

World Housing Encyclopedia

A Resource on Construction in Earthquake Regions



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HOUSING REPORT

Prefabricated timber frame building

Report#	178
Last Updated	10/06/2015
Country	Slovenia
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Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John

General Information

Building Type:	Prefabricated timber frame building
Country:	Slovenia
Author(s):	Miha Kramar Tomaz Pazlar
Last Updated:	10/06/2015
Regions Where Found:	Slovenia - all regions. The buildings account for approximately 4 % of the entire housing stock in Slovenia.
Summary:	<p>This is a typical single-family house commonly found in all Slovenian regions. They are usually low-rise with 1-2 stories. The basic building block is a prefabricated composite wall element - panel which may be of different size (large-panels were used in the past; nowadays only small-panels are produced). The wall panel consists of framing members and sheathing panels (e.g. chipboard, OSB, gypsum board, Betonyp, etc) connected with fasteners (staples or nails). The empty space between the framing is filled with insulation (e.g. mineral wool). The panels are extending through a single story and are connected at the top with a joist floor framing. A framed roof is mainly double-pitched or multi-pitched. The horizontal loading is resisted by a series of walls in both directions and roof/floor diaphragms. If properly designed, the seismic risk of such structures is relatively low due to small mass (mass is approx. a quarter of the mass of the masonry building). This was confirmed by recent earthquakes, which have not caused major damage to such buildings.</p>
Length of time practiced:	51-75 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwellingResidential, 2 units
Typical number of stories:	1-2
Terrain-Flat:	Typically

Terrain-Sloped:	Typically
Comments:	Prefabricated timber frame structures are most often used for single- or two-family residences. To a lesser extent these buildin

Features

Plan Shape	Square, solid; Rectangular, solid; L-shape; Irregular plan shape
Additional comments on plan shape	At the beginning (1960s-1970s) the geometry of the houses was very simple. Nowadays, houses are constructed of practically any shape (if necessary, steel elements are added).
Typical plan length (meters)	12
Typical plan width (meters)	10
Typical story height (meters)	2.5
Type of Structural System	Wooden structure: Load-bearing Timber Frame: Stud wall frame with plywood/gypsum board sheathing
Additional comments on structural system	The gravity load-resisting system consists of roof and floor system and panel walls. The roof system is double-pitched or multi-pitched timber roof framing made of joists, beams and rafters. The floors are also made of joists which are usually oriented in a single direction. The vertical loading is transferred from the roof and the floors to the wall panels. Within the wall panels the vertical loading is resisted by the framing, whereas the sheathing panels provide the stability in the horizontal direction. The lateral forces are resisted by a system of shear walls and floor/roof diaphragms. Horizontal forces are transferred from the roof and floors through diaphragm action to the supporting walls and eventually into the foundation. The shear walls can carry horizontal forces only in the in-plane direction while the out of plane resistance is negligible. The wood shear walls consist of framing and sheathing panels which are connected using fasteners. The fasteners deform and yield during the horizontal loading, thus allowing the ductile behaviour and energy dissipation. In Slovenia, different combinations of sheathing and fasteners have been used so far. In the past, the most frequently used

sheathing was chipboard and gypsum-cardboard which was attached to the farming with staples at the distance of 15 cm. This system is considered to be less safe. More recently, oriented strand boards (OSB), gypsum fibre boards (GFB), and plywood boards have been used for the sheathing wherein the distance between the fasteners (nails or staples) has been reduced to 7.5 cm at the exterior edges.

Gravity load-bearing & lateral load-resisting systems

Typical wall densities in direction 1

5-10%

Typical wall densities in direction 2

5-10%

Additional comments on typical wall densities

Wall Openings

The average area of a window opening in the exterior walls is 1.4 sqm. The door opening area in exterior and interior bearing walls is of the order of 1.8 sqm. The windows are evenly distributed over the entire surface of the walls. The estimated overall opening area expressed as a fraction of the overall wall surface area is equal to 25 % on the sunny side of the house and approximately 10 % on the shaded side of the house. If steel elements are included in structural design, structures can have larger openings.

Is it typical for buildings of this type to have common walls with adjacent buildings?

No

Modifications of buildings

Due to the pre-set installations the intervention in the structural system is more difficult than in the case of the masonry buildings. Therefore, such modifications are rarely made (the number of such interventions is not known since there is no statistical data available).

Type of Foundation

Shallow Foundation: Reinforced concrete strip footing

Additional comments on foundation

The type of foundation depends on the type of soil. Strip footing is usually used in case of stable and strong soils while mat foundation is used in other cases. Sometimes the houses are built on top of the reinforced-concrete basement slab. In general there are no differences between the building with

and without basement.

<p>Type of Floor System</p>	<p>Wood-based sheets on joists or beams</p>
<p>Additional comments on floor system</p>	<p>The rigidity of the floor diaphragm depends on the type of the sheathing. In most cases the floor is covered with panels that provide large in-plane rigidity. In rare cases, the floor is covered with planks making the floor diaphragm more flexible.</p>
<p>Type of Roof System</p>	<p>Wooden structure with light roof covering; Wooden beams or trusses with heavy roof covering</p>
<p>Additional comments on roof system</p>	<p>The roof diaphragm is rigid when properly braced (most cases).</p>
<p>Additional comments section 2</p>	<p>Typical section of the prefabricated timber frame house and the composition of structural elements is shown in Figure 3.</p>

Section of the house:

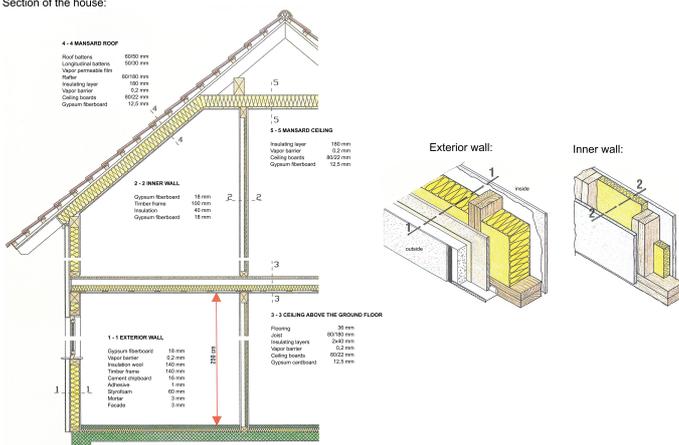


Figure 3: Structural elements of prefabricated timber frame house (courtesy of Jelovica Hise)

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Timber	Studs and rails: structural timber C24 (fm,k = 24 MPa); GL24 (fm,k = 24 MPa) OSB sheathing: Gmean = 1100 MPa; GFB sheathing: Gmean = 1600

		MPa; Staples: $f_u = 900$ MPa Nails: $f_u = 600$ MPa
Foundations	Reinforced concrete	Concrete: C30 ($f_{ck} = 30$ MPa); Steel: $f_y/f_u = 400/500$ MPa
Floors	Timber	C24 ($f_{m,k} = 24$ MPa) GL24 ($f_{m,k} = 24$ MPa) OSB sheathing: $G_{mean} = 1100$ MPa;
Roof	Timber	C24 ($f_{m,k} = 24$ MPa) GL24 ($f_{m,k} = 24$ MPa)
Other		

Design Process

Who is involved with the design process?	Engineer; Architect; Builder; Owner
Roles of those involved in the design process	There are two ways to design the prefabricated timber frame building. The owner can either choose from an existing standard design or decides to build a custom house. In the first case the house has already been designed by the architect and an engineer in advance. Additional planning is usually not needed. In case of the custom design the owner tells his wishes to the engineer (sometimes the architect is also involved), then they coordinate all the details of the house until the desired layout of the house is defined. In any case, the foundations are designed by structural engineer on the basis of geological data and applied loads. The design can be made by the builder (house manufacturer) or by a separate contractor.
Expertise of those involved in the design process	Engineer - B.Sc. in civil or structural engineering, professional license required Architect - B.Sc. in architecture, professional license required

Construction Process

Who typically builds this construction type?	Owner; Builder; Contractor
Roles of those involved in the building process	Houses of this type are usually built (assembled) by the manufacturer of prefabricated houses and/or their contractors. The basement, basement slab or the foundation slab (made of monolithic reinforced concrete) are usually prepared in advance by the owner who hires a mason.

Expertise of those involved in building process

Builder and contractor - specialized expertise in various fields (assembly, electrical, mechanical installations, roofing, plastering, etc). Contractors are usually chosen by their expertise and references. In some cases the subcontractors are certified by building products manufacturers (roof, tiles, facade, joinery, etc).

Construction process and phasing

The construction of a prefabricated timber building is technically divided into four phases: 1.) The first phase includes excavation, forming and stabilization of the ground, construction of concrete foundations. 2.) In the second phase the structure is built to the ground level (only relevant to structures with the basement). The reinforced concrete (RC) basement walls and RC basement slab is constructed. 3.) The third phase refers to the construction works on all floors including the roof. This involves erection of timber frame walls, construction of floors, installation of the roof structure and roofing. Walls and floors are prefabricated while roof structure is built on site. 4.) The fourth phase includes all the final works inside and outside the building, i.e. plastering, pavements, locksmith works, plumbing and electrical installations, carpentry (installation of windows and doors), etc. The process of building a timber frame structure begins in the factory where the workshop drawings are first elaborated. The wall panels are then constructed along with all the installation, openings and an external finish (usually without the final layer and without the building furniture). The ready-to-use panels are transported to the building site with the concrete-slab foundation prepared in advance. The assembly of a building is conducted in the following order (Figure 4): First, the external walls are placed in the position and anchored to the slab using different steel devices (threaded rods had been used in the past while more recently the hold-downs are applied on the inner side of the wall). At the corners, the walls are joined together by screws. The same procedure is repeated for the internal (partition) walls. Once the walls are erected, the joists are installed and fixed to the walls with screws. The joists are covered at the top with sheathing panels (OSB panels are mostly used). In some cases the floor structure is prefabricated. The floor structure is the basis for the next floor which is usually an attic containing only a small number of trapezoidal walls. These walls are also prefabricated and erected in the same manner as the lower floor walls. When the attic walls are set, the roof beams (wall ties) are screwed to the walls. This is followed by the

installation of rafters, planks and roofing. In some cases these elements are assembled in advance in the form of prefabricated roof elements.

Construction issues

Sometimes there are problems with assembling of prefabricated elements. If this issues are related to tolerances they are usually solved at the construction site. However, if there is a manufacturing error the prefabricated elements are replaced. Other problems encountered during construction typically relate to strong winds, fire or rainfall.

Building Codes and Standards

Is this construction type address by codes/standards?

Yes

Applicable codes or standards

In 2004, Slovenia adopted the Eurocode standards which replaced the former Yugoslavian standards. Since then, prefabricated timber frame structures have been designed according to Eurocode standards, in particular: Eurocode 5: Design of timber structures - Part 1-1: Common rules and rules for buildings; Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings According to the Construction Product Regulation (EU 305/2011) Timber Building Kits (including timber frame kits) are also considered as construction products. Consequently, the manufacturers have to mark their products with CE marking and issue a Declaration of Performance (DOP), based on European Technical Assessment (ETA). Currently, ETA (e.g. ETA, 2010) are prepared on the basis of Guideline for European Technical Approval ETAG 007 used as European Assessment Document (EAD).

Process for building code enforcement

Before 2004 Yugoslav standards (JUS) were used which basically conformed to European standards.

Building Permits and Development Control Rules

Are building permits required?

Yes

Is this typically informal construction?

No

Is this construction typically authorized as per development control rules?	Yes
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Additional comments on building permits and development control rules

Building Maintenance and Condition

Typical problems associated with this type of construction	Durability issues in case of long-term leaking/condensation.
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Who typically maintains buildings of this type?	Owner(s)
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Additional comments on maintenance and building condition	
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Construction Economics

Unit construction cost	Usually, the buildings of this type are sold to the client as a partially completed or fully completed product (i.e. turnkey house). The price of such an object depends on the finished stage of the construction, build-in materials, and complexity of the architecture. The price ranges from 500 Euro/sqm (unfinished interior, basic design) to 1,200 Euro/sqm (fully completed building, prestigious design), including VAT.
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Labor requirements	On average, the single-family house is erected in 30-40 working days depending on the size and complexity of the house. The occupation of prefabricated house is possible within 2 to 6 months, depending on the complexity of the building and the materials used.
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Additional comments section 3	
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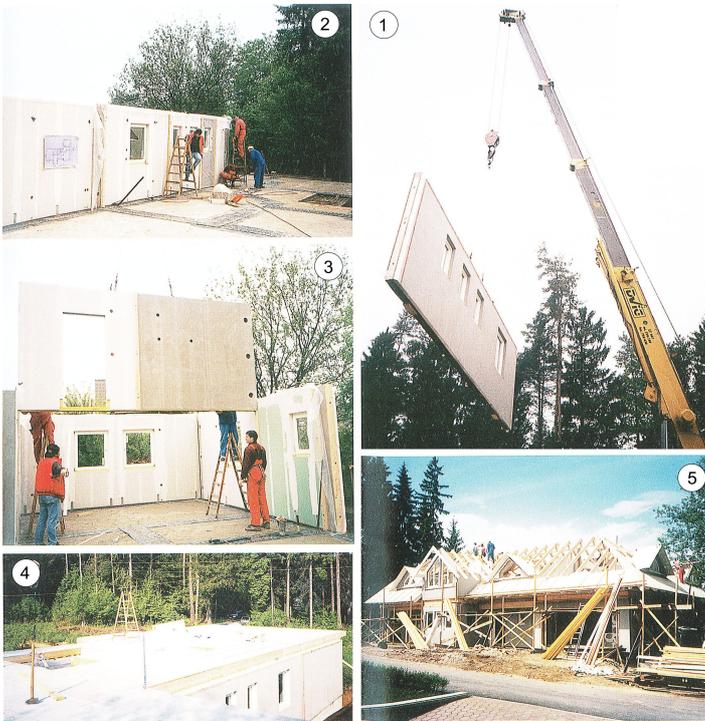


Figure 4: The assembly process of prefabricated timber frame building (courtesy of Jelovica Hise)

Socio-Economic Issues

Patterns of occupancy	The pattern of occupancy is determined by the family lifestyle. Family houses are usually empty during daily working hours and occupied during the afternoon, evening and night time.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	<5
Additional comments on number of inhabitants	
Economic level of inhabitants	Middle-income class
Additional comments on economic level of inhabitants	
Typical Source of	

Typical source of Financing	Personal savings; Commercial banks/mortgages
Additional comments on financing	
Type of Ownership	Own outright; Own with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	The insurance rate depends on the quality of the construction and on the probability of an earthquake. The quality of the construction is determined by the age of the construction while other seismically resistant features are generally not considered. The residential buildings are divided into two categories: older buildings, built before or during 1965, and newer buildings, built in 1966 or later. With regard to the probability of an earthquake, Slovenia is divided into two "seismic insurance zones". For the higher seismic zone, the annual insurance rate is 0.105 % of the building value for older buildings and 0.07 % for the newer buildings. For the lower seismic zone, the annual insurance rate is 0.07 % for older buildings and 0.045 % for newer buildings
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	Premium discount is available for new buildings in general. Seismically resistant features are generally not addressed.
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1976	Friuly, Italy

1998	Bovec, Slovenia
2004	Bovec, Slovenia

Past Earthquakes

<p>Damage patterns observed in past earthquakes for this construction type</p>	<p>No noticeable damage was observed in the past earthquakes for this construction type.</p>
<p>Additional comments on earthquake damage patterns</p>	<p>In the north-western region of Slovenia (the area affected by the latest earthquakes), the most common form of construction are massive buildings with mainly stone walls, wooden floors and heavy roofs (because of heavy winds they use very heavy covering material). Due to this, there is very little evidence of the behavior of timber frame buildings during earthquakes. However, following the Friuli earthquake (1976) around 500 prefabricated timber frame buildings were constructed to replace the demolished houses (Vidrih, 2008). The most famous is a complex of prefabricated houses in a village called Breginj (Figure 5). The region was hit again by earthquakes in 1998 and 2004 but these earthquakes were considerably weaker and they had the epicentre in Bovec (around 15 km of air distance from Breginj) so the area of Breginj and the surrounding villages (where the prefabricated timber frame houses were erected) were not severely affected. Nevertheless, no damage was reported for these houses, which demonstrates a good seismic resistance of this type of structures (Srpic, 2000).</p>

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than $\frac{1}{2}$ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than $\frac{1}{3}$ of the distance between the adjacent cross walls; For precast concrete wall structures: less than $\frac{3}{4}$ of the length of a perimeter wall.

Structural/Architectural Feature	Statement	Seismic Resistance
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.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	TRUE
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.	TRUE
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.	N/A
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE

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);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	TRUE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	TRUE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	TRUE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	TRUE

Building Irregularities

Additional comments on	Due to the relatively small mass and moderate seismicity the earthquake loading is not always the
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Additional comments on structural and architectural features for seismic resistance	largest horizontal loading. Often the horizontal action induced by wind is dominant (Srpic et al, 2009). Figure 6 shows a house that was damaged by the strong wind in north-western part of Slovenia.
Vertical irregularities typically found in this construction type	Torsion eccentricity
Horizontal irregularities typically found in this construction type	No irregularities
Seismic deficiency in walls	Insufficient anchoring of walls; Poorly implemented connections (e.g. in old houses curved metal sheets were used instead of the reinforced hold-downs or brackets); Brittle sheathing material (cardboards, plasterboards); Poor quality and small number of sheathing-to-framing connections;
Earthquake-resilient features in walls	Low weight; Capacity design of connections and anchoring; Ductile behavior of sheathing-to-framing connections;
Seismic deficiency in frames	N/A
Earthquake-resilient features in frame	N/A
Seismic deficiency in roof and floors	Insufficient in-plane rigidity of the roof or floors (joists are connected with single layer of planks)
Earthquake resilient features in roof and floors	Large in-plane rigidity of the floors (joists are connected with multiple layers of planks or strong boards)
Seismic deficiency in foundation	No seismic deficiencies.
Earthquake-resilient features in foundation	N/A

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

	High vulnerability		Medium vulnerability		Low vulnerability	
	A	B	C	D	E	F

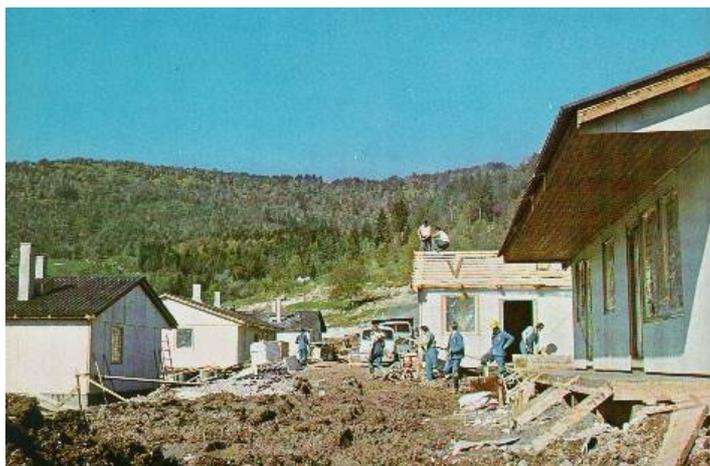


Figure 5: Complex of timber frame buildings in Breginj (during construction)



Figure 6: The wind has blown away the roof of prefabricated timber house and damaged the walls (location: near Nova Gorica, Slovenia)

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Inadequate lateral load resistance of walls	In theory, lateral resistance of the structure can be increased with: - construction of additional walls - applying additional sheathing and/or additional fasteners However, there are no information of practical implementation of such systems.
Inadequate lateral load resistance of roof	The roof structures can be restrained against lateral loading with additional bracing beams between the rafters
Insufficient in-plane rigidity of the floor	The in-plane rigidity of the floor is increased by gluing/screwing additional planks and/or boards on the top, in different orientation if possible (planks at an angle of 45 degrees with respect to the existing boards)
Additional comments on seismic strengthening provisions	

Has seismic

Since such structures are built in Slovenia only in

strengthening described in the above table been performed?	the last 40 years and no significant earthquake damage has been reported during this period, no data is available of such intervention.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Yes - the work was done mainly as a mitigation effort.
Was the construction inspected in the same manner as new construction?	Yes - the construction was inspected in the same manner as the new construction.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Information is not available.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Information is not available.
Additional comments section 6	

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