World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Lower and middle class residential building in rural areas of central Italy

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Report#	121
Last Updated	
Country	Italy
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Important

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General Information

Building Type:	Lower and middle class residential building in rural areas of central Italy
Country:	Italy
Author(s):	Riccardo Vetturini Fabrizio Mollailoli Paolo Bazzurro
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Central Italy. This housing type constitutes approximately 60% of the entire building stock in the rural areas of Umbria.
Summary:	Typical house occupied by low-income and middle-class families in rural areas of central Italy. The building studied in this report is located in the municipality of Nocera Umbra, province of Perugia, Umbria region, Italy. This type of building, with minor differences in construction practice and material, is frequently found throughout central Italy. The four-story building was constructed more than 200 years ago and is located on a steep hillside, with the elevation facing the valley completely above grade; the uphill elevation is two stories above grade, withthe two stories below ground-level surrounded on two sides by earth-retaining stone masonry walls. This building was severely damaged by the 1997 Umbria-Marche earthquake and was further weakened by the elements before repair and reconstruction efforts began in 2003. Figures 1 through 5 show the damaged building before reconstruction. Figure 6 helps to locate this building in the cluster of buildings around the old citadel.The overall floor plan of this building is L-shaped; it accommodates two residential units and has a basement with four separate spaces and entrances for housing farm animals and storing tools. Building plans showing the extent of wall and floor reconstruction can be seen in Figures 7 to 9. Figures 11 to 13 display details of the seismic retrofit. Most buildings of this type, however, are smaller in size, rectangular in shape, and often have one unit. It is very common for these buildings to share perimeter walls with adjacent buildings. In these rural regions it is typical for many generations of a single family to live in the same residence and the building has undergone numerous additions andmodifications over its life span to accommodate changing living requirements. The construction modifications are typical of Italian rural regions. The architecture is fairly plain with few architectural details of significant historic value; these were repaired and restored during the seismic reconstruction project.Gravity loads in the building ar
Length of time practiced:	76-100 years
Still Practiced:	Yes

In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	4
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	This construction type is still being practiced today, although someof the details and materials used in new buildings may not b

Features

Plan Shape	Rectangular, with an opening in planL-shape
Additional comments on plan shape	The shape is irregular, often rectangular. In this case it has a L-shaped configuration.
Typical plan length (meters)	20
Typical plan width (meters)	12
Typical story height (meters)	3.2
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	Stone masonry walls (see above) and slabs with wooden planks and beams or, more recently, with steel beams and small clay-brick vaults in between. Masonry walls are made of fairly regularly cut stones of regular size for the exterior wythe. The interior wythe is often made by stone of smaller size and rounder in shape. The space in between the wythes is filled with debris of even smaller size (walls "a sacco"). Bond-stones are often absent and the lime mortar is of poor quality. Thelocal presence of clay bricks is not unusual. Steel ties are rarely present.
Gravity load-bearing & lateral load-resisting systems	The building belongs to Type 1, except that lime mortar has been used instead of mud mortar. The exterior wythe,and sometimes the interior one as well, are made of stone blocks that are regularly cut in similar dimensions. Only thespace between the wythes is filled with rubble stones.
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on	

typical wall densities	
Wall Openings	About 15 openings for any typical floor. The dimensions of the windows are typically 1.0 m x 1.4 m and the dimensions of thedoors are 0.90 m x 2.0 m with a void-to-wall ratio of about 15%.
Is it typical for buildings of this type to have common walls with adjacent buildings?	Yes
Modifications of buildings	Over the centuries, these residential buildings have undergone several transformations, mainly due to the different living needs of the owners (e.g., more children and new marriages). These needs generated either enlargement of the living area and the addition of stories or, more simply, internal changes to the layout, to the internal and external openings, and to the fireplace locations. All these changes often weakened the existing structure because the new openings were frequently not coupled with adequate strengthening measures for the affected walls. It is common to find old doors and windows closed up by a simple layer of clay bricks and large niches or unused fireplaces, whichsignificantly compromise the structural uniformity of the walls. There is a unique means of egress from the main building and from each fo the basement units.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Vaulted masonry floorOther floor system
Additional comments on floor system	Timber: Wood planks or beams with ballast and concrete or plaster finishing. Floor diaphragms are flexible.
Type of Roof System	Roof system, other
Additional comments on roof system	The roof structure is made of timber trusses, connected by beams of local chestnut wood and purlins. The interior part of the roof cover is made of flat clay bricks covered by mortar, which provides the bed for two layers of the typical clay brick tiles called "coppi." "Coppo" is the name of a tile that is shaped like a half cylinder (cut through the longitudinal dimension). Timber: wood planks or beams with ballast that support clay tiles.
Additional comments section 2	This type of building can be found both on hilly and flat areas throughout central Italy. There is no typical distance between adjacent buildings of this kind. The separation distance could range between zero (i.e., common wall) to hundreds of meters in the case of isolated buildings in the countryside.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Stone blocks	Wall: Characteristic Strength-30 kPa (shear)Mix Proportion/Dimensions- The lime/sand (perhaps 1/3) mortar is of poor quality. The dimension of theblocks is variable: ranging from 50 x 30 x 20 cm for the largest blocks downto 10 x 5 x 3 cm for the smallest ones.Walls "a sacco"
Foundations	Stone blocks	Characteristic Strength: 30 kPa (shear)Mix Proportion/Dimensions: The lime/sand (perhaps 1/3) mortar is of poor quality. The dimension of theblocks is variable: ranging from 50 x 30 x 20 cm for the largest blocks downto 10 x 5 x 3 cm for the smallest ones.Taperedwalls "ascarpa"
Floors	Wood planks andbeams that support claytiles. Vaulted ceilings	Characteristic Strength: 50 MPa (tension-beams) 30 MPa(compression-beams)
Roof	Wood planks andbeams that support claytiles. Vaulted ceilings	Characteristic Strength: 50 MPa (tension-beams) 30 MPa(compression-beams)
Other		

Design Process

Who is involved with the design process?	OtherNone of the above
Roles of those involved in the design process	Input from engineers and architects was absent in most cases.
Expertise of those involved in the design process	The construction was based on the state of practice and it was dictated by purely geometrical rules. For example, the maximum distance between walls was determined by the length of the timber beams that the local trees (e.g., chestnut and oak) could provide. From these considerations it is apparent why the room dimensions rarely exceeded 5.5 m. The thickness of the walls ranged from 50 to 80 cm above ground and exceeded 1.0 m close to the foundation (walls a scarpa). In most cases the construction was essentially based on the mason's experience without supervision from formally trained professionals (engineers or architects).

Construction Process

Who typically builds this construction type?	OwnerOther
Roles of those involved in the building process	These buildings were usually inhabited by lower-income families. Local craftsmen or the owner themselves built these residential houses without any supervision by local architects. This construction type is common in predominately rural and agricultural areas. The construction process was generally influenced by the number of family members, animals, and agriculture tools that needed to be accommodated. The building layout, both in plan and in elevation, changed over time to serve evolving living requirements. The construction tools were simple (trowel, etc.).
Expertise of those involved in building process	The construction was based on the state of practice and it was dictated by purely geometrical rules. For example, the maximum distance between walls was determined by the length of the timber beams that the local trees (e.g., chestnut and oak) could provide. From these considerations it is apparent why the room dimensions rarely exceed 5.5 m. The thickness of the walls can range from 50 to 80 cm above ground and exceed 1.0 m close to the foundation (walls "a scarpa"). In most cases the construction was essentially based on the mason's experience without supervision from formally trained professionals (engineers or architects).
Construction process and phasing	The construction process was generally influenced by the number of family members, animals, and agriculture tools that needed to be accommodated. The building layout, both in plan and in elevation, changed over time to serveevolving living requirements. The construction tools were simple (trowel, etc.). The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size. Again, multiple additions and interior layout changes took place over time.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	This building type predated modern design codes.However, the seismic retrofit of the building was based on the local regulations DGR 5180/98 and L.61/98 of the Umbria region. Year that the first code or standard addressing this construction type was issued: 1981 Building Code, Material Codes, Seismic codes/standards: The first code was issued after the 1980 Irpinia earthquake. Decretory

	Ministerial 2-7-1981: ?Normative per la riparazione ed il rafforzamento degli edifici danneggiati dal sisma.? (Revised in 1986, 1996, and 2004). New brick masonry structures are addressed in a different standard. Most recent codes/standard addressing this construction type: 2004.
Process for building code enforcement	

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	At present, all these constructions are registered and subject to national urban codes. This, however, was not the case at the time of their original construction. Hence, the answers above are valid for retrofitting and seismic upgrade projects but not for the original construction. Building permits are required to build this housing type.

Building Maintenance and Condition

Typical problems associated with this type of construction	Low strength of the bearing walls due to poor quality of the building material, inadequate connection between the interior and exterior wythes, and suitable connections between orthogonal walls and floor slabs.Floor slabs and roof structures without a suitable connection to the walls (e.g., the timber roofs do not have a ring beam and lack adequate connection between primary and secondary beams.Outward thrust of the vaults is not balanced.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	In this region, the owners of collapsed buildings after the 1997 Umbria-Marche earthquake received an amount in the neighborhood of 700 $/m2 (about $550/m2) from the government to rebuild in accordance with the currentregulations for new buildings.This amount is a lower-range estimate of unit construction costs for new buildings.Please note

	that this construction technique is seldom used today for new buildings. The unit construction costs for retrofitted buildings vary significantly from case to case.
Labor requirements	Several months, depending on the size.
Additional comments section 3	

Socio-Economic Issues

Patterns of occupancy	Typically, one or two units in each building; two units in the exampleshown here. In addition, there are four spaces in the basement with separate entrances. Each space was used for housing farm animals and storing tools.Typical one bathroom and one latrine per housing unit.
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	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	The housing price can vary considerably, depending on location, the state of preservation, and the level of modern comforts present. These houses are usually inhabited by lower-class families with modest incomes and sometimes by middle-class families. Some houses are used today as holiday homes (mainly by relatives living in other parts of the country).Economic Level: The ratio of price of each housing unit to the annual income can be 10:1 for poor families.and 5:1 for middle class families.
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relatives
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No

What does earthquake insurance typically cover/cost	No earthquake insurance is available for residential building in Italy at the time of this writing.
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
1279	Serravalle Chienti, Nocera Umbra, Camerino
1747	Gualdo Tadino, Nocera Umbra
1751	Gualdo Tadino, Busche
1832	Valle Umbra, Cannara, Foligno

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	The area where this building is located, which was hit by the 1997 Umbria-Marche seismic sequence, belongs to a region of the Apennines with significant historical seismicity. The seismic catalogues and specific studies (e.g., Decanini et al. 2000 and 2002 in Section 11) show numerous earthquakes in this area with epicentral intensity between VII and X degrees of the Mercalli-Cancani-Sieberg scale. Within the examined seismic region, 15 destructive earthquakes with M greater than or equal to 6 may be found from the historical data.
Additional comments on earthquake damage patterns	(walls): Detachment between slabs and walls; collapse of the roof structure; detachment of the corner walls; diffuse diagonal cracks; compression of the base of the foundation "tapered" walls(roof/floors): Collapse of most of the roof structure. Figures 1 to 5 show the damage pattern that was caused by the 1997 Umbria-Marche

earthquake.

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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	FALSE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	FALSE
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 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).	FALSE

Building Irregularities

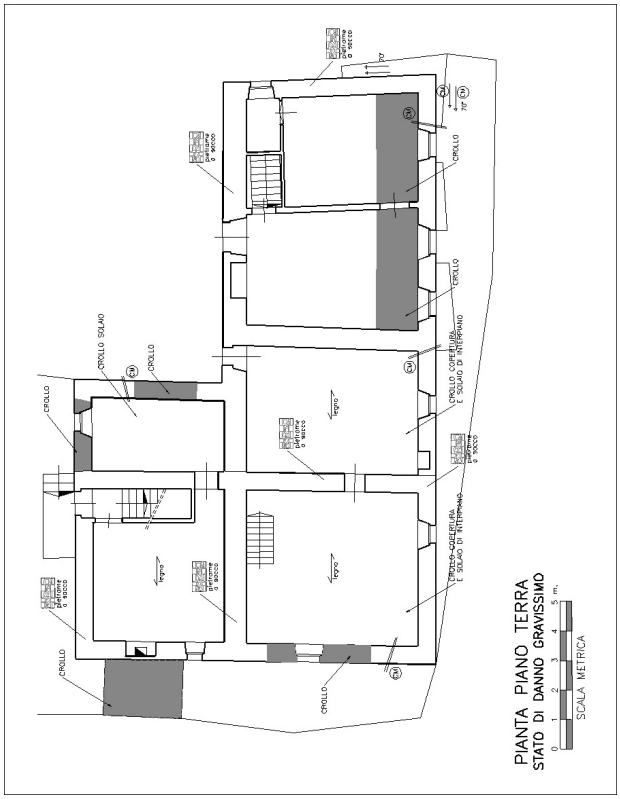
Additional comments on structural and architectural features for seismic resistance	The quality of workmanship and level of maintenance vary considerably from building to building. A typical value of the ultimateshear strength of this type of stone wall is about 3.0 t/m2 (30 kPa).

Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this construction type	No irregularities
Seismic deficiency in walls	Lack of efficient wall-to-wall connections; poor-quality wallconstruction due to the lack of bond stones between the wythes(walls a sacco are known to perform very poorly during earthquakes);lack of vertical alignment of openings in the facade that interrupts thecontinuity of walls from the foundation to the roof.
Earthquake-resilient features in walls	Presence of tapered walls ("a scarpa" - literally, shaped like a shoe) at the ground floor; thick walls throughout the building
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Lack of efficient slab-to-wall and roof-to-wall connections.
Earthquake resilient features in roof and floors	A limited number of tie-rods.
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					



First-floor (ground-level) plan illustratingextent of earthquake damage.

Retrofit Information

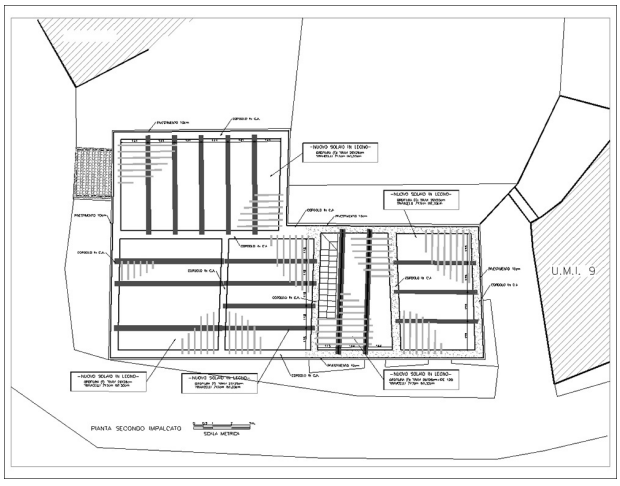
Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Ineffective connection between the wythes andexisting deficient structural components, (e.g.,flues, niches, etc.).	Injection of good-quality grout and the addition of artificial diatones (bond-stones). In the mostserious cases, the walls were replaced. The niches were closed and more seriously damaged wall partswere fixed using the cuci-scuci technique.
Lack of effective wall-to-wall connections.	Insertion of tie-rods inside the wall connections.
Lack of effective wall-to-slab connections	Insertion of tie-rods between the floor slabs and the adjacent walls
Lack of effective connection between the roofstructure and the walls.	Addition of a tie-beam at the connection between the roof structure and supporting walls.

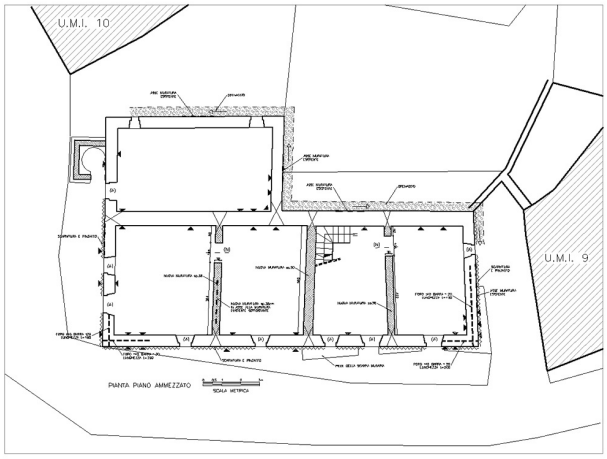
Additional comments on seismic strengthening provisions	The extent of the reconstruction of this building and several construction details of the strengthening measures thatwere adopted are shown in Figures 7 to 13.

Has seismic

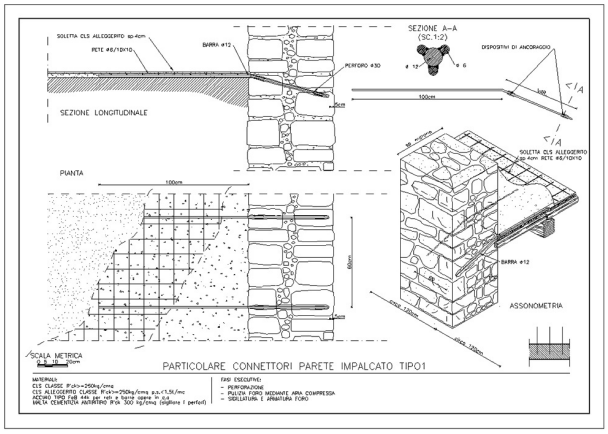
Has seismic strengthening described in the above table been performed?	Yes, the description of the retrofit measures provided in the table is routinely performed in design practice.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	As a repair 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?	The original design most likely did not involve engineers or architects; local masons and carpenters paid by the owner,or the owners themselves, undertook the construction. An engineer designed the retrofit and a contractor performedthe work.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	The retrofitted building has not experienced a significant earthquake since the completion of the strengthening.However, the strengthening measures adopted are believed to have significantly improved the seismic behavior of thisbuilding.
Additional comments section 6	



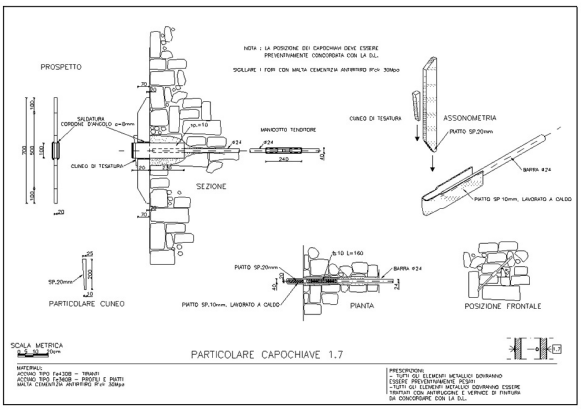
Second-floor plan illustrating floor reconstruction.



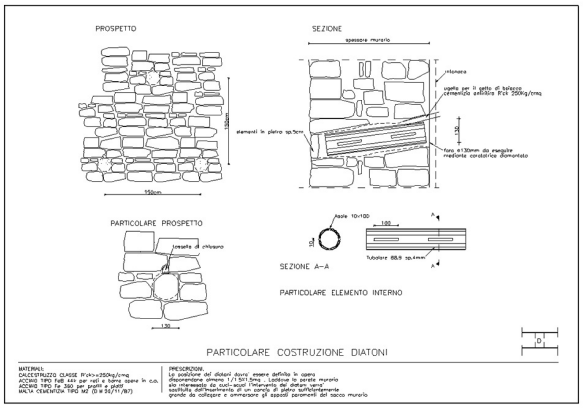
Typical floor plan illustrating the extent of stone masonry wall reconstruction.



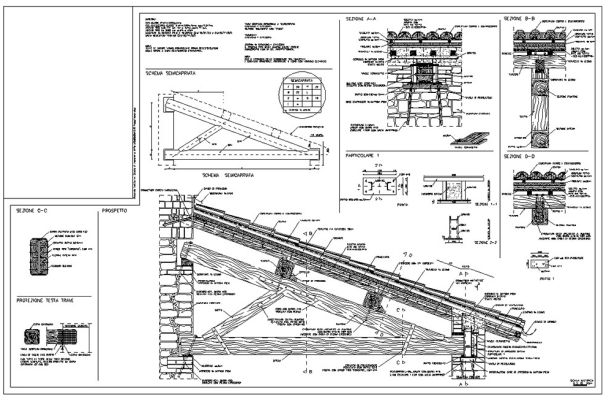
Typical floor-wall tie detail from floor diaphragm to new stone masonry wall construction.



Detail of a steel tie-rod anchoring the two outer wythes of stone masonry to the inner mortar bed



Structural Details



Roof-truss retrofit construction details and typical wood framing to stone masonry wall tie details.

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