World Housing Encyclopedia Report

Country: Italy

Housing Type: Reinforced concrete frame building

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1 General Information

1.1 Country

Italy

FIGURE 1A: Typical Building

1.3 Housing Type

Reinforced concrete frame building

1.4 Summary

This building type is commonly used for multi-family housing in urban areas of Italy and is particularly common for 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 historic 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, L-shaped columns and strengthening the foundation.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	X
< 75 years	
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
		X

Additional Comments: This building type is common in the cities, when the area was not the official seismic zone (pre-1980).

1.6 Region(s) Where Used

In many cities throughout Italy.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	X
In rural areas	
In suburban areas	
Both in rural and urban areas	

Additional Comments: This type of construction is also present in suburban areas.

2 Architectural Features

2.1 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%.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?		X
Is this type of construction typically found on sloped terrain? (hilly areas)	X	
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 8-10 meters

2.3 Building Configuration

Typical shape of the building plan is rectangular.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

2.5 Means of Escape

There is no additional exit stair besides the main stairs.

2.6 Modification of Buildings

The structural upgrade did not modify the building function (the same housing features were preserved after the upgrade).

3 Socio-Economic Issues

3.1 Patterns of Occupancy
One family per apartment (housing unit).

3.2 Number of Housing Units in a Building
20 units in each building.

Additional Comments: Typically 10 to 30 units in each building.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10		
10-20		
> 20	X	X
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit
Number of Bathrooms: 1
Number of Latrines: 1

Additional Comments: Typically 1 bathroom and 1 latrine per housing unit or a bathroom and a latrine together.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	/
Middle Class	X	/
Rich		/

Additional Comments: Very Poor lowest 10% Poor lowest 30% Middle Class lowest 30% to top 20% Rich top 20%

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	
Personal Savings	X
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	X

Additional Comments: At present time, the Government does not support any new construction of this type.

3.7 Ownership

Type of Ownership/Occupancy	
Rent	
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	X
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting System

Originally the buildings were designed for gravity loads only. Unreinforced masonry infill walls exist as partitions (non-load-bearing 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).

4.2 Gravity Load-Bearing Structure

Reinforced concrete frame.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	X
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	X
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

4.4 Type of Foundation

Type	Description	
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	X
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

Additional Comments: 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 (over consolidated clay) with resetting of bending moment.

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist	X	X
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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 single roof		
	Wood planks or beams that support clay tiles		
	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			

Additional Comments: The floor/roof is considered to act as a rigid diaphragm.

4.6 Typical Plan Dimensions

Length: 35 - 35 meters
Width: 35 - 35 meters
Additional Comments: The length varies from 20 to 50 m (35 m is stated as an average value).

4.7 Typical Number of Stories

4 - 10

4.8 Typical Story Height

3 meters

Additional Comments: In the older buildings of this type (with stone masonry infill walls) the typical story height is 3.50 - 4.00 m.

4.9 Typical Span
4.5 meters

Additional Comments: Span between the columns is on the order of 4.5 m.

4.10 Typical Wall Density
Approximately 0.05 (i.e. 5%)

4.11 General Applicability of Answers to Questions in Section 4
The current description relates to two characteristic buildings of this type, very common in Potenza. There may be examples of buildings with different structural and architectural features.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	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 form the building to the foundation.	X		
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.	X		
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.	X		
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.	X		
Wall and frame structures- redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).	X		
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	X		
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	X		
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	X		
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).	X		
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	X		
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).		X	
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	Unreinforced hollow clay tile infill walls		Diagonal ("X"-cracking) and failure see Figure 4A and 4B.
Frame (columns, beams)	Designed for gravity loads only		
Roof and floors	Designed for gravity loads only		

5.3 Seismic Vulnerability Rating

Vulnerability						
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class		<	0	>		

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1998	Pollino-Lauria	5.5	6.75 (MMI)
1991	Potenza	5	6.0 (MMI)
1990	Potenza	5.4	6.6 (MMI)
1980	Irpinia-Basilicata	6.8	8.7 (MMI

Additional Comments: The list includes the significant earthquakes in the Basilicata region after this construction practice has started.

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Wall/foundations	Reinforced Concrete Steel	300 kg/cm² 4400 kg/cm²		
Frame	Reinforced Concrete Steel	300 kg/cm² 4400 kg/cm		
Roof and floors	Reinforced Concrete Steel	300 kg/cm² 4400 kg/cm		

Notes:
1. Concrete compression strength, steel yield strength.
2. Different materials used in the mix for every cubic meter of concrete: 1) cement: 300 kg; 2) sand: 0.4 m³; 3) gravel: 0.8 m³; 4) water: 120 liters.

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

The builder typically lives in a building of this construction type.

7.3 Construction Process

This construction type is built by contractors.

7.4 Design/Construction Expertise

Design for building of this type: by a graduate technician (a college graduate).
Structural design: by a Civil Engineer.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: Italian Code
Year the first code/standard addressing this type of construction issued: 1971
National building code, material codes and seismic codes/standards: National ByLaw #1086, November 5, 1971 National ByLaw #64, February 2, 1974 Ministerial Order January 16, 1996
When was the most recent code/standard addressing this construction type issued? 1996

7.6 Role of Engineers and Architects

The structural design of this construction was completely done by a civil engineer. The architects usually design buildings with better aesthetic features (and functionality).

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction		X
Construction authorized per development control rules	X	

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size	X	

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	
No one	
Other	

7.10 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.

7.11 Typical Problems Associated with this Type of Construction

It is rather simple to design a building of this type which predates the seismic code, however a specialized knowledge and expertise is required for the seismic upgrade design.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

500 US/m^2

8.2 Labor Requirements (estimate)

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.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Pile Foundations	Strengthening
	RC Columns	Strengthening
	Deficient Lateral Load-Resisting Capacity	Installation of new RC shear walls
New Construction	Null	Null

Additional Comments: 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 variation of natural vibration periods for the same five-story building before and after the retrofit is illustrated in Figure 5H (corresponding to the building shown in Figures 1A, 2A and 3A). A similar chart is presented on Figure 5I, corresponding to a four-story building shown in Figures 1E, 2B and 3

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

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.

10.3 Was the work done as a mitigation effort on an undamaged building, or as repair following earthquake damage?

Repair and retrofit after the earthquake.

10.4 Was the construction inspected in the same manner as new construction?

No.

10.5 Who performed the construction: a contractor, or owner/user? Was an architect or engineer involved?

Contractor performed the construction and an engineer was involved.

10.6 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.

11 References

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

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

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13 Figures

FIGURE 1A: Typical Building

FIGURE 1B: Typical Building

FIGURE 1C: Typical Building

FIGURE 1D: Typical Building

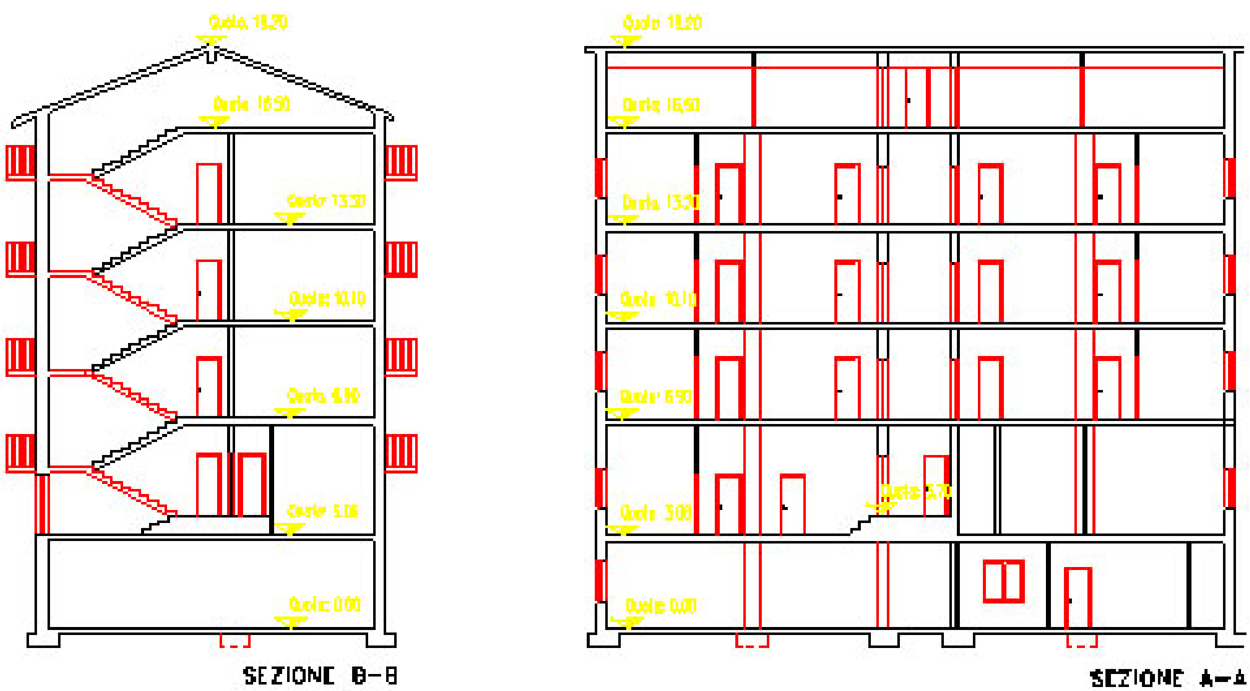

FIGURE 2A: Key Load-Bearing Elements (Building Shown on Figure 1A)

FIGURE 2B: Key Load-bearing Elements (Building Shown on Figure 1D)

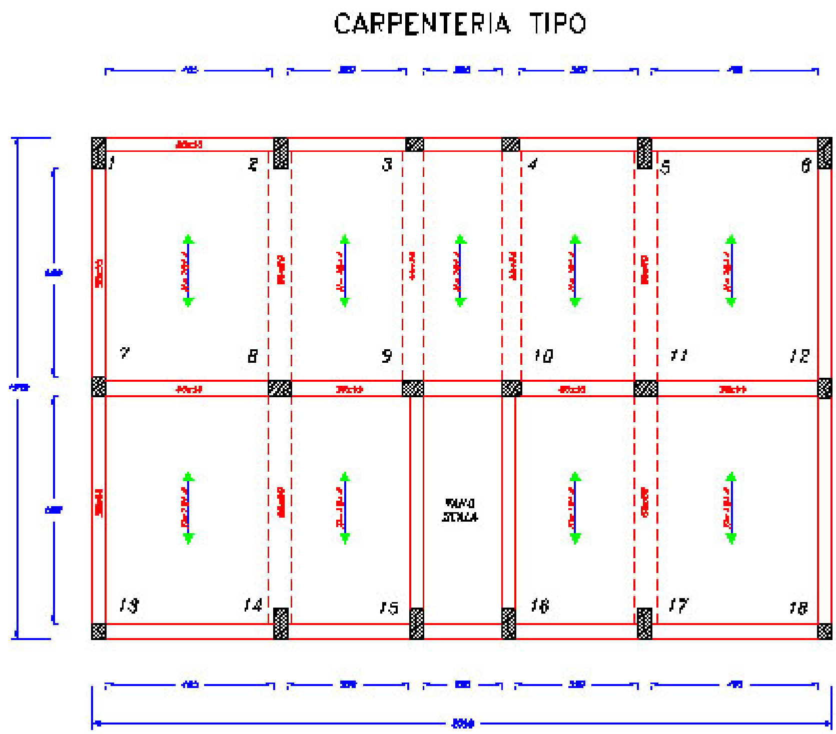

FIGURE 3A: Plan of a Typical Building

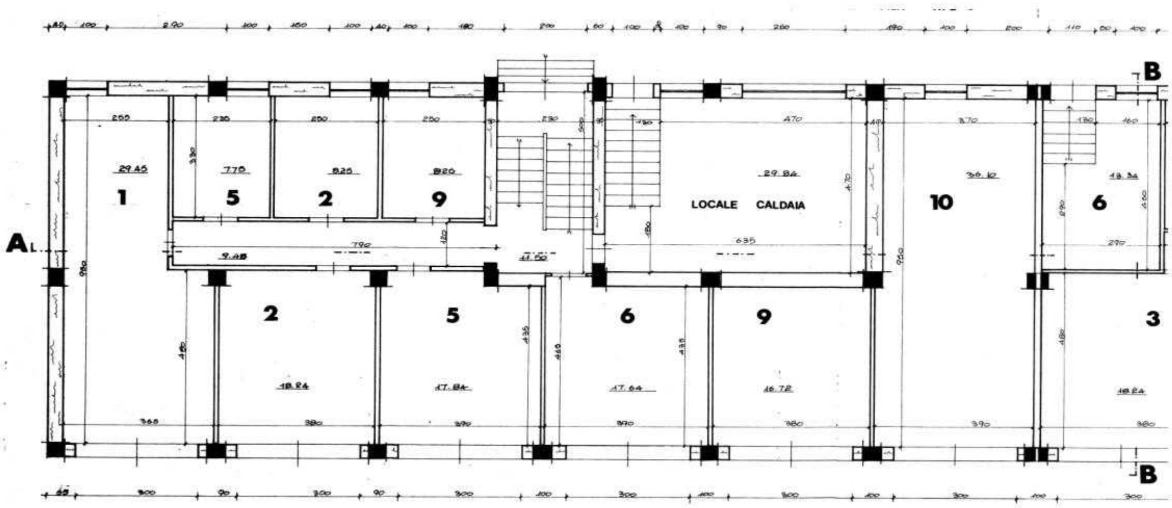

FIGURE 3B: Typical Floor Plan

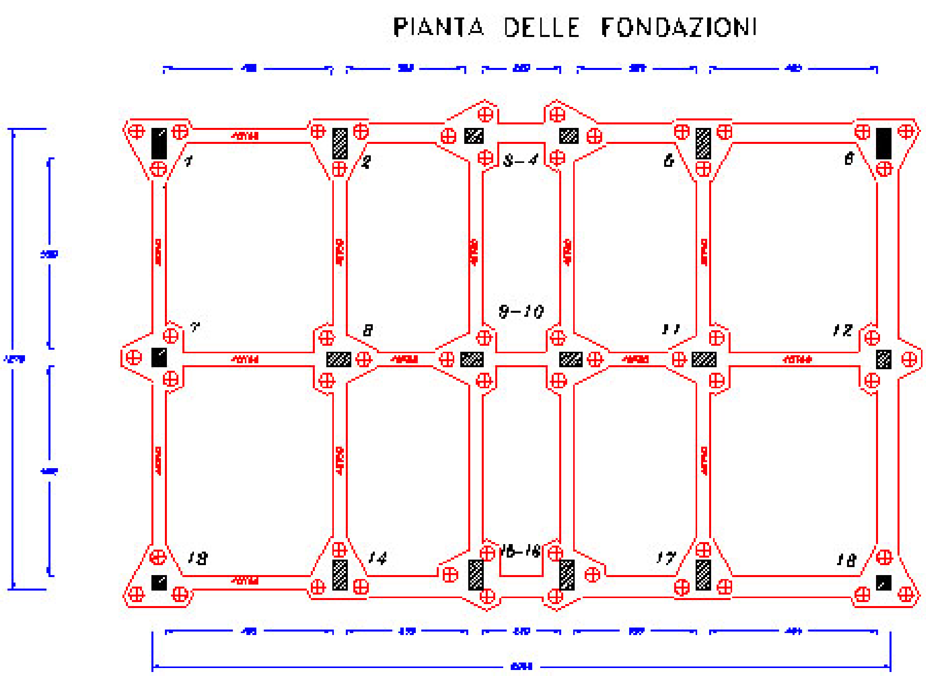

FIGURE 3C: Typical Foundation Plan

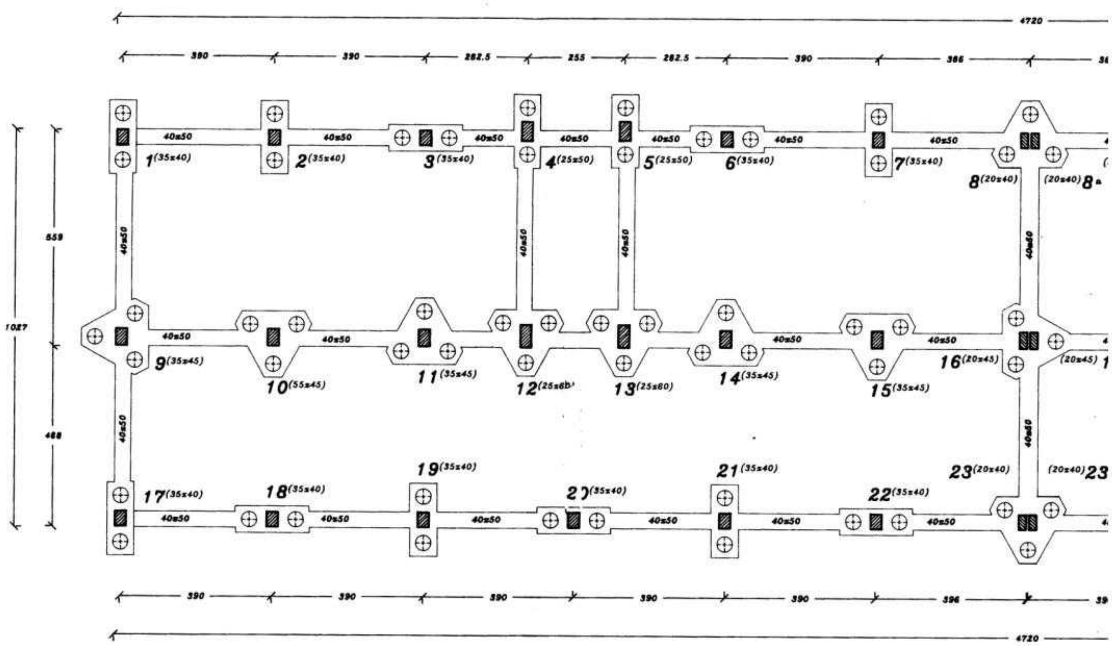

FIGURE 3D: Typical Foundation Plan

FIGURE 4A: Typical Earthquake Damage - Cracking of Hollow Clay Tile Partitions

FIGURE 4B: Typical Earthquake Damage-Cracking of Masonry Partitions

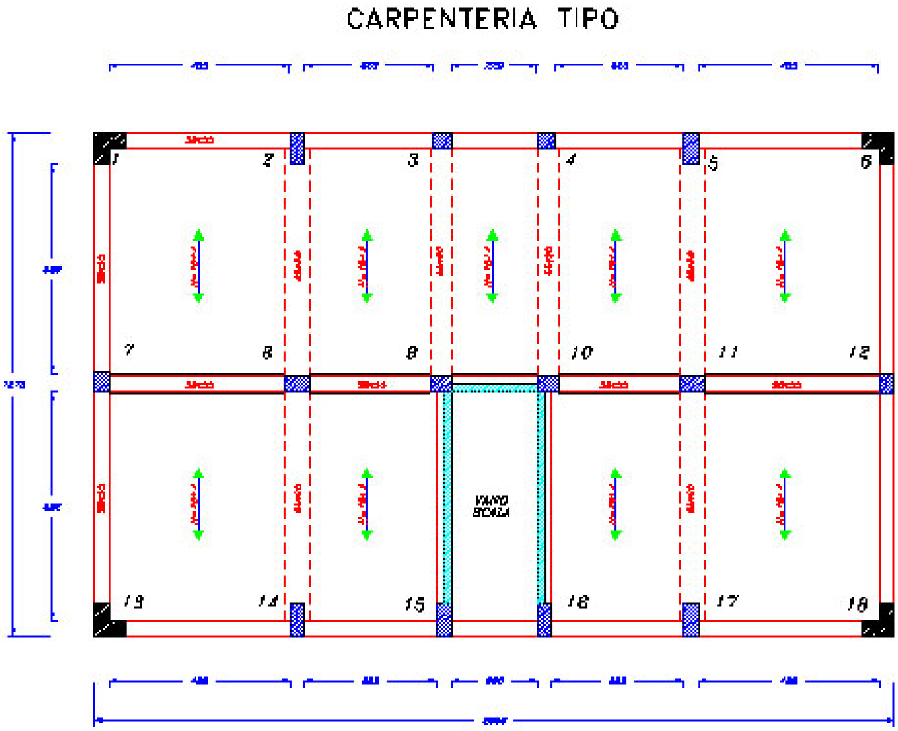

FIGURE 5A: Seismic Strengthening Techniques : Floor Plan of a Strengthened Building

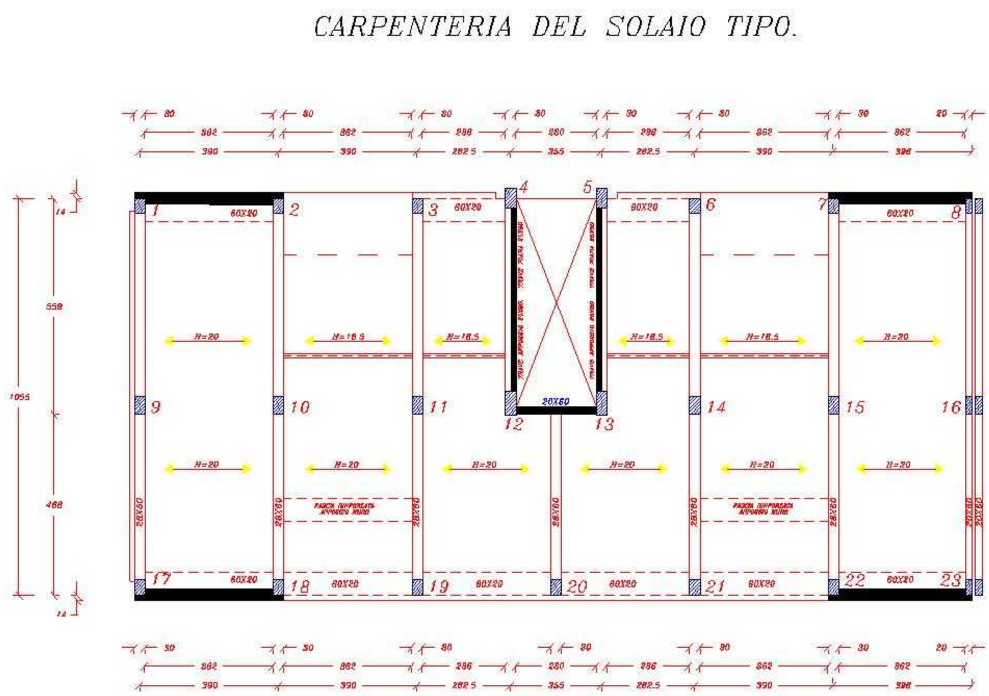

FIGURE 5B: Seismic Strengthening - Floor Plan of a Strengthened Building

PIANTA DELLE FONDAZIONI

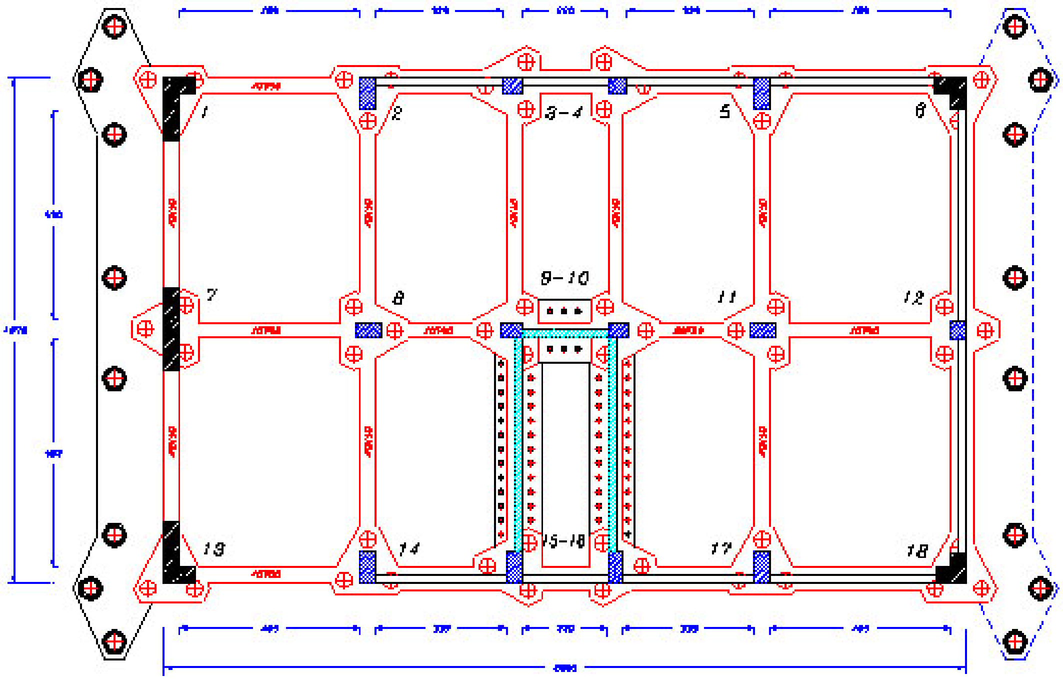

FIGURE 5C: Seismic Strengthening - Foundation Plan

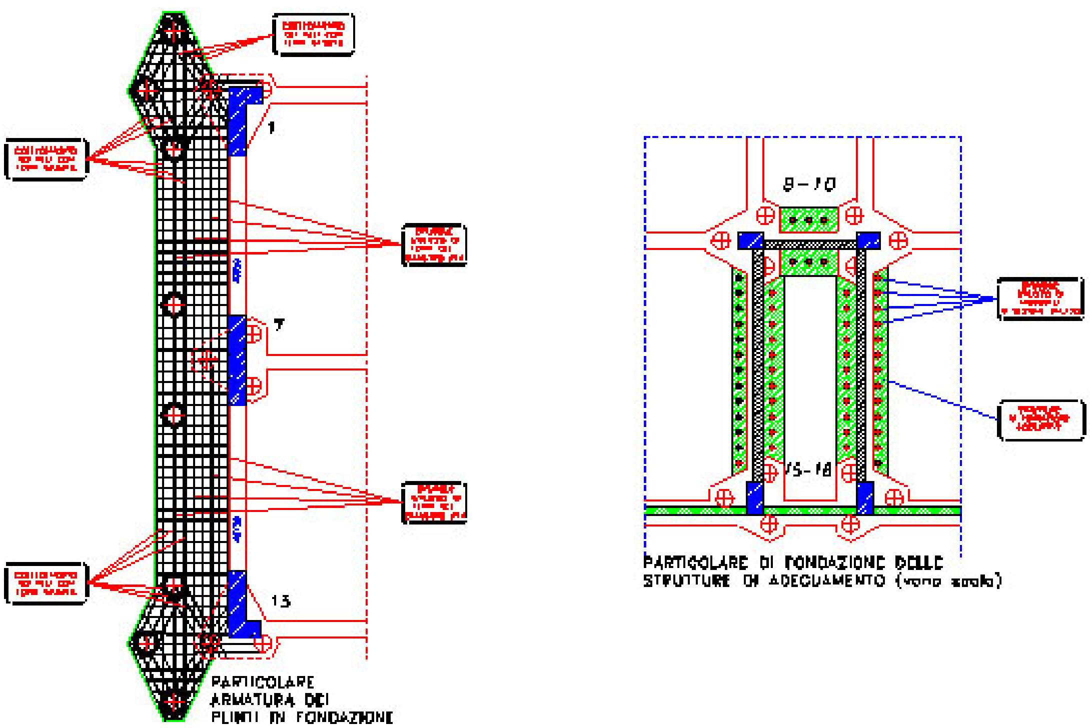

FIGURE 5D: Seismic Strengthening- Foundation Details

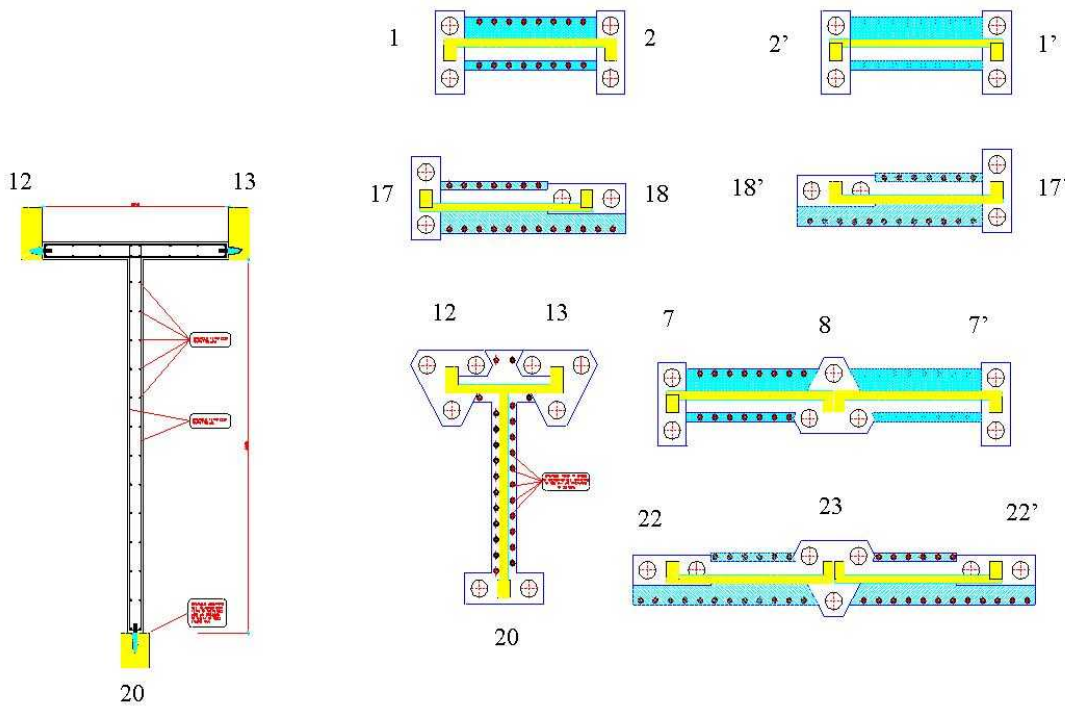

FIGURE 5E: Seismic Strengthening- Foundation and Wall Details

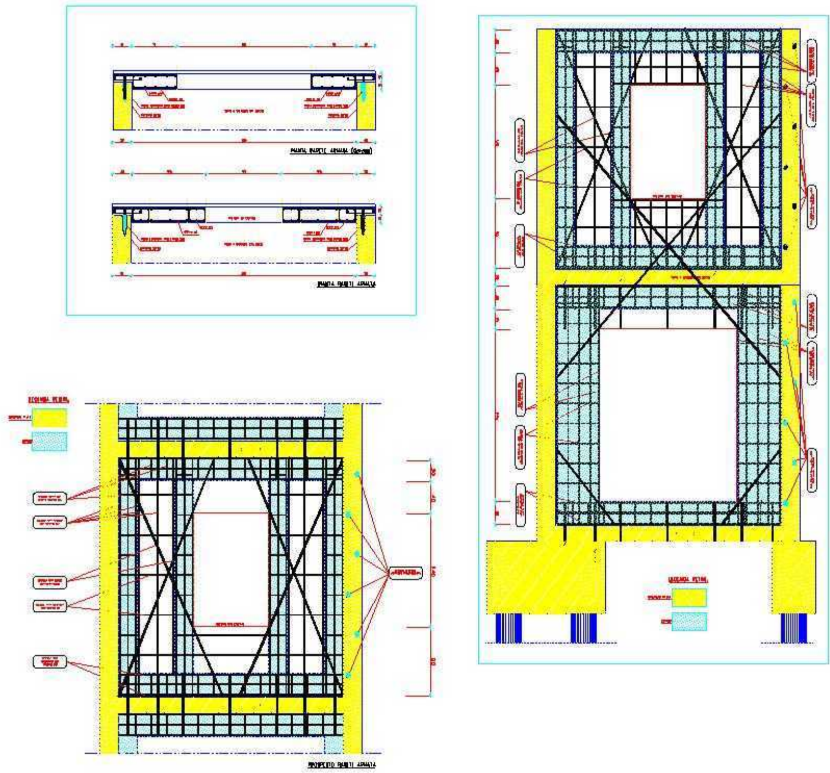

FIGURE 5F: Seismic Strengthening- Details of New RC Shear Wall

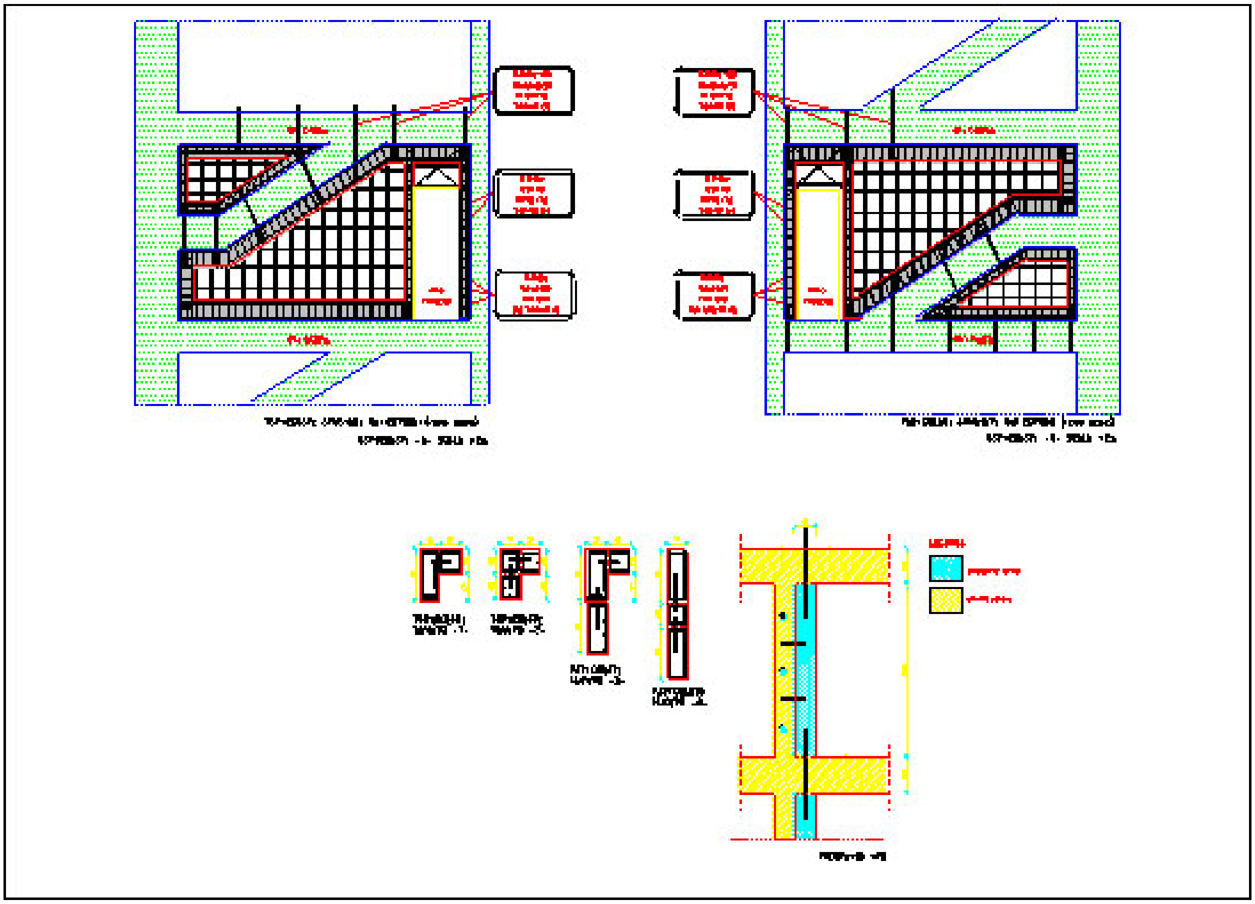

FIGURE 5G: Seismic Strengthening- Details of New RC Shear Wall

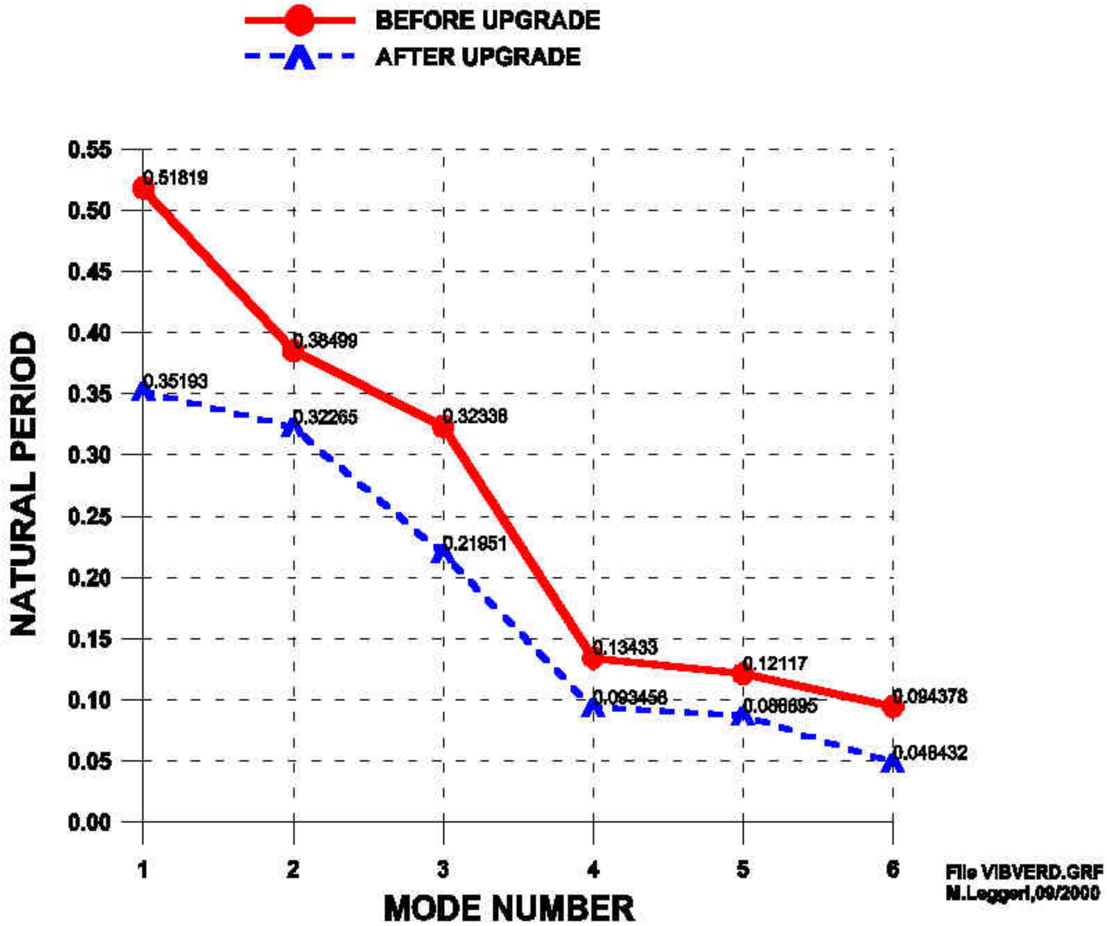

FIGURE 5H: Dynamic Characteristics (Natural Period) of a Five-Story Building Before and After the Retrofit (corresponding to the building shown on Figures 1A, 2A, and 3A)

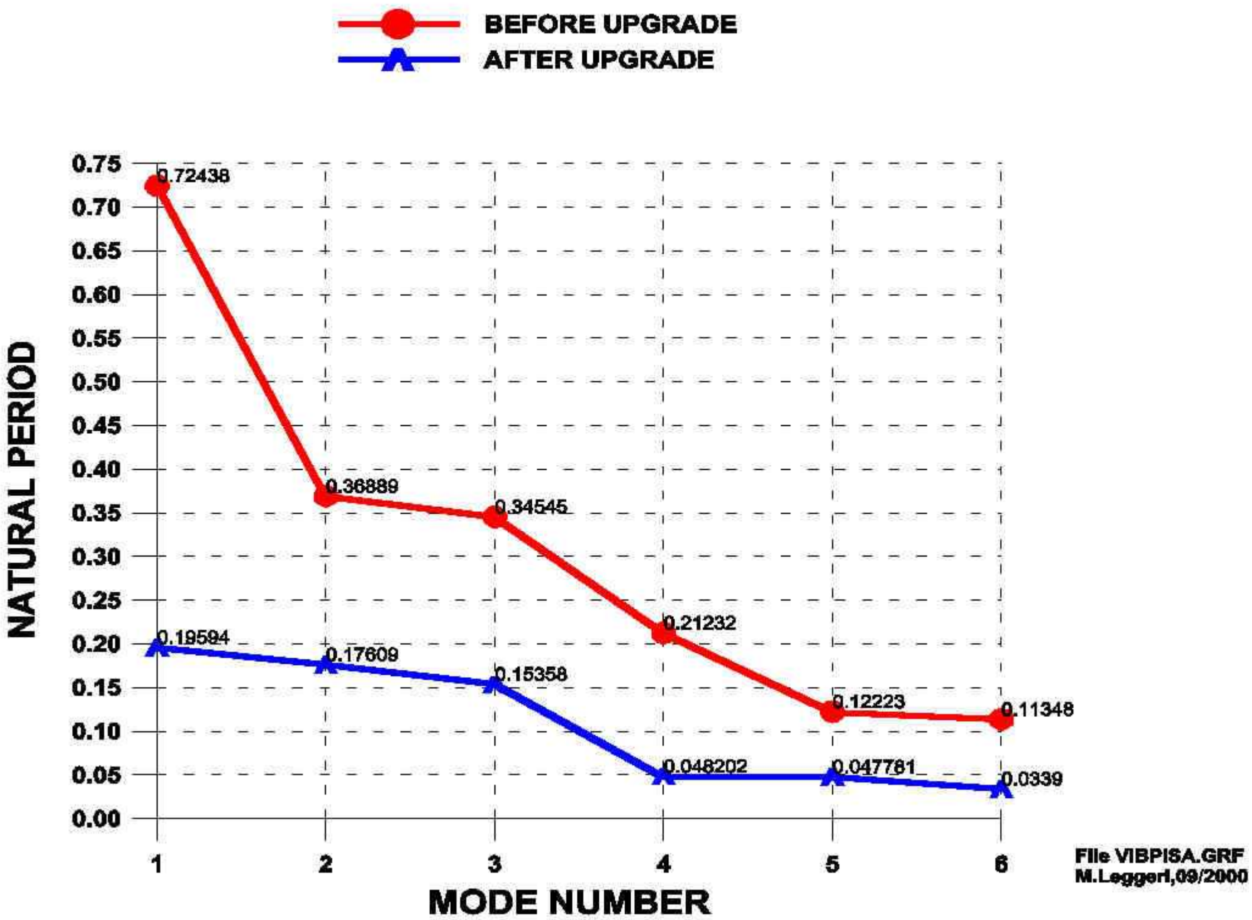

FIGURE 5I: Dynamic Characteristics (Natural Period) of a Four-Story Building Before and After the Retrofit (corresponding to the building shown on Figures 1E, 2B and 3B)