World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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

HOUSING REPORT

brick masonry farmhouse with a "dead door"

Report#	31
Last Updated	
Country	Italy
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Important

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General Information

Building Type:	brick masonry farmhouse with a "dead door"
Country:	Italy
Author(s):	Agostino Goretti Daniela Malvolti Simona Papa
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in the Emila-Romagna region and in the south of the Padania Plain. It is widespread in the Reggio Emila Province. The total number of this building type in the Reggio Emilia municipality is less than 9,000. The percentage The percentage of this housing type as a fraction of the entire housing stock in the Reggio Emilia Municipality is approximately 20%. This type of housing construction is commonly found in rural areas.
Summary:	This is a single family farmhouse construction, found throughout the Padania Plain (Reggio Emilia Province). This housing type accounts for approximately 20% of the entire housing stock in the Reggio Emilia Municipality. This building practice is no longer followed. Most of the existing buildings were built in the 19th and 20th century. The residential and agricultural sections of the house are separated by a central area closed at one end and hence called a "dead door". The residential section usually has two floors (typical story height 2.5-3.0 m), and a sloping roof. The agricultural portion, usually larger than the residential section, also has two floor levels. The first floor height is on the order of 2.5-3.0 m whereas the second story floor height ranges from 5.0 to 9.0m. As a result, roof in the agricultural part of the building is at the higher level as compared to the residential part. The first floor is used as a cowshed and the second as a hayloft. The loadbearing structure consists of brick masonry walls in lime mortar. The walls are characterized with variable thickness, decreasing from 280 mm at the first floor level to 150 mm at the second floor level. There are brick masonry columns in the interior of the agricultural portion at the second floor level. The buttresses can be found in the exterior brick masonry walls. Both the residential and agricultural sections have wooden floors; there are vaulted floors in the central area. In some cases, composite floors made of steel beams and perforated bricks can be found. Although the building plan is very regular, the seismic performance of this building type is rather

	poor due to the vertical irregularity (offset of the floors in the residential and agricultural sections), the absence of connections between walls and betweens walls and floors, the thrusting of the roof, and the deterioration of materials.
Length of time practiced:	101-200 years
Still Practiced:	No
In practice as of:	
Building Occupancy:	Single dwellingOther
Typical number of stories:	2
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	Single family house, mixed residential and agricultural (cowshed and hayloft) use.

Features

Plan Shape	Rectangular, with an opening in plan
Additional comments on plan shape	
Typical plan length (meters)	14
Typical plan width (meters)	10
Typical story height (meters)	3
Type of Structural System	Masonry: Unreinforced Masonry Walls: Brick masonry in mud/lime mortar
Additional comments on structural system	The load bearing structure consists of brick masonry walls in lime mortar. The walls are characterized with a variable thickness, decreasing from 280 mm at the first floor to 150 mm at the second floor level. Brick masonry columns (560 mm depth) are present in the interior at the second floor level in the agricultural portion, and the buttresses can be found in the exterior walls. Both the residential and agricultural sections have wooden floors, while the vaults are present in the central area. In some cases, composite floors made of steel beams and perforated bricks can be found. On the second floor of the agricultural portion, diagonal bracing is present
	Type 7 with lime mortar instead of mud mortar.

Gravity load-bearing & lateral load-resisting systems	Brick dimension typically 28 x14 x 6 cm. Lime mortar 1-2 cm thick. Some mortar deterioration, at times due to water infiltration, can be found. Typical Story Height: 2.5-3.0 m in the residential portion and in the first floor of the agricultural portion. 5.0-9.0 m in the second level of the agricultural portion.
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	4-5%
Additional comments on typical wall densities	The typical structural wall density is up to 5 %. 5% - 7% at first level, 3% - 4.5% at second level.
Wall Openings	In the residential portion a typical window size is 90 x120 cm. Windows are vertically aligned. At the first floor level in the agricultural portion, small windows are often densely distributed. Windows at the second floor level are used more for ventilation than for light in the hayloft. In the central part of the building there is a large door opening. Estimate of the overall window and door areas as a fraction of the overall wall surface area are: residential portion 25%, agricultural portion 15%, central portion 25%, overall 20%.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	No significant structural modification can be observed in this housing type. Bathrooms have been recently added.
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footing
Additional comments on foundation	In buildings close to rivers, fieldstone strip footing can be found.
Type of Floor System	Shallow-arched masonry floor
Additional comments on floor system	Wooden or steel beams with perforated bricks. Floors and roof are considered to be a flexible diaphragm.
Type of Roof System	Roof system, other
Additional comments on roof system	Wooden or steel beams with perforated bricks. Floors and roof are considered to be a flexible diaphragm.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Solid bricks with lime mortar	characteristic normal stress =6.0 MPa characteristic shear stress=0.3 MPa 1:3 lime/sand mortar mortar is often deteriorated
Foundations	Solid bricks with lime mortar	1:3 lime/sand mortar
Floors	Wooden (or steel beam with perforated bricks)	Characteristic Strength: +25 MPa, -12 Mpa (200 MPa)
Roof	Wooden (or steel beam with perforated bricks)	Characteristic Strength: +25 MPa, -12 Mpa (200 MPa)
Other		

Design Process

Who is involved with the design process?	OwnerOther
Roles of those involved in the design process	Engineers and architects were not involved in building construction in the past, now one can find them in charge of the structural design for building repairs or upgrades.
Expertise of those involved in the design process	Buildings were built relying on the experience of the local artisans, without any structural or architectural design.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	This housing type is used by farmers. Buildings were built by local artisans.
Expertise of those involved in building process	
Construction process and phasing	The need for cost control is demonstrated by structural elements that are not properly dimensioned and by the wall thickness reduction on the second floor. Buildings were built with poor tools and materials and with low quality standards.

	Buildings were constructed without any design.
Construction issues	The construction process was driven by the fact that the owners typically had limited financial resources.

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Technical rules for the design, execution, testing and strengthening of masonry buildings, Ministry of Public Works, 1987 The year the first code/standard addressing this type of construction issued was 1909. The most recent code/standard addressing this construction type issued was 1987 for vertical loads, 1996 for seismic loads
Process for building code enforcement	In the case of repairs resulting from earthquake damage, as well as upgrades and retrofit, code enforcement and controls during the design and construction are performed by local authority (Region) officials. Public financial contributions are used for repair of earthquake damage, but upgrades and retrofit are privately financed .

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	In the past, building permits and authorizations were not required for building construction. Permits and authorizations are required for the building repair or upgrade performed at the present time.

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on	

maintenance and building condition	

Construction Economics

Unit construction cost	500 Euro/m.sq. (430 $/m.sq.)
Labor requirements	90 days for 3-4 person team
Additional comments section 3	

Critical Structural Detail - Roof Beam Support

Seismic deficiency- inadequate wall connection

Socio-Economic Issues

Patterns of occupancy	One family typically occupies one house.
Number of inhabitants in a typical building of this construction type during the day	5-10

Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	Percentage of economic status: 50% Poor, 50% Middle Class. House Price over Annual Income has been set as a constant for different economic levels. In case of Middle Class Status, the annual income is greater but also the price ofthe house is greater, due to a higher level of maintenance. Economic Level: For Poor and Middle Class the ratio of Housing Unit Price to their Annual Income is 10:1.
Typical Source of Financing	Owner financedInformal network: friends or relativesSmall lending institutions/microfinance institutions
Additional comments on financing	This housing type is no longer built.
Type of Ownership	RentOwn outright
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
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
1996	Bagnolo in Piano, Reggio Emilia
1971	Parmense
1832	Reggiano
1547	Reggio Emilia

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	
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 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)	FALSE
Building Configuration-	The building is regular	FALSE

Horizontal	with regards to the plan. (Specify in 5.4.2)	
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.	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);	FALSE
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	FALSE

	with metal anchors or straps.	
Wall Openings		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
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).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	Quality of building materials judged on present codes and standards.
Vertical irregularities typically found in this construction type	Torsion eccentricity
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Absence of connections and/or iron ties able to prevent the out-of-plane wall overturning. At the second level, masonry wall is very slender with mortar often deteriorated. Earthquake Damage Patterns: Separation of orthogonal walls, out of plane overturning, shear cracks, corner diagonal cracks due to the roof thrust.
Earthquake-resilient features in walls	Regular layout and solid bricks.
Seismic deficiency in frames	At the second level of the agricultural portion (hayloft) columns can be up to 9.0m high
Earthquake-resilient	

features in frame	
Seismic deficiency in roof and floors	Flexible floors and roof are not effectively connected to walls. The vault in the central portion is usually very thin. The roof is often thrusting. Earthquake Damage Patterns: Separation of the floors and/or roof from the walls, beam hammering on walls.
Earthquake resilient features in roof and floors	Floors and roof are light.
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	|-	-|				

Wall damage (1996 Bagnolo earthquake)

Wall damage at the roof beam support (1996 Bagnolo earthquake)

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Wall	-replacement of bricks with similar ones (sometimes with the insertion of horizontal steel rebars); -insertion of transverse connections made by bricks or steel bars into the wall; -tying of the orthogonal walls; -installation of iron ties; -Concrete j
Floors	Construction of new RC slab atop existing beams, tying the floor to the walls, replacement of the existing floor with RC floor
Roof	-replacement of existing wooden beams, -reinforcement (doubling) of the wooden boarding, -construction of RC ring beam
Columns	#NAME?
Vaults	-RC slab on existing vaults

Additional comments on seismic strengthening provisions	Upgrade or retrofit work have been seldom performed on this housing type.
Has seismic strengthening described in the above table been performed?	Yes
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Mainly performed as a repair or upgrade following earthquake damage.
Was the construction inspected in the same manner as new construction?	Yes
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	A contractor performs the repair/upgrade construction. Architects or engineers are seldom involved in the construction phase, however they are involved in the design phase.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Good, provided that the retrofitting has been correctly performed.
Additional comments section 6	

Illustration of Seismic Strengthening Techniques

Seismic strengthening technique - installation of the iron ties

References

1. Cremaschi M. (1983). Case rurali nel forese di Reggio Emilia, Suppl. to Ricerche Storiche, n. 50-51 (In Italian)

2. Zaffagnin M. (1997). Le case della grande pianura, Alinea, Florence (In Italian)

3. Pietri C. & Pantaleoni L. (2000). Abitazioni rurali della Pianura Padana, Maggioli Ed. (In Italian)

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