World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

multistory tower masonry with stone pillars and wood or arched beams (Casa Torre)

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Country	Italy
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Important

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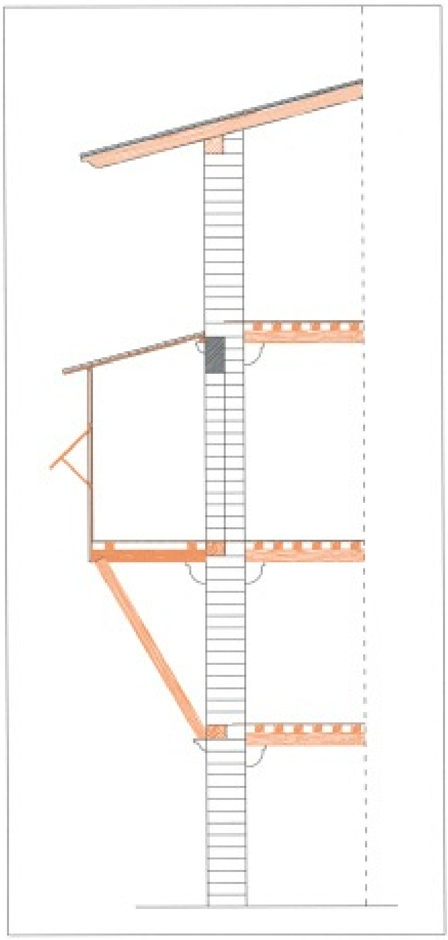
General Information

Building Type:	multistory tower masonry with stone pillars and wood or arched beams (Casa Torre)
Country:	Italy
Author(s):	Mauro Sassu Chiara Cei
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Tuscany, but some of these buildings are also found in surrounding regions. This type of housing construction is commonly found in urban areas.
Summary:	This construction originated during the Middle Ages in response to the threat of military invasions. The building plan is a square lattice, 5-7 meters, formed by three or four floors, with one room on each floor, and a total height of 15-20 m. It is a common technique found in Pisa but also found frequently in many municipalities of Tuscany and adjacent districts. The structure of the building is supported by four stone columns connected by arches (circle or oval) or by beams at each floor; the floor is supported by a series of wood beams (especially pine) with wood tables and/or clay blocks. The upper floors of the earlier historic buildings often contained a wood balcony supported by cantilevered wood beams. Some balconies were fully enclosed structures with clay-tile roofing. The entrance on the first floor could be accessed by means of a detachable wood staircase.
Length of time practiced:	More than 200 years
Still Practiced:	No
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	4-7
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	The Casa Torre technique has been used to increase the level of safety and protect inhabitants from invasion by foreign armies.

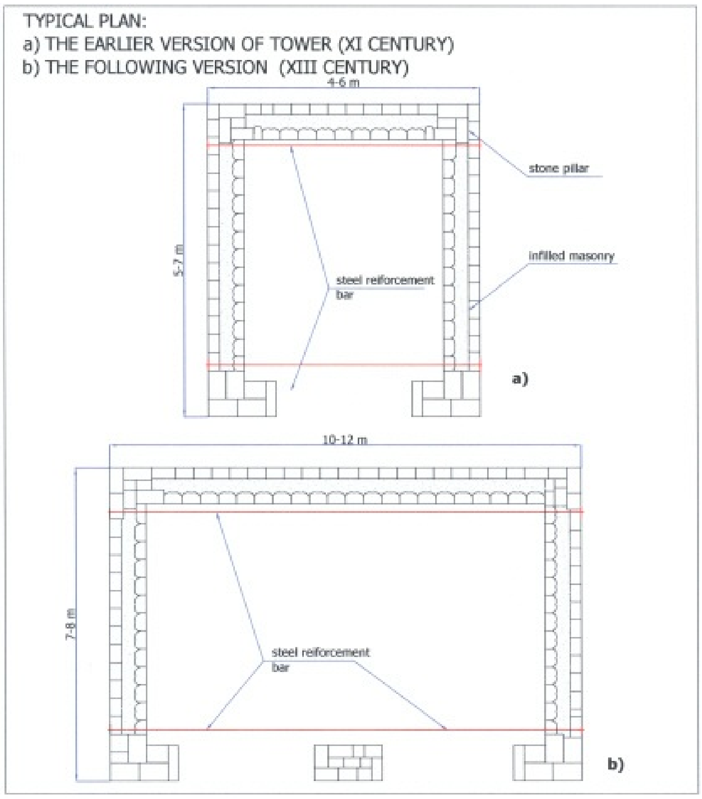
Features

Plan Shape	Square, solidRectangular, solid
Additional comments on plan shape	Three or four floors; one room over each other, in an approximately square plan.
Typical plan length (meters)	6-12
Typical plan width (meters)	4-8
Typical story height (meters)	3
Type of Structural System	Masonry: Stone Masonry Walls: Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)
Additional comments on structural system	The vertical load-resisting system is limestone masonry pillars infilled with clay or sandstone walls with openings supported by wood or brick lintels. The floor is supported by small wood beams (span 1.7 m: distance 25-30 cm) which rest on two or three primary wood beams (span 5 m: distance 1.7 m). The lateral load-resisting system consists of plane frames formed by stone pillars and wood beams or wood-masonry arches. The "moment-resisting" connections between pillars and beams or arches are generally well executed. The stones at the edges have high mechanical strength. There are no momentresisting connections between the floors and the walls or arches.
Gravity load-bearing & lateral load-resisting systems	The historic Casa Torre performs its structural functions by means of high-quality stones, moment-resisting connections of the beams, and regular plan shape.
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on typical wall densities	The typical structural wall density is 5 to 10 %.
Wall Openings	In the first version (ca 1100), the openings were situated on one, or perhaps two, opposite walls. In the second period (ca 1200), openings might be seen on all four walls. In most cases, the openings were centered, vertically aligned, and narrow (0.80-1.20 m) in relation to the total dimension of the wall (6 m). Originally, the ground floor contained no openings (the entrance was accessed on the first floor with the help of a ladder); afterwards, wider openings (1.5-2.5 m) were created, mostly at the ground-floor level.
Is it typical for buildings of	

this type to have common walls with adjacent buildings?	No
Modifications of buildings	Incorporating single masonry towers with adjacent buildings was often undertaken to create a unique "Palazzo" with wider buildings or multifamily dwellings.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone isolated footing
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls The existing wood floor/roof structures are not considered to be a rigid diaphragm unless they are tied with diagonal ties and connected to the walls.
Type of Roof System	Roof system, other
Additional comments on roof system	The existing wood floor/roof structures are not considered to be a rigid diaphragm unless they are tied with diagonal ties and connected to the walls.
Additional comments section 2	The typical plan dimensions of the Casa Torre were 6 meters; sometimes adjacent buildings were created with two common pillars. When separated from adjacent buildings, the typical distance from a neighboring building is 6 meters.



Typical section of the building



Design plan with the arrangement of steel reinforcement bars.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	"Verrucano" or limestone masonry for blocks; lime mortar joints	20 - 50 MPa (verrucano or limestone) compression strength; 1-4 MPa (mortar) compression strength. Big, regular-shaped blocks. The mortar layers are very thin and the gaps are not visible.
Foundations	"Verrucano" stone masonry support or clay units	10-20 MPa (clay unit) compression strength 1-4 MPa (mortar) compression strength.
Floors	Wood beams (chestwood and oak)	8-15 MPa (wood) collapse stress due to bending moment.
Roof	Wood beams (chestwood	8-15 MPa (wood) collapse

	and oak)	stress due to bending moment.
Other		

Design Process

Who is involved with the design process?	Builder
Roles of those involved in the design process	Technical historical knowledge and devices were remarkable; several original buildings constructed in the 12th century are well preserved with almost no specific maintenance problem.
Expertise of those involved in the design process	These buildings didn't require knowledge of engineering or analytical design: the builder followed unwritten rules and knowledge based on experience and tradition.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	The builder didn't live in this construction type. These buildings were made for rich and important families; the ordinary house is smaller and made of wood and clay units.
Expertise of those involved in building process	
Construction process and phasing	In the first two floors, the walls consist of two parallel stone wythes filled with clay units and lime mortar joints. Both wythes are made of large, sharp, squared stones with thin layer of mortar without gaps. The upper floors are made of smaller stones approximately shaped with bigger mortar gaps; large squared stones are still used in the corners and overlap masonry units in order to have adequate connection to the perimeter walls. Roof and floor beams are supported by particular shaped stones coming out of the walls. The framework is supported by wood beams embedded in specific holes in the front, which are still visible (see picture). The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. As they became richer and more powerful, many owners increased the height of their "casa torre" in a competition with the neighboring families for greater status.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	D.M. (Ministerial Decree) 20 November 1987 (Italian Code on Masonry Structures) D.M. 16 January 1996 (Italian Seismic Code). The year the first code/standard addressing this type of construction issued was 1974. Replaced O.M. (Ministerial Order) 20 March 2003 n. 3274 with further modifications. A national seismic code was issued in several Tuscany zones in July 1981.
Process for building code enforcement	Building Code enforcement was not available. From 1088-1092, church regulations limited the height of the towers in order to prevent any one family from gaining too much power and control. Constructing wood galleries on the outside walls has been prohibited for safety reasons since 1300.

Building Permits and Development Control Rules

Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Builder
Additional comments on maintenance and building condition	Typically, the building of this housing type is maintained by Builder. These buildings are commonly listed by the local heritage conservation office. (Soprintendenza ai Beni Architettonici, Artistici e Storici).

Construction Economics

Unit construction cost	In modern times, construction of building improvements and retrofitting is particularly concerned about preserving the original features. The average refurbishment cost is about 1.000 euros/m2.
	Refurbishment of this building type is under the strict control of the Historic Superintendent; only skilled laborers

Labor requirements	--- a builder, one assistant, a minimum of two skilled laborers and two manual laborers --- are allowed to perform work on these buildings.
Additional comments section 3	

Socio-Economic Issues

Patterns of occupancy	Houses of this type were occupied only by the owner-family.
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 classHigh-income class (rich)
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Owner financed
Additional comments on financing	
Type of Ownership	Own outright
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	Earthquake insurance is not available in Italy.
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	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1846	
1984	
1987	

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	No visible effects on load-bearing structures from earthquakes.
Additional comments on earthquake damage patterns	

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 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.

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	TRUE

	forces from the building to the foundation.	
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.	FALSE
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.	FALSE
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.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	FALSE
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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled 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.	FALSE
Wall Openings		FALSE
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 structural and architectural features for seismic resistance	There is sometimes evidence of vertical foundation movement due to the soil properties or to further interventions.
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Originally, the walls were not tied by means of steel or wood ties. The connection of the multileaf walls is partially ensured by the wood floor beams. Damage Patterns: Cracking (not necessarily due to an earthquake) at the interface of the pillars and walls.
Earthquake-resilient features in walls	Massive stone masonry cavity walls, filled with sand, clay units, and lime inserted between the stone pillars, capable of dissipating seismic energy
Seismic deficiency in frames	The corner pillars are made of large and squared stones with thin joints filled with lime mortar, well connected to

Seismic deficiency in frames	the beams: the moment-resisting connection between pillars and beams is not ductile.
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Made of simply supported wood beams and planks, so they do not provide an effective connection between two opposite walls.
Earthquake resilient features in roof and floors	Very lightweight and elastic structures.
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

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
Seismic vulnerability class	o					

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	**Seismic Strengthening**
Transverse connection between opposite walls	Steel tendons: grid wood floor frame
Vertical settlement	Reinforcement of the foundations with RC tub-fix micropiles

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Steel bars are used as connections between opposite walls or to absorb horizontal forces in the arched beams of several buildings.

Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Sometimes the work has been done to repair structural damage or to stop potential cracking of the masonry (not necessarily after an earthquake); sometimes it's undertaken just to stabilize the building.
Was the construction inspected in the same manner as new construction?	Inspections were not routinely performed.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	The building was constructed by a contractor without the involvement of an engineer or architect.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Generally remarkable, but highly dependent on the quality of the strengthening work; subsequent earthquakes have had no effect on load-bearing structures.
Additional comments section 6	

Opposite walls are connected by the use of tie-rods, with evident improvement in seismic behavior.

"Torre della Verga d'oro." Structural reinforcements: two large arched openings supporting horizontal forces at the base of the tower have been infilled by clay units.

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