World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Wood frame single family house

Report #	65
Report Date	05-06-2002
Country	USA
Housing Type	Timber Building
Housing Sub-Type	Timber Building : Stud-wall frame with plywood/gypsum board sheathing
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Summary

Wood frame construction is typical for single family houses throughout the USA. Historically, in the East, Midwestern and South, brick masonry and stone were used for house construction, but this began to be superseded by wood frame around the turn of the 19th century. In the earthquake-prone western part of the US, wood frame has been dominant over stone and brick. The development of present-day wood frame construction began with the

appearance of standardized sawn lumber and cheap machine-made nails. By 1840, the typical wood frame house was built of milled lumber in standard sizes. The standardized wood frame structure is now augmented by a wide range of compatible standardized components such as doors, windows, electrical and plumbing fixtures, and the like, that are designed to be easily installed in the wood structure. Because wood frame walls are hollow, alternative levels of insulation can be installed, enabling accommodation of any climatic conditions and easy installation of plumbing and electrical services within walls, in the open spaces above the ceilings, within the floor structure, and in the space between the first (ground) floor and the ground below. Because of their light weight (compared to brick or stone), their relatively large number of walls, and the use of a multiplicity of nails for connections, wood frame houses have traditionally performed well in earthquakes. Deaths and serious injuries are very rare in these structures. Today's wood frame construction is highly codified and regulated, with a good standard of inspection by suburban local building departments in earthquake-prone regions. In smaller towns and rural areas quality control may be lacking.

1. General Information

Buildings of this construction type can be found in In the earthquake-prone regions of the Western USA wood frame housing accounts for about 98% of existing and new single family houses that are constructed. There is also a considerable market for prefabricated manufactured houses, generally of low cost, that use a factory-built version of standard wood frame construction. This type of housing construction is commonly found in rural, sub-urban and urban areas.

There are many of these buildings in suburban areas too. Some wood frame single-family houses may still be found in a few urban areas: these are generally large houses that are now remodeled into a number of apartments or professional offices.

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. The standardized wood frame construction described here applies to houses built approximately from the 1940's to today. Many detailed improvements and refinements have occurred, such as the increasing use of nailed metal connection components in the last two decades. After World War 2, millions of Americans were housed in small wood frame houses constructed on speculation and sold by merchant builders: new financial systems resulting from post-war legislation enabled a very high percentage of single-family home ownership in the rapidly expanding suburbs. Wood frame construction became highly developed and put on a mass-production footing. Although the construction method was standardized, house design remained individual (although merchant builders achieved much of their low costs and fast construction times by using a small set of standardized plans and elevations). As the economy bloomed through the sixties and beyond basic house construction remained the same but houses increased in size and amenity. Such is the versatility of basic wood frame construction that it is used for all types of houses from low cost subsidized dwellings to huge millionaire's mansions.

Figure 1A: Typical Building

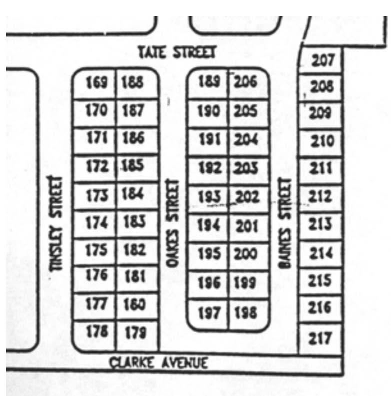

Figure 1B: Typical subarban high density housing

Figure 1C: Typical Building

site plan, California, 2001


Figure 1D: Partial one and two-story house on sloping site


Figure 1E: Example 2: elevation


Figure 1F: Duplex houses. Structure contains two separate housing units

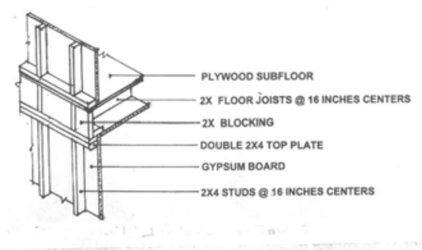

Figure 2A: Key Load-Bearing Elements

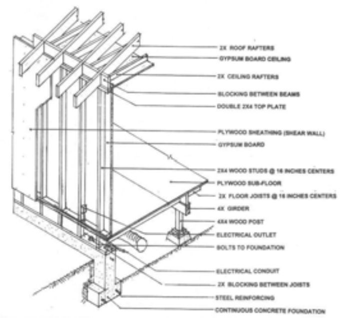

Figure 2B: Typical one-story wood frame construction

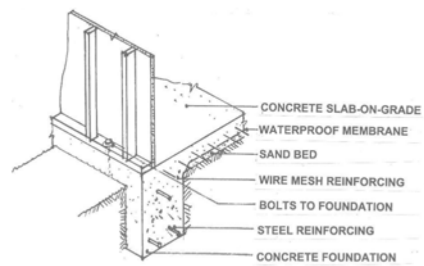

Figure 2C: Alternative concrete slab-on-grade construction

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They do not share common walls with adjacent buildings. This construction may be used on any terrain When separated from adjacent buildings, the typical distance from a neighboring building is 3-6 meters.

2.2 Building Configuration

There is great variation in building configuration. Early small houses were generally rectangular or L-shaped or U-shaped. As house increased in size many variations of these basic forms were used. In addition, setbacks on the upper floors are common, and combinations of one and two-story portions of the house. Sometimes portions of the house may be designed as post-and -beam structures, relying on sufficient shear walls to provide lateral resistance. In more recent merchant- built houses and architect designed houses two story interior spaces are common, often at the entrance or main living areas. Individual architect designed houses often have extreme configuration irregularities. There is great variation in openings in this type of construction. Early houses (1940s and 1950s) had relatively small openings, due to limitations in available window sizes. Architectural trends in the 1960s, together with the development of aluminum windows, resulted in large "picture windows", "window walls" and the use of large sliding glass doors ("patio doors".) Energy conservation requirements in the 1970s caused a reduction in window openings, but economic improvement and the development of standardized double glazed windows resulted in increasing openings. The mild climate in the western USA also encouraged large glazed areas and "indoor-outdoor living". In general, openings are large and irregular: large skylight areas are now common, which may diminish the integrity of the roof diaphragm.

2.3 Functional Planning

The main function of this building typology is single-family house. A variation of this house type is the "Duplex" or "Fourplex", which consists of two or four housing units in a single structure. The units share a common wall but in other respects are completely separate. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. There is wide variation of means of escape in the buildings of this type.

2.4 Modification to Building

Modifications are not widespread occurrence in this building type. Possible patterns of modification are demolishing interior walls and extensions to buildings.

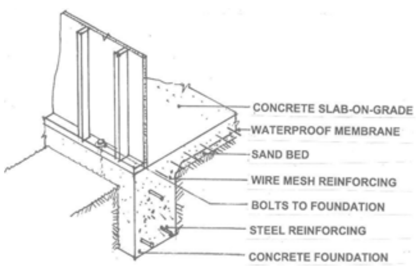

Figure 3A: Plan of a Typical Building

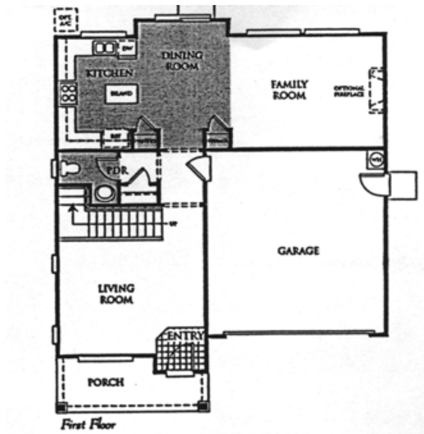

Figure 3B: Second floor plan of Example 1 (see figure 1_3 for first floor)

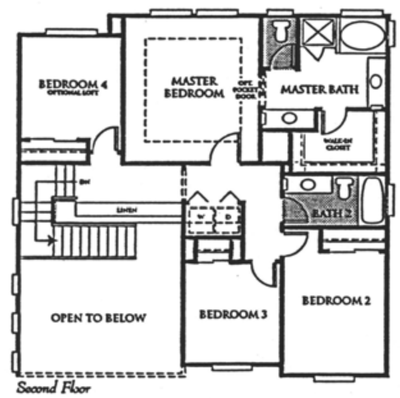

Figure 3C: Example 2: First floor plan

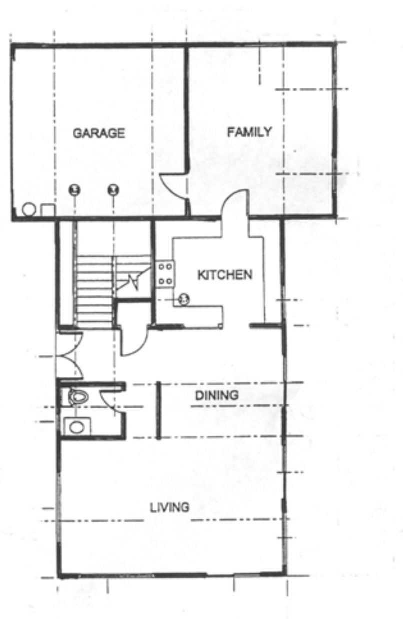

Figure 3D: Example 2: Second floor plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6		

Masonry			Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐
		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
			Wood frame (with special	

		40	connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☑
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Gravity loads are accommodated by wood "studs", commonly spaced at 16 inches (approx 400 mm.) centers. The entire structural system is typically constructed from milled lumber which is 2 inches (approx. 50 mm.) in thickness. Wood studs are 2 inches by 4 inches in section (approx 50 mm X 100 mm). If deemed necessary, the stud spacing may be reduced to 12 inches (approx 300 mm.) and the stud width increased to 6 inches (150 mm.). Floor and roof framing members are 2 inches in thickness and may be from 6 to 14 inches (150 mm to 350 mm) in depth. Construction lumber is supplied by merchants in standard dimensions of multiples of 2 inches: thus heavier beams are commonly 4 or 6 inches in width and 6 to 12 inches in depth. 2 inch wide members are connected by nails: larger members are connected by bolting. In the last two decades the use of metal nailed connectors has become common. (the finished dimensions of construction lumber are less than the nominal dimensions, which refer to the rough, unplaned material. A 2 X 4 is commonly 1½ inches wide by 3½ inches deep (approx. 40 mm. X 90 mm).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Lateral resistance is provided by a shear wall system consisting of plywood or manufactured wood panels ("particle board") nailed to the vertical wood studs, creating shear walls. In lower seismic zones shear resistance may be provided by gypsum sheathing nailed to the studs. The vertical studs are connected to the foundation by bolting, and to the plywood or particle board panel diaphragms by nailing. A direct load path from roof to foundation is provided. The thickness and types of shear panels and the size and spacing of nails are specified in the building code. Older houses, built from the turn of the century to the 1950's, before the common use of plywood, employed horizontal or diagonal sheathing nailed to the studs, or wood diagonal bracing nailed to the studs. When the structure is complete, waterproof building paper is attached to the exterior sheathing and the exterior finish material is applied. This is commonly cement plaster ("stucco"), wood or vinyl planks, or aluminum planks (in lower cost houses). In addition, brick masonry or stone is sometimes applied to the exterior as a non-load-bearing veneer.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 15 and 15 meters, and widths between 10 and 10 meters. The building has 1 to 3 storey(s). The typical span of the roofing/flooring system is 4.26 meters. Typical Plan Dimensions: There is a wide variation in plan dimensions Typical Story Height: Typical Story Height: 8 feet (2.43 m). Larger houses may have some floors that are 9 feet (2.74 m) or 10 feet (3.04 m) in height. Typcial Span: There is a wide variation in spans. Typical economic maximum clear span is about 14 feet (4.26 m). Larger spans will employ girders. The typical storey height in such buildings is 2.43 meters. The typical structural wall density is none. There is wide variation in wall density.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐

Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☐
	Wood shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☐
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☑	☑

Close spaced beams that support wood planks, plywood, or manufactured wood panel sub-floor or roof structure. Although plywood diaphragms are nominally flexible, in wood frame construction the lightness of the entire structure is such that the diaphragms are assumed to maintain structural integrity in a design earthquake. Close spaced beams that support wood planks, plywood, or manufactured wood panel sub-floor or roof structure Although plywood diaphragms are nominally flexible, in wood frame construction the lightness of the entire structure is such that the diaphragms are assumed to maintain structural integrity in a design earthquake.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	Reinforced-concrete isolated footing	☐
	Reinforced-concrete strip footing	☑
	Mat foundation	☐
	No foundation	☐
Deep foundation	Reinforced-concrete bearing piles	☐
	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐

	Caissons	☐
Other	Described below	☐

Other: Wood post and pier Houses constructed on soft of unstable soil or in wet conditions sometimes use a foundation composed of a number of short concrete piles.

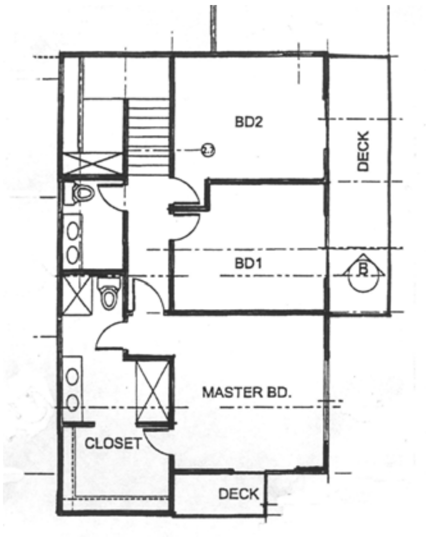

Figure 4A: Concrete slab-on-grade, complete with wood sills installed ready to receive stud walls


Figure 4B: Some wall framing is now installed


Figure 4C: Carpenters installing a stud wall which has been constructed on the concrete slab


Figure 4D: House is framed, sheathed with particle board and windows are installed

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5. Typically, in a house with pre-school children the day occupancy might be two or three. In a house with school age children, where both parents work, the day occupancy might often be zero. In a house with three or more children, the night time population might be five or more. At the upper income levels it is unusual for another relative beside the parents to live in the house. At the lower income levels extended families (grand parents, aunts, uncles) are fairly common.

4.2 Patterns of Occupancy

Typically one family will occupy a house. Sometimes the house owner may rent out rooms to others, and in very low economic groups two or more families may share the house.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☑
b) low-income class (poor)	☑
c) middle-income class	☑
d) high-income class (rich)	☑

The basic construction will apply to all houses: as the economic level rises the house will become larger, better finished and with superior equipment.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☐
4:1	☐
3:1	☐
1:1 or better	☑

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☑
Personal savings	☐
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☑
Commercial banks/mortgages	☑
Employers	☐
Investment pools	☐
Government-owned housing	☑
Combination (explain below)	☐
other (explain below)	☐

The majority of houses are financed by banks or other lending institutions. Few houses are government financed, but some may obtain bank loans that are assisted by specific federal government programs, such as for veterans of the armed forces. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

Larger houses may have an additional "half-bath" (sink and toilet) at the entry. Typical bathrooms contain a sink, toilet, and a bathtub with shower. In a two bathroom house, one bathroom may have a bathtub with shower, the other may have a shower only. One bathroom will be available only to the main "master" bedroom. Very large houses may have several bathrooms. .

4.4 Ownership

The type of ownership or occupancy is outright ownership and ownership with debt (mortgage or other).

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☑

Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

Very few houses are owned outright.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	☑	☐	☐
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	☑	☐	☐
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	☐	☐	☑
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☑	☐	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☑	☐	☐
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	☐	☐	☑
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and	☑	☐	☐

	standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☑	☐	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☑	☐	☐
Additional Comments	The entries in the table assume a well-designed building constructed in accordance with current codes.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall			
Frame (columns, beams)			
Roof and floors			
Other			

A well designed structure constructed in accordance with current codes should provide a satisfactory resistant structure. Common deficiencies in existing structures are: The most common is that of an unbraced "cripple wall". (The cripple wall is the short portion of wall between the foundation and the underside of the first floor structure) In older structures this often has no lateral bracing with the result that it racks and collapses. The damage is not life threatening but is expensive to repair and makes the building uninhabitable. Inadequate shear resistance may occur in older structures that are deficient in sheathing or bracing. This may result in racking that damages finishes and components such as windows. Many older houses were not bolted to their foundations and may move under ground motion, causing damage to the structure and possible severance of water, gas or electrical connection. Poor construction quality, even in newer structures, may result in damage.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is E: LOW VULNERABILITY (i.e., very good seismic performance), the lower bound (i.e., the worst possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), and the upper bound (i.e., the best possible) is F: VERY LOW VULNERABILITY (i.e., excellent seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☐	☐	☐	☑	☐	☑

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1971	San Fernando Valley	6.5	*
1983	Coalinga	6.7	*
1989	Loma Prieta California	7.1	*

The Northridge (Los Angeles) earthquake of 1994 is estimated to have experienced a magnitude of M L = 6.4 on the Richter scale. This was regarded as a moderately strong tremor but the specific characteristics of the earthquake showed it to be one of the worst in recorded history in the United States. A random sample of 340 single-family houses within a 10 mile radius of the epicenter provided the following analysis of damage: COMPONENT DAMAGE in % of sample NONE LOW MODERATE HIGH Foundation 90 8 1 1 Walls and roof 98 2 0 0 Exterior finish 50 46 3 1 Interior finish 50 46 4 0 Source: Adapted from report by NAHB (reference 3) The damage scale used was as follows: NONE No visible damage LOW Component stressed but functional MODERATE Severe stress evident, permanent deflection or near failure in any structural component HIGH Partial or complete failure of any structural component About 90% of the surveyed homes were built prior to 1970, using simple prescriptive requirements. Most of the homes were one-story. Structural damage was very infrequent and primarily located in the foundation system. Less than 2% of homes suffered moderate to high levels of damage and most occurrences were associated with localized site conditions including liquefaction, fissuring and hillside slope failures. In general, the three main types of damage are: Damage to exterior walls, particularly from unbraced cripple walls and where stucco (cement plaster) is used without wood sheathing. Damage (typically overturning) to water heaters Damage to interior gypsum faced walls.

Figure 5A: Cripple wall failure, large house, Morgan Hill earthquake, California, 1994

Figure 5B: Cripple wall failure detail, older house, Coalinga earthquake, California, 1983

Figure 5C: The porch in front of this house has collapsed due to inadequate bracing, Whittier earthquake (Los Angeles), California, 1987

6. Construction

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls				These are described in Section 4
Foundation				These are described in Section 4
Frames (beams & columns)				These are described in Section 4
Roof and floor(s)				These are described in Section 4

6.2 Builder

Commonly built by developers, or by a contractor for an individual owner.

6.3 Construction Process, Problems and Phasing

Typically built by a developer /builder (on speculation) or by a builder contracted by the owner. The illustrations below show steps in the construction process of a developer built house in the San Francisco Bay Area, 2001-similar to Example 1, Section 2.3. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

Basic framing is constructed by carpenters: sometimes this is subcontracted by the general contractor to a firm that specializes in wood frame construction. Installation of other components and specialized construction (such as installing windows or applying final finishes, exterior and interior, etc) is performed by specialized subcontractors to the general contractors. Each will be skilled in their specialty: a house may typically by employ over a dozen subcontractors. Single family houses are not required to be architect or engineer designed. Developer built housing is generally designed by draftspersons, who though not licensed architects, specialize in residential design. In California, an increasing number of larger developers are now using architectural firms that specialize in residential design. Since developers' houses are now often of considerable size and complexity, it is common to employ engineers. Houses designed for individual owners are more likely to be architect and engineer designed. It has been estimated that approximately 2% of houses in the United States are designed by architects.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Wood frame construction has been regulated for several decades in California. The current code (such as the Uniform Building Code, used in California) defines wood frame construction in Section 23, and Earthquake requirements in Section 1630 (Reference 3). Structures that are one or two stories in height can use prescriptive code requirements that define the size and quality of all materials and will size framing members relative to spans and loads without the need for structural analysis. Three story structures require structural analysis, and any structure of irregular configuration or with other non-typical characteristics may require analysis at the discretion of the building official. Title of the code or standard: Wood frame construction has been regulated for several decades in California. The current code (such as the Uniform Building Code, used in California) defines wood frame construction in Section 23, and Earthquake requirements in Section 1630 (Reference 3). Structures that are one or two stories in height can use prescriptive code requirements that define the size and quality of all materials and will size framing members relative to spans and loads without the need for structural analysis. Three story structures require structural analysis, and any structure of irregular configuration or with other non-typical characteristics may require analysis at the discretion of the building official.

Complete plans and specifications must be submitted to the local building department for checking and approval. Building inspectors will inspect the structure at key points in the construction process. These are at such times as just prior to pouring foundation concrete, and at the completion of structural framing.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

Construction cost varies widely, depending on the geographic region and the quality and complexity of the building. In California, construction costs vary from about 60 US$/ft² to 200 US$/ft² (approx. 540 US$/m² to 1800 US$/m²). Houses are generally sold by developers on an all-inclusive basis: house and land, with some basic appliances, ready for the owner to move in. The house shown in Example 1 in Section 2.3 is currently offered for sale at US$ 693,000. This house in constructed in the San Francisco Bay area, in a region with greatly inflated prices. In other parts of the Bay Area (further from the urban centers) the price might be half. In other parts of the country a comparable house might be one third the price or less. The difference is due to higher wage s and living costs in the western United States compared to many other states. The hypothetical house shown in Example 2, Section 2.3, is estimated to cost US$ 334,670 (in 2001 prices), or 127 US$/ft² in Los Angeles. These prices are for construction only and do not include land and marketing. They are median price estimates (Reference 2). Approximate regional variations are: Alaska: 146 US$/ft² Phoenix, Arizona 102 US$/ft². Seattle, Washington 111 US$/ft² San Francisco 136 US$/ft². Depending on size and complexity, a wood frame house takes from 4 months to a year to construct, exclusive of time required to obtain financing and necessary building and planning permits.

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. In earthquake-prone country, in which earthquake codes are in effect, it is assumed that the house is reasonably earthquake resistant, and so no premium discounts are offered for superior construction. After the Northridge earthquake of 1994.private agencies withdrew from the business of residential earthquake insurance. Subsequently, the state California Earthquake Authority was set up, which provides "mini" earthquake insurance policies, not covering pools, patios, fences, driveways or detached garages. The deductible is 15%: the policies cover no more than US$ 5000 worth of home contents and provide a minimum of US$ 1500 in living expenses. The cost of these policies varies throughout the state depending on the earthquake risk and the age and construction of the home. The cost is highest in San Francisco, where the policy for a US$ 300,000 wood frame house built before 1960 would cost US$ 1,710 per year. In Sacramento, the same policy would cost US$ 600. More recently, some private insurance companies have offered more favorable rates, with premium deductions if mitigation measures, such as bracing cripple walls, have been undertaken (Reference 4).

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
unbraced cripple wall	Unbraced cripple walls are the most common deficiencies in wood frame houses. The figure shows the typical way in which an unbraced cripple wall is strengthened. It is not necessary to brace the entire wall: all corners should be braced together with some intermediate portionsof wall , depending on the length of the walls. The work can be done at very low cost by a home owner who has moderate carpentry skills. If the work is performed by a contractor it may cost from $3,000 to $10,000 depending on the size and complexity of the work. See Figure 15.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

Figure 7: Typical unbraced cripple wall strengthening

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