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

Single-family reinforced concrete frame with masonry infill walls house

Report#	30
Last Updated	
Country	Italy
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Important

A, Martin & Associates, Inc. or the participant's organizations.

General Information

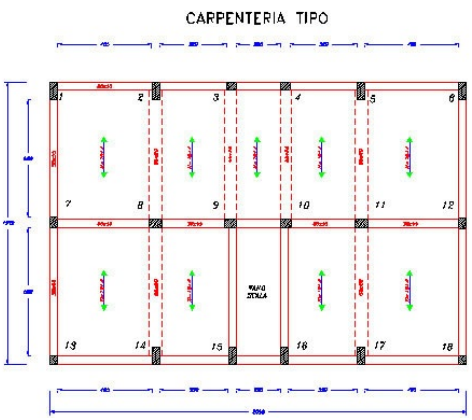
Building Type:	Single-family reinforced concrete frame with masonry infill walls house
Country:	Italy
Author(s):	Maurizio Leggeri Giuseppe Lacava Eugenio Viola
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in many cities throughout Italy. This type of housing construction is commonly found in urban areas. This type of construction is also present in suburban areas.
Summary:	This building type is commonly used for multifamily housing in urban areas of Italy and is particularly common in the region of Potenza (Basilicata). Prior to 1981, this region was not included in the official seismic zonation map of Italy, in spite of the historical evidence. However, after the major earthquake of November 1980, the entire Potenza province was recognized as a seismically prone area. Consequently, seismic considerations were not taken into account for in the building design projects predating the 1980 earthquake. The main load-bearing structure is reinforced concrete frame with masonry infill walls. Many buildings of this type were strengthened using the financial assistance provided by the government. The upgrade typically consists of installing new shear walls and L-shaped columns, and strengthening the foundation.
Length of time practiced:	25-60 years
Still Practiced:	No
In practice as of:	
Building Occupancy:	Residential, 20-49 units
Typical number of stories:	4-10
Terrain-Flat:	Typically
Terrain-Sloped:	Typically

Comments:	Currently, this type of construction is not being built. This building type was common in the cities when the area wasnot offic

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Typical shape of the building plan is rectangular.
Typical plan length (meters)	20-50
Typical plan width (meters)	12
Typical story height (meters)	3.5-4
Type of Structural System	Structural Concrete: Moment Resisting Frame: Designed for gravity loads only, with URM infill walls
Additional comments on structural system	Gravity: Reinforced concrete frame. Lateral: Originally, the buildings were designed for gravity loads only. Unreinforced masonry infill walls exist as partitions (nonloadbearing elements). The strengthening was carried out after the November 1980 earthquake, in order to incorporate elements of lateral load-resisting system. The upgrade consists of installing new RC shear walls, L-shaped concrete columns and strengthening the foundation (using internal micropiles and external macropiles).
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	4-5%
Typical wall densities in direction 2	4-5%
Additional comments on typical wall densities	The typical structural wall density is up to 5 %. Approximately 0.05 (i.e. 5%).
Wall Openings	The size of door opening is 0.80 m width and 2.00 m height. In the new RC shear walls installed as a part of the upgrade, there is only 1 door opening per apartment. The ratio of door area/shear wall area is approximately 9%.

Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	The structural upgrade did not modify the building function (the same housing features were preserved after the upgrade).
Type of Foundation	Deep Foundation: Reinforced concrete bearing piles
Additional comments on foundation	For all the buildings built before the 1980 earthquake, without any seismic features, the reinforcement of piles was limited to the first 2.50-3.00 m, for the anchorage to the plinths.Fortunately, foundation collapse was not reported due to very good soil conditions (overconsolidated clay) with resetting of bending moment.
Type of Floor System	Other floor system
Additional comments on floor system	The floor is considered to act as a rigid diaphragm.
Type of Roof System	Roof system, other
Additional comments on roof system	The floor is considered to act as a rigid diaphragm.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 8-10 meters. Currently, this type of construction is not being built. This building type was common in the cities when the area was not officially in the seismic zone (pre-1980).



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Reinforced Concrete Steel	300 Kg/cm.sq. 4400 Kg/cm.sq.
Foundations	Reinforced Concrete Steel	300 Kg/cm.sq. 4400 Kg/cm.sq.
Floors	Reinforced Concrete Steel	300 Kg/cm.sq. 4400 Kg/cm.sq.
Roof	Reinforced Concrete Steel	300 Kg/cm.sq. 4400 Kg/cm.sq.
Other		

Design Process

Who is involved with the design process?	Engineer
Roles of those involved in the design process	Design for building of this type: by a graduate technician (a college graduate). Structural design: by a Civil Engineer. The structural design of this construction was completely done by a civil engineer. The architects usually design buildings with better aesthetic features (and functionality).
Expertise of those involved in the design process	Graduate technician.

Construction Process

Who typically builds this construction type?	OwnerBuilderContractorOther
Roles of those involved in the building process	This construction type is built by contractors. The builder typically lives in a building of this construction type.
Expertise of those involved in building process	
Construction process and phasing	This construction type is built by contractors. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Italian Code 1971 National ByLaw #1086, November 5,1971 National ByLaw #64, February 2,1974 Ministerial Order January 16,1996
Process for building code enforcement	Building permit is issued if the design documents have been approved by the Building Committee of Town Municipality (Planning and Building Departments) and by the Regional Committee (named #Genio Civile#) for Structural Project.

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
Additional comments on building permits and development control rules	

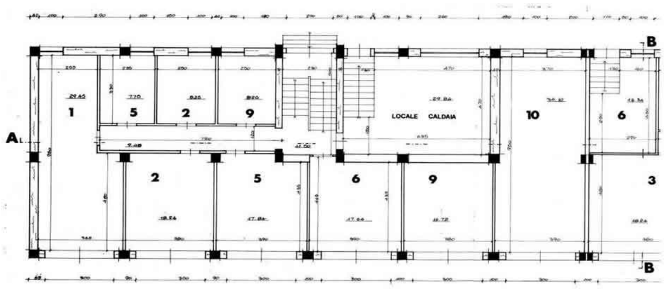
Building Maintenance and Condition

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

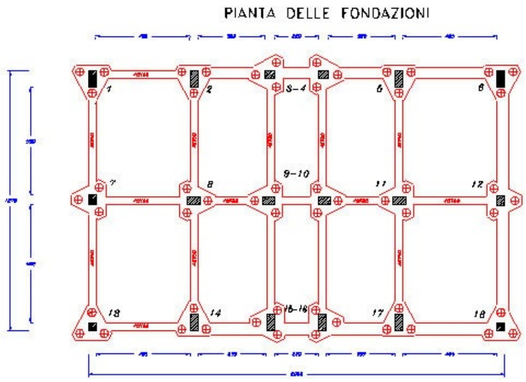
Construction Economics

Unit construction cost	500 $US/m.sq.

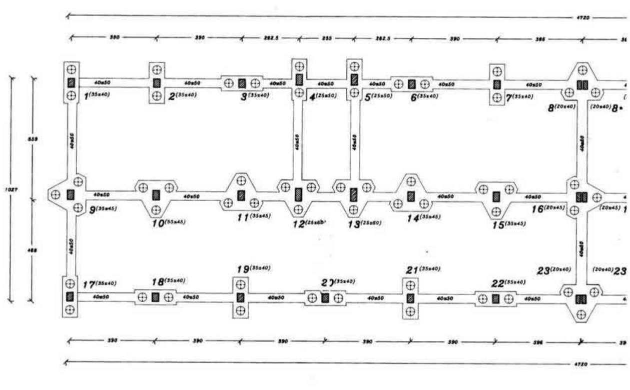
Labor requirements	The construction of a typical load-bearing structure of this type (5-story high) would take from 126 to 180 days for a team of 8-10 persons.
Additional comments section 3	



Typical Floor Plan



Typical Foundation Plan



Typical Foundation Plan

Socio-Economic Issues

Patterns of occupancy	One family per apartment (housing unit). Each building typically has 10-30 housing unit(s).
Number of inhabitants in a typical building of this construction type during the day	>20

Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	Very Poor: lowest 10%, Poor: lowest 30%, Middle Class: lowest 30% to top 20%, Rich: top 20%. Ratio of housing unit price to annual income: 1:1 or better
Typical Source of Financing	Personal savingsOther
Additional comments on financing	At present time, the Government does not support any new construction of this type.
Type of Ownership	Own outrightUnits owned individually (condominium)
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

1980	Irpinia-Basilicata
1990	Potenza
1991	Potenza
1998	Pollino-Lauria

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	The list includes the significant earthquakes in the Basilicata region after this construction practice has started.
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)	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.	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);	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.	TRUE
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).	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).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Unreinforced hollow clay tile infill walls Earthquake Damage Patterns: Diagonal ("X"-cracking) and failure see Figure 11 and 12.
Earthquake-resilient features in walls	

Seismic deficiency in frames	Designed for gravity loads only
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Designed for gravity loads only
Earthquake resilient features in roof and floors	
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	-|		

Typical Earthquake Damage - Cracking of Hollow Clay Tile Partitions

Typical Earthquake Damage-Cracking of Masonry Partitions

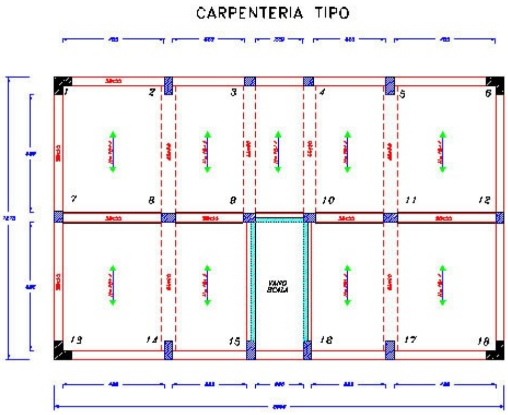
Retrofit Information

Description of Seismic Strengthening Provisions

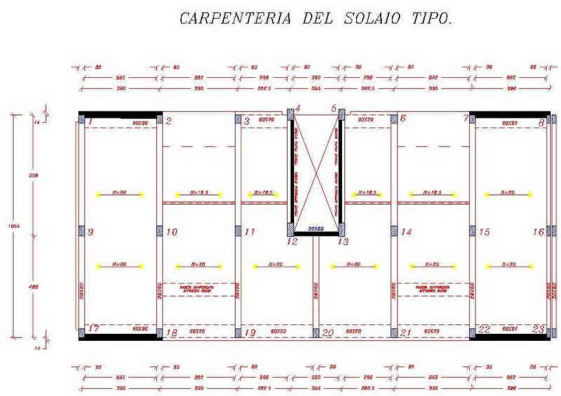
Structural Deficiency	Seismic Strengthening
Pile Foundations	Strengthening
RC Columns	Strengthening
Deficient Lateral Load-Resisting Capacity	Installation of new RC shear walls

Additional comments on seismic strengthening provisions	The initial phase of the seismic upgrade design included the evaluation of the existing building in order to identify seismic deficiencies. Dynamic analysis was performed using the Super ETABS software, and the natural periods of the structure for six different modes. After the strengthening design was performed, the new periods have been calculated, showing that the strengthened building is characterized with a significantly higher stiffness as compared to the original building. A chart showing the the variation of natural vibration periods for the same five-story building before and after the retrofit is illustrated in Figure 20 (corresponding to the building shown in Figures 1, 5 and 7). A similar chart is presented on Figure 21, corresponding to a four-story building shown in Figures 2 and 8.
Has seismic strengthening described in the above table been performed?	Yes. The strengthening has been performed in practice. This type of strengthening assures the protection of the building from seismic effects and improved dynamic response.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Repair and retrofit after the earthquake.
Was the construction inspected in the same manner as new construction?	No.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Contractor performed the construction and an engineer was involved.
What has been the	

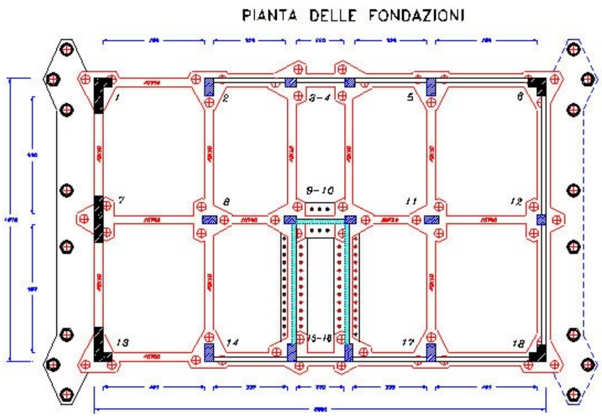
performance of retrofitted buildings of this type in subsequent earthquakes?	The performance of retrofitted building was excellent in the earthquakes of 1990/1991.
Additional comments section 6	



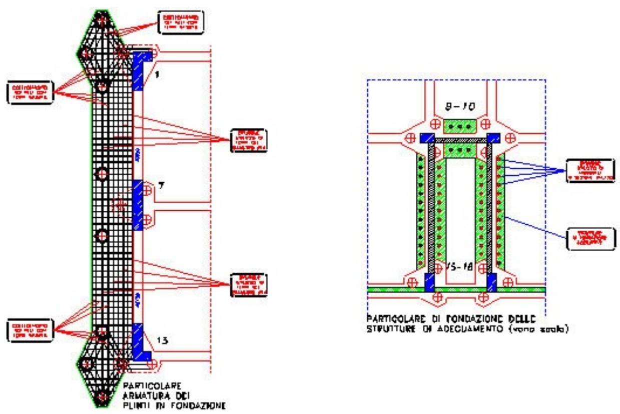
Seismic Strengthening Techniques : Floor Plan of a Strengthened Building



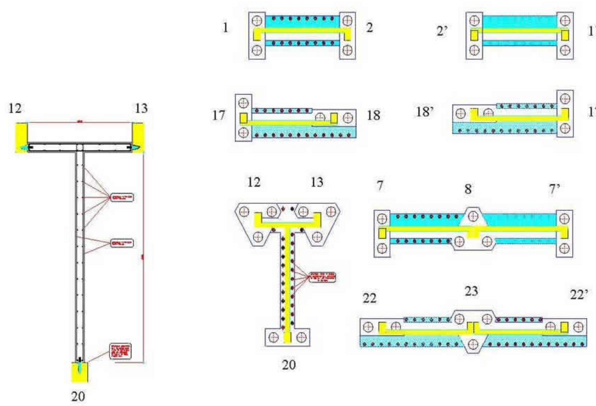
Seismic Strengthening - Floor Plan of a Strengthened Building

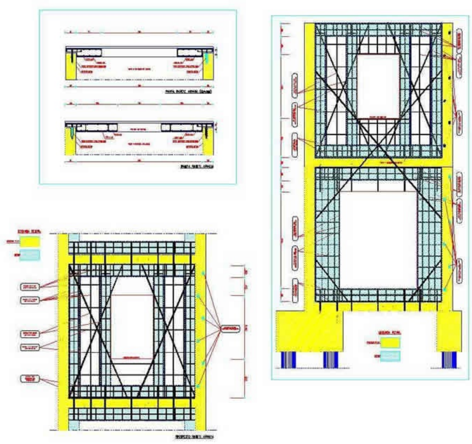


Seismic Strengthening - Foundation Plan

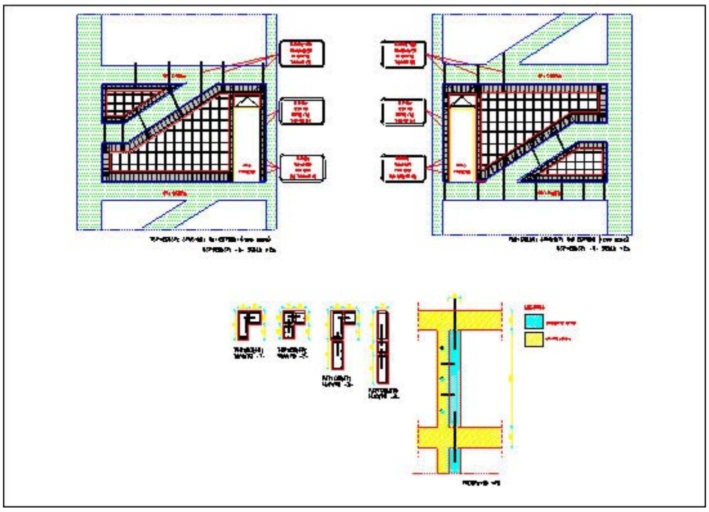


Seismic Strengthening - Foundation Details



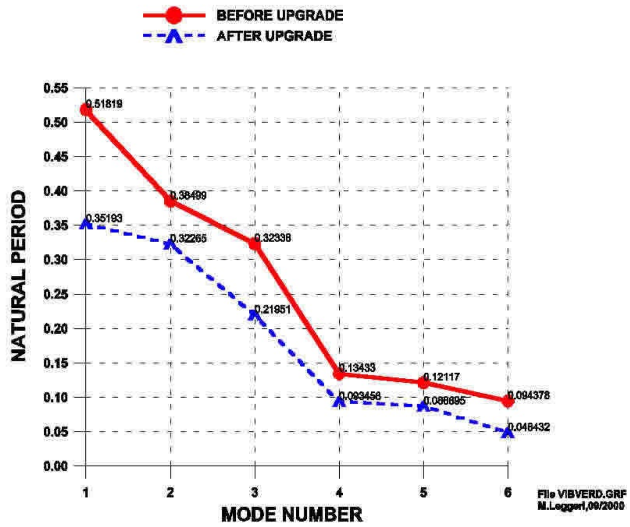


Seismic Strengthening-Foundation and Wall Details

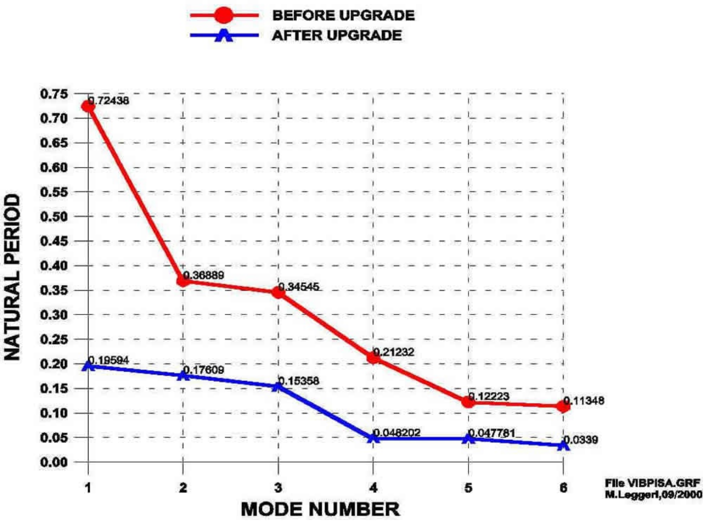


Seismic Strengthening- Details of New Shear Wall

Seismic Strengthening- Details of New RC Shear Wall



Dynamic Characteristics (Natural Period) of a Five-Story Building Before and After the Retrofit (corresponding to the building shown on Figures 1, 5, and 7)



Dynamic Characteristics (Natural Period) of a Four-Story Building Before and After the Retrofit (corresponding to the building shown on Figures 2 and 8)

References

Censimento ISTAT Popolazione ed Abitazioni Italian Seismic Code (in Italian) 1990

I Terremoti Della Basilicata Leggeri,M. Edizioni Ermes, Potenza, Italy (in Italian)

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