Canada Wood
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Wood Frame Multi-unit Residences

INTERNATIONAL
Building series | NO. 6

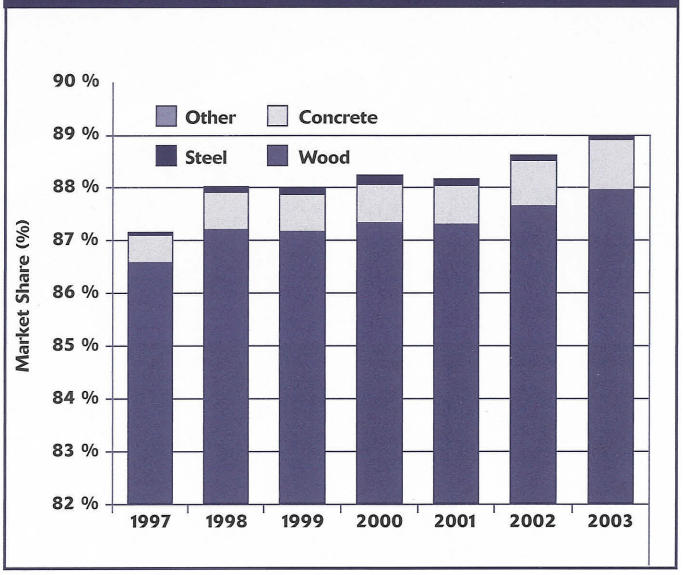
Wood-frame Multi-unit Residences in North America

North America is a continent rich in forest resources. Early pioneers looked to the wood resource to provide building materials for shelter, as well as many other uses. Initially wood construction was based on trial and error, and the use of large, hand-hewn timbers. The introduction of sawmilling resulted in more practical and economical sizes and grades of sawn lumber that made wood construction faster and more resource-efficient.

In the intervening decades, millions of residential units of all types have been constructed in North America using wood-frame construction. Today wood-frame construction is based on experience, best practices and code requirements based on many years of performance history and extensive research that have encompassed: moisture management, fire safety, sound control, indoor air quality, heating, cooling, energy efficiency, material performance, high wind and earthquake resistance, and labour and material cost efficiency. The scientific research and development on which codes and building techniques are based ensures the long-term safety, comfort and performance of Canadian wood-frame construction.

Wood-frame is the most common construction method for residential developments four storeys and less (Figure 1). Depending on the state of the economy, there are approximately two million housing starts in North America per year. For single-family residences, it is estimated about 95% of existing houses are wood-frame construction. For duplexes, row houses and three-storey apartments, about 85% of buildings are wood-frame construction.

FIGURE 1: Market Share for Residential Construction in North America
Adapted from National Association of Home Builders



Types of Wood-frame Dwellings

Wood-framing is a versatile construction method that is easily adapted to single-family residences and higher density row houses and apartments.

PHOTO 2: Single family
PHOTO 3: Duplex unit
PHOTO 4: Row housing
PHOTO 5: 3- Storey apartment building
PHOTO 6: 4- Storey apartment building
PHOTO 7: 5- Storey apartment with commercial occupancy on the ground floor

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Photo: AF&PA

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Advantages of Wood-frame Construction

Meeting Code Requirements

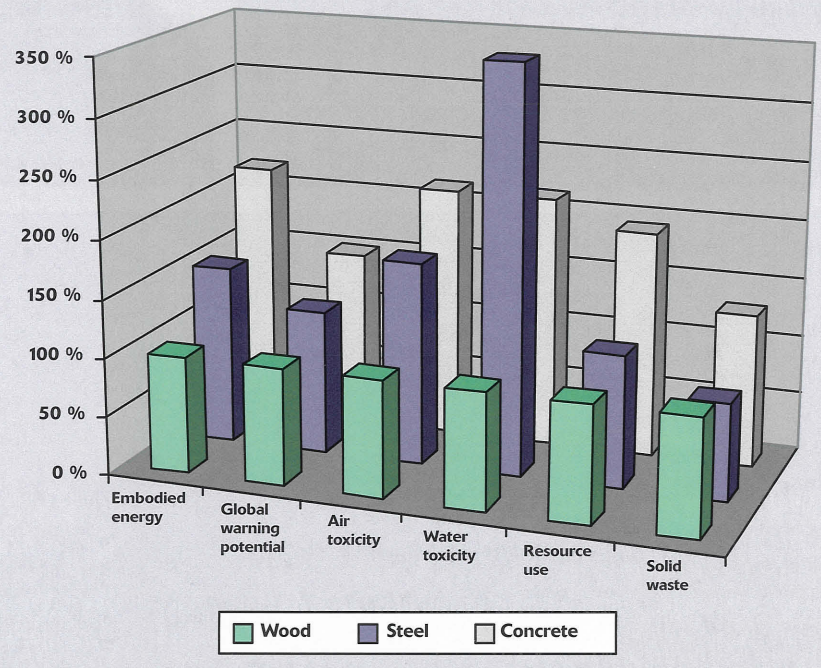
North American building codes require buildings to meet performance criteria using both simplified step-by-step building methods and engineering design requirements. The simplified methods have a proven performance history and continue to evolve to reflect new materials and new research information. The building code criteria are independent of the building materials or techniques used. This means wood-frame construction needs to deliver the same safety and performance as structures built of concrete, steel or other materials. Wood meets or exceeds these requirements and does so economically.

Environmental Compatibility

In an age of diminishing fossil fuels and increasing costs, wood-frame construction has two enormous advantages compared to other construction materials. First, wood building materials use much less energy to manufacture than steel or concrete, both of which require high temperatures for refining and manufacturing. Life cycle analysis, a scientific method for comparing the environmental affects of materials, shows that wood has relatively little impact on: energy consumption, air and water pollution and greenhouse gas emissions (Figure 2).

Second, wood-frame construction has the potential to significantly lower heating and cooling costs during the service life of a residential unit. While wood is a fairly good insulator compared to other building materials such as steel or concrete, the key to the energy efficiency of wood-frame construction is the voids between the framing members being filled with various types of insulation.

FIGURE 2: Environmental Impacts of Housing Types



Environmental impact relative to a typical wood-frame home (the 100 % baseline) is shown for an equivalent house in light-gauge steel and an equivalent in insulated concrete forms. Data addresses the life-cycle portion from resource extraction through construction and does not include environmental impacts of building occupancy and demolition.

Architectural Adaptability

Wood construction offers almost infinite adaptability in design. It is economically feasible to add offset walls, balconies, alcoves and other features that add interest and appeal and is especially true for roof shapes. Design software and advanced manufacturing processes permit the fabrication of wood roof trusses to suit a vast array of roof shapes, while meeting strength requirements. Wood-frame construction gives architects the ability to create interesting features while respecting

project budgets. In addition, wood-frame construction is easy to modify in the event that an addition, window, or other feature is desired in the future.

Space Economy

Wood-frame wall and ceiling assemblies are compact. All the building envelope needs are satisfied by compact assemblies (Figure 3). For example, a wall with 38 by 140 mm wood studs can accommodate insulation with an RSI of 3.5, while providing strength and supporting exterior and interior finishes.

Thinner walls mean more interior living space for the same building footprint. For larger developments, this can add up to an additional living unit per floor.

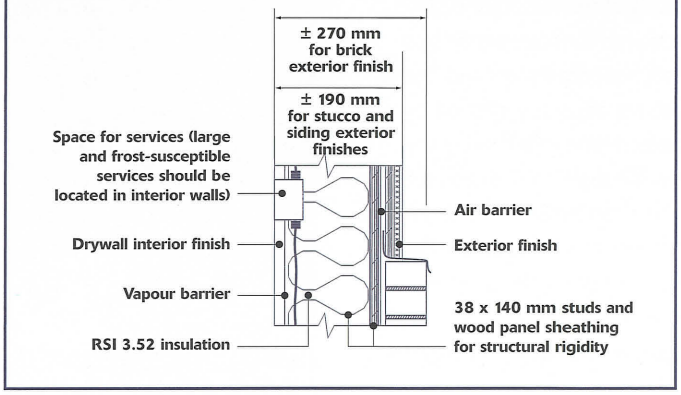
Durability

All buildings are susceptible to damage and failure if moisture is allowed to enter the building envelope; good design and maintenance are therefore essential to ensure trouble-free, long-term service.

There are many fine examples of wood buildings that have already lasted hundreds of years, yet often buildings are removed not because they have failed but because they no longer suit modern needs.

With the use of modern materials wood-frame construction is better equipped than ever to outlive, significantly, the original user's needs and predicted design life-spans. Wood multi-unit buildings have been shown to last as long as and even longer than other types of construction.

FIGURE 3: Wood-frame walls include weather protection, structural rigidity, thermal insulation, and interior finish in a compact assembly that maximizes livable floor area.



Ease of Installing Electrical and Mechanical Services

Interior wall and floor cavities enable installation of both vertical and horizontal services, including electrical wiring, plumbing, and heating ducts. Installing a drainpipe from floor to floor is possible with the use of wider wall framing by the relatively simple means of drilling through the upper and lower wall plates of an interior wall,

FIGURE 4: The moisture management principles to use to promote long service life

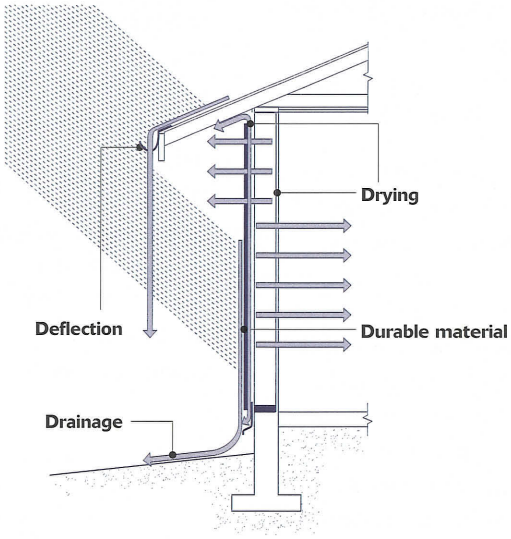


PHOTO 8: Wood-frame construction makes interesting architectural features economical

PHOTO 9: Many wood-frame buildings are into their second century of satisfactory service

something that is easy to do with wood. Although wood-frame construction facilitates the installation of services, care is still required to locate services so that horizontal joists and beams are not adversely affected by holes. Horizontal services are run through carefully located and sized holes drilled in the floor joists. Holes are provided in some engineered wood products, such as I-joists, to facilitate installation of services.

PHOTO 10: Heating ducts and other services run through the floor cavity. Plumbing, heating and electrical services are easily routed from floor to floor through interior wall partitions.

Affordability

For multi-unit residences wood-frame construction can be used to suit a wide range of needs, from affordable apartments for low-income residents to upscale condominiums. Certainly, a major reason why wood-frame construction has been so successful in North America, and is being considered by many countries to solve housing challenges, is its affordability.

The cost of a building is a combination of labour cost and materials cost. Labour cost depends on labour rates and the time it takes to perform a task. In North America, wood materials are relatively economical but labour rates are high. Wood-frame construction is fast – it is normal for an experienced crew of three to frame one floor per day per unit. In countries where wood-frame construction is new, an adaptation period is required before the speed of wood construction can be fully realized. In these countries, wood-frame construction can still offer initial savings in time and costs, and greater savings as familiarity builds. Factory-engineered components and off-site construction provide further possibilities for time and cost saving.

PHOTO 11: Design for earthquake resistance is supported by full-scale testing of wood-frame construction CUREE-Caltech Wood-frame Project, Consortium of Universities for Research in Earthquake Engineering, Richmond, California.

Providing Safety and Comfort Strength

Strength means the ability of a building system to resist the loads that it is likely to face during its lifetime and is directly related to occupant safety and building performance. Wood-frame building technology has several features that give multi-unit residential units the strength to resist loads:

- Numerous members and connections = many paths available to distribute loads evenly through the structure

- Lower mass = high strength to weight ratio
- Ability to flex during movement and dissipate energy

Wood roof, floor and wall assemblies must be able to support gravity loads including building loads, roof loads and floor occupancy loads. For example, wood-frame buildings in some parts of Canada are designed to withstand extreme snow loads. Wood buildings support heavier occupancy loads in multi-family and non-residential buildings. Advances in wood truss technology and the introduction of engineered wood systems have allowed longer spanning members and enhanced performance of roof and floor systems.

Buildings in high wind areas are challenged by the extreme forces of hurricanes or typhoons and building codes require additional features for all buildings in high wind areas. Wood-frame construction can easily be bolstered to meet these requirements. Evidence from recent hurricanes shows that wood-frame construction meeting current building codes requirements can withstand the effects of strong hurricanes.

North American single-family homes are considered by many

PHOTO 12: Wood-frame construction provides cavities for high levels of insulation

to be the safest place to be in an earthquake. The lightweight and high energy absorbing capabilities of wood framing provides a system strong enough to withstand the effects of powerful earthquakes. Experience from strong earthquakes in North America and around the world (Kobe Japan, 1995), has shown that well-constructed wood-frame buildings provide safety to their occupants.

North American wood-frame construction has a proven performance history under extreme loads. Extensive research and testing has been done to test wall and floor assemblies and entire housing units and as understanding of the mechanics involved grows the ability of wood-frame construction to withstand gravity, wind and earthquake loads is continually being improved.

Heating and Cooling

Wood-frame construction can be adapted to suit hot, humid climates and cold, northern climates. Frame construction provides cavities that can be used to provide high levels of thermal insulation economically. The inclusion of adequate insulation during construction will result in significant cost savings for heating and cooling over the life of a building. As energy costs increase, the savings grow even larger.

The amount of energy required to heat an apartment depends on the climate and the thermal resistance of the building. Compared to building techniques that rely solely on uninsulated heavy masonry construction (stone, brick, block or concrete) for shelter from the elements, typical wood-frame construction is about five times as energy efficient. The heating and cooling efficiency of wood-frame construction can be further increased by up to 40% with Super E® technology. This Canadian technology has been proven over 20 years and provides several construction advantages. Technical assistance is available for foreign markets (**www.super-e.com**).

Fire Safety

Modern research has resulted in a far better understanding of fire safety in buildings yet fire will always be a potential danger for building occupants. At one time it was thought constructing buildings of non-combustible materials would ensure safety. However, a number of disastrous fires in such buildings demonstrated that fire safety is far more complex. Many strategies are required to reduce fire risk including: reducing the risk of fires starting; warning occupants if a fire does start; improving the likelihood of occupants moving to a safe place in a fire emergency; containing fire and reducing the risk of collapse of physical elements due to fire. Although the potential for being killed or injured in a fire cannot be completely eliminated, fire safety in a building can be achieved through proven building design features intended to minimize the risk of harm to people from fire to the greatest extent possible.

Research and experience confirm that fire safety in a house or apartment has little to do with the combustibility of the structural materials used in its construction. Occupant safety is far more dependent on awareness of fire hazards (for example, open flames), the contents of a residence (for example, furniture), and the fire protection measures designed into the building. Research studies examining major causes of fatalities in residential buildings conclude that only 0.2% of the deaths were attributable to fires where a floor or wall collapsed. These studies also show that contents of the home, rather than structural members, are the first materials to be ignited in residential fires and that smoke and heat generated by these burning contents cause about 90% of deaths (National Fire Protection Association).

Many building codes throughout the world allow multi-family residential buildings up to four storeys in height using any construction material. Safety measures include requiring the floors and walls separating dwelling units to provide some level of structural fire resistance. As the buildings get larger, building codes require additional safety measures such as sprinkler systems and increased fire resistance for the load bearing structural elements. Most codes require four-storey residential buildings to be sprinklered and the structure must have the same fire resistance rating (one hour) regardless of whether the structure is wood, steel or concrete.

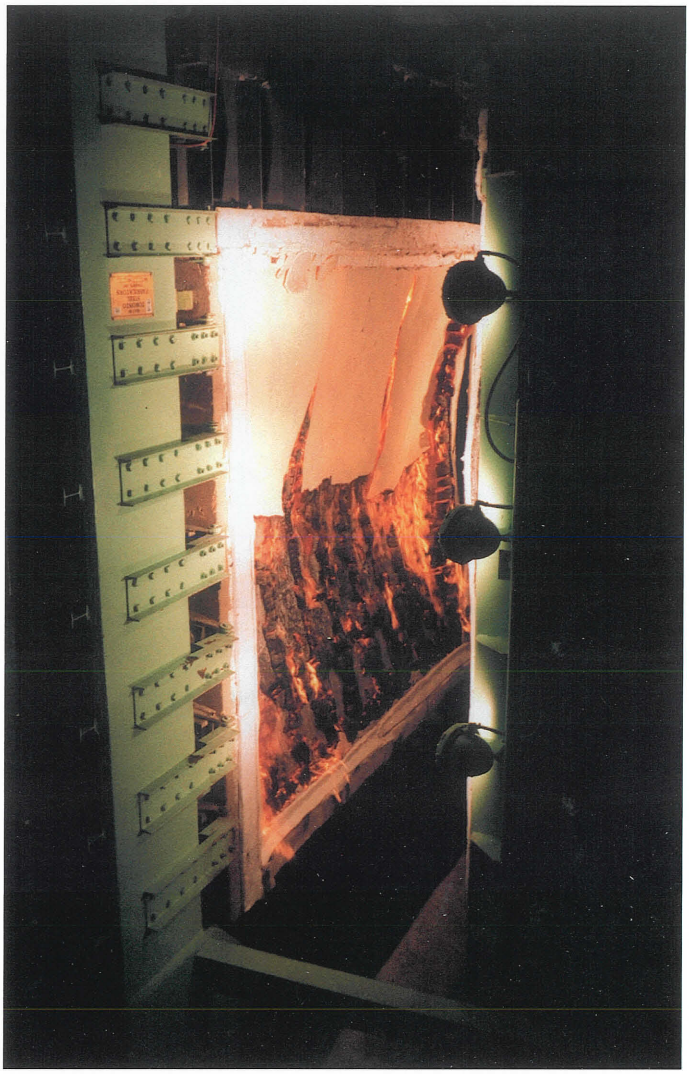


PHOTO 13: Heating ducts and other services run through the floor cavity. Plumbing, heating and electrical services are easily routed from floor to floor through interior wall partitions.

Fire loss statistics and research demonstrate that people are likely to be as safe from fire in wood-frame multi-family housing as they would be in housing built with any other material. The fire performance of wood-frame construction is based on many years of Canadian experience and extensive testing, including tests on full-size buildings. Wood-frame walls, floors and roofs using conventional wood framing, wood trusses and wood I-joists protected by gypsum board can be designed to provide fire resistance ratings up to two hours, the maximum required by North American codes for residential occupancies. Gypsum board is not only an economical way of providing smooth wall surfaces – it also provides essential protection of structural components for a certain period of time in the event of a fire.

Sound

The control of airborne and impact sound is an important building design consideration, especially for multi-unit residential buildings. For all building materials and methods, care is required in design and construction to ensure desired sound control is attained. The National Research Council of Canada has tested the sound transmission of many floor and wall assemblies, including wood-frame, and assigned a sound transmission class (STC) rating to each. The National Building Code (NBCC) requires an STC rating of at least 50 for walls and floors separating dwelling units. These minimum levels can be easily met with wood-frame construction. The most reliable levels of sound control are achieved by using design features such as resilient metal channels to attach gypsum board to framing members, and placing glass-fibre or rock-fibre insulation in the wall or floor cavities.

Impact noise, such as the dropping of a heavy object or the more persistent foot-fall, transmitted directly down through a floor, can be bothersome in all types of construction, including concrete. All types of construction, therefore, benefit from cushion materials between constructional layers, or carpet, to limit impact noise transmission.

Flanking sound transmission, the passage of sound from one dwelling unit to another through construction features, can result in higher noise levels than otherwise expected. Attention to detail and correct on-site assembly of these construction features will ensure noise transmitted through flanking paths is kept to an absolute minimum and even eliminated.

The design and construction of wood-frame construction is well researched and capable of providing good levels of sound privacy.

Termite Protection

Termites are a threat in warm, humid regions, including some parts of North America, where there is a long history of successful wood construction. Effective termite control is important for all buildings, but particularly for wood buildings.

Modern termite control involves a combination of several approaches including:

- Suppression – reduction of termite population density over a wide area
- Site management – removing site debris and nests
- Soil barrier – physical barriers that keep termites away from the residence
- Slab/foundation details – restricting access at key points
- Structural durability – using treated wood in key locations
- Surveillance and remediation

Recent advances in the resistance of wood products to termite attack include borate pressure treatment. Borates are harmless to humans but render the wood structure inedible for termites.

Sample Floor Layout

Modern lumber, engineered and truss products are capable of meeting the span requirements of a wide array of designs such as those shown in Figures 5 and 6. The affordability and adaptability of wood-frame construction means a limitless number of safe, comfortable floor plan designs can be created.

FIGURE 5: Sample row house layout (178 m²)

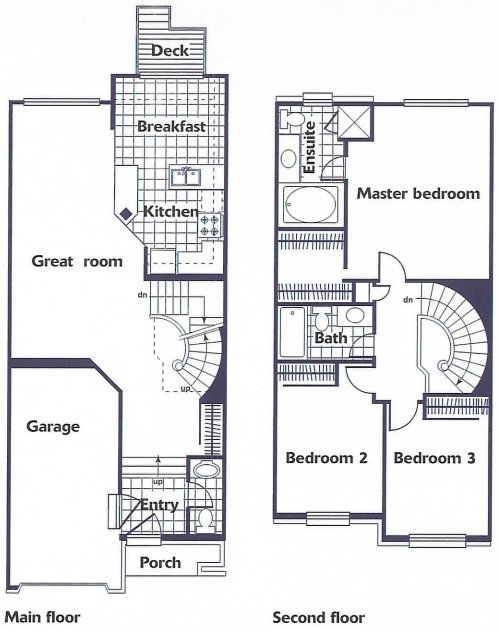
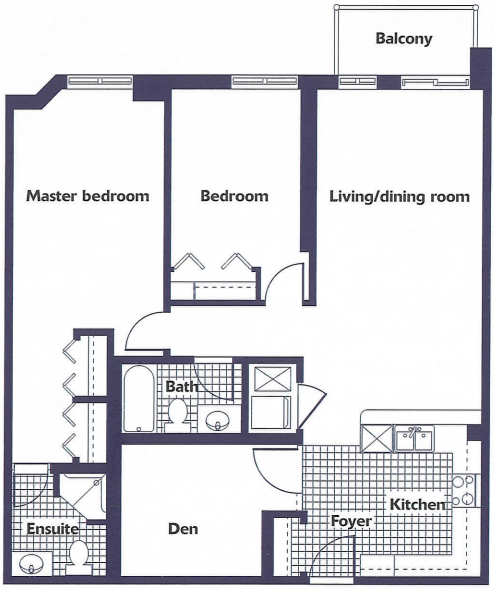


FIGURE 6: Sample apartment layout (120 m²)

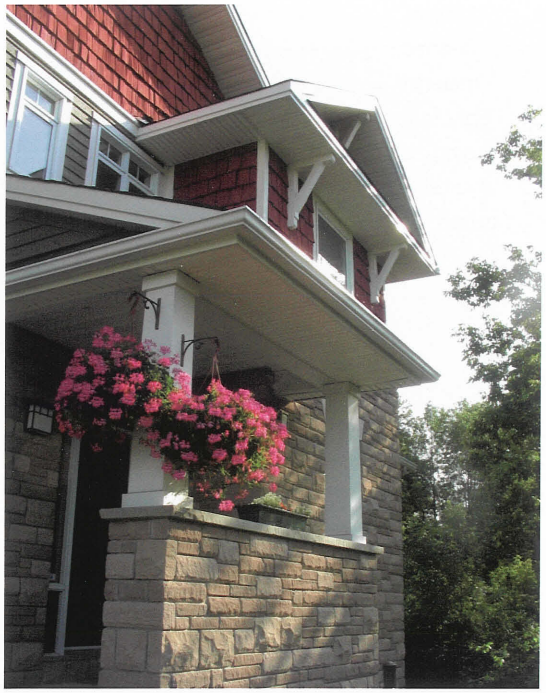


PHOTOS 14, 15, 16, 17, 18: Wood frame construction enables a wide array of designs.

Exterior Finishes

A variety of architectural finishes can be applied to wood-frame construction, including brick, stone, concrete panels, vinyl or wood siding, and stucco. Wood construction can blend with surrounding buildings by using similar exterior finishes.

The ease of fixing exterior finishes to a wood-frame structure can add to the economy of wood construction as buildings can generally be finished in a shorter time than with other types of structure.

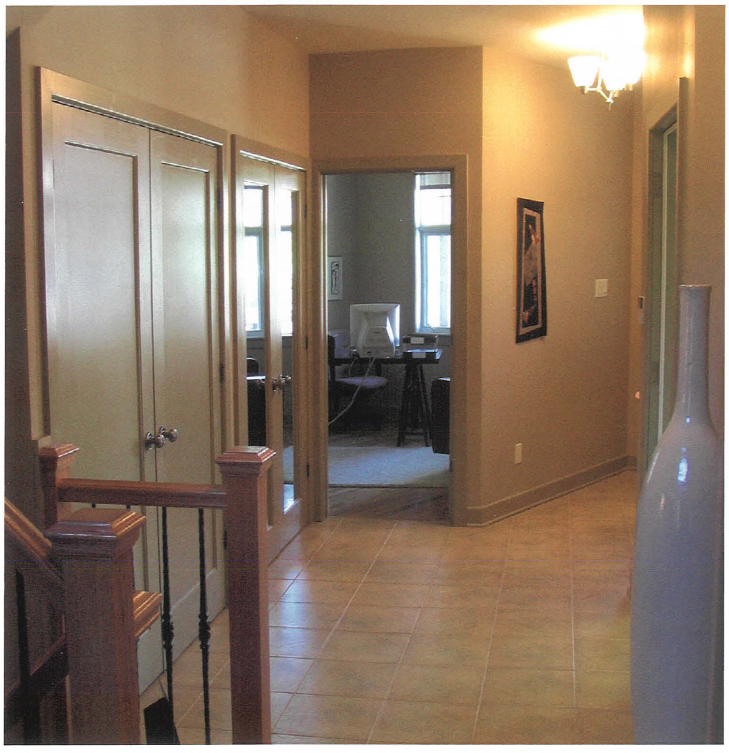


PHOTOS 19, 20, 21, 22: A variety of attractive finishes can easily be used on the exterior of wood-frame buildings.

Interior Finishes

The interior surface of wood construction is easily finished, since many types of materials can be attached directly to the structural members using nails, staples and screws. Typically, wood-frame construction includes gypsum board finishes on all interior walls. This surface is economical, provides a smooth substrate for paint and wallpaper finishes, and provides the necessary fire resistance. On exterior walls, the gypsum board can also serve as the air barrier and is used to enclose the thermal insulation.

Wood-frame floors accommodate a variety of floor finishes including resilient flooring, wood strip flooring, ceramic tile, and carpet. In addition, concrete or gypsum toppings can be added to affect certain performance factors or accommodate in-floor radiant heating systems.

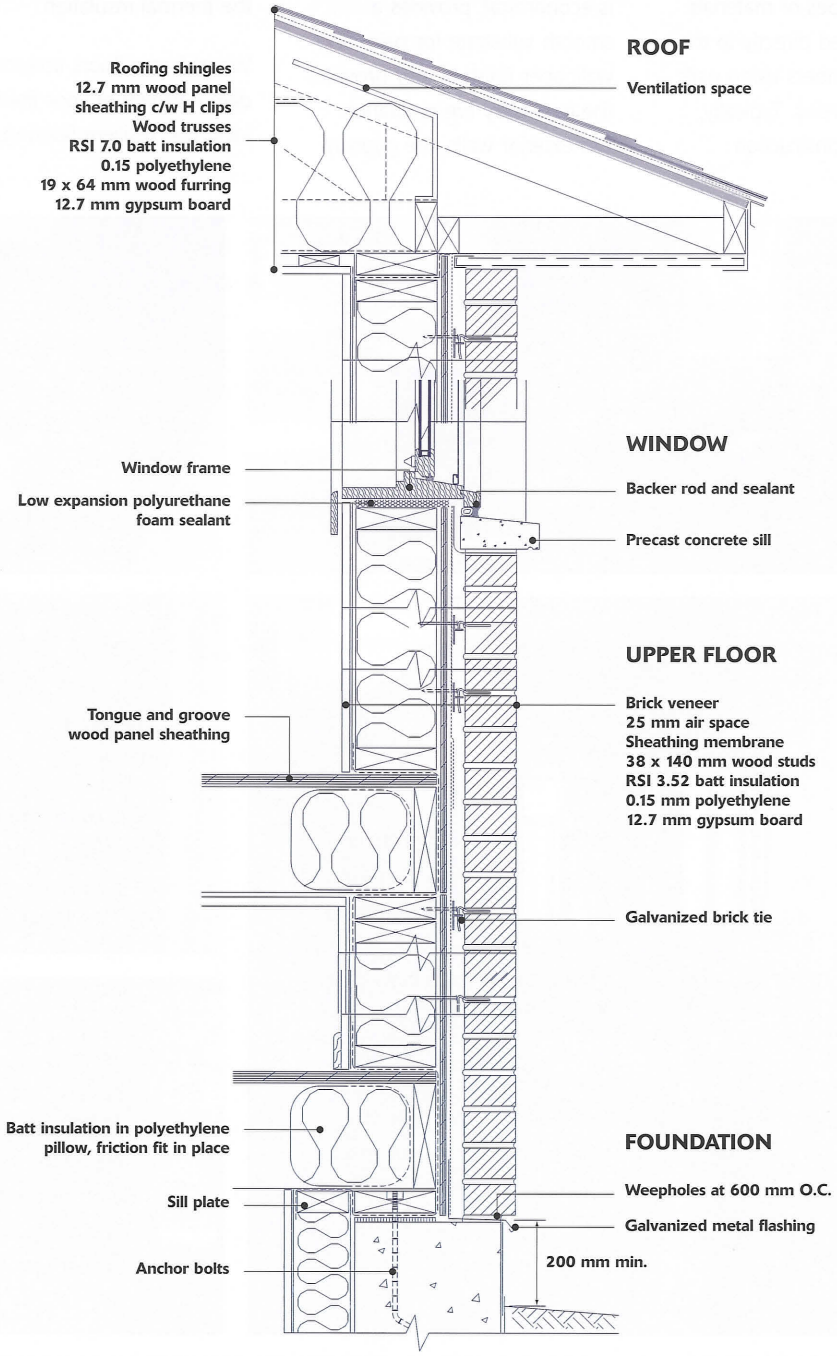


PHOTOS 23, 24, 25, 26, 27: Living areas are bright and comfortable. All standard floor and wall finishes are easy to install.

Sample Design Details

Wood-frame construction uses repetitive materials and methods for each storey. The completed floor is used as the work platform for fabricating the walls (when assembled on site), which are then lifted into the vertical position. Technical support, design details and training are readily available to help builders learn this better way of building multi-unit residential construction. Simplified details for walls with brick cladding are shown in Figure 7.

FIGURE 7: The wood-framing and brick is supported on the concrete foundation. The same details are used for each storey.



Conclusion

Wood-frame construction is receiving a high level of interest in Europe and Asia because it is a fast, affordable, reliable, proven method for constructing comfortable and safe multi-unit residential buildings.

Wood-frame construction offers improved building adaptability: for residential buildings many configurations are possible, from single family homes to apartment buildings several storeys in height.

The reliability and durability of wood-frame construction has evolved from a combination of building experience, research and the evolution of building codes. This successful building technology can be adapted to all types of climates and building performance expectations.

Wood in construction is environmentally superior to other common materials. In comparison with steel and concrete construction the manufacture of wood-frame buildings requires less energy and has a lower impact on air and water.

Townhouses, apartments and condominiums built with wood provide the architect the freedom to add interesting roof shapes and features that respect project budgets and add sales appeal. Walls and floors are compact and can accommodate electrical and mechanical services, maximizing livable floor space. There are many possibilities for exterior and interior finishes.

Multi-unit wood-frame residential buildings are easily designed to meet the most stringent requirements for fire safety and earthquake resistance as well as hurricanes and typhoons. Practical methods have been developed to ensure the durability of wood-frame construction in termite-prone areas. Sound control is an important design feature for apartment buildings and wood-frame construction can exceed code requirements for air-borne and impact sound.

Wood-frame construction is strong and durable. Like other methods of construction, attention to design details and construction quality will keep the building envelope dry and ensure a building meets service-life objectives.

Wood-frame construction has many advantages, but these alone would not account for the success of this method of construction if it were not economical to construct. Wood-frame residential units can be erected very fast. The components are light, easy to cut and fasten, and easy to fit with services and finishes. The speed of construction means units can be generating rental income sooner than other methods of construction.

Apartments and other wood-frame residential buildings will meet code requirements for earthquake and high-wind resistance, fire safety, and sound control. The high degree of thermal insulation that can be installed in the wall and roof cavities keeps heating and cooling costs low, reduces fossil fuel consumption, and makes comfortable temperatures affordable.

Millions of residential units and decades of proven performance demonstrate the appeal, affordability, comfort and safety of wood-frame construction. For more information on how to plan and develop successful multi-unit residential projects, use the contact information on the back page.

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