# World Housing Encyclopedia

***A Resource on Construction in Earthquake Regions***

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HOUSING REPORT

**Building of the Modern Movement - Reinforced concrete frame designed for gravity loads with no commercial ground floor**

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| **Report#** | 96 |
| **Last Updated** | |
| **Country** | Romania |
| **Author(s)** | Maria Bostenaru Dan, |
| **Reviewers** | Vanja Alendar, |

**Important**

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## General Information

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| **Building Type:** | Building of the Modern Movement - Reinforced concrete frame designed for gravity loads with no commercial ground floor |
| **Country:** | Romania |
| **Author(s):** | Maria Bostenaru Dan |
| **Last Updated:** | |
| **Regions Where Found:** | Buildings of this construction type can be found in the center but also other parts of Bucharest, the capital, on smallparcels. After an estimation of the author there are about 300 residential buildings from that time and with thatstructural type located in the city of Bucharest and around it. After Lungu et al. (2000b) slightly more than 20% ofBucharest's housing units were built before 1941 (which is when the pre-code benchmark period started) and furtheralmost 10% between 1941-1963 (1963 being the year of the first low-code, inspired by the Russian practice, again afterLungu et al., 2000b). However, this kind of buildings stopped to be constructed around 1948, with the nationalisationprocess. According to Lungu et al. (2000b) Bucharest city has about 750000 housing units in about 100000 buildings,from which 95000 are low rise (1-2 stories) and the rest in a 2/3 ratio high and mid-rise. A database compiled by theauthor for architecturally relevant buildings of the time has around 600 entries, including not realised projects and notresidential buildings. 125 of them are blocks of flats, and another 175 of them single family houses, from which 75 arecategorised as luxury villas. 44 out of 115 listed in the highest vulnerability class are purely residential. It is notable thatnot all buildings listed as highly risk-exposed are included into that database, but only 17 out of 115. All these leadedto the ESTIMATION of about 300 buildings of this structural type. This type of housing construction is commonlyfound in urban areas. |
| | This urban housing construction was practiced in Romania from 1907-1945, butpredominantly in the 1930s, in the capital city of Bucharest. These |

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| **Summary:** | buildings are mid- or high-rise (5-10 upper floors), often with two basements. Although there are several functionalvariations according to the usage and combination of flats, offices, and shops, this reportdiscusses exclusive housing use. The number of housing units is variable. While smaller mid-rise buildings may contain one large luxury unit on each floor, taller buildings may include asmany as eight small one-room flats, sometimes without a kitchen. The shape of the plan,containing L, U, H, or forms that cannot be described geometrically, and the elevation of thebuilding are highly irregular. Upper floors may have recesses in the facade and may havecorner towers. The load-bearing structure is RC skeleton designed for gravitational loads only.Columns are unevenly distributed so that beams at least one end are supported as secondarybeams. Some beams are supported by columns with inadequate reinforcement or reducedsections of the RC members impede the formation of moment-resisting frames. The facadewalls have solid clay brick masonry infill and improve the seismic behavior. The beneficialeffect of masonry infill is influenced by the wall thickness, the size/position of openings inwalls and the position of the partition wall to the frame. Staircases and elevators weaken thestructure by introducing concentrated holes in flexible, thin RC slabs. Bucharest is located onalluvial soil deposits on river banks. Sandy ground or high levels of underground water haveoften presented problems for the foundation of buildings. Damaging earthquakes (M>7.0),centered in Vrancea, recur three times every century. These buildings were affected by the1940 and 1977 earthquakes, but performed well relative to their high vulnerability. Out of the61 buildings heavily damaged in the 1977 earthquake, 28 were of this type but were high-rise(7-9 floors). |
| **Length of time practiced:** | 25-60 years |
| **Still Practiced:** | No |
| **In practice as of:** | 1947 |
| **Building Occupancy:** | Residential, 20-49 units |
| **Typical number of stories:** | 5-10 |
| **Terrain-Flat:** | Typically |
| **Terrain-Sloped:** | 3 |
| **Comments:** | The "boom" time for this type of construction has been 10years (1930-1940). However, isolated |

attempts of this type have been bu

## Features

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| **Plan Shape** | L-shapeH-shapeU- or C-shapeIrregular plan shape |
| **Additional comments on plan shape** | Irregular.Many of these buildings are U or H shaped, some are L shaped, few are rectangular.The configuration in elevation is also often irregular, with recesses of 1.2m at upper floors. However,there are buildings of this kind with no irregularities in elevation. |
| **Typical plan length (meters)** | 18-35 |
| **Typical plan width (meters)** | 9-15 |
| **Typical story height (meters)** | 3 |
| **Type of Structural System** | Structural Concrete: Moment Resisting Frame: Designed for gravity loads only, with URM infill walls |
| | The vertical load-resisting system is reinforced concrete structural walls (with frame). Reinforced concrete schelet,designed for gravitational loads only with two-way slabs on beams. Perimetrally clay brick masonry infill walls share theloads with the reinforced concrete structure (see figure 10-12). According to Balan (1980) P. 234-235: The design forgravitational loads has been made following the prescriptions from the German circular from 1925 (Prager, 1979). Notalways the prescriptions have been respected (sometimes the columns and beams might had been underdimensionedfor gravitational loads as well as described in Balan (1980) P. 241 for the Belvedere block, a block with commercialground floor, though). In Chapter 11, P. 273-305, Prager (1979) describes the construction particularities in severalresidential and office buildings of the time 1930-1940, and in 7.4. of those of the time 1918-1930. The building of theblock of flats "Spicul" (figure 16), arch. Arghir Culina, RC eng. Dim Marcu, is a good example showing the sequencesof building construction. This building have been finished between June and November 1928. After reaching the second floor the masonry works have been carried out parallel with those of the upper slabs. On the 1st of Octoberthe structure was ready on 5 floors and the finishing and installation works could began. (after Prager (1979) |

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| **Additional comments on structural system** | P. 143-145). This building is not typical for the type in this report as it includes also several shops in the ground floor besidesof the 54 flats on floors. A list of courses and studies which have been gradually become available (after Prager (1979)P. 481-482): - Prof. ing. Mihail Hangan [Curs de beton armat I, II, III] = "Reinforced concrete course I, II, III" - inRomanian, edited by the Bucharest Polytechnical School (1931-1933); - Prof. ing. Mihail Hangan: [Contractia betonuluisi influenta sa asupra aderentei] = "Concrete contraction and its influence on adherence" - in Romanian (1932); - Ing.N. Ganea: [Calculul betonului armat, diferite constructii, poduri] = "The calculation of reinforce concrete, differentconstructions, bridges" - 4 volumes, in Romanian (1932-1935); - Ing. N. Ganea: [Industrializarea betonului armat] ="The industrialisation of reinforced concrete" ? in Romanian (1935); - Ing. N. Ganea: [Calculul practic al betonuluiarmat] = "The practical calculation of reinforced concrete" - in Romanian (1935); - Ing. Stan Dumitru si ing. AlexeTauber: [Calculul fundatiilor stlpilor] = "Calculation of the foundations of columns" - in Romanian (1937); - Prof.ing. Mihail Hangan: [Tabele pentru calcul] = "Tables for calculation" - in Romanian (1938-1939); - Prof. ing. AurelBeles [Cutremurul si constructiile] = "The earthquake and the constructions" ? in Romanian (1941); - Ing. NicolaeGanea: [Constatare cu ocazia cutremurului din 1940] = "Statement on the occasion of the earthquake in 1940" - InRomanian (1941); - Prof. ing. Mihail Hangan: [Consolidari de fundatii si constructii n beton armat] = "Retrofit ofreinforced concrete foundations and constructions" PhD thesis in Romanian (1946).The lateral load-resisting system is reinforced concrete structural walls (with frame). The main load-bearing structureconsists of reinforced concrete beams and columns (see figures 19 and 20). The columns are unevenly distributed (seefigure 4) and the beams are distributed in a way often not forming moment resisting frames (see figure 5-9). Thismeans that most beams are not supported by two columns at their two ends, but often at at least one of them byanother beam. Additional to the spatial characteristics defavourising the formation for rigid frames the nodes aredeemed not to have been reinforced accordingly (Balan (1980) P. 238). Beams have also a very reduced section (many ofthem 15cmx30cm in the example building on a span of about 4m). Columns have also been inadequately reinforcedfor lateral loads, as shown by the short lap splicing, computed for compression loads out of |

gravity only (Balan (1980)P. 239). Usually at the facade there are clay brick masonry infill walls, contributing to the lateral load bearing (see figure10). The floor structure consists of cross reinforced slabs with 10 cm average thickness supported by beams masked inthe partition walls for spans under 4.5m and of reinforced concrete slabs with embedded hole brick elements, 21cmthick for spans of up to 6.5m (see figure 17). Lateral loads are taken over by the masonry infill walls especially in thefirst phase of seismic solicitations. In a second phase the infill walls were not compatible with the huge deformation ofthe schelet structure and were destroyed. The solicitations were then supported by solely the RC schelet, which washeavily damaged (especially the columns, fig. 21-26), as it hadn't corresponding resistance and deformability qualities.Due to the fact that the layout of infill walls was not structurally designed but dictated by the architectural plan, theglobal resistance to seismic loads was accordingly different from building to building. The quality of the infill masonry,their thickness (thick walls were usually on the facade), the position of the infill to the frame (filling it or not) and theposition and size of the openings in the infill walls had basically influenced the behavior during the earthquake.Sometimes the infill walls contributed to the break of short columns. (summarized from Balan (1980) P. 234-235).For functional reasons the staircases and lifts are often placed in such a manner that they weaken the slab (notstrengthening it with RC tubes as nowadays). In the example building it can be seen that the infill walls have beenplaced in the short direction and at the end of the units (bordering the huge holes given by the staircase and lift placedin the bar joining the two wings of the H shaped building) thus giving a quasi symmetric distribution of rigidities inthe two directions. A computation method for horizontal loads was totally missing at that time. Balan (1980) affirms(P. 242) that even structures designed for gravitational loads only have certain seismic qualities on the one side fromthe resistance reserves of the RC schelet, well designed for gravitational loads and on the other side from the resistancereserves of the infill walls. Figure 45 and 16 (see description at 4.2.) clearly shows that facade walls are erected after theconcreting. However, as it can be seen in figure 6, some "beams" (the blue ones) are indeed just a belt over themasonry walls, of 25cm width and 38cm height. This is basically different from all other beams,

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| | which are usually15cm wide and twice as high as wide. This belts are continuation of real beams perpendicular to the facade wall andsupport again real beams, which support thick masonry walls in the facade (but which are in console in upper levels). |
| **Gravity load-bearing & lateral load-resisting systems** | Following types are described by Prager(1979) to have been used at particularbuildings: - RC schelet with slabs with main and secondary beams; columns distributed according to aneconomic computation. The columns are recessed at the last floor following the roof line. - the generalschelet is out of reinforced concrete, cross-reinforced slabs, exterior infill walls out of clay brick. |
| **Typical wall densities in direction 1** | 5-10% |
| **Typical wall densities in direction 2** | 5-10% |
| **Additional comments on typical wall densities** | The typical structural wall density is 5 - 10%. Many of the walls are just partitions, see figure12. |
| **Wall Openings** | The windows for the model building considered are 2.40m wide and 1.35m high. There are 8 like this oneach floor. 6 of these are in console walls, which are thick and heavy, but not infill walls. Two of them, which alsoinclude doors to loggias, are in thick facade walls supported only by secondary beams. Smaller windows are for flatdependencies (bathroom, kitchen). Windows are regularly distributed in the walls. This has allowed the regulardistribution of the structural walls for retrofit in the solution presented within this report. The doors are 0.95m,0.80m, 0.75m, 0.70m or 0.60m wide and 2.00m high. Between the eating room and the living room there is a biggeropening of 2.65x2.60m in one of the flats. The distribution of doors is rather irregular (see fig. 11). There are severalopenings in the infill walls while some walls, with no infill function, have no openings, as the number, size andposition of openings have been dictated by functional, not structural considerations. |
| **Is it typical for buildings of this type to have common walls with adjacent buildings?** | Yes |
| **Modifications of buildings** | Some buildings were added new wings, out of metallic or RC schelet.New partition walls (fig. 11). |
| **Type of Foundation** | Shallow Foundation: Reinforced concrete isolated |

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| **Type of Foundation** | footingShallow Foundation: Mat foundation |
| **Additional comments on foundation** | The types of foundation differ according to the ground on which the building hasbeen made. Few buildings were made on good foundation ground, with isolated footing. Most foundationsraised some problems. Following types are described to be used at particular buildings by Prager(1979): -RC strips on sand, sometimes connected with beams. Some are founded on the sand layer under theunderground water layer. - deep foundations of 7-8m - general RC mat foundation designed for 1,2 kgf/sqcm for a block of flats with 7 floors on sandy ground with water mirror at 3,5m. On a similar weak terrain,with maximal allowed pressure 0.80kfg/cm2 and water saturated (near Cismigiu lake), mat foundation of50cm was used. Mat foundation was used in several another cases when founding on sandy terrain ataround -7.5m (two basements). Mat foundation was also used when underground water was high (-6m forbuildings close to Dambovita river). - a special foundation used at an office building of the same structuraltype was used on a special ground saturated with water. It was a mat foundation with difficult works. Tostrengthen the ground steel tubes were embeded into the mat at about 1m distance. After finishing thestructure of the building cement mortar was injected into these tubes at 3-4 at controlling the filling andspreading effect in the matt to the neighbouring holes. The building above was 30m high, the admittedpressure on the ground 1.2-1.4 kgf/square cm. It behaved well at the 1940 earthquake. - on aluviar soildeposit: perimetral columns founded on simple concrete continuous wall of 50cm thickness on the wholeheight of two basements. Middle columns going down to reinforced concrete strips which support also theweight of the basement wall between them. - a special foundation work was due when the neighbouringbuildings had a higher foundation. A case is described by Prager, when the foundation of theneighbouring building was 4m higher as the two basements for the new building. The new foundation wasin a sand and gravel layer, made through 5 vertical deep holes, connected by a tunnel-galery of1,6x1,8m, in which then the new reinforced concrete strip was constructed, on which the masonry of thetwo basement was made, in successive parts, after which the ground was excavated at 6,3m depth till thestreet. The neighbouring building was founded on a compact resistent "argila" layer and was laterextended vertically with 3 upper floors. Some other foundations opened realization problems as |

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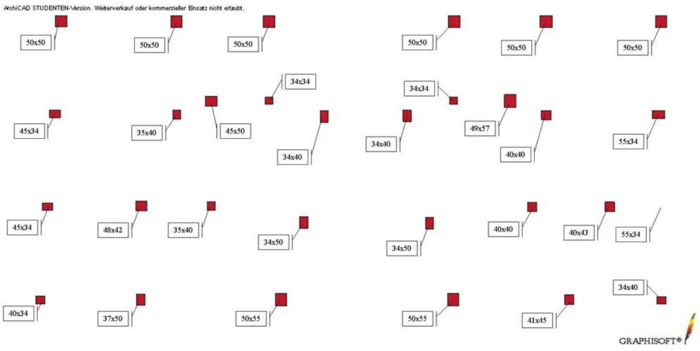
| | well.Such one was on sandy terrain where the foundations were made through deep holes, followed bycasting the slab over basement. The sand proved to be so clear that it could be used for theconcrete and masonry works. |
| **Type of Floor System** | Other floor system |
| **Additional comments on floor system** | According to Prager(1979): Slabs are usually cast in place, cross reinforced withbeams hidden in the partition walls. These slabs were appreciated to have an exaggerated elasticity whenthe span was over 4.5-5m (they have a thickness between 6cm and 11 cm, usually 10cm). Followingalternatives were considered: - special slabs with hole brick embedded elements in Pfeifer system. Theseare 21cm thick and heavier, but can be used with good behaviour up to 6.5 m span. The ceiling isstraight. - close numerous waffles, near which "trestie" boxes were introduced. The "beams" are spaced0.62m, 25cm high while the slab itself is 5cm high. - secondary beams with false ceiling out of mortar onmetal net. |
| **Type of Roof System** | Roof system, other |
| **Additional comments on roof system** | According to Prager(1979): Slabs are usually cast in place, cross reinforced withbeams hidden in the partition walls. These slabs were appreciated to have an exaggerated elasticity whenthe span was over 4.5-5m (they have a thickness between 6cm and 11 cm, usually 10cm). Followingalternatives were considered: - special slabs with hole brick embedded elements in Pfeifer system. Theseare 21cm thick and heavier, but can be used with good behaviour up to 6.5 m span. The ceiling isstraight. - close numerous waffles, near which "trestie" boxes were introduced. The "beams" are spaced0.62m, 25cm high while the slab itself is 5cm high. - secondary beams with false ceiling out of mortar onmetal net. |
| **Additional comments section 2** | Usually, thesebuildings were designed to have two common walls with their neighbours. Thus a building can sit between twoothers in a street front or on a corner. It can form a court in the middle, opened to the street or not. |




***Layout of columns in a typical building***

## Building Materials and Construction Process

### Description of Building Materials

| Structural Element | Building Material (s) | Comment (s) |
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| Wall/Frame | clay brick masonry | bricks mark C50: averagecompression strength:(5.0-7.5) N/mm2; minimalcompression strength: 2.6N/mm2; average bendingstrength: 1.5 N/mm2; minimalbending strength: 0.75N/mm2. bricks mark C75:average compressionstrength: (7.5-10.0) N/mm2;minimal compressionstrength: 5.0 N/mm2; averagebending strength: 1.8 N/mm2;minimal bending strength:0.90 N/mm2. brick markC100: average compressionstrength: over 10.0 N/mm2;minimal compressionstrength: 7.5 N/mm2; averagebending strength: 2.1 N/mm2;minimal bending strength:1.05 N/mm2.7cm (63mm;+/-3mm)x14cm(115;+/-4mm)x28cm(240;+5/-6mm) The numbersin the parenthesis concernthe brick itself, the othersinclude the dimensions in thewall, ie with |

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| | | mortar.Infill walls haveconsiderablyimproved theseismic behaviour.Infill walls areusually 28/34cmthick at the facadeand 10/16cm thickin the partition wallsinside the building. |
| Foundations | reinforcedconcrete | |
| Floors | reinforced concrete | For the model buildingconsidered it was usually 10cm thick (also 8, 9, 11,12 cm),but where the slab surfacewas smaller due to secondarybeams, especially over thebasement it was as thin as6cm. |
| Roof | reinforced concrete | For the model buildingconsidered it was usually 10cm thick (also 8, 9, 11,12 cm),but where the slab surfacewas smaller due to secondarybeams, especially over thebasement it was as thin as6cm. |
| Other | reinforced concrete | Columns: The distribution of re-bars in the column section have beengoverned by geometrical principles rather than by structural ones (more barson the long side). Reinforcement degree has been often under 0,5%. Thereweren't provided enough stirrups at columns and the ones provided w eresimple, connecting only the corner rebars, not all of them. (according toBalan(1980)) The reinforcement has had insufficient lap splicing. 100-120kgsteel/m3 concrete (according to Prager(1979)) Preferred diametres at stirrups:6-8mm. Maximum distance between longitudinal bars: 25-30cm, mediumdistance between stirrups: 25-35cm (in badly |

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| | | executed constructions up to1m) [Balan(1980) P. 382] Beams: 1906: 1,5m3 gravel at 1,0 m3 mortar(out of 1000/700 kg cement and 1m3 sand). This leaded to 215 kgf after28 days (Prager(1979)) 1890: pure cement had 45.30 kgf/cm2 in tensionand 408.23 kgf/cm2 in compression. The mortar 1:3 had 21.62 kgf/cm2 intension and 206.78 kgf/cm2 in compression (after Prager(1979)). No datafor reinforcement distribution. 100-120kg steel/M3 concrete.Cement with rapidhardening was oftenused in order to sparecosts (short times).Such one is the Fienicement, where only 10days for concretehardening is needed.[Prager (1979)] Due tomaintenance problemssometimes concretewas spalling afterreinforcementcorrosion before theearthquake. See figures13-15 forreinforcement details. |

## Design Process

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| **Who is involved with the design process?** | EngineerArchitect |
| **Roles of those involved in the design process** | A huge number of this kindof buildings have been designed by renowned architects. They are characteristic for Bucharest's today's face, and most ofthem are to be found along the main N-S boulevard in the city. Emil Prager writes extensively in his book about thehistory of reinforced concrete in Romania about the co-operation between engineers and architects in that time (seereference). This was somehow stopped during the economic crisis, but came back to life after its end. It was this co-operation which made many reinforced concrete building initiatives possible. Both engineers and architects could beemployed by |

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| | building site organization companies. Usually one or two architects (and their employees) made thearchitecture project. The reinforced concrete projects were made by an engineer. The supervision of construction workmay be made again by the same or another engineer, or by an architect. |
| **Expertise of those involved in the design process** | |

## Construction Process

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| **Who typically builds this construction type?** | Other |
| **Roles of those involved in the building process** | |
| **Expertise of those involved in building process** | Construction works were carried out byparticular "antreprize", leaded by engineers or architects employed by the benefactors of the design works (state or,especially, private). The presence of the engineer and of the building site leader was obligatory at the casting of RCmembers, which started after the control of the scaffolding and supports and at the "reception" through "processverbal" of the metal reinforcement mounted according to the project. |
| | According to Prager 1979: The building site organization includes terms for material delivery, scaffolding, casting,removing scaffolding and co-ordination with contractual obligations. Construction machinery was especially used forfoundation works, concrete and reinforced concrete, masonry. Thus the construction time has been shortened. Till1912 concrete had been prepared manually. 14 workers needed 10-12h/cubic meter. Concrete preparation wasmechanized 120. Mobile "betoniere" 150-250l, with thermal engines, were imported. After 1929 the "betoniere" weregenerally used. Concrete was prepared on the building site, with "betoniere" up to 1 cubic metre and special cups fortransportation, maneuvered by a crane. Also used were "bob"s, "paternoster" for lifting bricks, mud and so on, and afew platform-lifts which could serve 1500-3000 kgf (lifting holes and wagons used only at building sites of big size).For lifting works the first electrical tower cranes with mobile arm appeared. The first crane of this type Wolf-Heilbron,with a capacity of 1,5-3 tf, electrically served, with a 15m arm and up to 40m working height, was used in 1929 at ablock of flats |

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| **Construction process and phasing** | building site. The transport of concrete to the work point has been usually made with wagons having thecapacity of 0,5-0,75 cubic meter, circulating on metallic rails of 500-600mm, as well as "bob" and lifts with frictiontrolleys. Through a good organization of delivery and transport castings of 25-30 cubic meter/day could be achieved.Many building sites made the concrete casting over night, especially on warm summer days. An installation to castfluid concrete with a 70m tower has been tried out at a fabrique building but found little interest for blocks of flats.1935-1940 the mechanisation is extended to other operations on some building sites throughout the country,through the appearance of surface vibrators, scaffolding vibrators and vibrating platforms. Machinery on somebuilding sites uses electricity like: - "Torkret" for shotcrete out of concrete and cement mortar - "jony" - pneumatictransporter for the transport of concrete of French fabrication. - "injection pump" for cement mortar - "electricalcirculars, pneumatic hammer, perforator" - "ecluze pneumatice" for Wolfholz pilots manually diggen through tubes infoundation works on sandy ground under water. Some enterprises did not use any machinery and had no technicalorganization. These had to save costs at material economy (cement and even reinforcement) and by letting workers work 10-12h a day. Some of these disappeared due to competition after 1930. HGV were also used. The specialisedconstruction companies has teams of qualified workers able to assure the technical realisation obligations. Figure 16shows a typical building site of the time for this structural type. It features the so-called "vertical building site" (Prager,1979), in which first the RC schelet, then the infill walls and then the finishings were erected in such a succession, thatwhen the RC members were finished at lower floors the masonry works could start at these while casting the concretefor the upper floors and when masonry works were ready at lower floors the finishing works could start at these whiledoing the casting for the uppermost floors and the masonry works for the middle ones (as shown in thefigure). The construction of this type of housing takes place in a single phase. Typically, the building is originallydesigned for its final constructed size. |
| **Construction issues** | |

## Building Codes and Standards

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| **Is this construction type address by codes/standards?** | Yes |
| **Applicable codes or standards** | - control methods -. The year the firstcode/standard addressing this type of construction issued was 1932 prescriptions, 1941 precode. 1932 - prescriptionswhich spread fast: - granulometric study of the aggregates: a/c relation; - probes on cubes at 28 |
| **Process for building code enforcement** | |

### Building Permits and Development Control Rules

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| **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** | 1936 the master plan of Bucharest, one of the most innovative from that time appeared and this has prescribed thebuilding rules. 1,2m recesses above a certain height have been prescribed in that regulations, for example, in order tolower street shadowing by high buildings. The height itself has been also prescribed, and there were prescriptionspermitting a relatively high ground floor occupancy. The commercial ground floors have been supported by theregulation. Prager (1979) P. 90-96: After 1908 the main problem was the division of legal responsibility for the successof the works for which the owner has employed the architect as general designer and which had the responsibility ofchoice of the specific designer and of the supervision of works. This initial phase was influenced by the honorary quotefor the reinforced concrete works design, which had to be stated by the architect. At that stage collegial agreements weremade. After 1918 the signature of an engineer on the authorisation (permit) plans was required by the municipalservices. |

### Building Maintenance and Condition

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| **Typical problems** | |

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

### Construction Economics

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| **Unit construction cost** | This type of multiple housing units are not build any more. After Prager (1979): The reinforced concrete schelet didcost 12-15% of the complete construction cost. This is why prefabrication of metal parts after western model has notbeen practiced so much. The cast in place system was also chosen due to the low cost of the timber for scaffoldingworks and the lower cost of working force due to the mechanization of casting works. No data are available about theabsolute cost of such a building. However, Prager (1979) gives some figures about the costs variation: Average costsindices: - a block of flats at 1000 cubic meter built volume, with RC schelet: 1933 (100%), 1934 (102%), 1935 (104%),1936 (110%), 1937 (120%), 1938 (127%), 1939 (137%), 1940 (187%), 1941 (298%), 1942 sem. I (426%) - a singlefamily house type "The Society for Cheap Dwellings" Bucharest: 1933 (100%), 1934 (100%), 1935 (106%), 1936(108%), 1937 (115%), 1938 (119%), 1939 (128%), 1940 (174%), 1941 (269%), 1942 sem. I (370%) Between 1926-1927material prices increased, transportation means were lacking and inflation leaded to variation in the price of workingforce. After Prager (1979): A well organized construction enterprise had clear advantages. The high cost of themachinery described at 7.3 as well as the missing continuity of work on building site and the maintenance and useexpenses determined that the "small mechanization" developed only in special works, where their necessity wasobvious. |
| | Some buildings have been constructed with great spread. An example: at a block of flats with 6 floors: 2weeks for a floor of 600 sqm, the whole building being finished between June and November 1925. Availability oftechnology after Prager (1979) p. 456: For scaffolding antique means of wooden works were used. Bending andbinding with wire of reinforcement bars was fast learned by the workers. It also did not need extensive work, |

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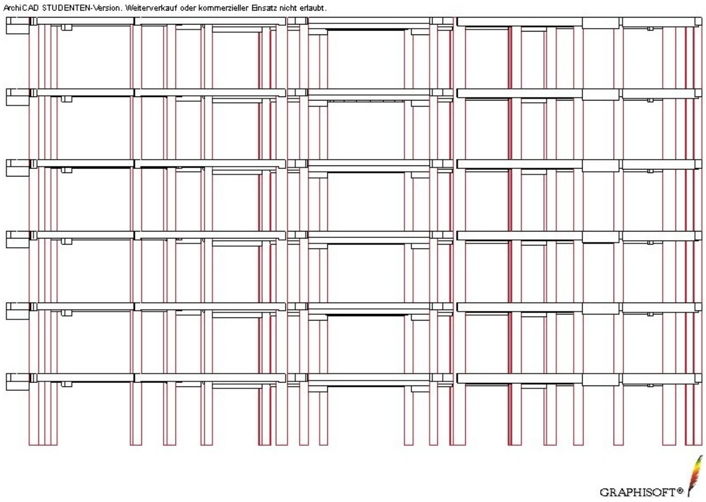
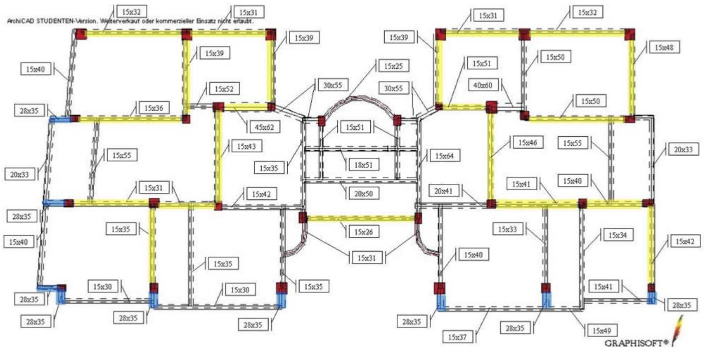
| **Labor requirements** | sincethere were less than 100-120 kg steel/m3 concrete. Preparing of concrete out of local aggregates was fast learned by theconstructors, as it was similar to the preparation of mortar. Casting of concrete was a new technique, but fast learned,and made easier by different successively created mechanisms. The key of the success was the quality of works, all detailsregarding the dimensions of the elements (scaffolding) and supporting the weak concrete in formwork till hardening,the dimensions and the plan of the steel reinforcement. This had to be assured by the civil engineers, fast educated andspecialised. The Romanian engineers were quite well informed about the technical progress in the Occident. After 1910they were almost exclusively educated in Romania. Technical construction work force was well qualified and available insufficient number for wooden works, masonry works, concrete works. The seasonal unqualified work force wasinsufficient. The reputation of the construction enterprise was definitory for the engineers working for, which in manycases could organise on the building sites without prescriptions or mandatory norms the succession of construction,the mix and casting of concrete, and to respect the deadlines which were generally sufficient for hardening during thespecific climatic conditions of the year. |
| | Prager (1979) p. 184-185 provides a list of the publications used 1907-1918 for the design of reinforced concretebuildings. That time there were no tables or similar to make computations easier. The methods for elasticcomputation of RC frames were neither known nor used. After 1918 following tables were used: - [Beton Kalender] ="Concrete Calendar" - in German (1903) - Bazali Marian: [Tabele pentru placi] = "Tables for slabs" - in Romanian(1907) - Wesse: [Tabele de calcul] ="Calculation tables" - in Romanian (1912). Also elastic computation methods areused. Beams are designed very carefully. Between 1907-1918 had been used, according to Prager (1979) P. 183-185: - Ing. M. Koenen: [Das sistem Monier, in seine Anwendung] = "The Monier sytem, in its use" - in German (1887) -Prof. P. Christophe: [Le beton arm et ses applications] = "The reinforced concrete and its use" ? in French (1899) -Prof. E. Mrsch: [Der Eisenbetonbau] = "The Iron-Concrete-Construction" - in German (1902) - Prof. R. Saliger:[Der Eisenbetonbau, seine Berechnung] = "The Iron-Concrete-Construction, its calculation" - in German (1906) -Prof. M. Foerster: [Das Material und die statische Berechnung] = "The material and the |

| | |
|---|---|
| **Additional comments section 3** | statical calculation" - inGerman (1907) - Ing. C. Kersten: [Der Eisenbetonbau] = "The Iron-Concrete-Construction" - in German (1908) -Ing. Ejner Bjrnstad: [Die Berechnung von Steifrahmen] = "The calculation of rigid frames" - in German (1909).Between 1920-1926 design offices specialised in reinforced concrete appeared. Construction works were carried out byparticular "antreprize" like: "ing. Constantin M. Vasilescu", "Societatea de Beton si Fier" (founded 1906), "Antreprizaing. Tiberiu Eremia", "Societatea Edilitatea", "Societatea Unirea", "Societatea Constructia Moderna" etc. They wereorganised for such works. Some owned modern specialised machinery, personal for technical leading, for steel, iron,scaffolding, wood works, repairing. They employed well formed masters for different working branches, on salary orhour base. There was a licitation system at state works based on guarantees, sometimes with invitation to licitation by"antreprize" verified for the technical capacity, the machinery inventory and the financial means. 1865 the "LegeaContabilitatii Publice" stated the rules for getting contracts, making payments and receiving ("receptie") the work. Thegeneral conditions were updated 1894. On the building sites there were technical control methods for the quality ofaggregates, water, cement. Strength trials are made for compression on concrete cubes. Trials for break of reinforcedconcrete beams are also made. 1932 building site laboratories appeared, which monitored the quality of concrete andaggregates but only at public works. Further data about the progress in reinforced concrete design of the time aredescribed by Prager (1979), p. 481-483. For a list of publications see 4.2. To the authors knowledge as frames aredefined as a beam supported directly by two columns, which was very rarely the case in such constructions due tobeams outside the axis and/or reduced section of the elements (see figure &, also pointed out in Balan (1980) P. 234).Balan (1980) additionally points out that the node reinforcement was designed for gravitational loads only,theoretically following the German circular from 1925 (P. 234 Balan (1980), P. 274 Prager(1979)), later method Cross.Also to the authors knowledge and supported by other research (ex. Penelis & Kappos (1997)) infill walls haven't beenconsidered in computations until recently. Infill walls arranged as one single brace are mention ed in the contemporarycode (P100-92). More even, it is known that the constructions of the time were designed as much more flexible as |

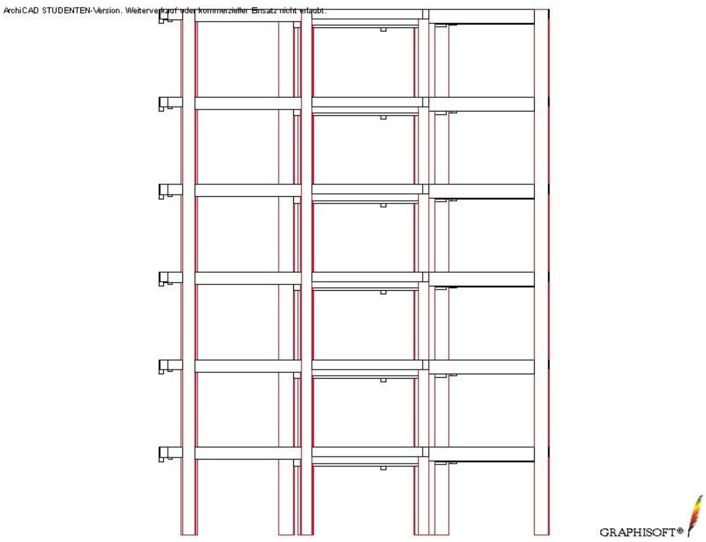
theyproved as the masonry infill was not taken into consideration (see Balan (1980) P. 235). According to Prager (1979): Some buildings have been constructed with money gathered from the future owners, butsome are simply money investments in central blocks of flats for speculation. Urban population has grown and rentwas high. Thus, many people wanted to own housing and this encouraged speculation. During the increasedconstruction activity 1936-1940 speculation characteristics grew. The construction enterprises had a technical commercialorganisation based on large bank means or own funds. The competition leaded to economies at cement and steel.Sometimes works did not get finished. Especially between 1918 and 1932 the housing construction activity has beenaccentuated by important capital investments attracted by real estate speculations. As described by Prager (1979) in the boom time (1933-1942) the dimensioning was made following the Germanprescriptions from 1916 and 1932 as well as [Prima lectie de beton armat] = "The first reinforced concrete lesson" inRomanian (1903) transformed in 1914 into [Curs de beton armat] = "Reinforced concrete course" in Romanian and1930 into [Conferinta de beton armat] = "Reinforced concrete conference" (in Romanian). Until the 1940 earthquakethe design was made based on the German circular, which stipulated computation for gravitational and wind loads.After the 1940 earthquake, which leaded to heavy deteriorations at numerous buildings throughout the country, theMinistry of Public Works made a commission with the duty to elaborate the obligatory prescriptions for thecomputation and design of reinforced concrete works. The first provisional guidelines, preceding codes appeared 1942.The prescriptions published 1942 contained directives and dispositions very valuable for the design and realisation ofconstructions with reinforced concrete structure, obligatory for the design engineers which had to sign the permitprojects. Especially the fall of the "Carlton" building, a block of flats of this type but with cinema at the lower floors,based on the "Consiliul Tehnic Superior din Ministerul Lucrarilor Publice" (The Superior Technical Council of thePublic Works Ministery) the "Instructiuni pentru prevenirea deteriorarii constructiilor din cauza cutremurelor"(Instructions for preventing the deterioration of constructions due to earthquakes) was published in "MonitorulOficial" no. 120 from May 1945. After that this type of buildings has been continued in a slightly different manner, asdescribed in report #71.



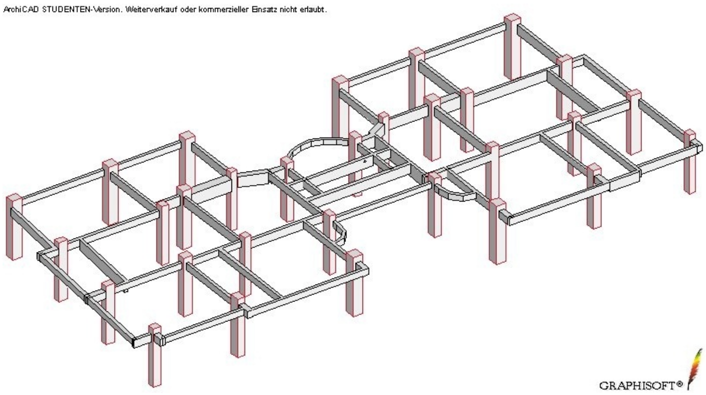

***Longitudinal view of load bearing elements***



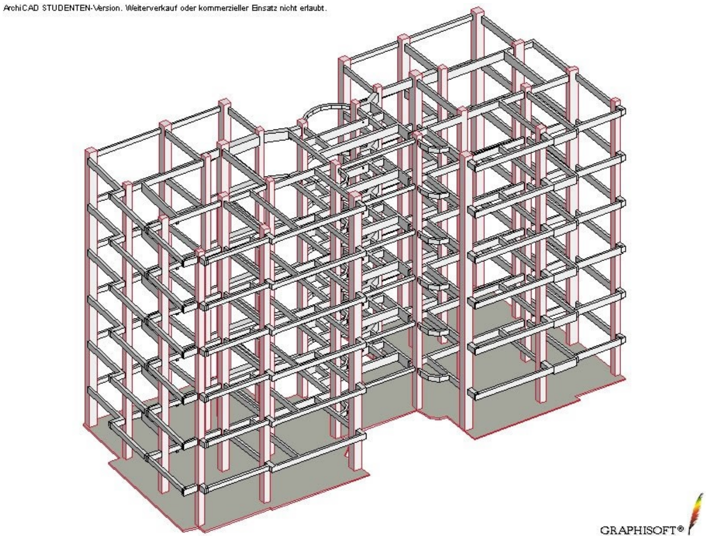

***Layout of beams and columns in a typicalbuilding. Note that only few (the yellow ones) form frames.***




***Transversal view of load bearing elements***

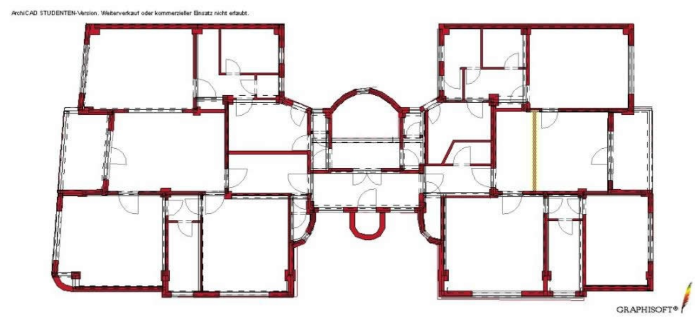



***"Schelet" of a current floor.***

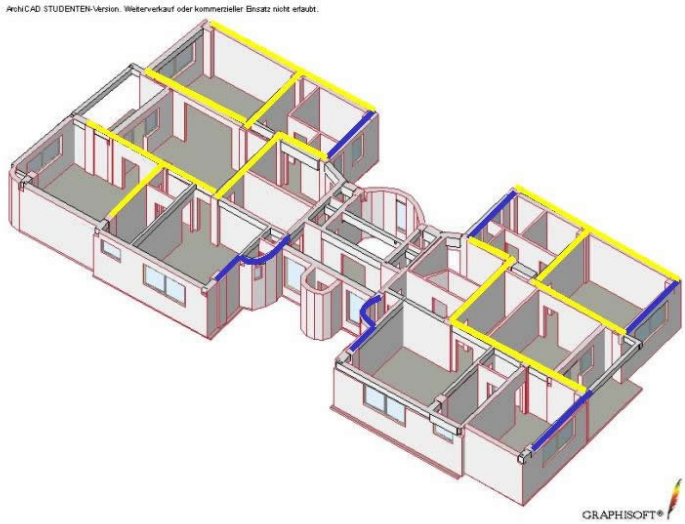



***Beam-column schelet for the wholebuilding.***

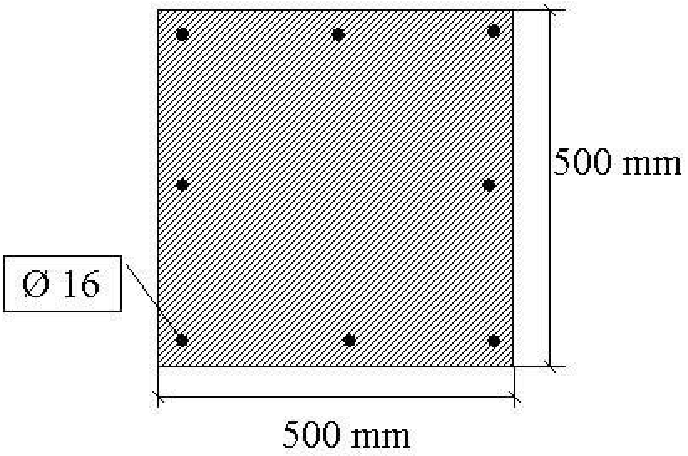
***Side wall of a typical building (fromBostenaru(2004))***



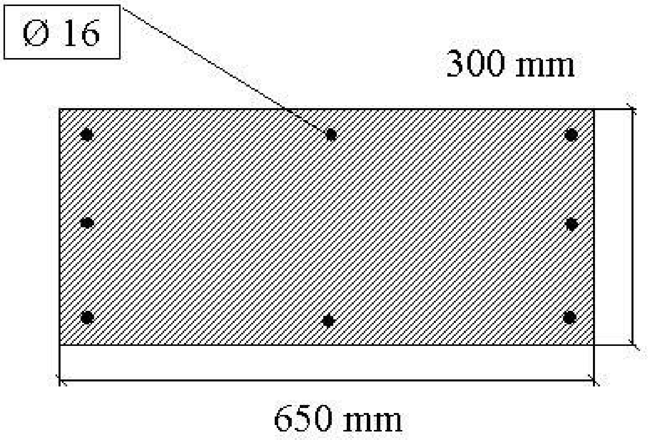

***Architectural plan of a current floor(after Bostenaru(2004)). Yellow marks newpartition walls.***




***Axonometric view of a current floor.Frames infilled with 34cm masonry are markedwith blue, frames infileld with 10-15cm masonryare marked with yellow in the section plane.***

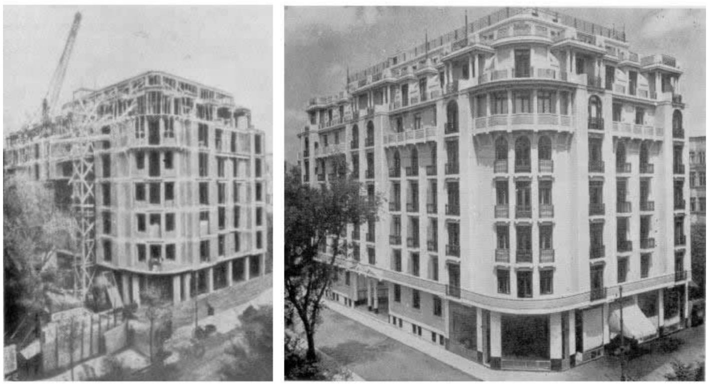



***Reinforcement detail of a typical squarecolumn. (from Bostenaru(2004))***

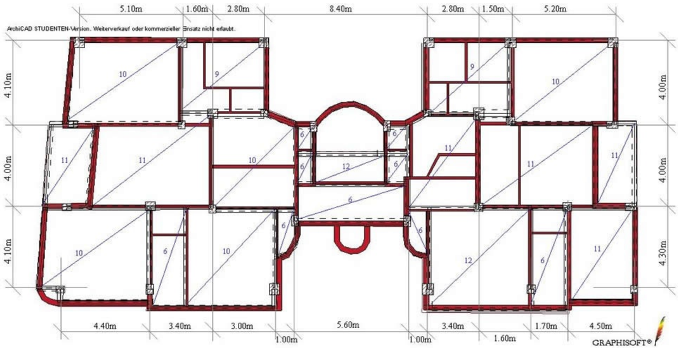



***Reinforcement detail at a rectangularcolumn. Note that the geometric characteristics,not the physical ones, have been taken intoconsideration at the distribution of the bars.***

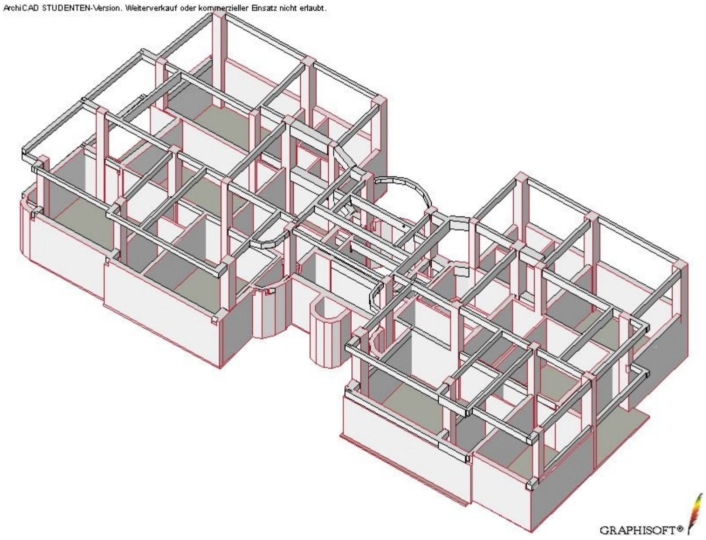
***Structural detail***



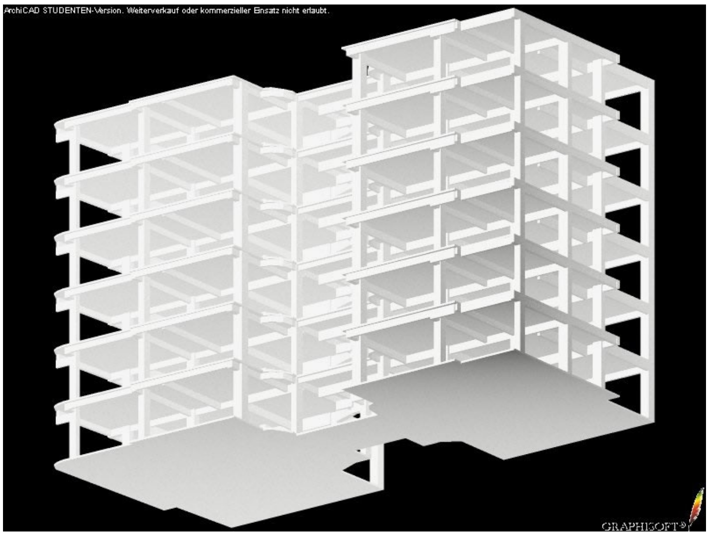
***Construction site of a building of similartype (after Prager(1979), Figures 7.4.9. on p. 144and 7.4.10. on p. 145, featuring on the left theorganization of the building site at block of flats"Spicul" and on the right the finished block)***



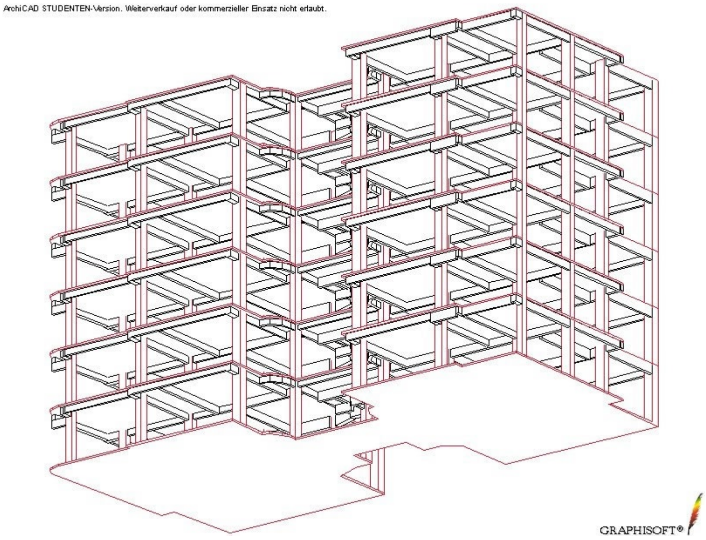

***Floor plan including the load bearingelements as masonry walls and slab thickness(blue), as well as the spans. (afterBostenaru(2004))***




***Axonometric view of the relationshipbetween load bearing elements and masonry walls(from Bostenaru(2004))***




***Load bearing structure of a typicalbuilding (from Bostenaru(2004))***




***Axonometric view of load bearingelements, not rendered***

## Socio-Economic Issues

| | |
|---|---|
| | Usually one family (about 4 persons) in a housing unit.The housing units are of various sizes.Each building typically has 21-50 housing unit(s). 25 units in each building. For the highest vulnerability class thenumber of housing units ranges between 3 and 104 for a building. Half of them have between 16 and 31housing units. For the purely residential ones out of these (53) several values have been computed: - storey: average7.37 (the closest is the Frida Cohen building of architect Marcel Iancu with |

| | |
|---|---|
| **Patterns of occupancy** | 53 flats), min 5.5 (for 3 buildings from 1933with 17 flats, from 1936 with 10 flats and from 1935 with 20 flats), max 10 (for a building from 1940 with 28 flats); -number of flats: average 23.2 (with the closest a building from 1929 with 22 flats on 7.5 storeys), min 6 (for twobuildings of 1300 respectively 1280 sqm, both from 1935 and both with 6 storeys), max 83 (for a building with 13670sqm on 8 storeys from 1938); - surface: average 3092 (the closest building being the Frida Cohen building), min 918(for a building with 8 flats on 6 storeys from 1938), max 13670; - flats/floor: average 3.17, min 1 (for two buildingsfrom 1935 with 6 floors each, one with 1300 the other with 1280 sqm), max 10.38 for the big building mentioned (83flats); - surface/flat: average 141.58 (for a building from 1940 with 36 flats on 7 floors), min 76.41 (for a building from1933 with 17 flats on 5.5 floors), max 234.26(for a building from 1940 with 19 flats on 9 floors); - surface/floor:average 418.94 (for a building from 1939 with 31 flats on 7.5 floors), min 153 (for the building with the smallestsurface), max 1708,75 (for the building with the biggest surface). Not so highly vulnerable buildings have between 3and 42 housing units, most of them either 10 or 25, depending on the number of floors. The model building chosenhas 12 residential units. |
| **Number of inhabitants in a typical building of this construction type during the day** | Other |
| **Number of inhabitants in a typical building of this construction type during the evening/night** | Other |
| **Additional comments on number of inhabitants** | |
| **Economic level of inhabitants** | High-income class (rich) |
| **Additional comments on economic level of inhabitants** | These buildings have been designed as luxury residences. They were taken over in state property in the communismtime and have been recently given back to their previous owners. |
| **Typical Source of Financing** | Combination |
| | According to Prager(1979): The state and public administration built little, apartfrom reparation |

| | |
|---|---|
| **Additional comments on financing** | works after WWI and some blocks of flats from the social assurance fond. After 1929 andthe monetary reform investments were made into blocks of flats especially from richer people from theprovince wishing to move to the capital. They were supported by bank credits. Especially in the sustainedactivity after 1929 the urban housing was built on credit base. More future owners contributed to the construction financing. |
| **Type of Ownership** | Units owned individually (condominium) |
| **Additional comments on ownership** | This time a characteristic urban housing type develops: the block of flats withresidences under the same roof, constituting the common property of a civile association, ruled by aspecial law of common use. |
| **Is earthquake insurance for this construction type typically available?** | No |
| **What does earthquake insurance typically cover/cost** | |
| **Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?** | Off |
| **Additional comments on premium discounts** | |
| **Additional comments section 4** | |

## 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** | Damages in the 1940 earthquake occurred accidentally and at isolated buildings (after Prager (1979)): - fall of finishingplates, infill walls - end of columns at the part where it is embedded into the slab as that is the place of the castingjoints, where the reinforcement is not continuous and the solicitations out of bending are maximal. The maximumstresses were 60-80 kgf/cm2 (more than the maximum limit in the German circular used for design that time). - moveof the vertical reinforcement to the centre of the section - significant damages were noticed at reinforced concretebuildings with consoles (bow-windows), at the beams which were supported by beam parts and at the infill walls ofreinforced concrete schelet made after the structure was ready and thus not conlucreting with that. - damages alsooccurred due to interventions at the load bearing structure following the introduction of installation pipes. --------------------------------------------------------- Most of the damaged blocks in the 1977 earthquake have been L shaped, with thecorner higher than the rest of the building. After Balan (1982) : There have been old buildings with reinforced concreteskelet which, also not designed for seismic loads, behaved correspondingly, due to clear constructive schemes, havingcolumns and beams with larger sections, corresponding reinforcement and built out of concrete of better quality. It isknown that such buildings, even if not dimensioned specially for horizontal forces (out of wind or earthquakes) havethough a certain anti-seismic strength capacity provided on one side by the strength reserves of the reinforced concreteskelet, well designed for gravity loads, and on other side from the strength reserve of the infill masonry walls, especiallywhen these are well filled into the columns and beams of the skelet and realised with high quality mortar (with mudand cement). Observed damages according to Balan (1980): at columns: - rifts of different sizes in concrete, usually atcontour or corner columns, with inclined orientation and sometimes huge concrete spalling resulting from shear; -concrete crushing, especially at one end of the column, at ground floor or first floor level, |

| | |
|---|---|
| | associated sometimes withsecondary shear and mostly by buckling of re-bars and concrete "expulzare" on one or two faces in the action sense ofthe earthquake, till complete damage of the concrete section and column collapse from compression associated withoblique flexure. at beams: - rifts near supports, vertically, at 45 or slightly variable and closer to horizontal, in thelength of the beams; the rifts have relatively small openings, but sometimes they are till 1mm; - crushing ofcompressed concrete at the lower face of the beam, near supports, or even in the span, sometimes with buckling oflongitudinal reinforcement. In the 1977 earthquake 13 pre-war RC building collapsed totally and 10 partially(accordingto Lungu et al., 2000a), compared to 5 pre-war masonry buildings and 3 new RC buildings. They were constructedbetween 1905 and 1946 and were GF+6S till GF+13S high. With two exceptions their main function was housing(between 12 and 89 housing units a building, average 40). The area of the buildings ranged between about 1000 andabout 8500 sqm (average at 4500), with 150 to 800 sqm/storey (average 450). There were 2 to 10 flats with an averageof four on a floor with the area of a residential unit of between 50 and 175 sqm (average 100 sqm). The figures werecomputed using 14 buildings of those collapsed. 10 of these collapsed totally. To the author is known that at least 6 ofthem had commercial occupancy of the ground floor so they are not subject of this report. The ratio partial/totaldamage was unevenly distributed with height. |
| | Strong rifts, dislocation, X rifts in piers. SOFT STOREY: "svelte" columns: - concrete destroying and spalling/buckling oflongitudinal reinforcement at plastic articulations (shear damage in figure 21, bendingdamage in figure 22) Basement: corrosion of reinforced steel. Columns at ground, 1stand 2nd floor are damaged from previous EQs ---------------------------------------------------- middle and short columns: - brittle breaks with oblique 45 rifts sectioning thecolumn ? detaching of transversal reinforcement in oblique dislocation of columns >CAN DIRECTLY COLLAPSE ? rifts or brittle breaks from interaction with stairs(shorter working height) > AFFECT GENERAL STABILITY ---------------------------------------------- CURRENT STOREY: - horizontal rifts immediately under or overthe beam perpendicular on column axis (fig. 23), concrete spalling (fig. 22), bucklingof longitudinal reinforcement (fig. 21- 24), |

| | |
|---|---|
| **Additional comments on earthquake damage patterns** | possible hazardous plastic articulations (fig21-24). Sometimes only the outer concrete, much weaker, spalls. (figure 23, acolumn on the second floor) - oblique X rifts --- especially for this kind of buildings:rifts of different sizes with concrete dislocation, destruction at end in GF and 1 F(corner column in figure 26), break of concrete section with reinforcement bucklingat the end of columns (fig. 21, 24, 25) and some brittle breaks with oblique rifts inGF and lower floors (figure 24) rifts in all RC elements (synthesis for theobservations in Balan (1980)) Pounding damage (figure 26) LONG BEAMS: plastic articulation, rotation near node with rifts at upper and lowerpart; concrete failure only at lower side SHORT BEAMS: rifts in oblique sectionsopening the beam in whole height from the lower side with isolated dislocationsboth not dangerous oblique rifts have brittle character -- characteristic for this type ofbuilding: - 0-45 rifts at end, sometimes buckling (synthesis from the observationsin Balan (1980)) ROOM SLAB less rifts in old RC frame buildings BALCONIES: less rifts in old RCframe buildings STAIR FLIGHTS: less rifts, more at the change of stair flights in oldRC frame buildings (synthesis from the observations in Balan (1980)) |

## Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.

| Structural/Architectural Feature | Statement | Seismic Resistance |
|---|---|---|
| Lateral load path | The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation. | FALSE |
| Building Configuration-Vertical | The building is regular with regards to the elevation. (Specify in 5.4.1) | FALSE |

| | | |
|---|---|---|
| Building Configuration-Horizontal | The building is regular with regards to the plan. (Specify in 5.4.2) | FALSE |
| Roof Construction | The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area. | 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. | FALSE |
| 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); | N/A |
| Foundation-Wall Connection | Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation. | TRUE |

| | | |
|---|---|---|
| Wall-Roof Connections | Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps. | FALSE |
| Wall Openings | | N/A |
| Quality of Building Materials | Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate). | FALSE |
| Quality of Workmanship | Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards). | TRUE |
| Maintenance | Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber). | FALSE |

## Building Irregularities

| | |
|---|---|
| **Additional comments on structural and architectural features for seismic resistance** | |
| **Vertical irregularities typically found in this construction type** | Other |
| **Horizontal irregularities typically found in this construction type** | Other |
| **Seismic deficiency in walls** | Some of them are located onconsoles of the facade. They aretwo heavy and supported bysecondary beams only. Collapse offacade infill walls may be fatale forthe building equilibrium and lead tocollapse under the subsequenttorsion effects. (as described forthe Calrton building |

| | |
|---|---|
| | inPrager(1979)) |
| **Earthquake-resilient features in walls** | Beneficialeffect ofinfill wallsthat save thestructures ofbeingcollapsed byincreasingtheir lowstiffness. |
| **Seismic deficiency in frames** | Columns: Do not form moment resistingframes with the beams. Executionaccidents may affect columns:deviations from verticality,sometimes due to irregular andunfavorable section shapes (long"svelte" rectangles). In somebuildings constructed speculativelythe cement and the reinforcementmight not be sufficient.Prager(1979) quotes as cause forthe damages in 1940 earthquake: -0,6% or less reinforcement alsowith steel bars of less than 10mmdiametre for buildings - missingconnection of the columnreinforcement to that of the inferiorfloor (lap splicing) - missingstirrups or fallen down stirrups(free translation after afterPrager(1979))Beams: Do not form moment resistingframes with the beams (many ofthe beams in at least one directionare secondary beams).In somebuildings constructed speculativelythe cement and the reinforcementmight not be sufficient. (freetranslation after Prager(1979)) |
| **Earthquake-resilient features in frame** | Most beams are reinforced andrealised carefully. (afterPrager(1979)) |
| **Seismic deficiency in roof and floors** | Simple slab floors may be tooelastic when spans are over 4.5m.Construction deffects may lead tonot-plane effects. In somebuildings constructed speculativelythe cement and the reinforcementmight not be sufficient. (after Prager(1979)) |
| **Earthquake resilient features in roof and floors** | Alternativesolutions forslab rigidityhave beenlooked forand appliedin somecases(embededhole bricks,wafflesystem). |
| **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

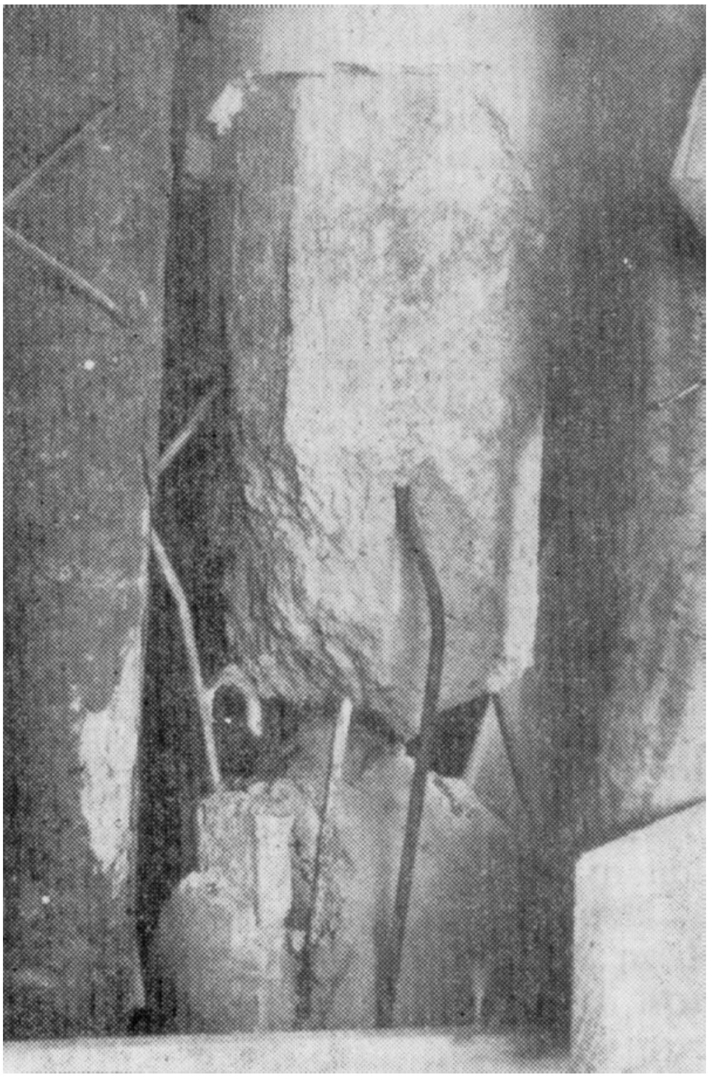
| | High vulnerability | Medium vulnerability | Low vulnerability |
|---|---|---|---|

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Seismic vulnerability class | \|- | | o | -\| | | |

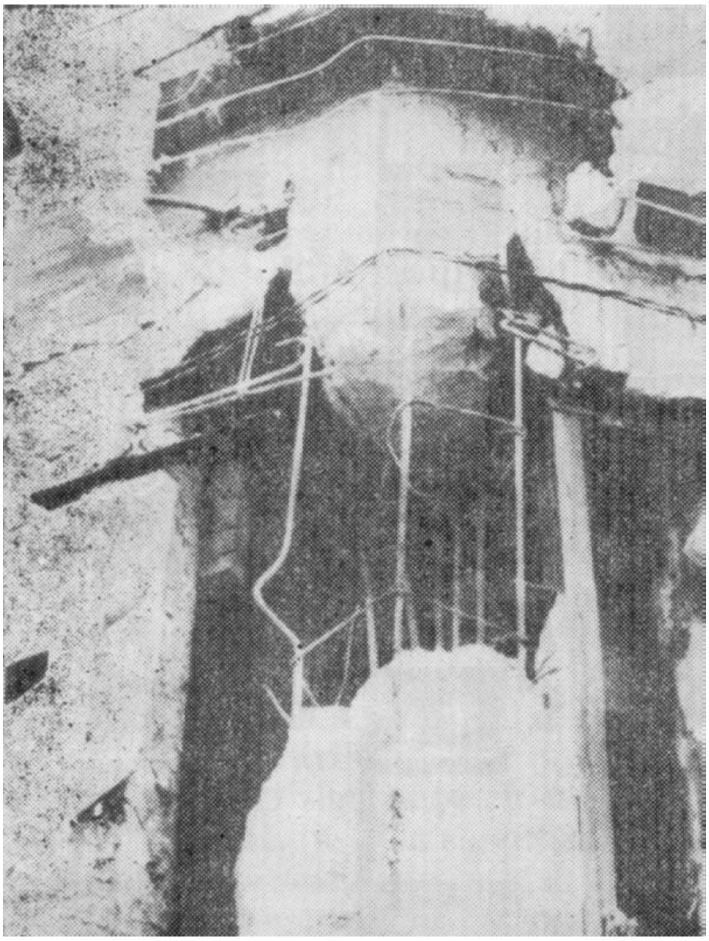
***Column destroyed in shear at laterdemolished building (see Balan, 1980: FigureVI.18.b. on page 246)***

***Bending damage at lower node of acolumn at the same building as image #6 (seeBalan, 1980: figure VI.19.a on page 246)***

***Bending damage at upper end of acolumn in a block with partial collapse (see Balan,1980: Figure VI.19:b. on page 246)***



***Column broken in the lower node,after complex solicitations. The lack of stirrups canbe clearly seen. (see Balan, 1980: figure VI.20.b. onpage 247)***



***Corner column, destroyed on ~1mheight at the upper part (see Balan, 1980: fig.VI.20.c. on P. 247)***

***Ground floor column, destroyed due topounding with neighbouring building (see Balan,1980: figure VI.20.d. on page 247)***

## Retrofit Information

### Description of Seismic Strengthening Provisions

| Structural Deficiency | Seismic Strengthening |
|---|---|
| damagedRCcolumns | local repairing after (fracture)+crush+spall+(yield)+crack (fig. 28) 1. Breaking up masonry around the column; 2. Taking over loads fromthe column with bolts; 3. Breaking up concrete; 4. Disposing removed concrete; 5. Cutting damaged portions of the reinforcement; 6.New reinforcement; 7. Treatment of the concrete and reinforcement surface; 8. Making and mounting new stirrups; 9. Anchoring of stirrups to the re-bars; 10. Scaffolding (fig. 27); 11. Casting concrete; 12. Removing scaffolding; 13. Plastering inside and outside. (fromBostenaru(2004)) |
| deeplydamagedRC beams | local repairing after (fracture)+crush+spall+(yield)+crack (fig. 31) 1. |

| | |
|---|---|
| | Removing plastering; 2. Removing floor finishing; 3. Reducing thecurvature; 4. Breaking up concrete; 5. Disposing of broken up material; 6. Cutting of damaged reinforcement; 7. Boring holes in the slab(10x10cm); 8. Surface treatment of concrete and reinforcement; 9. Cleaning the surface; 10. Mounting new reinforcement; 11. Mountingnew stirups; 12. Anchoring of stirups to re-bars; 13. Scaffolding; 14. Casting concrete; 15. Removing scaffolding; 16. Plastering; 17.Repairing of floor finishing. (see Bostenaru(2004)) |
| superficiallydamagedRC beams | Repairing with plating with woven glass embedded in epoxy resins. (fig. 36): 1. Removing plastering; 2. Mechanical hole bore; 3. Injectionof rifts; 4. Plating with weaving; 5. New plastering. (c) INCERC(2000) further documents following details: injection of rifts up to 3mmopening with epoxy resins on 15cm depth, 2cm bore holes and Rooving type weaving. |
| Rifts inmasonryinfill walls | Injecting masonry walls: 1G/R. Removing plaster; 2G/R. Widening the rift with hammer and chiesel, hole making; 3G. Cleaning the rift;4G/3R. Injecting rifts with cement mortar; 5G. Transport of break off plaster to rubbish container; 6G. Disposal of removed plaster;7G. Minitray and transport to rubbish deposit; 8G/4R. New plaster. (see Notes) |
| Reducedcolumnsection---Reducedbeamsection | R = Column jacketing; G = side walls (see Notes): 1G. Scaffolding; 2G. Screening; 3G. Building up and removing drop tub; 1R.Removing inside and/or outside plaster; 2R. Removing floor finishing; 3R. Breaking through the slab; 4G/R. Knocking off the masonrywall around columns; 5R. "Spituire" concrete; 6R. "Suflare" with compressed air (Shotcrete); 5G. Relieving the column through pins; 6G.Cleaning up the masonry; 7R/G. Reinforcement works; 8R/G. Mounting reinforcement 120kg/mc out of PC52 8-28mm(for jointcolumns not just bars but also L profiles 40x40x4mm); 9G/10R. Formwork; 10G/11R. Casting B300 concrete; 11G. Removingformwork and pins; 12aR. Interior plastering; 12bR. Exterior plastering; 13R. Repair of floor finishing; evtl. 14R. Filling the joint. R =provisions as described by (c) INCERC(2000) for typical Romanian buildings while G = provisions as developed with Bourlotos(2001)for typical Greek buildings. See figure 29 for this measure. See figure 30 for an alternative measure with rigid reinforcement. See figures37-43 for position of jacketed columns in the model building retrofit solution. ---beam jacketing in different ways: RC jacket (fig. 32); concrete plating (fig. 33); jacketing with stiff profiles (fig. 34); plating with steel |

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| | fixedwith epoxy resins (fig. 35). |

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| **Additional comments on seismic strengthening provisions** | Strengthening of New Construction :Insufficientstiffness- Adding structural walls: 1G. Scaffolding; 2G. Screening; 3G. Building up and removing drop tub; 1aR. Removing outside plaster; 1bR.Removing inside plaster; 4G/2R. Knocking off the masonry wall; 5G/3R. Breaking through the slab; 6G: Cleaning up masonry; 4R."Spituire" concrete; 5R. "Suflare" with compressed air; 7G/6R. Reinforcement works 120kg/mc (OB 37 D=6-8mm; PC52 D>10);8G/7R. Anchoring the reinforcement into the existing RC frames; 9G/8R. Formwork for shearwalls and evtl. columns; 9R. Bindinganchors between masonry walls and shear walls; 10R. Mounting the binding anchors; 10G/11R. Casting concrete in shear walls andevtl. columns; 12aR. Interior plastering; 12bR. Exterior plastering; 13R. Repair of masonry. (see Notes) See figures 37-43 for position ofnew walls (either in existing frames as in the Greek provisions or with new boundary elements as in the Romanian provision) in themodel building retrofit solution. |
| **Has seismic strengthening described in the above table been performed?** | Yes.The exact number of retrofitted buildings is unknown, but from the ones (110) today listed for the firstcategory of risk 92 have been retrofitted totally after the 1977 earthquake, and 43 of them are purelyresidential. The Retrofit methods used at the residential buildings were: masonry repairs, jacketing ofbeams and columns, mortar injections, finishes, epoxy resins injections.Some of them have been previously retrofitted after the 1940 earthquake. Retrofitting after the 1940earthquake or after bombing was usually local reinforced concrete jacketing. Emil Prager(1979) describessuch a measure at p. 426-427. At a block of flats with 7 floors in the city centre the perimetre columns andthe ones at the corner suffered permanent displacements of 8.5-11cm vertically. The proves madeafterwards showed some dimensioning errors of the project. The retrofit was made through replacingsome of the damaged columns through metalic columns supported by RC "cuzinet", through jacketingand "fretare" of the rifted ones and through the retrofit of rifted beams with metalic profiles welded to thereinforcement. The works were performed between November 1940 and March 1941. To perform theretrofit the building has been lifted by 8 hydraulic presses of 100 and 200 tf. According to Balan (1980) P. 235 the main measurestaken after the 1940 earthquake |

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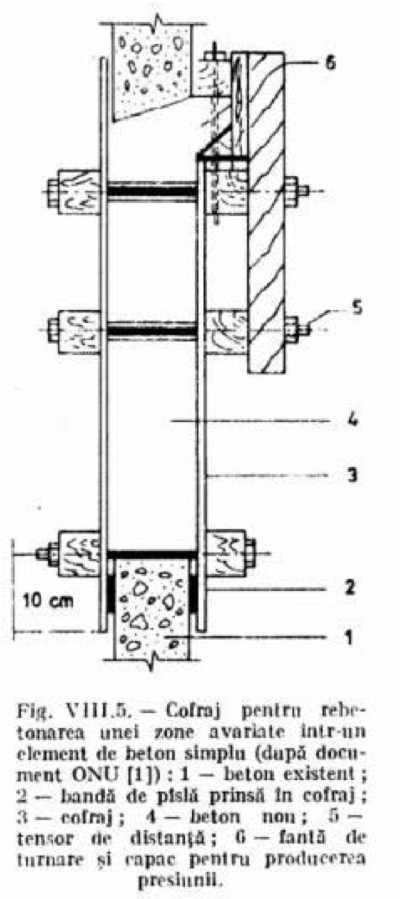
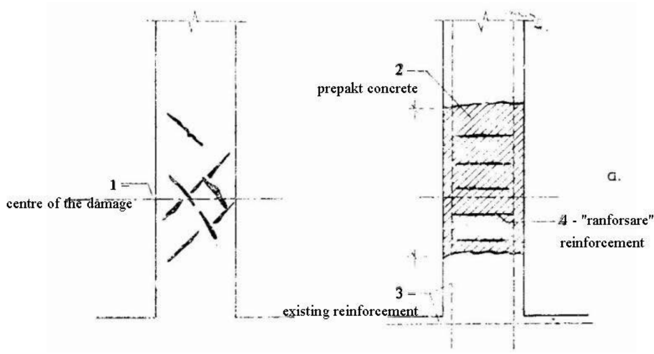
| | have been repairing measures, which haven't even reestablish the state before theearthquake. |
| **Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?** | Most works until today have been made following earthquake damage. The srengthening prescribedtoday is thought to be a mitigation effort. |
| **Was the construction inspected in the same manner as new construction?** | No, but the inspection determining the risk class today is thought like that. |
| **Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?** | Contractor |
| **What has been the performance of retrofitted buildings of this type in subsequent earthquakes?** | After the repair measures following the 1940 earthquake buildings preformed rather poorly in the 1977one, as there were only small scale reparations.In the case analysed by Prager(1979) described above 60% of the permanent displacement was reducedand the building was considered to be brought to the initial state. There are no data about theperformance of this particular building in the 1977 earthquake.In the earthquake from 1940 one building withcommercial occupancy collapsed and further 8 of this construction type, some with commercial occupancy, somewithout have been severely damaged. The damages were rifts and breaks in the columns of the ground floor andsometimes of first and second floor. Some of them have been partially retrofitted and many of them collapsed partiallyor totally in the 1977 earthquake. [Balan (1980) P. 237, further reference Beles(1941)]. Details on the behavior of suchbuildings with commercial ground floor is not object of this report. |
| **Additional comments section 6** | For measures 4, 5 and 7: R = provisions as described by (c) INCERC (2000) for typical Romanian buildings while G =provisions as developed with Bourlotos (2001) for typical Greek buildings. The highly irregular structures withoutproper stiffening elements of highest vulnerability are mainly repaired, not strengthened. Retrofit works arebeing carried out (fig. 44). After the 1977 the main retrofit method has been jacketing of beams and columns. The restof the interventions was reduced to repairing of masonry (mainly with mortar injections), of RC members (mainlywith epoxy resin |

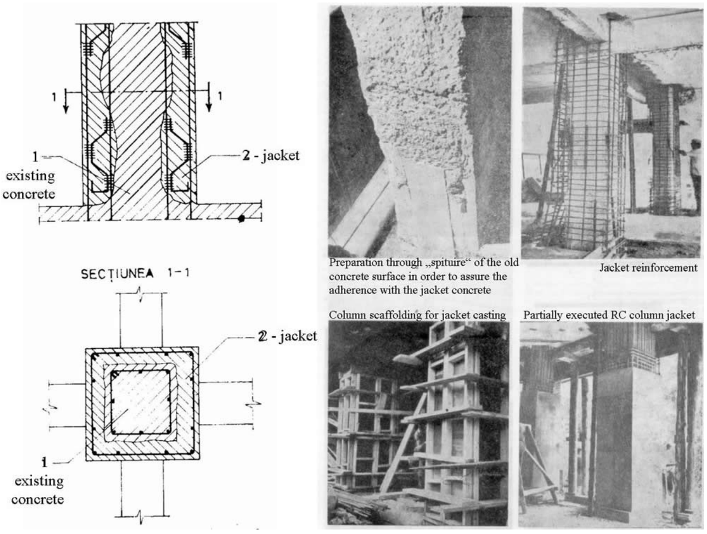
injections) and of finishings.



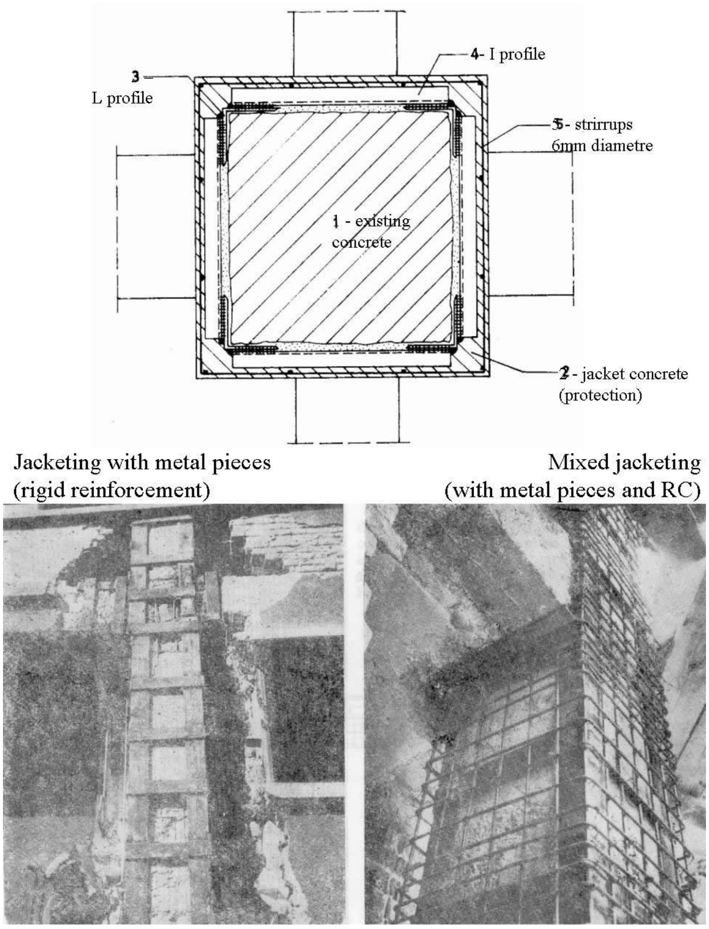

***Scaffolding for repairing a damaged zonein a concrete member.***



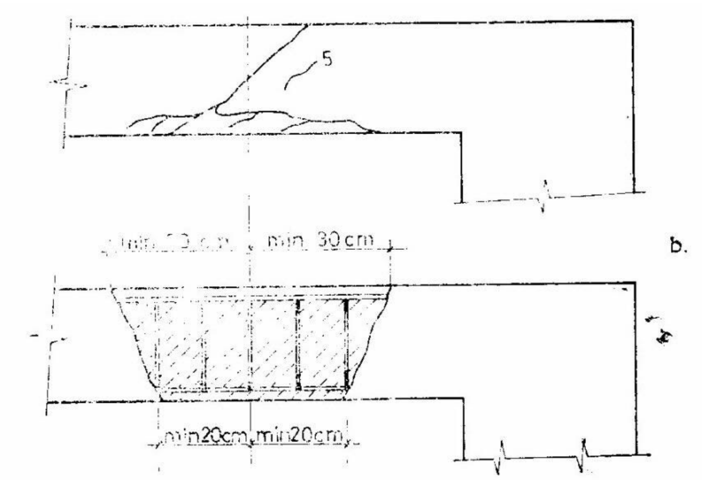

***Repair of a column (see Balan, 1980:figure VIII.8.a., quoting ONU, on page 417)***



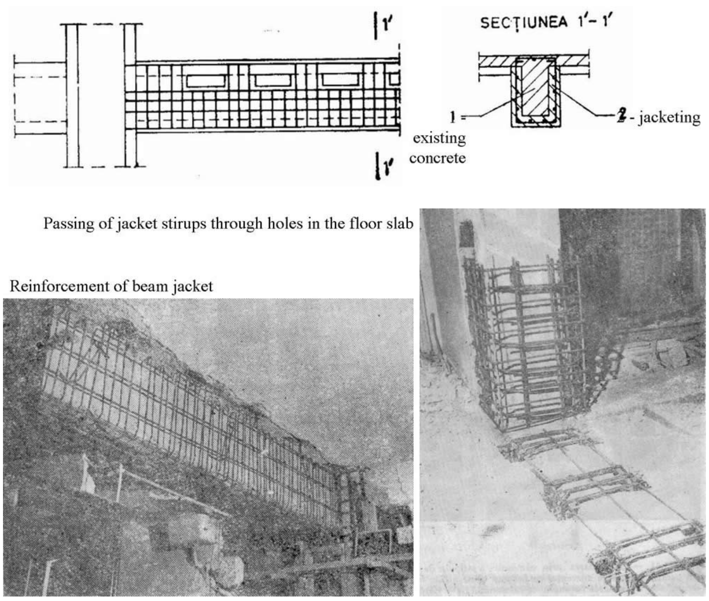

***RC Column retrofit through jacketing(see Balan, 1980: figure VIII.9.a. on page 418 andfigure VIII.11. on page 419)***




***Jacketing of a column with metalprofiles (see Balan, 1980: figure VIII.10.a. on page418 and VIII.12.a. and b. on page 420)***




***Repair of a beam: 5- rifts (see Balan,1980: figure VIII.8.b., after ONU, on page 417)***




***Beam retrofit through jacketing (afterBalan, 1980: figure VIII.9.b. on page 418 andfigure VIII.13.a. and b. on page 420)***

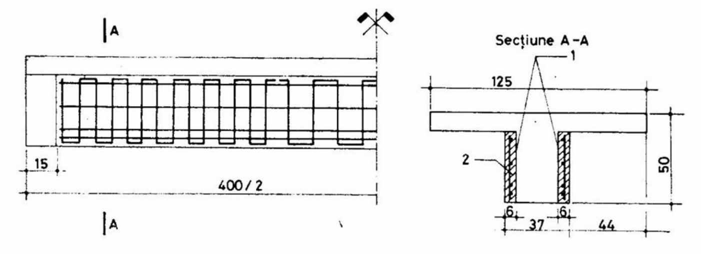
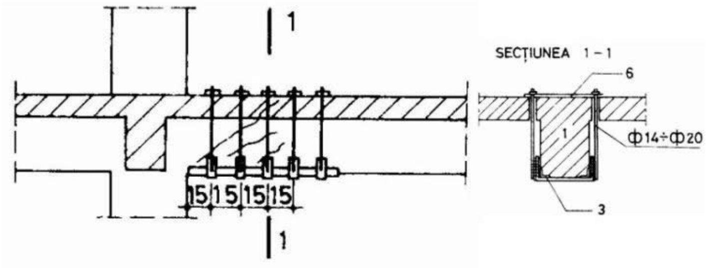



Fig. VIII.16. — Consolidarea unei grinzi prin placare cu beton armat la imobilul din București, Bd. Dacia 58 : 1 — strat de rășină epoxidică ; 2 — placare cu beton B 500.

***Retrofit of a beam by plating: 1 - epoxyresin layer; 2 - plating with concrete mark B500(see Balan, 1980: figure VIII.16. on page 423)***




***Jacketing of a beam with stiff profiles: 1- existing concrete, 3 - L profile, 6 - plate("Platbanda") (see Balan, 1980: figure VIII.10.b.on page 418)***

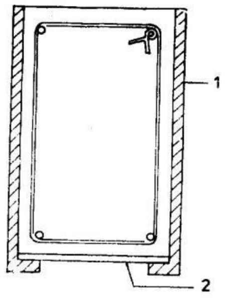
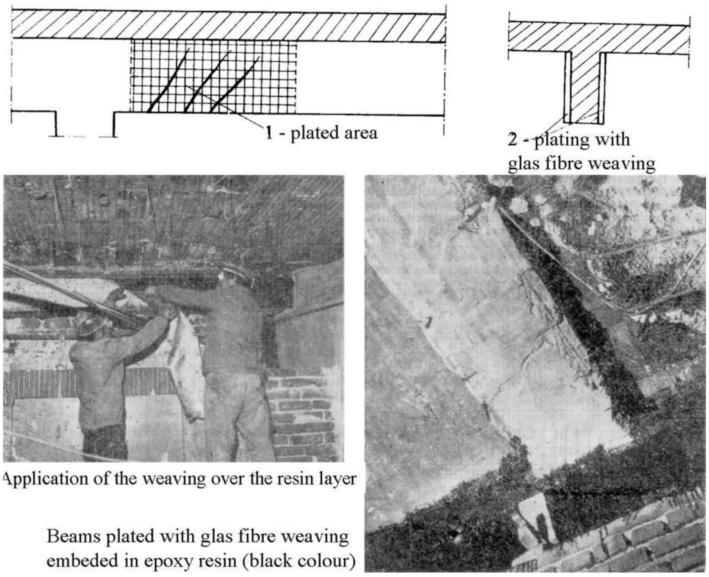


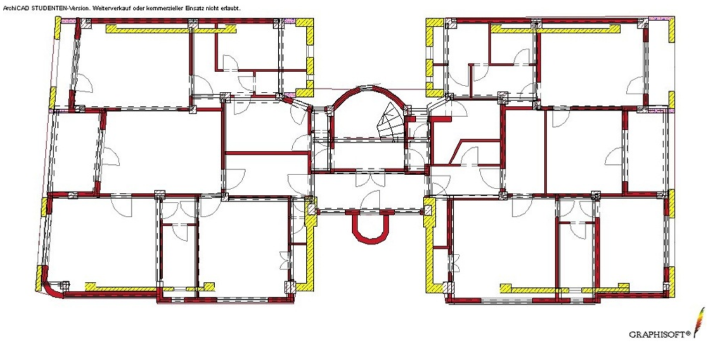

Fig. VIII.17. — Consolidarea unei grinzi prin placare exterioară cu plăci de oțel fixate cu rășini epoxidice : 1 — plăci de ranforsare la forfecare ; 2 — placă de ranforsare la încovoiere.

***Retrofit of a beam by plating with steelfixed with epoxy resins: 1 - "ranforsare" plates atshear; 2 - "ranforsare" plate at bending (see Balan,1980: figure VIII.17. on page 423)***

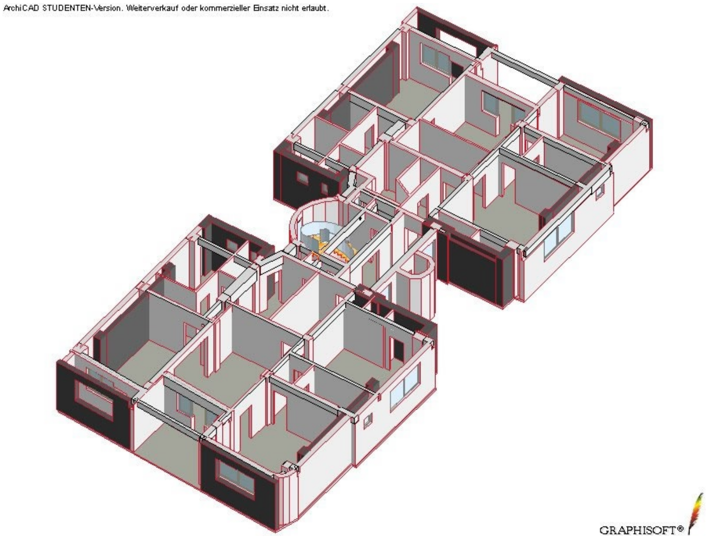



***Surface reparation of RC beams throughplating with woven glass embeded in epoxy resins:(see Balan, 1980: figure VIII.18. on page 423 andfigure VIII.19.a. and b. on page 424)***

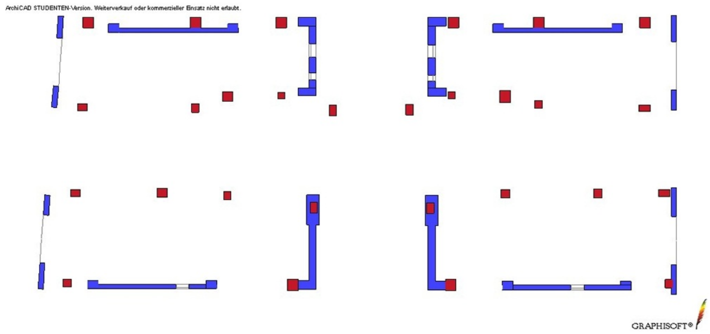

***Perspective view after retrofit***



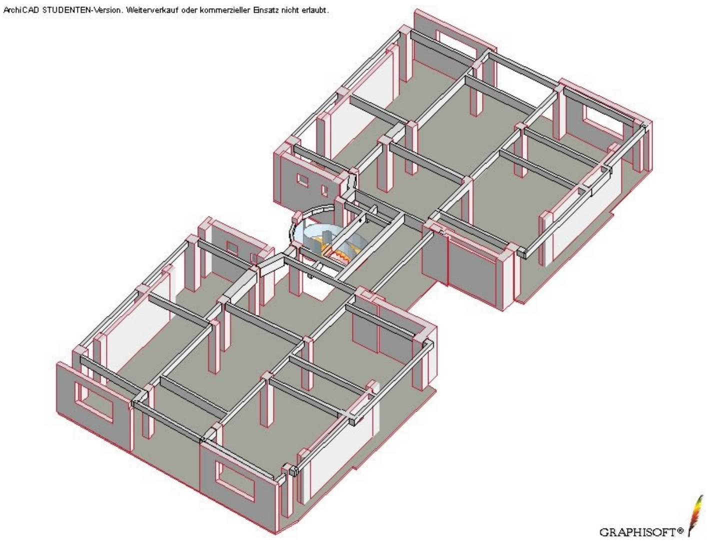

***Retrofit plan for the typical buildingconsidered, using shear walls and column jacketing.The retrofit elements are highlighted.(fromBostenaru(2004))***



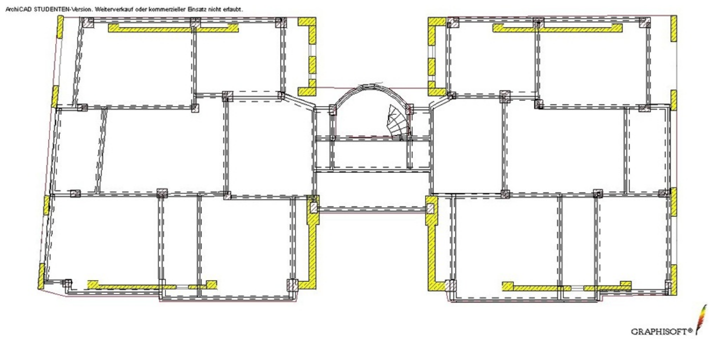

***Axonometric view of a typical floorafter retrofitting***



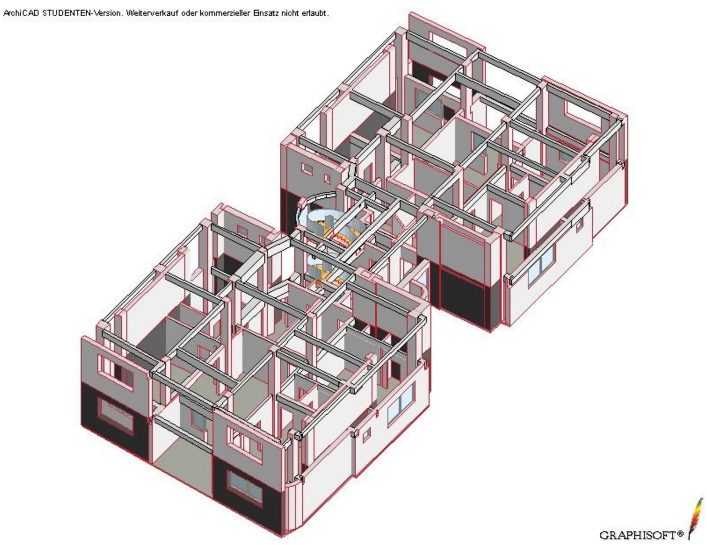

***Layout of vertical load bearing elementsafter retrofit***




***Axonometric view of the load bearingparts on a current retrofitted floor***




***Load bearing elements after retrofitting,with highlighting on the retrofit parts***




***Axonometric view of the relationshipbetween load bearing elements and masonry wallsin the***

***structure of the retrofitted building. (fromBostenaru(2004))***


***Current retrofit of a block of flats fromthat time***

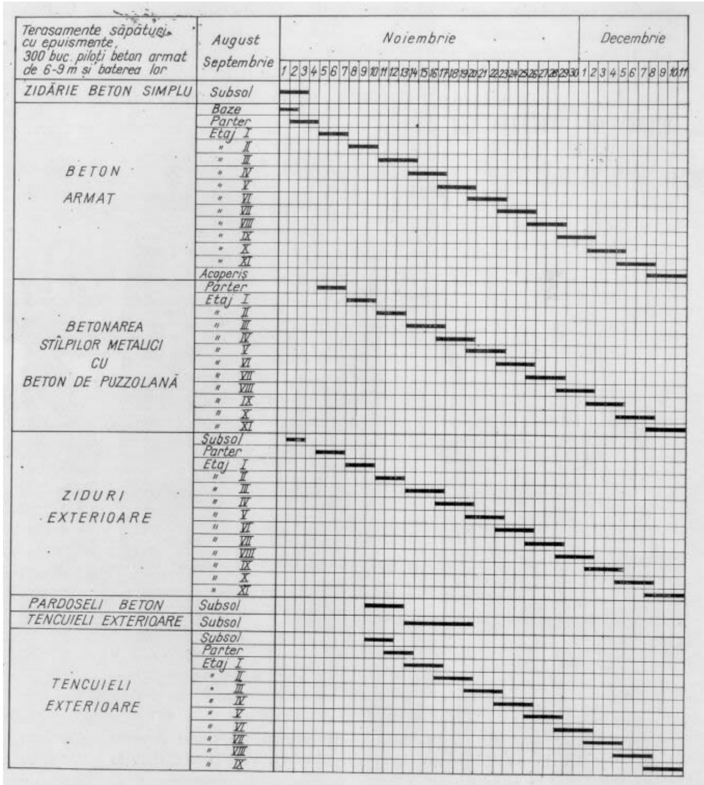



Fig. 9.4.6. Programul de execuţie al uscătoriei de cereale din portul maritim Constanţa—1930, întocmită de ing. Emil Prager.

***Sequences of building constructionshown in the execution program of a building ofthe same structural type from the same time(1930). "Zidarie de beton simplu" = simpleconcrete masonry; "beton armat" = reinforcedconcrete***

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## Authors


| Name | Title | Affiliation | Location | Email |
|---|---|---|---|---|
| Maria Bostenaru Dan | Dipl.-Ing. | Urban and Landscape Design Department, Ion Mincu University of Architecture and Urbanism | str. Academiei nr. 18-20, Bucharest 010014, ROMANIA | maria.bostenaru-dan@alumni.uni-karlsruhe.de |


## Reviewers


| Name | Title | Affiliation | Location | Email |
|---|---|---|---|---|
| Vanja Alendar | Research Associate | Dept. of Civil Engineering, University of Belgrade | Belgrade 11001, SERBIA | vanja@imk.grf.bg.ac.yu |