World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

One family one storey house, also called "wagon house"

Report#	85
Last Updated	
Country	Romania
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Important

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General Information

Building Type:	One family one storey house, also called "wagon house"
Country:	Romania
Author(s):	Maria Bostenaru Dan Ilie Sandu
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in small towns, near centre districts. This type of housingconstruction is commonly found in both sub-urban and urban areas. The areas have been suburban at the time when these buildings have been constructed.
Summary:	This is one of the oldest housing types in Romania with a statistically significant number ofbuildings in existence. The overwhelming majority of residential buildings in Romania havebeen built after 1850. Today. only churches remain from the previous "post-Byzantine"period. Issues relating to the age of historical buildings of cultural value are also discussedwithin the report. This urban housing type is particularly common in Romanian towns,especially in the southern part of the country, such as in the former Wallachia. It is a middle-class family house constructed from the end of the 19th century until the Second World War.The houses were designed to be semidetached, but have been constructed individually. Thus,in most of cases, the adjacent building, separated structurally, is a totally differentconstruction type, The design of this housing is astonishingly homogeneous, especiallyconsidering the relatively lengthy time span the construction has been practiced. The single-unit housing is generally characterized by a rectangular, elongated-shape plan, with anentrance on the long side. The load-bearing system consists of two longitudinal unconfinedbrick masonry walls and several transversal unconfined brick walls, usually 28 cm thick, whichform a wagon-like arrangement -- hence the name of this building type. The horizontalstructural system is made out of wood plates and joists separated by a distance of 0.70 m.Buildings of this type have been affected by

	damaging earthquakes in November 1940 and inMarch 1977, and by two earthquakes of lower magnitudes in 1986 and 1990. They performedwell except for the occurrence of some minor cracking in the plaster.
Length of time practiced:	101-200 years
Still Practiced:	No
In practice as of:	1947
Building Occupancy:	Single dwelling
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	3
Comments:	Practiced until 1947. Many of them have been demolished inthe Ceausescu era. However, there are still enough existing to provide

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	20-25
Typical plan width (meters)	3.5-5
Typical story height (meters)	3.5
Type of Structural System	Masonry: Unreinforced Masonry Walls: Brick masonry in lime/cement mortar
	Vertical load-resisting system: Timber slabs with joists every 0.70m (interaxes) and asuspended ceiling out of lime mortar on slat and cane form the upper floor structure. The roof itself consists of woodframework ("acoperis pe scaune" in Romanian, fig. 12). The girders are perpendicular and sustained by the longitudinalwalls (fig. 25). The roof is simply supported by the walls. In some cases the load floor structure below the groundfloor consists of jack arches on metal joists. In other cases the difference between the ground floor and

Additional comments on structural system	the upper floorwill consist on the timber type, as shown in the Simetria (2000) publication: fir tree for the upper floor and oak tree forthe ground floor. The load bearing elements (timber or metal joists) are linear and transmit the loads into onedirection only. Floor joists are simply supported by the walls, not anchored. There are no tie beams. The materials ofthe foundations varied significantly across time. Thus the oldest buildings of this type have clay brick foundations(some of them being built on the remained basement of previous constructions). An example building from thesecond half of the 19th century had already strip foundations out of unreinforced concrete, under all load bearing walls.In the (c) Simetria(2000) publication more details are available: around 1900 such a foundation consisted of hydrauliclime mortar concrete in 20cm layers. The depth of the foundations is known to be 1.10m, as required by theRomanian freezing limit. The ground floor lays about 0.5m above the ground level. As drawings in the Simetria(2000) publication show, half of the space between the ground level and the floor under the ground floor were filledwith a different material than earth, but the nature of this is unknown. The size of foundations for this building was0.50mx0.42m (depth x width) for exterior walls and respectively the wall separating the part with basement from thatwithout (see the device catalog in Simetria, 2000). For interior walls the size of the foundations for the same buildingis shown to be 0.28mx0.50m (width x depth) in plan. The length is the same as that of the wall. Totally 13.18m offoundation material were needed for such a typical building. A partial basement of 3m depth was also found in somecases. The structural system is characterized by the "honeycomb" (in Romanian "fagure") plan layout. In a "fagure"layout masonry structure all rooms are prescribed as box type units with less than 30-35 sqm surface (for this buildingtype 9-16m2) (fig. 13). Lateral load-resisting system: There are two longitudinal and several transversal 28 cmthick unreinforced brick in hydraulic lime mortar masonry bearing walls (see a sketch of main load bearing elements infig. 15). This dimension is usual for interior walls of all building of this type. Older buildings might have thickerexterior walls (42cm, up to 50cm). The transversal walls separating room units are not load-bearing (they are onlyloaded with their own weight). The Romanian terminology identifies them as stiffening walls (Romanian"contravantuire", meaning contribution to lateral load bearing system only).

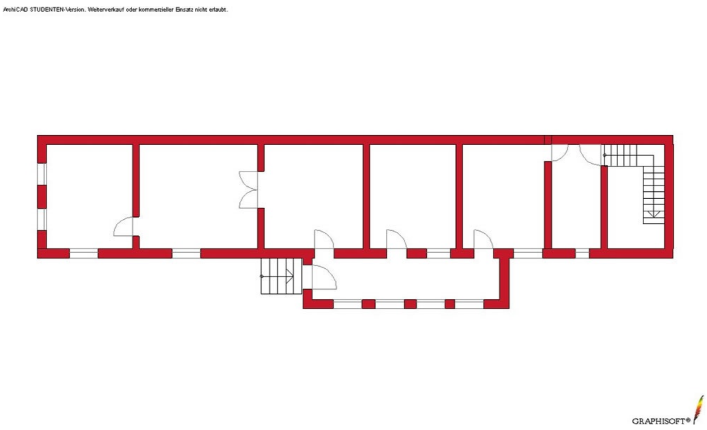
Typically, there are no further, structural ornon-structural separation walls in longitudinal direction. The only exception where three parallel walls in longitudinaldirection may appear is at the entrance, enlarged by an increased building width (fig. 18 and 19). The distance betweenthe two longitudinal walls varies between 3.0 and 4.0m depending on the presence or absence of a special vestibuleroom. The distances between the transversal walls is fairly typical, and starting from the street wall the span sequencesare 4.25m, 2.25m, 4.25m, 3.25m, 3.25m and 1.75m for 19th century buildings and 3.0m, 4.0m, 3.5m, 3.0m, 2.75m,1.75m, 2.0m for 20th century buildings respectively. Therefore it can be stated that typical spans are 3.0-4.0m in bothdirections, except for the last rooms where these can be smaller. All walls have sufficient stiffness to contribute toresisting lateral loads, both in terms of load capacity and deformation. Although stiffness isn't evenly distributedbetween the walls no damage due to torsional effects has been observed, despite rigid back longitudinal wall with noopenings. This is supposed to be owed to the floors, which do not assure a spatial collaboration of the structure andthus the existing stiffness asymmetries loose weight. The back longitudinal wall is not common for two neighboringbuildings, which completely separate structural units. Currently in Romania there are 4 kinds of mortar used inmasonry construction: "fat lime mortar" ("mortar de var gras" in Romanian), "lime mortar with added cement","cement mortar with added lime" and "cement mortar". Today under "lime" is meant the non hydraulic lime, andcontemporary mortar only behaves well in humidity conditions if cement is added. In some cases brick dust mightbeen added (after Bratu, 1992), to increase the hydraulic quality. While so-called "weak lime" ("var slab" in Romanian;6-12% clay and $CaCO_3$) had never been produced in Romania, "middle lime" and "strong lime" (12-24% clay) hadbeen used formerly to obtain mortar, but not for this type.

Gravity load-bearing &	In the constructions of the type analysed in this report hydraulic lime based mortar, considered to be the highestpossible quality mortar of that time, have been used. For common buildings (ie not in very wet environments)hydraulic lime mortar has been used. This was prepared solely out of "fat lime" ("var gras" in Romanian), sand andwater. The lime is obtained through burning of calcar stones ($Cao+CO_2$) in either field or vertical ovens.The obtainedCaO was then treated with water in boxes called "varnite" in Romanian. As a result the lime

lateral load-resisting systems	called "varnite" in Romanian. As a result the lime paste or lime putty isobtained: $Ca(OH)_2$ with relatively high water content. The paste is then left at least one year in a dug hole to "mature"("decantare" in Romanian). Characteristic for this kind of mortar is that it does not present hardening, as this dependson the permeability of bricks. Hardening takes place when the CO_2 in the air reacts with the $Ca(OH)_2$ in the lime togive $CaCO_3$. See figure 12 for the way how masonry bricks are crossed woven ("tesatura incrucisata" in Romanian).
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on typical wall densities	The typicalstructural wall density is 7.5% - 12.5% ~ 10% in both directions.
Wall Openings	5-10 openings, depending on the number of rooms. ~20% (Figure 10 shows a typical building in axonometric view.) For the building taken asmodel for this report (late building of this type): A typical window in the longitudinal wall to the courtyard is 1.44sqmin size. There are smaller ones for secondary rooms, of 0.36sqm or 0.9sqm. Bigger windows are 1.2mx1.9m (2.28sqm),to the vestibule. To be noted is that all windows to main rooms are 1.2m wide. A typical door is 0.8mx2.1m(1,68sqm). Smaller doors to the secondary rooms are 0.7mx2.1m (1.47sqm), and also door openings for double doorsof 1.4mx2.1m (2.94sqm). The entrance door is wider (0.9m), but same height. In older buildings the windows wereall like those to the vestibule (fig. 20) in this one. The back longitudinal wall is usually solid without openings, as it issituated on the cadastral unit boundary, where it is expected that the adjacent semidetached twin unit will be built.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Typical changes in time are additional floors over the existing ones (especially taking in consideration the thickness ofthe walls, considered to be able to carry one floor more, see fig. 6) or additions of "wings", typically one room morewith vestibule (fig. 5). Some of these can be used as office, study room, artists workshop and similar. A typical

	modification includes filling the windows to the street with masonry infill (fig. 7-9). This has been also performed atthe model building considered for this report.
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	Some buildings (like those from the first half of the 19th century) of this kind might have clay brick foundation. Later(begin of 20th century) this changed to unreinforced concrete: hydraulic lime mortar concrete, as stated in a documentin (c) Simetria (2000). The above classification refers to a newer building of the same type, constructed in 1929 (see fig.14 for the plan of foundations).
Type of Floor System	Wood-based sheets on joists or beams
Additional comments on floor system	Other: Timber- wood plank, plywood or manufactured wood panels on joists supported by beams or walls For: timber floor structure in plan and respectively in axonometric view figures 16 and 17, for roof structurein plan and respectively in axonometry figures 21 and 22 and for typical sections through timber floor and roofsystems figure 29 (legend in Romanian). Some buildings of this kind may have composite masonry and metal joiststructure, not practiced any more (fig. 28).
Type of Roof System	Roof system, other
Additional comments on roof system	Timber: Wood planks or beams supporting naturalstones slates; Wood planks or beams that support slate,metal, asbestos-cement or plastic corrugatedsheets or tilesFor: timber floor structure in plan and respectively in axonometric view figures 16 and 17, for roof structurein plan and respectively in axonometry figures 21 and 22 and for typical sections through timber floor and roofsystems figure 29 (legend in Romanian). Some buildings of this kind may have composite masonry and metal joiststructure, not practiced any more (fig. 28).
Additional comments section 2	They do not share common walls with adjacent buildings. This isthe separation between the long wall (the one perpendicular to the street) and the cadastral unit boundary. Dependingon the position of the building on the adjacent cadastral unit, the distance to this one may be up to 3.8m (see Figures3 and 4). There is no typical separation at the back of the house - it may be again 1.9m with the same observation,when windows provided, or no distance at all, when no windows provided When separated from adjacent buildings,the typical

	distance from a neighboring building is 1.9 meters.



Ground floor plan

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: clay brick, mortar	Characteristic Strength: clay brick: bricks mark C75: compression strength:average (7.5-10.0) N/mm2; minimal 5.0 N/mm2;bending strength: average 1.8 N/mm2; minimal 0.90N/mm2. Further values are available in UAIM(2000).mortar: strength of masonry (in N/mm2): C50+M10:2.8; C75+M10: 3.4; C100+M10: 4.0. Bending strengthof mortar (in N/mm2): in horizontal joint: M10 - 0.2; inzig-zag joint: M10 - 0.4. Longitudinal module of elasticitydepending on mortar mark for clay brick masonry (inN/mm2): M10 - 1200. Characteristic curvature(/oo):M10 - 1.75, ; at ultimate M10 - 2.5. Further values areavailable in UAIM (2000).Mix Proportions/Dimensions:

		clay brick: 7cm(63mm;+/-3mm)x14cm(115;+/-4mm)x28cm(240;+5/-6mm) Thenumbers in theparenthesis concern thebrick itself, the othersinclude the dimensions inthe wall, i.e. with mortar.mortar.Today's cement-clay is cement:clay:sand =1:2:8 (compared to 0:1:3for clay and 1:0:4 forcement mortar) see BalanP. 372Comments:clay brick: Values according to UAIMbrick of middle class mark are shown.Also C50 and C100 exist. The markshow s 10 times the lowestcompression strength. mortar: Valuesout of experimental works valid forRomanian historical buildings,recommended as input data foranalytical methods(see UAIM2000).Values for mortar M10 have beentaken (Romanian cement-clay, andEC6 M2), after the experiments ofSofronie
Foundations	masonry	older buildings have clay brickfoundations, newer buildings concretefoundations.
Floors	Roof/Floors:timberFloors: steel(and claybrick)	Characteristic Strength: timber (Roof/Floors) : Fir scantling strength (N/mm2):bending, compression along fiber: 10.0; tension alongfiber: 7.0; compression perpendicular on fiber: 1.5;bending shear, along fiber: 2.0; shear perpendicular onfibre: 4.5; "strivire" perpendicular on fibre: 1.5; "strivire"at supporting surfaces: 2.5. Broad-leafed

		scantlingstrength (N/mm2): tension, bending, compression and"strivire" along fibers: 1.1-1.3; compression and "strivire"perpendicular on fiber 1.6-2.0; shear 1.3-1.6.Floors (steel(and clay brick): tension, compression and bendingstrength 120.0 N/mm2; sliding strength 96.0 N/mm2respectively 0.8 in the other direction. For anchors and"tirant"s: 100.0 N/mm2. The steel module of elasticity isto be considered: 210.000 N/mm2.Comments: Usually out of fir tree, bothmid XIXth century and begin of XXthcentury. Basement might be oak.Floors (steel (and clay brick): for metalelements there are no experimentalresults available. Here what the UAIM(2000) recommendations say has beendocumented.
Roof	Roof/Floors:timber	Characteristic Strength: timber (Roof/Floors) : Fir scantling strength (N/mm2):bending, compression along fiber: 10.0; tension alongfiber: 7.0; compression perpendicular on fiber: 1.5;bending shear, along fiber: 2.0; shear perpendicular onfibre: 4.5; "strivire" perpendicular on fibre: 1.5; "strivire"at supporting surfaces: 2.5. Broad-leafed scantlingstrength (N/mm2): tension, bending, compression and"strivire" along fibers: 1.1-1.3; compression and "strivire"perpendicular on fiber 1.6-2.0; shear 1.3-1.6.Comments: Usually this

		type ofbuilding has ovens, usually out of"terracota" corresponding to eachroom. The roof is usually also out offir tree, fixed with metal parts. At theturn-of-the century German iron hasbeen popular as covering.
Other		

Design Process

Who is involved with the design process?	ArchitectOther
Roles of those involved in the design process	This is rather an informal type of building. However, some of them are designed by architects. An exampleof a building designed by an architect ("inginer-arhitect" has been the title of the time), G. Brezeanu (not a renownedone), 1904 is given in "Povestea Caselor" p. 53-56, including drawings and some construction management tables.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	OwnerBuilder
Roles of those involved in the building process	Typically the builder lives in this construction type. If it is a typical middle class house the owner might be thedeveloper but not the actual builder contractor.
Expertise of those involved in building process	
	Construction process adapted for a building from 1904, from a figure by Dinescu in Simetria (2000): Digging theground and reinforced concrete foundation (reinforced concrete already, like in the model building considered for thisform) - 2 positions; Making clay brick masonry wall works - one position; Wood works - two positions; Wood worksfor the roof - one position; Metal works for the roof (the covering) - three positions; Interior plastering - twopositions; Exterior plastering - two positions; Floors - one position; Filling between the

Construction process and phasing	joists - three positions; Stonestairs at the vestibule - one position; Wood works for windows and doors - two positions; Fir tree mobile staircase-one position; Toilette with everything - one position; Basalt tubes - one position; "terracota" ovens - one position;Decorative plastering - one position; Iron cover - one position. For retrofit: According to the UAIM methodologycracks under 2mm in masonry walls cannot be injected during retrofit works as this implies availability of materials andequipment hard to be found today in Romania. The construction of this type of housing takes place incrementallyover time. Typically, the building is originally not designed for its final constructed size. Changes in time may because of later damages. Such ones are: geometry changes: widening of openings, removal or addition of walls or floors(fig. 9); stiffness changes through closing up windows (fig. 6-9); material degradation (fig. 28, 32, 33); load changes:addition of floors without approval, use change (fig. 6); missing maintenance: especially related to water damages (ex.from rain, missing facade plaster, as visible in figures 27 and 28 for walls and floors); previous damages fromearthquakes or fire (fig. 30-33).
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	It was not built any more when the provisional guidelines, preceding the first seismic code in Romania, appeared.
Process for building code enforcement	It's not built any more. It has been built both in times when building permits were required and not. However, evenin the time when no urban development rules were enforced, "act" (i.e. documents) were required to juristically declarethe buildings, the begin of the construction process and give some details about, like building materials and successionin the construction process.

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal	

Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	Yes
Additional comments on building permits and development control rules	

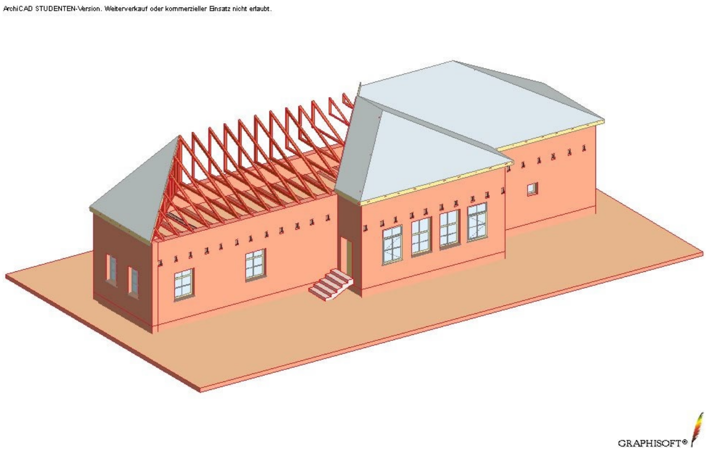
Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	Typically, the building of this housing type is maintained by Owner(s). which are also the inhabitants.

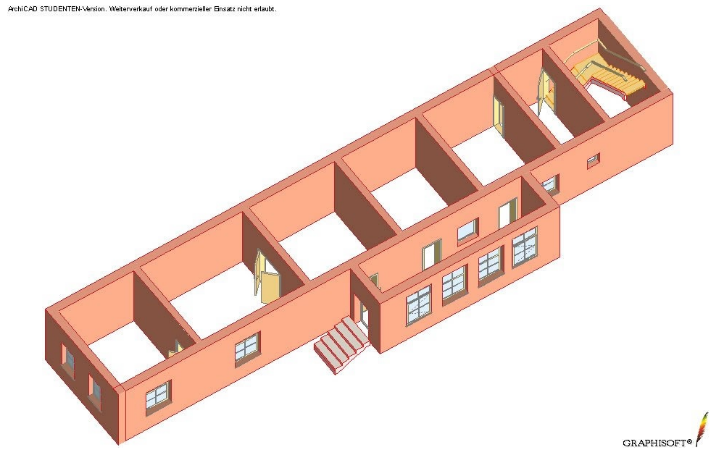
Construction Economics

Unit construction cost	No equivalent possible, as they used to be built before WWII. In the mid XIXth century the value of a recently builthouse of this type was around 200 Austrian "galbeni" or respectively Romanian lei, later on, as documented byDinescu in Simetria (2000). Turn of the century the builder (Romanian "antreprenor") got 7% benefit of theconstruction cost. This has been, including that benefit, around 50 months pensions of a retired functionary or 30months salary of a functionary, who were the typical inhabitants (a bit lower than the value of an existing house). Theproportions did not change 10 years later between salary-house price, although the prices absolutely doubled, as it canbe understood from the Simetria (2000) publication. Prices for the positions in the construction process of a typicalhouse at the begin of the XXth century (1904) can bee seem in Simetria (2000) page 55, in the reproduction of anoriginal document. Detailed are presented: the digging for the foundations, the foundation works themselves, and themasonry works with dimensions in a typical form of the time ("ante-mesuratorea si pretuirea lucrarilor" in Romanian,which means "pre-measuring and cost estimation for the works").

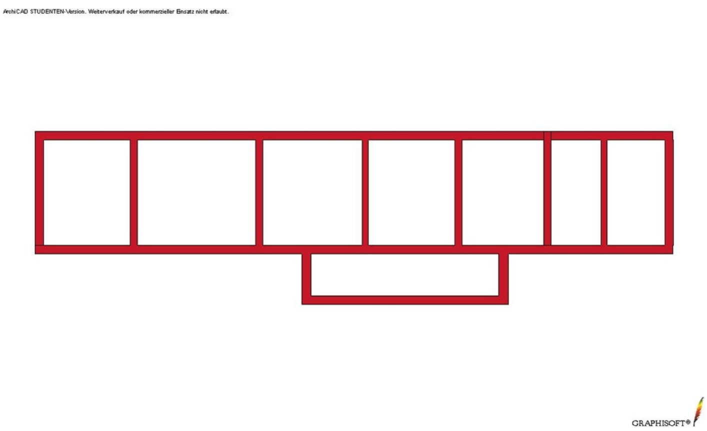
Labor requirements	A house of this type has been built withing twoyears of work, both in 1865 and 1904, from which one might be spent with planning and only one with theconstruction itself, as it can be understood from the description given by Dinescu in Simetria (2000)
Additional comments section 3	



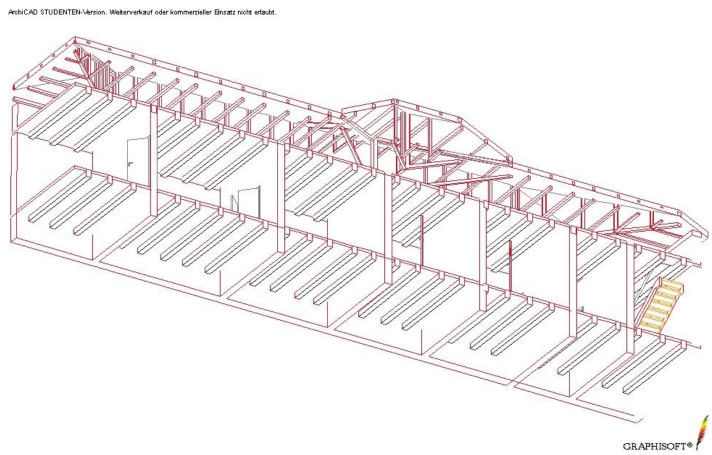
Axonometrie with view to the roof



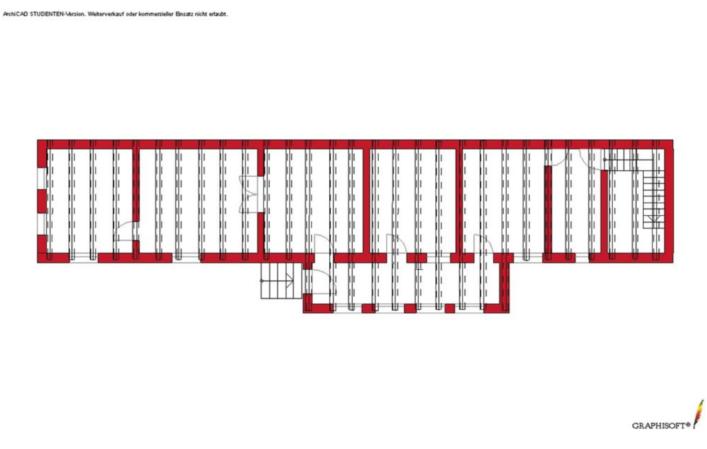
Axonometric view with load bearingwalls and openings



Plan of foundations



3D section



Ground floor plan with timber joists

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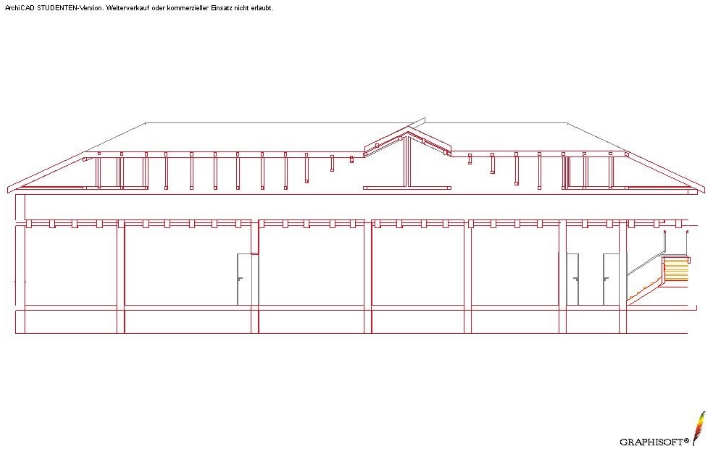
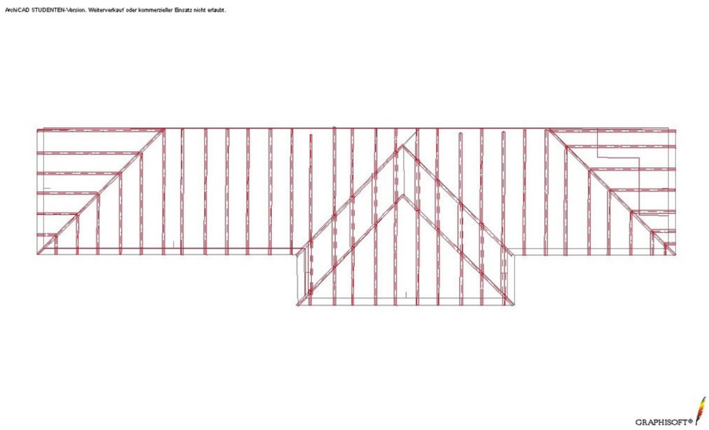
Axonometric view show ing timberjoists (from Bostenaru, 2004, TAFEL VII)

Transversal section

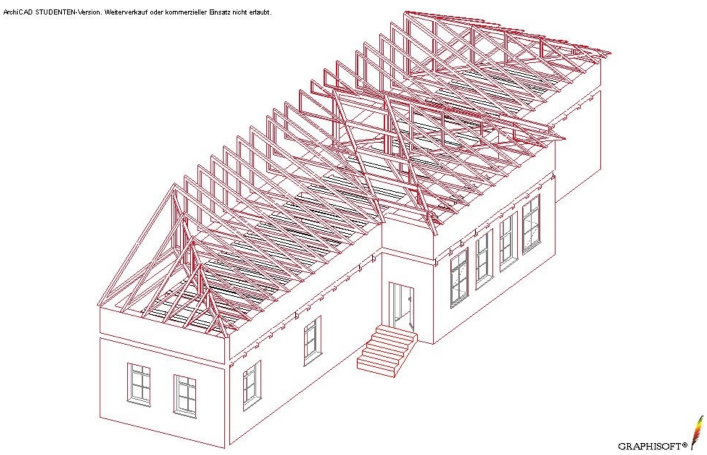


Longitudinal section

3D view - detail

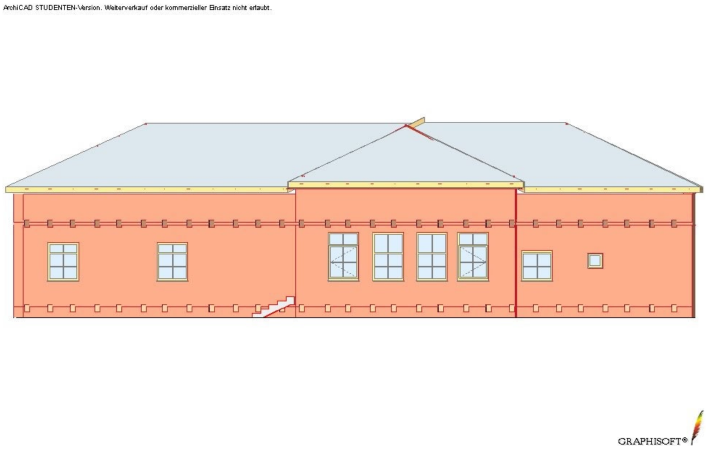


Roof plan

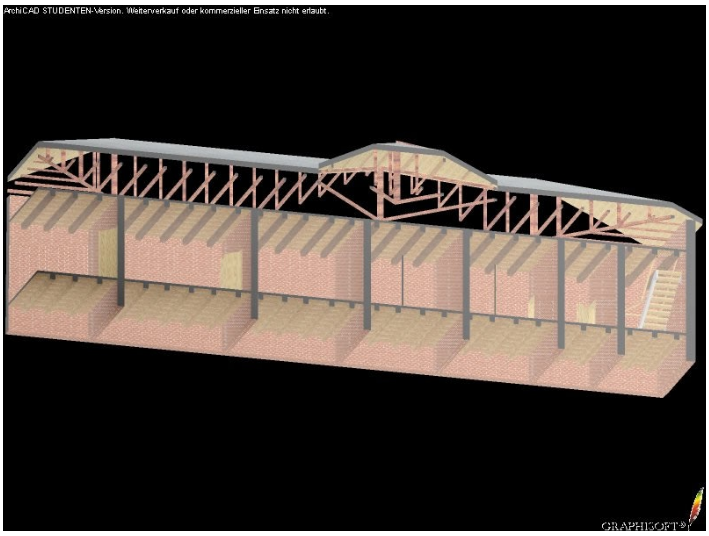


Axonometric view showing the roof

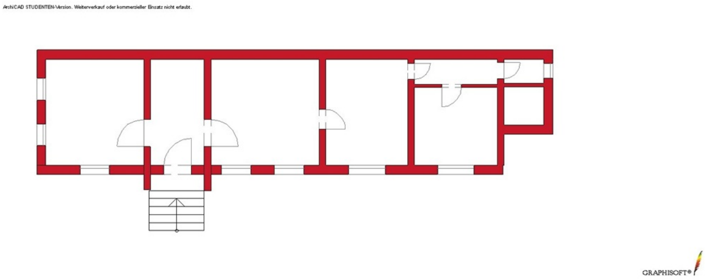
View to street



View to courtyard



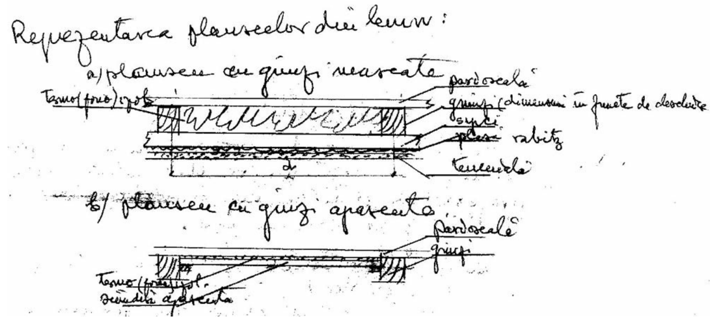
3D section with rendering (fromBostenaru, 2004, TAFEL VII)



Ground floor type when the vestibule isnot specially marked; in this case the width of thehouse is about 4.6m; length is about 20m (fromBostenaru, 2004, TAFEL VII)

Masonry detail (from Bostenaru, 2004,TAFEL VII)

Masonry detail (from Bostenaru, 2004,TAFEL VII)



Typical sections through floor and roof

Socio-Economic Issues

Patterns of occupancy	One family consisting of usually 4 persons. In the XIXth century there might have been 6-7 persons in afamily living in such a house (ex. parents, 4 children and an older person).
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
Additional comments on number of inhabitants	During the crisis years in the late 20s rooms might be rented with strongly specifiedcontracts, in the cases when the number of the persons in the family decreased (ex. only the old retiredpersons remaining). During communism times new inhabitants have been "let" to rent rooms in suchbuildings, leading to up to 3 families (each 2-4 persons) occupying a building (usually one in 1-2 rooms).
Economic level of inhabitants	Middle-income class
	The house price/annual income ratio refers to that when this kind of buildings were constructed. Today this kind ofconstruction is not practiced anymore and the price raised. At the time this kind of buildings were constructed (notbuilt today

Additional comments on economic level of inhabitants	anymore), the house price/income ratio ranged between 2.5/1 and 4/1 and the worse value has beenchosen. Today the price of the house depends a lot on the place in the town where it is situated and on the facilitiesavailable (like gas central heating, for instance), but it is estimated that they are much more expensive to buy than, forexample, dwellings in blocks of flats where this ratio ranges between 6/1 and 10/1. What is less expensive in this kindof houses compared to the block of flats are the monthly running costs for water, gas, heating and electricity. Economic Level: For Middle Class the ratio of Housing Price Unit to their Annual Income is 4:1.
Typical Source of Financing	Owner financed
Additional comments on financing	Credit has been possible to complete the price (1/3 from owner for example, the rest from Credit), as documented inSimetria (2000) p.33. In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1bathroom(s) including toilet(s). This is valid for the example building for this report, which is from the 20s. In the buildings described by Dinescu inSimetria (2000) there were no bathrooms, only latrines (Romanian "closet"), and this is considered to be typical forthat time. Many of the housing units from that time have been upgraded, but the authors estimate that not all ofthem.
Type of Ownership	Own outright
Additional comments on ownership	Renting was possible. For such a building the rent in 1928 had been about 12.5%of the insured value, and this did not vary dramatically. In 1942 the rent was almost 10% of the insured value/year (for details see Simetria, 2000).
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	Dinescu in Simetria (2000) mentions documents proving the insurance of thehouse between 1920 and 1950. These were against fire and lightning, no earthquake, and show the change in the valueof the building as well as the premiums (see reference, p. 57).
Are premium discounts or higher coverages available for seismically strengthened buildings or	No

new buildings built to incorporate seismically resistant features?	
Additional comments on premium discounts	
Additional comments section 4	Dinescu in Simetria(2000) mentions documents attescting the insurance of thehouse between 1920 and 1950. These were against fire and lightning. No earthquake, and show thechange in the value of the building as well the premiums (see reference, p. 57).

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1940	Vrancea
1977	Vrancea
1986	Vrancea
1990	Vrancea

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	The occurrence of slight or heavy damages depends mainly on the construction quality of this building type(foundations, masonry, roof, wood works and so on), which ranges from poor to excellent. These buildings maypresent: slight damages: falling of of finishing and decorations from walls and ceilings; crack nets, isolated rifts inmasonry or later introduced concrete elements; large rifts in later introduced non-structural walls; heavy damages: bigrifts, dislocations, sliding of construction elements, joint degradation, remaining deformations. The most frequentdamage appears in the stiffening walls (these are the transversal walls, which are not designed as gravity load bearingwalls, but contribute to the lateral load system), sometimes the timber joists detached from

construction type	the walls, rifts at 45 at thelintels. There is thus an evident difference between the damage patterns of longitudinal walls (compressed by verticalload) and unloaded transversal walls. Global damage includes leaning from the vertical of the whole building by 4 to 9cm (INCERC 2000). The most usual ones are the rifts. In Simetria (2000) p.38 detaching of ceiling border after the1940 earthquake at such a house is documented. Generally this type of buildings is affected at the upper part: cracks,rifts, dislocations under and above the openings, in wall piers and wall fields; wall collapse especially in walls in theroof part (if inhabited), party wall and chimneys.
Additional comments on earthquake damage patterns	Wall: Some cracks in the plaster Vulnerability to pounding In some buildings-diagonal cracks on the facades and on the party wall. Corner damage (seefigure 31)Roof/Floors: In some buildings the timber floors were damaged to collapse (INCERC,2000, page 13). Specifically in a 19th century building described in Simetria(2000) the edge of the floor above the ground floor w as separated from thew all, but the building w as not damaged significantly (P. 38). Also Balan(1980) mentions that floors at building of this kind, both with timber andmetal joists might present numerous rifts, especially on the contour (P.232). UAIM (2000) classifies small rifts in the ceiling plastering as beingcharacteristic for both not affected and light affected buildings, while inaffected buildings the floor joists might move from their supports. Themovement and collapse of the roof is also characteristic for affectedbuildings. For more details including figures see Agent (P. 72-78). Damagecan also occur from neighbouring buildings (fig. 34). Openings: In some buildings- X shaped cracks above the openings; Z shaped crackson the "parapet" (under the window); cracks in the lintels over the entrydoor (fig. 30); cracks in the piers of the facade.The data in the table is based on Bostenaru (2004), Table 2-6, P. 41. Roof damage: Due to excessive tensile stresseswould fibers can fail (Croci, 2000, P. 59-60). In the opinion of the authors this type of failure is similar to the mostcommon type of damage in RC beams, which is cracks in the tension zone. According to Penelis & Kappos (1997) thevertical component of the seismic action makes visible the microcracks due to bending of the tension zone. Althoughthe vertical component at Vrancea earthquakes (those affecting Romania) is important, as the earthquakes occur deep,this is seems not to be that kind of damage, but rather bending shear effect. Roof systems are considerably moresensible to missing maintenance,

as the ruins of buildings of this type show (fig. 32-33).

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)	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.	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.	N/A
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.	N/A
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).	N/A
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	N/A

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	The disposition of wallssometimes does not respectrules concerning uniformdistribution of mass andstiffness. Brickwork can beextensively worn out (poormaintenance, decay) Noreinforced concrete verticalposts. Height differences toadjacent buildings possible. Useof mortars with moderatestrength.
Earthquake-resilient features in walls	Good quality (hydraulic)lime mortar. Because ofthe wall-roof connection,which do not assure thespatial cooperation of thestructures, the appearedasymmetries don't causesignificant general torsioneffects under the action ofseismic forces.
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	No stiff floors so no co-operation of load bearing wallsand floors, so eventual capacitydeficiencies of walls cannot becompensated by a uniformdistribution of loads through thefloors to walls with highercapacity. Linear load bearingelements with one direction loadtransmission, not anchored tothe walls. No tie beams.Buildings are lower height thantheir neighbours.

Earthquake resilient features in roof and floors	Timber floors with joistsevery 70cm assure anuniform distribution ofrigidities in the planeavoiding torsional effects.Timber joists are sustainedby the longitudinal walls.Roof support on thesegirders leads to the factthat horizontal forces fromearthquakes are absorbedwithout causing significantdamages.
Seismic deficiency in foundation	Foundations are clay brickmasonry as well, and rarely stonemasonry or concrete.
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 over opening (from Bostenaru,2004, TAFEL VII)

Damage at corner

Ruins of such a building

Ruins of walls of a building of this type

Fig. VI.6. — Calcan prăbuşit la cutremur la o clădire veche de zidărie (Bucureşti, str. Şelari 9 — 11, parter şi 3 etaje) Prăbuşirea calcanului a produs avarierea acoperişului la clădirea învecinată.

Fallen party wall in neighbouringmasonry building, damaging the roof of a buildingof this type (see Balan, 1980: figure VI.6. on page234)

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Small cracks in structural walls	Injection with cement milk of small cracks (after Bourlotos, 2001, and (c)INCERC, 2000): 1. removing plaster; 2.widening the rift with hammer and chiesel or mechanical

	hole making; 3. cleaning the rift; 4. injecting the rift withmortar; 5. transport of break-off plaster to rubbish container; 6. disposal of removed plaster; 7. new plaster. (Fig.40)
Large diagonal cracks in thewalls or wall dislocations	Shotcrete ("torcretare" in Romanian) (after Bourlotos, 2001, compared with (c) INCERC, 2000; see also report#84): 1. Removal of plaster; 2. Removal or mortar in horizontal joints up to 1cm; 3. Cleaning of the wall withwater; 4. Shotcrete of 4~8mm. Alternatively cast-in-place concrete, about 10cm thick.
Serious wall damage	Reinforced concrete jacketing (after (c) INCERC, 2000, completed after Bourlotos, 2001): 1. Scaffolding; 2.Screening; 3. Building up an removing drop tub; 4. Removing outside and inside plaster; 5. Knocking off themasonry wall; 6. Breaking through the slab; 7. Cleaning up the masonry; 8. Concrete roughening; 9. Blastingcompressed air; 10. Reinforcement works; 11. Formwork; 12. Binding anchors between masonry walls and shearwalls; 13. Mounting the binding anchors; 14. Concrete casting; 14. Dismanteling the formwork; 16. Interior andexterior plastering, for interior M100 mortar recommended by INCERC; 17. Masonry repair. (Fig. 39)
Low capacity of wall-to-wall andwall-to-floor joints and/ordamage along these joints	Anchoring two neighbouring w alls or floors to walls by means of metal tension struts (in Romanian "tirant"): 1.dismanteling plastering; 2. breaking holes through the w all; 3. anchor head for the strut; 4. fixing of the solidisationmetal plates; 5. making and mounting of the screw dispositiv for screwing in; 6. mounting of the protection tubefor guiding the tyrants through the walls; 7. making and mounting the metal strut; 8. filling in the holes; 9. remakingplastering. (see fig. 41 and after INCERC, 2000)
Anchoring two neighbouring walls or floors to walls by means of metal tension struts (in Romanian "tirant"): 1.dismanteling plastering; 2. breaking holes through the wall; 3. anchor head for the strut; 4. fixing of the solidisationmetal plates; 5. making and mounting of the screw dispositiv for screwing in; 6.	Replacement of timber floors or of floors out of brick vaults on metal joists with reinforced concrete slabs(summarised after (c) INCERC, 2000; for both if not specified otherwise): 1. Demolishing of partition walls; 2.Dismanteling of doors; 3. Dismanteling of plaster on the walls; 4. Dismanteling of flooring. 5. (timber) Dismantelingof under-flooring; 5a. (vaults) Dismanteling filling

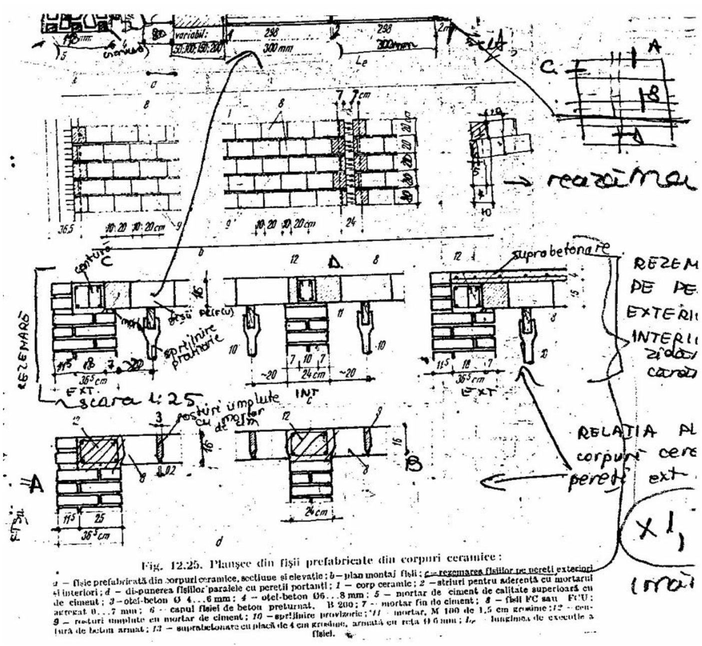
mounting of the protection tubefor guiding the tyrants through the walls; 7. making and mounting the metal strut; 8. filling in the holes; 9. remakingplastering. (see fig. 41 and after INCERC, 2000)	materials over the vaults; 5b. (vaults) Demounting brick-vault-floors; 5c. (vaults) Demounting metal joists over 4m length; 6. Realization of fingerprints and binding openings inthe walls of different thicknesses (but over 14cm); 7. Formwork; 8. (timber) Support out of metal joists for theslab; 9. (vaults, before formwork) Mounting the reinforcement (out of OB37 and PC52 steel); 10. Concrete casting(B250) into the fingerprints; 11. Concrete casting (same quality) into the slabs; 12. Support layer for flooring; 13.Realization of the floor and its finishing; 14. Floor-wall finishing pieces; 15. Plastering of the interior walls; 16.Plastering of the ceiling; 17. Rebuilding the partition walls; 18. Mounting the doors. (Fig. 36).

Additional comments on seismic strengthening provisions	Out of plane walls after earthquake (reparation work): Replace collapsed portions of old walls with new masonry walls: 1. loads to be carried usually by the walls are holdoff and directed to the sustainable subsoil (with bolts); 2. knock off of the old wall; 3. building of a new wall; 4.reloading of the wall (disassembling the support). (after Bourlotos, 2001) SRENGTHENING OF NEW CONSTRUCTION: Inadequate capacity of structural walls - Strengthening with polymer grids (TENSAR), see report #84Lintels are brick vaults, timber or metaljoists; Not always respecting the actualprescriptions regarding the dimensions andthe areas of openings in walls; Piers ofreduced sections compared to the loads tobe supported - Reinforcement of door frames: 1. old door and door architrave are knocked off and disposed; 2.eventually available lintel is also knocked off and disposed; 3. masonry around the door opening is alsoknocked off and disposed; 4. cleaning works; 5. the reinforcement of the reinforced concrete frame isanchored to the floor plate; 6. other reinforcement works are in progress; 7. setting up formwork; 8.casting concrete; 9. dismanteling formwork; 10. the new door is build in. (after Bourlotos, 2001, see fig.37) no reinforced concrete vertical posts - Strengthening of corners: 1. Loads from roof or floor are first hold off with a scaffolding construction.Slamming in two directions along the interior side of the wall (distance between the steel columns~0,60m); 2. Knocking off and cleaning away the broken masonry; 3. Reinforcing the corner post; 4.Setting up the formwork, casting the concrete, dismantling the formwork of the corner

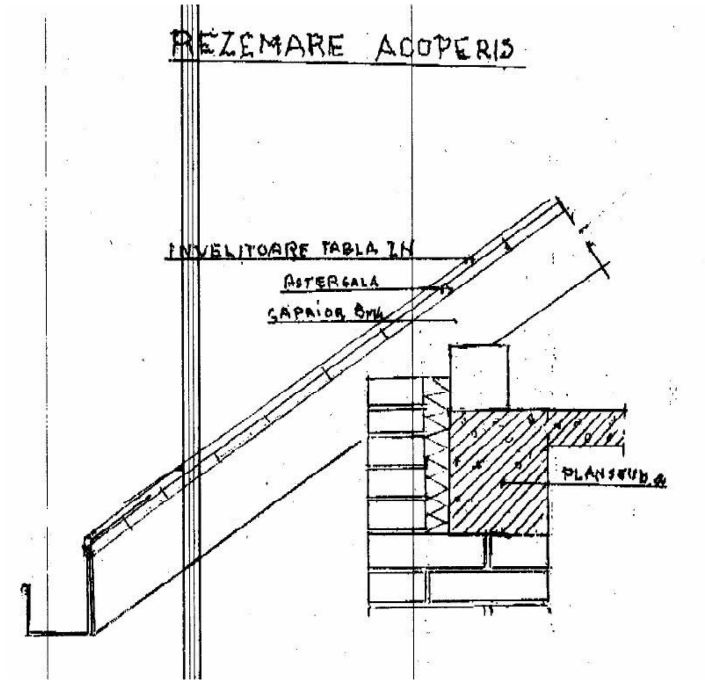
	post; 5. buildingup reinforced masonry in the area of the corner post. (after Bourlotos, 2001; fig. 38)
Has seismic strengthening described in the above table been performed?	After the earthquakes form 1940, 1977, 1986, 1990 in case of the model building considered for this form onlysuperficial rifts occurred which have been repaired. After the 1977 earthquake following strengthening methods havebeen used: crack injection with cement paste (most widely used), replacement of collapsed portions of old walls withnew masonry walls built in cement mortar, shotcrete, replacement of heavy walls with light walls or connection ofthose with the walls of the load bearing system. The last one of these has been described in report #84. Addedreinforced concrete vertical posts leads to changing the structural type into reinforced masonry and thus might besuitable for historic constructions of this type. Tension struts and floor replacement have been also used for buildingsof this type as shown in the figure. Reinforcement of door frames addresses like floor replacement specific seismicdeficiencies of this type again. For the other ones this report presents a new view, comparing the Romanian practiceafter the 1977 earthquake with provisions from today, as it resulted from joint research work of one of the authorswith a student from Greece (see Bourlotos, 2001).
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Strengthening measures like repairing cracks, rifts, out of plane wall collapses are made following an earthquakedamage. Strengthening measures like reinforcement of door openings, providing of vertical posts are made onundamaged/previously repaired buildings. Strengthening of walls with reinforced mortar (see report #84), jacketing,as well as strengthening of floors can be made for both cases.
Was the construction inspected in the same manner as new construction?	"Functional specifications" are required today. For example for the application of TENSAR strengthening a so called"Agrement tehnic" i.e. technical provisions, issued by MLPAT (The Ministry for Public Works and Regional Planning),with no. 008-01/017-1999 is used.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Owner
What has been the	The model building wasn't damaged significantly. However, Balan (1980) documents failure of

What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	reinforced concreteposts at masonry buildings (P. 376), so this type of damage should be taken into account also for reinforced buildings.Thus also the potential reinforcement elements, like vertical posts, can be damaged in Vrancea earthquakes, as shownin figure 42.
Additional comments section 6	There is no information available about preparing beddings for new slabs and the way of anchoring them tosupporting walls. Figure 35 shows contemporary composite masonry and concrete joist in Romania, an alternative forthe replacement of the similar ones with metal joists. For more comments about strengthening with polymer grids seereport #84. For more measures see Bostenaru(2004), Tabelle 2-7 on P. 42 and Tabelle 2-8 on P. 43. Strengtheningworks may be applied independently (on a new building) or together with reparation (UAIM, 2000). Retrofit methods with reinforced plaster (polymer grids and shotcrete) can be also applied as repair measures, not only on undamagedbuildings. The same is valid for the replacement of floors, which can follow floor destruction in either earthquakes ormissing maintenance. Main reparation works which can be performed on historical masonry buildings are according toUAIM2000: re-weaving with bricks similar to the original ones; injection with lime grout; injection with cement grout;injection with cross-shaped metallic incisions; closing of rifts with cement mortar; treatment of large dislocations withmortar-concrete reinforced with flexible bars; closing of rifts on painted walls with special mortar ("caseinat de calciu");injecting of cracks with special past ("caseinat de calciu"). Specific for small residential buildings of historical value are:no additional structural walls; old: composite out of masonry within reinforced concrete or reinforced mortar. Theseshould be on bigger surfaces and smaller thickness; possible with polymer grids in one of the following ways: gridsbetween the horizontal brick rows, jacketing of walls, confinement of structural parts, according to the respectivetechnology; reinforced masonry or with included metal elements may be added; timber floors may be replaced withreinforced concrete slabs; metal floors may get an overconcrete layer or metal diagonals connecting the metal joists; Incase of a minimum intervention: at least one floor shall be of reinforced concrete or metal with comparable stiffness,usually the roof one, timber joists must be reigidised at 45; complete change of interior structure is allowed whenonly the exterior appearance is of historical significance, exterior

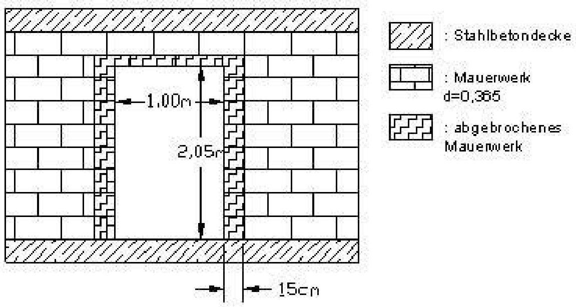
walls should be strengthened concomitently; in exceptional cases when any structural changes would affect the cultural values base isolation is recommended; beam ties or tension struts ("tirant") shall be realized.



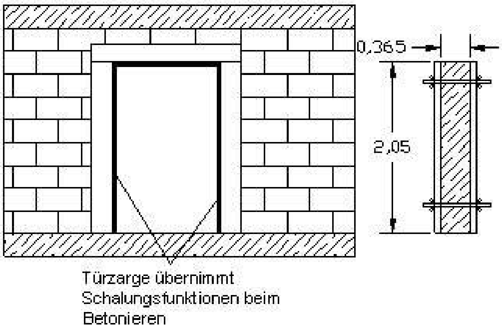
Sections through a brick and metal joistsfloor structure: a - prefabricated sheet out of bricks,section and elevation; b - mounting plan; c -support of the sheets on exterior and interior walls;d - layout of the sheets parallel to the bea



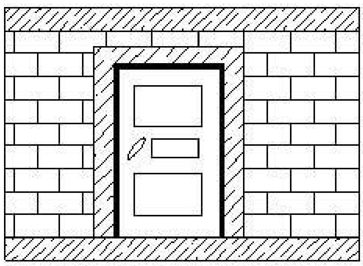
View of roof-wall-floor connection incase of proposed retrofit of rigid slab at roof level.



1. Knocking off the masonry around for door strengthening

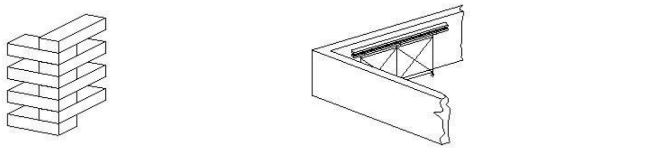


2. Concrete casting for a reinforced concrete frame around the door opening for its strengthening



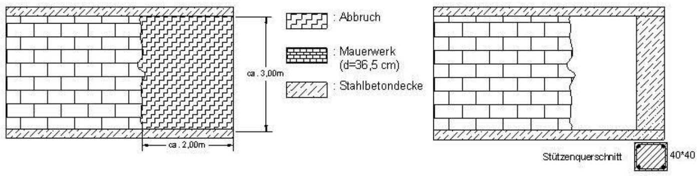
3. Mounting of a new door

Reinforcement of doorways (afterBourlotos, 2001)



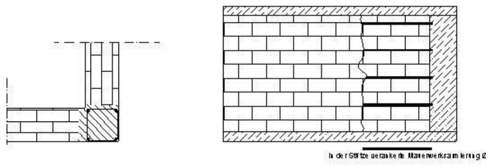
1. Initial state of the corner

2. Floor support for strengthening the masonry corners



3. Break of the masonry for strengthening the masonry corners

4. Corner post out of reinforced concrete in masonry wall corner strengthening



5. Reinforced masonry in strengthening of masonry corners

Strengthening of masonry corners (afterBourlotos, 2001)

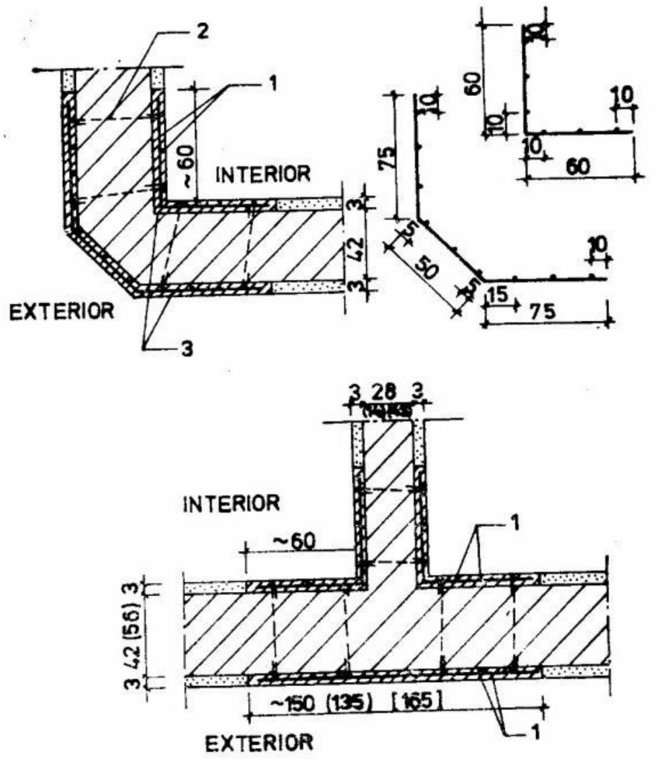
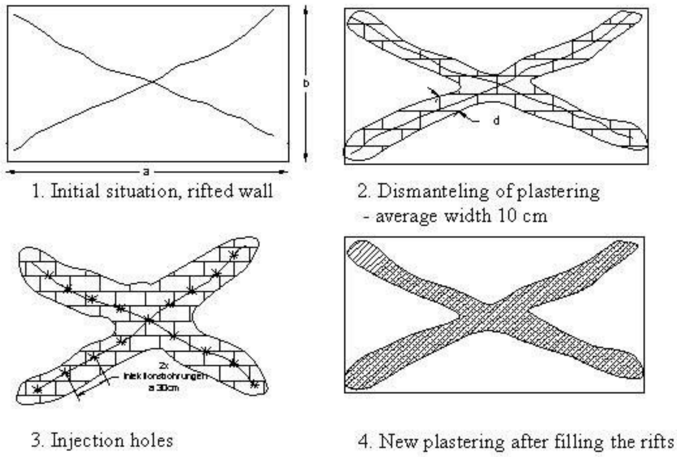


Fig. VIII.24. — Cămășuirea zidăriei cu plase sudate, amplasate în tencuială. (Clădirea din București, Calea Victoriei nr. 190) : 1 — plase sudate ; 2 — agrafe de legătură ; 3 — tencuială cu mortar de ciment.

Masonry jacketing with steel nets, in theplaster: 1 - nets; 2 - joining anchors; 3- plaster withcement mortar. (see Balan, 1980: figure VIII.24.on page 428)



Masonry wall reparation through riftsinjection (after Bourlotos, 2001)

Reinforcement with tension strut, inRomanian "tirant" (from Bostenaru, 2004, TAFELVII)

Damages at a vertical post at the

cornerof a midrise masonry building in the 1977earthquake. (from Balan, 1980: figure VI.28.b. onpage 253)

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