World Housing Encyclopedia

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

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

HOUSING REPORT
Unreinforced concrete and masonry bearing wall construction (designed for gravity loads only)

Report #	49
Report Date	05-06-2002
Country	PALESTINIAN TERRITORIES
Housing Type	Stone Masonry House
Housing Sub-Type	Stone Masonry House : Dressed stone masonry (in lime/cement mortar)
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Summary

This building type is usually found in most cities of the West Bank and less often in the Gaza Strip. It is a traditional, non-engineered, low-rise construction practice. The main lateral load-resisting system consists of bearing walls with unreinforced concrete strip foundation. The

interior masonry walls consist of plain concrete (system #2) or two wythe stone masonry walls filled with plain concrete (system #1). The exterior bearing walls consist of stone masonry facing with a plain concrete backup. Wall thickness ranges from 400 to 500 mm (system #1) to 300-mm thickness in system #2. It is important to note that system #1 represents the old practice for bearing-wall construction while system #2 represents the new trend which was developed and used from the 1950s to the 1970s. This construction is not practiced at the present time.

1. General Information

Buildings of this construction type can be found in the main cities of West Bank like East of Jerusalem, Nablus, Ramallah, Bethlehem and Jenin. It represents 20 to 30% of the housing stock in these cities. For Gaza Strip, it was applied on a small scale because the stone blocks needed were not available there. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is not being built. This type of construction has not been practiced during the last 30 years.


Figure 1A: Typical Building


Figure 1B: Typical Building


Figure 1C: Typical Building

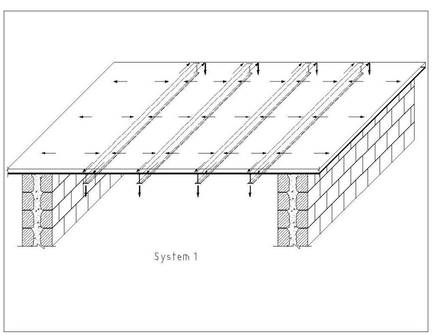

Figure 2A: Key Load-Bearing Elements

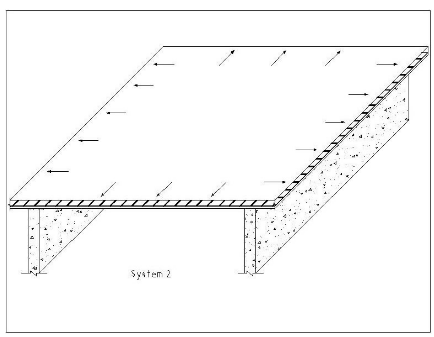

Figure 2B: Key Load-Besring Elements

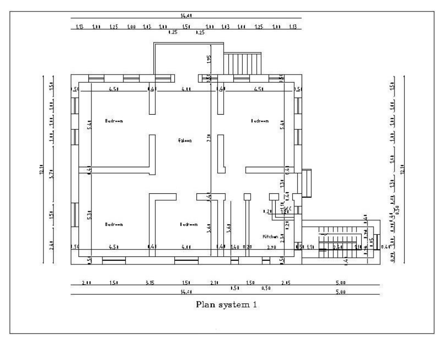

Figure 3A: Plan of a Typical Building

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. The distance between adjacent buildings varies from 6 to 10 meters in the areas classified for housing purposes and zero for commercial areas When separated from adjacent buildings, the typical distance from a neighboring building is 6 meters.

2.2 Building Configuration

Most of the buildings within this system are of rectangular shape. The windows and doors are usually centered within the wall. The height of the windows usually varies from 1.8 to 2.0 meters, and the width has a variable size depending on the architect's experience and personal judgment. Generally, the windows represent 10 to 20% of the wall area. The doors are 1.2 to 1.5 meters wide and 2.2 to 2.5 meters high as an average.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential use). In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Generally, there are no additional doors besides the main entry, also there are no additional exit stairs besides the main ones.

2.4 Modification to Building

Investigations on this type of buildings showed the following: - Some changes in the size and location of the openings are made especially in the internal walls. - Extensions to buildings are applied in many cases using either short, medium or long time intervals. - Staircases are added whenever additional floors are needed. This happens in very few cases where staircases do not exist in single floor buildings. - When adding additional floors, the bearing wall system is usually changed according to the new function, architectural and structural system adopted.

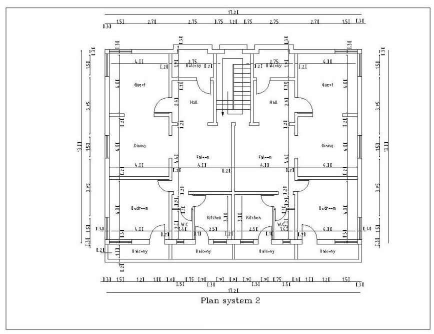

Figure 3B: Typical Plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	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	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	☐
		11	Clay brick/tile masonry, with wooden posts and beams	☐

	Confined masonry	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)	☐
		40	Wood frame (with special 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)	☐

The selection of the type of structural system represents system #1 mentioned earlier, whereas system #2 can be classified as masonry concrete with stone covering for the external walls and without for the internal walls.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). The vertical and lateral load bearing systems are the same. These walls transfer the vertical loads to the foundations. The foundations typically consist of spread footings of plain concrete with stone boulders resting on stiff soil or rock.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). The lateral load resisting system consists of bearing walls resting on unreinforced concrete strip foundation. These masonry walls consist of plain concrete with or without stone. They are very thick (40-50 cm) and of high density. Thus the building weight is very high, and it generates high inertia forces during earthquake. The walls are not connected properly to the foundation, to the floor slabs and to each other. The buildings are generally regular and have only minor variation in stiffness between different floors, except the irregularity due to some variations or changes in the stiffness of the internal walls. The initial stiffness of these walls is not a reliable measure of its strength since it degrades very quickly after the first earthquake shock. This is especially for the buildings having more than two stories (see Figures 5A, 5B and 5C).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 20 and 20 meters, and widths between 20 and 20 meters. The building is 2 storey high. The typical span of the roofing/flooring system is 4-6 meters. Typical Plan Dimensions: Length and width are varied from 10 to 20 meters. Typical Story Height: Typical story height is 4 - 5 meters. Typical Span: Usually typical span ranges from 4 to 6 meter. The typical storey height in such buildings is 5 meters. The typical structural wall density is none. 10% - 15% total wall area/plan area (for each floor) is the range between the ratios of the area of all the walls in each principal direction divided by the total area of the plan.

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	☑	☑

(cast-in-place) reinforced-concrete slabs resting on steel girders (see Figure 4C). (cast-in-place) reinforced-concrete slabs resting on steel girders (see Figure 4C).

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	☐

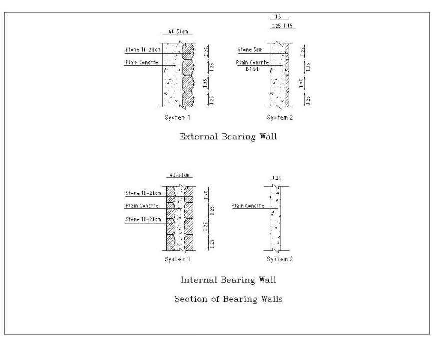

Figure 4A: Critical Structural Details (e.g. wall section, foundations, roof-wall connections, etc.)

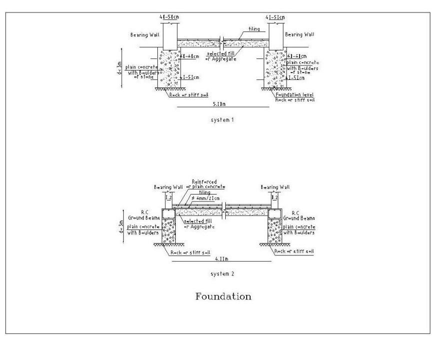

Figure 4B: Critical Structural Details

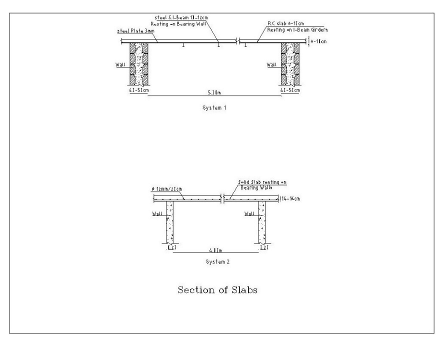

Figure 4C: Critical Structural Details

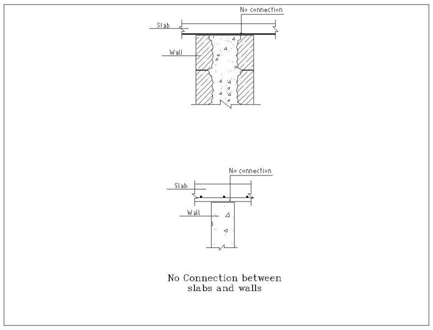

Figure 5A: An Illustration of Key Seismic Features and/or Deficiencies

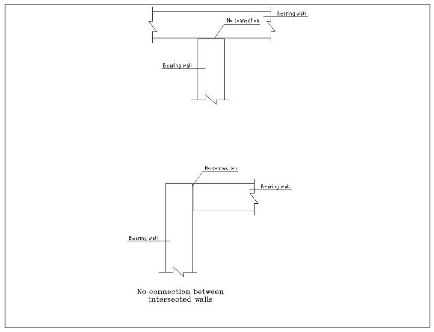

Figure 5B: Key Seismic Features and/or Deficiencies

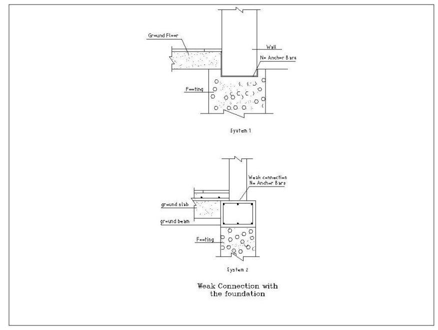

Figure 5C: Key Seismic Features and/or Deficiencies

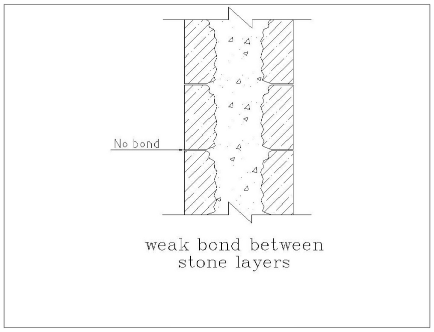

Figure 5D: Key Seismic Features and/or Deficiencies

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 4 housing unit(s). 4 units in each building. The number of housing units in the type considered in this study (as Figure 1A) varies between 2-4. In few cases, especially in Nablus and Ramallah cities, the number of the units may reach up to 8 units in each building. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 11-20.

4.2 Patterns of Occupancy

One family generally occupies one housing unit. We can find in very few cases or even rarely more than one family in one housing unit. Each building typically has multiple housing units. Ground floor can be used for commercial purposes.

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)	☐

These figures represent the present cost. The cost of construction was much lower when these building were constructed. Economic Level: For Poor Class the Housing Unit Price is 40,000 and Annual Income is 5,000. For Middle Class the Housing Unit Price is 40,000 and the Annual Income is 9,000.

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)	☐

In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership and ownership by a group or pool of persons.

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)	☐

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	Other: Interconnection of different components: foundation, walls, roof slabs is poor.			

5.2 Seismic Features

Structural Element	**Seismic Deficiency**	**Earthquake Resilient Features**	**Earthquake Damage Patterns**
Wall	- The weight of the walls is very high which results in increase in the seismic forces. - No connection between walls and slabs. Also no connection between transverse walls at the points of intersection. - No mechanical bond between the concrete and the stone layers. - No additional reinforcement added around the window and door openings. - Poor connection with the foundation. - Weak bond between stone layers.		
Frame (columns, beams)			

Roof and floors	- Low durability due to the type of the material composing the concrete, and lack of maintenance. - Heavily loaded cantilever slabs sometimes exist.		
Foundations	The footings are not well connected to achieve the necessary stiffness		

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *C: MEDIUM VULNERABILITY (i.e., moderate 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
1927	Jericho		MMI,VIII
1995	Aqaba Gulf		MMI, VII - VIII

- The magnitude of the Aqaba Gulf earthquake ranged between 6.2-6.5. -The magnitude of the Jerico earthquake ranged between 6.2-6.3. - In the 1995 earthquake, the Epicenter was located about 100 kilometers south of Aqaba and Elat cities where MMI was VII. On the other hand, MMI near the zone of the Epicenter was VIII. - PGA for 1995 earthquake was 0.20 g. -The Dead Sea earthquake caused damage to masonry structures in Nablus and other historic cities in the Palestinian territories. A report on the earthquake from the Earth Sciences and Seismic Engineering Center of An-Najah National University is available at the EERI Learning from Earthquakes web site.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Concrete bearing wall (internal) Concrete/Stone (external)	1.0-2.0/15-20 /1.0-2.0 1.0-2.0/15-20/1.0-2.0	1:3:6 - 1:3:5	The stone used for decorative purposes in the external walls is neglected in the strength (Represents system 2 only since system1 was not governed by identified parameters)
Foundation	Concrete	1-2/15-20/1-2	1:3:6	(Represents system 2 since system 1 was not governed by identified parameters).
Frames (beams & columns)				
Roof and floor(s)	Concrete	1-2/15-20/1-2	1:3:6	(Represents system 2 since system 1 was not governed by identified parameters).

6.2 Builder

The builder lives in this type in many cases. Also, a developer sometimes built the house for investment purposes and others bought or rented it.

6.3 Construction Process, Problems and Phasing

The construction process can be briefly described as follows: (1) For system 1 : - A draftsman or a licensed engineer (very rarely) made the drawings for the building. The drawings followed only the traditional forms used by people at that time. Sometimes the owners with the help of the local builders made their own houses without preparing drawings by specialized people. - Many of the buildings had the same design concerning heights, dimensions, openings, and sometimes number and distribution of rooms and spaces. - The drawings which usually included only architectural design without any detailing were signed by the designer mentioned above and submitted to the municipality or the authorized departments for building license. - A contractor or a builder was assigned by the owner to build the house without using any procurement process. - The work was not usually done under the supervision of the engineers who were not available. - Generally, traditional building methods were applied and all the work was done manually using traditional tools and depending on the personal experience of the builders. - The time of construction used to be very long and sometimes lasted for years. (2) For system 2 - The architectural and structural drawings were prepared by the engineer (usually the same) without preparing the necessary detailing. - The drawings were signed by the authorized engineer and submitted to the municipality for building license - No electrical or mechanical design was made. This was usually applied on site and during construction by skilled labors who used only their personal experience and conventional methods. - The work was awarded by the owner to local contractors or builders. Procurement methods were rarely applied.. - More effective building techniques were applied but still conventional and also the personal experience of the contractor or builder governed the process. - The time of construction as a result was relatively long but less than that for system 1 - Some of the buildings were built under the supervision of engineers. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size.

6.4 Design and Construction Expertise

For system 1, no engineers were available except for very few number of draftsmen or authorized designers. The engineers association was not there. For system 2, very few engineers were available and the engineers association was just started. In both cases, the personal experience of the workmen and the conventional methods governed the process. As mentioned above, the engineers played only a limited role especially in preparing the drawings for system 2 . The major role during the construction process was played by the contractors and local builders.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

There was no national code for this type of construction. Also no specified court of law was applied to ensure good quality construction.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and not 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) and Tenant(s).

6.8 Construction Economics

These housing systems are not used anymore. To build a housing unit of this type or even to buy it, the cost is more than 50000 $US. The estimated cost at the time of construction (during the 1950s) is around 2000 $US (This does not include the land price which was generally cheap at that time). For a housing unit of system 1 nearly 1500 workdays or person days were required to complete the construction and for system 2 the number was 1000 workdays.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

The retrofitting of these structures is not described in any provisions. It is performed rarely by individual engineers without applying unique principles and tools. In general, jacketing using reinforced concrete or steel is used for strengthening purposes.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?

Information not available.

8.3 Construction and Performance of Seismic Strengthening

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