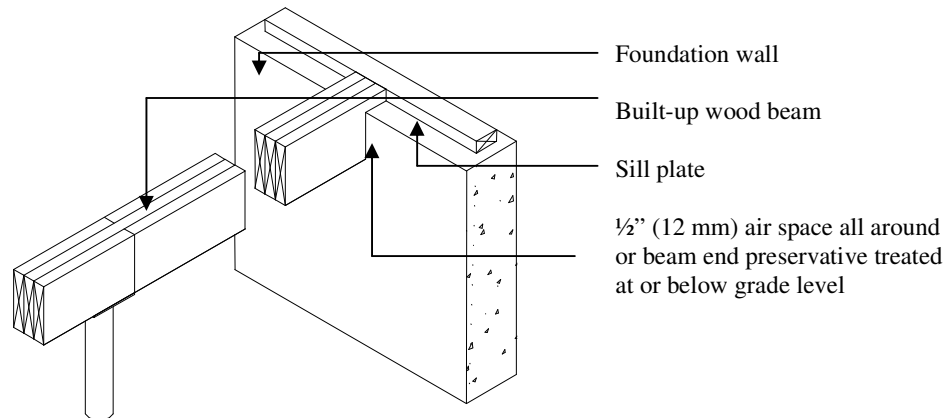
The top plate should be as wide as the beam it supports and either be bolted to the flange where a steel beam is used or nailed to the wood beam. [5]

Wood columns at least 6" x 6" (140 x 140 mm) may be solid or built up of 2" (38 mm) lumber. Generally 3" (76 mm) nails spaced at 12" (300 mm) on center are used to fasten the built up members together. Wood columns should be the same width as the beam they support and cut to ensure even bearing at top and bottom. Each column is nailed to the beam at the top and separated from the concrete base at the bottom by damp proofing material such as 6 mil (0.15 mm) polyethylene or Type S roll roofing. [6-10]

Ends of the beams should bear at least 3 1/2" (89 mm) on concrete or masonry walls or columns. There is a decay hazard, however, where beams are tightly set into wall notches, such that moisture can not escape readily. Therefore the ends of wood beams located at or below grade and framed into masonry or concrete walls, should be treated to prevent decay or have a 1/2" (12 mm) air space at the ends and sides. [6-10]

### 3.1.2.3 Beam and Joist Installation

The simplest method of beam and joist framing is to have the joists rest on the top of the beam (Figure 3-2) in which case the top of the beam is level with the top of the sill plate (Figure 3-1). [6-10]

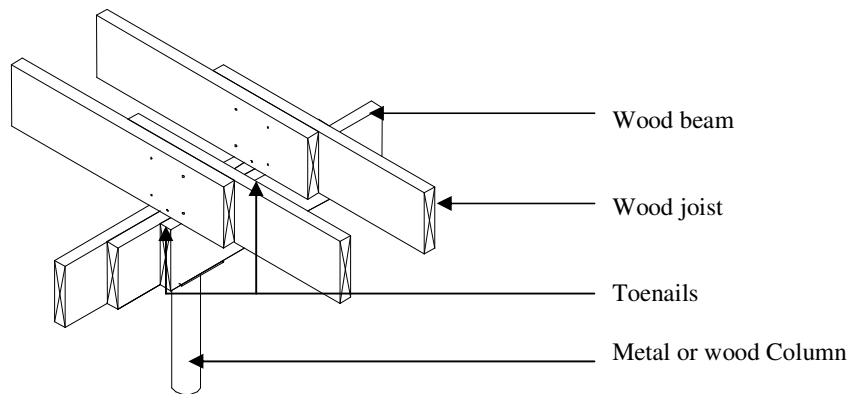


**Figure 3-1: Built-up Wood Beam [11,12]**

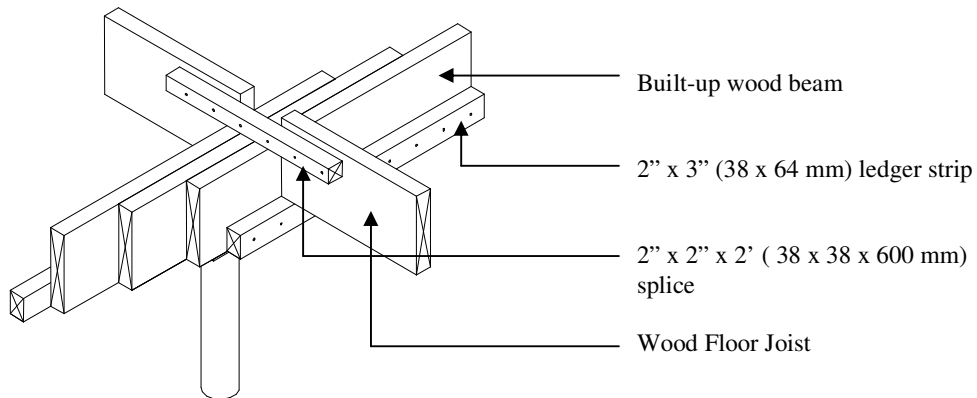
Where a more clearance under a wood beam is desired, joists may be supported by joist hangers or other structural connectors attached to the beam. In lieu of joist

hangers, The National Building Code allows joists to be supported on ledger strips attached to the wood beams (Figure 3-3). The 2" x 3" (38 x 64 mm) ledger strip is nailed to the beam with two 3 1/4" (82 mm) nails per joist. The ends of the joists may be spliced or notched as shown in Figure 3-3. [7-8]

Joists framed into the side of a steel beam may be supported on the bottom flange or on a 2" x 2" (38 x 38 mm) ledger strip bolted to the web with 1/4" (6.3 mm) bolts space 24 " (600 mm) on centre. The joists should be spliced and a 1/2" (12mm) space provided on top of the beam to allow for joist shrinkage.[5, 7, 8]



**Figure 3-2:** Joists supported on top of wood beam and fastened to the beam by toenailing. [11, 12]



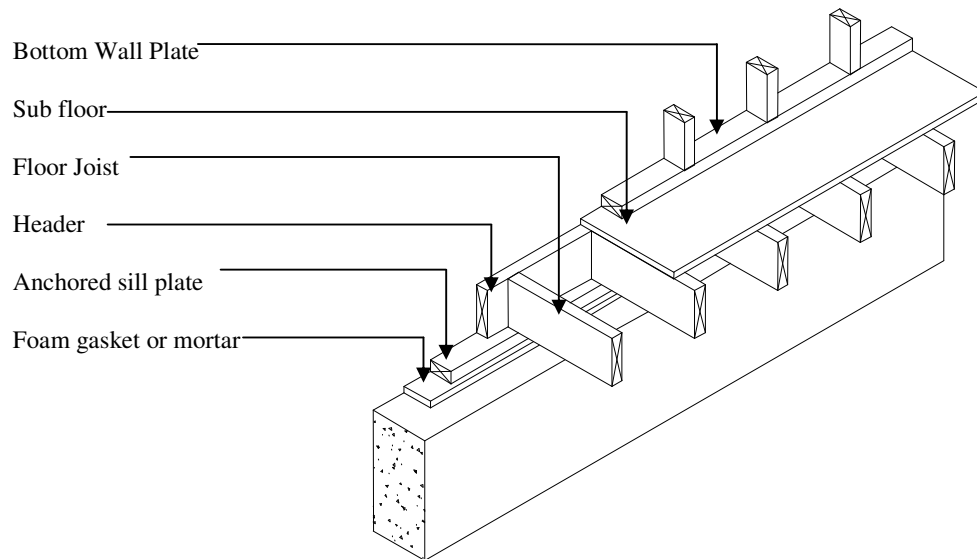
**Figure 3-3:** Joists supported on ledger strip nailed to the beam with two 3 1/4" (82mm) nails per joist.[11, 12]

### 3.1.2.4 Foundation Wall and Joist Connection

The two general types of floor joist construction used over the foundation wall conform either to platform or balloon frame construction. Platform framing is by far the most common used. In platform framing, two methods of wall and joist connection are used and are generally referred as the sill-plate method and the joist-embedded method. [5]

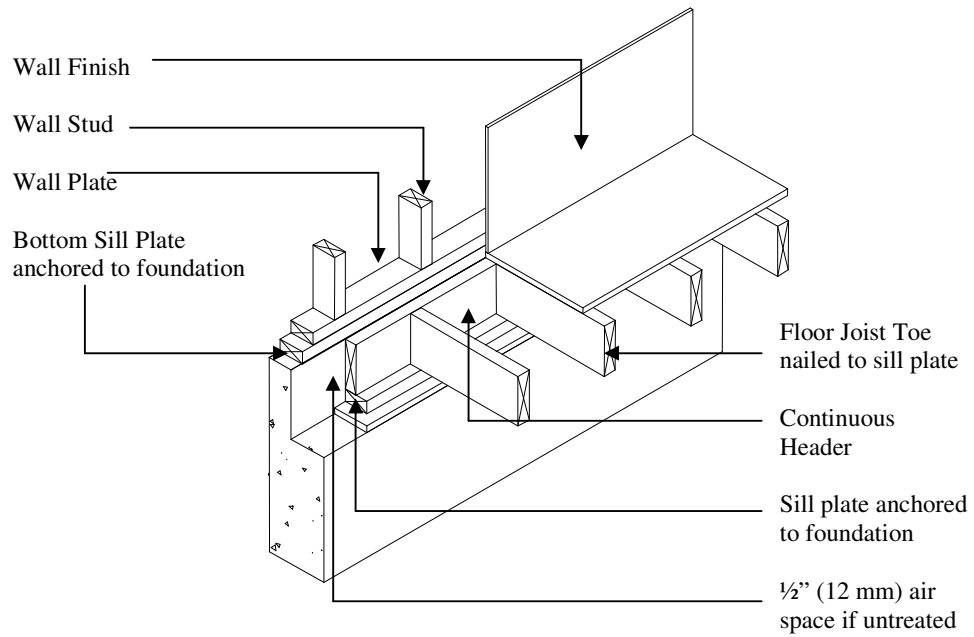
#### Sill-Plate Method

This method can be used with either concrete or concrete block foundation walls. It consists of a wood sill plate anchored to the foundation wall (Figure 3-4) for the support and fastening of the joists and header at the end of the joists. The sill plate is usually supported on the top of the foundation wall. In this case, the bottom of the sill plate should be at least 6" (150 mm) above the finished grade. [5,7-10]

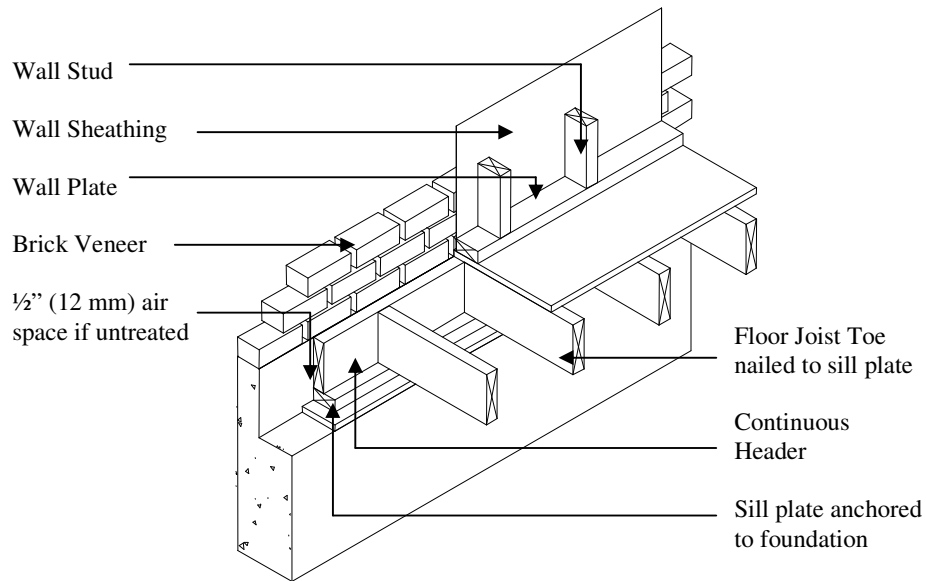


**Figure 3-4:** Sill-Plate method used in platform construction [11, 12]

Where it is desirable to lower the elevation of the main floor, the top of concrete foundation walls may be reduced to 3 ½" (90mm) in thickness. The wall framing is supported on a sill plate anchored to the top of the wall, and the floor joists rest on a separate sill plate located on a ledge formed in the wall (Figure 3-5). [5, 7-10]



**Figure 3-5:** Floor joist supported on a ledge formed in the foundation wall. [11, 12]

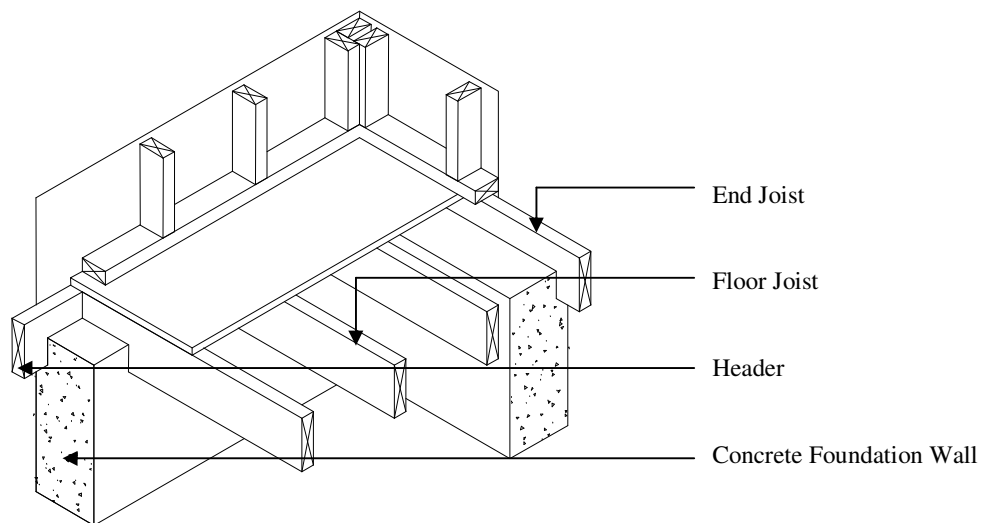


**Figure 3-6:** Floor Joists supported on a ledge formed in the foundation wall. [11,12]

Where a masonry finish is used, such as brick veneer, the masonry is supported on the top of the foundation wall, and wall framing is supported on the floor framing (Figure 3-6) If the thickness of the wall is reduced, as noted above, the height of the reduced section should not exceed 14" (350 mm).[7-10]

### Joist-Embedded Method

This method can only be used with cast-in-place concrete foundation walls. Beams, Joists and headers are positioned before the concrete is placed. Floor framing is temporarily supported on the inside concrete form and wedges used to level the framing. Filler pieces placed between the floor joists and along the end walls retain the fluid concrete between the joists. These filler pieces are set flush with the inner face of the foundation wall (Figure 3-7). Joist headers and end joists serve as outside forms for the concrete. Beam ends are treated to prevent decay when they are located at or below grade. The concrete is then placed so that at least two-thirds of the depth of each joist is embedded in the concrete, thus providing suitable anchorage for the floor-framing members. [5-8]



**Figure 3-7:** Joist-Embedded method used in platform construction [11, 12]

#### 3.1.2.5 Floor Joists

Joists are selected to meet strength and stiffness requirements. Strength requirements depend on the loads to be carried. Stiffness requirements, on the other hand are intended to limit the cracking of ceiling finishes under live loads and, even more important, to limit vibrations from moving loads.[5-6]

Wood floor joists are generally 2" (38 mm) thick and either 6,8,10 or 12" (140, 184, 235 or 286 mm) deep. The size depends upon the loading, length of the span, spacing

between joists, the species and grade of lumber used, and the deflection which may be allowed. Table 3-1 shows the spans which are allowable for the various grades and species of lumber and for different loading conditions.[7-10]

**Table 3-1: Maximum Spans for Floor Joists [14]**

		Maximum Span, ft-in. (m)									
		Joist Spacing, in/ (mm)									
Commercial Designation	Grade	Joist Size, in. (mm)	With Strapping			With Bridging			With Strapping and Bridging		
			12 (300)	16 (400)	24 (600)	12 (300)	16 (400)	24 (600)	12 (300)	16 (400)	24 (600)
Douglas fir - larch	No. 1 and	2x6 (38x140)	10-2 (3.09)	9-7 (2.91)	8-7 (2.62)	10-10 (3.29)	9-10 (2.99)	8-7 (2.62)	10-10 (3.29)	9-10 (2.99)	8-7 (2.62)
		2x8 (38x184)	12-2 (3.71)	11-7 (3.53)	11-0 (3.36)	13-1 (4.00)	12-4 (3.76)	11-3 (3.44)	13-9 (4.19)	12-10 (3.90)	11-3 (3.44)
	No. 2	2x10 (38x235)	14-4 (4.38)	13-8 (4.16)	13-0 (3.96)	15-3 (4.66)	14-4 (4.38)	13-6 (4.11)	15-10 (4.84)	14-10 (4.51)	
		2x12 (38x286)	16-5 (4.99)	15-7 (4.75)	14-10 (4.52)	17-2 (5.26)	16-2 (4.94)	15-3 (4.65)	17-10 (5.43)	16-7 (5.06)	15-6 (4.72)
Hem-fir	No. 1 and	2x6 (38x140)	10-2 (3.09)	9-7 (2.91)	8-7 (2.62)	10-10 (3.29)	9-10 (2.99)	8-7 (2.62)	10-10 (3.29)	9-10 (2.99)	8-7 (2.62)
		2x8 (38x184)	12-2 (3.71)	11-7 (3.53)	11-0 (3.36)	13-1 (4.00)	12-4 (3.76)	11-3 (3.44)	13-9 (4.19)	12-10 (3.90)	11-3 (3.44)
	No. 2	2x10 (38x235)	14-4 (4.38)	13-8 (4.16)	13-0 (3.96)	15-3 (4.66)	14-4 (4.38)	13-6 (4.11)	15-10 (4.84)	14-10 (4.51)	
		2x12 (38x286)	16-5 (4.99)	15-7 (4.75)	14-10 (4.52)	17-2 (5.26)	16-2 (4.94)	15-3 (4.65)	17-10 (5.43)	16-7 (5.06)	15-6 (4.72)
Spruce - pine - fir	No. 1 and	2x6 (38x140)	9-7 (2.92)	8-11 (2.71)	8-2 (2.49)	10-4 (3.14)	9-4 (2.85)	8-2 (2.49)	10-4 (3.14)	9-4 (2.85)	8-2 (2.49)
		2x8 (38x184)	11-7 (3.54)	11-0 (3.36)	10-6 (3.20)	12-5 (3.81)	11-9 (3.58)	10-9 (3.27)	13-1 (3.99)	12-2 (3.72)	10-9 (3.27)
	No. 2	2x10 (38x235)	13-8 (4.17)	13-0 (3.96)	12-4 (3.77)	14-6 (4.44)	13-8 (4.17)	12-10 (3.92)	15-1 (4.60)	14-1 (4.29)	13-2 (4.00)
		2x12 (38x286)	15-7 (4.75)	14-10 (4.52)	14-1 (4.30)	16-4 (5.01)	15-5 (4.71)	14-6 (4.42)	17-0 (5.17)	15-10 (4.82)	14-9 (4.49)

Alternatives to dimension lumber floor joists include laminated veneer lumber joists, parallel chord trusses and wood I joists. Allowable spans for these engineered wood products are provided by their manufacturers. Where a sill plate is used, the joists are installed after the sill plates have been leveled on the mortar bed and anchored to the foundation wall. [5, 6, 13]

Joist spacing of 16” (400 mm) on center is most commonly used, although for heavy loads or when space is limited, 12” (300 mm) spacing of shallower joists may be substituted. Conversely, if floor thickness is not a limitation, deeper joists at 24” (600 mm) spacing may prove more economical.[5, 7-10]

A header joist is end-nailed (Figure 3-8) or toe nailed (Figure 3-5) to each joist. In platform construction each joist including the end joist parallel to the exterior walls is

toe nailed to the sill (Figure 3-8). The inner ends of the joists are supported on the top of the beam (Figure 3-2) or framed into the side of the beam (Figure 3-3). [13]

Floor pans often require a load bearing wall to be located at right angles to the floor joists, but offset from the joist support. Load bearing interior wall should be located not more than 36" (900 mm) from the joist support when the wall does not support a floor, and not more than 24" (600 mm) from the joist support when the wall supports one or more floors, unless the joist size is designed to support such concentrated loads.[5, 6, 13]

Non-load bearing partitions parallel to the joists should bear on joists or on blocking between the joists. This blocking should be 2" x 4" (38 x 89 mm) lumber and spaced 4' (1200 mm) or less. [7-10, 13]

When framing for large openings, such as stairwells or fireplaces, trimmer joists are doubled if they support header joists more than 32" (800 mm) long. Header joists longer than the 4' (1200 mm) should also be doubled. Where unusually large openings occur, trimmer joists that support header joists more than 6'-6" (2000 mm) long and header joists that are more than 10'-6" (3200 mm) long should be designed according to accepted engineering practice.[5,6,13]

Intermediate support may be provided by the following methods:

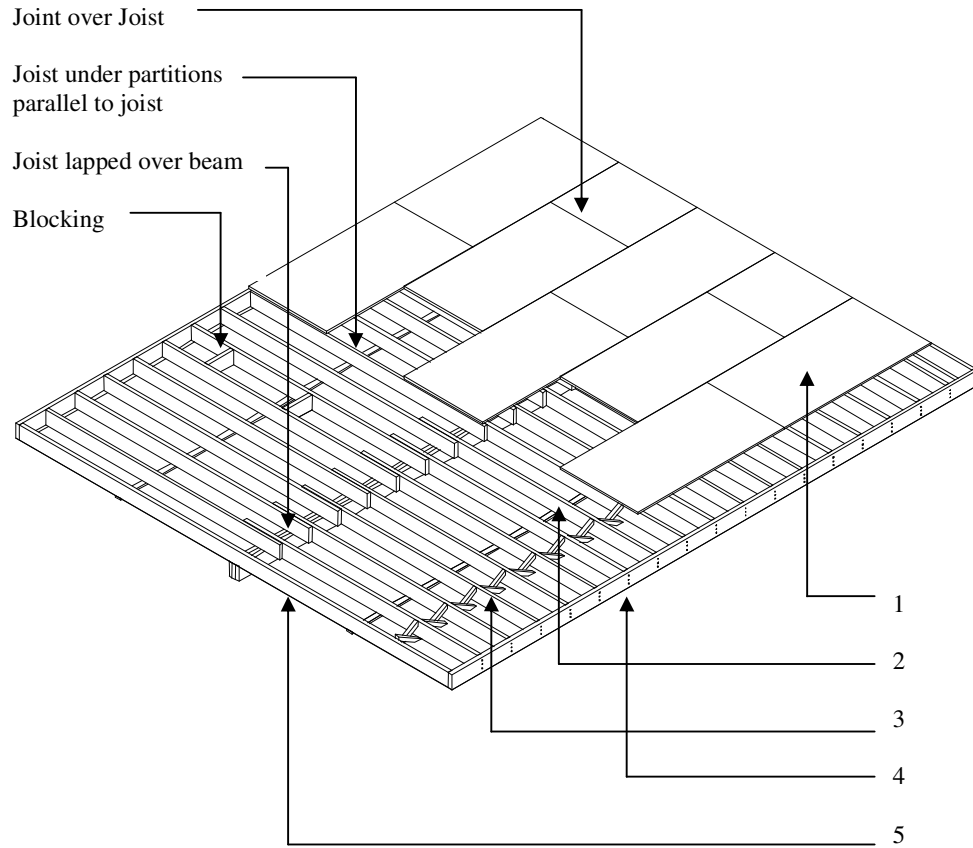
1" x 3" ( 19 x 64 mm) or 2" x 2" (38 x 38 mm) cross bridging or 2" (38 mm) full depth blocking fastened between joists together with continuous wood strapping of 1" x 3" (19 x 64 mm) nailed to the bottom of the joists. [12, 13]

As shown in Figure 3-8 (1) subfloor nailed with 2" (51 mm) nails to joists: (2) 1" x 3" ( 19 x 64 mm) continuous wood strapping nailed at bottom with two 2 ¼" (57 mm) nails: and/or (3) 2" x 2" (38 x 38 mm) cross bridging nailed with two 2 ¼" (57 mm) nails: (4) header joist end nailed to joists with three 3 ¼" (82 mm) nails: (5) header toenailed to sill plate with 3 ¼" (82 mm) nails 24" (600 mm) on center: (6) floor joists toenailed to sill plate with two 3 ¼" (82 mm) nails, one on each side. [11, 12, 13]

#### **3.1.2.6 Sub floor**

Subflooring should consist of plywood, oriented strand board, waferboard or square edge, ship lap, or tongue and grooved lumber no wider than 8" (184 mm). The

minimum thicknesses of plywood, oriented strand board, waferboard and lumber for subflooring are shown in Table 3-2. [5, 13]



**Figure 3-8:** Floor Framing [11, 12]

**Table 3-2:** Minimum thickness of subflooring. [14]

	Minimum Subflooring Thickness for Maximum Joist Spacing at		
	16" (400 mm)	20" (500 mm)	24" (600 mm)
Plywood and OSB, O-2 Grade	5/8" (15.5 mm)	5/8" (15.5 mm)	11/16" (18.5mm)
OSB, O-1 grade and waferboard R-1 Grade	5/8" (15.5 mm)	5/8" (15.5 mm)	3/4" (19.0 mm)
Particleboard	5/8" (15.5 mm)	3/4" (19.0)	1" (25.4 mm)
Lumber	11/16" (17.0 mm)	3/4" (19.0)	3/4" (19.0)

Floor stiffness can be substantially increased, and floor squeaks minimized, by applying elastomeric glue between the floor joists and the plywood sub floor. By using this method, the plywood, adhesive and joists act together as a strengthened floor frame, thus reducing deflection between adjacent joists. [6]

### **3.1.2.7 Floor Framing at Projections**

Floor joists sometimes project beyond the foundation wall to provide support for a bay window or additional floor space in the upper rooms. The cantilevered portion of the frame should not exceed 16" (400 mm) for 2" x 8" (38 x 184 mm) joists and 24" (600 mm) for larger joists. Insulation should be fitted carefully, and placed on the top of the soffit finish under the cantilevered floor and up the inside face of the joist header and end joists. The vapor barrier should be placed on the warm side of the insulation and neatly fitted and fastened in place. [6-10, 13]

### **3.1.3 Wall Framing**

The term "wall-framing" includes the vertical and horizontal members of exterior walls and interior partitions. These members referred to as studs, wall plates and lintels, serve as a nailing base for all covering material and support the upper floors, ceiling and roof. [5,6]

Exterior wall studs are vertical members to which the wall sheathing and cladding attached. They are supported on a bottom of a plate of foundation sill and in turn support the top plate. Studs usually consist of 2" x 4" (38 x 89 mm) or 2" x 6" (38 x 140mm) lumber and commonly spaced at 16" (400 mm) on center. This spacing may be changed to 12" (300 mm) or 24" (600 mm) on center depending on the load and the limitations imposed by the type and thickness of the wall covering used (Table 3-3). Wider studs 2" x 6" (38 x 140 mm) may be used to provide space for more insulation. Insulation beyond that can be accommodated within a 3 1/2" (89 mm) stud space can also be provided by other means, such as rigid or semi-rigid insulation or batts between 2" x 2" (38 x 38 mm) horizontal furring strips, or by attaching rigid or semi-rigid insulation sheathing to the outside of the studs.[5, 6, 7-10]

The studs are attached to the horizontal top and bottom wall plates of 2" (38 mm) lumber that are the same widths with the studs.[6]

**Table 3-3: Size and Spacing of Studs [7, 14]**

Type of Wall	Supported Loads (including dead loads)	Minimum Stud Size in. (mm)	Maximum Stud Size in. (mm)	Maximum Unsupported Height ft-in (m)	
Interior	No Load	2 x 2 (38 x 38)	16 (400)	8-0 (2.4)	
		2 x 4 (38 x 89)	16 (400)	11-10 (3.6)	
		2 x 3 (38 x 64)	24 (600)	9-10 (3.0)	
	Attic not accessible by a stairway	2 x 3 (38 x 64)	16 (400)	8-0 (2.4)	
		2 x 4 (38 x 89)	24 (600)	11-10 (3.6)	
		2 x 4 (38 x 89)	16 (400)	8-0 (2.4)	
	Attic Accessible by a stairway plus one floor Roof Load plus one floor	Attic not accessible by stairway plus two floors	2 x 4 (38 x 89)	16 (400)	11-10 (3.6)
			Roof Load plus one floor		
		Attic accessible by stairway	2 x 3 (38 x 64)	16 (400)	8-0 (2.4)
			Attic not accessible by a stairway plus one floor	2 x 4 (38 x 89)	24 (600)
		Attic accessible by stairway plus two floors	2 x 4 (38 x 89)	12 (300)	11-10 (3.6)
			Roof Load plus two floor	2 x 6 (38 x 140)	16 (400)
		Attic accessible by stairway plus three floors	2 x 6 (38 x 140)	12 (300)	13-9 (4.2)
	Exterior	Roof with or without attic storage	2 x 4 (38 x 89)	16 (400)	8-0 (2.4)
		Roof with or without attic storage plus one floor	2 x 6 (38 x 140)	16 (400)	9-10 (3.0)
Roof with or without attic storage plus two floors		2 x 6 (38 x 140)	16 (400)	9-10 (3.0)	
Roof with or without attic storage plus three floors		2 x 6 (38 x 140)	16 (400)	6-0 (1.8)	

Lintels are the horizontal members placed over windows, door and other opening to carry vertical loads to the adjoining studs. Lintels are usually constructed of 2” (38 mm) separated by spacers to the width of the studs and nailed together to form a single unit. The preferable spacer material is rigid insulation. The depth of a lintel is determined by the width of the opening and vertical loads supported.[5, 6, 13]

### 3.1.3.1 Platform Framing

There are two methods of framing a house. Balloon framing was common until the late 1940s, but since that time, platform framing has become the predominant form of house construction.[3]

This method of framing wall sections horizontally on the sub floor prior to erection is widely used. The top and bottom plates are end nailed to each stud with two nails at least 3 1/4” (82 mm) in length. Studs are doubled at openings, the jack stud being cut to receive the lintels which are placed and end nailed through the outer studs. [5, 6]

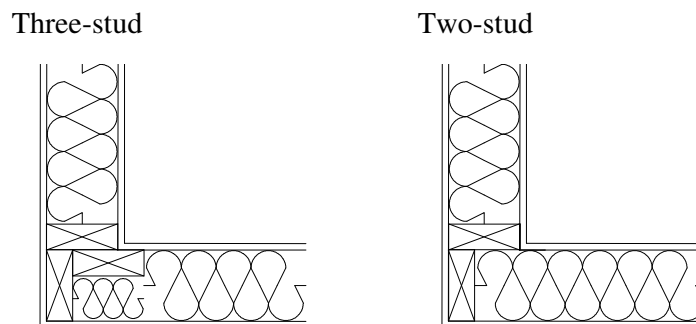
Wall sheathing usually applied to the framing prior to erection, thus the need of a scaffold is eliminated. Some types of sheathing will provide bracing to keep the walls square. Others should be reinforced with diagonal wood or metal bracing let into the studs.[5, 6, 13]

The completed wall sections are raised and put in place, temporary braces added and the bottom plates nailed through the sub floor to the flooring framing members.[6]

Interior partitions supporting floor, ceiling or roof loads are called load bearing walls, others are called non-load bearing walls or simply partitions. Interior load bearing walls are framed the same way as exterior walls. Studs are usually 2" x 4" (38 x 89mm) lumber spaced at 16" (400 mm) on center.[5,13]

Partitions can be built with 2" x 3" (38 x 64 mm) or 2" x 4" (38 x 89 mm) studs spaced at 16" (400 mm) or 24" (600 mm) on center depending on the type and the thickness of the wall finished used. [6, 7-10]

Multiple stud post made up of at least three studs, or the equivalent, is generally used at exterior corners, and intersections to secure a good tie between adjoining walls and to provide nailing support for the interior finish or exterior sheathing. Corners and intersections, however, must be framed with at least two studs. Figure 3-9 illustrates the commonly used exterior corners.[13]



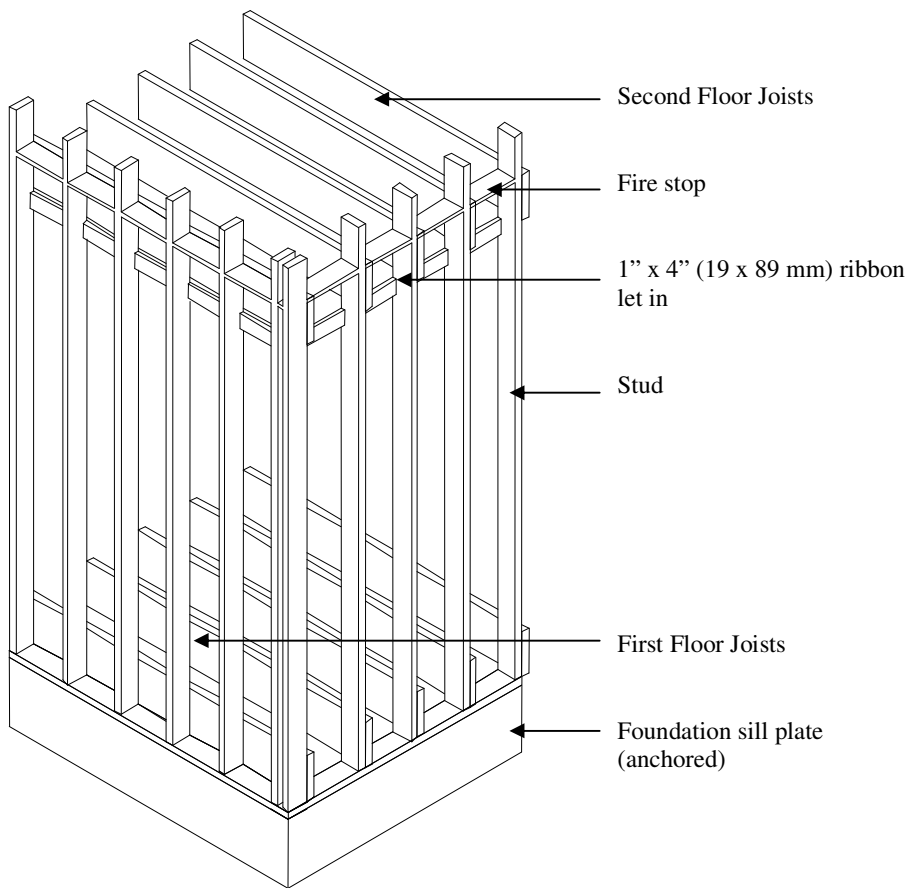
**Figure 3-9:** Multiple stud arrangements at exterior corner

### 3.1.3.2 Balloon Framing

In balloon framing construction, both the studs and first floor joists rest on the foundation sill plate (Figure 3-10) and the center beam or the bearing wall. Studs are

toe nailed to these supports with four 2 ½” (63 mm) nails: the joists in turn are nailed to the studs with two 3” (76mm) nails. When lumber sub floor is laid diagonally, blocking is required between the joists at the wall lines to support the ends of the boards.[6,13]

Second floor joists bear on a 1”x 4” (19 x 89 mm) ribbon that has been let into the studs, and the joists are nailed to the studs. The end joists parallel to the exterior wall on both first and second floors are similarly nailed to the studs.[7-10]



**Figure 3-10:** Wall framing using balloon construction method [11,12]

When framing the floor, blocking should be inserted between joists at the wall to support the ends of diagonal sub floor boards. As the space between the studs are not interrupted by wall plates (as in platform framing) , fire stops are required at floor and ceiling levels to eliminate continuous passage in the wall and thus resist the spread of fire. Lumber blocking 1 ½” (38 mm) thick is commonly used for this

purpose. Fire stops, however are not required where the wall space is filled with insulation.[7, 13]

The imperial convention is based on the using of the framing square, and the run is always expressed as 12, based on 12 inches to a foot. For example, a roof with a slope of 45° is expressed as 12/12 pitch. A roof with 4/12 pitch has a rise of 4 inches for every 12 inches of run.[13]

Using metric convention, for slopes less than 45°, the first number should always be one. A ratio of 1:5, for instance indicates a rise of 1 mm for every 5 mm of horizontal dimension, or 1m for every 5m. For slopes steeper than 45°, the second number (that is, the horizontal component) should always be one to facilitate easy verification. A ratio of 5:1 expresses a rise of 5mm for a horizontal dimension of 1mm, or 5m for each 1m. The use of mixed units, such as 1mm in 10m, should be avoided.[13,16]

For purposes of definition, flat roofs might be classed as those having less than 1:6 slope. [16]

### **3.1.3.3 Pitched Roofs**

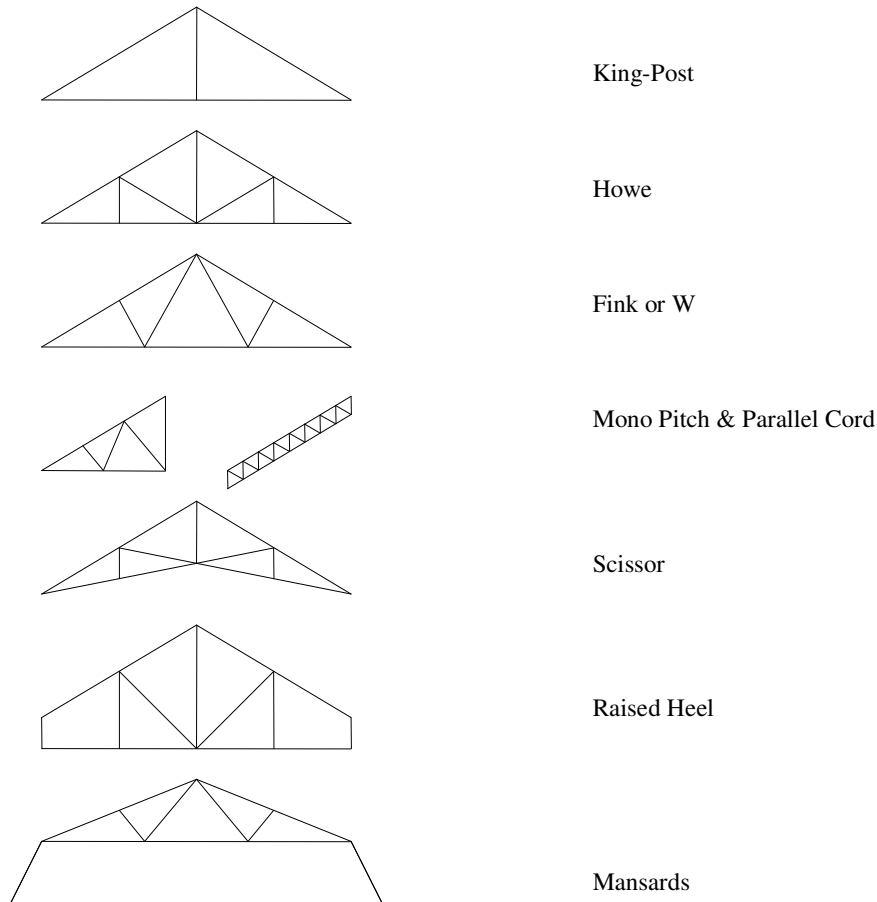
Roof trusses are most often pre assembled, although they can be constructed on site. Pitched roofs can also be stick-built, although this is a time consuming process. Of the pitched roofs, the gable roof is the simplest to construct, especially with the use of lightweight roof trusses. Other configurations, such as the hip roof and L-shape roof, though more complexes, can also be framed with trusses.[5, 6, 16]

#### **Pre-assembled Roof Trusses**

Pre-assembled roof trusses offer many advantages in that they save material and speed up the process of enclosing the house. They provide, in one step, the surface for the roof sheathing, a surface for the ceiling material and space for insulation. Ventilation of the attic space is easily accomplished through eaves or gables or both, and at or along the ridge. In most cases trusses are designed to span from exterior wall to exterior wall with no intermediate load bearing walls to support the roof loads (Figure 3-11). Thus, the entire house may be used as a one large workroom during the construction. This increases the flexibility of interior planning, because partitions can be placed without regard to structural requirements. Additional flexibility and speed is gained with pre- assembled components and add on features such as garage

roof trusses, porch roofs, simulated mansards and window canopies, which can also be supplied by the truss manufacturer. [16]

Metal plate connected trusses can be delivered to the construction site and placed on a flat, clean portion of the site. Trusses under a 20' (6m) span are usually installed by hand. Trusses longer than 20' (6m) require special lifting techniques to avoid damage. [7-10, 16]



**Figure 3-11:** Types of prefabricated roof trusses [16]

The trusses must be lifted into position with care to prevent excessive lateral bending. The first to be put in place is the gable truss, which is braced to the ground and wall. Each additional truss is lifted into position generally 24" (600 mm) on center toe nailed to the top plates and temporarily braced. When all trusses are plumbed and properly positioned, they are brace permanently. The stiffness of the roof is increased after the sheathing is applied. [13, 16]

## **Gable End Framing and Projections**

After the roof-framing members are up, the gable end studs are cut to fit and nailed in place. Studs in unfinished attics may be placed with the wide face parallel to the wall. The ends of the studs are then cut to fit the angle of the rafter and are toe nailed to the wall plate and to the underside of the rafter with four 2 ½" (63 mm) nails at each end.[6,16]

As with eave projections, the soffit is covered with ¼" (6 mm) sanded plywood or pre finished aluminum or vinyl sheets, and fascia board is added to the outside framing member. [5,13,16]

## **3.2 ROOF SHEATHING AND COVERINGS**

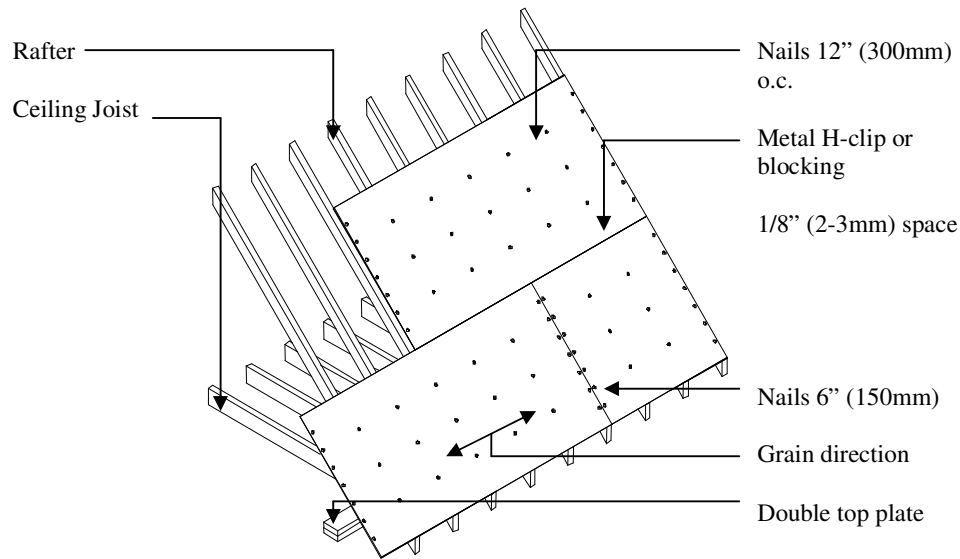
### **3.2.1 Roof Sheathing**

Roof sheathing is applied over roof trusses or rafters and usually consists of plywood, oriented strand board (OSB), structural wood panels or lumber. Sheathing provides a nailing base for the roof covering and laterally braces the roof framing.[5, 16]

#### **3.2.1.1 Installing Roof Sheathing**

When plywood or OSB is used for roof sheathing, it is laid with the face grain at right angles to the framing (Figure 3-12). Sheathing-grade structural wood panels (SWP) are used for this purpose. To obtain a good tie across the roof framing, the end joints of the panels should be staggered on the framing members. The edges of the panels should be separated by at least a 1/8" (2 to 3 mm) to prevent buckling when minor expansion occurs during wet weather. [7,16] The thickness of the plywood, OSB or structural wood panel used for roof sheathing depends to some extent on the spacing of the rafters, roof joists or trusses and whether or not the edges of the sheets are supported. To prevent damage to the roof covering when thinner panels are used, the joints running across the framing should be supported by 2x2" (38x38 mm) blocking, nailed securely between the roof framing members, or by metal H-clips inserted between sheets. The latter method is widely used because the installation is simple and economical. Minimum thicknesses for plywood and other roof sheathing are shown in Table 3-4. Staple fastening for 3'8" (9.5 mm) roof

sheathing must be 1/16" thick, 1 1/2" long with 3/8" crown (1.6 mm thick, 38.1 mm long with a 9.5 mm crown), and be driven with the crown parallel to the framing. Thicker roof sheathing which is no less than 5/8" (15.5 mm), is required for built-up roofing on a flat roof where it is used as a walking deck. In these cases, Table 3-2 should be used to determine the minimum thickness for the sheathing. [7-10, 16]



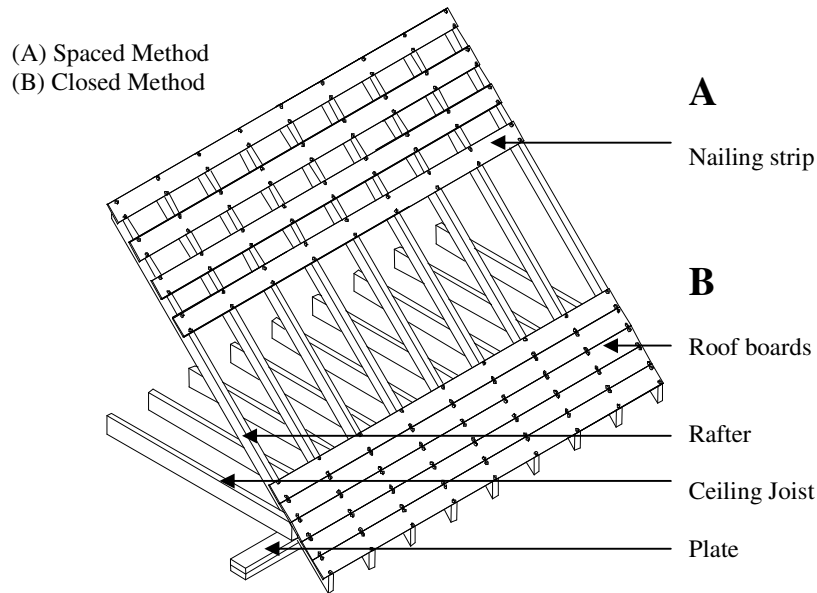
**Figure 3-12:** Application of structural wood panel roof sheathing [12,16]

**Table 3-4:** Minimum Thickness of Roof Sheathing for Sloping Roofs [7, 14]

		Sheathing Thickness, in (mm) for Truss or Rafter Spacing at			
		12" (300mm)	16" (400mm)	20" (500mm)	24" (600mm)
Plywood and OSB, O-2 Grade	Supported edges	5/16" (7.5mm)	5/16" (7.5mm)		3/8" (9.5mm)
	Unsupported edges	5/16" (7.5mm)	3/8" (9.5 mm)		1/2" (12.7mm)
OSB,o-1 Grade and waferboard R-1 Grade	Supported edges	3/8" (9.5 mm)	3/8" (9.5 mm)		7/16" (11.1mm)
	Unsupported edges	3/8" (9.5 mm)	7/16"(11.1mm)		1/2" (12.7mm)
Panel Mark (performance-rated panels)	Supported edges	-	1R16	1R20	1R24
	Unsupported edges	-	2R16	2R20	2R24
Lumber		11/16" (17mm)	11/16" (17mm)		3/4" (19mm)

Under materials requiring solid and continuous support, such as asphalt shingles and built-up roofing, lumber sheathing must be laid closed (Figure 3-13B). The boards are usually 3/4" (19 mm) thick, but this thickness may be reduced to 11/16" (17 mm) where supports are spaced at 16" (400 mm) on centre. Boards 8" (184 mm) or less wide are nailed to the framing members with two 2" (51 mm) nails per bearing.

Those wider than 8" (203 mm) should be nailed with three 2" (51 mm) nails per bearing. Boars wider than 12" (305 mm) should not be used for roof sheathing. For a wood shingle roof, the roof boards may be spaced the same distance apart on centre as the shingle exposure. This method (Figure 3-13A), commonly used in damp climates, permits freer movement of air around the boards and under shingles, thus reducing the possibility of decay.[5, 6, 7, 16]



**Figure 3-13:** Installation of wood-board roof sheathing [12, 16]

### 3.2.1.2 Roof Sheathing Details

Where openings occur in the roof structure for interior chimneys, the roof sheathing and framing members should have a clearance of 2" (50 mm) from the finished masonry, or metal chimney, on all sides for fire protection. This clearance may be reduced to ½" (12 mm) for exterior masonry chimneys. Roof sheathing should be securely nailed to the rafters and headers around the opening.[7, 11, 12, 16]

Roof sheathing at valleys and hips should be fitted to give a tight joint and should be securely nailed to the valley or hip rafter. This will give a solid and smooth base for flashing. [16]

### 3.2.2 Roof Coverings

The roof covering is usually installed as soon as the roof framing and the sheathing has been completed and before any other interior or exterior finishing work starts.

This sequence produces a weatherproof working space within the building early in the construction process so that other trades can begin their work. It also protects the lumber and interior panel products from excessive moisture.[16, 18]

Roof coverings should provide a long-life, waterproof finish that will protect the building and its contents from rain and snow. Many materials have withstood the test of time, and have proven satisfactory under various conditions. [16]

Asphalt shingles are by far the most commonly used roof covering for pitched roofs. Galvanized steel or aluminum roofing is also common in some regions. At normal roof pitches, metal roofs will generally shed snow, a desirable characteristic in heavy snowfall areas. Roll roofing, wood shingles, hand split shakes, sheet metal and concrete or clay tile among others are also used. For flat or low-pitched roofs, built-up roofing with a gravel topping or cap sheet is frequently used, and 1.3 for hand split shakes and asphalt shingles (using normal application). Built-up roof coverings are rarely used on roofs where the slope exceeds 1:4. [16]

The minimum and maximum slopes for the different types of roof coverings are presented in Table 3-5

**Table 3-5: Roofing Types and Slope Limits for Roofs [7, 14]**

Type of Roofing	Slope	
	Minimum	Maximum
<b>Built Up Roofing</b>		
Asphalt base (graveled)	1 in 50	1 in 4
Asphalt base (without gravel)	1 in 25	1 in 2
Coal-tar base (graveled)	1 in 50	1 in 25
Cold process	1 in 25	1 in 1.33
<b>Asphalt shingles</b>		
Normal application	1 in 3	No Limit
Low slope application	1 in 6	No Limit
<b>Roll roofing</b>		
Smooth and mineral surfaced	1 in 4	No Limit
19" (480mm) wide selvage asphalt roofing	1 in 6	No Limit
Cold application felt	1 in 50	1 in 1.33
<b>Wood Shingles</b>		
Hand split shakes	1 in 3	No Limit
Asbestos-cement corrugated sheets	1 in 4	No Limit
Corrugated metal roofing	1 in 4	No Limit
Sheet metal shingles	1 in 2	No Limit
Clay tile	1 in 2	No Limit
Glass fiber reinforced polyester roofing panels	1 in 4	No Limit

In order to avoid water damage caused by melting snow, which sometimes forms into ice dams at the eaves, shingle or shake-covered roofs must have additional protection. This protection usually consists of either Type S (smooth surface) or Type M roll roofing laid with the joints lapped at least 4" (100 mm) and cemented together. Placed over the roof sheathing, this protection sheet extends from the edge of the roof to a line at least 12" (300 mm) beyond the inside of the inner face of the exterior walls, thus preventing water penetration through joints in the roof sheathing. The eave protection must extend at least 36" (900 mm) up the roof slope.[7-10 ,16]

### **3.2.3 Asphalt Shingles on Slopes 1:3 or Greater**

Asphalt strip shingles should be a minimum No. 210 grade. Square-butt strip shingles are usually 12x36" (310 x 915 mm) or 13 ¼ x 39 3/8" (335 x1000 mm) in size, have three tabs and should be laid with 5" (130 mm) or 5 ¾" (145 mm) of their width exposed to the weather. Since there are approximately 21 to 26 strips in a bundle, a bundle will cover about 32 sq. ft. (3 m<sup>2</sup>). [7-10]

Bundles should be piled flat for storage so that strips will not curl when the bundles are opened. Care should be taken in piling shingles on the roof; if too many are piled together, the load capacity of the framing may be exceeded. [16]

Eave protection is first provided by one of the methods already described. A starter strip at least 12" (300 mm) wide is then placed along the eaves before the first course of shingles, so that it extends at least ½" (12 mm) beyond the eaves, rakes and fascia board to form a drip edge. Starter strips with metal drip edges can also be used. This projection prevents water from backing up under the shingles by capillary action. A shingle strip laid with the tabs facing up the roof slope is often used for this purpose. Type M (mineral-surfaced) roll roofing may be used as a starter strip and when continued up the roof slope will also serve as eave protection. The starter strip is nailed along the bottom edge at 12" (300 mm) intervals. The first course of shingles is then laid with the butt edge in line with the bottom of the starter strip.[5, 7, 16]

In shingle application, the exposure distance is important, and the exposure depends on the roof slope and the type and length of shingle used. [16]

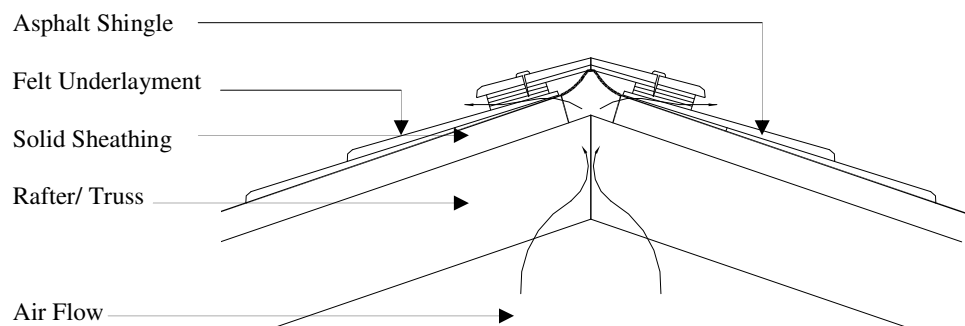
Several chalk lines will help align the shingle courses so that tabs and tab notches will be in a straight line which creates a good appearance. Each shingle strip should be stapled or nailed. Four large-head roofing nails should be used on each strip and

should be long enough to penetrate through or ½” (12 mm) into the roof sheathing. Good nailing is important. When a nail penetrates a crack or knothole, another nail should be driven alongside into sound wood. Cementing the tabs of strip shingles is recommended for all areas. [5,16]

Plastic cement can be used for this purpose with a spot approximately 1” (25 mm) in diameter being placed under the centre of each tab. Most shingles are manufactured with an adhesive strip on the underside of the tabs. Interlocking and other special shingles should be laid according to the manufacturer’s directions. [16]

### 3.2.3.1 Asphalt Shingles on Low Slopes of 1:6 to 1:3

Additional precautions must be taken on low slopes to ensure a waterproof roof covering. Except for the first two courses, three thicknesses of shingles are used on the entire roof including hips and ridges. This is achieved by using an exposure of not more than one-third the full height of the shingle. A starter strip is first installed as described for higher-sloped roofs, but laid on a continuous band of cement not less than 8” (200 mm) wide. The first course of shingles is then cemented to the strip with a continuous band of cement that is 4” (100 mm) wider than the shingle exposure. For example, a 10” (250 mm) band of cement should be used when the shingle exposure is 6” (150 mm). The succeeding courses of shingles are laid on a band of cement 2” (50 mm) wider than the shingle exposure, so that an 8” (200 mm) band is used when the exposure is 6” (150 mm). [7, 8, 16]



**Figure 3-14:** Application of Asphalt Shingles [15]

To avoid defacing the exposed surface of the shingles with cement, the band should be located between 1 and 2” (25 and 50 mm) above the butt edge of each succeeding

course of shingles. Each shingle strip should be stapled or nailed in place with four nails. [7, 16]

If cold application cement is used, it should be applied at a rate of approximately 1 gal./100 sq. ft. (0.5 L/m<sup>2</sup>) of cemented area. Hot application cement is applied at a rate of approximately 0.2 lb/sq. ft. (1 kg/m<sup>2</sup>) of cemented area. The above technique is necessary only for slopes lower than 1:4 since there are special low-slope shingles of sufficient length to maintain the three thicknesses necessary at this roof pitch.[5, 16]

### **3.2.3.2 Wood Shingles**

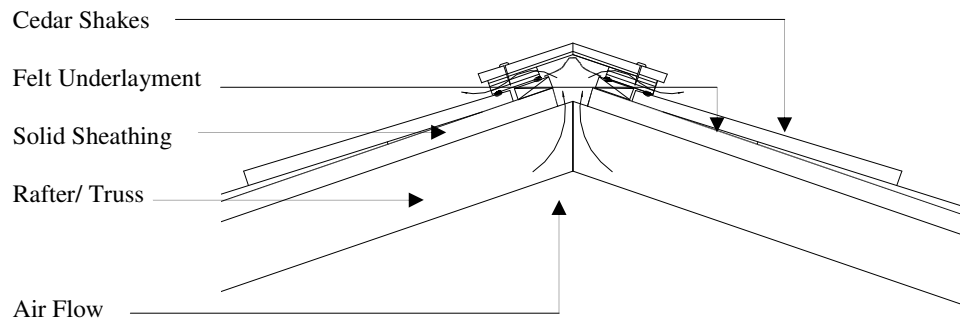
Wood shingles commonly used for houses are No. 1 and No. 2 grade. Red or white cedars are the principal species of wood used for shingles, because their heartwoods have high decay resistance and low shrinkage. Pine and yellow cedar are also used for shingles. The width of wood shingles varies, but the maximum width is 14" (350 mm) with a minimum width of 3" (75 mm) [7, 16].

As is the case for asphalt shingles, underlay and roofing felt is not usually required for wood shingles, but eave protection, as described previously, should be installed (Figure 3-15: Application of Wood Shingles). [5, 6]

The first shingle course should be laid double with the upper shingles overlapping the joints in the course beneath and both rows extending about 1" (25 mm) beyond the fascia boards at the eaves. This precaution will prevent water from backing up underneath the shingles. Shingles should be laid ¼" (6 mm) apart to allow for swelling when wet. The joints between shingles in one course should be offset at least 1 9/16" (40 mm) from the joint between shingles in the course below. The joints in succeeding courses should be spaced so that the joint in one course is not in line with the joints in the two previous courses laid. [5, 7, 16]

Only two nails should be used for each shingle. The distance of the nails from the butt edge of the shingle being nailed should be the shingle exposure plus 1 9/16" (40 mm), with an edge distance of about 13/16" (20 mm). For example, if the shingle exposure is to be 5" (125 mm), add 1 9/16" (40 mm), and thus the nail should be 69/16" (165 mm) from the butt edge of the shingle being nailed. Shingles are fastened with hot-dip galvanized or other corrosion-resistant shingle nails. Flat grain

shingles wider than 8" (200 mm) are sometimes split and nailed as two shingles to avoid problems with cupping and warping. [7-10]



**Figure 3-15:** Application of Wood Shingles [15]

### 3.2.3.3 Handsplit Shakes

Cedar hand split shakes must not be less than 18" (450 mm) long and 4" (100 mm) wide. They must also be no wider than 13 3/4" (350 mm). The butt thickness should be between 3/8 and 1 1/4" (9 and 32 mm). [7-10, 16]

Shakes may be applied over spaced or closed roof sheathing. When spaced sheathing is used, 1x4" (19x89 mm) (or wider) strips are placed on centers equal to the weather exposure at which the shakes are to be laid, but never more than 10" (250 mm). In areas where wind-driven snow conditions prevail, closed roof sheathing is recommended.[7-10,16]

Proper weather exposure is important. As a general rule, 7 1/2" (190 mm) exposures is recommended for 18" (450 mm) shakes, and a 10" (250 mm) exposure for 24" (600 mm) shakes. The minimum recommended roof pitch for handsplit shakes is 1:3. [7-10, 16]

A 36" (890 mm) strip of No. 15 roofing felt should be laid over the sheathing boards at the eave line. The beginning or starter course of shakes should be doubled; for extra texture, it can be tripled. The bottom course or courses can be 15" (380 mm) or 18" (450 mm) shakes, the former being made expressly for this purpose.[16]

After each course of shakes is applied, an 18" (450 mm) wide strip of No. 15 roofing felt should be laid over the top portion of the shakes, extending onto the sheathing. The bottom edge of the felt should be positioned above the butt at a distance equal to

twice the weather exposure. For example, 24” (600 mm) shakes laid with 10” (250 mm) exposure would have felt applied 20” (500 mm) above the shake butts. Thus, the felt will cover the top 4” (100 mm) of the shakes and extend out about 15” (350 mm) onto the sheathing [7-10]

Shakes should be spaced between ¼ to 3/8” (6 to 9 mm) apart. Side joints should be offset no less than 1- 9/16 in (40 mm) over the adjacent courses. When straight split shakes are used, the “fro-end” (the end from which the shakes have been split and which is smoother) should be laid uppermost (towards the ridge). [5]

#### **3.2.3.4 Finish at Ridge and Hips**

Asphalt shingle squares (one-third of a strip) are used over the ridge or hip and blind-nailed. Each shingle is lapped to provide the same coverage as the roofing shingles. It is good practice to lay the ridge cap so as to provide the maximum protection from the prevailing wind.[5, 6, 26]

In the case of wood shingles, 6” (150 mm) wide shingles are alternatively lapped and blind-nailed. Flashing is sometimes used under a wood-shingle ridge.[5]

#### **3.2.3.5 Built-up Roofs**

Built-up roof coverings are installed by roofing firms that specialize in this work. Roofs of this type may have three or more layers of roofing felt. Each layer is mopped down with tar or asphalt, the final surface being coated with the same material. The surface is then covered with gravel (embedded in the asphalt or tar) or with a cap sheet. This covering provides ballast and protection from the sun’s ultraviolet radiation. It is important to note that coal tar products and asphalt products are not compatible and must not be used together.[5, 6]

The eave line of projecting roofs is usually finished with metal edging or flashing. A gravel stop or can strip is used in conjunction with the flashing at the eaves when the roof is covered with gravel. Where built-up roofing is finished against another wall (except a masonry-clad wall), the roofing is mopped to the cant strip and turned up the wall at least 6” (150 mm). The wall sheathing paper and siding is then applied over the roof membrane. Where a built-up roof intersects a masonry-clad wall, the roof membrane is similarly returned up the face of the masonry. Counter-flashing is then added. This counter-flashing should be embedded into the mortar joints at least

1" (25 mm), extending down the wall about 6" (150 mm) and lapping over the flashing at least 4" (100 mm). [5, 7-10]

Single-ply membranes can also be used for flat roofs. They consist of various synthetic materials that are resistant to freeze-thaw cycling, ozone attack and ultraviolet degradation. They are relatively simple to lie, but are not often used on the small roofs that are typically part of wood-frame construction.[5]

### **3.2.3.6 Sheet Metal Roofing**

Sheet metal roofing is manufactured in 30 to 36" (762 mm to 914 mm) widths, depending on the profile of the corrugation, and in any lengths specified by the builder. It comes with the necessary accessories for treating the various details of the roof, such as hips, valleys, eave starters and edges. The usual method of fastening the metal roof sheets is to lay 1x4" (19x89 mm) wood nailing strips across the rafters at no more than 16" (400 mm) on centre. For more positive attachment and better nailing, 2x4" (38x89 mm) purlins can be used. There must be a nailing strip underneath each end joint. The choice of metal thickness is steel or aluminum will depend on the local snow load, but it should not be less than 0.013" (0.33 mm) for galvanized steel, 0.018" (0.46 mm) for copper or zinc and 0.019" (0.48 mm) for aluminum. The required thicknesses for specific snow loads are given in tables provided by the manufacturer. [16]

### **3.2.3.7 Concrete and Clay Tile Roofing**

When considering the use of concrete or clay tile, it must be remembered that these materials are considerably heavier than other roofing systems, and thus the roof supporting structure of rafters or trusses must be designed to withstand the additional load. A professional engineer should be consulted to obtain a proper design. [6]

## **3.3 WINDOWS AND DOORS**

The appropriate selection and proper installation of windows and doors represents a very important aspect of wood-frame house construction. Windows and doors are often able to play a role in a number of systems within the building. Daylight, view, natural ventilation and means of egress are all affected by the windows and doors that are selected.[19,20]

Poor quality windows and doors can lead to high energy bills and maintenance costs. Irrespective of their quality, window and door problems may also be caused by poor installation. Unlike paint and wall paper, the cost of replacing poorly performing windows and doors is extremely high, and often quite disruptive. It is generally more cost effective to invest in good quality windows and doors, and to ensure that these are properly installed rather than having to upgrade these components later.[20]

There are several important factors to consider when selecting windows and doors. The energy efficiency of doors, and particularly windows, is a critical consideration. These components can account for a high fraction of a dwelling's heat loss. It is important to consider the size and swing of exterior doors, not only to comply with building code requirements but also to accommodate the easy movement of people and furnishings into and out of the dwelling. The size and style of windows should be carefully considered since this will influence the appearance of the house as well as the natural ventilation and natural light which are provided. Durability and maintenance are two additional factors which apply to any exterior component of the dwelling, and especially to windows and doors. Finally, some thought should also be given to providing adequate resistance to forced entry through the type and location of windows and doors.[11, 20]

### **3.3.1 Light, View and Ventilation**

Windows and doors with glazing can provide light and view for the occupants provided they are appropriately sized and located. Specific rooms call for unobstructed windows large enough to allow natural light. Normally, living and dining rooms require glazing to be no less than 10 percent of the area of the room. Other rooms such as bedrooms, dens and family rooms should have windows that represent at least 5 percent of the floor area of the room. These requirements promote healthful indoor spaces that consider the psychological well-being of the occupant.[7-10, 20]

Windows can also provide natural ventilation by allowing outside air to flow inside. Operable windows can eliminate the need for mechanical ventilation during the non-heating season. For most rooms where the window is used to provide natural ventilation, this requires an unobstructed, operable window area of at least 3 sq. ft. (0.09 m<sup>2</sup>) in area. Unfinished basements need operable windows that represent at

least 0.2 percent of the basement floor area if non-heating season mechanical ventilation is to be eliminated. [7-10]

While windows can provide benefits of light, view and ventilation they can also pose a fire hazard to adjacent properties. Because fire can spread from windows to adjacent houses, building codes place strict limits on the amount of glazing in walls that are close to property lines. Glazed openings are not permitted in walls that are within 4 ft. (1.2 m) from a property line. Walls more than 4 ft. (1.2 m) may contain limited glazed openings depending on the distance from the property line and the area of the wall facing the property line.[7-10, 20]

### **3.3.2 Means of Egress**

Windows can play a part in the building's means of egress, allowing occupants to escape to the outdoors in case of emergency. These windows, typically located in bedrooms, should open to the outside without special hardware. They should also have an unobstructed open portion with no dimension less than 15" (380 mm) and with an open area of at least 3.8 sq. ft. (0.35 m<sup>2</sup>) as shown in Figure 3-16. For example, a window with an opening which measures 18 x 30" (450 x 750 mm) would conform to this requirement.[7-10]

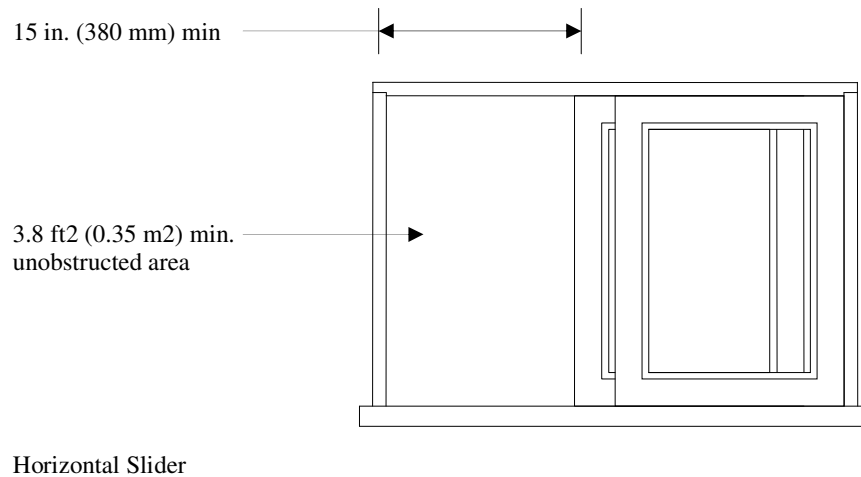
Windows intended to serve as egress windows should have a sill height no more than 39" (1.0 m) above the floor, and not be more than 23ft. (7.0 m) above ground level. Access can be improved to windows high on walls and intended to serve as egress windows by using built-in furniture. The furniture can act as a step, allowing easy escape in fire situations.[7-10]

### **3.3.3 Window Styles**

There is a wide variety of windows available today categorized under several common styles (Figure 3-17). Each style has its own advantages and disadvantages which should be carefully considered when selecting windows.[20]

**Fixed windows** are generally the least expensive, and usually offer the best level of energy efficiency and resistance to forced entry. They do not offer any natural ventilation and cannot serve as a means of egress from the dwelling in case of fire. [20]

**Single or double hung windows** are a traditional style. Only one sash (usually the bottom unit) operates in single hung windows, while both sashes operate in double hung units. Prior to advances in window technology, these windows did not perform well in terms of ease of operation and air leakage. However, modern types have been developed to address these factors, and can also offer good resistance to forced entry. [20]

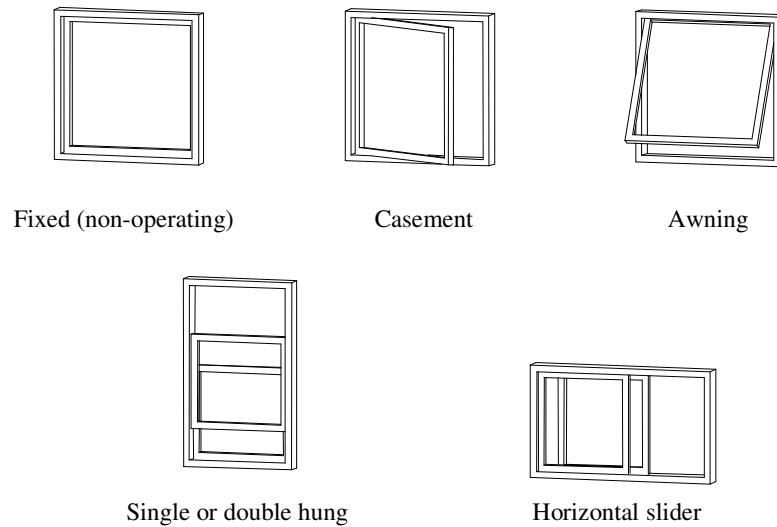


**Figure 3-16:** Minimum dimensions for egress windows [20]

**Horizontal and vertical slider windows** are easy to operate, and, because they do not project out from or into the dwelling, are safer since they do not act as obstacles. Their operation tends to make horizontal sliders less airtight than casement, awning and tilt-and-turn windows since the weather-stripping is exposed to wear due to friction. [20]

**Casement and awning windows** are among the more expensive styles. Due to their operation, these windows are very airtight and offer good resistance to forced entry. Casement windows are well suited to deflecting prevailing winds into the dwelling for natural ventilation and passive cooling. Awning windows have the advantage of shedding rain effectively when open. [20]

**Tilt-and-turn windows** are the most flexible of all window styles. Some types can act like casement and awning windows. These windows can be very airtight when fitted with compression-type closing devices.[20]



**Figure 3-17: Common Window Styles [20]**

### 3.3.4 Window Performance

Significant advances in window technology have been achieved through ongoing research and development by government and industry. These advances are available as options in most manufacturers' products. It is important to appreciate how these contribute to improved performance when making a selection.[19,20]

#### 3.3.4.1 Multi-pane Windows

In order to reduce the potential for condensation, windows that separate heated space from unheated space or the exterior must be at least double glazed. Each pane of glazing helps to increase the inside surface temperature of the innermost pane of glass, thereby reducing the potential for condensation.[19, 20]

Condensation, a common home-owner complaint, can be reduced by installing good, energy efficient windows. Some condensation on windows is normal and should be expected, particularly around the edges of the glazing during cold weather. Nonetheless, multi-pane windows with thermally broken frames and good quality spacers can go a long way towards reducing the likelihood of condensation in today's houses. [20]

#### **3.3.4.2 Low-emissive Coatings**

A large proportion of the heat loss and gain through a window is due to radiation – a process where warmer objects radiate heat to cooler objects, as in the case of the sun warming the earth with its radiant energy. A low emissive (Low-E) coating is a thin metallic film deposited on glass which acts as a mirror to radiant heat, reflecting it back into the dwelling during cold weather, and back to the outdoors during hot weather. Low-emissive coatings work to reduce heating and cooling bills. They provide a double-glazed window with about the same performance as a clear, triple-glazed window, but at less additional cost. An increasing proportion of window manufacturers are offering Low-E glazing as a standard feature due to their improved resistance to condensation on the inside glazing during cold weather. [19]

#### **3.3.4.3 Gas Fills**

Another innovation in window technology is the replacement of air with inert gas fills between panes of glass in a sealed unit. Inert gases have a higher insulating value than air because they are heavier, resulting in lower convective and conductive heat losses between the panes of glass. Argon is the most commonly used gas due to its availability and low cost. Gas fills are a cost-effective upgrade over conventional air-filled glazing. [19]

#### **3.3.4.4 Edge Seals**

The thermal efficiency of a sealed glazing unit can be significantly improved by using a low-conductivity edge seal or spacer between panes of glass. Traditionally, edge seals have been made of aluminum which conducts heat rapidly resulting in cold areas around the edges of glazing units. Plastic, silicone and glass fiber spacers are now used to reduce thermal bridging at the perimeter of sealed glazing units. [19]

#### **3.3.4.5 Frames with Thermal Breaks**

Window frames made from metal, plastic or fiberglass can conduct a large amount of heat unless a thermal break made from an insulating material is provided. Without thermal breaks, window frames can become so cold that frost forms on the side during extremely cold weather. This is less of a problem in wood windows, due to the relatively higher insulating value of wood, as well as in windows that have extruded frames filled with insulating materials. It is important to check the

construction of windows to ensure that the frames are either well insulated or have a thermal break. [19]

### 3.3.5 Energy Rating

The Energy Rating (ER) is a useful measure of the overall heating season performance of a window in a typical dwelling. The ER considers heat loss due to transmission and air leakage, along with solar heat gain, averaged over north, south, east and west exposures. The ER may be positive or negative. A positive ER indicates that on average, the window gains more heat from incoming solar energy than it loses over the heating season. Most ER ratings for windows are negative, as can be seen in Table 3-6. Many manufacturers quote thermal resistance values for the centre of glazing in their windows. [19]

This is always higher than the effective thermal resistance of the window when the effects of the edge seal and window frame are taken into account. Typical effective thermal resistance values are provided in Figure 88 in both imperial (R) and metric (RSI) units. Numerous studies on cost-effective energy efficiency improvements to new housing indicate that as a minimum, windows should have an ER of approximately -13 or higher. This translates into a double-glazed window with Low-E coating and argon gas fill. [19, 20]

**Table 3-6:** Comparison of typical window thermal efficiencies [19]

R (RSI) Energy Rating	Aluminum Frame with Thermal brake	Wood or Vinyl frame	Fiberglass frame
Double glazed clear with air fill	1.59(.28) / -40.6	2.04 (.36) / -24.9	2.38 (.42) / -19.0
Double glazed low-E with air fill	1.99 (.35) / -32.7	2.67 (.47) / -17.1	3.12 (.55) / -11.5
Double glazed with low-E with argon fill	2.10 (0.37) / -29.0	2.90 (.51) -13.3	3.46 (.61) / -8.0
Triple glazed clear with air fill	1.99 (.35) / -32.7	2.84 (.50) / -11.8	3.18 (.56) / -10.8
Triple glazed low-E with air fill	2.21 (.39) / -27.9	3.41 (.60) / -9.5	3.86 (.68) / -6.2
Triple glazed with low-E with argon fill	2.33 (.41) / -25.2	3.69 (.65) / -6.8	4.25 (.75) / -5.4

#### 3.3.5.1 Air tightness, Water Resistance and Wind Load Resistance

Windows in Canada are expected to conform to the CSA standard, CAN/CSA-A440-M, Windows. The standard includes a window classification system that rates

windows according to their air tightness, water resistance and wind load resistance characteristics. Normally, the ratings achieved by each window are marked on the window. Windows installed in houses should be identified as meeting the A1 (airtightness), B1 (water resistance), and C1 (wind load resistance) ratings of the CSA standard. [20]

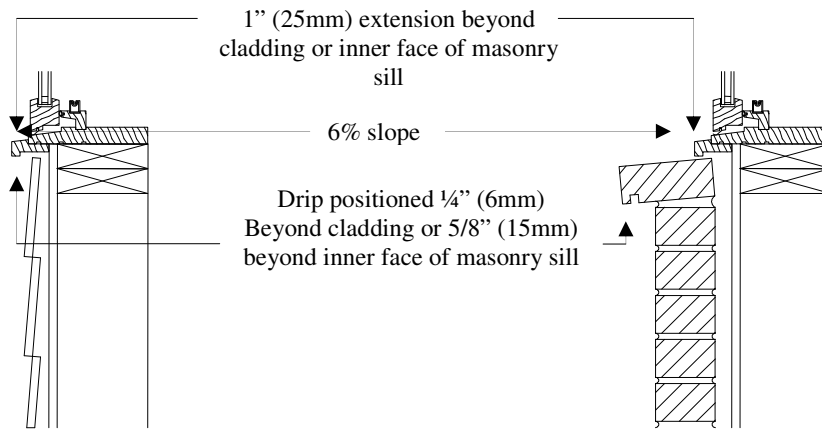
### **3.3.6 Window Selection**

Windows are seldom selected solely the basis of minimum building code requirements for light and natural ventilation. The contribution of windows to the external appearance of the dwelling, a pleasing view (or privacy), natural light and passive solar heating are often more important considerations. The style and operating characteristics of windows should be carefully considered within this context. The provision of effective natural ventilation does not require every window to be operable. The selective use of operating windows can reduce window costs, thereby permitting an investment in higher quality windows. [20]

Durability and maintenance should be considered both for exterior and interior applications. Maintenance free finishes are highly recommended to reduce the need to paint windows. These are also highly advisable for two-and three-storey houses where access for maintenance is difficult. In areas such as bathrooms, water resistant interior finishes for windows are recommended. This avoids potential water damage to sashes and frames, reducing the need for continued maintenance. [20]

### **3.3.7 Window Installation**

Windows are normally installed after the house framing and roof covering are complete. Proper scheduling should ensure delivery of the windows at this stage. However, it may be necessary to accept earlier delivery and arrange for storage of the windows on site. It is recommended to store windows upright on a dry, level surface, in their original packaging, and leaving the temporary bracing in place. When stored outside, a vented platform covered with a large tarpaulin is the preferred means of storage. Remember to label and store screens separately. If left on windows during construction, screens may be damaged or clogged with dust. [11, 20]



**Figure 3-18: Window Sill [8]**

Prior to installation; it is important to review the manufacturer’s installation instructions, and ensure that all of the proper tools, fasteners and materials are available. Windows must be installed plumb and level within the rough opening using shims to maintain the window true and the spaces around it even. Depending on the technique used to insulate and air sealed.[20]

### 3.3.8 Exterior Doors

Exterior doors, like windows, contribute to the external appearance of a dwelling and are most often selected on the basis of style and finish. With the exception of custom doors, most exterior doors come as pre-hung manufactured units ready for installation within a rough opening. Exterior doors are typically manufactured in wood, steel, plastic and fiberglass. Wood doors are normally solid, while other types consist of inner and outer structural panels filled with insulation. These modern door types are generally more energy efficient. However, wood doors have proven performance and a traditional appearance which has maintained their popularity in the marketplace. Irrespective of the style and appearance of the door, a number of common considerations are worth nothing. [6,11]

Hardware, in particular locksets and hinges, are important items both in terms of functionality and durability. The main entry door to a dwelling will be locked and unlocked, opened and closed countless number of times over its useful life. Low-cost hard-ware may not prove the least costly in the long run. [6]

Requirements for resistance to forced entry apply to door hardware under the National Building Code. Deadbolt locks in exterior doors to houses should have a cylinder with no fewer than five pins and a bolt throw of at least 1" (25 mm). Double doors should have heavy duty bolts top and bottom with an engagement of at least 5/8" (15 mm). Hinges need to be fastened to wood doors with wood screws not less than 1" (25 mm) long, and to wood frames penetrating at least 1 3/16" (30 mm) into solid wood. [7-10]

Resistance to forced entry extends beyond door hardware to the framing for the door as well. Solid blocking should be provided on both sides of the door way at lock height between the jamb for the door and the structural framing so that the jambs resist spreading by force. Additional screws in the drywall around the door frame will also strengthen resistance to forced entry. [7-10]

Weather-stripping is the primary line of defense against air leakage around doors, and should be carefully examined when selecting an exterior door. It should be effective, durable and easy to replace. Air leakage of items such as mail slots should also be considered.[7 -10]

Glazing in exterior doors should be thermally efficient, and depending on its size and location, may also have to be tempered glass for added safety. Generally, glass sidelights greater than 20" (500 mm) wide that could be mistaken for a door and glass in storm or sliding doors is required to be safety glass. Double-glazed sidelights are recommended, and when no glazing is provided, a door viewer should be considered for security purposes. Similar to windows, glazing in side doors near property lines, may be restricted depending on the distance to the property line. [7-10]

At present, practically all windows and doors are purchased and installed as complete manufactured systems. There may be cases, however, where a custom door or window may be desired, or an existing window in an older house may require improvement. In these cases, certain components may have to be milled prior to assembly and installation or retrofit.[11]

### **3.4 FRAMING DETAILS FOR ROUGH-INS**

One advantage of wood-frame construction is that the space between the framing members in wood-frame walls, floors and roofs provides a safe and economical location to conceal the greater part of the heating, plumbing and electrical distribution system. [11, 12]

Most of the electrical wiring and many plumbing pipes and heating and ventilating ducts run parallel to the joists and studs and can easily be concealed in the space between the members. Where it is necessary to run pipes or wires at right angles to the joists and studs, the wood members may be notched or drilled. Within certain limitations, the structural strength of a framing member is not seriously reduced by these notches or holes. [11]

#### **3.4.1 Cutting The Framing Members**

##### **3.4.1.1 Notching of roofs, ceilings or floor joists.**

Notches made in the top at the end of the joists should be within one-half the joist depth from the edge of the bearing. The depth of the notch should be no more than one-third of the joist depth (Figure 3-19B). [7-10]

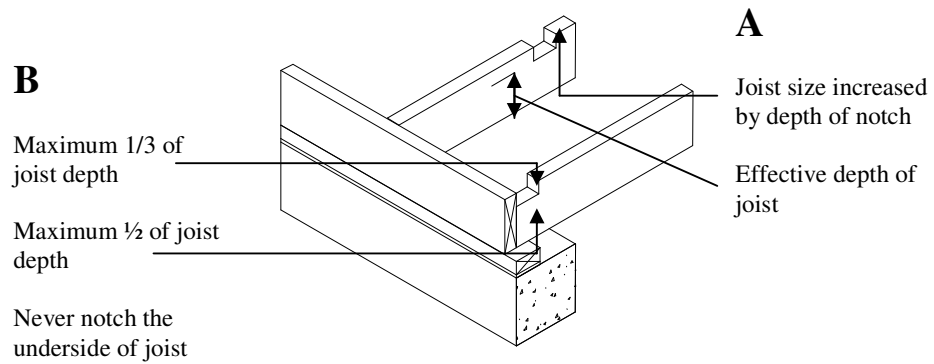
If notches are necessary elsewhere in the span (Figure 3-19A), this should be considered when deciding the size of joist to use, so that the size of joist can be increased by the depth of the notch. The bottom edge of joists should not be notched, since this may cause a joist to split when it deflects under load. [7-10]

##### **3.4.1.2 Drilling holes in joists.**

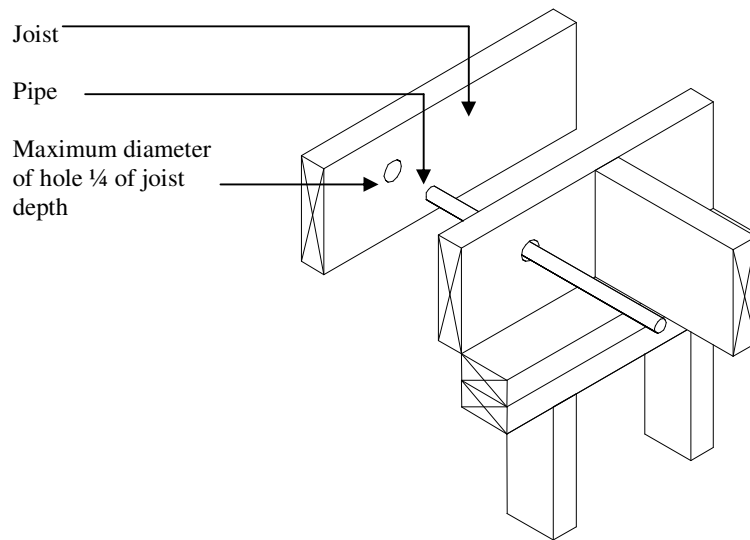
Normally, holes drilled in joists should not be larger than one-quarter the joist depth or closer than 2" (50 mm) to either edge (Figure 3-20).[7-10, 11]

##### **3.4.1.3 Notching and Drilling of Studs.**

Load bearing wall studs that have been notched or drilled to more than one third of their depth must be reinforced, usually with 2" (38 mm) lumber nailed to the side of the studs and extending about 24" (600 mm) each side of the notch or hole. Similar reinforcing is used when notched partition studs have less than 1 9/16" (40 mm) of solid wood remaining.[11,13]



**Figure 3-19:** Example of notch limitations [13]



**Figure 3-20:** Maximum size of holes drilled in joists [13]

#### 3.4.1.4 Notching and Drilling of Top Plates.

In load bearing walls, top plates are also reinforced with 2” (38 mm) lumber when the solid wood remaining in the plates is less than 2” (50 mm) in width. If the required reinforcing must be placed on the face of the plate or stud, sheet metal is normally used so that the wall finish may readily be applied over it.[7-10, 11, 13]

### **3.4.2 Framing Details For Plumbing Systems**

The installation of the plumbing system usually begins after the framing. This initial work is called “roughing-in.” It includes putting in the plumbing vents and drains and all the hot and cold water piping which will be enclosed in the walls and ceilings and under the basement floor. Piping in outside walls should be insulated. Since the bathtub must be put in before the wall finish can be applied, bathtub installation is usually included in roughing-in. Plumbing fixtures and accessories are not connected until the installation of the interior finish has been completed. The design and installation of the entire plumbing system is usually regulated by provincial or municipal codes. [3, 9]

When 3” (75 mm) copper or plastic piping is used, the stack wall may be made of 2x4” (38x89 mm) material. Sealing the area around the pipe is necessary to prevent air leak-age into the attic space.[9]

Where soil stack or large pipes must run horizontally at right angles to the joists, it will be necessary to frame out the joists. To do this, headers are installed between the joists. Alternatively, services are suspended and enclosed in a bulkhead. [9, 12]

### **3.4.3 Framing Details For Heating Systems**

There are many ways to heat a house. Heating systems range from the multi-controlled electric or hot-water heating systems to the relatively simple single space heater. [3]

The three prevalent heating systems are: forced warm air, electric baseboards and forced flow hot-water heating. Other less frequently used systems are: air, ground or water source heat pumps with electric resistance back-up, heat pumps with natural gas back-up, and solid fuel-burning (wood or coal) furnaces.

All types of heating systems may be safely and easily installed in wood-frame houses. Certain clearances, however, must be maintained between parts of the system and combustible material. Installers of heating equipment should be aware of local regulations before starting work. [3]

For a warm-air heating system, the ducts for supply and return air are usually located between studs in walls and between joists in floors. When planning the house,

locating joists, beams and studs to suit the requirements of the duct system must be considered.[3, 11, 12]

Provision must be made for controlled ventilation when planning the heat distribution system of the house. Assuming good airtight construction, the ventilation system must be designed to exhaust house air (primarily from bathrooms and kitchen but also from other rooms) and draw in outside air so that the air quality of the house is maintained.[11]

### **3.4.3.1 Warm-air and Ventilation Systems**

Normally, wall studs and joists are located so that they do not have to be cut to install heating ducts. When ducts must pass up through a wall to heat the room above, the top and bottom plates must be removed at these points, and the ducts are then fitted between the studs [12].

When a partition is supported on doubled floor joists and a heating duct is to go in the partition, the joists are ordinarily spaced apart, with blocking, to allow room for the duct. This eliminates the need to cut framing members unnecessarily or to use intricate duct angles.[ 12]

Return air grilles, usually located on inside walls near the floor level, can be connected to a duct or an enclosed stud space. At this point, the bottom plate and subfloor is cut to make a passage for the duct or air space. Blocks are nailed between the joists to support the ends of boards if diagonal subflooring has been used. Sometimes, the studs have to be cut to accommodate large return air grilles. Where this occurs, a lintel is used to support the studs that have been cut, and the opening is framed in the same way as the door opening shown in Figure 42. When enclosed, the space between the floor joists may be used as a return air duct and other return air ducts connected to the same joist space. Non-combustible material, such as metal, should be used to line the joist space within 24" (600 mm) of the furnace, under floor registers, and at the bottom of vertical ducts. [7-10, 11]

Warm-air registers are usually placed in the floor close to the outside walls, preferably under the windows. These registers are fitted with vanes to direct the warm air over the wide area of the outside walls. Where possible, ducts leading to these registers are located between joists with a shaped "boot" connecting the duct

and register. Then, only the subfloor and floor covering need to be cut. Diagonal subflooring must be supported by blocking at this point. [11, 12]

In houses with a crawl space, a warm-air furnace can either be put in a special compartment on the floor of the house, hung under the floor or mounted on a concrete base in the crawl space beneath the house. In the first two cases, the joists will have to be designed to carry the weight of the furnace.[12]

Ventilation is often coupled to the warm air heating system of the house, using the heating ducts to also distribute ventilation air. In some cases, particularly for houses without forced air heating systems, dedicated, whole-house ventilation systems are used. These systems often require ducts that are smaller than those required for used for heating purposes. They are accommodated by the framing in a manner similar to the warm air systems.[ 11, 12]

#### **3.4.3.2 Hot-water Systems**

Where the heating system requires only small pipes for a supply-and- return system, pre-planning the structural framing layout to accommodate the pipes is not normally necessary. [12]

Baseboard-type convectors are usually selected and located under windows along outside walls. In this manner, warm air rising through the convector blankets the outside walls. Virtually no cutting of the studs or joists is required with this type of installation as the baseboard type of convector is positioned on the surface of the wall. [12]

#### **3.4.3.3 Electric Baseboard Heating Systems**

Because it is easy to conceal wiring in walls and floors, the accommodation of this type of electric heating system requires little or no planning in the structural framing. As with hot-water and warm-air systems, electric heating units are usually located along outside walls, so that the air warmed by the heating elements blankets the walls. Because the heating elements are mounted on the surface of the wall, there is no need to cut the wall studs. Radiant heating with the heating elements located in the ceiling is also used.[11, 12]

With hot-water systems and electric systems which use baseboard radiators, it is important, especially in a well-constructed, well-sealed house, to provide for room-

air replacement and not rely entirely on natural convection and infiltration. If measures for air circulation are not implemented, humidity levels may rise to the point where condensation will occur. [11]

#### **3.4.4 Framing Details For Wiring**

Wiring a house for electrical services is usually started after the house has been closed in, that is, after the exterior wall sheathing and roof have been completed. [3]

This initial phase of wiring, also termed roughing-in, includes the installation of wiring and the boxes for the switches, lights and outlets. [3]

Roughing-in is done before applying the inside finish and ordinarily before placing the insulation in walls or ceilings. Lighting fixtures, switches, outlets and cover plates are installed after the interior finish and painting operations. [3]

The design and installation of the entire wiring system is usually regulated by a provincial electrical code. All provincial codes are closely modeled on the Canadian Electrical Code published by the Canadian Standards Association. The provincial codes usually require installation to be done by a licensed electrician. Owners are advised to check with the local authority before doing any wiring.[3, 21]

##### **3.4.4.1 Box Location**

The location of switches and outlets is important. The wiring plans should be studied carefully to ensure that everything is included. Today's house uses electricity for a multitude of purposes from radios and televisions to major appliances that require their own circuit. The location of outlets for all these purposes should be carefully planned. [3, 11, 21]

The amperage of the electrical service and the number of circuits and outlets installed should also take into account future needs; after the house is finished, alterations and additions are expensive. To accommodate the multitude of electrical appliances in a modern house, electrical services are usually 200 amps. [3]

##### **3.4.4.2 Switches**

Switches are commonly located just inside the door of a room so that they may be easily reached upon opening the door. Switches may service a wall outlet for a table

or a floor lamp as well as the usual ceiling or wall lights. It is common practice to locate the switch boxes about 4 ft. 6" (1.4 m) above the floor.[11, 12]

Multiple-control switches are convenient in many locations so that lights may be controlled from more than one switch. A living room light could have a switch near the outside entrance door and another at inner doors leading to the kitchen or to a bedroom hallway. In two-storey houses, three-way switches should be provided at the bottom and at the top of the stairway to control stairway lighting. Three-way switches can control light from more than one location. Basement stair lights should also be controlled by three-way switches at the head and ft. of the stair, particularly if there is living accommodation in the basement, or if there is an outside exit from the basement.[11, 12]

### **3.5 WALL SHEATHING AND EXTERIOR FINISHES**

Wall sheathing is the outside covering used over the wall framework and is nailed directly to the wall framing members. Sheathing provides a nailing base for some types of siding and backing for others. It can also be used to brace the structure, although in most cases sufficient bracing is provided by the interior wall finish. Insulating sheathing materials will not normally provide the required temporary or permanent bracing. When such sheathing is used, let-in braces of wood or metal can be used as bracing if required. Sheathing must be applied to the gable ends and walls where the exterior cladding is a type that requires solid backing.[5, 6]

Several types of sheathing are used in present-day construction: fiberboard, gypsum board, plywood, oriented strand board, rigid insulation and lumber. Table 3-7 lists the various types of sheathing and the minimum thickness necessary to provide sufficient backing for exterior finishing materials.[6]

#### **3.5.1 Types And Installation Of Sheathing**

Oriented strand Board and Wafer-board are structural panels made from thin, short wood wafers that are bonded together with a waterproof phenolic adhesive. While wafer-board contains wafers that are randomly arranged, oriented strand board contains wafers that are narrower and that are oriented in the long direction. The designation O-1 or O-2 indicates an oriented panel, while an R-1 designation indicates a panel containing randomly arranged wafers.[5,6]

The panels are formed into sheets 4 ft. (1.2 m) wide and usually 8 ft. (2.4 m) long. The minimum thickness that should be used is 5/16” (7.9 mm) for studs up to 2 ft. (600 mm) on centre and ¼” (6.35 mm) for studs up to 16” (400 mm) on centre. Oriented strand board and wafer-board sheathing can be installed the same as plywood (Table 3-7).[3, 7-10]

**Table 3-7: Minimum Thickness of Wall Sheathing [7]**

Types of Sheathing	Minimum Thickness in. (mm)		
	With Supports 16 (400)	With Supports 20 (500)	With Supports 24 (600)
<b>Structural</b>			
Fiberboard (insulating)	3/8 (9.5)	-	7/16 (11.1)
Gypsum sheathing	3/8 (9.5)	-	1/2 (12.7)
Plywood (exterior type)	1/4 (6.0)	-	5/16 (7.5)
OSB, O-1 grade and wafer board R-1 Grade	1/4 (6.0)	-	5/16 (7.9)
Panel mark (performance rated panels)	W16	W20	W24
Lumber	11/16 (17.0)	-	11/16 (17.0)
Mineral fiber, rigid board, type 2	1 (25)	-	1 (25)
OSB, O-2 Grade	1/4 (6.0)	-	5/16 (7.5)
Phenolic, faced	1 (25)	-	1 (25)
<b>Non Structural</b>			
Expanded Polystyrene (Types 1 and 2)	1-1/2 (38)		1-1/2 (38)
Expanded Polystyrene (Types 3 and 4)	1 (25)		1 (25)
Urethane and isocyanurate (Type 3)	1 (25)		1 (25)
Urethane and isocyanurate (Types 1 and 2)	1 (25)		1 (25)

Panel-type sheathing, such as fiberboard, plywood, oriented strand board or waferboard, is often applied vertically. The panels are nailed to the wall framework before the wall is raised to position. This sequence helps the wall maintain its square ness, avoids the need for scaffolding, and closes the house in as soon as the framing is completed. Often the window openings are covered by the sheathing panels and are not cut until after the windows are delivered.[3, 6]

The sheathing panels can also be applied horizontally, in which case the vertical joints should be staggered wherever possible.[6]

A space at least 1/8” (2 to 3 mm) wide should be left between the sheets to permit expansion without buckling. The panels are nailed to the framing at 6” (150 mm) on center along the edges, and 12” (300 mm) along the intermediate supports.[7-10]

**Plywood** is usually sheathing grade, unsanded, laminated with a waterproof adhesive and may contain knots. The minimum thickness for exterior type plywood wall sheathing should be 5/16” (7.5 mm) for studs 24 in (600 mm) on center, and ¼” (6 mm) for studs up to 16” (400 mm) on center. Sheets are 4 ft. (1.3 m) wide and usually 8 ft. (2.4 m) long.[3, 7]

**Fiberboard sheathing** should be at least 7/16" (11.1 mm) thick for studs 24 in (600 mm) on center and 3/8" (9.5 mm) for studs 16" (400 mm) on center. It is supplied in sheets 4 ft. (1.2 m) wide and generally 8 ft. (2.4 m) long, and is usually impregnated with an asphalt material to increase water resistance.[3, 7]

**Gypsum board sheathing** consists of gypsum filler faced on both sides with treated paper. It should be at least 1/2" (12.7 mm) thick for studs 24 in (600 mm) on center and 3/8" (9.5 mm) thick for studs 16" (400 mm) on center. It is supplied in sheets 4 ft. (1.2 m) wide and 8 ft. (2.4 m) long. The sheets are applied horizontally across the studs and nailed to the framing members.[3, 7]

**Insulating sheathing** is available in a number of types. One type is a semi-rigid glass-fiber panel with an exterior vapor-permeable, waterproof membrane. The others are rigid panels of expanded polystyrene, extruded polystyrene, polyurethane, isocyanurate or phenolic material. They come in different thicknesses, and the insulating value per unit thickness varies.[3, 7]

They are installed on the wall like any other panel sheathing but with special large-headed nails. A good reason for fastening this insulating sheathing before the wall is raised is its lightness and, for some types, its brittleness. Even a mild wind can make it difficult to install insulating sheathing on the vertical. Rigid glass fiber sheathing with vapor-permeable membrane can become man air barrier when the joints are sealed with contractor sheathing tape.[3, 6]

There are two methods of installing sheathing down to the foundation sill. Either the panel extends beyond the bottom wall plate by the required length and the missing part at the top plate is filled in, or longer panels of 9 ft. (2.74 m) length are used, where available, to cover the wall down to the sill area. It is advantageous to cover the header and sill with the same wall sheet because this reduces air infiltration.[3, 6]

**Lumber sheathing**, which should not be less than 11/16" (17 mm) thick, is used in boards 6 to 12" (140 to 286 mm) wide. It is milled in a shiplap, tongue-and-groove or square-edge pattern. The boards are nailed at each stud with two nails for the 6 to 8" (140 and 184 mm) widths and three for the 10 to 12" (235 and 286 mm) widths. End joints in the board must be placed over the center of the studs with the joints staggered on different studs. Lumber sheathing may be put on either horizontally or

diagonally and is extended beyond the subfloor to cover the header joist and the sill plate. The angle cuts in the diagonal approach require more time and materials.[6, 7]

### **3.5.2 Wall Sheathing Membrane**

Sheathing membrane (traditionally referred to as sheathing paper) should be water resistant but vapor permeable. New materials, such as spun bonded polyolefin and polypropylenes, are being used today that are not paper products. The sheathing membrane's function is to provide a second barrier to the entry of any wind and rain that might penetrate the cladding. It is also intended to direct water, which does penetrate the cladding, over the flashing at the base of the wall. It must be permeable enough, however, to permit any water vapor to escape from the interior that may penetrate imperfections in the air and vapor barriers. One layer of sheathing membrane is generally used over wall sheathing and may be applied horizontally or vertically with 4" (100 mm) laps at the joints. At horizontal flashings, the upper sheet should be lapped over the lower sheet to direct moisture outward.[3, 18]

Where wall sheathing is not used, two layers of sheathing membrane are needed unless a large panel siding such as plywood is used. Both layers are applied vertically, with the joints lapped 4" (100 mm) at the studs. Both layers are stapled to the framing members, the top layer with staples spaced every 6" (150 mm) along the edges of the sheet to hold it securely in place. [18]

#### **3.5.2.1 Exterior Cladding**

Because the type of exterior cladding used on the walls will greatly affect the appearance of the house and the amount of maintenance, it should be selected with care. Common types of cladding used are: metal, vinyl, hard-board or lumber siding; panel siding made of plywood, oriented strand board, waferboard or hardboard; wood shingles or shakes; stucco, and masonry cladding such as brick, both clay and concrete, concrete block and stone.[3]

Most siding can be affected by moisture and should be kept 8" (200 mm) off the ground and 2" (50 mm) from an adjoining roof surface.[18]

### **3.5.2.1.1 Metal and Vinyl Sidings**

Metal and vinyl sidings are used extensively and are virtually maintenance free since they come with factory-finished surfaces. They are produced in different shapes and patterns, some of which simulate the appearance of wood bevel siding and vertical board and batten. They come in configurations designed for continuous interlocking between boards so that only the upper side of the board is nailed while the bottom edge is locked to the upper part of the board below (Figure 3-21A). Interior and exterior corners, termination points of the soffit and gable ends as well as windows and doors, are all treated with specially designed trim pieces. The installation follows the same simple steps that are generally applicable to any kind of siding of the small 6 to 8" (150 to 200 mm) width.[5, 6, 18]

**Horizontal Application:** The wall is prepared by applying the sheathing membrane as described. In wet and humid coastal climates, furring on the wall is recommended to provide a "rain screen" and a vented space to facilitate drying. A level line is established around the house for the starter strip that is normally placed a minimum of 6 to 8" (150 to 200 mm) above finished grade. All trim pieces for corners, windows, doors and openings and starter strips are fastened. The siding is then applied in successive courses to the underside of the soffit. [5, 6, 7]

Laps of adjacent boards should be staggered more than 24" (600 mm) apart and should all face in the same direction away from the general viewing angle.[7]

An important point that must be remembered in each step of the installation is the needs to let the siding, especially vinyl siding, expand and contract with temperature changes. [18]

### **3.5.2.1.2 Hardboard Siding**

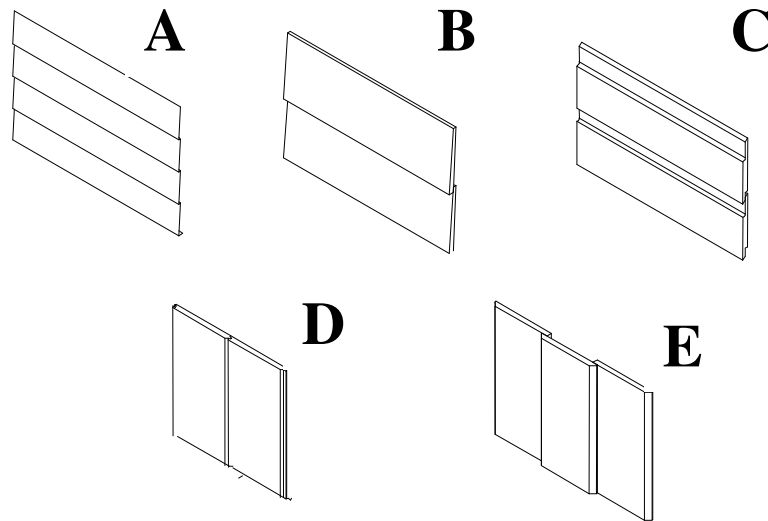
Hardboard horizontal siding comes with a primed or prefinished surface in a variety of colors. It often has plastic spines (Figure 3-22) which function as locking devices between panels. It is installed in a similar manner to metal and vinyl siding. In some cases, manufacturers suggest installing the siding over furring.[5, 18]

### **3.5.2.1.3 Lumber Siding**

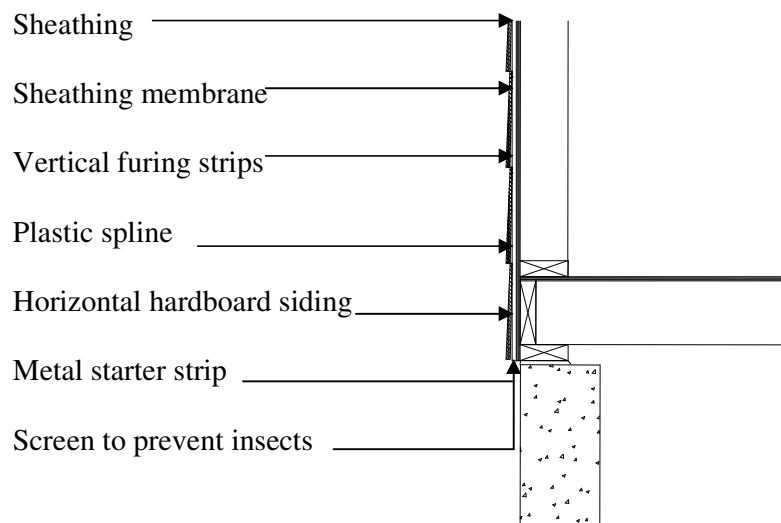
Lumber siding should be sound and free of not holes, loose knots, checks or splits. Easy working qualities and freedom from warp are desirable features. The species

most commonly used are cedars, pines and redwood. It has also become more common to use pressure-treated siding may be manufactured from pine or other species. The moisture content of the siding at the time of application should be the same as it will experience in service, that is, about 12 to 18 percent, depending on the region's humidity and climate. [6, 7]

- (A) aluminum or vinyl
- (B) bevel or feather-edge
- (C) drop siding
- (D) tongue and groove with V-joint
- (E) board on board



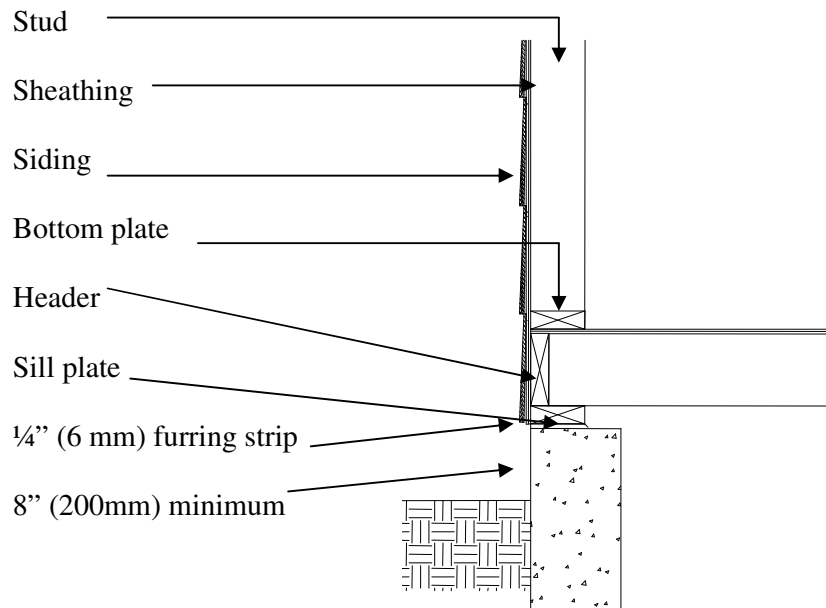
**Figure 3-21:** Types of siding [18]



**Figure 3-22:** Horizontal hardboard siding [15]

In wet, humid climates, such as the coastal regions of Canada, an air space is often formed behind the siding to prevent water penetration and to vent moisture away from the wall. This is done by mounting the siding on furring strips nailed on top of the sheathing paper to the studs behind. In these cases, a screen should be installed at the base of the wall to protect against insects and the top should be blocked to compartmentalize the wall. [18]

**Horizontal Application:** Bevel or feather-edge siding (Figure 3-21B) generally starts with the bottom course of boards furred out as shown in Figure 3-23. A ¼” (6 mm) thick furring strip is used for this purpose. Each succeeding course overlaps the upper edge of the lower course, the minimum lap being usually 1” (25 mm). Spacing for the siding should be carefully laid out before the board is applied. To determine the maximum board spacing (or exposure), the minimum lap should be deducted from the overall width of the siding. The number of board spaces between the soffit and the bottom of the first course at the foundation wall should be such that the maximum exposure will not be exceeded. This may mean that the boards will have less than the maximum exposure. Where possible, the bottom of the board that is placed over the top of the windows should coincide with the top of the window cap.[7]



**Figure 3-23:** Installation of siding [15]

Bevel siding should have a butt thickness of at least 1/2" (12 mm) for widths of 8" (184 mm) or less and 9/16" (14.3 mm) for widths greater than 8" (184 mm). The top edge should not be less than 3/16" (5 mm) thick. [7-10]

Drop (or matched) siding should be at least 9/16" (14.3 mm) for widths greater than 8" (184 mm) or less in width. It comes in a variety of patterns with matched or shiplap edges. Figure 3-21D shows a common pattern for drop siding. [7-10, 15]

Where bevel or drop siding is used, the butt joints between boards in adjacent courses should be staggered as much as possible. Butt joints should be made over a stud. The siding should be carefully fitted and be in close contact with other members and adjacent pieces. Ends should be sealed. Loose-fitting joints allow water to get behind the siding which can cause paint deterioration around the joints and lead to decay at the ends of the boards. One method sometimes used to obtain a tight joint is to place a small bead of caulking compound or putty along the end of each board after it is nailed and then press the next board into the compound. The excess compound is struck off, leaving a smooth waterproof joint. Joints occurring elsewhere, such as at window or door trim, can be similarly treated.[5, 6]

Bevel and drop siding should be face-nailed to lumber sheathing or studs. The size of the nail depends on the thickness of the siding and the type of sheathing used. One method of nailing often used is to drive the nail through the siding just above the lap so that the nail misses the top edge of the piece of siding beneath. This method permits each siding board to expand and contract as the moisture content changes. Thus, there are fewer tendencies for the boards to split as may occur when both edges of the board are nailed. Since the amount of swelling or shrinking is proportional to the width of the wood siding, nailing above the lap is more important with wide boards than with narrow boards. [3, 5]

**Vertical Application.** Lumber siding that can be applied vertically includes: plain matched boards; patterned matched boards; patterned matched boards; square-edge boards covered at the joints with a batten strip, or square-edge boards spaced apart and covered with another board. Vertical siding is usually 9/16" (14.3 mm) thick. Boards should not be wider than 12" (286 mm). Vertical boards may be fastened to 9/16" (12.5 mm) plywood or 1/2" (12.5 mm) plywood or 1/2" (12.5 mm) plywood or 1/2" (12.5 mm) oriented strand board or waferboard, 2"x2" (38x38 mm) blocking fitted between the studs at 24" (600 mm) on center. Butt joints should be mitered to

prevent the entry of water into the joint. When the spaced method (sometimes called “board-on-board”) is used (Figure 3-21E), the boards next to the wall are normally wider than the top boards and are fastened with one row of nails near the center of each board. The top board is then applied so that it laps the edges of the first board at least 1” (25 mm). These top boards are fastened with two rows of nails driven slightly outside the edges of the boards underneath. This method of nailing permits the wider board to expand and contract without splitting.[5,7-10]

The board and batten method uses square-edge boards which are ordinarily 8” (184 mm) or less in width. The boards are applied with the edges at least ¼” (6 mm) apart and fastened with one row of nails near the center of each board. To cover the joint, a narrow batten is used which laps the edges at least ½” (12 mm). This batten is fastened with one row of nails driven in the joint between the two boards or the batten strip. Since the batten also serves to prevent the board edges from curling outward, the nailing should be secure and closely spaced.[7-10]

Tongue-and-groove matched siding (Figure 3-21C) is commonly 8” (184 mm) or less in width. The first board is face-nailed near the grooved edge and angle-nailed through the tongue. Each successive board is driven in closely and angle-nailed through the tongue. A nail set is used to finish off the nailing.[5,18]

Nails cost little compared with the cost of the siding and labor, but the use of good nails is important. It is poor economy to buy siding that will last for years and then fasten it with nails that will rust badly within a short period. Corrosion-resistant nails, such as hot-dipped galvanized nails, will hold the siding permanently and will not disfigure the paint surface. Casing or siding nails are normally used for this purpose. Heads are driven flush with the face of the siding and later covered with paint. If finishing nails are used, the heads should be set below the surface and the hole filled with putty after the prime coat of paint is applied. The length of the nails depends on the thickness of the siding and the type of sheathing used. Nails should be long enough to penetrate at least 1” (25 mm) into the nailing support.[ 18]

#### **3.5.2.1.4 Plywood Panels**

Exterior type plywood is also used as a wall covering. The plywood sheets are made with a plain or grooved surface and are usually applied vertically. The joints may be V-grooved or flush or may be covered with a resin-impregnated raft paper laminated

to the face. This provides a smooth, moisture-resistant surface which resists checking or splitting after painting.[5, 18]

The minimum thickness of plywood applied as sheathing is 1/4" (6 mm). It may be applied directly to unsheathed wall framing. The minimum thickness used is 1/4" (6 mm) for stud spacing of 16" (400 mm) on center and 5/16" (80 mm) on center. This assumes the face grain is installed at right angles to supports. Where the face grain is installed parallel to supports the minimum thickness is 5/16" (80 mm) and 7/16" (110 mm) for studs spaced at 16" (400 mm) and 24" (600 mm) respectively.[7-10,18]

After the plywood panels are cut and fitted, all edges should be protected with a suitable paint or sealer before installation. A 1/8" (3 mm) space between the sides and ends of the panels and butted ends of the battens will permit expansion without bulging. Vertical joints are filled with caulking or covered with a batten. Horizontal joints are flashed or lapped at least 1" (25 mm). [7-10]

The edges of plywood panels should be supported and fastened with corrosion-resistant nails, usually 2" (51 mm) long. The nails are spaced 6" (150 mm) along the edges and 12 in (300 mm) at intermediate supports. [7-10]

#### **3.5.2.1.5 Corner Treatment for Siding**

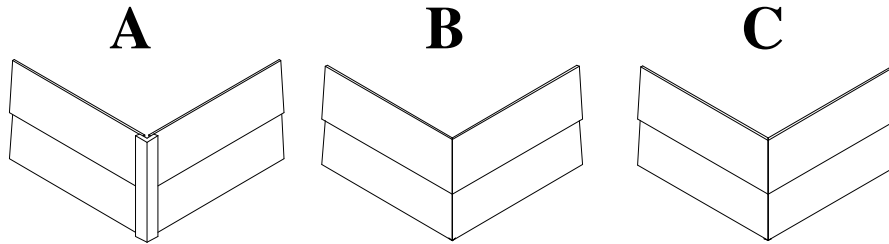
The method of finishing siding at the corners may be influenced by the house design. Corner boards may be appropriate to some designs and mitered joints to others.[5]

For lumber siding applied horizontally (Figure 3-24), mitered corners are most common, but metal corners or corner boards may also be used. [5, 6]

Mitered corners (Figure 3-24) must fit tightly and smoothly for the full depth of the miter. To maintain a tight fit at the miter, it is important that the siding is properly seasoned before delivery and protected from rain when stored at the site. The ends are often set in caulking compound or putty when the siding is applied.[5]

At interior corners, the siding is usually butted against a corner strip of 1 or 1-1/2" (25 or 38 mm) material, depending upon the thickness of the siding. Metal corners (Figure 3-24). Used as a substitute for mitered corners, are made of light-gauge metals such as aluminum or galvanized steel. The application of metal corners requires less skill than making good mitered corners or fitting siding to a corner board. [5]

- (A) Corner Boards
- (B) Mitered Corners
- (C) Metal Corner



**Figure 3-24:** Corner Treatment for sidings [5, 15]

Corner boards (Figure 3-24) are generally used with drop siding, but may be used with other types of siding as well. The boards are made of 1 or 1 ½” (25 or 38 mm) material, depending on the thickness of the siding. The corner boards are applied against the sheathing with the siding fitted tightly against the narrow edge of the corner boards. Joints between the siding and corner boards should be filled with caulking compound or putty when the siding is applied.[5, 15]

Plywood and hardboard are usually lapped at the corners or fitted to a corner board. Lumber siding applied vertically is lapped at the corners.[5]

#### **3.5.2.1.6 Wood Shingles and Machine-grooved Shakes**

Wood shingles or machine-grooved shakes are sometimes used for wall covering. A large selection is available, including special wall shingles in lengths of 16, 18 and 24” (400, 450 and 600 mm), factory-painted or stained.[5, 6]

Shingles are usually separated into three grades. The first grade is composed of clear shingles, all heartwood, and all edge grain. The second grade consists of shingles with clear butts and permits defects in the part of the shingle which is normally covered in use. The third grade includes shingles that have defect in the part of the shingle which is normally covered in use. The third grade includes shingles that have defects other than those permitted in the second grade. These shingles may be used for under coursing.[5, 6]

Shingles are made in random widths varying in the first grade from 2 ½ to 14” (65 to 350 mm); only a small proportion of the narrow width is permitted in the first grade.

Shingles of a uniform width, known as dimension shingles, are also available. Widths of 4, 5 or 6" (100, 125 or 150 mm) may be specified. Lumber, oriented strand board, waferboard or plywood sheathing should be used under shingles or shakes.[5, 6]

When the single-course application is used, the joints in succeeding courses should be offset at least 19/16" (40 mm), and care taken that the joints in any two or three courses do not line up.[5]

To obtain deep shadow lines, shingles can be laid in what is called double-coursing. This may be done by using a lower grade shingle under the shingle exposed to the weather. The exposed shingle butt extends about 1/2" (12 mm) below the butt of the undercourse. Where double-coursing is used, wider exposure to the weather is possible. Joints in the outer course should be offset from joints in the undercourse by at least 1 9/16" (40 mm).[5, 6]

Shingles should be fastened with corrosion-resistant nails. Shingles up to 8" (200 mm) wide require only two nails. Those more than 8" (200 mm) wide require three. Nails should be driven about 13/16" (20 mm) from the edges and 1" (25 mm) above the exposure line for single-course application, and 2" (50 mm) for double coursing. [7-10]

### **3.5.2.2 Stucco Finishes**

Stucco generally consists of a mixture of Portland cement and well-graded sand, with hydrated lime added to make the mixture more plastic. An alternative stucco mixture calls for replacing the lime with masonry cement. Other proprietary stucco mixes are available. Their formulations will vary depending on the manufacturer of the mix. [3]

Applied in three coats (two base coats and one finish coat), the stucco is held in place by stucco mesh or wire lath. A variety of finish coats are available, from standard colored cement finishes to finely textured acrylic finishes. The "stone dash" finish is seldom used except in retrofit applications.[3]

Stucco reinforcing of self-furring welded mesh, or fully primed or galvanized woven mesh, is stretched horizontally over sheathing paper, with the joints in the mesh lapped at least 2" (50 mm). External corners are reinforced either by extending the mesh from one side 6" (150 mm) around the adjacent corner, or by vertical strips of

reinforcing that extend 6" (150 mm) on either side of the corner. Stucco must be no closer than 8" (200 mm) from finished grade except where it is applied over concrete or masonry.[3, 7-10]

A well-detailed layer of heavy weight building paper, lapped 4" (100 mm) at the edges, must be applied. It is very important to apply flashings around penetrations in the walls. The building paper must be carefully applied around window openings and lapped correctly to ensure that water does not enter at the window flanges. Tar-saturated felts or papers should not be used beneath the stucco. The tar can bleed through the stucco causing unsightly discoloration.[3,11]

Galvanized steel fasteners should be used to hold the mesh in place. Suitable fasteners are 1/8" (3.2 mm) diameter nails with heads that are about 7/16" (11.1 mm) or alternative with 0.078" (2.0 mm) thick staples. Fasteners are spaced 6" (150 mm) vertically and 16" (400 mm) horizontally, or 4" (100 mm) vertically and 24" (600 mm) horizontally. Other fastening patterns may be used, provided there are at least two fasteners per square ft. (20 fasteners per square meter) of the wall surface. Where the sheathing is other than lumber, waferboard or plywood, the fasteners should penetrate the sheathing and go into the framing member (stud or plate) at least 1" (25 mm). [7-10]

The base coat consists of two layers of stucco. The first layer (scratch coat) of stucco is applied to a thickness of 1/2" (12 mm) that completely embeds the wire lath or mesh. The scratch coat surface must be scored or raked to provide a bonding key for the second coat. Curing time will depend on outdoor temperature and weather conditions. It is not uncommon to allow 48 hours of cure time before the second coat is applied.[3, 5]

Just before putting on the second coat, the base is dampened to ensure a good bond between the coats. The second coat is applied at least 1/4" (6 mm) thick and firmly troweled into the scored surface of the base.[3]

A wide variety of finishes are available today, from standard white or colored cement to modified and acrylic finishes. Acrylic finish coats are often applied over conventional Portland cement, with good results. It is important that the chosen product has good weather ability and is vapor permeable. In cases where a wall

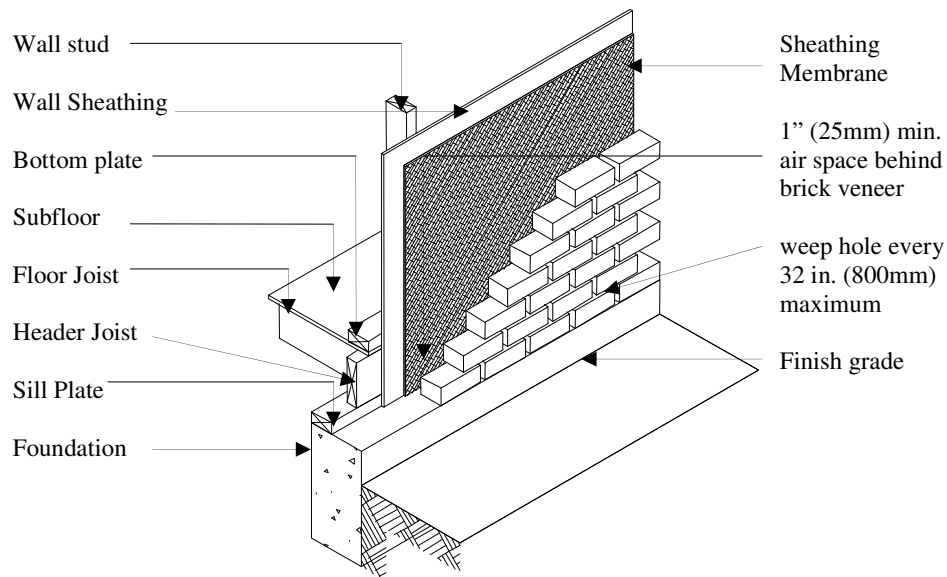
requires a fire rating, the base coat thickness will need to be checked to ensure it is sufficiently thick.[11]

For finish coats, the second coat should be moist-cured for at least 48 hours and then left to dry for five days, preferably longer, before the finish coat is applied. The base should be dampened to ensure a good bond and the finish applied to a depth of at least 1/8" (3 mm). [11]

In dry warm weather, fresh stucco should be kept damp to ensure proper curing. In cold weather, each coat of stucco should be kept at a temperature of at least 50 °F (10 °C) for 48 hours after application.[7-10, 11]

### 3.5.2.3 Masonry Veneer

If masonry veneer is used for the exterior cladding of above-grade walls, the foundation must include a supporting ledge or offset wide enough to allow a space of about 1" (25 mm) between the masonry and the sheathing paper (Figure 3-25: Masonry veneer support on foundation wall).[11]



**Figure 3-25:** Masonry veneer support on foundation wall [11,14]

A base flashing should extend from the outside face of the wall over the top of the ledge and at least 6" (150 mm) up the wall behind the sheathing paper. Corrosion-resistant metal ties, nailed to the studs and embedded in the mortar joints between the masonry, should be used to tie the veneer to the framework. When fastened to every

other stud these are usually spaced 32" (800 mm) apart horizontally and 16" (400 mm) vertically. Alternatively when fastened to every stud, they may be spaced 24" (600 mm) horizontally and 20" (500 mm) vertically, or 16" (400 mm) horizontally and 24" (600 mm) vertically, depending on the stud spacing.[7-10, 11]

Weep holes serve both a venting and a drainage function. They should be placed about 32" (800 mm) apart in the bottom course of the masonry veneer and above-grade windows and doors. This can be done by omitting the mortar from the vertical joints. [7-10]

Masonry veneer should be at least 3 ½" (90 mm) thick where there are raked joints and 2 ¾" (75 mm) thick where the joints are un-raked.[7-10]

If a brick veneer is used, the bricks selected should be hard, absorb little water and be manufactured for exposure to the weather. Stone veneers should be selected from the materials known locally to be durable.[11]

Brick or stone should be laid in a full bed of mortar. Care should be taken to avoid dropping mortar into the space between the veneer and sheathing paper, because this will block the cavity behind the veneer. Outside joints must be tooled to a smooth finish to provide maximum resistance to water penetration. Masonry laid during cold weather should be protected from freezing until after the mortar has set. The temperature of the masonry and mortar should be maintained above 41 °F (5 °C) for at least 24 hours after installation. [7, 11]

## **3.6 INSULATIONS**

### **3.6.1 Thermal Insulation**

The effectiveness of a building assembly such as a wall or ceiling in resisting the flow of heat is measured as its thermal resistance or R-value (RSI value). [22]

Although most materials have some resistance to the flow of heat, the materials used for structure, cladding and finish generally have relatively low resistance. Insulation is, therefore, added to reduce the loss of heat from the house. Wood-frame construction is quite easy to insulate since it incorporates many cavities which can be readily filled with relatively inexpensive types of insulation. The cavities or air

spaces themselves have appreciable resistance to heat flow, but it is greatly increased by placing insulation in the space. [22]

### **3.6.1.1 Types of Insulations**

Insulation is manufactured from a variety of materials and variety of forms. These forms can be grouped into four basic types.[22]

#### **Batts**

Batts consists of fiber of glass or steel mill slag spun together with a binding agent into a blanket like strip of convenient length and width to fit standard framing spaces and in a range of thickness. This type is called “friction fit” because it is made slightly wider than the standard stud space so that it is held in place by friction. [22]

It is often necessary to use insulation batts in cavities which are not as deep as the batts thick. For example, 6” (150 mm) batts might be used in a wall built 2” x 6” (38 x 40 mm) studs. The resulting compression has an insignificant impact on the thermal resistance of the batts. [7-10, 22]

#### **Loose Fill**

Many types of insulation are made in loose form for pouring or blowing into place. Common materials include glass and mineral wool fiber, and cellulose fiber.[22]

#### **Rigid**

Rigid insulation is manufactured in sheets or boards using materials such as wood fiber, and expanded or extruded foamed plastic.[22]

#### **Semi Rigid**

Semi rigid insulation boards are relatively flexible compared to rigid insulation products, and is not as easily damaged by impact or bending. Typically, these are formed from glass and mineral wool fibers. [22]

#### **Foamed in Place**

Processes are available for spraying or injecting under pressure materials, such as polyurethane and isocyanurate in a foamed liquid state. The foam sets into a rigid mass within minutes of insulation. Because this foaming insulation is , in effect, the

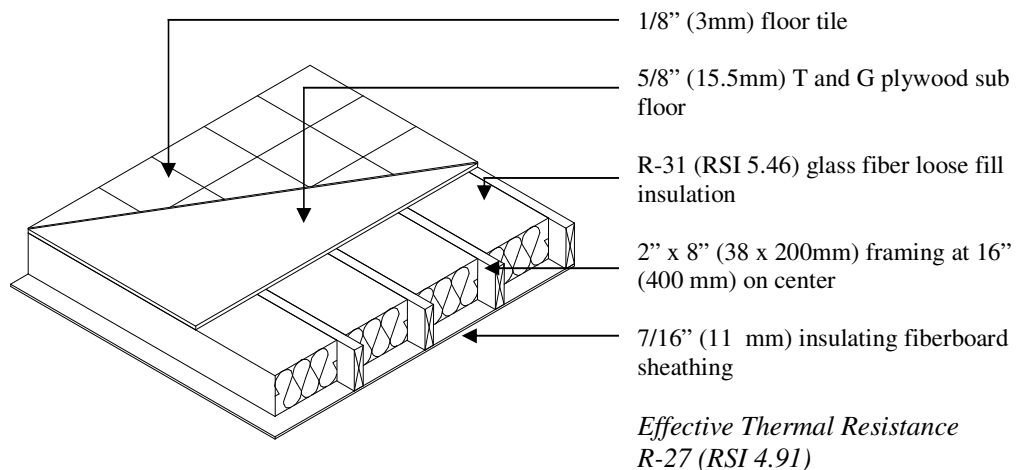
last stage of manufacturing the product, and it occurs at the building site, the installer must be highly skilled and very conscientious to provide a product of uniform quality and consistency. [22]

### 3.6.1.2 Insulation of Floors

Floors over unheated crawl spaces should or over heated or unheated garages should be insulated.[7-10]

Where there is no finished ceiling on the underside of the floor, some material must be added to support the insulation. For friction fit type batts or for rigid insulation, wire lath or “chicken wire” tacked to the bottom of the joists may be the most economical method. For loose fill type insulation (Figure 3-26), the support must be provided by a material which is solid (to prevent the insulation from falling through) but permeable (to avoid trapping water vapor which happens to penetrate the vapor barrier). [7-10, 22, 23]

The vapor barrier must be installed on the upper or warm side of the insulation. No additional vapor barrier need be installed where a plywood sub floor with tight fitting or sealed joints are used, because it is generally a good air barrier and a very good vapor barrier.[23]



**Figure 3-26:** Floor over unheated crawl space insulated with loose fill insulation

[22]

The insulation must be tightly fitted around cross bridging or blocking between joists. This requires particular care with batt and rigid insulation. It is also important

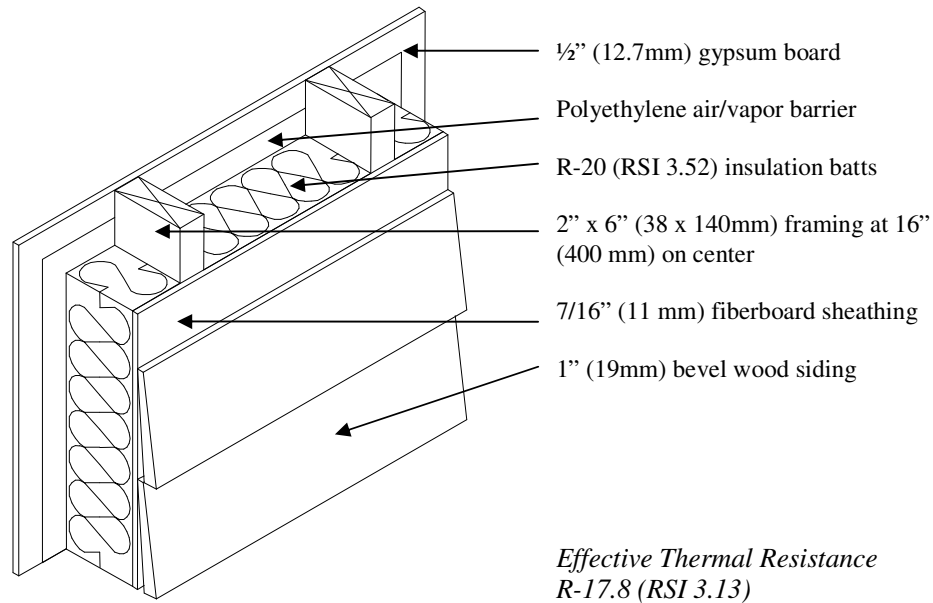
not to omit insulation in small spaces such as between blocked double joists or between the wall and the first joist. In such cases, the insulation should be cut slightly oversized and carefully installed to avoid bunching and excessive compression. [7-10, 22, 23]

When the insulation is installed only at the bottom of the joist space, the area at the ends of the joists must be carefully considered. The area of the joist header is, in effect, a wall and should be insulated accordingly. Also a well-sealed air barrier must be provided around the perimeter and beneath the insulation to minimize the possibility of cold air leaking into the joist space and “short circuiting” the insulation. [23]

### **3.6.1.3 Insulation of Walls**

With normal 2” x 4” (38 x 89 mm) stud framing, the maximum effective thermal resistance can be achieved by filling the cavity with batt-type insulation and using normal finishing, sheathing, and cladding materials is approximately R-12 (RSI 2.1). By careful selection of the sheathing and cladding, this can be extended to about R-13 (RSI 2.3). This assembly, while suitable for seasonal buildings, does not meet current code requirements. Going beyond this level requires special measures. One such approach is to use deeper studs, such as 2” x 6” (38 x 140 mm), in order to accommodate thicker batt insulation (Figure 3-27). Insulation products with higher thermal resistance values are simple alternative for enhancing the efficiency of the wall assembly (Figure 3-28). Another approach is to use 2” x 4” (38 x 89 mm) studs with cavities filled with batt insulation, and rigid insulation applied to the outside either in place of, or in addition to, the normal sheathing. This latter method has the merit of providing a significant proportion of the wall’s thermal resistance in a form which is continuous over the framing, thus reducing heat loss through the framing members.[7-10, 22]

Some types of semi-rigid insulation come with a spun bonded polyolefin sheet attached to one surface. This material is vapor permeable but air impermeable, and can constitute a good air barrier if the joints between the sheets are taped.[23]



**Figure 3-27:** A 2" x 6" (38 x 140mm) wall [22]

Materials such as spun bonded polyolefin or perforated polyethylene are available in 4' and 9' (1200 and 2700mm) rolls, and can be applied to the exterior of any wall assembly to create an effective air barrier.[7-10, 23]

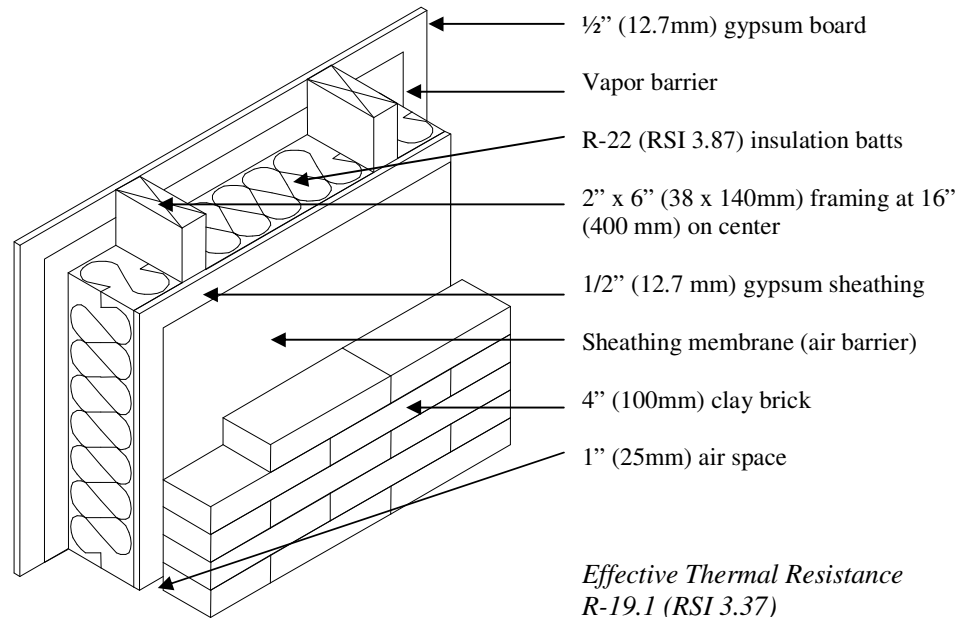
Other types of insulation, such as rigid plastics, have low water vapor permeance and are also air and water impermeable. If they are placed with the joints butted and caulked, they could also form a good air barrier. [23]

The use of sheathing membrane on top of the insulating sheathing is required as a rain shedding device, unless joints in the sheathing are, sealed or designed to shed water.[23]

Except, where unavoidable, electrical and mechanical facilities such as boxes, pipes and ducts should not be installed in exterior walls. Where this cannot be avoided, insulation should be fitted tightly around the item and the outside surface in a manner which will minimize compression of the insulation. [12]

Insulation for small spaces at intersections corners and around openings should be cut only slightly oversize and carefully installed to avoid bunching and excessive compression. [12]

Walls between dwelling units and garages should be insulated to the same degree as exterior walls whether the garage is heated or not, since garages are left open for extended periods. [12]



**Figure 3-28:** A 2" x 6" (38 x 140mm) wall with higher efficiency insulation [22]

### 3.6.1.4 Insulation of Truss or Rafter Type Roof Ceilings

The thicker batts now available for insulating roofs are made in widths equal to the full center to center distance of standard roof framing. The lower portion is slightly compressed when installed between the framing, but the upper portion retains its width and covers the tops of framing, thus reducing heat loss through the framing. [22]

Loose-fill insulation can also be used to cover the framing and, unlike the standardized batts, offers the advantage that only the amount desired need be installed. On the other hand, care must be exercised to ensure it is installed at the correct density or settling may occur. Loose-fill insulation must also be prevented from, spilling onto eave vents and from being displaced by wind entering the vents. Baffles must be used to avoid blocking air circulation. [22]

### 3.6.1.5 Insulation of Joist Type Roof Ceilings

When the ceiling finish is applied directly to its bottom surface, a roof framing member is called joist rather than a rafter. This type of construction is round in flat

roofs and some “cathedral” or sloping ceilings. When such roofs are insulated between the ceiling and the sheathing, condensation problems can occur because the space between the insulation and the sheathing is divided into small compartments which are difficult to ventilate. Thus, any moisture which leaks through imperfections in the air/vapor barrier is not dissipated but accumulates and condenses.[22, 23]

Another approach to avoid condensation problems in joist type roof ceilings is to place insulation above the sheathing, as is commonly done with flat roofs. [22]

### **3.6.2 Vapor and Air Barriers**

Many normal activities which take place within a house, such as cooking, dishwashing, laundering and bathing, generate considerable amounts of water vapor which are absorbed by the air in the house, increasing its humidity. If during cold weather, this water vapor is allowed to pass into the outer shell of the building, the low temperature within the thickness of the shell can cause the water vapor to condense back into liquid or frost. Since wetting of the structure, cladding and insulation is obviously undesirable, some means must be used to contain the water vapor within the dwelling. This is the function of the building component which has traditionally been called the “vapor barrier”. [5]

Two mechanisms tend to drive water vapor through the building shell: vapor pressure and air movement. [5]

In the winter, there is more water vapor in the air inside the house than the outside air. As a result, the difference in vapor pressure tends to force the water vapor to diffuse through materials making up the shell. Most building materials are, to some degree, permeable to the passage of water vapor, but those classified as vapor barriers have very low permeability and thus are very resistant to the diffusion mechanism.[5, 23]

The second mechanism by which water vapor is forced through the building shell is air movement. There are often differences in air pressure from inside to outside the house created by a stack effect, the operation of fans, or the action of wind. When the air pressure inside is greater than that outside, air will tend to flow outwards through any holes and cracks in the building envelope, carrying with it the water vapor it contains. It has been recognized that this air movement plays a much greater role in

the transmission of water vapor that the diffusion mechanism. The most important aspect of an air barrier is continuity – an air barrier is only as good as it is continuous. Many materials, such as drywall, qualify as an air barrier even though they do not perform as well as a vapor barrier. [5]

Common practices use polyethylene to perform both functions of air and vapor barrier. This combination is workable, although it does not overcome the difficulty of creating a continuous air barrier. Certain spots on the envelope, such as headers, openings, services, vent stacks, chimneys, electrical, plumbing and mechanical system penetrations, and unusual framing details, are hard to seal well.[5, 12]

However, once it is well understood that there should not be a direct path from the house interior to the outside through wall cavity, additional precautions and measures can supplement the function of the material chosen to be the air/vapor barrier. The air barrier must be able to resist wind pressures which occasionally become very strong. Vapor pressure, on the other hand, is not as forceful and can be easily resisted.[5]

### **3.6.2.1 Placement**

While the air barrier can be placed at any point on the building envelope, the vapor barrier must be placed on the warm side of the structure. When air and vapor barriers are combined in the same material, the warm side is again the correct location. A slight deviation from this rule is permitted with extra thick walls. In this case, one-third of the total thermal resistance or R-value (RSI value) can be located inside of the air/vapor barrier.[5,22]

The preferable method is to use polyethylene film. The film is available in large, room height sheets which can be applied with a minimum of joints, thus reducing the chance of openings through which air can move. Any joints which do occur should be lapped over two adjacent framing members. The National Building Code requires that when polyethylene is used as an air barrier or as a vapor barrier where a high resistance to vapor movement is required, such as in wall constructions that incorporate exterior cladding or sheathing having a low water vapor permeance, it must be a minimum thickness of 6 mil (0.15 mm) and comply with applicable material standards.[7-10]

It is very important to avoid storing polyethylene in any manner which may lead to sustained exposure to sunlight. Ultraviolet radiation can significantly degrade the

integrity of polyethylene, so it should be stored in an opaque container away from direct sunlight and high temperatures.[5]

The ceiling air vapor barrier should overlap on the wall air vapor barrier, and both should be continuous on top of and behind intersecting interior partitions. Since interior partitions usually framed before the insulation and air vapor barrier are installed, this latter condition is usually achieved by covering the top and ends of the interior partitions during construction with strips of air vapor barrier at least 18" (450 mm) wide which are subsequently lapped onto the main air vapor barrier. It is often necessary to use the tops of interior partitions as a walking surface when installing roof framing. In such cases, in order to avoid damage to the air vapor barrier strips and to provide better footing, they are installed between the two top plates. In the case of non load bearing partitions, the upper plate can consist of 1" (19mm) lumber since its only function is to protect the air vapor barrier.[5, 7-10]

The air vapor barrier should overlap and be stapled to door and window framing, and can be taped to any wires or pipes which penetrate it. It must also be continuous behind electrical boxes located in the exterior walls. This can be achieved by wrapping the box with a piece of 6 mil (0.15mm) polyethylene and taping or caulking, or both, the polyethylene to the wires entering the box. The piece can then be lapped onto the surrounding air vapor barrier when it is installed. The lap should be at least 4" (100 mm) and occur over framing members or be sealed. Alternatively, special polyethylene box covers can be used. Ideally, it is best to avoid locating electrical outlets on exterior walls if at all possible.[5, 7-10, 22]

It is also important to provide vapor barrier protection to insulation installed between the ends of the floor joists in the header space. It is usually very difficult to achieve an effective air barrier at this location because the materials must be cut and fitted between the joists. Extra care is therefore required, especially on the higher floors where air exfiltration is more likely to occur due to stack effect. When the exterior wall has sufficient insulating sheathing, it may be carried over the header; however it is generally preferable to use an air barrier, such as spun bonded polyolefin or perforated polyethylene, at this location. If additional is placed on the inside, a vapor barrier will be necessary on the inside face of the insulation to ensure that no moisture laden air reaches the header and condenses on it. [5]

### **3.7 FIRE AND SOUND CONTROL**

When a building is designed for multiple occupancy, as in the case of a duplex or semi-detached housing unit, there is a need for resistance to fire penetration and sound transmission control between the units. [7-10]

These construction methods should provide resistance to sound transmission in walls and floors to a degree that meets acceptable requirements.[7-10]

Resistance to the spread of fire can be provided when the interior cladding and wall assembly meets the necessary fire resistance rating. Various claddings on the market offer ratings by recognized testing agencies.[7-10]

#### **3.7.1 Smoke Alarms**

The National Building Code and most local building codes require early-warning, fire-detecting devices in dwellings, usually a self-contained combined smoke detector and an alarm that is wired into the electrical system. The two basic types of smoke alarms are: ionization (or “products-of-combustion”) and photoelectric.[7-10]

##### **3.7.1.1 Location and Installation**

Smoke alarms should be located in or near each bedroom and on each storey including basements. Smoke alarms should be mounted on the ceiling or on a wall between 8 and 12” (200 and 300 mm) from the ceiling. Building codes usually require smoke alarms to be permanently connected (hard-wired) to an electrical circuit. There should be no disconnecting switch between the smoke alarms and the electrical service panel and the circuit should not be connected to a wall outlet. Where electric power is not available, battery-powered smoke alarms may be used. These units are designed to operate for at least one year, followed by a seven-day trouble signal when the battery runs down.[7-10]

## 4. CASE STUDY

This case study has been conducted between the dates April 15th, 2006 to June 15th, 2006 on a construction located in Ontario, Canada. The construction has been supervised by Cengiz Derinoz from start to the current situation. This case study will be used to show some of the designs, techniques and materials that are used in real life construction sites. A brief explanation will be supplied with each picture.

Although these techniques, materials and design do not cover the whole thesis scope I would be helpful for the reader to visualize most of the aspects explained above

### 4.1 Rough Framing



**Figure 4-1:** Foundation Walls right before backfilling.

The foundation walls have been poured with a 4" (38mm) ledge for the future brick veneer exterior finishing. The Anchor Bolts have been dig into the foundation wall right after the concrete pouring. Sill Plates will be bolted to these anchors in the next stage. The Exterior of the foundation wall is first covered with asphalt bitumen based

protector and then wrapped with membrane to achieve a high level of water and moisture protection from the soil.



In the next stage the sill plates have been bolted to the anchor bolts. Later on the floor joists have been nailed to the sill plates. For addition stability rim boards have been nailed on the other edges. These rim boards will be doubled later to carry the 2" x 6" (38 x 140 mm) exterior wall studs.

To achieve the continuity of the vapor barrier before the exterior walls have been erected the rim boards will be wrapped with tyvek paper.

**Figure 4-2:** Sill Plate and Floor Joist detail.



**Figure 4-3:** Steel Beam.

For long spans Steel Beams are used. The Floor Joists are rested on the steel beam. Later they will be fixed with rim board and floor sheathings.



**Figure 4-4:** Joist Hangers.

In situations where the floor joists have to be attached to the main beams butt to butt, special trust hangers have to be used. The hangers are nailed to the main beam on 8 points. Later the joists are put into the hanger and nailed from the bottom. There should be no space between the hangers and the joists.



**Figure 4-5:** Installation of Floor Sheathing.

After all the floor joists have been installed and fixed by the rim boards and hangers the floor sheathings are nailed onto them. One important point in this application is to avoid future problems and sound problems the floor boards have to be chosen as tongue and groove style and must be glued and nailed on to the joists.



**Figure 4-6:** Exterior Walls.



**Figure 4-7:** Exterior Walls.

After the installation of the floor boards, exterior walls are assembled on the floor. The exterior sheathing is applied onto them and then they would be raised and fixed to their location. They must be braced until the whole rough framing is finished.



**Figure 4-8:** Roof Trusses.

When the rough framing of the floors and walls are done; pre-manufactured roof trusses are placed on the roof. They are nailed according to the manufacturer's specifications. Following this they are sheathed with the special roof boards.

#### **4.2 Framing Details**



**Figure 4-9:** Framing Details for Plumbing.



**Figure 4-10:** Framing Details for Heating.

In most situations the cavities in the wall members are used for plumbing, heating and electrical system details. In cases that a cut is needed; it has to apply with the building code requirements.



**Figure 4-11:** Framing Details for Heating and Electrical Cables.

### **4.3 Exterior Wall Sheathing**

In this case the exterior finishing materials were brick and limestone. Because these finishing materials are heavy a concrete ledge has to be formed in the process of the foundation walls. If this can not be done Angle irons have to be bolted to the concrete foundation walls and the weight of the materials have to be transferred to concrete basement walls



**Figure 4-12:** Brick and Stone Details.

Before the application of the stone or brick material the exterior sheathing have be warped with tyvek paper to achieve moisture and water control. 1” (25 mm) air space has to be let between the finishing material and the exterior sheathing. This air space has to be vented by small holes left throughout the application.

#### **4.4 Insulation**



**Figure 4-13:** Batt Insulation and Vapor Barrier on a Cathedral Ceiling

On cases where blow-up insulation can not be used batt insulation has to be used. After the batts installation the vapor barrier is applied continuously all over the

exterior walls and ceiling. Any junction or open ends have to be taped with the appropriate material



**Figure 4-14:** Batt Insulation and Vapor Barrier on walls and vapor barrier on the ceiling

In most cases blow up insulation is the best option for ceiling insulation. On this occasion no batt or any other insulation is required. Only vapor barrier has to be applied under the roof trusses

#### **4.5 Conclusion**

This case study represents the most common details, materials and techniques used in a common 2 storey wood frame house. All these details, materials and techniques are approved by the local building departments, Bylaws and Building Codes.

## 5. CONCLUSION

Wood Building systems have been used throughout the country for decades as the main type of construction. But with the emerging technologies and other building materials as of steel and concrete these traditional building systems have cast aside as old and useless system.

After the tragic earthquake in 1999 the search for the alternative light building systems has opened new frontiers for the wood construction. But because no research or work has been done for the last 30 -40 years in the wood building technologies, materials and techniques along with the poor preservation of the forest areas cause the inability of using the traditional system as is.

On the other hand other countries like Canada and USA have continued to use wood frame housing system as the main building system for low rise residential construction. With the developing technologies and materials the wood frame house construction in these countries are well updated and current.

To adapt the wood construction back in turkey we must transfer technology, material and design from these current wood frame systems. To do that properly we have to have a well understanding of the materials, techniques, designs and technologies that are used in these systems.

This thesis shows the common and standard uses of techniques and designs to simplify the technology transfer. In the first part of the thesis, the traditional wooden construction techniques and materials in Turkey have been discussed in order to understand the existing building systems. In the second part, the codes and standards of the Canadian construction techniques have been examined in detail in order to transfer technology knowledge regarding the modern, rational wooden construction techniques that are used in North American Countries. In the subsections, the wood framing techniques, roof sheatings, windows and doors, framing details for rough ins and wall sheatings and exterior finishes have been explained in detail. In addition to that, the techniques used for insulation and fire and sound control have also been

discussed in order to enlighten the reader about the rational styles that are used in wood framed houses.

In the last part of the thesis, a case study conducted in Toronto, Canada has been discussed in order to help the readers to better visualize as a real life example of using the systems , materials and designs that are introduced here.

The scope of this thesis is to encourage the revival of wooden construction in Turkey and to improve the technology, knowledge and design regarding this building system.

To introduce the wood framing system back to Turkey we should have a Wood Frame building standards and material technologies and designs. The traditional systems have to be updated with the introduction of current techniques and materials. Another aim of this thesis is to transfer knowledge and technology regarding wooden construction in North American countries and to create the opportunity for these technologies to be used as a new design tool.

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