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

Confined Masonry Building : Clay brick masonry, with concrete tie-columns and beams

Report#	69
Last Updated	
Country	Serbia
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Important

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General Information

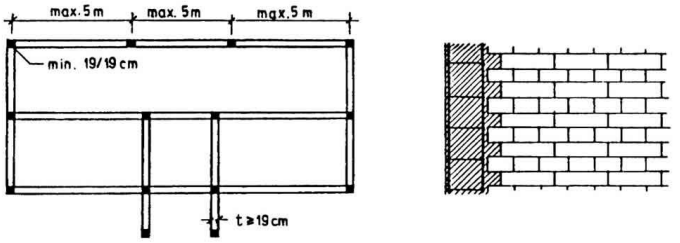
Building Type:	Confined Masonry Building : Clay brick masonry, with concrete tie-columns and beams
Country:	Serbia
Author(s):	Nikola Muravljov Radovan Dimitrijevic
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in urban and rural areas of Yugoslavia.
Summary:	This type of construction has been used for single-family and medium-rise residential buildings throughout urban and rural Yugoslavia during the past 30 years. The structure consists of load-bearing masonry (brick, stone, concrete block) walls confined with reinforced-concrete posts and tie-beams. The walls are typically made of hollow clay tiles. Floor slabs are composed of prefabricated joists infilled with brick elements and topped with a reinforced-concrete slab in-situ.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, 10-19 unitsResidential, 50+ units
Typical number of stories:	2-4
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	Buildings of this type are single family houses frequent, but there are a lot of multiple housing units and mixed too.

Features

Plan Shape	Other
Additional comments on plan shape	Usually regular shape.

Typical plan length (meters)	10
Typical plan width (meters)	10
Typical story height (meters)	2.8,3.0
Type of Structural System	Masonry: Confined Masonry: Clay brick masonry with concrete posts/tie columns and beams
Additional comments on structural system	Masonry walls transfer all gravity loads from the roof and floor slabs to the foundations. Minimum thickness for bearing masonry walls is 190 mm (as prescribed by the code). The Yugoslav National Building Code classifies masonry buildings into three categories, depending on the wall layout: - buildings with walls in transverse direction; - buildings with walls in longitudinal direction, and - buildings with walls in both directions. The main lateral load-resisting system for this housing type is a wall structure in with brick walls laid in both directions (transverse and longitudinal) carry lateral seismic forces and transfer them to the foundations. Reinforced concrete posts and tie-beams are effective in increasing the stiffness and ductility in this construction type and providing an improved level of seismic safety for this type of construction. Details of concrete posts and tie-beams are shown in Figure 9. A possible failure mechanism for confined masonry walls is illustrated in Figure 13.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	10-15%
Additional comments on typical wall densities	The typical structural wall density varies from 6% to 12%.
Wall Openings	According to the Yugoslav National Building Code, size of the openings should not exceed 2.5 to 3.5 meters (depending on the seismic zone). The size can be increased up to 30% if the openings are confined with reinforced concrete posts and tie beams.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	The most common pattern of modification in residential houses is complete removal or displacement of interior walls and columns. House owners usually perform modifications without seeking an advice of a competent technician (engineer/architect).
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing

Additional comments on foundation	Foundation details are illustrated in Figure 10.
Type of Floor System	Other floor system
Additional comments on floor system	Structural Concrete: waffle slabs (cast-in-place) According to the National Building code, floor/roof must act as rigid diaphragm.
Type of Roof System	Roof system, other
Additional comments on roof system	Structural Concrete: waffle slabs (cast-in-place) According to the National Building code, floor/roof must act as rigid diaphragm.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters. Typical Plan Dimensions: Plan dimensions (i.e. length and width) of this building type should not exceed 40 to 50 meters. Length to width ratio is usually on the order of 3-4. In case the plan dimensions exceed these values, the walls need to be divided into sections by means of control joints. Typical Story Height: Typical floor height for residential buildings is 2.8 m, and 3.0 m for public buildings. Total height for buildings of this type should not exceed 20 meters (according to the code). Typical Span: Typical span (between the adjacent concrete posts) ranges from 3 to 6 m. The National Building Code prescribes the maximum span of 5 meters.



Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Bricks/hollow clay tiles mortar Frame:Concrete posts and tie-beams: -Concrete -Steel reinforcement	Wall: Characteristic Strength-Bricks : from 7.5-20 MPa Hollow clay tiles: from 5.0 to 20.0 MPa Mortar: from 5-15 MPa) Frame: Characteristic

		Strength- Concrete posts and tie-beams: Concrete minimum strength 20 MPa Steel: minimum yield stress 240 MPa Mix Proportion/Dimensions- Concrete posts and tie-beams: Minimum 3 fractions of gravel and 250 kg/sq. m of cement
Foundations	Concrete and steel reinforcement	Characteristic Strength: Concrete: minimum compressive strength 15 MPa Steel: minimum yield stress 240 MPa Mix Proportion/Dimensions: Minimum 3 fractions of gravel and 200 kg/sq. m of cement Foundation details are illustrated in Figure 10.
Floors	Concrete -Steel reinforcement	Characteristic Strength: Concrete strength 15-30 MPa steel yield stress min. 240 MPa Mix Proportion/Dimensions: Minimum 3 fractions of gravel and 300 kg/sq. m of cement Details of prefabricated floor-slab construction are shown in Figure 11.
Roof	Concrete -Steel reinforcement	Characteristic Strength: Concrete strength 15-30 MPa steel yield stress min. 240 MPa Mix Proportion/Dimensions: Minimum 3 fractions of gravel and 300 kg/sq. m of cement
Other		

Design Process

Who is involved with the design process?	EngineerArchitect
Roles of those involved in the design process	Architects and engineers design buildings of this type. If certified engineers are not involved in the building design (i.e. non-engineered construction), National Building Code allows the construction of a building up to max. two-storey high. Engineers and architects work jointly on developing project for buildings of this construction type.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Builder
Roles of those involved in the building process	Typically, builders (developers) build the housing of this type. In some cases, builders live in the houses of this type, too.
Expertise of those involved in building process	
Construction process and phasing	In this construction system, brick elements must be built and tied together in a specific way. Thickness of reinforced concrete vertical posts must be equal to the wall thickness. Minimum reinforcement to be provided in vertical posts consists of 4 -14 mm diameter steel bars tied with 6 mm diameter stirrups spaced at 250 mm on centre. Tie beams are constructed after the bricklaying is completed. Minimum reinforcement required in the tie beams consists of 4 - 12 mm diameter bars tied with 6 mm stirrups at 250 mm on centre spacing. In seismic areas lime/cement mortar has to be used. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size. In some cases there are changes and differences between the designed and the constructed building. In such case, National Building Code prescribes the development of technical documentation describing the "as constructed" condition. Modifications (especially vertical expansion) for the buildings of this type are common, especially in case of single-family houses.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	The year the first code/standard addressing this type of construction issued was 1987. Technical regulations for construction in seismically prone areas, Title of the code or standard: Technical regulations for masonry construction. For all newly constructed buildings, building permits confirming that the construction has been done in conformance with the National Building Code must be issued; the code also prescribes the seismic zone the buildings are located in. Yugoslavia (and Serbia) are the part of the Balkan Peninsula, which is known to be one of the most seismically prone regions of Europe. However, until the catastrophic 1963 Skopje (Macedonia) earthquake, there were no seismic codes or regulations in the country. In 1964, the Preliminary National Building Code (including the seismic provisions) was issued. The latest edition of the National Building Code was issued in

	1987. In addition to the National Code, Euro Codes have been used in the country as well.
Process for building code enforcement	For all newly constructed buildings, building permits confirming that the construction has been done in conformance with the National Building Code must be issued; the code also prescribes the seismic zone the buildings are located in. Yugoslavia (and Serbia) are the part of the Balkan Peninsula, which is known to be one of the most seismically prone regions of Europe. However, until the catastrophic 1963 Skopje (Macedonia) earthquake, there were no seismic codes or regulations in the country. In 1964, the Preliminary National Building Code (including the seismic provisions) was issued. The latest edition of the National Building Code was issued in 1987. In addition to the National Code, Euro Codes have been used in the country as well.

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	

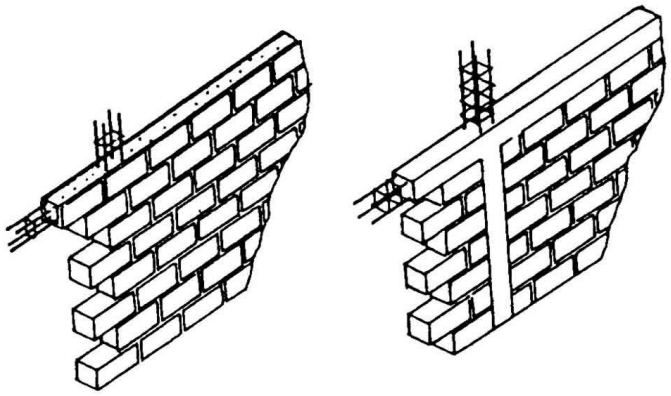
Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	In the urban areas, public companies take care of maintenance for the housing stock.

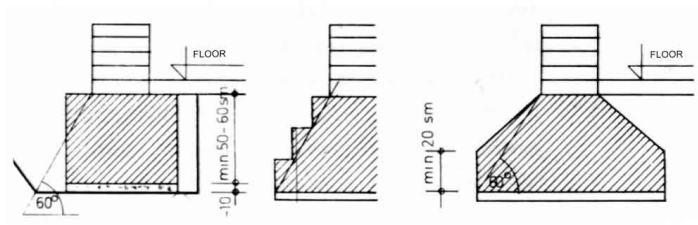
Construction Economics

Unit construction cost	Construction cost is about 100 to 150 $US/m# of built-up area (structure only), whereas the price of the finished building is on the order of 200 to 300 $US/m# of built-up area.
	Construction of a typical building of this type (built-up area of 120-200 m#) takes approximately 6 months, depending on the finances. It should be also noted that

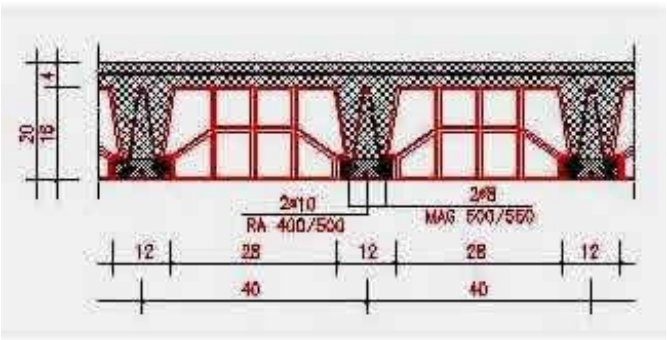
Labor requirements	this type of construction requires a limited number of trained labor and technical personnel. Majority of the other construction labor involved in this type of construction are generally unskilled.
Additional comments section 3	



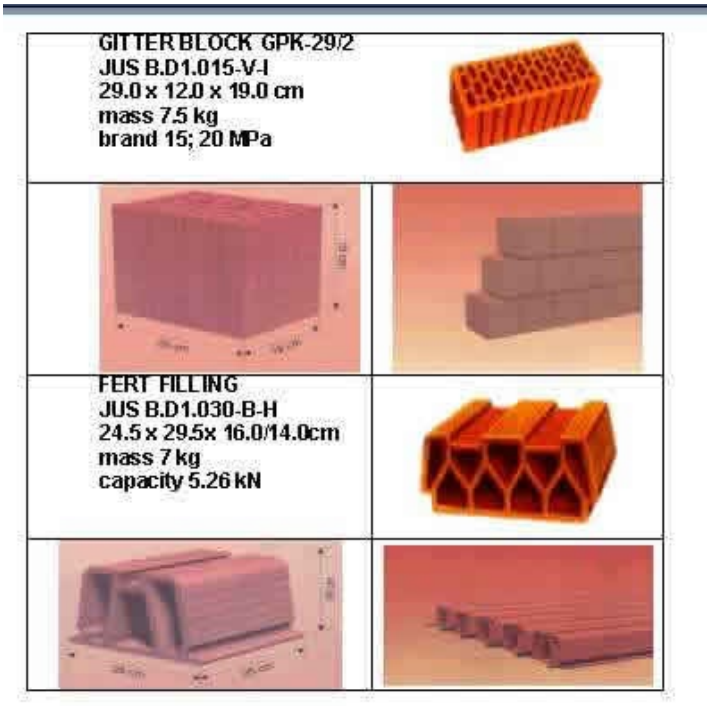
Details of concrete posts and tie beams



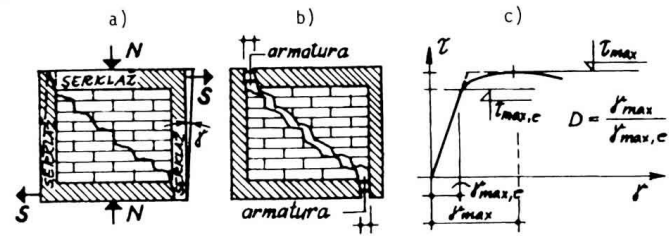
Foundation Details



Floor slab details (an example of a precast floor slab type LMT)



Typical masonry units used in wall and floor-slab constructions



A possible failure mechanism for confined masonry walls

Socio-Economic Issues

Patterns of occupancy	Usually one family occupies one housing unit. Each building typically has 10-20 housing unit(s). It varies from one unit per building (single-family house) to 50 units in condominiums.
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	10-20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)Middle-income class
Additional comments on economic level of inhabitants	In the last 10 years, the economic situation in Yugoslavia has been very bad. The average net salary is less than 50 $ US per month. Economic Level: For Poor Class the ratio of the Housing Price Unit to their Annual Income is 50:1. For Middle Class the ratio of the Housing Price Unit to their Annual Income is 30:1.
Typical Source of Financing	Owner financedCommercial banks/mortgagesGovernment-owned housing
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)Units owned individually (condominium)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	The annual insurance rate is 0.45% of the building value increased by 15% to account for earthquake risk.
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
1969	Banja Luka
1980	Kopaonik
1980	Banja Luka
1987	Kraljevo
1998	Mionica
1999	Trstenik

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Damage to confined masonry buildings in these earthquakes was not extensive. Figure 14 shows damage to masonry buildings in the 1998 Mionica earthquake (magnitude 5.7). A number of older unreinforced masonry buildings were damaged in the earthquake however confined masonry buildings performed well and did not suffer any significant damage, as illustrated in the figure.
Additional comments on earthquake damage patterns	Typical Earthquake Damage Patterns (Wall): Diagonal tension cracks

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	TRUE

	walls); Less than 13 (unreinforced masonry walls);	
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).	TRUE

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	Low shear strength and diagonal tension cracking as a result of brittle seismic response of unreinforced masonry walls subjected to seismic shear forces and gravity loads; brittle behavior.
Earthquake-resilient features in walls	Typical brick strength is more than 20 MPa.
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	In some cases inadequate rigidity of roof and floor slabs
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			

Damage to masonry buildings in the 1998 Mionica earthquake

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Walls: Low shear strength and diagonal tension cracking as a result of brittle seismic response of unreinforced masonry walls subjected to shear forces and gravity loads; brittle behavior	Reconstruction of damaged walls; New reinforced concrete w all overlay; Injection grouting of cracks; Application of carbon fiber laminates bonded diagonally to the walls

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Yes, all strengthening methods were used in design practice. Structural engineers provide design specifications for the seismic strengthening design.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake	In most of the cases, seismic strengthening has been performed as a part of post-earthquake rehabilitation (e.g. after the 1979 Montenegro earthquake or 1998 Mionica

repair following earthquake damages?	earthquake).
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?	Usually it was owner/user who performed the construction, with competent participation of an architect and engineer.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	The buildings that were seismically upgraded were generally not subjected to another major earthquake. However, it is expected that the strengthened buildings would show improved seismic performance if subjected to an earthquake.
Additional comments section 6	

References

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