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Vernacular and Modernist Housing in Germany and Romania

An Analysis of Vulnerability to Earthquakes

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in the memory of Ilie Sandu
the colleague
with whom I compiled many "World Housing Encyclopedia" reports

Contents

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Introduction:
Traditional and modern

In this introduction we try to deconstruct the term of ‘modernity’. Deconstruction is method introduced by the French philosopher Jaques Derrida (course notes Ciprian Mihali, 2008). A way of deconstruction is to analyse it in a contrasting pair, which is that of ‘traditional’ and ‘modern’. Harrison (2003, p. 188) sees another contradictiong pair ‘modernism’ and ‘classicism’, which we do not handle though in this work.

Hobsbawn (1994, p. 78) sees a third sustainer of the “nation as invented tradition” public monuments. In this work we will refer to architecture in modernity, but not only to monuments, but to urban interventions in crucial times for the respective people.

Hutchinson (1994) starts through describing the common elements of the political and cultural nationalism, to which count the rejection of traditionalism in the realization of the civic ideal of educated citizens united through the law similarly to the polis in antiquity. The political nationalists, being situated in a specific territorial homeland can adopt ethnical-historical identities and become thus “re-traditionalised” (Hutchinson, 1994, p. 122). Cultural nationalists see the nation as a result of the “unic historical, cultural and geographic profile”, organic and in communion with the nature (Hutchinson, 1994, p. 122). In continuation, Hutchinson elaborates on the conflict with traditionalism. The essence of the article of Hutchinson, prefigurated in the title, is approached in the second page of the article (Hutchinson, 1994, p. 123): “cultural nationalism is a movement of moral regeneration”, in this context it “tends to reunite traditional and modern”, something what cannot be realised by politicians, but by historians and artists.

The historical novel in modernity

In the following Hutchinson refers to the history of the nation in triumphs and disasters, through which the “members of the nation can discover their authentic mission” (Hutchinson, 1994, p. 123), an affirmation which we will comment closed. Nietzsche (1873) identifies three types of history: antiquarian history, monumental history and a third necessary variant, critical history. Antiquarian history attributes value to everything what comes from the past and rejects the new, it knows how to preserve life but not how to generate it (Nietzsche, 1873). It is something what is opposed fundamentally to the fundament of modernity, we would say. Monumental history on the contrary starts from the rememoration of big moments of a people from the premise that "what was once, can be repeated" (Nietzsche, 1873). This we can see put in connection with the cultural nationalism mentioned by Hutchinson, and the writing of Nietzsche was in full modern times of the 19th century, actually it critiques in a latter passage that in German cities everything is conventional, not national. Actually Hobsbawn (1994, p. 78-82) analyses largely the tradition invented in the Second German Empire, at all three levels, including architecture. The same idea is underlined by the affluence of historical novels aimed at strengthening the national conscience in difficult moments at the begin of the 20th century. Hutchinson himself quotes some examples from literature, after emphasysing that the role of the historian for the cultural nationalism is overcome by that of the artist, since the cultural nationalism does not have profets (Hutchinson, 1994, p. 123). He quotes epic poems which evoque historic legends which are lessons for the present (Hutchinson, 1994, p. 124). These are numerous, we could complete the list with the Luisiades (Luis de Camoens, 1572, see Guy, 1998) in which the Portuguese glory from the time of blossoming of the country, when the big geographic discoveries were made is evoqued. Apart of the example of Mickiewicz for Poland has to be mentioned also the Nobel laureate Sienkiewicz who evoqued the medieval glory of the Polish people in his trilogy "Through fire and sword", "Potop" and "Pan Wołodyjowski". This came in a crucial moment of the nation in which this was struggling being divided between tsarist Russia and Germany. The evocation of the past glory is exactly in the sense of the monumental history of Nietzsche (1873), and the referral to tradition is made in the sense invoqued by Hobsbawn (1994). Alexandrescu (2008) sees Eminescu as not being a modern writer. "Scrisoarea III" (Letter III) refers this way to a glorious past, adding though that the contemporary time does not get to the same height, a concept which contradicts the monumental history of Nietzsche (1873). Although the literary approach of historic topics is made difficultly, the comment of these from the point of view of the modernity of the text, since they do not approach the life way introduced by modernity, they are modern texts approaching this subject connected to cultural nationalism and implicitely modernity. We will stop in this context also on the historical novel of Anne and Serge Golon "Angelique". The novel was thought with the nostalgy of the qualities of the nobiliary in full burguese époque. Although it treats the époque of

Ludovic the 14th, the Sun King, the life of the main hero, Angelique, is characterized by the attributes of modernity, as they are described by Giddens (1991). This has more etapes in life, which are separate one of the other, like the volumes of the book, changing the life environment simultaneously with the spectacular changes in her life: nobility, the poverty of Paris, the Versailles courtyard, sclavagism, Canadian forests, Quebec. This is characteristic to Modernity, in pre-modernity such things were not possible, people remaining generally connected to the medium where they were born. Also historical topics, but at abstract level, ar treated by Hermann Hesse in "Narziß and Goldmund". Goldmund has the experience of going through the Great Pest, and, although "Narziß şi Goldmund" isn't classified as being one of the novels of Hermann Hesse with expressionist influences, the expression of anxiety plays here a key role: those who are anxious of getting ill of pest are getting il, and Goldmund not, although he has contact to those ill of pest. Art in Theory (2001) and Bahr (1998) refer to expressionism also in the plastic arts. The treatment of anxiety is a topic of modernity, according to Giddens (1991), although this does not refer to anxiety as to something concrete, as would be illness. The relationship with the anxiety of illness is completely other at Selma Lagerlöf in "Gösta Berling": the beautiful Marianne, who runs without caring the illness during the winter, gets ill of smallpox. Another novel from Skandinavian literature, that of Sigrid Undset, treats also the meeting with the Big Pest, also in an unfortunate way, in Kristin Lavransdatter, but the hero dies in peace with herself after a life of modern type, with sudden situation changes, even if not of the same anvergure as in the popular novel "Angelique". Also in the best-seller type literature the same tendency is continued, for example in the historic novel "Pillars of the Earth" by Ken Follet. The life of Aliena, although situated in the Middle Ages, is so full of radical changes specific to modernity, as those described by Giddens (1991), that a similar situation of love between the poor boy and the girl of good family as the one in "Wuthering Heights" of Emily Brontë finds its solution. Through this literary reference we try to make the transit to the following paragraphs. In the centre of "Pillars of the Earth" is the construction of a cathedral, the architecture being seen as mean of unity for the respective community also before modernity, but invoquing the innovation in construction, not tradition.

Traditional architecture which is modern

In 2009 the UNESCO office in New Delhi published a book about traditional architecture in Kashmir (Langenbach, 2009), which is promoted on the internet site http://www.traditional-is-modern.net/ . As the name sais, the theory of the author is that traditional architecture has to be seen today, in post-modern time, as something modern. In order to explain this paradox we have to report ourselves at those told by Hutchinson (1994) regarding the report between modernity and tradition in case of cultural nationalism.

The hypothesis Langenbach (2009) and also other articles of the same author (ex. Langenbach, 2007), makes is based when tracing the connection between the traditional and the modern architecture that traditional architecture has a better performance in earthquakes than the architecture of modernism (see Art in Theory, 2001, for definitions of modernity and modernism). So, in numerous countries affected by earthquakes (Switzerland and the earthquake in Basel, 1356, Turkey and the earthquake in 1999, Pakistan and the earthquake in 2005) constructions with timber skeleton behaved better in earthquakes than the modernist ones with reinforced concrete structure. So this traditional construction type has to be promoted, it has to become "modern".

Langenbach's argumentation doesn't distinguish though between two ways in which this construction type spread in seismic areas: the vernacular mode, the traditional construction, or the mode imposed by political authorities. Thus indeed in Germany/Switzerland there is the type "Fachwerk", in "Turkey "himiş", in Kashmir "dhaji dewari" as vernacular types, which become the so-called "local seismic culture", namely the adaptation of the popular constructive type to earthquakes which repeatedly affect the region. But in Portugal (the type "gaiola pombalina") and in Italy (the type "casa barracata") these were introduced following earthquakes by the respective governments (the marques de Pombal after the 1755 earthquake and respectively the Bourbon government after the Calabria earthquake in 1783). Shklar (1990, quoted by Fuchs in Proceedings, 2005) considers the 1755 earthquake in Lisbon one of the many birthdays of modern times through the intellectual response, the discussion of (theological) theories in whole Europe so that some suffering types will not be seen any more as “”acts of God, but caused by the action or inaction of those at power”. Also Harrison (2003, p. 188) places the start of modernism at more possible dates, one of them being the first two productive decades of the 20th century, but letting the possibility of the end of the 18th century. Since the earthquake in Lisbon 1755 is considered birthday of modernity, the “gaiola pombalina” type of construction, although it is a traditional typology in many zones, some of them listed above, is a modern type of construction. At the same time we remark that his architecture is a response to the modern concept of anxiety, as it was seen by Giddens (1991). The earthquake, which shocked whole Europe, was a critical moment when the marques de Pombal mobilized the nation, despite the contrary theological opinions of resignation of the iezuit Malagrida, and reconstructed the city. The new architecture type is a symbol of reconstruction till today. It is considered that the inspiration for this type did not come from the traditional earthquake resistant types in other countries, but from the Portuguese experience in ship construction, since the timber skeleton resists also to the horizontal force of waves, an additional argument being that in Lisbon 1755 the earthquake was followed by a tsunami. So it is about a tradition basis in a crucial moment for the nation, in the sense of Hobsbawn (1994). In Lima, Peru, after a major earthquake also in the birth time of modernity (1746) pre-collonial tradition was asked for, with the type “quincha” (Oliver-Smith, 1997).

Modern architecture which is traditional

Tafuri (1980) considers also that “the many forms of Avant-Garde from the begin of the century were a form of Revolution” and that “it has to be reconsidered if the Modern Movement has to be seen as mono-block”.

It is known that the Modern Movement in architecture had as purpose to break with historic roots. It has to be remarked from the begin that the history of architecture seldomly makes the difference between Avant-Garde and Modernism, the Modernism being considered the Modern Movement, based in great part on Avant-Garde architecture. The association between Modernism and Avant-Garde is also made by Greenberg quoted by Harrison (2003, p. 191) but negated by Gibson (2003, p. 203). On the other hand, the Avant-Garde can be classified in two Avant-Gardes, from which the right wing is the Modernism of Greenberg (Gibson, 2003, p. 213). In 2006 in Istanbul and Ankara took place the 9th International DOCOMOMO Conference (DOcumentation and COnservation of buildings, sites and neighbourhoods of the MOdern MOvement), with the topic "Other Modernisms". The topic of the conference, as it could be read from the call for papers, was connected to "other modernisms, different from the main stream Modernism of the Avant-Garde", so the Avantgarde is considered classical Modernism. "Other Modernisms" are frequent, as the Modernism of the Avant-Garde was especially connected to the problematic in Western Europe, and so on other continents or in the periphery zones of Europe "another modernism" developed, in fact a true modernism, different from the Avant-Garde. Gibson (2003, p. 207-208) remarks the fact that the Avant-Garde responses through the new style to the new forms of life. In this regard the architecture of the "classical" Modernism does not differ from "another modernism", the way of life differs. In West social housing answers were looked for; in countries like Romania, Greece, Portugal the architecture of the Modern Movement responded to the need of densification of the cities with luxury dwellings. It is to be remarked that the division on states which present "another modernism" is different from that proposed by Gardes (2004) in which there is a differentiation between those in which the national state is of ethnical type and that of "social contract" type. So in Germany, where the state got unified late, we find a "classic modernism", thus "Avant-Garde". At the same time Italy, apart of the Rationalist movement, also called "contextual" (ambiental) modernism, developed the so-called "Novecento" movement, with referings to the Italian palaces. At the same time it is remarkable that the Rationalism is closer to the ideals of modernity in aesthetics, but not also in the answer to the modern way of life which asked for another organization of the interior space, which remained conventional. On the other hand Novecento, even if it did not adhere to the spatiality of the Avant-Garde, responded to the comfort requests brought by the technological progress (Bostenaru, 2009). Through "contextual Modernism" it is understood that the new buildings are integrated in the urban context, but we have to add that also here exists the connection with traditions, for example in the use, especially in the decoration, of other materials than those promoted by the Modern Movement (metal, concrete and glass: natural stone in which Italy is very rich. Also this can be seen as an architectural act of tradition created in a crucial moment in the sense of Hutchinson (1994) and Hobsbawm (1994), as Rationalism was the architecture of fascism. Also in Germany apart of the Avant-Garde in architecture, the "classic modernism" of Rudolph Fränkel practiced a modern architecture, in which the approach to the connections between spaces was not the radical one, with a play of vertical and horizontal planes as at Le Corbusier, but with walls and doors like in the traditional architecture. Sonne (2009) has a study on the reformed urban blocks raised between 1890-1940 treating the sustainability of this type of construction. Reformed urban blocks differ of the Avant-Garde through the type of the urban tissue, this being traditional, not of Le Corbusier type as in many of the Siedlungen in so-called "Zeilenbau". At the same time, we observe that in crucial moments for the nation, as it is the earthquake recovery mentioned more times in this article, in the reconstruction of l'Aquila after the earthquake of the 6th of April 2009 in progetto C.A.S.E., the "Zeilenbau" was used for reconstruction, and not the traditional typical Italian urban issue. Given their placement in the periphery, as many of the social housing quarters, this seems though to be a viable solution.

In this context of the use of materials we wish to tell about a recent experience. In Estonia traditional architecture is out of timber or limestone. Estonia had rare times when it was a national state, being devaoured by the vicinity to Russia. The interwar time, however, was a time of flourishing as national state, and this was reflected also in architecture. Such, the architecture of the modern time, be it also of the begin of the century (Art Nouveau) or of the Modern Movement, was also contextualist like the Italian one and many representative buildings used as structural construction material apparent stone. The annexed images exemplify this approach. For the national Estonian variant of the Modern Movement, also "another Modernism" there is the consecrated name of "limestone functionalism" (since the buildings resulted from the Modern Movement, especially after the war, were called functionalist, following the maxime "form follows function"). So in the crucial moment, of creation of a late national state, in order to emphasize this identity, a local variant of an architecture known otherwise as international was adopted, in the sense of Hutchinson (1994) and Hobsbawm (1994).

Another dialogue between traditional and modern can be observed in the architecture of Henrietta Delavrancea-Gibory, a Romanian architect who built most of her villas in the seaside resort of Balchik, now Bulgaria. The villas feature traditional roofs, and apparent stone, but otherwise modern language. A sad event of late 2009 was the demolition of the only building in Bucharest ressembling the architecture in Balchik, the villa Prager in Bulevardul Aviatorilor 92. One of the "justifications" was the inability to provide seismic retrofit by maintaining at the same time the expression of cultural value of the house. This phenomenon is wide spread. Romania started several years ago the so-called "red-dot" programme, to mark buildings vulnerable to earthquakes which need seismic retrofit. For the intermediate depth Vrancea earthquakes which affect Bucharest these are the mid- to highrise buildings. However, the "red-dot" programme is being misused and up to nearly half of the buildings in the list are low rise (Lungu, 2009).

At urban level, Ljubljana was destroyed by an earthquake, in 1895, little time before the spread of the Art Nouveau style. In that time Slovenia belonged to the Austro-Hungarian empire. After the earthquake architects of the Viennaise school were invited, such as Camillo Sitte and Maks Fabiani to elaborate reconstruction plans (Herscher, 2003). But for reasons of grow of the national sentiment the plan of the City Construction Office was preferred. Later on, the Slovene architect Jože Plečnik elaborated a plan of Ljubljana in 1929, which put its fingerprint on the city. Here the crucial moment of the reconstruction of the city coincided with the moment of intensification of the national sentiment, ripe for the detach from the Austro-Hungarian empire.

Discussion

At the round table "Contemporary public space", on Satuday, the 23rd of May 2009, 10:30-12:30, Dalles hall, in frame of the exhibition "In Favour of Public Space" in frame of the Architecture Annual 2009 "Public. Public Space", Bucharest, the writer Jordi Punti intervenes bringing into discussion the relationship public-private. If one writes a book and nobody reads it, it has no signification. The same is the situation for the public space. If nobody goes into the created space, it has no signification. We would extend this definition for the representative buildings for key moments in history, according to the vision of

Hutchinson (1994) and Hobsbawm (1994). Starting from this point of view we can derive a relationship between the way how Hutchinson (1994) sees the artist, especially the writer, as bearer of a message for the integration of tradition with modernity and cultural nationalis, and Hobsbawm (1994) the invented tradition in order to sustain a nation in crucial moments.

The relationship between literature and architecture is one with multiple facetes, apart of the two mentioned writers can be active also in the mediation between user and architect, especially for the public space (http://www.urbanwords.org.uk/), in order to articulate the options of the user in participative architecture.

Still, the cultural nationalists in Hutchinson (1994, p. 124) see differently the recreation of tradition and through this of the national identity than Hobsbawn (1994), and namely as a bottom up approach. Hobsbawn (1994, p. 77) sees the politics in the 19th century as being at the scale of the nation.

The approach by Langenbach (2009) "traditional is modern" is in the sense of Gellner cited by Hutchinson (1994, p. 128). Modern materials and techniques were adopted by the Modern Movement with rapidity, in currents which lasted 10-20 years, but in most cases these were not yet sufficiently tested. The traditional ones are the result of an adaptation of tens or even hundreds of years to the local seismic conditions. The collapse of those of the Modern Movement can be the result of not respecting the characteristics of the material. It is the hard to assimilate industrial culture according to Gellner. As it can be seen, it can be talked even today of approaches such as that of Gellner, but with the mobile in the scientific zone, not in the cultural one. Still Harrison (2003, p. 189) defines modernism exactly through this prelucration with the aport of industry, and in this sense its "modernizing" action. On the other hand, Gibson (2003, p. 209) remarks the fact that the Avant-Garde did not always break with crafts: Arts and Crafts and Jugendstil (the English and the German form of Art Nouveau) were extended to de Stijl and Bauhaus.

The urban blocks in the sense of Sonne (2009) prove today to be more sustainable as these middle- to highrise buildings are more protected from speculative interventions of the same kind as done for the Henrietta Delavrancea-Gibory villa in Bucharest.

The difference between the two types of tissue, traditional and "Zeilenbau" can be used to classify the architectural-urbanistic patterns in a GIS analysis at city scale for earthquake vulnerability, as we intend to do in our project.

Cultural nationalists reject both traditionalism and modernism and accept only their integrative movement (Hutchinson, 1994, p. 129). This attitude of "both-and" as well as the one promoted by the architect Venturi, cited by Gibson (2003, p. 204) is anti-Avant-Garde. Cultural nationalists see what is "modern" as being "vest", like the classification of the Modernist Movement in architecture.

Like the representants of the African culture cited by Hutchinson (1994, p. 130-131) also in Romania of today it is discussed that the West came to sterility, for example literary, and it is the turn, for example, of Latin America, to bring innovation. In this sense the discussion from Hutchinson (1994) can be also reported to the society of today.

We started this work from the idea to deconstruct the term of modernity. The deconstruction does not anulate the opposite terms, so the approach cultural nationalists had towards modernity can be seen as a deconstructive attitude.

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Figure 1-1: Block of flats on Brezoianu street (1946-48), architect Henrietta Delavrancea-Gibory, combining traditional and modern elements. Photo by Maria Bostenaru, 2010.

Figure 1-2. Examples of Art Nouveau building, Tallinn, Estonia, architect Jaques Rosenbaum, photos by Maria Bostenaru, 2009

Figure 1-3. Example of buildings of “limestone functionalism”; Tallinn, Estonia, architect Herbert Johanson, photo by Maria Bostenaru, 2009

Figure 1-4. Traditional Estonian architecture of the Toompea castle, Tallinn, Estonia, photo by Maria Bostenaru, 2009.

Traditional housing in Germany: Half-timbered house in the "border triangle" (Fachwerkhaus in Dreiländereck)

(Report # 108 in the "World Housing Encyclopedia"
http://www.world-housing.net/)

Summary

This type of construction can be found in both the urban and rural areas of Germany, Switzerland, northern France, and England. The main load-bearing structure is timber frame. Brick masonry, adobe, or wooden planks are used as infill materials depending on the region. This report deals with the two latter types, because they are located in areas where strong earthquakes occur every century. However, this construction has proven particularly safe, and some of the buildings have existed for 700 years. These buildings have characteristic windows and a rectangular floor plan, with rooms opening to a central hall, which were later replaced by a courtyard. Typically, each housing unit is occupied by a single family. While in the past this was the housing of the poor, today affluent families live in these historic buildings. The load-bearing structure consists of a timbered joists and posts forming a single system with adobe or wooden infill. The walls consist of a colonnade of pillars supported by a threshold on the lower side and stiffened by crossbars and struts in the middle. On the upper part they are connected by a "Rahmholz." The roof is steep with the gable overlooking the street. The floors consist of timber joists parallel to the gable plane with inserted ripples. The only notable seismic deficiency is the design for gravity loads only, while numerous earthquake-resilient features - the presence of diagonal braces, the achievement of equilibrium, the excellent connections between the bearing elements, the similar elasticity of the materials used (wood and eventually adobe) and the satisfactory three-dimensional conformation - have completely prevented patterns of earthquake damage. Since 1970, buildings in Switzerland are regulated by earthquake codes (latest update 1989). The 2002 edition will incorporate EC8 recommendations.

1. General Information

This kind of building can be found in Switzerland (fig. 2-2) in regions located at a specific distance from mountainous areas, in northern France (figures 2-6 and 2-7), and in southern (fig. 2-3) to central (fig. 2-5) Germany as well as in Tirol. Uhde (1903) documents the existence of such buildings in France in Normandie, Bretagne and Alsace (Dreux, Laval, Annonay, Bayeux/stone infilled), Morlaix, Dol, Yville, Compiegne/stone infilled, Rouen, Rheims, Abbeville, Boulogne, Beauvais, Angers, Lisieux, St. Brieux, Caen, Strassbourg). Except in central Germany, these areas are affected by Alpine earthquakes with epicenters originating in Switzerland. The earthquake on the 22nd of April, 1884 was recorded to badly damage the area of Essex in England. Buildings of this type remained nevertheless well preserved. Some of many half timbered house in the town centre of Colchester, Essex, England are illustrated on http://www.camulos.com/virtual/guidec.htm (2004), the Virtual Tour of Colchester. Uhde (1903) documents such buildings in England (Shrewsbury, Coventry, Cheshire, Lanchshire, Darthmouth, York, Bristol, Chester). This type of housing construction is commonly found in both rural and urban areas.

See figure 2-1 for examples of urban and rural buildings of this type in southern and central Germany.

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. In Germany, there are about 2 million houses of this type (source: http://www.fachwerk.de/fachwerkhaus/fachwerk.html, 2004). The "new" ones began to be built after 1970 (fig. 2-4). This type of housing has been constructed in this area since Roman times (Uhde, 1903). The first documented building is a house constructed with 2 upper and 2 roof stories in Marburg in 1320. Most of those still existing, however, are 150 years older than this one. The historical development can be seen at:
http://www.fachwerk.de/fachwerkhaus/15_Jahrhundert.html (2004) - 15th century
http://www.fachwerk.de/fachwerkhaus/16_Jahrhundert.html (2004) - 16th century
http://www.fachwerk.de/fachwerkhaus/17_Jahrhundert.html (2004) - 17th century
http://www.fachwerk.de/fachwerkhaus/18_Jahrhundert.html (2004) - 18th century
http://www.fachwerk.de/fachwerkhaus/19_Jahrhundert.html (2004) - 19th century Particularly relevant ist the information on the homepage of the town of Wetzlar in mid-Germany, featuring a house from exactly 1356 (the year of the big earthquake in Basel, Switzerland); a typical middle age building:
http://www.wetzlarvirtuell.de/asp/main_frame_addr.asp?address_id=1

15 (2004) Abraxas Basel GmbH (2004) documents on the own webpage their domicile in a half-timbered house in Basel, protected as monument. The construction type is said to correspond to that of the 12th century, when the house was built: between two sandstone struts of the church of St. Martin, and that it survived the big earthquake of 1356. The back is built by a natural rock. It has several upper floors and was carefully renovated by the owners over more years: View from inside at: http://www.meteoriten.ch/www/laden1.html (2004); View from outside at: http://www.meteoriten.ch/www/laden.html (2004).

Figure 2-1: "Fachwerk" houses in Germany: a. in an urban area; b. and c. in rural areas; a. and c. southern Germany; b. central Germany. a. and c. photos by Michael Kauffmann, 2004, b. by Maria Bostenaru, 1997.

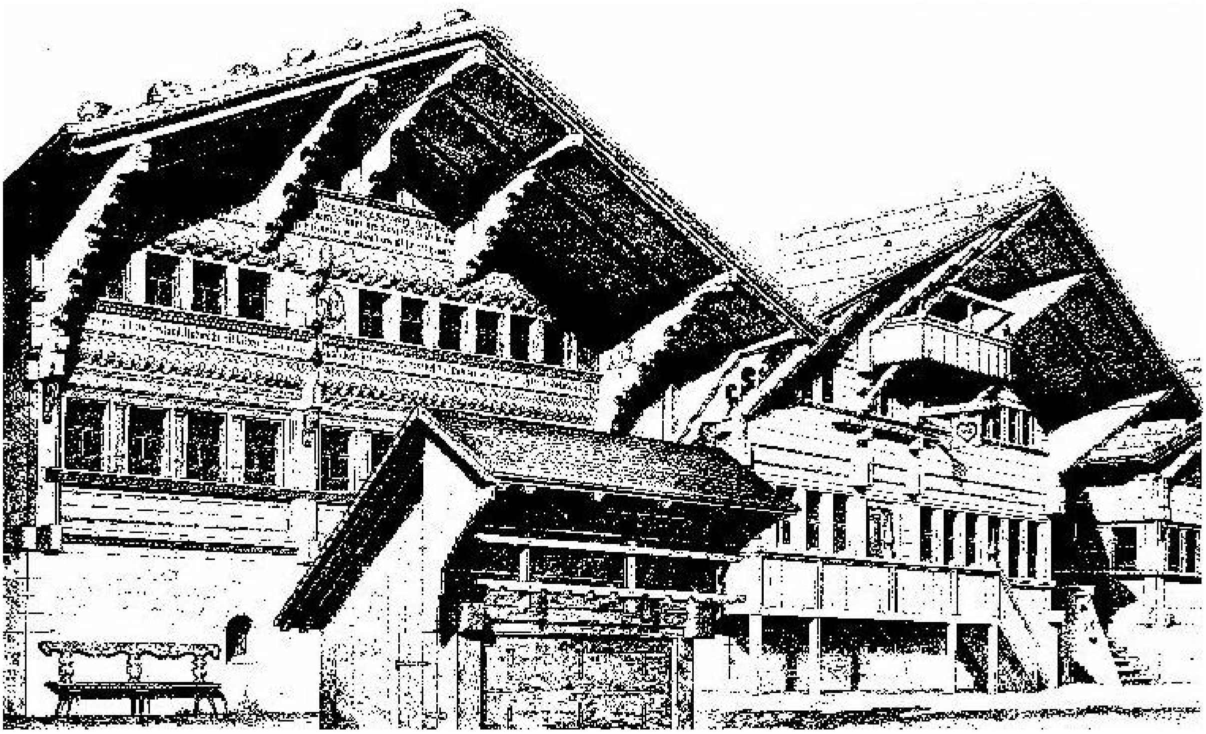

Figure 2-2: Historical houses in Switzerland. Source: Uhde (1903), Fig. 354 on page 305, after Gladbach.

Figure 2-3: House from mountaineous areas from Southern Germany. Photo by Michael Kauffmann, 2004.

Figure 2-4: Typical new building in Southern Germany: perspective view, view of the gable and detail. Photos by Michael Kauffmann, 2004.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. Urban houses are adjacent; rural houses have varying separation distances.

2.2 Building Configuration

The building configuration is rectangular. Village dwellings consisted of a middle floor where cooking could be done, and a staircase. To the left of the stairs were the storage rooms and the stables, and to the right, the living quarters and bedrooms, which were oriented to the street (fig. 2-14). Urban houses do not have side openings. The central hall is accessible from the street through a passageway and opens onto a courtyard. The kitchen is a separate room, but the front and back rooms remain connected at all levels by the galleries. The residential spaces are situated mainly in the upper floors (figures 2-15 and 2-16). Windows slide open from bottom to top. Doors were not adapted to the position of the pillars. Builders made use of the "Rahmholz" (fig. 2-11) to configure these differently. Doorways end at the upper side in arcs (fig. 2-8). In the Middle Ages, and from the 16th century on, doors were increasingly rectangular in shape. Figures 2-17, 2-19 and 2-20 show typical windows and their ornaments.

2.3 Functional Planning

The main function of this building typology is single-family house. Different patterns dividing the storage, work, and living space areas occur in various regions of Germany, Switzerland, and Tirol, but generally they follow the scheme mentioned above. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. The means of escape is through the middle hall and through the courtyard and galleries as described at 2.6. In these spaces either rectangular or spiral-shaped staircase can be found. Unlike today, there were no staircases with windows. The staircase was part of the hall and illuminated through the opening. Rural buildings have two escape doors - one into courtyard and one into the hall; urban houses are accessible through a passage as explained in 2.6. (fig. 2-23).

Figure 2-5: Half timbered houses in central Germany: Römerberg, Frankfurt on the Maine. Photo by Maria Bostenaru, 2001.

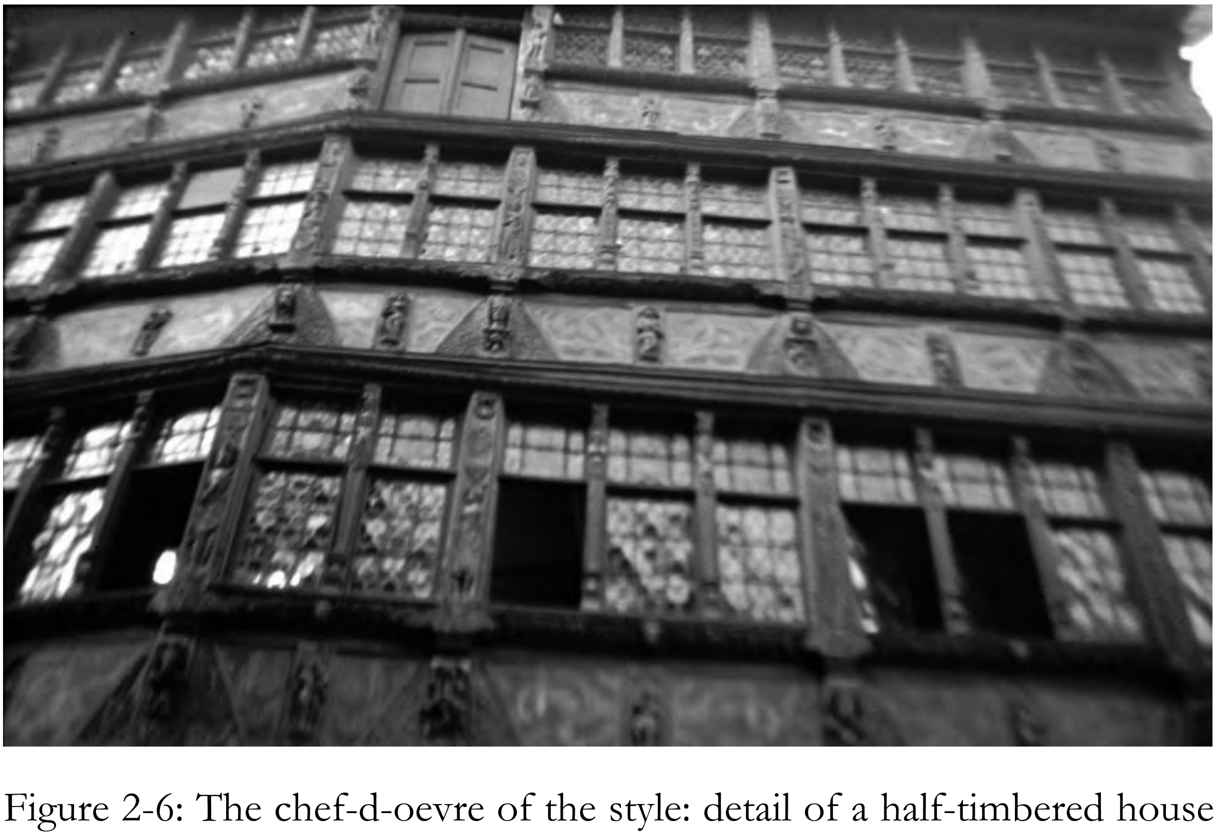

Figure 2-6: The chef-d-oevre of the style: detail of a half-timbered house in Strassbourg, France. Photo by Maria Bostenaru, 1997.

Figure 2-7: Half timbered houses in Strassbourg, France. See the relationships between the dome and the narrow medieval streets and/or facades. Photos by Maria Bostenaru, 1997.

Figure 2-8: Typical door. Photo by Michael Kauffmann, 2004.

2.4 Modification to Building

Some pillars or transversal connections have been demolished. During restoration, several positive modifications have become possible, such as new floors or new infills, but also some negative changes have been introduced as shown at http://www.fachwerkhaus.de/fh_haus/basis/suenden.htm (2004).

Figure 2-9: Ornamented pillar. Photo by Michael Kauffmann, 2004.

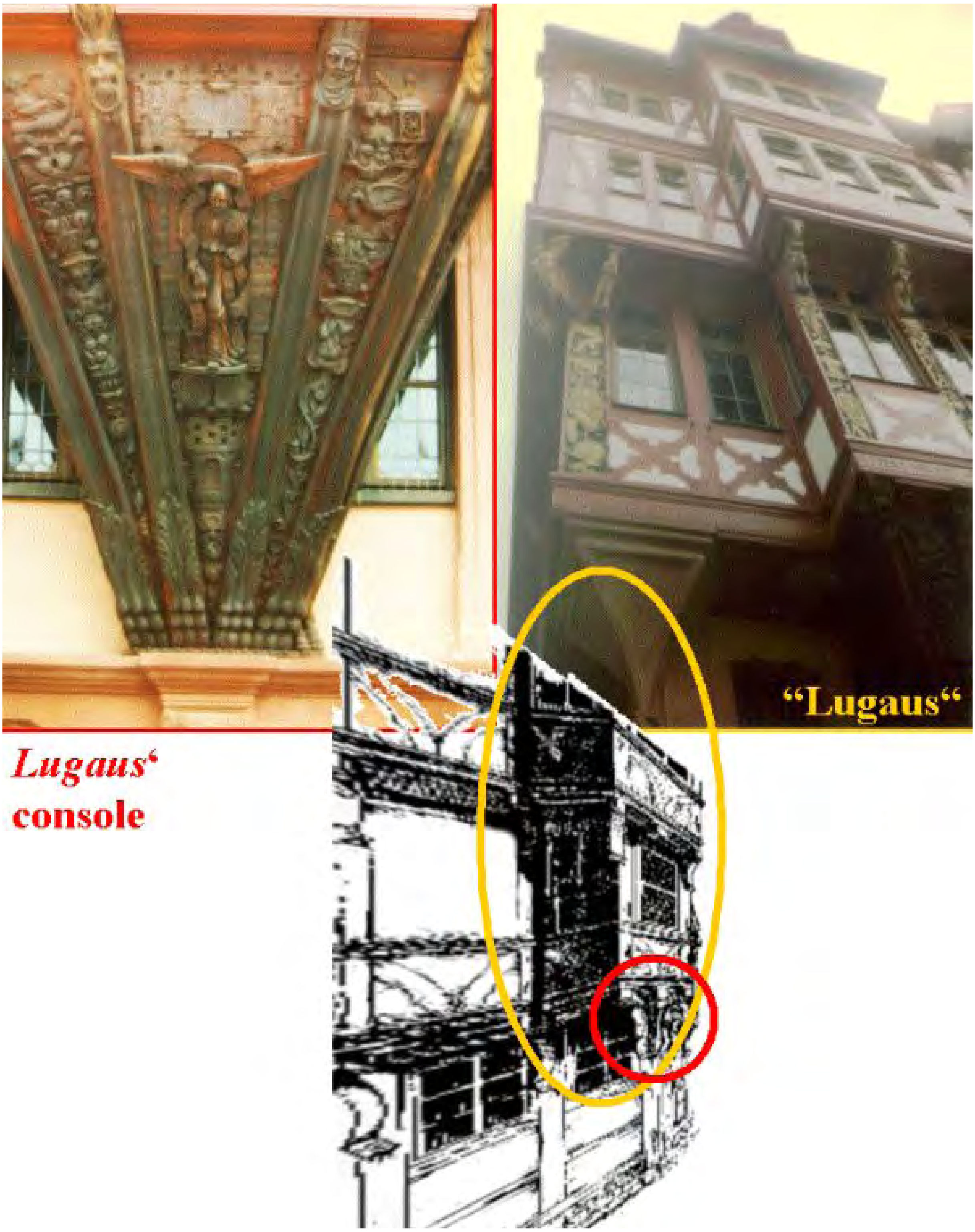

Figure 2-10: Details of a "Lugaus": photo of such a form in central Germany/Frankfurt, Maine (top right), console detail/Frankfurt, Maine (top left), drawing after examples of Lachner (1885) (bottom)

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Dressed stone masonry (in lime/cement mortar)	
	Adobe/ Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	
		8	Brick masonry in mud/lime mortar with vertical posts	
		9	Brick masonry in lime/cement mortar	
		10	Concrete block masonry in cement mortar	
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	
		12	Clay brick masonry, with concrete posts/tie columns and beams	
		13	Concrete blocks, tie columns and beams	
	Reinforced masonry	14	Stone masonry in cement mortar	
		15	Clay brick masonry in cement mortar	
		16	Concrete block masonry in cement mortar	
Structural concrete	Moment resisting frame	17	Flat slab structure	
		18	Designed for gravity loads only, with URM infill walls	
		19	Designed for seismic effects, with URM infill walls	
		20	Designed for seismic effects, with structural infill walls	
		21	Dual system – Frame with shear wall	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	Structural wall	22	Moment frame with in-situ shear walls	
		23	Moment frame with precast shear walls	
	Precast concrete	24	Moment frame	
		25	Prestressed moment frame with shear walls	
		26	Large panel precast walls	
		27	Shear wall structure with walls cast-in-situ	
		28	Shear wall structure with precast wall panel structure	
Steel	Moment-resisting frame	29	With brick masonry partitions	
		30	With cast in-situ concrete walls	
		31	With lightweight partitions	
	Braced frame	32	Concentric connections in all panels	
		33	Eccentric connections in a few panels	
	Structural wall	34	Bolted plate	
		35	Welded plate	
Timber	Load-bearing timber frame	36	Thatch	
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		38	Masonry with horizontal beams/planks at intermediate levels	
		39	Post and beam frame (no special connections)	
		40	Wood frame (with special connections)	
		41	Stud-wall frame with plywood/gypsum board sheathing	
		42	Wooden panel walls	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Other	Seismic protection systems	43	Building protected with base-isolation systems	
		44	Building protected with seismic dampers	
	Hybrid systems	45	other (described below)	

Pillars are not placed vertically one over the other.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is timber frame load-bearing wall system. The gravity load-bearing structure consists out of a timbered joist-and- post system forming a unitary schelet with infill (figures 2-8 and 2-13). This infill can be of adobe on willow baskertry. In mountainous regions the masonry infill is replaced by wooden planks. The stories aren't usually placed one over the other, but are built as consoles, thus the upper floors progressively become enlarged from the street level. Not all joists are horizontal and thus different crossing figures out of "braces" and "ties" are created. The figures drawn out of posts, braces and ties give hints about the time the "Fachwerk" building was constructed (figures 2-11, 2-13 and 2-18). Joists are situated at about 0.9m distance, pillars at about 1.2m. Beams are about 30cm high and joists about 10 x 1 cm. Typical structural details can be seen in Böhm (1991) in the chapter, "The Half Timbered Wall," especially from pages 204-264.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is timber frame load-bearing wall system. The key load-bearing elements and their original German names are depicted in fig. 2-11. Basically, in this schelet structure the gravity and the lateral load-bearing structure are the same (fig. 2-13). According to Lacher (1885), the outside walls consist out of an array of pillars ("Ständer" in German, fig. 2-11). They are supported from a threshold ("Schwelle" in German) on the bottom, and stiffened by crossbars ("Riegel" in German) and struts ("Streben" in German) in the middle. In the upper part they are connected by a "Rahmholz". Windows are placed arbitrarily as dictated by the interior function and are set out of the wall plane (fig. 2-17). The pillars are firmly connected with the threshold and "Rahmholz" and there is no danger of out-of-plane failure. Thus there are no diagonal pillars to reinforce the connection between the pillars and the threshold (fig. 2-13). A characteristic of the Fachwerk houses in this region are the scantlings ("Eckholz" in German), which are placed in the orthogonal angle between the threshold/Rahmbalken and pillars (fig. 2-18). The panels are infilled with willow basketry (fig. 2-12) with puddle and plastered. Thus the fields are of smaller area compared to the northern German ones, where brick infill was common. Small bars are introduced, with both a decorative and constructive role (fig. 2-19). Sometimes the infill is made of wooden planks (fig. 2-2 and 2-3). In isolated cases the wall is covered with timber planks. The roof is steep and there are two attic floors (fig. 2-4). The gable overlooks the street in most cases. Several "Kehlbalken" constitute the main load-bearing parts of the roof. Some longitudinal beams on free posts support them. Angle bonds and bows strengthen the connections in both directions. The rafters are set through tapping and indenting the roof joists and are supported at the bottom end ("Auschieblinge), which are plated directly on the ends of the roof joists in the facade plane (This gable solution originated from Switzerland and spread over southern Germany.) The roof is cantilevered over the wall surface, in order to protect this from weather. The wall frame joists of the longitudinal side run out from the gable wall and "head bands" ("Kopfband" in German) are added to support them. In order to support the "Aufschieblinge" and the rafters end pieces of an interrupted gable threshold lay on the wall frame joists. This solution is also widespread in Alsace. The floors consist of parallel joists with inserted ripples (fig. 2-21), so that the lower side remains visible. Sometimes cassette ceilings are seen. In instances with spans crossing larger spaces, beams were added to the floor joists. The joists are parallel to the street while long orthogonal walls are common on the street side between neighbouring buildings. The distance between the joists is as low as 1 1/2 joist thickness. Characteristic of this type of construction in southern Germany are outbuildings and annexes, like "Erker," "Chörlein," "Ecktürmchen" (fig. 2-5), "Lugaus," and "Dacherkertürmchen" (combinations of balconies and towers). "Lugaus" are rectangular front buildings spanning more stories, starting either on ground floor level or in a console/cantilever over the stone ground floor. At the upper side it ends with an independent little tower (figure 2-10). "Erker" and "Chörlein" are polygonal front buildings spanning a single story only, while the first one begins at street level and the second one at the console. "Rundchörlein" are round front buildings. Multiple combinations are possible.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 8 and 20 meters, and widths between 6 and 10 meters. The building has 1 to 8 storeys. The typical span of the roofing/flooring system is 1.2 meters. There is a great variety of plan dimensions. Typical are two "normal" stories and a two-storied attic. Historical Fachwerk-houses have had up to eight stories (according to http://www.fachwerkhaus.de/fh_haus/basis/suenden.htm, 2004). Today, for example, 7.40m to the corniche are prescribed in some local codes (see http://www.fachwerkhaus.de/fh_haus/info/drei.htm, 2004). Typical Story Height is an average height, as story heights of 2.1m (even today!) or of 4.0m (the higher stone ground floor) are possible. According to Stade (1904) there was one intermediary horizontal element in cases where the height was 2.5m, two elements at a height of 3.5m, and three at 4m or more. Typical span distance describes that found between pillars. Unequal distances between pillars are characteristic. Spans are typically in a range between 1 and 2m though spans of 0.6-1.5m for intermediary fields and 1.5-1.6m for corner fields are also found. The fields were typically 0.6-0.9m high according to Stade, [1904]). The typical storey height in such buildings is 2.5 meters. The typical structural wall density is up to 10 %. 6% - 10% These are not load-bearing infill walls.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted		
	Composite system of concrete joists and masonry panels		
Structural concrete	Solid slabs (cast-in-place)		
	Waffle slabs (cast-in-place)		
	Flat slabs (cast-in-place)		
	Precast joist system		
	Hollow core slab (precast)		
	Solid slabs (precast)		
	Beams and planks (precast) with concrete topping (cast-in-situ)		
	Slabs (post-tensioned)		
Steel	Composite steel deck with concrete slab (cast-in-situ)		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood shingle roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams supporting natural stones slates		
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other	Described below		

Wood planks on wood joists, sometimes forming cassette ceilings. Rafter ("Sparrendach" in German) or stringer roof ("Pfettendach" in German).

3.6 Foundation

Type	**Description**	**Most appropriate type**
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced-concrete isolated footing	
	Reinforced-concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced-concrete bearing piles	
	Reinforced-concrete skin friction piles	
	Steel bearing piles	
	Steel skin friction piles	
	Wood piles	
	Cast-in-place concrete piers	
	Caissons	
Other	Described below	

For new buildings. Old buildings had a masonry foundation, usually stone masonry (foundation stones).

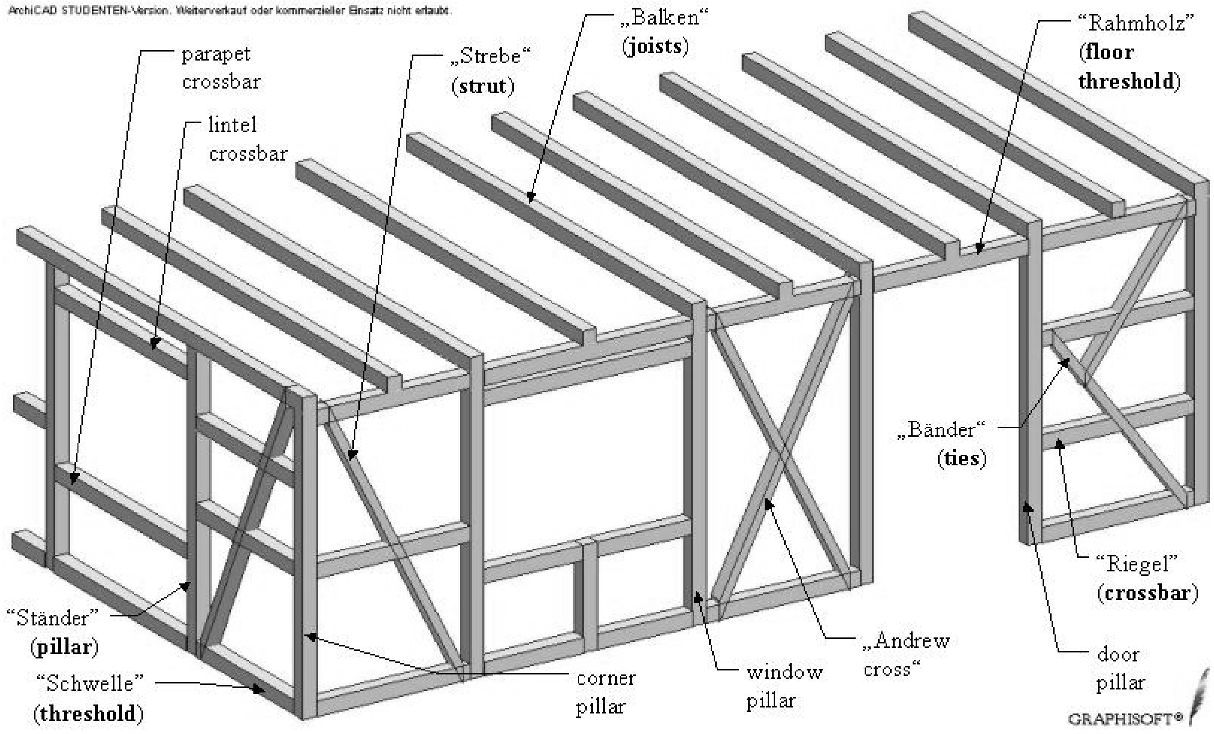

Figure 2-11: Names of the key load bearing elements.

Figure 2-12: The infill material: on the left - drawing of willow basketry, used for infilling; on the right - close view of adobe infilled panels.

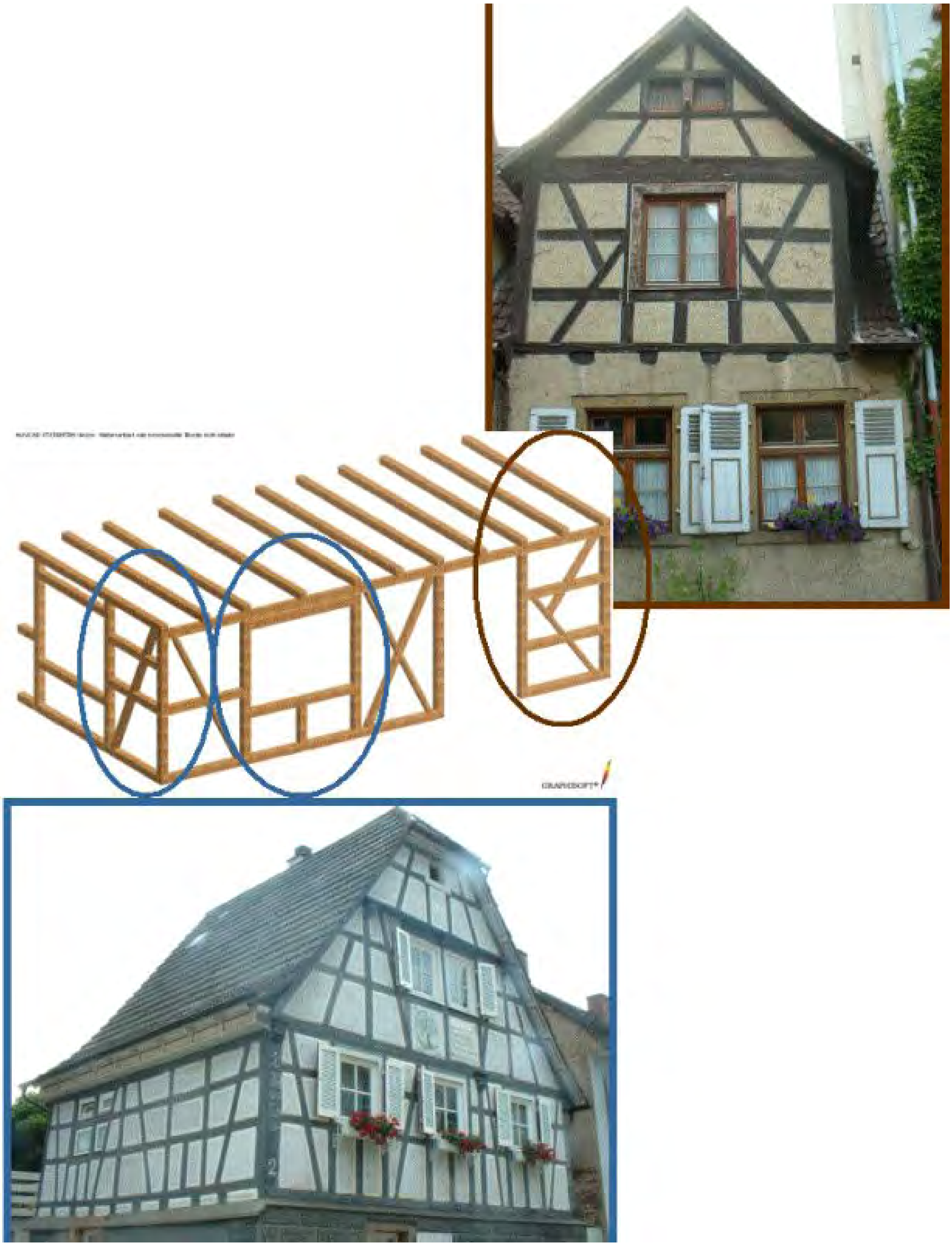

Figure 2-13: Key load bearing elements exemplified on two typical buildings. Photos by M. Kauffmann, 2004.

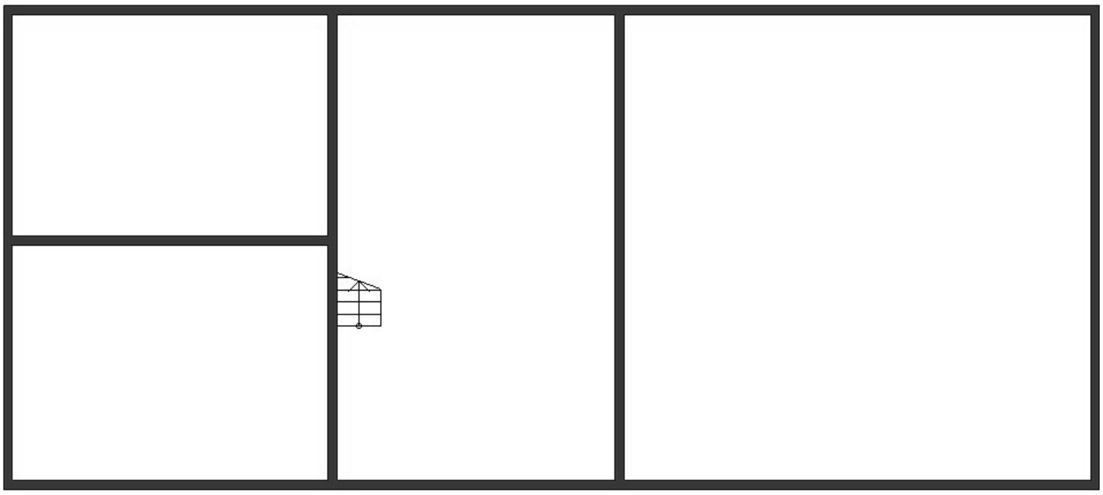

Figure 2-14: Scheme of the floor plan of a rural building.

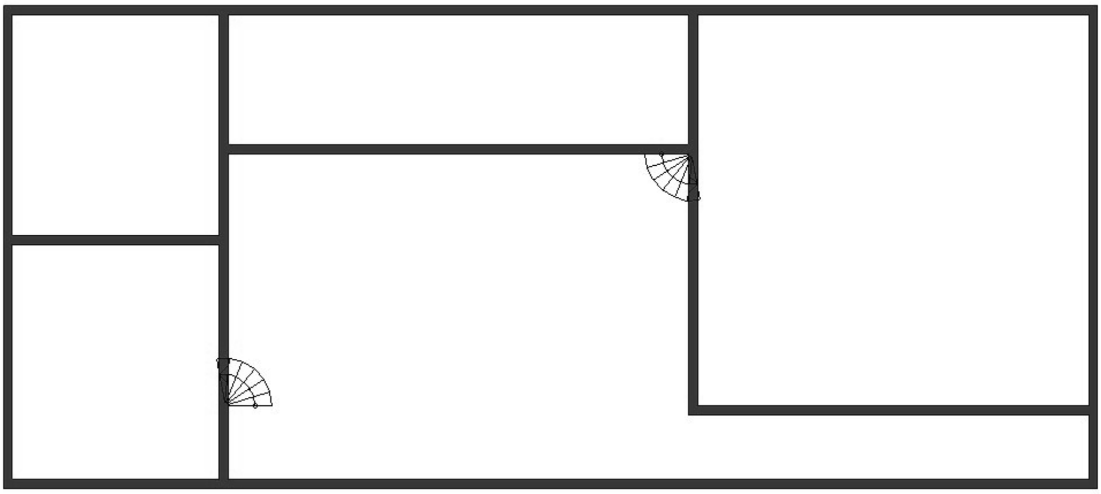

Figure 2-15: Scheme of the ground floor plan of an urban building.

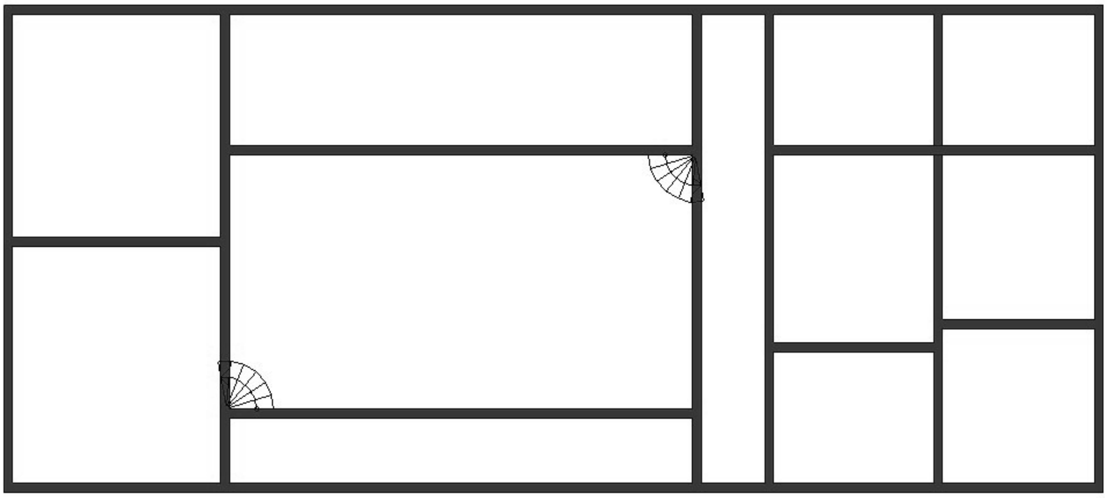

Figure 2-16: Scheme of the upper floor plan of an urban building.

Figure 2-17: Typical window. Photo by Michael Kauffmann, 2004.

Figure 2-18: Connection between horizontal and vertical load bearing elements: side wall (top) and typical gable solution (bottom). Photos by Michael Kauffmann, 2004.

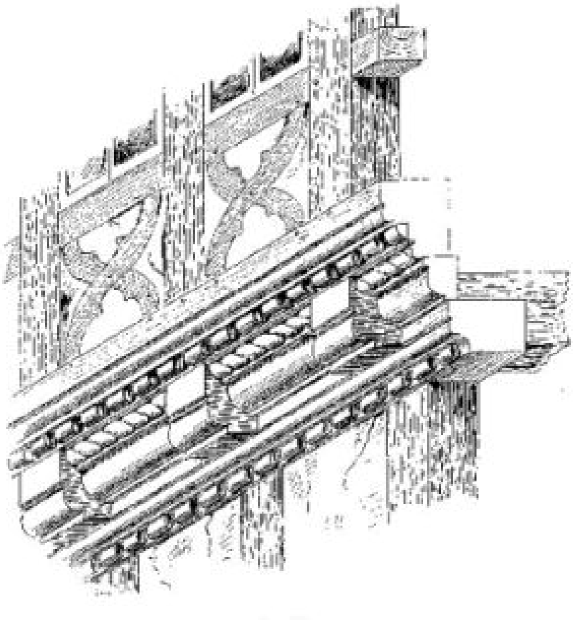

Fig. 288.

Von einem Hause in Wildungen, erbaut Mitte bis Ende des XVI Jahrh.

Figure 2-19: Parapet ornaments: top - at a house in Wildungen, built in the middle till end 16th century. Source: Uhde (1903), Fig. 288 on page 252; bottom - at a house in Durlach. Photo by Michael Kauffmann, 2004.

Figure 2-20: Various kinds of ornament around the windows. Photos by Michael Kauffmann.

Figure 2-21: Construction details of floors (new building): from bottom to top different steps in finishing. Photos by Maria Bostenaru, 1998.

Figure 2-22: Key seismic features. Photo by Michael Kauffmann, 2004.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5.

4.2 Patterns of Occupancy

Until the 19th century one family (spanning several generations) occupied a house. After that, different rooms or floors might be rented out.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	
b) low-income class (poor)	
c) middle-income class	
d) high-income class (rich)	

Applicable today. In the Middle Ages these houses were inhabited by the poor. Economic Level: The ratio of price of housng unit to the annual income can be 4:1 for rich families.

Ratio of housing unit price to annual income	**Most appropriate type**
5:1 or worse	
4:1	
3:1	
1:1 or better	

What is a typical source of financing for buildings of this type?	**Most appropriate type**
Owner financed	
Personal savings	
Informal network: friends and relatives	
Small lending institutions / micro-finance institutions	
Commercial banks/mortgages	
Employers	
Investment pools	
Government-owned housing	
Combination (explain below)	
other (explain below)	

In each housing unit, there are 2 bathrooms.

The numbers above refer to contemporary buildings. Bathrooms exist only in buildings from the 19th century and after. Latrines were not always part of the main building until then.

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership and ownership with debt (mortgage or other).

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	**False**	**N/A**
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.			
Building Configuration	The building is regular with regards to both the plan and the elevation.			
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.			
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.			
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.			
Wall and frame structures- redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			
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);			
Foundation-wall	Vertical load-bearing elements (columns, walls) are attached to the foundations;			

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	N/A
connection	concrete columns and walls are doweled into the foundation.			
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			
Wall openings	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).			
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)			
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall frame	Designed for gravity loads only. Joists not always in the same plane as the pillars.	- Presence of diagonal braces (fig. 2-22); - Astonishing feeling of the carpenters of the time for equilibrum; - Very well-made connections between the wooden frame elements; excellent technique in cutting the wood for doing this.	
Frame infill	Designed for gravity loads only.	Similar elasticity to that of the frame in this type (infill is out of adobe or wood) as compared to the northern type (infill is out of bricks). Contemporary construction uses brick more and more.	
Floors	Designed for gravity loads only. Joists not always in the same plane as pillars, and thus are supported by beams instead of directly by pillars.	Timber floors and joists ensure a uniform distribution of rigidities in-plane and energy absorption. Similar elasticity to that of the walls.	
Roof	Designed for gravity loads only.	Good three-dimensional conformation of the roof. Similar elasticity to walls and floors.	

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance)*, the lower bound (i.e., the worst possible) is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), and the upper bound (i.e., the best possible) is *E: LOW VULNERABILITY (i.e., very good seismic performance)*.

Vulnerability	**high**	**medium-high**	**medium**	**medium-low**	**low**	**very low**
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F

5.4 History of Past Earthquakes

Date	**Epicenter, region**	**Magnitude**	**Max. Intensity**
1356	Basel (30 km to south)		IX (MSK)
1601	Vierwaldstättersee		VIII-IX (MSK)
1755	Oberwallis near Brig/Visp		VIII-IX (MSK)
1946	Sanetschpass (Central Wallis)		VIII (MSK)

Damage due to the 1356 Basel earthquake occured up to 300 km distance from its epicenter (Burgundy, France). This kind of building was not affected, though, and in Basel there are buildings still standing from ~1200, which survived the earthquake and the years since (http://www.meteoriten.ch/, 2004). See http://www.wetzlarvirtuell.de/asp/main_frame_addr.asp?address_id=115 (2004) for a typical Middle Age house from exactly the year of the Basel earthquake 1356 in Wetzlar, central Germany (Broadshirm street 6). Affected by the 1356 earthquake were constructions of stone, like castles and churches, and not the wooden construction inhabited by the poor. The 1601 earthquake was felt according to D-A-CH (1989) in the entire area of central Europe. Two historically strong earthquakes with epicenters in Oberwallis near Brig/Visp have occurred: one in 1755 as listed above and one in 1855 with IX (MSK) intensity. The earlier one was felt in the whole Alpine region as well as in southern Germany and northern Italy. The 1855 earthquake was the strongest earthquake in Switzerland in the 19th century and was strongly felt in southern Germany and northern Italy. In the time period between these two events, Switzerland was affected by a strong earthquake in 1774, with VIII MSK intensity and an epicenter in central Switzerland that affected numerous cantons. (after D-A-CH, 1989) The stongest earthquake in Switzerland in the 20th century occurred in 1946. It was felt in Austria (Innsbruck), France (Alsace, Grenoble), southern Germany (Stuttgart) and northern Italy (Milano) (after D-A-CH, 1989). Data are available for several recent earthquakes with magnitudes over 4.0 occurring in Switzerland in the European Strong Motion Database (2002): an earthquake with magnitude 4ML in 1996 at Kirchberg, an earthquake with magnitude 4.3ML in 1999 in Fribourg, an earthquake with magnitude 4.9 Mw in 1999 in Piz Tea Fondada, and an earthquake with magnitude 4.1Mw in 2000 with an epicenter in Monte Solena. A complete earthquake catalogue is available at: http://histserver.ethz.ch/intro_e.html (2004) See the general references for examples of historical earthquakes affecting this type of construction in Switzerland and Austria.

Figure 2-23: Courtyard of a house in Strassbourg from 1657 (left). Source: Uhde (1903) Fig. 307 on page 269 from "Strassbourg and its buildings" and passage to the courtyard in Durlach (right). Photo by Michael Kauffmann, 2004.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Wall infill (less mountainous region): Adobe Wall infill (mountain region): Oak timber planks	Wall infill (less mountainous region): N/A Wall infill (mountain region): Elasticity modulus 70000-120000; tension 1310 kg/qcm; compression 510 kg/qcm; bending 1020 kg/qcm; shear 79 kg/qcm	Wall infill (less mountainous region): Clay (10%) Silt Sand Gravel 4-5 stabs (oak, 3-5cm wide) were needed to fill the basketry in 1m width tiber frame. Often chaff was added. Wall infill (mountain region): 2.5-3.25cm planks. The resulting wall is 4-5cm thick. (Stade, 1904)	In new buildings, adobe prefabricated plates can be used (these are then cut to the dimension needed for the infill). However, using adobe today is expensive (personal costs) even if the material is almost free, so brick masonry is used more and more.
Frames (beams & columns)	Timber frame (old buildings): Oak (sometimes fir) wood Timber frame (new buildings): Douglas fir or laminated wood	Timber frame (old buildings): Elasticity modulus 70000-120000; tension 1310 kg/qcm; compression 510 kg/qcm; bending 1020 kg/qcm; shear 79 kg/qcm Timber frame (new buildings): Elasticity modulus 72000-144000; tension 250 kg/qcm; compression 1080 kg/qcm;	"Ganzholz" (wood originating from a whole tree stem), "Halbholz" (half of a stem) and "Kreuzholz" (a quarter of a stem) Lower horizontal elements: 13/18, 13/20, 15/20, 13/21 or 16/21 cm (Stade, 1904). Upper horizontal elements: 12/12, 13/13, 12/14, 13/15, 13/18 cm. (Stade, 1904) Corner pillars: 13/13, 15/15, 13/16, 16/16, 21/21 cm (Stade, 1904). Intermediary pillars:12/12, 13/13, 12/14, 13/15, 12/16 or 13/16cm (Stade, 1904). Diagonals: 12/16 or 13/18	For traditional houses.

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
		bending 840 kg/qcm; shear -	cm (Stade, 1904). Upper horizontal elements (sustaining the roof): 12/16, 13/18 or 16/21cm (Stade, 1904).	
Roof and floor(s)	Oak timber	Elasticity modulus 70000-120000; tension 1310 kg/qcm; compression 510 kg/qcm; bending 1020 kg/qcm; shear 79 kg/qcm	Floors: Planks are 2-5 cm thick. The joists are between 2.5cm (0.80m span) to 16cm (4.5m span). Roof: Timber between 8/8 cm and 28/30cm. (Stade, 1904)	

6.2 Builder

The builder typically lives in this construction type, but regardless, it is not built for speculation.

6.3 Construction Process, Problems and Phasing

Großmann (1986) describes in detail the construction process for a historical Fachwerkhaus (pages 10-44) and included illustratrations of the materials, steps, typical drawings and tool kits used. After the planning is completed, the work is begun in the carpenter's workshop. There were two kinds of work: processing the wood from tree logs to lumber and creating tenons and related work. Saws, axes, knives, chisels, planers, and drillers were used. The joists, ties, pillars, etc. were marked for assembly. The assemblage was made often for a whole wall at once, especially for multistoried buildings. Sometimes a safer construction method was used (depending on the number of persons available for the work), namely, connecting the pillars to the foundation and to the threshold and then adding the struts and bands. In Baden-Württemberg the floor was finished after each story was constructed. After the assemblage was connected, it was nailed together. The next step was infilling. Holes were created to add the basketry on which adobe was curled up in a single layer from both sides. Added chaff prevented the creation of cracks while the adobe was drying. The infills were then plastered with calc. Another kind of infilling was done with wooden planks. After this, the floors were constructed followed by the roofing. The next step involved constructing the windows and doors, as well as of stairs,wall wardrobes, and other smaller items, by the joiner ("Bautischler" in German). Plastering and painting the wood came last. The construction process for a new building is illustrated in a report at http://www.fachwerkhaus.de/fh_haus/info/drei.htm (2004). See http://www.fuhrberger.de/leistung/fachwerk/acer.shtml (2004) for images regarding the construction of a house, http://www.fuhrberger.de/leistung/sanierung.shtml (2004) for images regarding the rebuilding an old house after a picture and http://www.fuhrberger.de/leistung/bauzeitenplan.shtml (2004) for a construction plan. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

According to Großmann (1986): Construction literature was used from the 17th century on, as is seen, for example, in C. F. Mayer (1778) for the region around Schwäbisch-Hall. These books were written for developers. The detailed planning was done by the master builder, usually a carpenter by trade. Architects played a role only from the end of the 19th century on. In the 19th century there were construction enterprises by carpenters and master masons. The carpenter had this role exclusively in urban areas until the 18th century and in rural areas until the 19th century. Specific plans for "statics" (structural plans) were drawn. These were used both for construction authorization process and for the construction itself. In previous centuries this was not so widespread as it is today. Contractors used books like "Architektura Civilis" by Johann Wilhelm, from Frankfurt am Main (Nürnberg, 1649 and 1668), which encouraged building models out of paper and wood. This book also recommended estimating costs in advance and drawing up a contract between the developer and the building overseer. The author emphasized the importance of the survey. Knowledge of geometrical forms was important for the planning. See 7.4.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Title of the code or standard: Switzerland: Norm SIA 160

"Einwirkungen auf Tragwerke" (Ausgabe 1989) des Schweizerischen Ingenieur- und Architekten-Vereins (SIA). For codes addressing the buildings in Germany see report #95. In France structures under seismic risk are addressed by Règles PS92, Norme NF P 06-13, 1992 (García et al, 2004) The Austrian seismic regulations are called ÖNORM B 4015 (García et al, 2004) Year the first code/standard addressing this type of construction issued: 1970 - SIA 160 Ausgabe 1970. National building code, material codes and seismic codes/standards: Short descriptions of the provisions, especially regarding the seismic zoning, for Switzerland, Germany, France and Austria are included in García et al (2004), but not for the UK. When was the most recent code/standard addressing this construction type issued? Switzerland: 1989. A new code, update of the old, was updated into a new code (SIA 261), but SIA 160/89 will remain valid until 2004. The Austrian seismic regulations have been updated in 2002 (García et al, 2004). The French regulations are, according to García et al (2004), currently revised in view of Eurocode regulations. Before 1970, no norms. 1970-1989 SIA 160 first edition (pushover analysis, depending on frequence only; no reponse spectra and no ductility factors) 1975-1989 SIA 160/2 recommendations (practical measures for protection of buildings against earthquakes) 1989-2002 SIA 160 1989 edition (three building classes, pushover curve varies according to structural type, response spectra, measures) 2002 SWISSCODES (ductility classes, capacity) to incorporate EC8 recommendations.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by owner(s) and tenant(s).

6.8 Construction Economics

According to a source in northern Germany (http://www.fuhrberger.de/leistung/index.shtml, 2004), construction prices today are as follows: - ca. $1,500/sq m; - meaning ca. $200,000 (+/- $40,000) for a single-family house, $350,000 for a two-family house, ca. $400,000 for a block of flats with four apartments. Comparable costs are found for similar buildings in northern France. Costs for Switzerland itself are unknown. Historical prices can be seen in Stade (1904) on page 90. According to Großmann (1986) the construction of an historical house (after the wood for it was processed to the necessary "fachwerk" elements, and the connection points created and correspondingly marked) took several days to few weeks. But many workers were needed therefore (for example, 8 carpenters and their helpers). Up to this point only half of the works are completed. For a new building it takes four days to build the "fachwerk" skeleton (out of pre-fabricated timber parts) of three stories, and another three days for the complete roof - see http://www.fachwerkhaus.de/fh_haus/info/drei.htm (2004) See figure 42 for a typical work plan.

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. According to http://www.gvz.ch/GVZ%5CGVZHome page.nsf/WEBViewPages/Erdbebendeckung? (2004), open document buildings in the canton of Zürich have earthquake coverage under building insurance policies (see source for details). The earthquake hazard in this canton is the lowest in Switzerland and calculations are based upon the Basel earthquake from 1356. Customized earthquake insurance for single or multiple housing units is nevertheless available: for example, through Lloyds (source http://www.erdbeben.at/versicherung.htm, 2004). Even in this case, the premium is influenced primarily by the site. More typical are higher fire insurance premiums for these timber buildings. Typically, buildings and their contents can be insured.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Not necessary, as this type of building was not damaged.

8.2 Seismic Strengthening Adopted

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

Not applicable, as there is no seismic damage.
Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
Not applicable, as there is no seismic damage.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Not applicable, as there is no seismic damage.
Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
Not applicable, as there is no seismic damage.
What was the performance of retrofitted buildings of this type in subsequent earthquakes?
Not applicable, as there is no seismic damage.

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[Edbeben - Versicherung] = "Earthquake - Assurance"
http://www.erdbeben.at/versicherung.htm

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Modernist building in Germany: Prefabricated metal construction of the Modern Movement

(Report # 95 in the "World Housing Encyclopedia"
http://www.world-housing.net/)

Summary

This urban housing construction was practiced for about 20 years during the early 1900s in Germany. Single-family houses and blocks of flats, both built according to the same construction system, are included in this report. This construction was built in what were once the outlying areas of German cities. Typically, these low-cost housing units are rented by the residents. The buildings consist of a row of several individual, 20-meter-long units, each of which usually contains two apartments on each floor. The load-bearing system is iron skeleton with brick infill. Usually, the skeleton is made out of columns and beams, but dense column grids were sometimes used to minimize the spans of metal joists as a cost-saving measure. Experiments with various materials for the bricks were tried as part of the continuous search for improved insulation. The floors are also made out of bricks on iron joists. Stiffening is usually provided by diagonal ties at the staircases, which are placed in the middle of each building unit. Because of the seismic activity, both along the Rhine and in the Swabian Jura affecting Baden-Wuerttemberg, seismic codes (DIN) were issued in 1981 and have been updated. Standards have existed since 1957 and are expected to be included in the new European code, Eurocode 8.

1. General Information

Buildings of this construction type can be found in Karlsruhe (1929 Dammerstock: Fig. 3-3, 3-4), Frankfurt, Berlin, Stuttgart (1927 Weissenhof: Fig. 3-7), Kassel (1929 Rothenberg), Celle (1930 Blumlagerfeld) and others. Some 300,000 residential units (see "Weisse Vernunft", 1999) were built. This type of housing construction is commonly found in sub-urban areas. This construction type has been in practice for less than 100 years. Currently, this type of construction is not being built. This construction type had been practiced up to the world economy crisis.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. Figures 3-5 and 3-8 are typical views in a Siedlung.

Figure 3-1: Typical photo of a multistorey house of the type (in Karlsruhe; same type to be found in Kassel). Photo: M. Bostenaru, 2004.

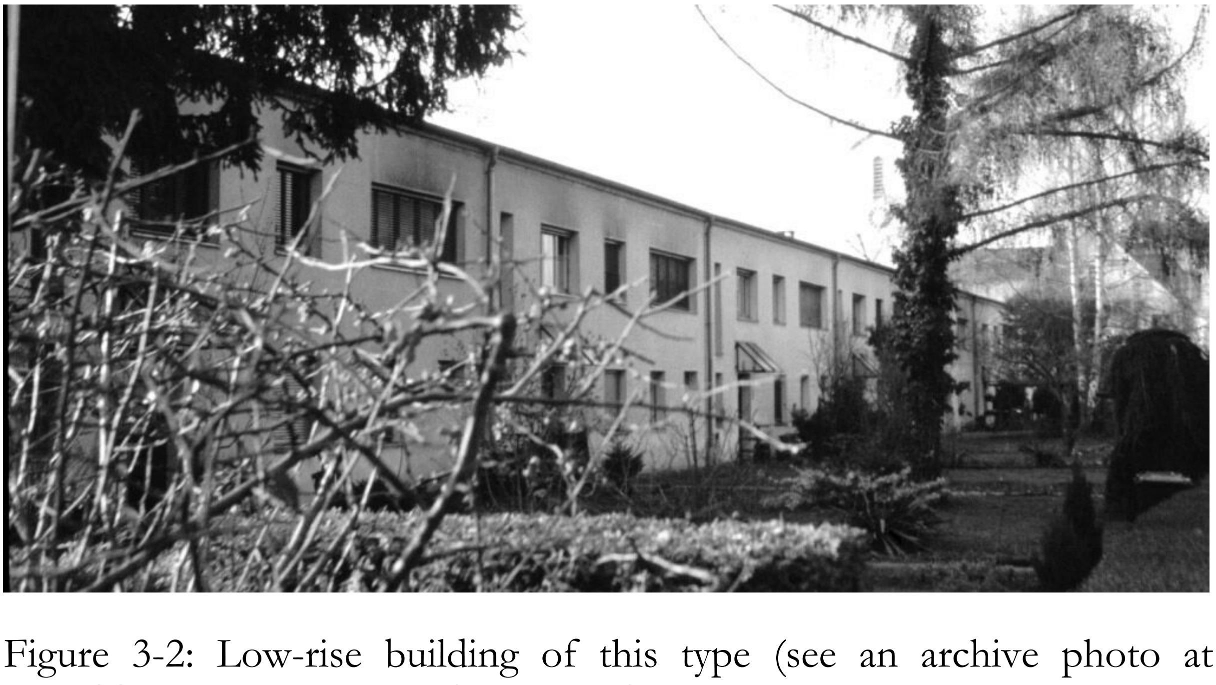

Figure 3-2: Low-rise building of this type (see an archive photo at http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/Bilderbogen/bau-damm_3.jpg or http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/bilder_w.php). Photo by Maria Bostenaru, 2004.

Figure 3-3: Mid-rise building of this type in context - entry situation in Karlsruhe-Dammerstock. Photo by Maria Bostenaru, 2004.

Figure 3-4: Low-rise building of this type in context (Karlsruhe). Photo by Maria Bostenaru, 2004.

Figure 3-5: View through the rows in a typical Siedlung (Karlsruhe). Photo by Maria Bostenaru, 2004.

Figure 3-6: Another mid-rise building of this type (in Stuttgart). Top: view from the back. Bottom: view from the front. Photo by Maria Bostenaru, 2002.

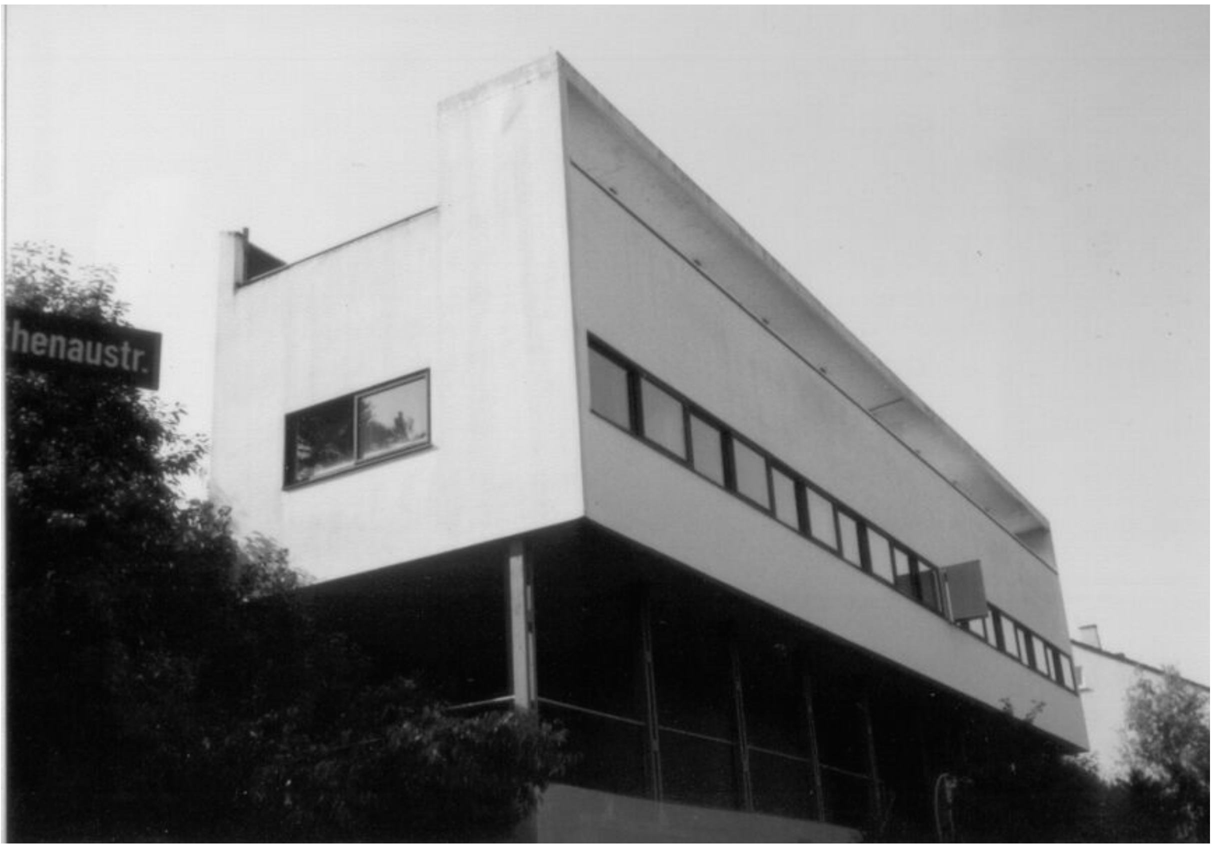

Figure 3-7: A renowned building of this type: Le Corbusier's building in Stuttgart Weissenhof (1927) - a mix of reinforced concrete and metal structure: free standing columns out of metal. Photo: M. Bostenaru, 2002

Figure 3-8: View along the rows in a typical Siedlung (Karlsruhe). Photo by Maria Bostenaru, 2004.

2.2 Building Configuration

Rectangular. The openings are usually 85cm wide, which also determined the spacing of metal elements used, for example in Celle (where many joists were missing). Images showing details of openings in mid-rise buildings can be seen in fig. 3-17 (long facade of a typical building) and 3-19 (short facade of a typical building bar). The size and the distribution of windows in a typical low-rise building can be seen in figure 3-22.

2.3 Functional Planning

This construction type was both used for single family housing and multiple housing units, but multiple housing units were more common. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Staircases are the primary means of escape. The staircases that are designed according to the norms were first used in some of the buildings of this type.

DAMMERSTOCK

Mustersiedlung des „Neuen Bauens" in Karlsruhe

1110 Erste Erwähnung von „Dagemersdung" als Besitz des Klosters Gottesaue. Die Siedlung geht im Mittelalter unter.

1907 Mit der Eingemeindung Beiertheims entstehen Pläne zur Bebauung des Dammerstock-Geländes als „Industriegebiet mit Gleisanschluß".

1925 Beginn von Kanalisationsarbeiten zur Erschließung des Dammerstocks.

1926 Der von dem zuständigen Bau-Bürgermeister Hermann Schneider veröffentlichte Entwurf eines Generalbebauungsplans für Karlsruhe sieht eine Wohnsiedlung im Dammerstock vor.

1928 Im Juni beschließt der Stadtrat zur Linderung der Wohnungsnot die Erschließung des Dammerstocks südlich der späteren Nürnbergerstraße. Für die Bebauung mit Klein- und Mittelwohnungen wird ein Architektenwettbewerb ausgeschrieben. Mit möglichst geringen Kosten soll für breite Schichten bezahlbarer Wohnraum entstehen. Als ein Bauträger wird die gemeinnützige städtische Baugenossenschaft „Volkswohnung" gegründet.

1928 Im November spricht das Preisgericht dem Bauhausgründer Walter Gropius den ersten und Otto Haesler den zweiten Preis zu. Weitere Architekturbüros - auch aus Karlsruhe - erhalten Preise.

1928 Im Dezember wird Gropius zum künstlerischen Oberleiter des Projekts ernannt. Für die Gestaltung gelten gemäß den Prinzipien des „Neuen Bauens" einfache Baukörper, Flachdächer, vereinheitlichte Fenster- und Türelemente, gleiche Geschoßhöhen und Farbgebung.

1929 Ab Januar werden die konsequent in Nord-Süd-Richtung liegenden Zeilen der Geschoßwohnungsbauten und der Reihenhäuser errichtet. Die meisten Preisträger werden am Bau der Siedlung beteiligt.

1929 Im Oktober findet in dem fertiggestellten ersten Bauabschnitt mit 228 Wohnungen die Ausstellung „Dammerstock-Siedlung, die Gebrauchswohnung" statt. Gezeigt werden 30 moderne, zweckmäßig gestaltete und eingerichtete Kleinwohnungen. Das graphische Konzept der Präsentation entwickelt der Typograph und Dadaist Kurt Schwitters.

1934–1939 Das Konzept des „Neuen Bauens" wird nicht fortgeführt. Die neuen Machthaber der NSDAP wollen die „fremdländische Architektur" verdecken. Es entstehen vor allem nördlich der Marie-Mattheis-Straße und auch an der Mainzer Straße Ein- und Zweifamilienhäuser in der „einheimischen Bauart mit spitzen Giebeldächern".

1936 Bau der St. Franziskus Kirche mit einem Pfarrkloster der Kapuzinermönche.

1942 Bau des Luftschutzbunkers.

1949 Fortsetzung der Bebauung im Dammerstock. Im Süden nimmt der Architekt van den Kerkhoff mit den Laubenganghäusern Elemente des „Neuen Bauens" auf.

■ vor 1933
■ 1933 – 1945
■ ab 1945
○ Standort

Figure 3-9: The entry poster to such a Siedlung, including the plan with times of construction. The aerial archive view - postcard from 1950 - can be seen at http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/postkarte-dammer_1.jpg (or http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/bilder_z.php).

2.4 Modification to Building

The original light walls were later replaced by the masonry partition walls. The empty rooms were later used for residential occupancy.

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Dressed stone masonry (in lime/cement mortar)	
	Adobe/ Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	
		8	Brick masonry in mud/lime mortar with vertical posts	
		9	Brick masonry in lime/cement mortar	
		10	Concrete block masonry in cement mortar	
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	
		12	Clay brick masonry, with concrete posts/tie columns and beams	
		13	Concrete blocks, tie columns and beams	
	Reinforced masonry	14	Stone masonry in cement mortar	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
		15	Clay brick masonry in cement mortar	
		16	Concrete block masonry in cement mortar	
Structural concrete	Moment resisting frame	17	Flat slab structure	
		18	Designed for gravity loads only, with URM infill walls	
		19	Designed for seismic effects, with URM infill walls	
		20	Designed for seismic effects, with structural infill walls	
		21	Dual system – Frame with shear wall	
	Structural wall	22	Moment frame with in-situ shear walls	
		23	Moment frame with precast shear walls	
	Precast concrete	24	Moment frame	
		25	Prestressed moment frame with shear walls	
		26	Large panel precast walls	
		27	Shear wall structure with walls cast-in-situ	
		28	Shear wall structure with precast wall panel structure	
Steel	Moment-resisting frame	29	With brick masonry partitions	
		30	With cast in-situ concrete walls	
		31	With lightweight partitions	
	Braced frame	32	Concentric connections in all panels	
		33	Eccentric connections in a few panels	
	Structural wall	34	Bolted plate	
		35	Welded plate	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Timber	Load-bearing timber frame	36	Thatch	
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		38	Masonry with horizontal beams/planks at intermediate levels	
		39	Post and beam frame (no special connections)	
		40	Wood frame (with special connections)	
		41	Stud-wall frame with plywood/gypsum board sheathing	
		42	Wooden panel walls	
Other	Seismic protection systems	43	Building protected with base-isolation systems	
		44	Building protected with seismic dampers	
	Hybrid systems	45	other (described below)	

Typical skeleton with I shaped members is shown in Ahnert (2002) Vol. III in Tafel 10 on P. 41.

Figure 3-10: A bar of four buildings (also five building in a bar possible), here the variation with external staircase.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Iron schelet (fig. 3-11 – 3-13) with infill walls of half clay or "Schwemmstein" bricks support the gravity loads. The connections are made with screws over corner elements in the upper floors and in the basements and at column base with nits (fig. 3-16). The statics were computed for a 10cm thick brick-iron floor. Iron/steel frames are one storey high and later infilled with masonry (Stuttgart, Karlsruhe). In Celle many joists are missing and vertical load bearing elements are spaced 85cm. Gravitational loads are transmitted directly to the foundation. Here the skelet serves as "Fachwerk" up to the corniche.

3.3 Lateral Load-Resisting System

Lateral load resistance is provided by iron skeleton stiffened by brick infill walls (fig. 3-21) and by wind bracing within the staircase walls (fig. 3-20). The floor is the so called "Kleine" brick-iron-floor system with I-profile joists. The "Kleine" floor system was characterised through concrete reinforced with round iron bars at about 30 cm distance.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 20 and 160 meters, and widths between 5.5 and 8.5 meters. The building has 2 to 4 storeys. The typical span of the roofing/flooring system is 3 meters. Typically a building is divided into rectangular units of about 20m long, separated by joints. One to eight such units can form a building, the typical number being 3 to 5 (fig. 3-9 and 3-10). An aerial view today of a typical siedlung showing these relationships can be seen at http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/Bilderbogen/luft-dam.jpg)or http://www1.karlsruhe.de/Stadtteile/Weiherfeld-

Dammerstock/bilder_quu.php). The typical number of stories for multiple housing units vary from 2 to 4 depending on the region. The average number of stories is 4 (1 ground floor (GF)+3 regular) in Stuttgart (fig. 3-6), 4 (1 basement +GF+3 regular) in Kassel and in Karlsruhe (fig. 3-1). The single family houses are 2 storys (1 basement+GF+1 regular) in Celle and Karlsruhe (fig. 3-2). Typical Span: For typical buildings the spans in unreinforced systems are 1-2m (and rarely 3-4m). In the cases where anchors were used, the spans were around 2.5m and in case of "Stahlsteindecken" it is aproximate 3m. By 1925, the spans for no iron were usually 1.3-1.4m. In the dry-mounting application the spacing is 1.06m. The span for example buildings: 3.2m all at facade in longitudinal direction except at staircase where 1.8m; 4.8 the long ones in transversal direction (the short ones remaining 3.6 m). Other buildings have spans of 0.85, 1.06 for the secondary joists. The typical storey height in such buildings is 2.8 meters. The typical structural wall density is none. 5% - 8% This density is given for infill walls.

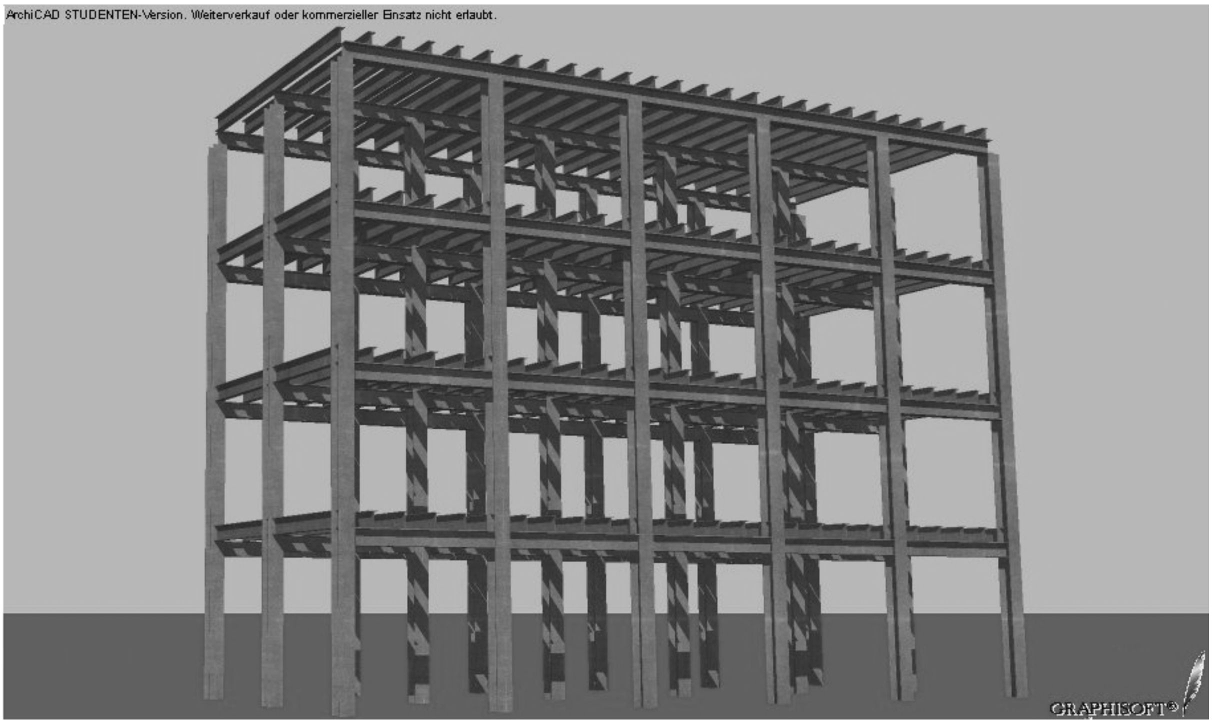

Figure 3-11: Perspective view of key load bearing elements: Variant 1 (for a structure of this type see Dammerstock Gruppe 3 by architect Otto Haesler in "Kunst und Handwerk" Heft 9. 1929. page 259)

3.5 Floor and Roof System

Material	**Description of floor/roof system**	**Most appropriate floor**	**Most appropriate roof**
Masonry	Vaulted		
	Composite system of concrete joists and masonry panels		
Structural concrete	Solid slabs (cast-in-place)		
	Waffle slabs (cast-in-place)		
	Flat slabs (cast-in-place)		
	Precast joist system		
	Hollow core slab (precast)		
	Solid slabs (precast)		
	Beams and planks (precast) with concrete topping (cast-in-situ)		
	Slabs (post-tensioned)		
Steel	Composite steel deck with concrete slab (cast-in-situ)		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood shingle roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams supporting natural stones slates		
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other	Described below		

Composite masonry and steel joist: Ahnert (2002) shows the details of such a structure in Tafel 6 on P. 36, Vol. III (with "Kleine" floor). More details are given in the "Kleine" floor in Tafel 18 on P. 57 in Ahnert (2002), Vol. II. Here and in the adjacent Tafel 17 also another floor system of the same type (I joists and holed bricks) was used in Germany for common buildings at that time: "Secura", "Wingen", "Kelling", "Rhein", "Förster", "Ludwig" and finally "Hourdis". Hourdis is the French name for hollow bricks. This system was also used with "Bimsbeton" (special kind of concrete, based on pumice). All these systems are unreinforced floor system types. Later on round steel was used to bind the I joists (see Ahnert, 2002, Vol. II, Tafel 22 on P. 164) to the exterior walls and within these with higher density in the basement (Ahnert, 2002, vol. II, Tafel 23, P. 65). With added round steel wide variations of the floor type, called "Stahlsteindecken" (steel stone floors) were created and some of them from 1936 are shown in Ahnert (2002), Vol. II, in Tafel 25 on P. 78 and Tafel 26 on P. 79. These were addressed from 1943 on by the code DIN 1046. Later cross reinforcing of such floors was possible, as documented by Ahnert (2002), Vol. II, Tafel 31 on P.88.

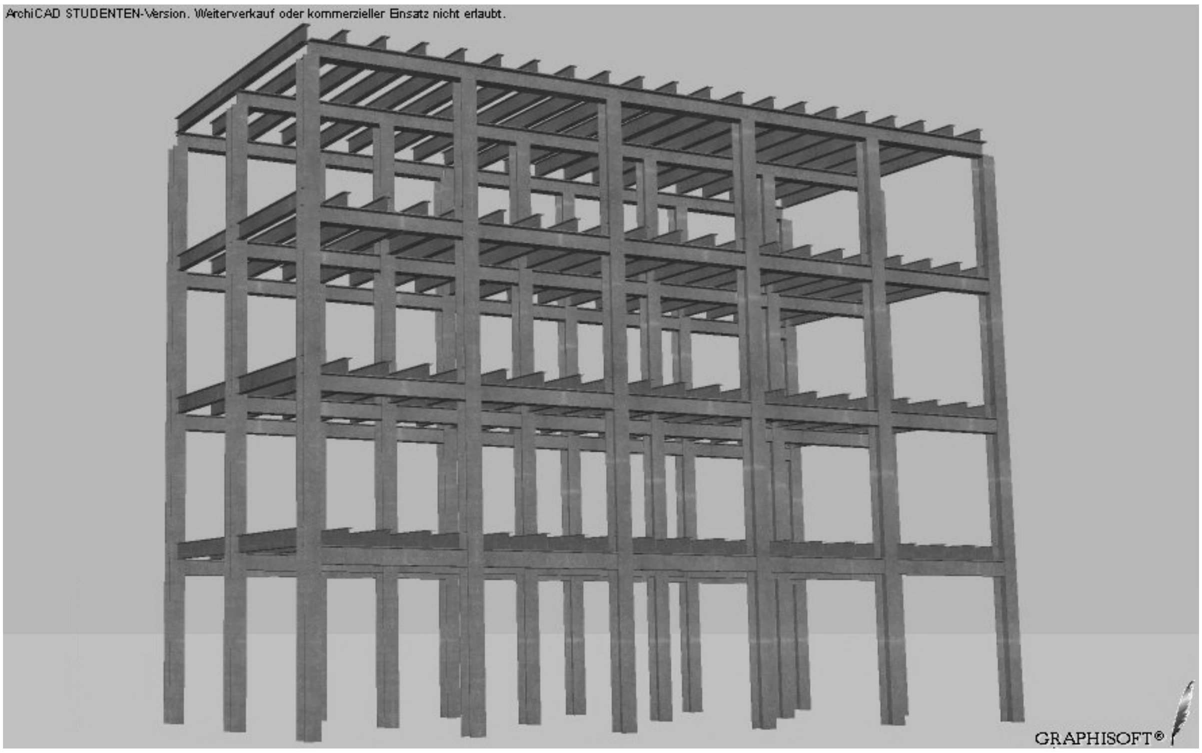

Figure 3-12: Key load bearing elements: Variant 2 (a structure of this type is to be seen in Kassel-Rothenberg by architect Otto Haesler in Haesler: "Mein Lebenswerk als Architekt". 1957. Page 32)

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced-concrete isolated footing	
	Reinforced-concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced-concrete bearing piles	
	Reinforced-concrete skin friction piles	
	Steel bearing piles	
	Steel skin friction piles	
	Wood piles	
	Cast-in-place concrete piers	
	Caissons	
Other	Described below	

Figure 3-13: Axonometric view of key load bearing elements in variant 1

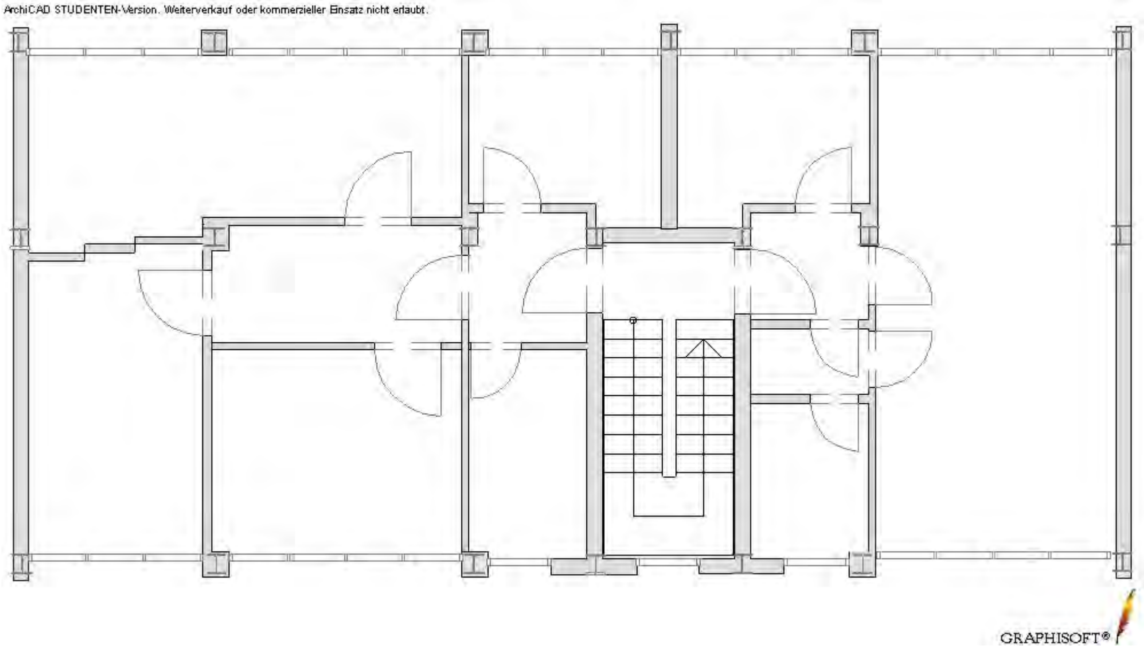

Figure 3-14: Plan of a typical building

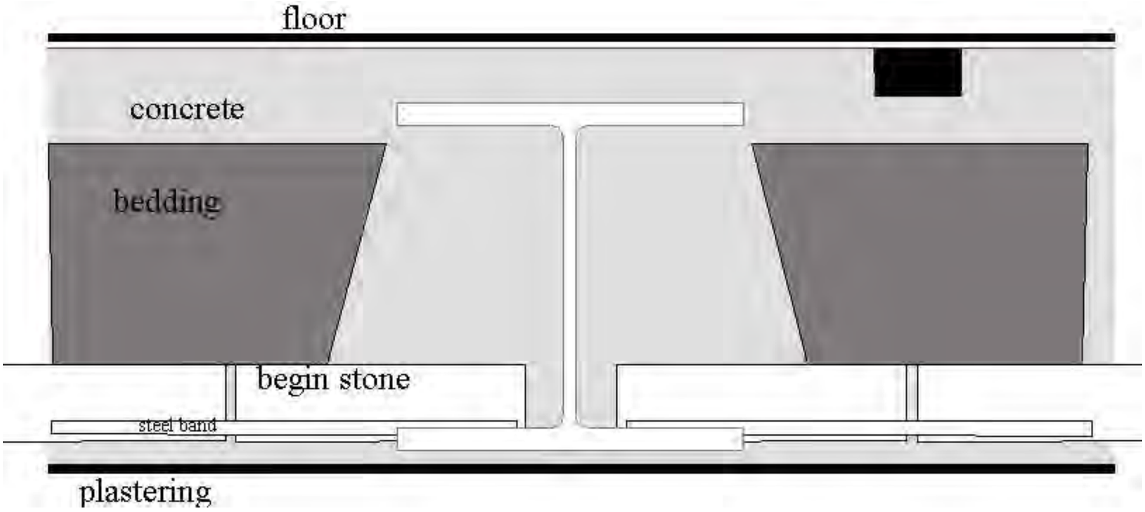

Figure 3-15: Critical structural floor detail ("Kleine" floor)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing units: 24 units in each building. The average number of units in a typical multiple family building is 24. The number of inhabitants in a building during the day or business hours is as described below. The number of inhabitants during the evening and night is as described below. The average number of inhabitants in a typical building depends on the number of units. Approximately 96 inhabitants reside in a typical building.

Figure 3-16: Critical structural detail: column-joist connection (an archive photo of such a structure in Kassel-Rothenberg, architect Otto Haesler, can be seen in Stein Holz Eisen 1929)

Figure 3-17: Facade detail from a mid-rise building of this type (Stuttgart). Photo by Maria Bostenaru, 2002.

Figure 3-18: Details showing the way horizontal and vertical (iron)reinforced concrete and vertical metal elements are combined in Le Corbusier's building in Stuttgart Weissenhof. Photos by Maria Bostenaru, 2002.

Figure 3-19: Corner detail for a mid-rise building of this type (Stuttgart). Photo by Maria Bostenaru, 2002.

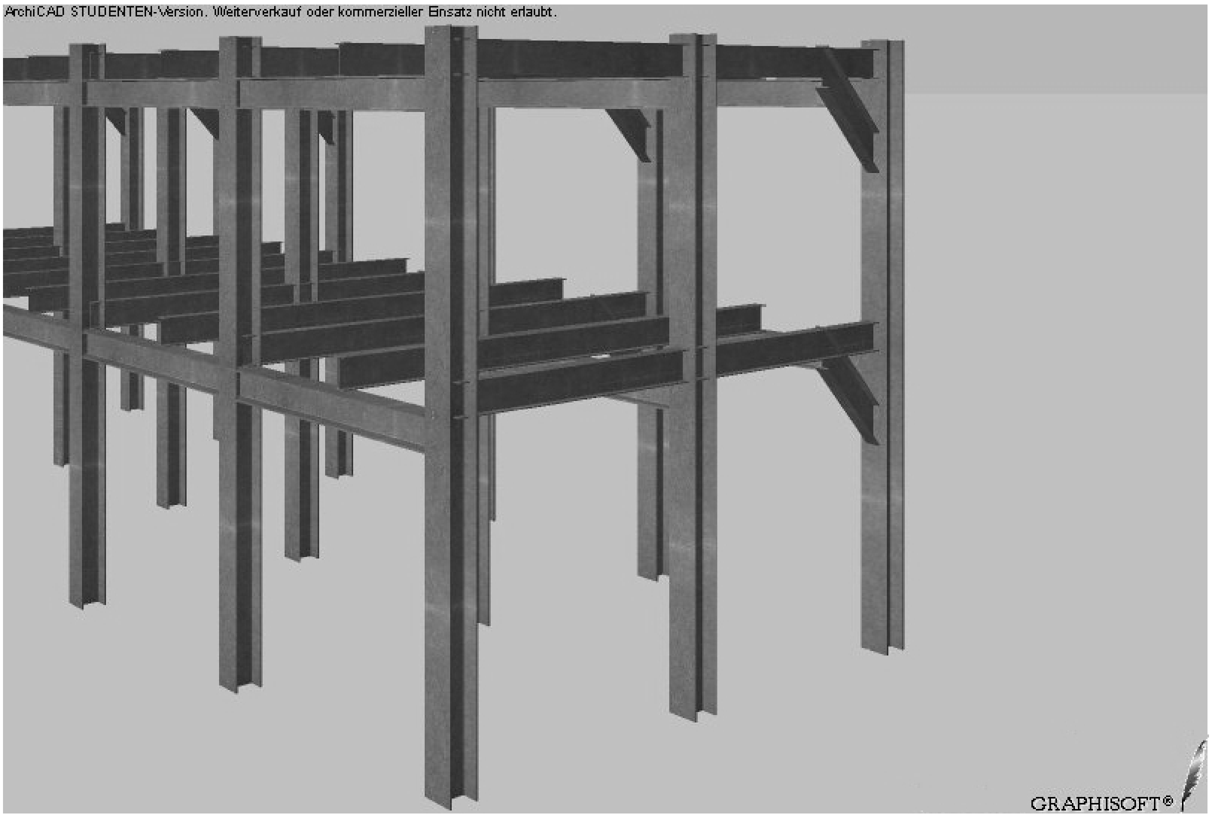

Figure 3-20: Key seismic features: Stiffening in the staircase area (an archive photo where such stiffening elements can be observed is found in Nägele, 1992, on page 104)

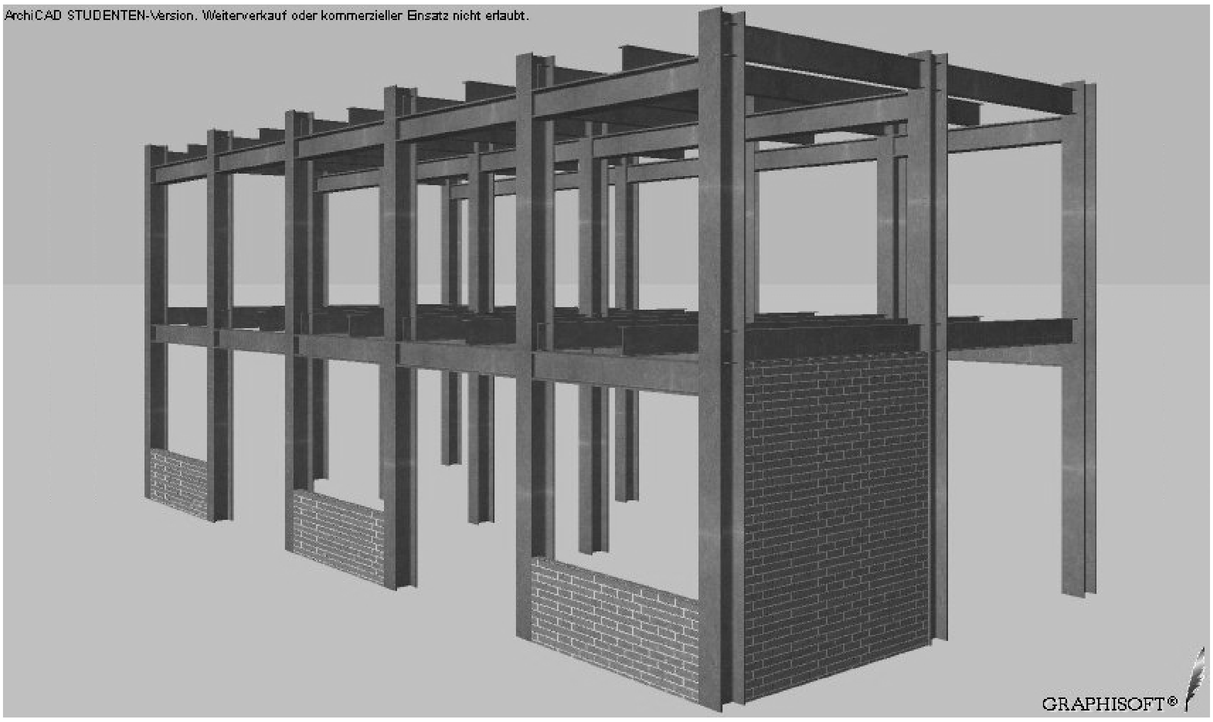

Figure 3-21: Key seismic features: infill walls (an archive photo showing infilling of metal frame on the building site is found in the Nägele, 1992, on page 104)

Figure 3-22: Seismic feature (small openings in infill walls): Facade of a low-rise house (Karlsruhe). Photo by Maria Bostenaru, 2004.

4.2 Patterns of Occupancy

The type of occupancy is generally residential. The number of inhabitants in a unit varies depending on the size of the units. There are units that can accommodate 2 (32-34m²) to 8 (60-78m²) persons. The size of the units, on the other hand, is determined by the degree of "luxury". The most common unit is designed for a family of 3 to 5 persons (see figure 3-14).

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	
b) low-income class (poor)	
c) middle-income class	
d) high-income class (rich)	

This construction type was considered as social housing for poor inhabitants based on the minimum living space principle of the Modern Movement. The rent was about 150-500 RM per month. Economic Level: For Poor Class the ratio of Houisng Price Unit to their Annual Income is 11:1.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	
4:1	
3:1	
1:1 or better	

After 1918 the state took the initiative to support housing construction in mainly two ways: cheap credits to private persons and financing of housing construction from public money, through the so-called [Wohnungsbaugesellschaften] = "Housing construction societies". A coresponding legislative framework and different instruments (taxes and housing construction support programmes about how to distribute these taxes) had been created. This replaced the "free housing market". Before World War I (WWI), 25% of construction price was provided by the investor, 60% by the first hypotheque (=credit got by the investor) and the rest by the second hypotheque (this followed an English model concerning the separation between capital and interest). After WWI, problems were encountered with thesecond hypotheque . This model is still implemented in the Dammerstock Siedlung in Karlsruhe. The Hypotheque is just 35% but there is an interest aid spanning over 12 years. In Frankfurt 40% of the cost is covered by the so-called [Hauszinssteuer] = "House interest tax" and 20% comes from the Wohnungsbaugesellschaft. The Karlsruher financing model is thus more independent from state money. Research societies were also financing innovative residential buildings. For further details see "Weisse Vernunft" (1999): [Wohnugnsnot/Sozialpolitik] (="Housing shortage/Social politics") and [Finanzierung] (=Financing). In each housing unit, there are 1 bathroom.

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	
Personal savings	
Informal network: friends and relatives	
Small lending institutions / micro-finance institutions	
Commercial banks/mortgages	
Employers	
Investment pools	
Government-owned housing	
Combination (explain below)	
other (explain below)	

4.4 Ownership

The type of ownership or occupancy is renting. The rent of the units in this construction type had gone down (up to 25% less) because of the newer buildings constructed with other techniques.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appr. type		
		True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.			
Building Configuration	The building is regular with regards to both the plan and the elevation.			
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.			
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.			
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.			
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			
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);			
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.			
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			
Wall openings	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			

Structural/ Architectural Feature	Statement	Most appr. type		
		True	False	N/A
	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).			
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)			
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	hollow bricks, large window openings	fills the frame	no data
Frame (Columns, beams)	especially the column bases oxydates, as it lays without protection in the concrete	presence of stiffening elements	no data
Roof		rigidity through large concrete volume or reinforcement	
Floors	heavier than computed and thus inducing additional loads into the structure; sensitive to oscilation	rigidity due to large concrete volume or reinforcement	curvature up to 5cm of the floor; the out of plane deformation of reinforcing iron (30 cm).

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance)*, the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance).*

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1970	Albstadt, Swabian Jura		VIII
1977	Sigmaringen	3.8	
1978	Tailfingen-Onstmettingen (Albstadt)	5.3	VII-VIII
1980	Onstmettingen (Albstadt, Swabian Jura)	3.5	

For further details on the earthquake in 1978 see: http://www.iaag.geo.uni-muenchen.de/sammlung/Zollerngraben.html The following earthquakes affecting Germany are documented in Ambraseys et al. (2002): 1977 - Albstadt, Swabian Jura (Magnitude 3.2 Ms); 1982 - Abstadt, Swabina Jura (Magnitude 3.5 ML); 1983 - Grosselfingen (in Zollernalbkreis in front of the Swabian Alb; Magnitude 3.6 ML); 1992 Wutöschingen (north of the Rhein and south of Donaueschingen, west from Bodensee in the Black Forest; earthquakes from there registered in Basel, Zürich and many other locations with both rock and stiff soil; Magnitude 3.9 ML); 1996 - Gottmadingen (close to Wutöschingen, west from Bodensee, between Singen and Zürich; 3.1 ML); 1997 - Binzen (locality laying at the frontier between Germany, France and Switzerland; earthquake registered in Basel; 3.1 ML); 1998 - Degerfelden (part of Rheinfelden, in the extreme SW Black Forest, next to the Swiss frontier; 2.6 ML); 2000 - Steisslingen (near Singen next to Konstanz; 3 ML). See also: http://www.iaag.geo.uni-muenchen.de/sammlung/Stockach.html for more recent earthquake activity. Historically on the 18th of October 1356 the biggest earthquake of middle Europe destroyed the city of Basel. 1869/71 a strong earthquake in Groß-Gerau (north of Basel on the Rhein) followed. A new earthquake map for Baden-Württemberg has been proposed on: http://www.lgrb.uni-freiburg.de/d/akt/lgrb_n0202.pdf Damages caused by earthquakes among other "elementary natural forces" in south-west Germany (Albstadt) are documented in the dissertation of Plapp (2003) and available online (in German) as follows: http://www.ubka.uni-karlsruhe.de/cgi-bin/psview?document=2003/wiwi/10&search= erdbeben&format=1&page=262 Thus the earthquake of 22 January 1970 in Zollerngraben (MMI = VIII) caused a total loss of 1 Million as a result of the damage. The earthquake of 18 September 1977 in Sigmaringen (M=3.8) caused only low damage in buildings. During the earthquake of 3 September 1978, 5000 buildings were damaged, 60 of them collapsed. 20000 people were affected, 23 injured, 100 left homeless, 300 homes were evacuated. The total loss was 275 Million DM, of which 120 Million DM was insured. In the earthquake of 21 April 1980 only the phone connection in Albstadt was damaged. Damages caused by earthquakes among other "elementary natural forces" on the lower Rhein in Germany (Cologne) are documented in the dissertation of Plapp (2003) and available online (in German) as follows: http://www.ubka.uni-karlsruhe.de/cgi-bin/psview?document=2003/wiwi/10&search=erdbeben&format=1&page=258 - on the 13th of April 1992 an earthquake of M 5.2, max. Intensity VII-VIII occured with epicenter in Roermond, the Netherlands. In Cologne, houses and vehicles were damaged. The main damage area was in the Netherlands but it was felt in Cologne as well.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/ dimensions	Comments
Walls	Infill Walls: hollow clay brick or other stone Tekton cover inside reinforced with steel on both sides of light isolating concrete filling (Karlsruhe) OR pumice concrete with tekton cover. Basement Walls: simple concrete (not reinforced)	Basement Walls: B50-B225 (prescribed since 1894)	brick masonry 12cm thick tekton cover 6-10cm thick 25-12-6.5cm ("Reichsformat") in 1870.	System Benzinger (the name given to a mounting construction system out of "stauß" bricks and frames)
Foundation	concrete			
Frames (beams & columns)	iron/steel	See tables for typical loads for computing columns as well as computation examples in Ahnert vol. III, P. 23-42. See tables for typical loads for computing joists as well as computation examples in Ahnert vol. III, P. 9-16.	Double T profiles OR Z profiles for columns, I profiles for joists	in mortar – System Benzinger for mounting OR dry mounted Typical construction details are shown in Ahnert vol. III on page 32 (Tafel 6) and page 41 (Tafel 10).
Roof and floor(s)	Floors: hollow clay brick and I iron profiles, sometimes brick and RC (concrete reinforced with round iron bars) (Stuttgart) OR pumice cement floorboards with overconcrete (Celle) OR cement holed floorboards on T steel joints with overconcrete (Karlsruhe) with pumice overconcrete OR pumice floorboards on I joists (Stuttgart) Roof: RC (Stuttgart) OR pumice concrete (Celle) OR cement holed floorboards on T steel joints with overconcrete (Karlsruhe)	10cm thick - 1,25 kN/m^2; 12cm thick - 1.5 kN/m^2. The "Kleine" floor (fig. 3-15) had 15cm thickness for 2.85m span and 10cm thickness for 1.90m span prescribed for housing. Overconcrete in the middle: B80, at the ends: B120.	"Lochstein" (holed brick) 10x15x25cm or 10x12x25cm. Mortar: 1:1:5-6 (cement:calc:sand) Round steel for reinforcement: diametre of 5,6,7,8,9,10cm... or mixed 8+10, 10+12cm...	System Benzinger

6.2 Builder
No. This construction type was typically built as social housing.

6.3 Construction Process, Problems and Phasing
New construction methods: Central ideas were rationalisation, typisation and standardisation. Industrial mounting methods aimed saving in time and costs. The construction flow had to be optimised in a process plan (see an example of processual planing in an axonometrical construction schema of Walter Gropius in "Weisse Vernunft", 1999). This time the Net Plan so used today has come to life as the model used for process planning was similar to the net plan of operating railways (or to machine models Ford's). All elements which could be prefabricated were done so. Then instead manufacturing construction machines had been extensively employed. The construction flow was optimised regarding the employment of construction machines. This could be only done due to the line-shaped planimetry of the Siedlungen of that time. Regarding the construction technique itself the prefabricated building elements used to be mounted. In case of dry mounting the house could be inhabitated immediately after being finished. First the schelet was made, one week after that the surface on the ground was made, about ten days later the walls with openings, for which an exterior screening was needed, were constructed. For characteristic images see Stein Holz Eisen P. 769). The walls of the staircases were infilled first, then the other exterior walls (with windows) from the bottom to the top (fig. 3-23, 3-24) were placed. For an archive photo of a low-rise building of this type during construction process see http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/bau-damm_1.jpg (or http://www1.karlsruhe.de/Stadtteile/Weiherfeld-Dammerstock/bilder_v.php) In certain cases the construction without using any wet techniques was proposed, so that the house could be occupied right after the rough structure was completed. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise
Columns for this type of building have been addressed by standards since 1876 and by norms (DIN) since 1934. The last DIN adressing them is DIN4114 released in 1952. Joists for this type of building have been addressed by standards since 1876 and by norms since 1934. The

DIN1050 was updated in 1937 and 1947 retained its name. More detailed infromation on standardisation is given in Section 7.1. Engineers had a technical role. High enterprises constructing bridges and industrial facilities came into the market of small houses. Architects acted as managers and designers of the construction process. Architects envisaged the optimisation of housing prices. They designed building element types for industrial serial production while accounting for spatial considerations as well. Some German architects came back after a stay in the USA where prefabrication and rationalisation were used more.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Year the first code/standard addressing this type of construction issued: In 1917, the first code (DIN = [Deutsche Industrie Norm] = "German Industrial Standard") for the construction industry appeared. The board was initated by Muthesius, Behrens and the Deutsche Werkbund. When was the most recent code/standard addressing this construction type issued? DIN 4149 [Bauten in deutschen Erdbebengebieten - Lastannahmen, Bemessing und Ausführung üblicher Hochbauten] = "Building in German earthquake regions - loading assumptions, dimensioning and execution of common buildings" was issued in 1981. This then became a technical prescription. First standards for earthquake safe buildings in Baden Württemberg appeared in 1957 and 1972. Since 1981 (this means after the earthquake from Swabian Alb in 1978) the DIN 4142 has been used. It is foreseen that this will appear in the Eurocode 8. For details see: http://www.lgrb.uni-freiburg.de/d/akt/lgrb_n0202.pdf.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by others.

6.8 Construction Economics

Generally 10-15% cheaper than traditional building. Otto Haesler is one of the few architects who reached a notable cost sinking through rationalisation in this type of building. The material price of steel was low at the time. According to "Weisse Vernunft" (1999): the cost for multiple housing unit of this type is 52RM/m^3; and for dry mounting example is 80RM/m^3. Other buildings of innovative type costed 64 (example with iron-concrete)-85 RM/m^3. RM = Reichsmark. Workmanship prices of the time were aprox. 1.5 RM/h, while material prices looked like: ~50RM/1 t cement, ~70RM/1m^3 gravel, ~200RM/1t steel (after Ahnert, 2002, vol. I, P. 13). Realisation in record speed owes to the optimised construction flow (see 7.3), the so-called Taylorisation. Most of the construction is based on the extensive prefabrication of parts. The size of prefabricated parts was dictated by the lifting force of the machinery or eventually of a worker, although manual work had been tried to be avoided. The construction site management becomes almost like managing industrial lines. For further examples, including numerous films of prefabrication and construction process, see "Weisse Vernunft" (1999): [Baustelle] (="construction site"). Ex. on the Gropius building site in Dessau-Törten 130 residential units were constructed in 88 working days, ie 5 1/2 days for one unit. The Gropius siedlung there belongs nevertheless to another construction type than the one described in this report but uses similar construction methods. Martin Wagner had had an innovative concept of the construction enterprise, where the workers free of making decisions: the "Bauhütte". For details see "Weisse Vernunft" (1999).

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. Research to assess seismic risk for buildings in Germany is running and the aspects about insurance necessity are included in this research. According to this, some of the damages from the earthquake in 1978 were covered by insurance (see 6.1). However, earthquake insurance is separated from house insurance. More details (in German) about insurance for "elementary damages" (this is, damages caused by natural forces) can be found at: http://www.diw.de/deutsch/produkte/publikationen/wochenberichte/docs/02-35-2.html#HDR2.

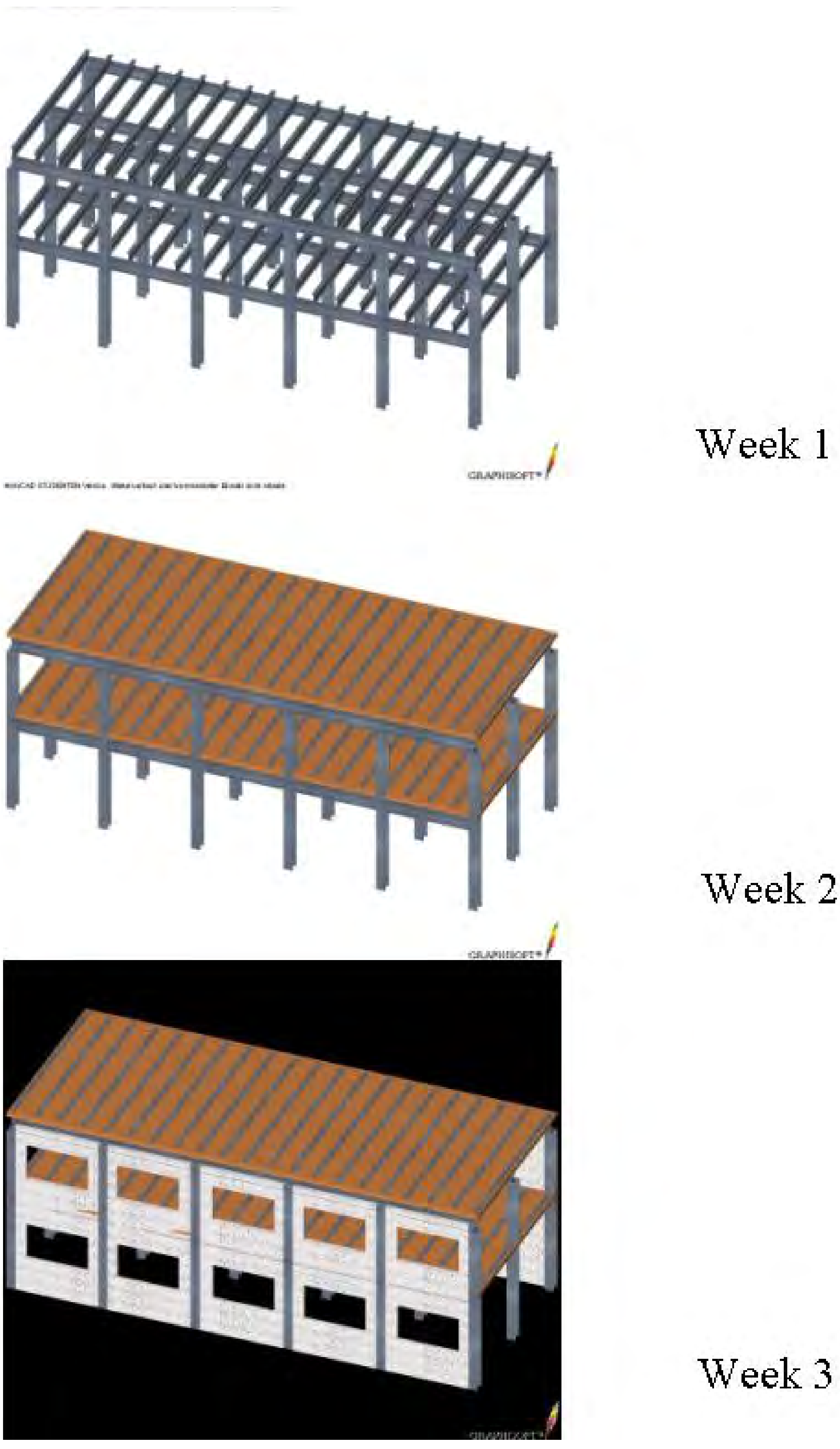

Figure 3-23: Building process (archive views of steps in building Dammerstock Gruppe 16, architect Otto Haesler, can be seen in Stein Holz Eisen. 1929. on page 769)

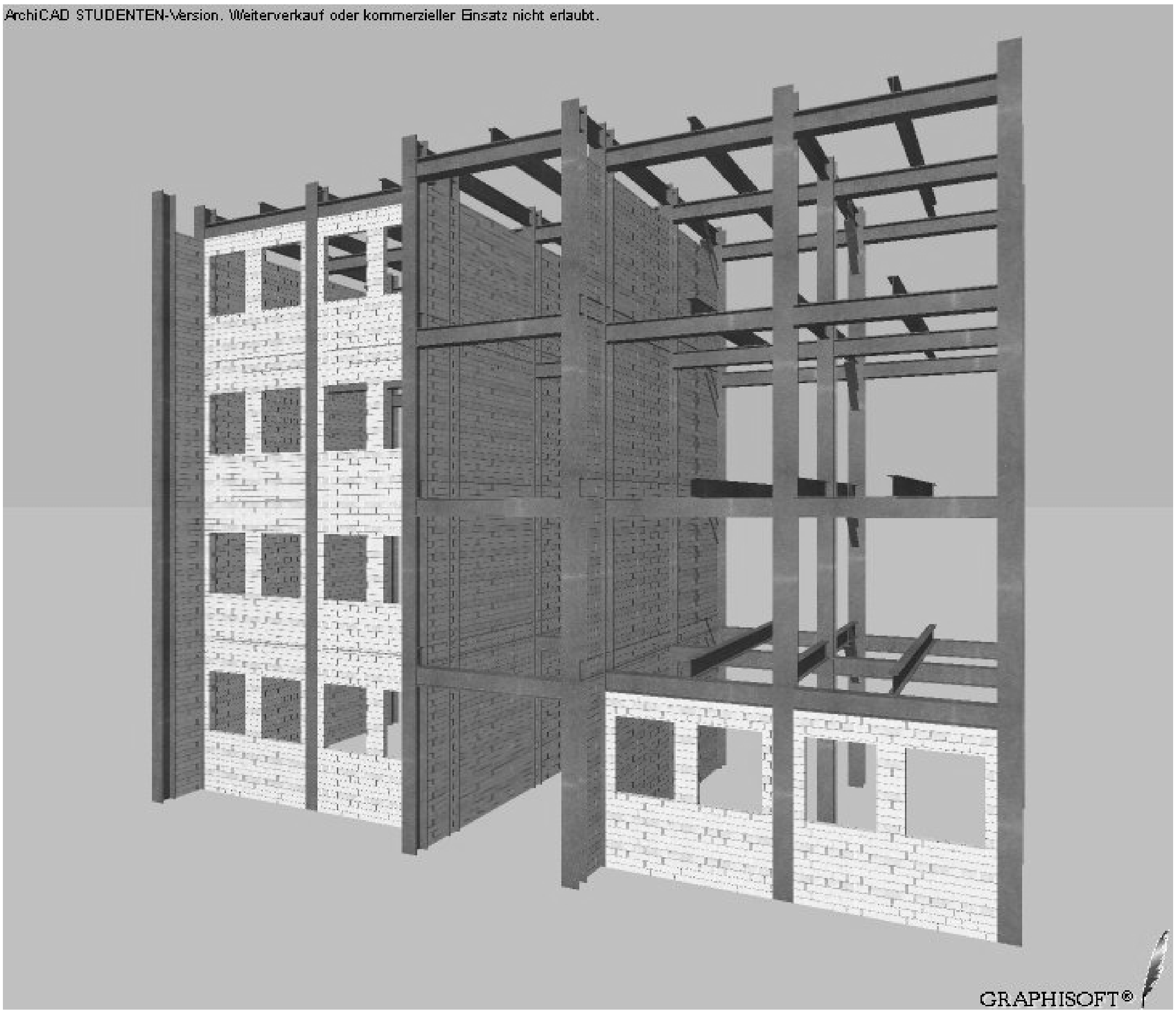

Figure 3-24: Highrise building of the type during the building process. (archive photo presenting such a succession in the construction process can be seen on the example of Kassel-Rothenberg, architect Otto Haesler, in Haesler: Mein Lebenswerk als Architect. 1957, on page 33)

8. Strengthening

8.1 Description of Seismic Strengthening Provisions Strengthening of Existing Construction :

Seismic Deficiency	**Description of Seismic Strengthening provisions used**
The structure is heavier than designed one, which imposes additional loads to the structure; sensible to oscilation	Replacement of damaged floors with new ones; reducing gravitational load at terraces (strengthening through replacement of thermal insulation material with a ligher one)

These measures were applied because of general structural system problems, not necessarily due to seismic deficiencies.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?
It was performed in practice, in Stuttgart, see Nägele (1992), P. 112-114.
Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
The building was damaged but not by an earthquake.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
Yes.
Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
The German government contracted the work. A workgroup was created including representatives from the finance and construction ministries, the direction of monuments of the state and of the city of Stuttgart, the Association of the Friends of the Siedlung. They had to determine the way of approach and a concrete rehabilitation concept. In the first phase the state of the siedlung in 1927 was documented. In a second phase a building survey was conducted. In the third phase the rehabilitation concept was developed. This included the construction technique, the infrastructure technique, the concept for implementation with the tenants, costs estimation, application for financial means and detailed plans for monument conservation. Architects were involved; they had to identify themselves with the role of the "protector of a cultural monument".
What was the performance of retrofitted buildings of this type in subsequent earthquakes?
No data is available on this.

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Traditional building in Romania: One family one storey house, also called "wagon house"

(Report # 85 in the "World Housing Encyclopedia" http://www.world-housing.net/)

Summary

This is one of the oldest housing types in Romania with a statistically significant number of buildings in existence. The overwhelming majority of residential buildings in Romania have been 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 discussed within 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 different construction type, The design of this housing is astonishingly homogenous, especially considering the relatively lengthy time span the construction has been practiced. The single-unit housing is generally characterized by a rectangular, elongated-shape plan, with an entrance on the long side. The load-bearing system consists of two longitudinal unconfined brick masonry walls and several transversal unconfined brick walls, usually 28 cm thick, which form a wagon-like arrangement hence the name of this building type. The horizontal structural system is made out of wood plates and joists separated by a distance of 0.70m. Buildings of this type have been affected by damaging earthquakes in November 1940 and in March 1977, and by two earthquakes of lower magnitudes in 1986 and 1990. They performed well except for the occurrence of some minor cracking in the plaster.

1. General Information

Buildings of this construction type can be found in small towns, near centre districts. This type of housing construction is commonly found in both sub-urban and urban areas.

The areas have been suburban at the time when these buildings have been constructed.

This construction type has been in practice for less than 100 years.

Figure 4-1: Typical building (from Bostenaru, 2004, TAFEL VII)

Figure 4-2: Variant of the building with high basement. Photo by Maria Bostenaru, 2002.

Figure 4-3: Coupled buildings. Photo by Maria Bostenaru, 2002

Figure 4-4: Buildings of this type not coupled, but in vis-a-vis. Photo by Maria Bostenaru, 2002.

Currently, this type of construction is not being built. It was practiced until 1947. Many of them have been demolished in the Ceauşescu era. However, there are still enough existing to provide specific character to the district of Bucharest in which they are most common, just outside the city centre.

Figure 4-5: Building from the courtyard side, with added unit over the time (from Bostenaru, 2004, Abb. 2-19 on P. 40)

Figure 4-6: Structural modifications: partial upper floor and closed windows to the street. Photo by Maria Bostenaru, 2002.

Figure 4-7: Structural modification: Facade with walled-up windows. Photo by Maria Bostenaru, 2002.

Figure 4-8: Whole view of the building with closed windows to the street (from Bostenaru, 2004, Abb. 2-4 on P. 24)

Figure 4-9: Structural modification: one closed facade window and one changed to door opening. Photo by Maria Bostenaru, 2002.

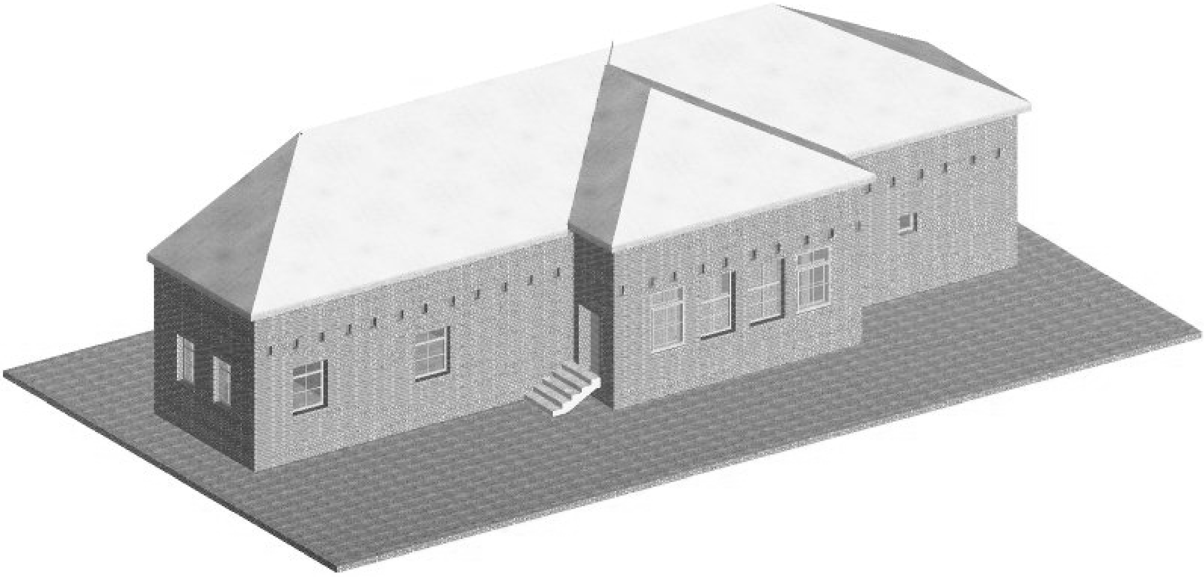

Figure 4-10: Axonometric view

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. This is the separation between the long wall (the one perpendicular to the street) and the cadastral unit boundary. Depending on the position of the building on the adjacent cadastral unit, the distance to this one may be up to 3.8m (fig. 4-3 and 4-4). There is no typical separation at the back of the house. It may be 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 1.9m.

2.2 Building Configuration

rectangular (see fig. 4-11 and 4-26 for possible recesses). Figure 4-10 shows a typical building in axonometric view. 5-10 openings, depending on the number of rooms (see fig. 4-23 and 4-24 for their layout). ~20% For the building taken as model for this report (late building of this type): A typical window in the longitudinal wall to the courtyard is 1.44m^2 in size. There are smaller ones for secondary rooms, of 0.36m^2 or 0.9m^2. Bigger windows are 1.2mx1.9m (2.28m^2), to the vestibule. To be noted is that all windows to main rooms are 1.2m wide. A typical door is 0.8mx2.1m (1,68m^2). Smaller doors to the secondary rooms are 0.7mx2.1m (1.47m^2), and also door openings for double doors of 1.4mx2.1m (2.94m^2). The entrance door is wider (0.9m), but same height. In older buildings the windows were all like those to the vestibule (fig. 4-20) in this one. The back longitudinal wall is usually solid without openings, as it is situated on the cadastral unit boundary, where it is expected that the adjacent semidetached twin unit will be built.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Escape through the vestibule directly into the yard.

2.4 Modification to Building

Typical changes in time are additional floors over the existing ones (especially taking in consideration the thickness of the walls, considered to be able to carry one floor more, see fig. 4-6) or additions of "wings", typically one room more with vestibule (fig. 4-5). 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. 4-7 - 4-9). This has been also performed at the model building considered for this report.

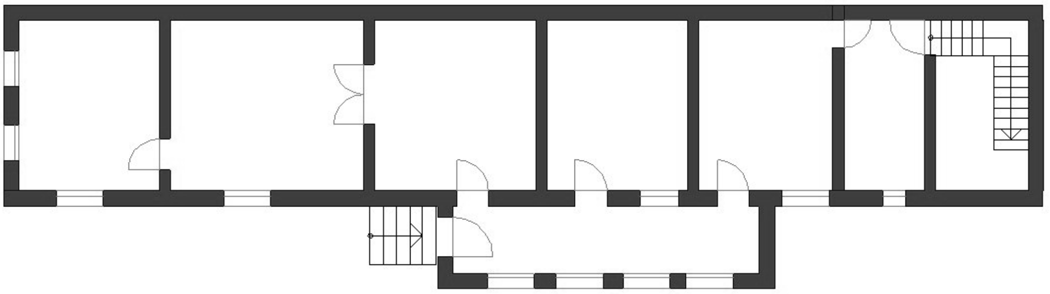

Figure 4-11: Ground floor plan

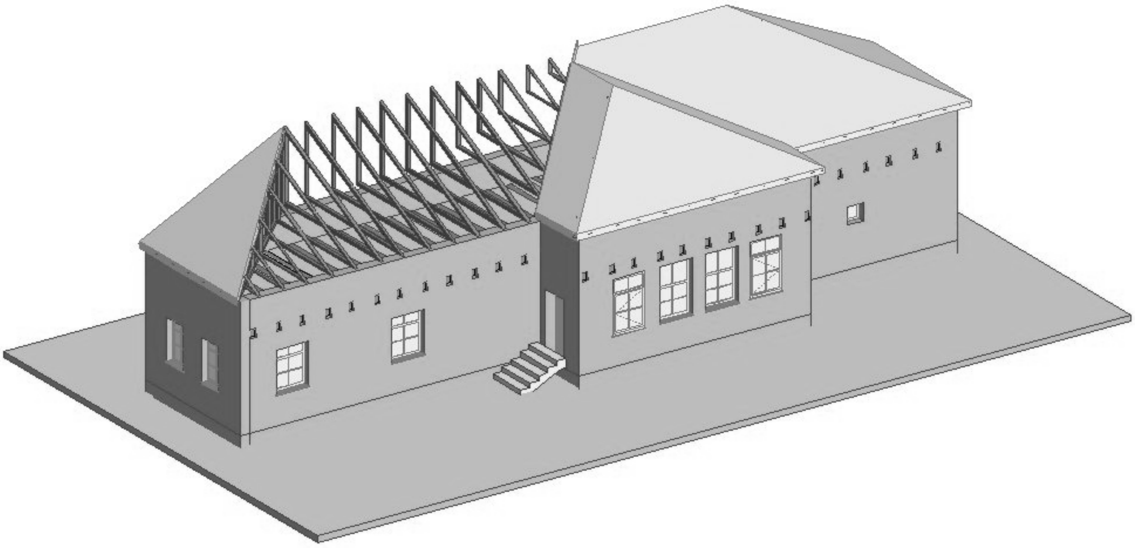

Figure 4-12: Axonometrie with view to the roof

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Dressed stone masonry (in lime/cement mortar)	
	Adobe/ Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	
		8	Brick masonry in mud/lime mortar with vertical posts	
		9	Brick masonry in lime/cement mortar	
		10	Concrete block masonry in cement mortar	
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	
		12	Clay brick masonry, with concrete posts/tie columns and beams	
		13	Concrete blocks, tie columns and beams	
	Reinforced masonry	14	Stone masonry in cement mortar	
		15	Clay brick masonry in cement mortar	
		16	Concrete block masonry in cement mortar	
Structural	Moment resisting frame	17	Flat slab structure	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
concrete		18	Designed for gravity loads only, with URM infill walls	
		19	Designed for seismic effects, with URM infill walls	
		20	Designed for seismic effects, with structural infill walls	
		21	Dual system – Frame with shear wall	
	Structural wall	22	Moment frame with in-situ shear walls	
		23	Moment frame with precast shear walls	
	Precast concrete	24	Moment frame	
		25	Prestressed moment frame with shear walls	
		26	Large panel precast walls	
		27	Shear wall structure with walls cast-in-situ	
		28	Shear wall structure with precast wall panel structure	
Steel	Moment-resisting frame	29	With brick masonry partitions	
		30	With cast in-situ concrete walls	
		31	With lightweight partitions	
	Braced frame	32	Concentric connections in all panels	
		33	Eccentric connections in a few panels	
	Structural wall	34	Bolted plate	
		35	Welded plate	
Timber	Load-bearing timber frame	36	Thatch	
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		38	Masonry with horizontal beams/planks at intermediate levels	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
		39	Post and beam frame (no special connections)	
		40	Wood frame (with special connections)	
		41	Stud-wall frame with plywood/gypsum board sheathing	
		42	Wooden panel walls	
Other	Seismic protection systems	43	Building protected with base-isolation systems	
		44	Building protected with seismic dampers	
	Hybrid systems	45	other (described below)	

In the constructions of the type analysed in this report hydraulic lime based mortar, considered to be the highest possible quality mortar of that time, have been used. For common buildings (i.e. not in very wet environments) hydraulic lime mortar has been used. This was prepared solely out of "fat lime" ("var gras" in Romanian), sand and water. The lime is obtained through burning of calcar stones (Cao+CO_2) in either field or vertical ovens.The obtained CaO was then treated with water in boxes called "varnite" in Romanian. As a result the lime paste or lime putty is obtained: $Ca(OH)_2$ 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 depends on the permeability of bricks. Hardening takes place when the CO_2 in the air reacts with the $Ca(OH)_2$ in the lime to give $CaCO_3$. Masonry bricks are crossed are woven ("țesătură încrucişată" in Romanian).

3.2 Gravity Load-Resisting System

The vertical load-resisting system is described below. Timber slabs with joists every 0.70m (interaxes) and a suspended ceiling out of lime mortar on slat and cane form the upper floor structure. The roof itself consists of wood framework ("acoperiş pe scaune" in Romanian, fig. 4-12). The girders are perpendicular and sustained by the longitudinal walls (fig. 4-25). The roof is simply supported by the walls. In some cases the load floor structure below the ground floor consists of jack arches on metal joists. In other cases the difference between the ground floor and the upper floor will consist on the timber type, as shown in the Simetria (2000) publication: fir tree for the upper floor and oak tree for the ground floor. The load bearing elements (timber or metal joists) are linear and transmit the loads into one direction only. Floor joists are simply supported by the walls, not anchored. There are no tie beams. The materials of the 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 the second half of the 19th century had already strip foundations out of unreinforced concrete, under all load bearing walls. In the Simetria (2000) publication more details are available: around 1900 such a foundation consisted of hydraulic lime mortar concrete in 20cm layers. The depth of the foundations is known to be 1.10m, as required by the Romanian 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 filled with a different material than earth, but the nature of this is unknown. The size of foundations for this building was 0.50m x 0.42m (depth x width) for exterior walls and respectively the wall separating the part with basement from that without (see the device catalogue in Simetria, 2000). For interior walls the size of the foundations for the same building is shown to be 0.28 m x 0.50 m (width x depth) in plan. The length is the same as that of the wall. Totally 13.18m^3 of foundation material were needed for such a typical building. A partial basement of 3m depth was also found in some cases. The structural system is characterised 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 30-35m^2 surface (for this building type 9-16m^2) (fig. 4-13).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is described below. There are two longitudinal and several transversal 28 cm thick unreinforced brick in hydraulic lime mortar masonry bearing walls (see a sketch of main load bearing elements in fig. 4-15). This dimension is usual for interior walls of all building of this type. Older buildings might have thicker exterior walls (42 cm, up to 50 cm). The transversal walls separating room units are not loadbearing (they are only loaded with their own weight). The Romanian terminology identifies them as stiffening walls (Romanian "contravântuire", meaning contribution to lateral load bearing system only). Typically, there are no further, structural or non-structural separation walls in longitudinal direction. The only exception where three parallel walls in longitudinal direction may appear is at the entrance, enlarged by an increased building width (fig. 4-18 and 4-19). The distance between the two longitudinal walls varies between 3.0 and 4.0m depending on the presence or absence of a special vestibule room. The distances between the transversal walls is fairly tipical, and starting from the street wall the span sequences are 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 both directions, except for the last rooms where these can be smaller. All walls have sufficient stiffness to contribute to resisting lateral loads, both in terms of load capacity and deformation. Although stiffness isn't evenly distributed between the walls no damage due to torsional effects has been observed, despite rigid back longitudinal wall with no openings. This is supposed to be owed to the floors, which do not assure a spatial collaboration of the structure and thus the existing stiffness assymetries loose weight. The back longitudinal wall is not common for two neighbouring buildings, which completely separate structural units. Currently in Romania there are 4 kinds of mortar used in masonry 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, and contemporary mortar only behaves well in humidity conditions if cement is added. In some cases brick dust might ben 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) had been used formerly to obtain mortar, but not for this type.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 20 and 25 meters, and widths between 3.5 and 5 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4 meters. Typical Story Height: Up to 4.5 when monumental. Houses are at least 30cm over street level and the roof floor is at least 1.2m high. Typical Span: between 3 and 5m. The typical storey height in such buildings is 3.5 meters. The typical structural wall density is 7.5% - 12.5% ~ 10% in both directions.

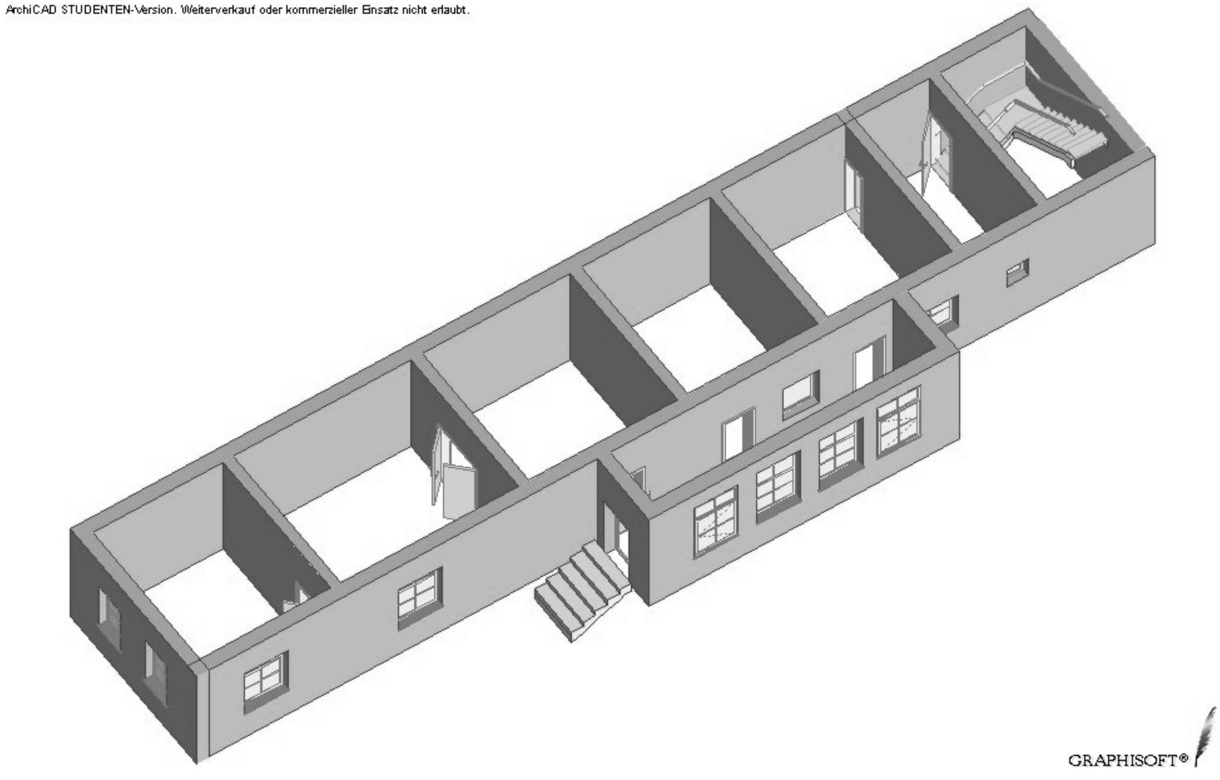

Figure 4-13: Axonometric view with load bearing walls and openings

3.5 Floor and Roof System

Material	**Description of floor/roof system**	**Most appropriate floor**	**Most appropriate roof**
Masonry	Vaulted		
	Composite system of concrete joists and masonry panels		
Structural concrete	Solid slabs (cast-in-place)		
	Waffle slabs (cast-in-place)		
	Flat slabs (cast-in-place)		
	Precast joist system		
	Hollow core slab (precast)		
	Solid slabs (precast)		
	Beams and planks (precast) with concrete topping (cast-in-situ)		
	Slabs (post-tensioned)		
Steel	Composite steel deck with concrete slab (cast-in-situ)		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood shingle roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams supporting natural stones slates		
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other	Described below		

see 4.2. See for: timber floor structure in plan and respectively in axonometric view figures 4-16 and 4-17, for roof structure in plan and

respectively in axonometry figures 4-21 and 4-22 and for typical sections through timber floor and roof systems figure 4-29 (legend in Romanian). Some buildings of this kind may have composite masonry and metal joist structure, not practiced today any more (fig. 4-28).

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced-concrete isolated footing	
	Reinforced-concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced-concrete bearing piles	
	Reinforced-concrete skin friction piles	
	Steel bearing piles	
	Steel skin friction piles	
	Wood piles	
	Cast-in-place concrete piers	
	Caissons	
Other	Described below	

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 document in Simetria (2000). The above classification refers to a newer building of the same type, constructed in 1929 (see fig. 4-14 for the plan of foundations).

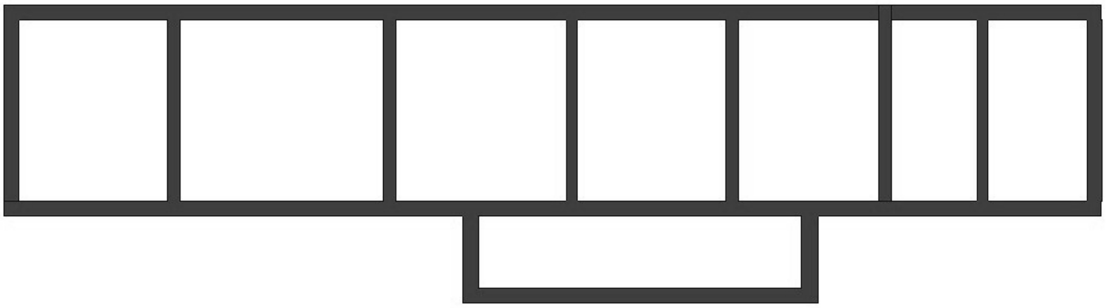

Figure 4-14: Plan of foundations

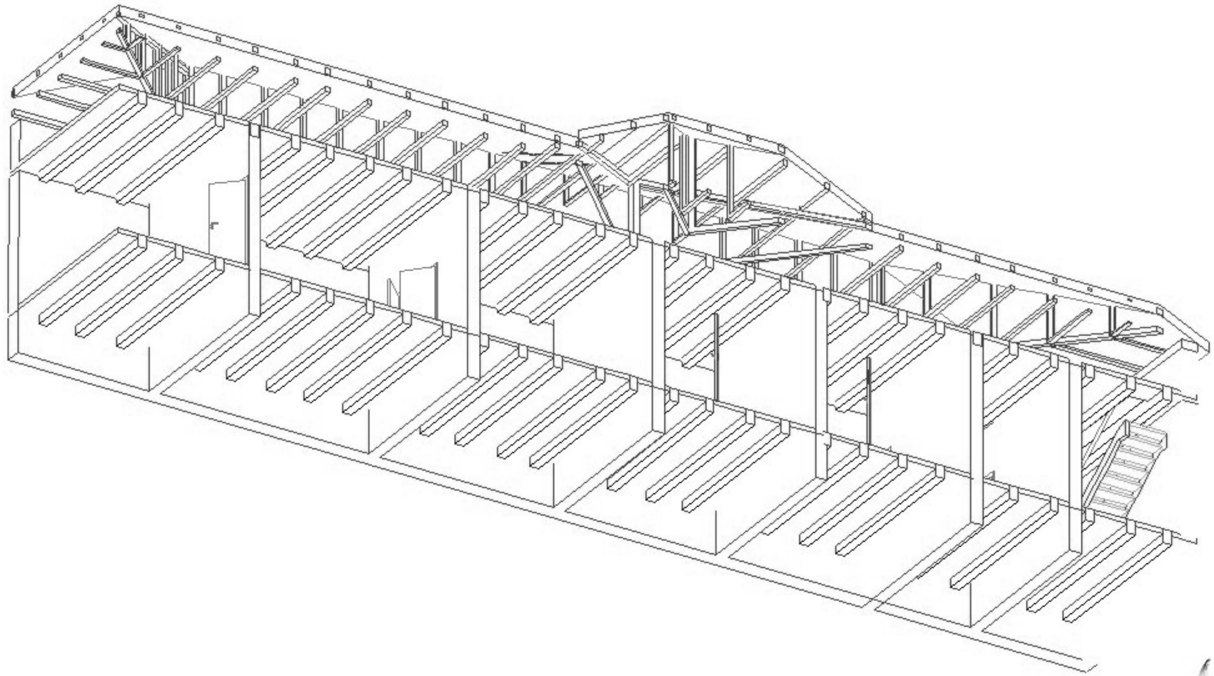

Figure 4-15: 3D section

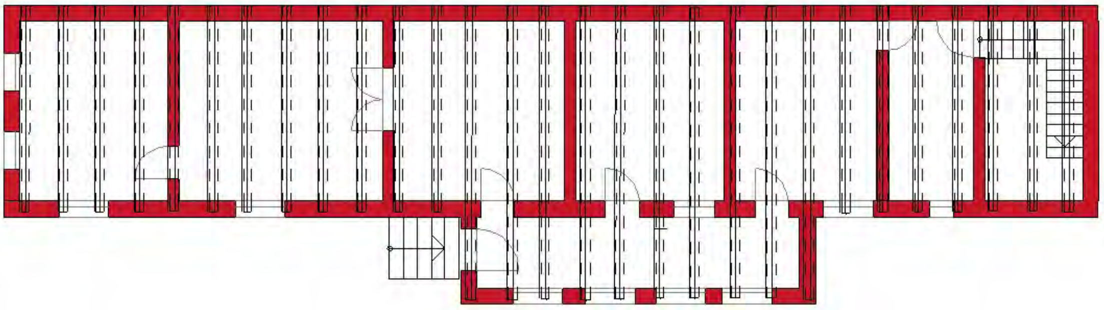

Figure 4-16: Ground floor plan with timber joists

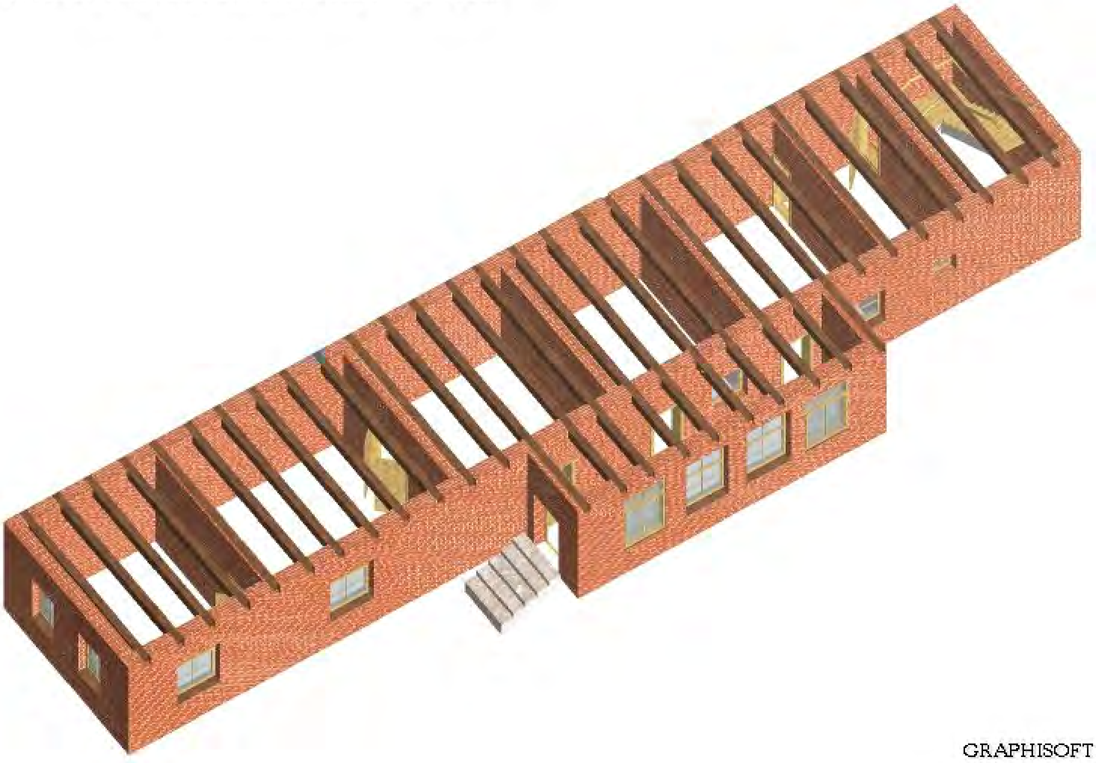

Figure 4-17: Axonometric view showing timber joists (from Bostenaru, 2004, TAFEL VII)

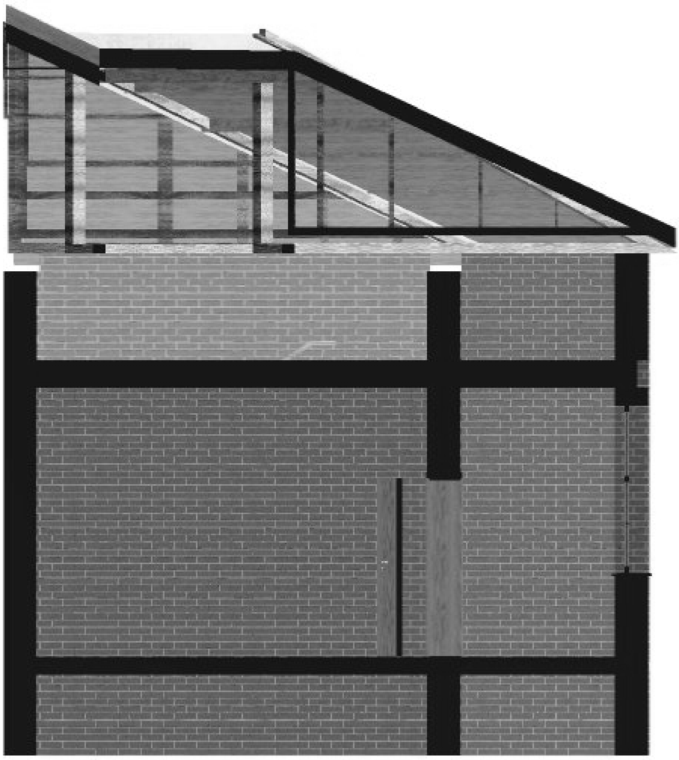

Figure 4-18: Transversal section

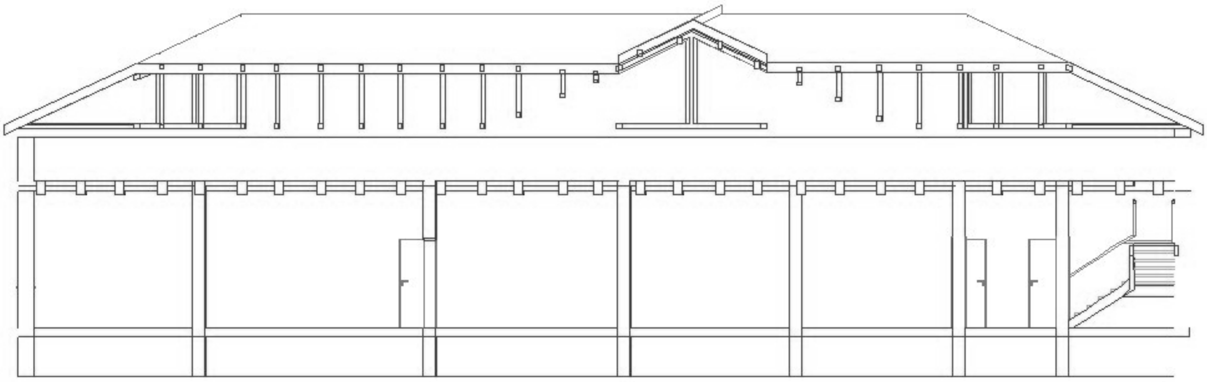

Figure 4-19: Longitudinal section

Figure 4-20: 3D view – detail

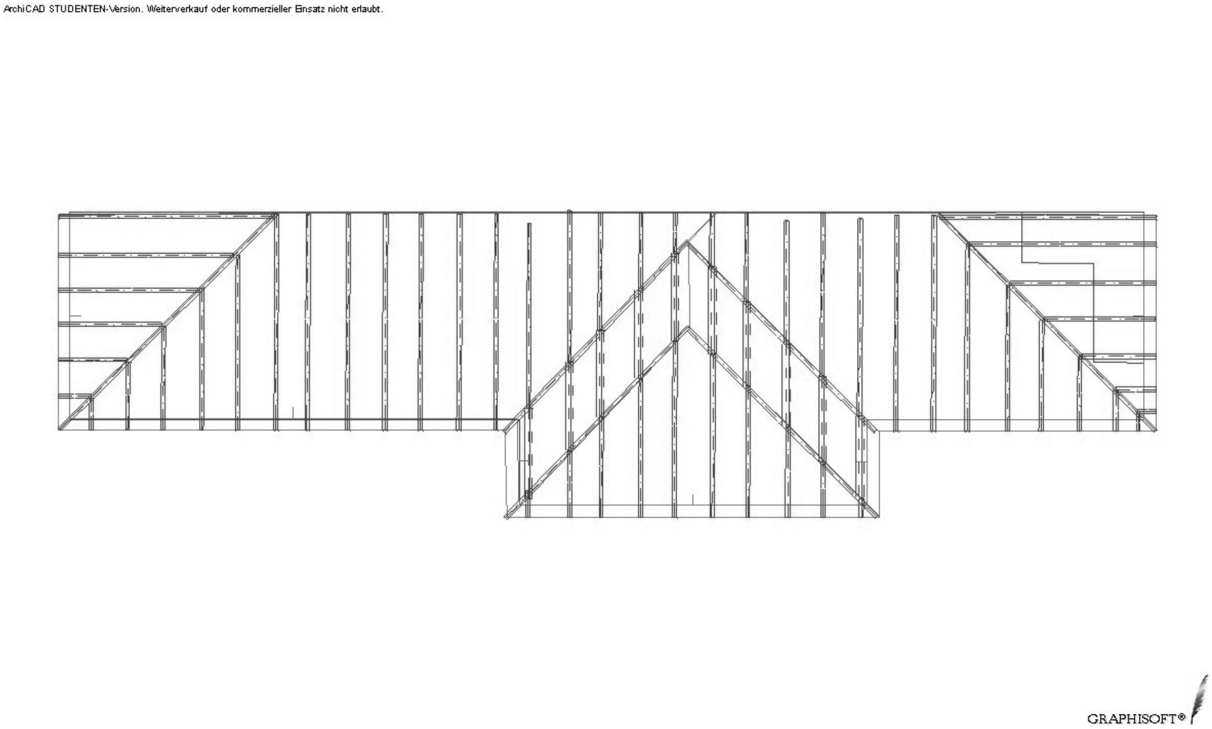

Figure 4-21: Roof plan

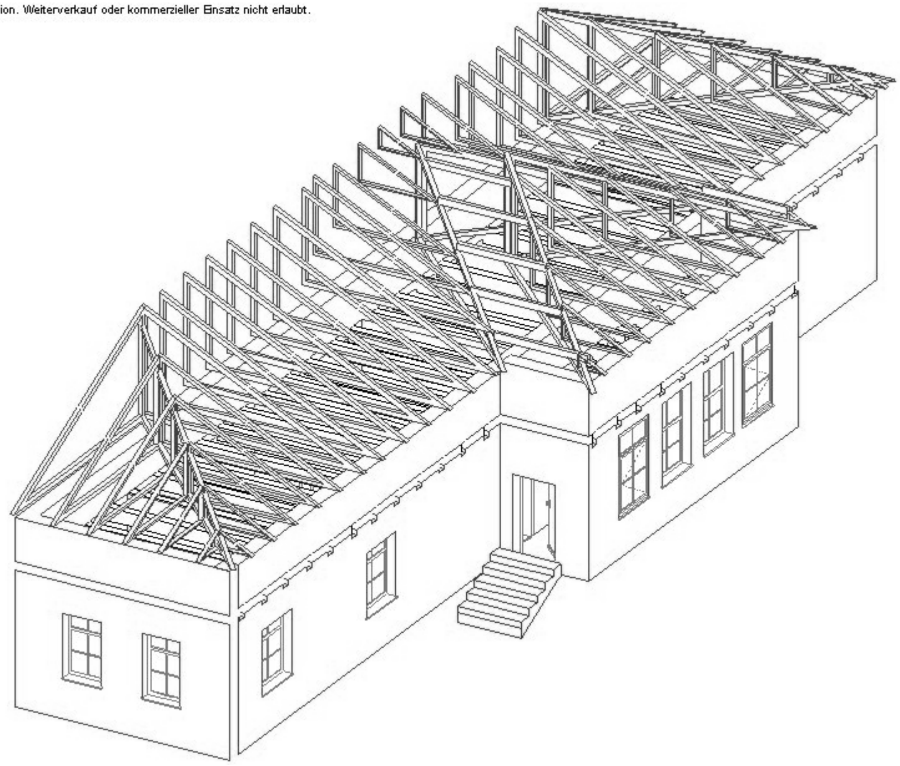

Figure 4-22: Axonometric view showing the roof

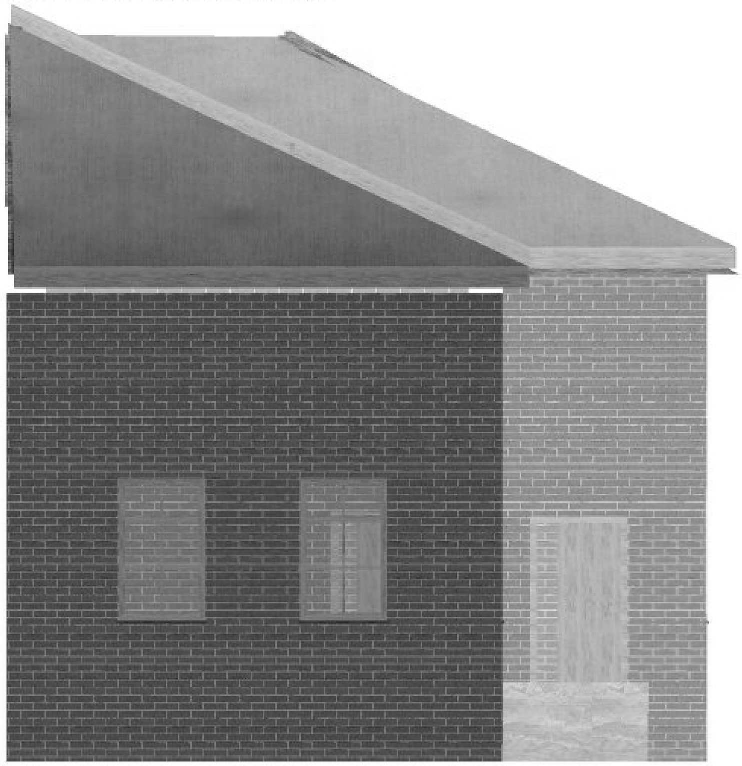

Figure 4-23: View to street

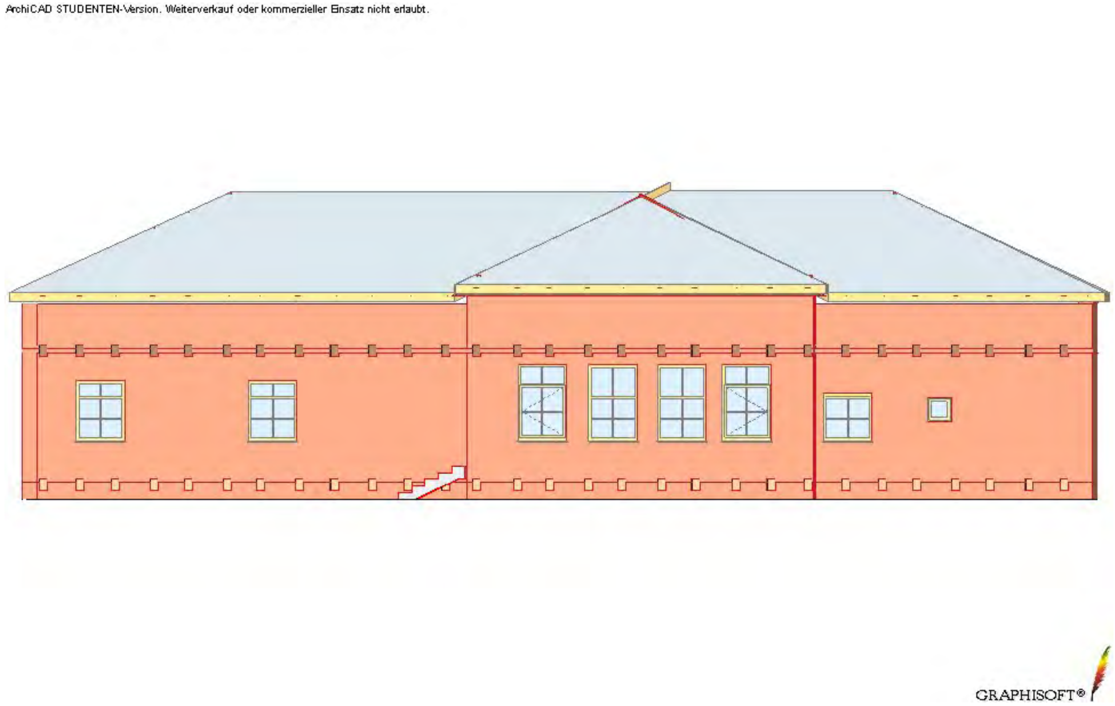

Figure 4-24: View to courtyard

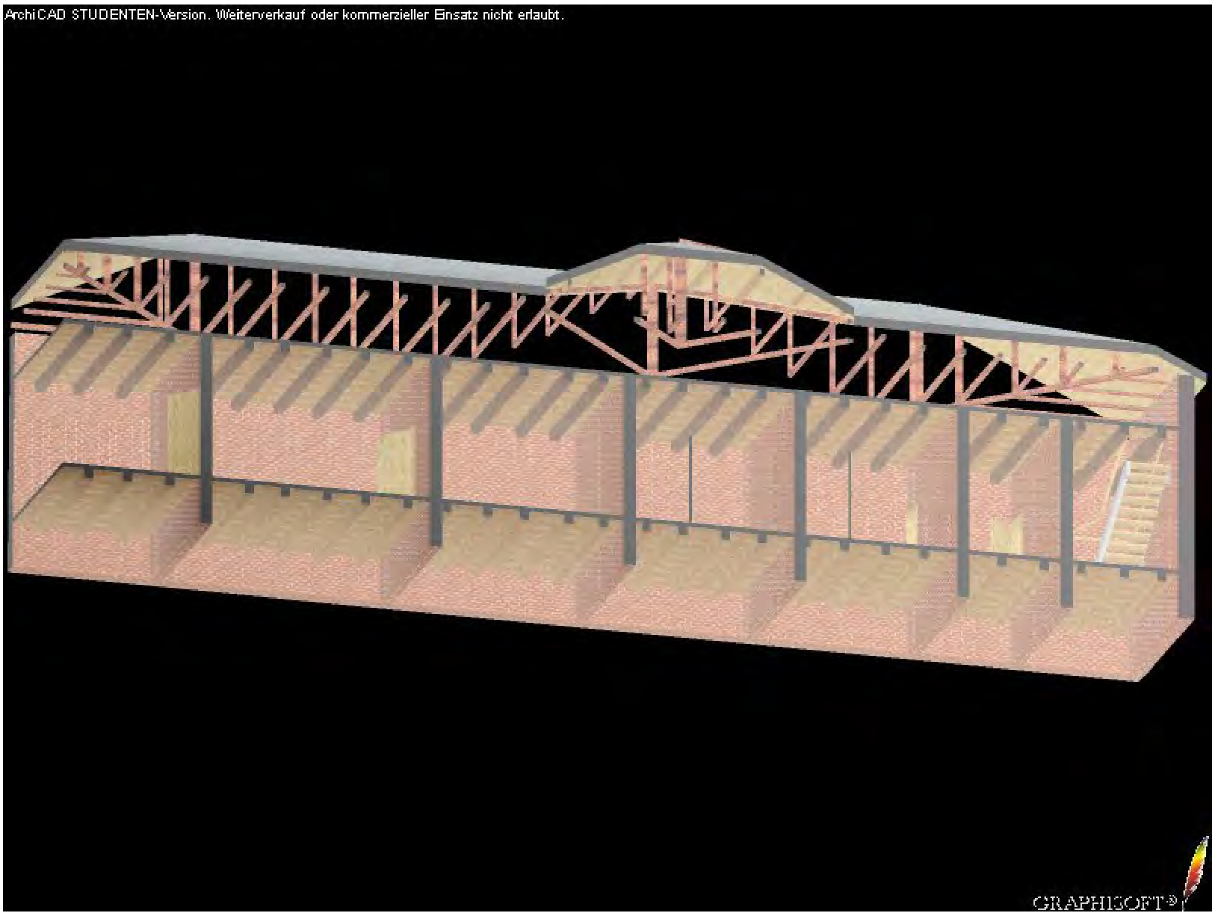

Figure 4-25: 3D section with rendering (from Bostenaru, 2004, TAFEL VII)

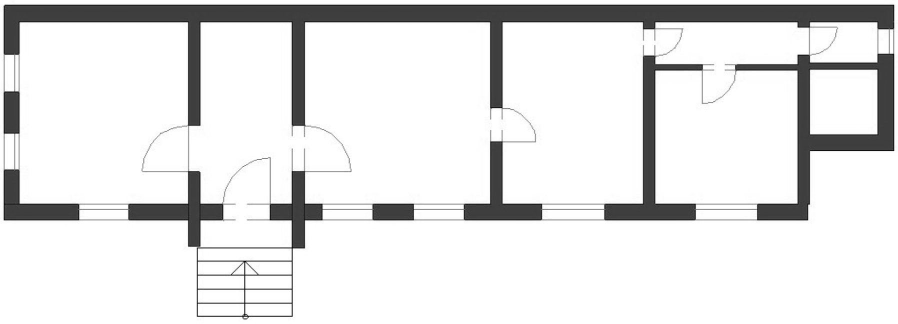

Figure 4-26: Ground floor type when the vestibule is not specially marked; in this case the width of the house is about 4.6m; length is about 20m (from Bostenaru, 2004, TAFEL VII)

Figure 4-27: Masonry detail (from Bostenaru, 2004, TAFEL VII)

Figure 4-28: Photo of a brick and metal joists floor structure. Photo by Maria Bostenaru, 2002.

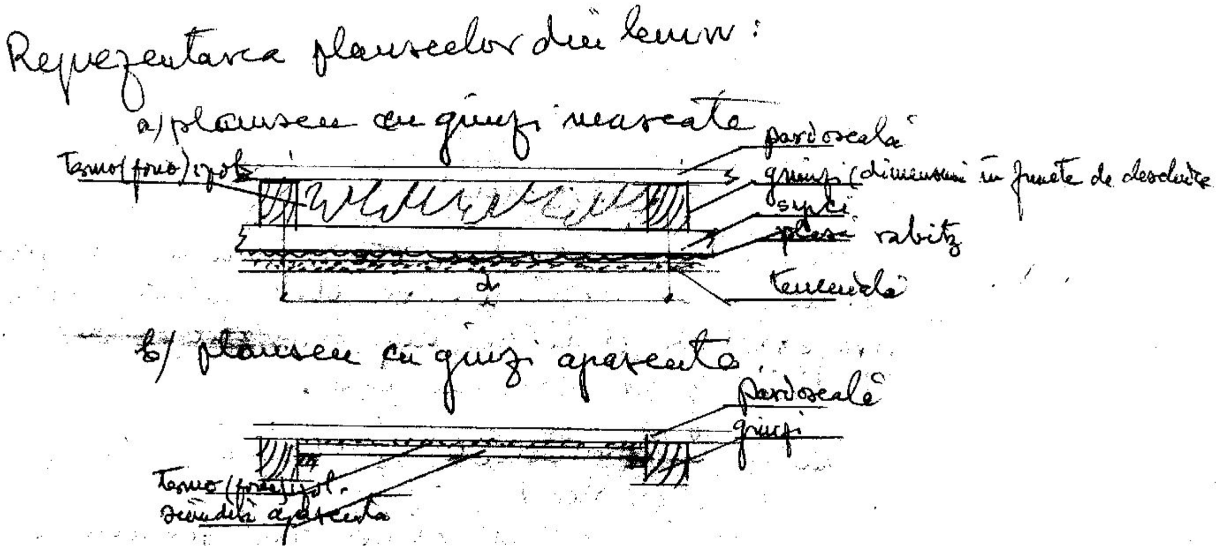

Figure 4-29: Typical sections through floor and roof

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5. During the crisis years in the late 20s rooms might be rented with strongly specified contracts, in the cases when the number of the people in the family decreased (ex. only the old retired persons remaining). During communism times new inhabitants have been "let" to rent rooms in such buildings, leadings to up to 3 families (each 2-4 persons) occuping a building (usually one family in 1-2 rooms).

4.2 Patterns of Occupancy

One family consisting of usually 4 persons. In the 19th century there might have been 6-7 people in a family living in such a house (ex. parents, 4 children and an older person).

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	
b) low-income class (poor)	
c) middle-income class	
d) high-income class (rich)	

The house price/annual income ratio refers to that when this kind of buildings were constructed. Today this kind of construction is not practiced anymore and the price raised. At the time this kind of buildings were constructed (not built today anymore), the house price/income ratio ranged between 2.5/1 and 4/1 and the worse value has been chosen. Today the price of the house depends a lot on the place in the town where it is situated and on the facilities available (like gas central heating, for instance), but it is estimated that they are much more expensive to buy than, for example, dwellings in blocks of flats where this ratio ranges between 6/1 and 10/1. What is less expensive in this kind of houses compared to the block of flats are the monthly running costs for watter, gas, heating and electricity. Economic Level: For Middle Class the ratio of Housing Price Unit to their Annual Income is 4:1.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	
4:1	
3:1	
1:1 or better	

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	
Personal savings	
Informal network: friends and relatives	
Small lending institutions / micro-finance institutions	
Commercial banks/mortgages	
Employers	
Investment pools	
Government-owned housing	
Combination (explain below)	
other (explain below)	

Credit has been possible to complete the price (1/3 from owner for example, the rest from Credit), as documented in Simetria (2000) p.33. In each housing unit, there are 1 bathroom.
This is valid for the example building for this report, which is from the 20s. In the buildings descibed by Dinescu in Simetria (2000) there were no bathrooms, only latrines (Romanian "closet"), and this is considered to be typical for that time. Many of the housing units from that time have been upgraded, but the authors estimate that not all of them.

4.4 Ownership

The type of ownership or occupancy is outright ownership. Renting was possible. For such a building the rent in 1928 was about 12,5% of the insured value/year, and this did not vary dramatically. In 1942 the rent has been almost 10% of the insured value/year (for details see Simetria, 2000).

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	**Statement**	**Most appropriate type**		
		True	**False**	**N/A**
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.			
Building Configuration	The building is regular with regards to both the plan and the elevation.			
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.			
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.			
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.			
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			
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);			
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.			
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			
Wall openings	The total width of door and window openings in a wall is:			

Structural/ Architectural Feature	**Statement**	**Most appropriate type**		
		True	**False**	**N/A**
	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).			
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)			
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	The disposition of walls sometimes does not respect rules concerning uniform distribution of mass and stiffness. Brickwork can be extensively worn out (poor maintenance, decay) No reinforced concrete vertical posts. Height differences to adjacent buildings possible. Use of mortars with moderate strength.	Good quality (hydraulic) lime mortar. Because of the wall-roof connection, which do not assure the spatial co-operation of the structures, the appeared dissimetries don't cause significant general torsion effects under the action of seismic forces.	Some cracks in the plaster Vulnerability to pounding In some buildings: diagonal cracks on the facades and on the party wall. Corner damage (see figure 4-31)
Foundations	Foundations are clay brick masonry as well, and rarely stone masonry or concrete.		no data
Roof and floors	No stiff floors so no co-operation of load bearing walls and floors, so eventual capacity deficiencies of walls cannot be compensated by a uniform distribution of loads through the floors to walls with higher capacity. Linear load bearing elements with one direction load transmission, not anchored to the walls. No tie beams. Buildings are lower height than their neighbours.	Timber floors with joists every 70cm assure a uniform distribution of rigidities in the plane avaoiding torsional effects. Timber joists are sustained by the longitudinal walls. Roof support on these girders leads to the fact that horizontal forces from earthquakes are absorbed without causing significant damages.	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 was separated from the wall, but the building was not damaged significantly (P. 38). Also Bălan et al (1982) mentiones that floors at building of this kind, both with timber and metal joists might present numberous rifts, especially on the contour (P. 232). UAIM (2000) classifies small rifts in the ceiling plastering as being characteristic for both not affected and

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
			light affected buildings, while in affected buildings the floor joists might move from their supports. The movement and collapse of the roof is also characteristic for affected buildings. For more details including figures see Agent (P. 72-78). Damage can also occur from neighbouring buildings (Fallen party wall damaging the roof of a building of this type, in Bălan, 1982: fig. VI.6. on p. 234).
Openings	Not always respecting the actual prescriptions regarding the dimensions and the areas of openings in walls. Piers (between windows) of reduced sections compared to the loads to be supported. Lintels are usually brick vaults, timber or metal joists.		In some buildings: X shaped cracks above the openings; Z shaped cracks on the "parapet" (under the window); cracks in the lintels over the entry door (fig. 4-30); cracks in the piers of the facade.

The data in the table is based on Bostenaru (2004), Tabelle 2-6, P. 41. Roof damage: Due to excessive tensile stresses would fibres can fail (Croci, 2000, P. 59-60). In the opinion of the authors this type of failure is similar to the most common type of damage in RC beams, which are cracks in the tension zone. According to Penelis&Kappos (1997) the vertical component of the seismic action makes visible the microcracks due to bending of the tension zone. Although the 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 more sensible to missing maintenance, as the ruins of buildings of this type show (fig. 4-32, 4-33).

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance)*.

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1940	Vrancea	7.4	7, MERCALLI
1977	Vrancea	7.2	8, MERCALLI
1986	Vrancea	7	8, MERCALLI
1990	Vrancea	6.7	7, MERCALLI

The occurance 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 may present: slight damages: falling of of finishing and decorations from walls and ceilings; crack nets, isolated rifts in masonry or later introduced concrete elements; large rifts in later introduced non-structural walls; heavy damages: big rifts, dislocations, sliding of construction elements, joint degradation, remaining deformations. The most frequent damage appears in the stiffening walls (these are the transversal walls, which are not designed as gravity load bearing walls, but contribute to the lateral load system), sometimes the timber joists detached from the walls, rifts at 45° at the lintels. There is thus an evident difference between the damage patterns of longitudinal walls (compressed by vertical load) and unloaded transversal walls. Global damage includes leaning from the vertical of the whole building by 4 to 9 cm (INCERC 2000). The most usual ones are the rifts. In Simetria

(2000) p.38 detaching of ceiling border after the 1940 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 wallpiers and wall fields; wall collapse especially in walls in the roof part (if inhabited), party wall and chimneys.

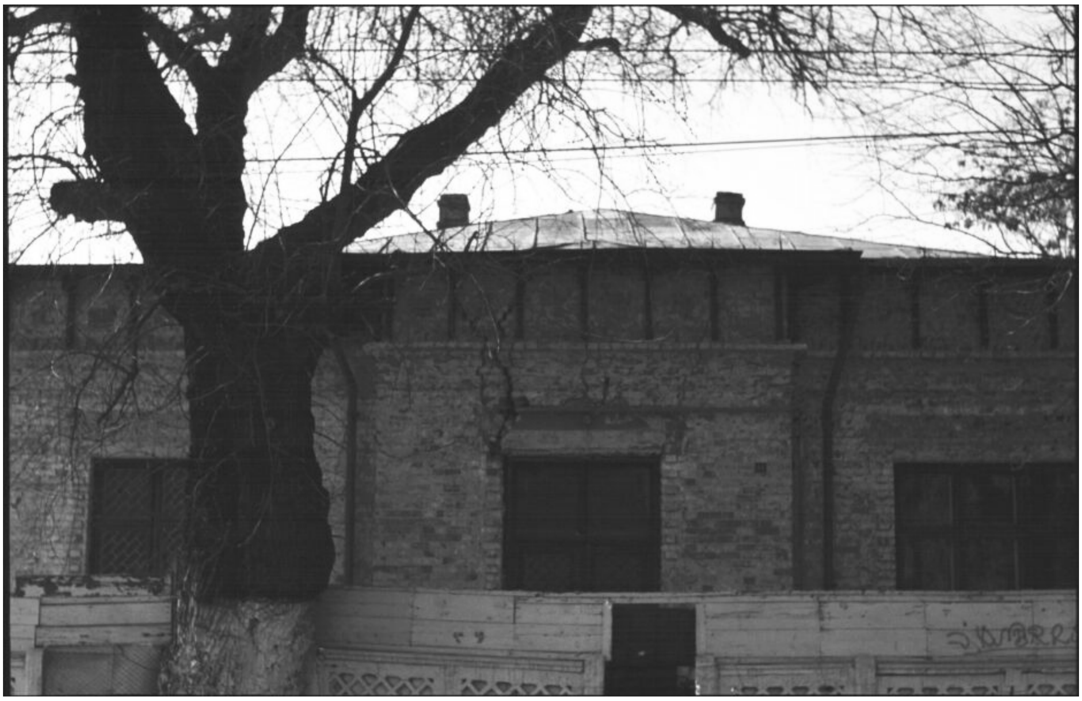

Figure 4-30: Damage over opening (from Bostenaru, 2004, TAFEL VII)

Figure 4-31: Damage at corner. Photo by Maria Bostenaru, 2002.

Figure 4-32: Ruins of such a building. Photo by Maria Bostenaru, 2002.

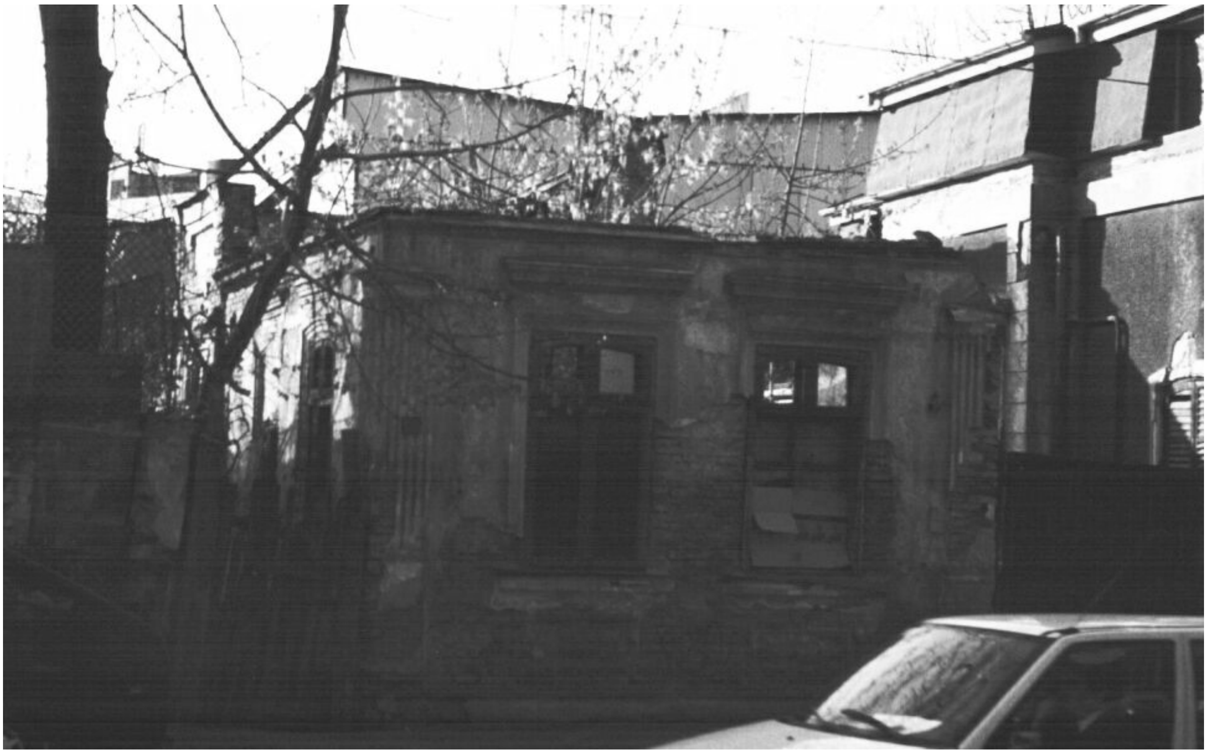

Figure 4-33: Ruins of walls of a building of this type. Photo by Maria Bostenaru, 2002.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	clay brick mortar	clay brick: bricks mark C75: compression strength: average (7.5-10.0) N/mm^2; minimal 5.0 N/mm^2; bending strength: average 1.8 N/mm^2; minimal 0.90 N/mm^2. Further values are available in UAIM (2000). mortar: stregth of masonry (in N/mm^2): C50+M10: 2.8; C75+M10: 3.4; C100+M10: 4.0. Bending strength of mortar (N/mm^2): in horizontal joint: M10 - 0.2; in zig-zag joint: M10 - 0.4. Longitudinal module of elasticity depending on mortar mark for clay brick masonry (in N/mm^2): M10 - 1200. Characteristic curvature (°/oo): M10 - 1.75, at ultimate M10 - 2.5. Further values are available in UAIM (2000).	clay brick: 7cm (63mm;+/-3mm)x14cm (115;+/-4mm)x28cm (240;+5/-6mm) The numbers in the paranthesis concern the brick itself, the others include the dimensions in the wall, ie with mortar. mortar: Today's cement-clay is cement:clay:sand = 1:2:8 (compared to 0:1:3 for clay and 1:0:4 for cement mortar) see Bălan et al (1982) P. 372	clay brick: Values according to UAIM (2000) brick of middle class mark are shown. Also C50 and C100 exist. The mark shows 10 times the lowest compression strength. mortar: Values out of experimental works valid for Romanian historical buildings, recommended as input data for analytical methods (see UAIM, 2000). Values for mortar M10 have been taken (Romanian cement-clay, and EC6 M2), after the experiments of Sofronie.
Foundation	masonry			older buildings have clay brick foundations, newer buildings concrete foundations.

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Roof and floor(s)	Roof/Floors: timber Floors: steel (and clay brick)	timber (Roof/Floors) : Fir scantling strength (N/mm^2): bending, compression along fibre: 10.0; tension along fibre: 7.0; compression perpendicular on fibre: 1.5; bending shear, along fibre: 2.0; shear perpendicular on fibre: 4.5; "strivire" perpendicular on fibre: 1.5; "strivire" at supporting surfaces: 2.5. Broad-leafed scantling strength (N/mm^2): tension, bending, compression and "strivire" along fibres: 1.1-1.3; compression and "strivire" perpendicular on fibre 1.6-2.0; shear 1.3-1.6. Floors (steel and clay brick): tension, compression and bending strength 120.0 N/mm^2; sliding strength 96.0 N/mm^2 respectivelly 0.8 in the other direction. For anchors and "tirant"s: 100.0 N/mm^2. The steel module of elasticity is to be considered: 210.000 N/mm^2.		timber (Roof): Usually this type of building has ovens, usually out of "teracota" corresponding to each room. The roof is usually also out of fir tree, fixed with metal parts. At the turn-of-the century German iron has been popular as covering. timber (Floors): Usually out of fir tree, both mid 19th century and begin of 20th century. Basement might be oak. Floors (steel and clay brick): for metal elements there are no experimental results available. Here what the UAIM (2000) recommendations say has been documented.

6.2 Builder

Typically the builder lives in this construction type. If it is a typical middle class house theowner might be the developer but not the actual builder contractor.

6.3 Construction Process, Problems and Phasing

Construction process adapted for a building from 1904, from a figure by Dinescu in Simetria (2000): Digging the ground and reinforced concrete foundation (reinforced concrete already, like in the model building considered for this form) - 2 positions; Making clay brick masonry wall works - one position; Wood works - two positions; Wood works for the roof - one position; Metal works for the roof (the covering) - three positions; Interior plastering - two positions; Exterior plastering - two positions; Floors - one position; Filling between the joists - three positions; Stone stairs 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; "teracota" ovens - one position; Decorative plastering - one position; Iron cover - one position. For retrofit: According to the UAIM (2000) methodology cracks under 2mm in masonry walls cannot be injected during retrofit works as this implies availability of materials and equipement hard to be found today in Romania. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. Changes in time may be cause of later damages. Such ones are: geometry changes: widening of openings, removal or addition of walls or floors (fig. 4-9); stiffness changes through closing up windows (fig. 4-6 - 4-9); material degradation (fig. 4-28, 4-32, 4-33); load changes: addition of floors without approval, use change (fig. 4-6); missing maintening: especially related to water damages (ex. from rain, missing facade plaser, as visible in figures 4-27 and 4-28 for walls and floors); previous damages from earthquakes or fire (fig. 4-30 – 4-33).

6.4 Design and Construction Expertise

No data. This is rather an informal type of building. However, some of them are designed by architects. An example of a building designed by an architect ("inginer-arhitect" has been the title of the time), G. Brezeanu (not a renowned one), 1904 is given in "Povestea Caselor" p. 53-56, including drawings and some construction management tables.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

It was not built any more when the provisonal guidelines, preceding the first seismic code in Romania, appeared.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules.

It's not built any more. It has been built both in times when building permits were required and not. However, even in the time when no urban development rules were inforced, "act" (i.e. documents) were required to juristically declare the buildings, the begin of the construction process and give some details about, like building materials and succession in the construction process. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by owner(s). which are also the inhabitants.

6.8 Construction Economics

No equivalent possible, as they used to be built before WWII. In the mid 19th century the value of a recently built house of this type was around 200 Austrian "galbeni" or respectively Romanian lei, later on, as documented by Dinescu in Simetria (2000). Turn of the century the builder (Romanian "antreprenor") got 7% benefit of the construction cost. This has been, including that benefit, around 50 months pensions of a retired functionary or 30 months salary of a functionary, who were the typical inhabitants (a bit lower than the value of an existing house). The proportions did not change 10 years later between salary-house price, although the prices absolutely doubled, as it can be understood from the Simetria (2000) publication. Prices for the positions in the construction process of a typical house at the begin of the 20th century (1904) can bee seem in Simetria (2000) page 55, in the reproduction of an original document. Detailed are presented: the digging for the foundations, the foundation works themselves, and the masonry works with dimensions in a typical form of the time ("ante-mesurătorea şi prețuirea lucrărilor" in Romanian, which means "pre-measuring and cost estimation for the works"). A house of this type has been built withing two years of work, both in 1865 and 1904, from which one might be spent with planning and only one with the construction itself, as it can be understood from the description given by Dinescu in Simetria (2000).

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is available. Dinescu in Simetria (2000) mentions documents proving the insurance of the house between 1920 and 1950. These were against fire and lightning, no earthquake, and show the change in the value of the building as well asthe premiums (see reference, p. 57).

8. Strengthening

8.1 Description of Seismic Strengthening Provisions
Strengthening of Existing Construction:

Seismic Deficiency	Description of Seismic Strengthening provisions used
Small cracks in structural walls	Injection with cement milk of small cracks (after Bourlotos, 2001, and 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 with mortar; 5. transport of break-off plaster to rubbish container; 6. disposal of removed plaster; 7. new plaster. (Fig. 4-37)
Large diagonal cracks in the walls or wall dislocations	Shotcrete (after Bourlotos, 2001, compared with 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 with water; 4. Shotcrete of 4~8mm. Alternatively cast-in-place concrete, about 10cm thick.
Serious wall damage	Reinforced concrete jacketing (after INCERC, 2000, completed after Bourlotos, 2001): 1. Scaffolding; 2. Screening; 3. Building up a removing drop tub; 4. Removing outside and inside plaster; 5. Knocking off the masonry wall; 6. Breaking through the slab; 7. Cleaning up the masonry; 8. Concrete roughening; 9. Blasting compressed air; 10. Reinforcement works; 11. Formwork; 12. Binding anchors between masonry walls and shear walls; 13. Mounting the

Seismic Deficiency	Description of Seismic Strengthening provisions used
	binding anchors; 14. Concrete casting; 14. Dismanteling the formwork; 16. Interior and exterior plastering, for interior M100 mortar recommended by INCERC; 17. Masonry repair. (Masonry jacketing with steel nets, in the plaster see Bălan et al, 1982: fig. VIII.24. on page 428)
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 hold off 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)
Low capacity of wall-to-wall and wall-to-floor joints and/or damage along these joints	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 solidisation metal plates; 5. making and mounting of the screw dispositiv for screwing in; 6. mounting of the protection tube for guiding the tyrants through the walls; 7. making and mounting the metal strut; 8. filling in the holes; 9. remaking plastering. (see fig. 4-38 and after INCERC, 2000)
No stiff floors so no co-operation of load bearing walls and floors, so eventual capacity deficiencies of walls cannot be compensated by an uniform distribution of loads through the floors to walls with higher capacity The load bearing elements (timber of metal joists) are linear and transmit the loads into one direction only	Replacement of timber floors or of floors out of brick vaults on metal joists with reinforced concrete slabs (summarised after 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) Dismanteling of under-flooring; 5a. (vaults) Dismanteling filling materials over the vaults; 5b. (vaults) Demounting brick-vault-floors; 5c. (vaults) Demounting metal joists over 4m length; 6. Realisation of fingerprints and binding openings in the walls of different thicknesses (but over 14 cm); 7. Formwork; 8. (timber) Support out of metal joists for the slab; 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. Realisation 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. 4-34).

Strengthening of New Construction:

Seismic Deficiency	Description of Seismic Strengthening provisions used
Inadequate capacity of structural walls	Strengthening with polymer grids (TENSAR), see report #84
Lintels are brick vaults, timber or metal joists; Not always respecting the actual prescriptions regarding the dimensions and the areas of openings in walls; Piers of reduced sections compared to the loads to be 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 also knocked off and disposed; 4. cleaning works; 5. the reinforcement of the reinforced concrete frame is anchored 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. 4-35)
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, dismanteling the formwork of the corner post; 5. building up reinforced masonry in the area of the corner post. (after Bourlotos, 2001; fig. 4-36)

There is no information available about preparing beddings for new slabs and the way of anchoring them to supporting walls. Smighelschi (1992) shows contemporary composite masonry and concrete joist in Romania, an alternative for the replacement of the similar ones with metal joists. For more comments about stengthening with polymer grids see report #84. For more measures see Bostenaru (2004), Tabelle 2-7 on P. 42 and Tabelle 2-8 on P. 43. Strengthening works 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 undamaged buildings. The same is valid for the replacement of floors, which can follow floor destruction in either earthquakes or missing maintenance. Main reparation works which can be performed on historical masonry buildings are according to UAIM (2000): re-weaving with bricks similar to the original ones; injection with lime grout; injection with cement grout; injection with cross-shaped metalic incisions; closing of rifts with cement mortar; threatment of large dislocations with mortar-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. These should be on bigger surfaces and smaller thickness; posible with polymer grids in one of the following ways: grids between the horizontal brick rows, jacketing of walls, confinement of structural parts, according to th respective technology; reinforced masonry or with included metal elements may be added; timber floors may be replaced with reinforced concrete slabs; metal floors may get an overconcrete layer or metal diagonals connecting the metal joists; In case of a minumum 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 when only 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 realised.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?
After the earthquakes form 1940, 1977, 1986, 1990 in case of the model building considered for this form only superficial rifts occured which have been repaired. After the 1977 earthquake following strengthening methods have been used: crack injection with cement paste (most widely used), replacement of collapsed portions of old walls with new masonry walls built in cement mortar, shotcrete, replacement of heavy walls with light walls or connection of those with the walls of the load bearing system. The last one of these has been described in report #84. Added reinforced concrete vertical posts leads to changing the structural type into reinforced masonry and thus might be suitable for historic constructions of this type. Tension struts and floor replacement have been also used for buidings of this type as shown in the figure. Reinforcement of door frames adresses like floor replacement specific seismic defficiencies of this type again. For the other ones this report

presents a new view, comparing the Romanian practice after the 1977 earthquake with provisions from today, as it resulted from joint research work of one of the authors with a student from Greece (see Bourlotos, 2001).

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

Strengthening measures like repairing cracks, rifts, out of plane wall collapses are made following earthquake damage. Strengthening measures like reinforcement of door openings, providing of vertical posts are made on undamaged/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.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the 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 seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

Owner.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

The model building wasn't damaged significantly. However, Bălan et al (1982) documents failure of reinforced concrete posts 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 shown in damages at a vertical post at the corner of a midrise masonry building in the 1977 earthquake. (from Bălan et al., 1982: figure VI.28.b. on page 253).

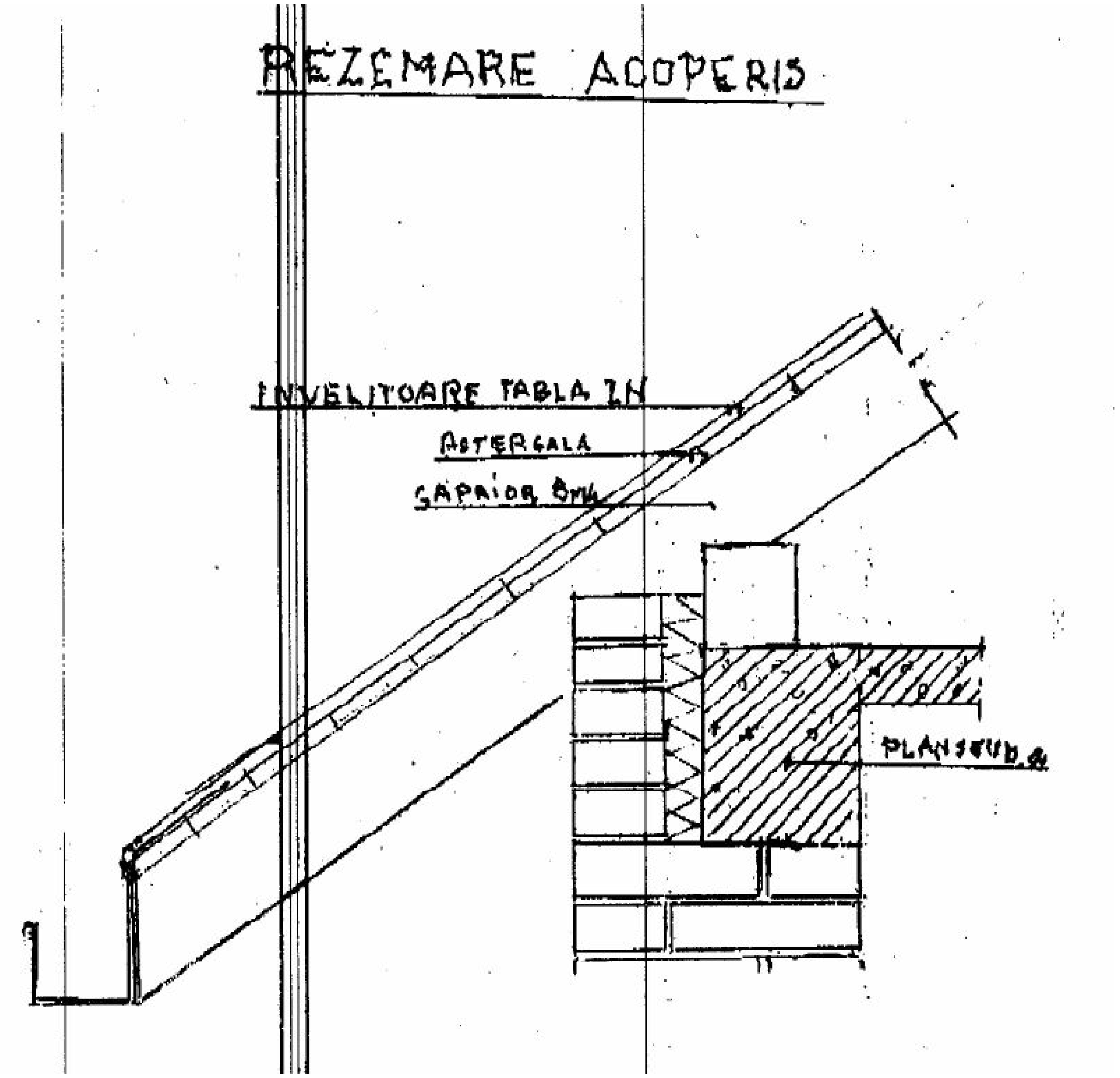

Figure 4-34: View of roof-wall-floor connection in case of proposed retrofit of rigid slab at roof level.

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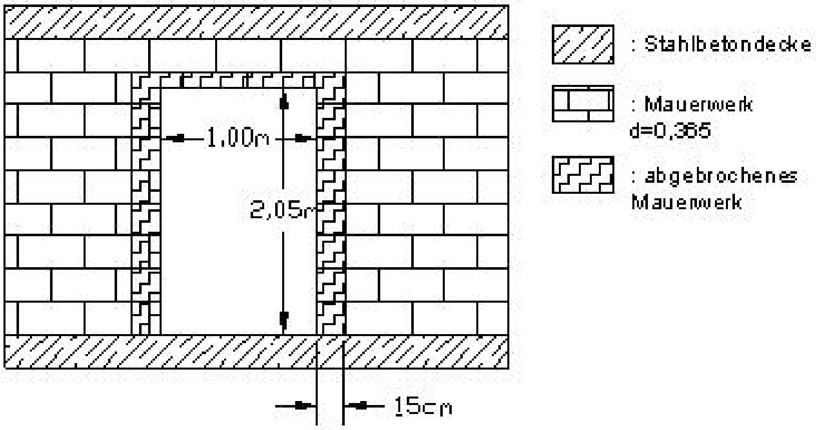
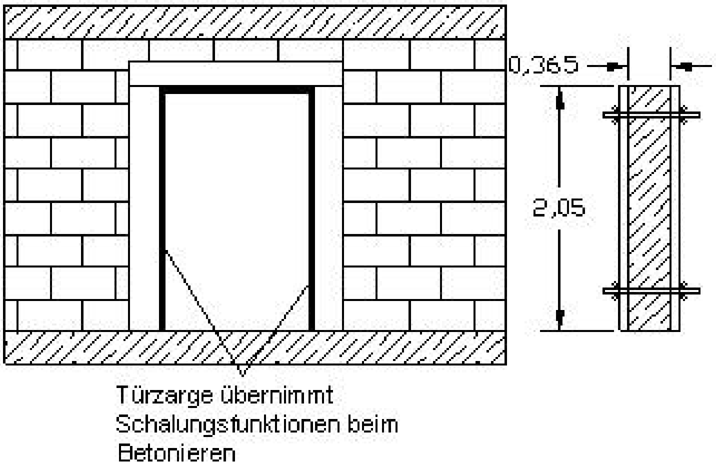
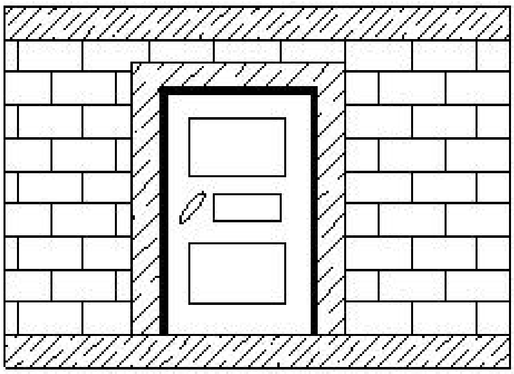


1. Knocking off the masonry around for door strengthening



Türzarge übernimmt
Schalungsfunktionen beim
Betonieren

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

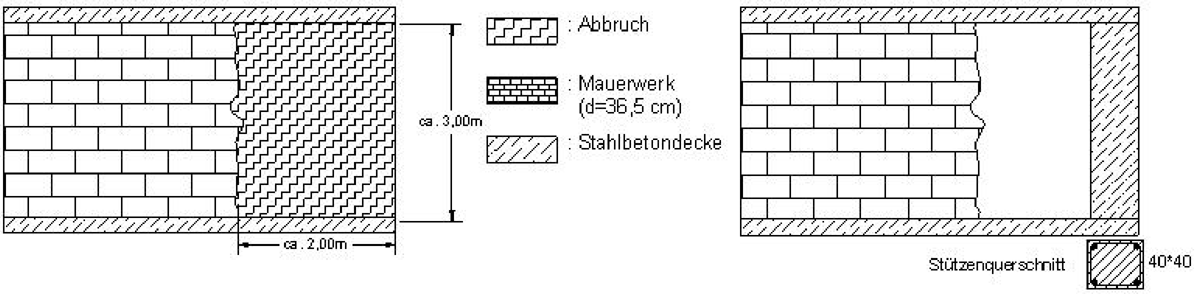


3. Mounting of a new door

Figure 4-35: Reinforcement of doorways (after Bourlotos, 2001)

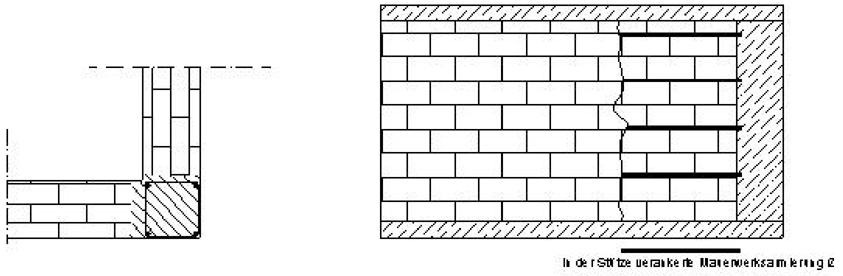
1. Initial state of the corner

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

Figure 4-36: Strengthening of masonry corners (after Bourlotos, 2001)

Bourlotos, Gregor: [Kostenermittlung in der Erdbebenertüchtigung alter Gebäude] = "Costs estimation in the seismic retrofit of old buildings" (in German), study work at the Institute for Construction Management and Machinery at the University of Karslruhe (TH), 2001.

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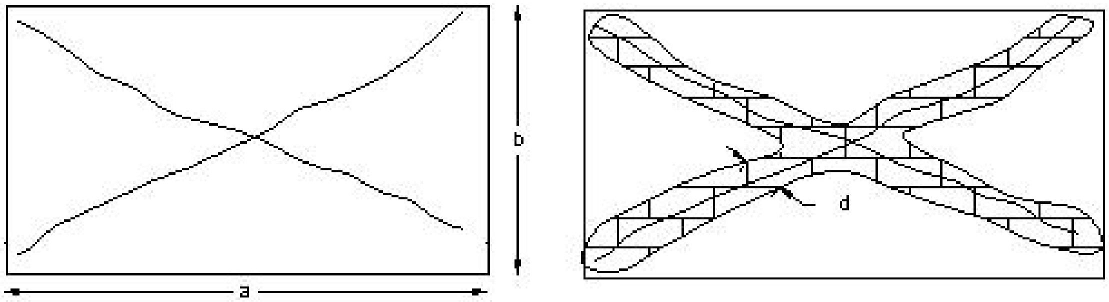
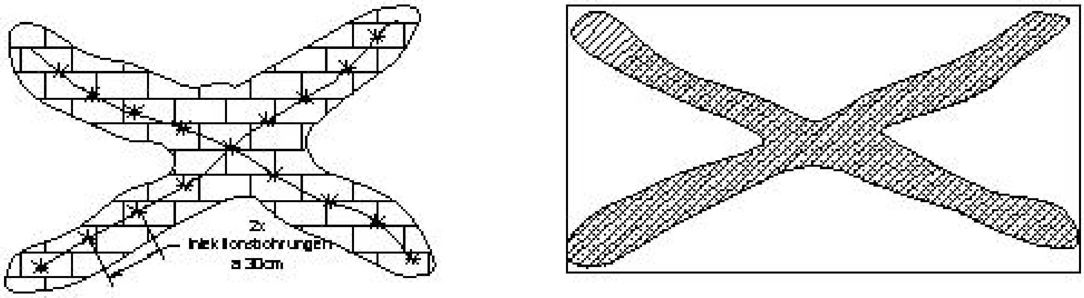


1. Initial situation, rifted wall

2. Dismanteling of plastering
- average width 10 cm



3. Injection holes

4. New plastering after filling the rifts

Figure 4-37: Masonry wall reparation through rifts injection (after Bourlotos, 2001)

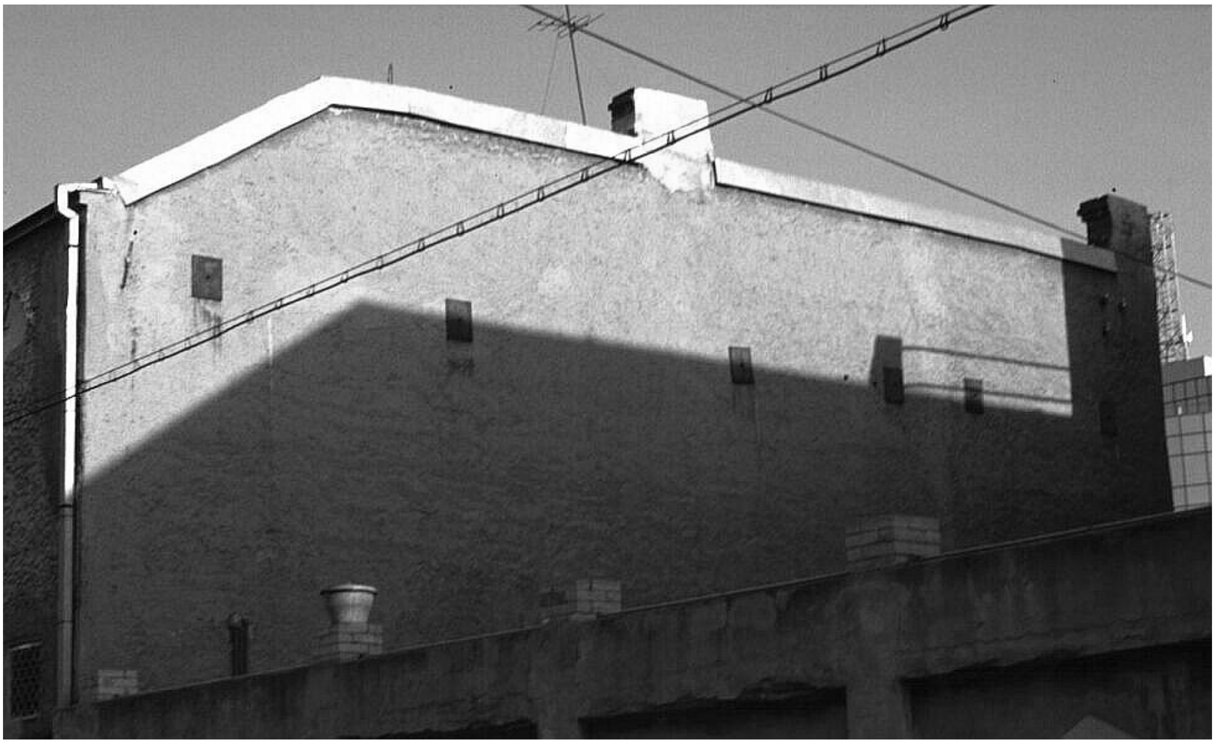


Figure 4-38: Reinforcement with tension strut, in Romanian "tirant" (from Bostenaru, 2004, TAFEL VII)

Bostenaru, Maria: [Wirtschaftlichkeit und Umsetzbarkeit von Gebäudeverstärkungsmaßnahmen zur Erdbebenertüchtigung] = "Applicability and Economic Efficiency of Seismic Retrofit Measures on Existing Buildings", PhD Dissertation, submitted 2004, withdrawn 2006, and published in 2006 under the same title at Shaker Verlag, Aachen.

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Modernist housing in Romania: Early RC frame condominium building with masonry infill walls designed for gravity loads only

(Report # 96 in the "World Housing Encyclopedia"
http://www.world-housing.net/)

Summary

This urban housing construction was practiced in Romania from 1907-1945, but predominantly in the 1930s, in the capital city of Bucharest. These buildings are mid- or high-rise (5-10 upper floors), often with two basements. Although there are several functional variations according to the usage and combination of flats, offices, and shops, this report discusses 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 as many 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 the building are highly irregular. Upper floors may have recesses in the facade and may have corner towers. The load-bearing structure is RC schelet designed for gravitational loads only. Columns are unevenly distributed so that beams at least one end are supported as secondary beams. Some beams are supported by columns with inadequate reinforcement or reduced sections of the RC members impede the formation of moment-resisting frames. The facade walls have solid clay brick masonry infill and improve the seismic behavior. The beneficial effect of masonry infill is influenced by the wall thickness, the size/position of openings in walls and the position of the partition wall to the frame. Staircases and elevators weaken the structure by introducing concentrated holes in flexible, thin RC slabs. Bucharest is located on alluvial soil deposits on river banks. Sandy ground or high levels of underground water have often 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 the 1940 and 1977 earthquakes, but performed well relative to their high vulnerability. Out of the 61 buildings heavily damaged in the 1977 earthquake, 28 were of this type but were high-rise (7-9 floors).

1. General Information

Buildings of this construction type can be found in Centre but also other parts of Bucharest, the capital, on small parcels. After an estimation of the author there are about 300 residential buildings from that time and with that structural type located in the city of Bucharest and around it. After Lungu et al (2000b) slightly more than 20% of Bucharest's housing units were built before 1941 (which is when the pre-code benchmark period started) and further almost 10% between 1941-1963 (1963 being the year of the first low-code, inspired by the Russian practice, after Lungu et al, 2000b). However, this kind of buildings stopped to be constructed around 1948, with the nationalisation process. According to Lungu et al (2000b) Bucharest city has about 750000 houring units in about 100000 buildings, from which 95000 are low rise (1-2 storeys) and the rest in a 2/3 ratio high and mid-rise. A database compiled by the author for architecturally relevant buildings of the time has around 600 entries, including not realised projects and not residential buildings. 125 of them are blocks of flats, and another 175 of them single family houses, from which 75 are categorised as luxury villas. 44 out of 115 listed in the highest vulnerability class are purely residential. It is notable that not all buildings listed as highly risk-exposed are included into that database, but only 17 out of 115. All these leaded to the ESTIMATION of about 300 buildings of this structural type. This type of housing construction is commonly found in urban areas.

Reinforced concrete was suitable for multistorey buildings, which were permited by the new urban law, especially in the parts of the capital looked for, with high m² prices for the ground.

This construction type has been in practice for less than 100 years.

Figure 5-1: Perspective drawing of a model building

Figure 5-2: Axonometric view of the whole building

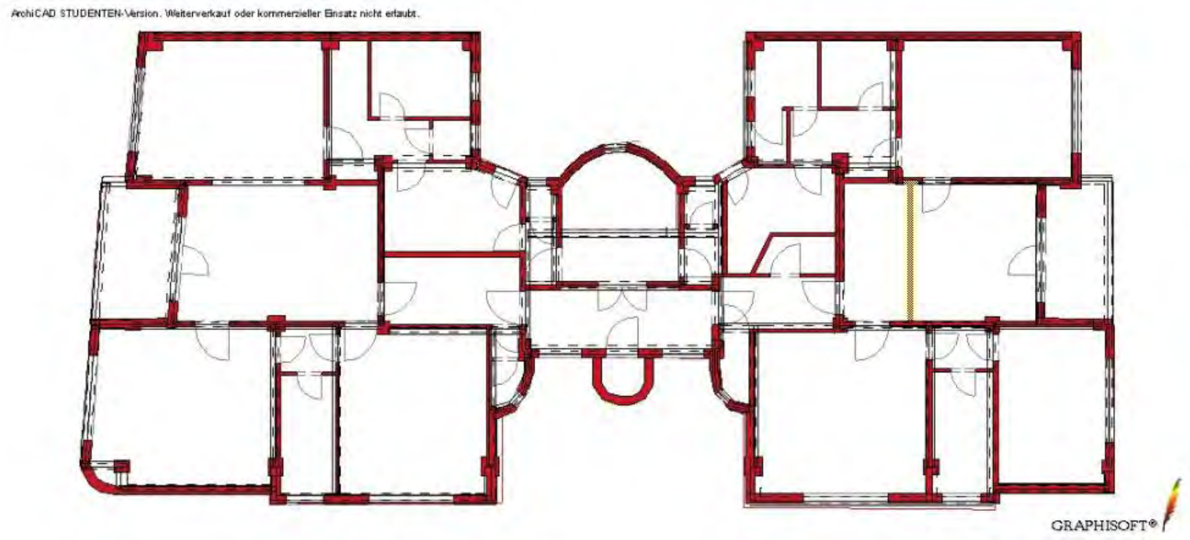

Figure 5-3: Architectural plan of a current floor (after Bostenaru, 2004). Yellow marks new partition walls.

Figure 5-4: Perspective view of typical building (from Bostenaru, 2004) figure 3-2).

Currently, this type of construction is not being built. The "boom" time for this type of construction has been 10 years (1930-1940). However, isolated attempts of this type have been built since 1907 and till 1947.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. Usually, these buildings were designed to have two common walls with their neighbours. Thus a building can sit between two others in a street front or on a corner. It can form a court in the middle, opened to the street or not

2.2 Building Configuration

Irregular. Many of these buildings are U or H shaped, some are L shaped (often in sharp angle), 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. For this report an H-shaped example building has been chosen. The windows for the model building considered are 2.40m wide and 1.35m high. There are 8 like this on each floor. 6 of these are in console walls, which are thick and heavy, but not infill walls. Two of them, which also include doors to loggias, are in thick fassade walls supported only by secondary beams. Smaller windows are for flat dependencies (bathroom, kitchen). Windows are regularly distributed in the walls. This has allowed the regular distribution 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 lving room there is a bigger opening of 2.65x2.60m in one of the flats. The distribution of doors is rather irregular (see fig. 5-3). There are several openings in the infill walls while some walls, with no infill function, have no openings, as the number, size and position of openings have been dictated by functional, not structural considerations.

2.3 Functional Planning

The main function of this building typology is multi-family housing. Several variants of this structural type exist: solely multistorey housing, evtl. with parking in the ground floor or high basement; multistorey housing with commercial ground floor; multistorey housing with cinema halls in the ground floor and basements; mixed use as housing and offices, with offices in additional wings or at several of the lower floors. Buildings with commercial ground floor were subject of Bostenaru (2005). In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Two staircases were usuall for this type of buildings: a main one and a service one. Both served all flats. Additionally, at higher buildings there were elevators. In case of the luxury flats two each unit served by a vertical node (usually comprising two staircases - main and service - and eventually lift) are the most usual. In the example building in this report the elevator is accomodated in the half-round shaft vis-a-vis of the bigger half-round volume of the stairs-shaft. The main staircase is replaced in some buildings by just the lift, like in the example building in this report.

2.4 Modification to Building

Some buildings were added new metalic or RC schelet wings. New partition walls (fig. 5-3).

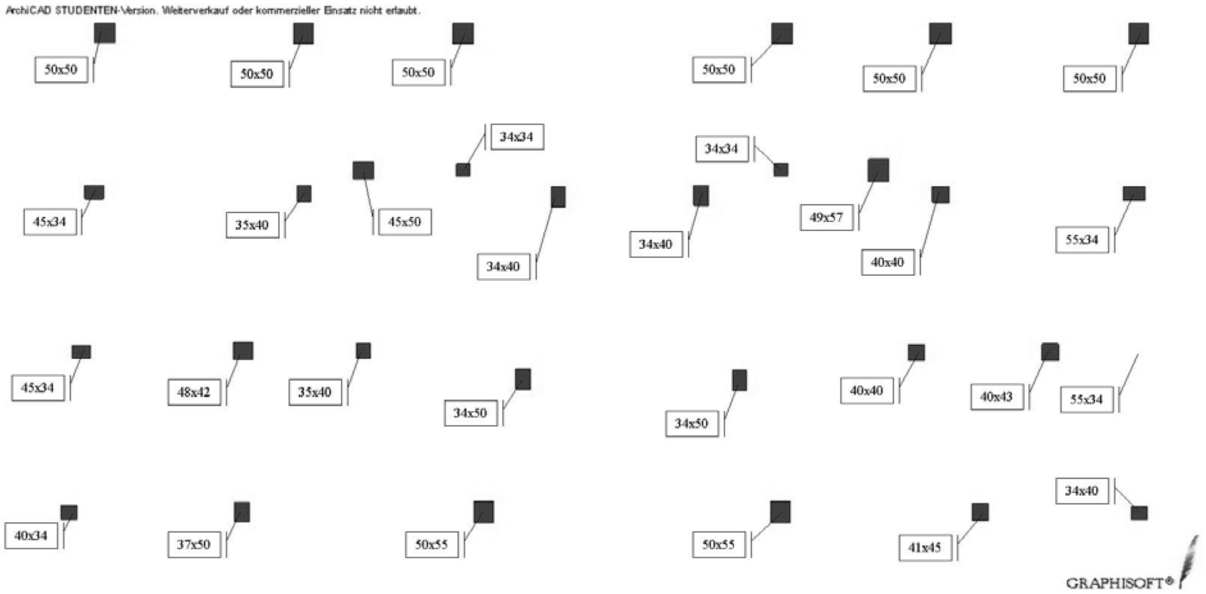

Figure 5-5: Layout of columns in a typical building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Dressed stone masonry (in lime/cement mortar)	
	Adobe/ Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	
		8	Brick masonry in mud/lime mortar with vertical posts	
		9	Brick masonry in lime/cement mortar	
		10	Concrete block masonry in cement mortar	
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	
		12	Clay brick masonry, with concrete posts/tie columns and beams	
		13	Concrete blocks, tie columns and beams	
	Reinforced masonry	14	Stone masonry in cement mortar	
		15	Clay brick masonry in cement mortar	
		16	Concrete block masonry in cement mortar	
Structural	Moment resisting frame	17	Flat slab structure	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
concrete		18	Designed for gravity loads only, with URM infill walls	
		19	Designed for seismic effects, with URM infill walls	
		20	Designed for seismic effects, with structural infill walls	
		21	Dual system – Frame with shear wall	
	Structural wall	22	Moment frame with in-situ shear walls	
		23	Moment frame with precast shear walls	
	Precast concrete	24	Moment frame	
		25	Prestressed moment frame with shear walls	
		26	Large panel precast walls	
		27	Shear wall structure with walls cast-in-situ	
		28	Shear wall structure with precast wall panel structure	
Steel	Moment-resisting frame	29	With brick masonry partitions	
		30	With cast in-situ concrete walls	
		31	With lightweight partitions	
	Braced frame	32	Concentric connections in all panels	
		33	Eccentric connections in a few panels	
	Structural wall	34	Bolted plate	
		35	Welded plate	
Timber	Load-bearing timber frame	36	Thatch	
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		38	Masonry with horizontal beams/planks at intermediate levels	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
		39	Post and beam frame (no special connections)	
		40	Wood frame (with special connections)	
		41	Stud-wall frame with plywood/gypsum board sheathing	
		42	Wooden panel walls	
Other	Seismic protection systems	43	Building protected with base-isolation systems	
		44	Building protected with seismic dampers	
	Hybrid systems	45	other (described below)	

Following types are described by Prager (1979) to have been used at particular buildings:
- RC schelet with slabs with main and secondary beams; columns distributed according to an economic computation. The columns are recessed at the last floor following the roof line.
- the general schelet is out of reinforced concrete, cross-reinforced slabs, exterior infill walls out of clay brick.

3.2 Gravity Load-Resisting System

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 the loads with the reinforced concrete structure (see figure 5-10 – 5-12). According to Bălan et al (1982) P. 234-235: The design for gravitational loads has been made following the prescriptions from the German circular from 1925 (Prager, 1979). Not always the prescriptions have been respected (sometimes the columns and beams might had been underdimensioned for gravitational loads as well as described in Bălan et al (1982) P. 241 for the Belvedere block, a block with commercial ground floor, though). In Chapter 11, P. 273-305, Prager (1979) describes the construction particularities in several residential and office buildings of the time 1930-1940, and in 7.4. of those of the time 1918-1930. The building of the block of flats "Spicul" (Construction site of a building of similar type in Prager, 1979, Figures 7.4.9. on p. 144 and 7.4.10. on p. 145, featuring on the left the organisation of the building site at block of flats "Spicul" and on the rigth the finished block), arch. Arghir Culina, RC eng. Dim Marcu, is a good example showing the sequences of building construction. This building has been finished between June and November 1928. After reaching the second floor the masonry works have been carried out paralelly with those of the upper slabs. On the 1st of October the structure was ready on 5 floors and the finishing and installation works could began. (after Prager, 1979, P. 143-145). This building is not typical for the type in this report as it includes also several shops in the ground floor besides of 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" - in Romanian, edited by the Bucharest Polytechnical School (1931-1933); - Prof. ing. Mihail Hangan: [Contractia betonului si 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, different constructions, 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 betonului armat] = "The practical calculation of reinforced concrete" -in Romanian (1935); - Ing.

Stan Dumitru si ing. Alexe Tauber: [Calculul fundatiilor stâlpilor] = "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. Aurel Beles [Cutremurul si constructiile] = "The earthquake and the constructions" – in Romanian (1941); - Ing. Nicolae Ganea: [Constatare cu ocazia cutremurului din 1940] = "Statement on the occasion of the earthquake in 1940" - In Romanian (1941); - Prof. ing. Mihail Hangan: [Consolidari de fundatii si constructii în beton armat] = "Retrofit of reinforced concrete foundations and constructions" PhD thesis in Romanian (1946). For earlier publications see 7.4.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). The main load-bearing structure consists of reinforced concrete beams and columns (see figures 5-18 and 5-19). The columns are unevenly distributed (see fig. 5-5) and the beams are distributed in a way often not forming moment resisting frames (see fig. 5-6 - 5-10). This means that most beams are not supported by two columns at their two ends, but often at at least one of them by another beam. Additional to the spatial characteristics defavourising the formation of rigid frames the nodes are deemed not to have been reinforced accordingly (Bălan et al, 1982, P. 238). Beams have also very reduced section (many of them 15cm x 30cm in the example building on a span of about 4m). Columns have also been unadequately reinforced for lateral loads, as shown by the short lap splicing, computed for compression loads out of gravity only (Bălan et al, 1982, P. 239). Usually at the facade there are clay brick masonry infill walls, contributing to the lateral load bearing (see fig. 5-12). The floor structure consists of cross reinforced slabs with 10cm average thickness suported by beams masked in the partition walls for spans under 4.5m and of reinforced concrete slabs with embedded hole brick elements, 21cm thick for spans of up to 6.5m (see figure 5-16). Lateral loads are taken over by the masonry infill walls especially in the first phase of seismic solicitations. In a second phase the infill walls were not compatible with the huge deformation of the schelet structure and were destroyed. The solicitations were then supported by solely the RC schelet, which was heavily damaged (especially the columns), 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, the global 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 the position and size of the openings in the infill walls had basically influenced the behaviour during the earthquake. Sometimes the infill walls contributed to the break of short columns (summarised from Bălan et al., 1982, P. 234-235). For functional reasons the staircases and lifts are often placed in such a manner that they weaken the slab (not strengthening it with RC tubes as nowadays). In the example building it can be seen that the infill walls have been placed in the short direction and at the end of the units (bordering the huge holes given by the staircase and lift placed in the bar joining the two wings of the H shaped building) thus giving a quasi simetric distribution of rigidities in the two directions. A computation method for horizontal loads was totally missing at that time. Bălan et al (1982) affirms (P. 242) that even structures designed for gravitational loads only have certain seismic qualities on the one side from the resistance reserves ot the RC skeleton, well designed for gravitational loads and on the other side from the resistance reserves of the infill walls. Prager (1979) figure 9.4.6. on page 212 (Sequences of building construction shown in the execution program of a building of the same structural type from the same time (1930): simple concrete masonry; reinforced concrete; casting concrete into the metalic columns; exterior masonry; concrete floor; exterior plastering) (see description at 4.2.) clearly shows that facade walls are erected after the concreting. However, as it can be seen in figure 5-7, some "beams" (the blue ones) are indeed just a belt over the masonry walls, of 25cm width and 38cm height. This is basically different from all other beams, which are usually 15cm wide and twice as high as wide. These belts are continuation of real beams perpendicular to the facade wall and support again real beams, which support thick masonry walls in the facade (but which are in console in upper levels).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 18 and 35 meters, and widths between 9 and 15 meters. The building has 5 to 10 storey(s). The typical span of the roofing/flooring system is 4.5 meters. A typical building has about 380m^2 floor area and rectangular shape (15x30m). From the purely residential buildings listed in the highest vulnerability category: 1% have 9 upper floors, 3,5% have partially 9 upper floors, 12,5% have 8 upper floors, 20% have 7 upper floors, 9% have partially 7 upper floors, 11% have 6 upper floors, 11% have partially 6 upper floors, 23% have 5 upper floors, 7% have partially 5 upper floors and 1% have partially 4 upper floors. Reinforced concrete was the structural material to realise the heights permited by the new urban regulations. There are often two basements, from which the first basement can be a half basement (Romanian "demisol"). The unclear urban legislation permited different storey heights to the next buildings. This was used out for speculation purposes. Typical Span: some up to 6.5m. Spans are variable and dictated in most of the cases by the destination of the rooms. To the author is only one case known of free distribution of partition walls with regard to the columns. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 10 %: 5% - 10% Many of the walls are just partitions, see figure 5-12.

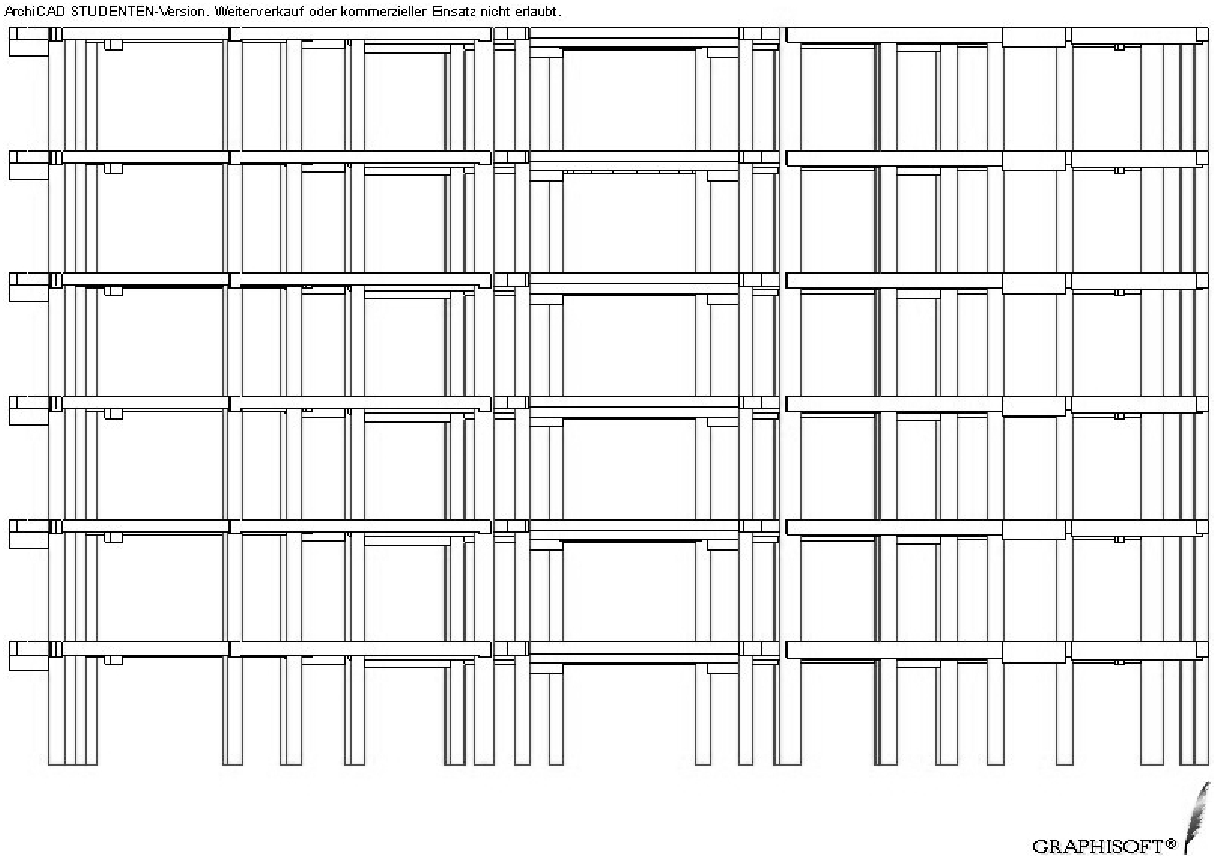

Figure 5-6: Longitudinal view of load bearing elements

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted		
	Composite system of concrete joists and masonry panels		
Structural concrete	Solid slabs (cast-in-place)		
	Waffle slabs (cast-in-place)		
	Flat slabs (cast-in-place)		
	Precast joist system		
	Hollow core slab (precast)		
	Solid slabs (precast)		
	Beams and planks (precast) with concrete topping (cast-in-situ)		
	Slabs (post-tensioned)		
Steel	Composite steel deck with concrete slab (cast-in-situ)		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood shingle roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams supporting natural stones slates		
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other	Described below		

According to Prager (1979): Slabs are usually cast in place, cross reinforced with beams hidden in the partition walls. These slabs were appreciated to have exagerated elasticity when the span was over 4.5-5m (they have a thickness between 6cm and 11 cm, usually 10cm). Following alternatives were considered:

- special slabs with hole brick embeded elements in "Pfeifer" system. These are 21cm thick and heavier, but can be used with good behaviour up to 6.5 m span. The ceiling is straight.
- close numberous waffles, near which "trestie" boxes were introduced. The "beams" are spaced 0.62m, 25cm high while the slab itself is 5cm high.
- secondary beams with false ceiling out of mortar on metal net.

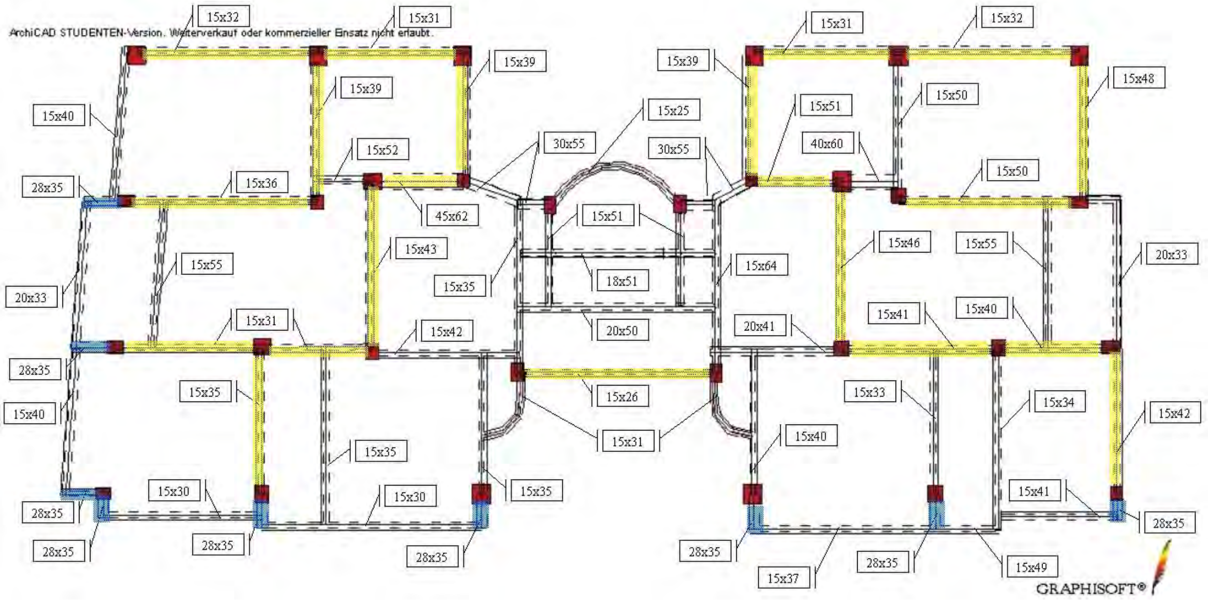

Figure 5-7: Layout of beams and columns in a typical building. Note that only few (the yellow ones) form frames.

3.6 Foundation

The types of foundation differ according to the ground on which the building has been made. Few buildings were made on good foundation ground, with isolated footing.

Type	Description	Most appropriate
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced-concrete isolated footing	
	Reinforced-concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced-concrete bearing piles	
	Reinforced-concrete skin friction piles	
	Steel bearing piles	
	Steel skin friction piles	
	Wood piles	
	Cast-in-place concrete piers	
	Caissons	
Other	Described below	

Most foundations raised 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 the underground water layer.
- deep foundations of 7-8m
- general RC mat foundation designed for 1,2 kgf/cm^2 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/cm^2 and water saturated (near Cismigiu lake), mat foundation of 50cm was used. Mat foundation was used in several another cases when founding on sandy terrain at around -7.5m (two basements). Mat foundation was also used when underground water was high (-6m for buildings close to Dâmbovița river).
- a special foundation used at an office building of the same structural type was used on a special ground saturated with water. It was a mat foundation with difficult works. To strengthen the ground steel tubes were embeded into the mat at about 1m distance. After finishing the structure of the building cement mortar was injected into these tubes at 3-4 at controlling the filling and spreading effect in the matt to the neighbouring holes. The building above was 30m high, the admitted

pressure on the ground 1.2-1.4 kgf/cm^2. It behaved well at the 1940 earthquake.

- on aluviar soil deposit: perimetral columns founded on simple concrete continuous wall of 50cm thickness on the whole height of two basements. Middle columns going down to reinforced concrete strips which support also the weight of the basement wall between them.

- a special foundation work was due when the neighbouring buildings had a higher foundation. A case is described by Prager, when the foundation of the neighbouring building was 4m higher as the two basements for the new building. The new foundation was in a sand and gravel layer, made through 5 vertical deep holes, connected by a tunnel-galery of 1,6x1,8m, in which then the new reinforced concrete strip was constructed, on which the masonry of the two basement was made, in successive parts, after which the ground was escavated at 6,3m depth till the street. The neighbouring building was founded on a compact resistent clay layer and was later extended vertically with 3 upper floors. Some other foundations opened realisation problems as well. Such one was on sandy terrain where the foundations were made through deep holes, followed by casting the slab over basement. The diggen sand proved to be so clear that it could be used for the concrete and masonry works.

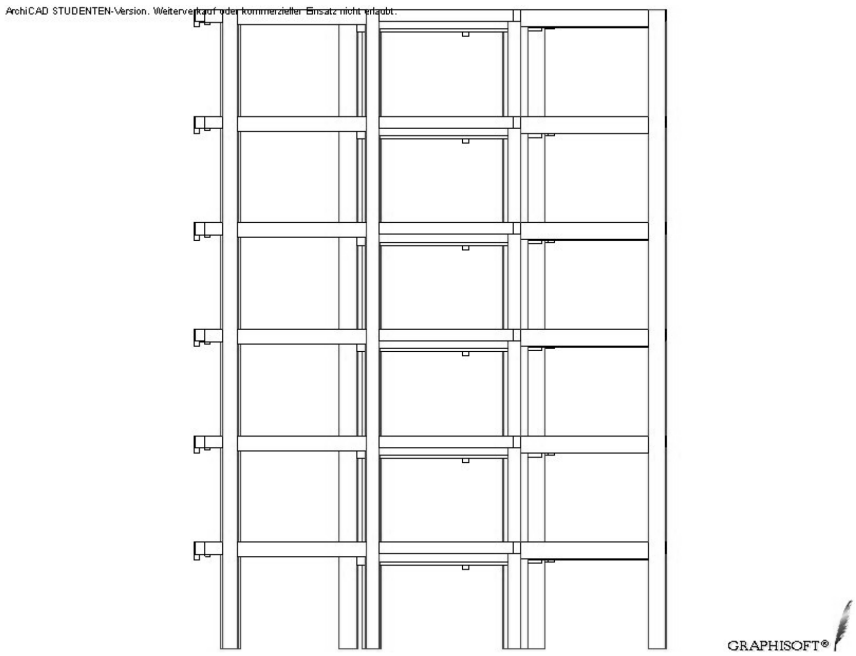

Figure 5-8: Transversal view of load bearing elements

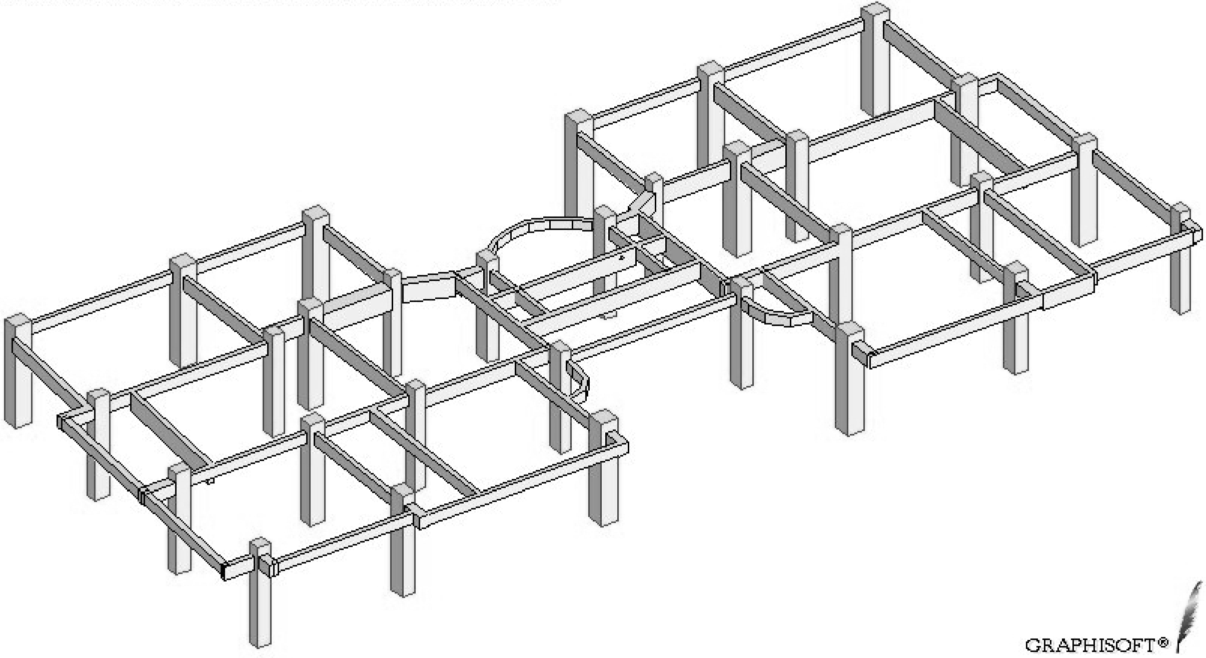

Figure 5-9: Skeleton of a current floor.

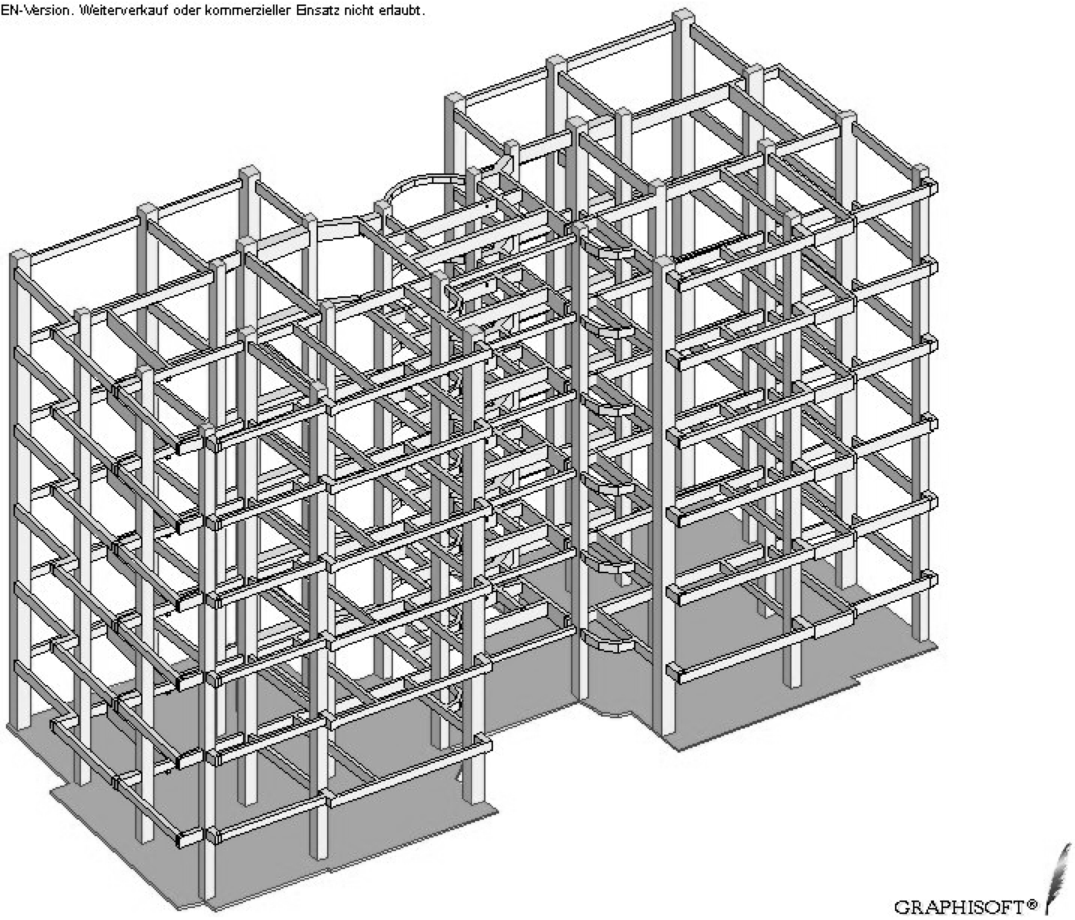

Figure 5-10: Beam-column schelet for the whole building.

Figure 5-11: Side wall of a typical building (from Bostenaru, 2004)

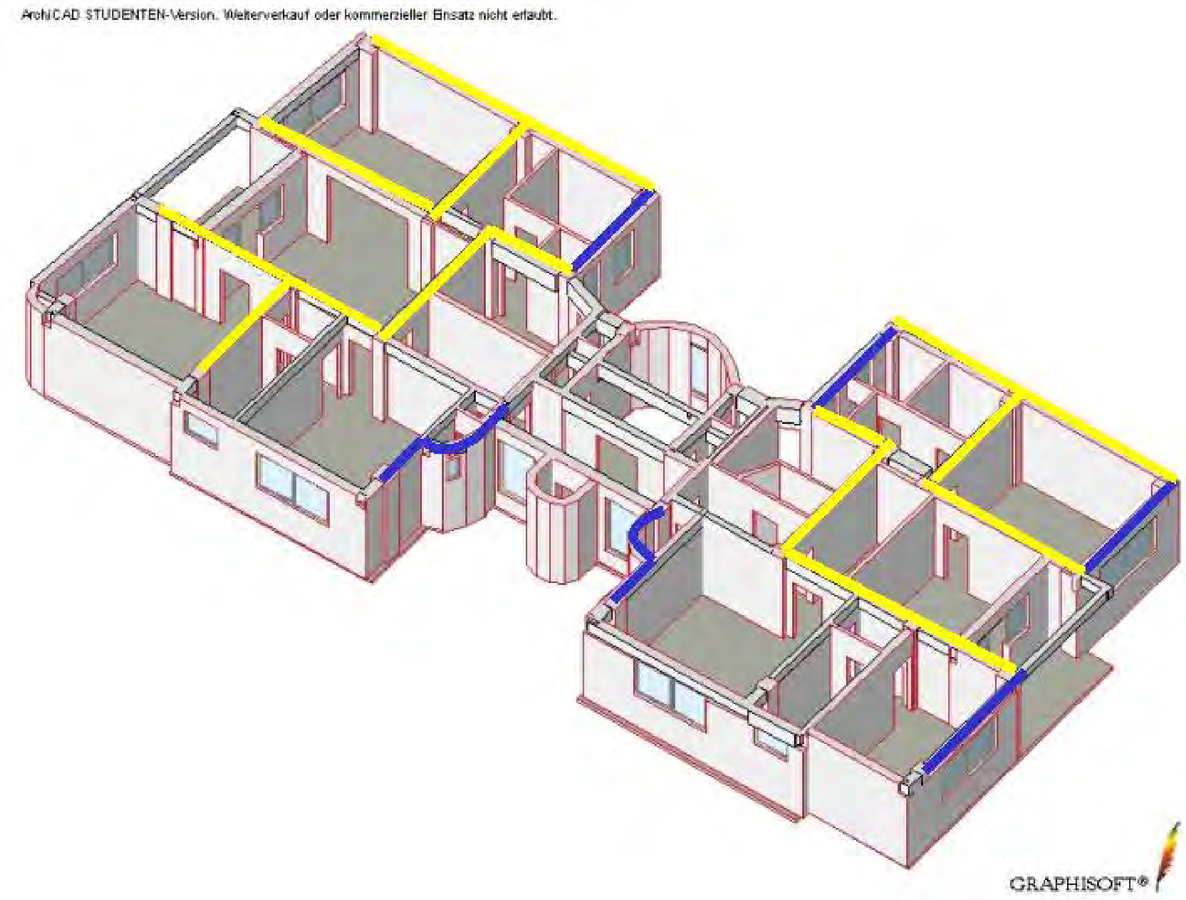

Figure 5-12: Axonometric view of a current floor. Frames infilled with 34cm masonry are marked with blue, frames infileld with 10-15cm masonry are marked with yellow in the section plane.

Figure 5-13: Structural detail. Photo by Maria Bostenaru, 2002.

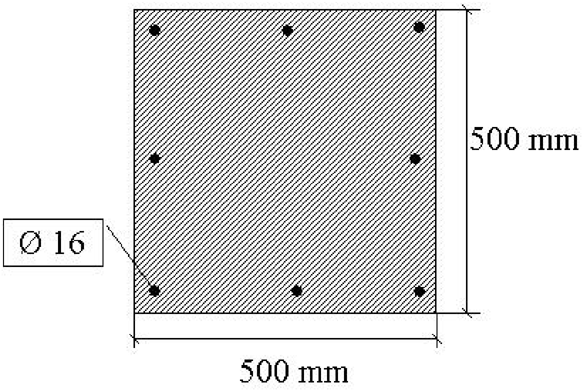

Figure 5-14: Reinforcement detail of a typical square column. (from Bostenaru, 2004)

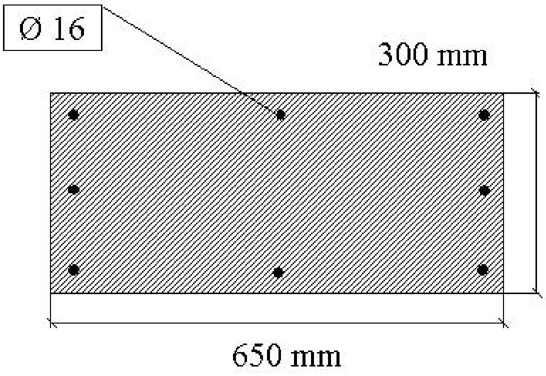

Figure 5-15: Reinforcement detail at a rectangular column. Note that the geometric characteristics, not the physical ones, have been taken into consideration at the distribution of the bars.

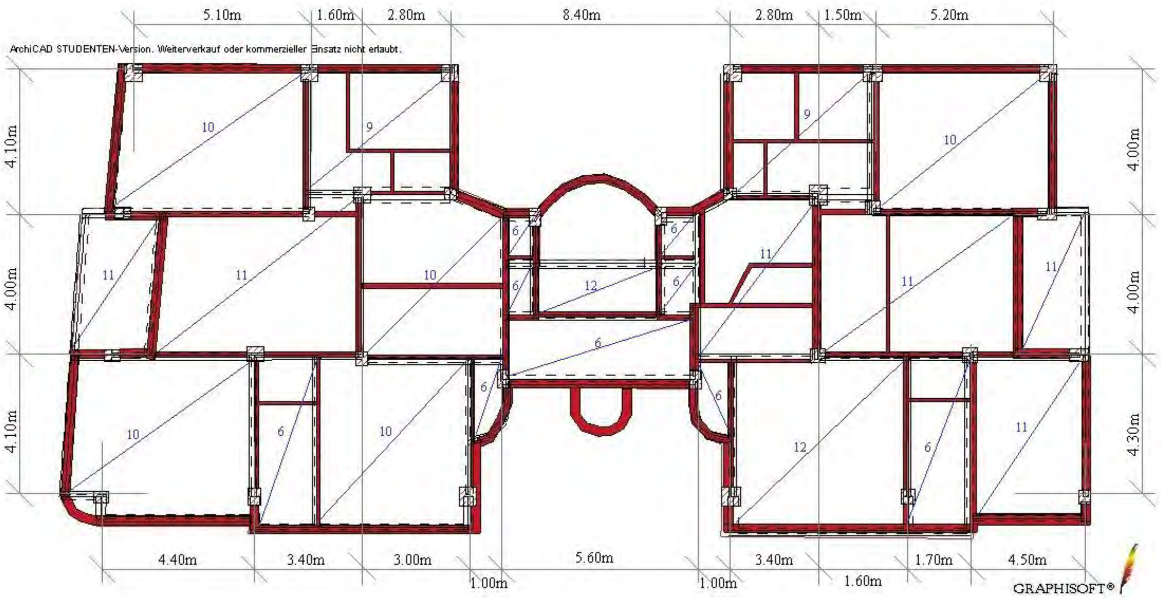

Figure 5-16: Floor plan including the load bearing elements as masonry walls and slab thickness (blue), as well as the spans. (after Bostenaru, 2004)

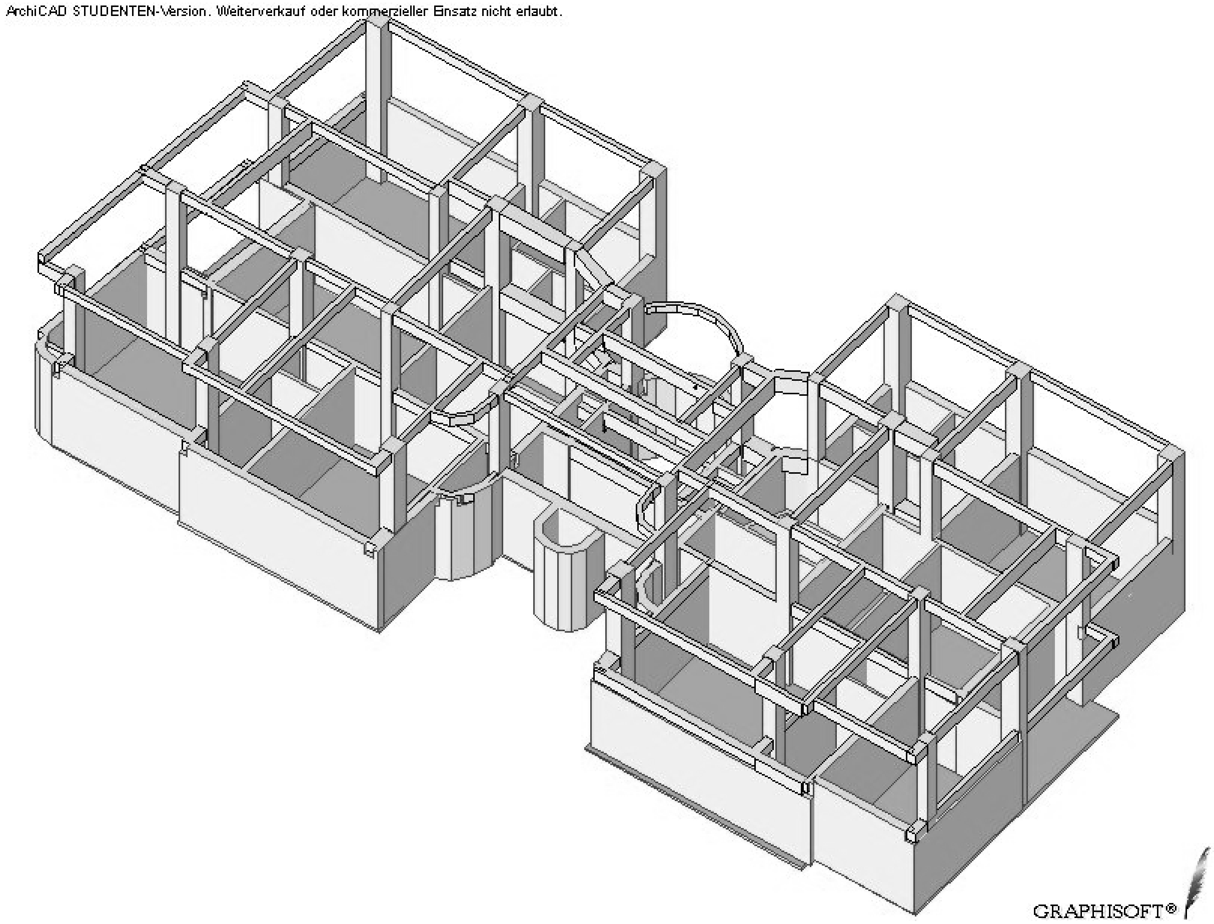

Figure 5-17: Axonometric view of the relationship between load bearing elements and masonry walls (from Bostenaru, 2004)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing units: mean 25 units in each building. For the highest vulnerability class the number of housing units ranges between 3 and 104 for a building (see 4.11). Half of them have between 16 and 31 housing units. For the purely residential ones out of these (53) several values have been computed:

- storey: average 7.37 (the closest is the Frida Cohen building of architect Marcel Iancu with 53 flats), min 5.5 (for 3 buildings from 1933 with 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 two buildings of 1300 respectively 1280 sqm, both from 1935 and both with 6 storeys), max 83 (for a building with 13670 sqm on 8 storeys from 1938);

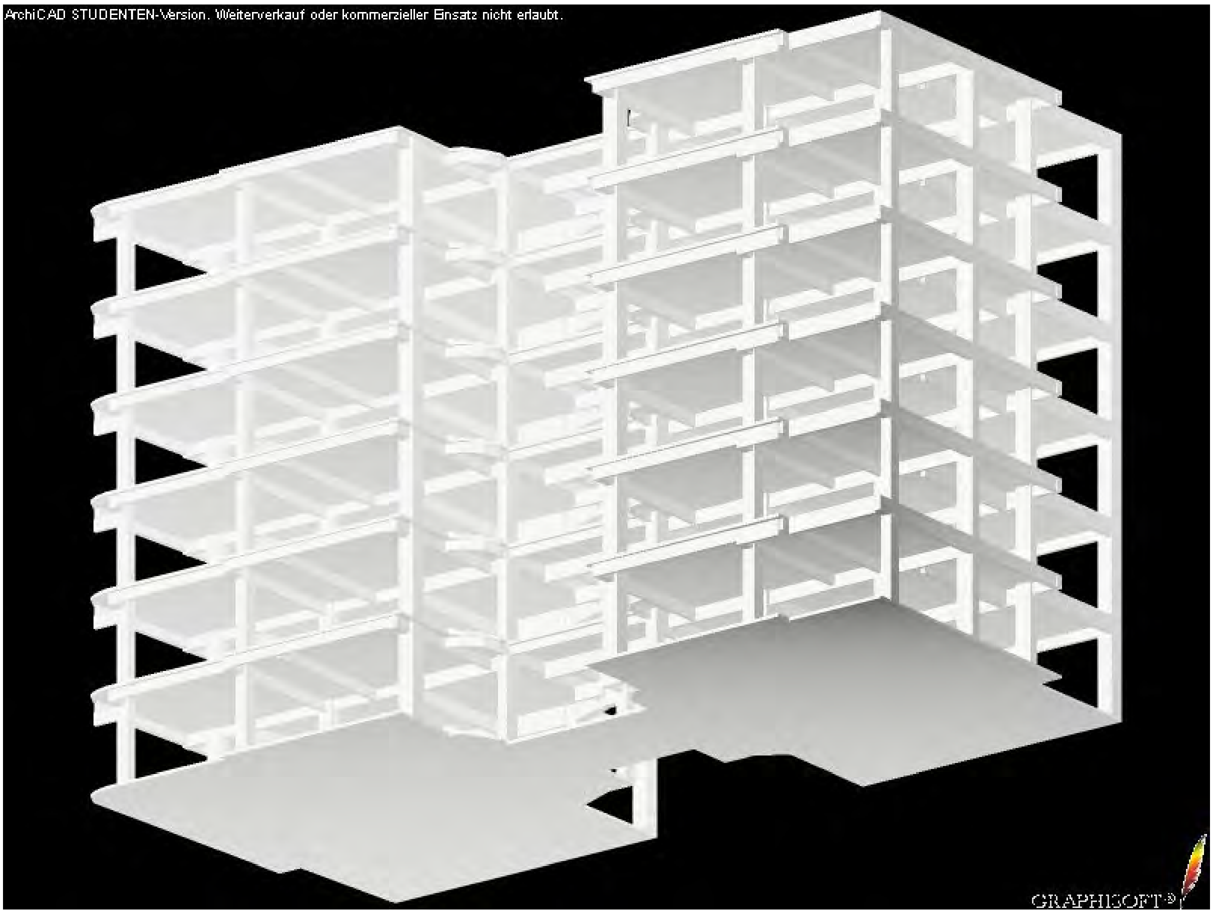

Figure 5-18: Load bearing structure of a typical building (from Bostenaru, 2004)

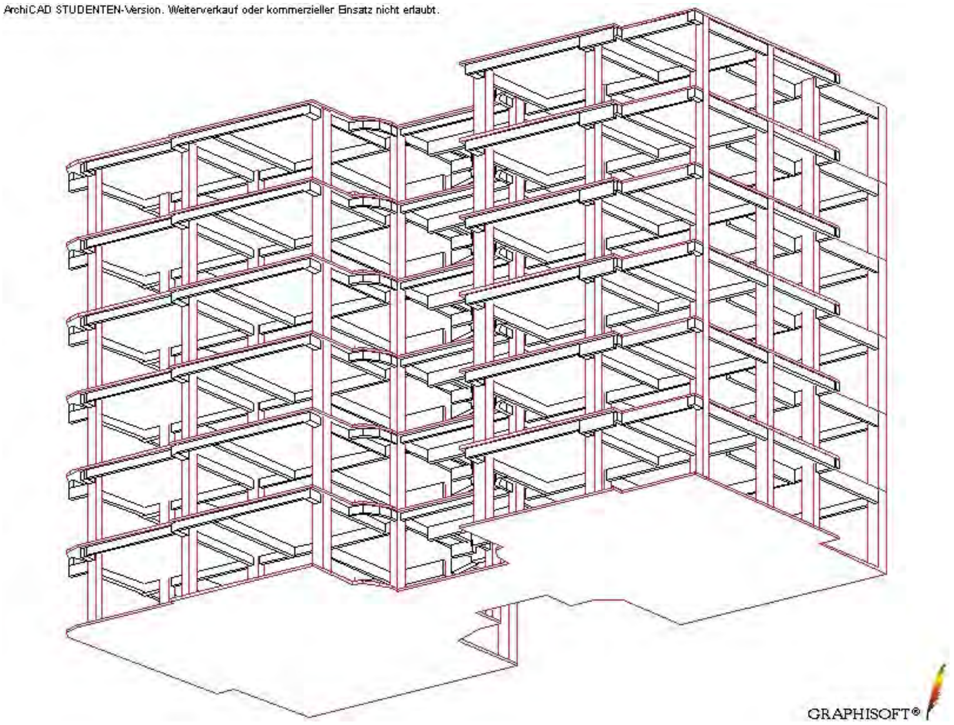

Figure 5-19: Axonometric view of load bearing elements, not rendered

- 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 buildings from 1935 with 6 floors each, one with 1300 the other with 1280 sqm), max 10.38 for the big building mentioned (83 flats);
- surface/flat: average 141.58 (for a building from 1940 with 36 flats on 7 floors), min 76.41 (for a building from 1933 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 buioding from 1939 with 31 flats on 7.5 floors), min 153 (for the building with the smallest surface), max 1708,75 (for the building with the biggest surface).

Not so highly vulnerable buildings have between 3 and 42 housing units, most of them either 10 or 25, depending on the number of floors. The model building chosen has 12 residential units. The number of inhabitants in a building during the day or business hours is others (as described below). The number of inhabitants during the evening and night is others (as described below).

4.2 Patterns of Occupancy

Usually one family (about 4 persons) in a housing unit. The housing units are of various sizes.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	
b) low-income class (poor)	
c) middle-income class	
d) high-income class (rich)	

These buildings have been designed as luxus residences. They were taken over in state property in the communism time and have been recently given back to their previous owners.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	
4:1	
3:1	
1:1 or better	

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	
Personal savings	
Informal network: friends and relatives	
Small lending institutions / micro-finance institutions	
Commercial banks/mortgages	
Employers	
Investment pools	
Government-owned housing	
Combination (explain below)	
other (explain below)	

According to Prager (1979): The state and public administration built little, apart from reparation works after WWI and some blocks of flats from the social assurance fond. After 1929 and the monetary reform investments were made into blocks of flats especially from richer people from the province wishing to move to the capital. They were supported by bank credits. Especially in the sustained activity after 1929 the urban housing was built on credit base. More future owners contributed to the construction financing. In each housing unit, there are 1 bathroom and 1 toilet.

4.4 Ownership

The type of ownership or occupancy is individual ownership.

This time a characteristic urban housing type develops: the block of flats with residences under the same roof, constituting the common property of a civile association, ruled by a special law of common use.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.			
Building Configuration	The building is regular with regards to both the plan and the elevation.			
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.			
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.			
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.			
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			
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);			
Foundation-wall	Vertical load-bearing elements (columns, walls) are attached to the foundations;			

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	N/A
connection	concrete columns and walls are doweled into the foundation.			
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			
Wall openings	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).			
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)			
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Infill panels	Some of them are located on consoles of the facade (see figure 5-17). They are two heavy and supported by secondary beams only. Collapse of facade infill walls may be fatale for the building equilibrum and lead to collapse under the subsequent torsion effects. (as described for the Carlton building in Prager, 1979)	beneficial effect of infill walls that save the structures of being collapsed by increasing their low stiffness	strong rifts, dislocation, X rifts in piers
Columns	Do not form moment resisting frames with the beams. Execution accidents may affect columns: deviations from verticality, sometimes due to irregular and unfavourable section shapes (long "svelte" rectangles). In some buildings constructed speculatively the cement and the reinforcement might not be sufficient. Prager (1979) quotes as cause for the damages in 1940 earthquake: - 0,6% or less reinforcement also with steel bars of less than 10mm diametre for buildings - missing connection of the column reinforcement to that of the inferior floor (lap splicing) – missing stirrups or fallen down stirrups (free translation after after Prager, 1979)		SOFT STOREY: "svelte" columns: - concrete destroying and spalling/buckling of longitudinal reinforcement at plasticarticulations (shear damage at later demolished building, see Bălan et al, 1982: Figure VI.18.b. on page 246, bending damage at lower node of a column at the same building as image #6, see Bălan et al, 1982: figure VI.19.a on page 246) Basement: corrosion of reinforced steel. Columns at ground, 1st and 2nd floor are damaged from previous EQs middle and short columns: - brittle breaks with oblique 45° rifts sectioning the column – detaching of transversal reinforcement in oblique dislocation of columns > CAN DIRECTLY COLLAPSE – rifts or brittle

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
			breaks from interaction with stairs (shorter working height) > AFFECT GENERAL STABILITY CURRENT STOREY: - horizontal rifts immediately under or over the beam perpendicular on column axis (Bending damage at upper end of a column in a block with partial collapse, see Bălan et al, 1982: Figure VI.19:b. on p. 246), concrete spalling (see Bălan et al, 1982: fig. VI.19.a on page 246), buckling of longitudinal reinforcement (figures shown so far and column brocken in the lower node, after complex solicitations. The lack of stirrups can be clearly seen, Bălan et al, 1982: figure VI.20.b. on page 247), possible hazardous plastic articulations (same figures as till now). Sometimes only the outer concrete, much weaker, spalls. (see Bălan et al, 1982: Figure VI.19:b. on page 246, a column 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: ground floor column, destroyed due to pounding with neighbouring building, see Bălan et al, 1982: figure VI.20.d. on page 247), break of concrete section with

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
			reinforcement buckling at the end of columns (Corner column, destroyed on ~1m height at the upper part, see Bălan et al, 1982: fig. VI.20.c. on P. 247) and some brittle breaks with oblique rifts in GF and lower floors (see Bălan et al, 1982: figure VI.20.b. on page 247) rifts in all RC elements (synthesis for the observations in Bălan et al, 1982) Pounding damage (see Bălan et al, 1982: figure VI.20.d. on page 247)
Beams	Do not form moment resisting frames with the columns (many of the beams in at least one direction are secondary beams).In some buildings constructed speculatively the cement and the reinforcement might not be sufficient. (free translation after Prager, 1979)	Most beams are reinforced and realised carefully. (after Prager, 1979)	LONG BEAMS: plastic articulation, rotation near node with rifts at upper and lower part; concrete failure only at lower side SHORT BEAMS: rifts in oblique sections opening the beam in whole height from the lower side with isolated dislocations both not dangerousoblique rifts have brittle character characteristic for this type of building: - 0°-45° rifts at end, sometimes buckling (synthesis from the observations in Bălan et al, 1982)
Roof and floors	Simple slab floors may be too elastic when spans are over 4.5m. Construction deffects may lead to not-plane effects. In some buildings constructed speculatively the cement and the reinforcement might not be sufficient. (after Prager, 1979)	Alternative solutions for slab rigidity have been looked for and applied in some cases (embeded hole bricks, waffle system).	ROOM SLAB less rifts in old RC frame bldgs. BALCONIES: less rifts in old RC frame bldgs. STAIR FLIGHTS: less rifts, more at the change of stair flights in old RC frame buildings (synthesis from observations in Bălan et al, 1982)

Following defficiencies are described by Prager (1979) p.426 to be present in some of the buildings of this type:
- washing of weak concrete by the rain during casting;
- use of aggresive water;
- wrong positioning of reinforcement;
- use of concrete with small cement apport;
- casting of concrete with holes;
- early removal of scaffolding;
- use of not corresponding agggregates or cement;
- frozing of concrete;
- foundation collapse (through washing of the ground);
- huge dilatations;
- fire damage;
- earthquake damage.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance)*.

Vulnerability	**high**	**medium-high**	**medium**	**medium-low**	**low**	**very low**
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1940	Vrancea	7.4	7 (Mercalli)
1977	Vrancea	7.2	8 (Mercalli)
1986	Vrancea	7	8 (Mercalli)
1990	Vrancea	6.7	7 (Mercalli)

Damages in the 1940 earthquake occured accidentally and at isolated buildings (after Prager, 1979):
- fall of finishing plates, infill walls
- end of columns at the part where it is embeded into the slab as that is the place of the casting joints, where the reinforcement is not continous and the solicitations out of bending are maximal. The maximum stresses were 60-80 kgf/cm^2 (more than the maximum limit in the German circular used for design that time).
- move of the vertical reinforcement to the centre of the section
- significant damages were noticed at reinforced concrete buildings with consoles (bow-windows), at the beams which were supported by beam parts and at the infill walls of reinforced concrete schelet made after the structure was ready and thus not conlucreting with that.
- damages also occured 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 the corner higher than the rest of the building.

After Bălan et al (1982): There have been old buildings with reinforced concrete skelet which, also not designed for seismic loads, behaved correspondingly, due to clear constructive schemes, having columns and beams with larger sections, corresponding reinforcement and built out of concrete of better quality. It is known that such buildings, even if not dimensioned specially for horizontal forces (out of wind or earthquakes) have though a certain antiseismic strength capacity provided on one side by the strength reserves of the reinforced concrete skelet, well designed for gravity loads, and on other side from the strength reserve of the infill masonry walls, especially when these are well filled into the columns and beams of the skelet and realised with high quality mortar (with mud and cement).

Observed damages according to Bălan et al (1982):
at columns:
- rifts of different sizes in concrete, usually at contour 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 with secondary shear and mostly by buckling of re-bars and concrete "expulzare" on one or two faces in the action sense of the earthquake, till complete damage of the concrete section and column collapse from compression associated with oblique flexure.

at beams:
- rifts near supports, vertically, at 45° or slightly variable and closer to horizontal, in the length of the beams; the rifts have relativelly small openings, but sometimes they are till 1mm;
- crushing of compressed concrete at the lower face of the beam, near supports, or even in the span, sometimes with buckling of longitudinal reinforcement.

In the 1977 earthquake 13 pre-war RC building collapsed totally and 10 partially (according to Lungu et al, 2000a), compared to 5 pre-war masonry buildings and 3 new RC buildings. They were constructed between 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 and about 8500 m² (average at 4500), with 150 to 800 sqm/storey (average 450). There were 2 to 10 flats with an average of four on a floor with the area of a residetial unit of between 50 and 175 sqm (average 100 m^2). The figures were computed using 14 buildings of those collapsed. 10 of these collapsed totally. To the author is known that at least 6 of them had commercial occupancy of the ground floor so they are not subject of this report. The ratio partial/total damage was unevenly distributed with height.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/ dimensions	Comments
Foundation	reinforced concrete			
Frames (beams & columns)	reinforced concrete	70-150 daN/cm^2 (based on tests at 7 buildings from 1935-1940, including hotels, department stores and office buildings as well), average 120-130 daN/cm^2 (concrete mark B120) (from Bălan et al(1982) P. 385-391). Cement 240-270 kg/m^3, with very fine aggregates (0-3mm) (Bălan et al, 1980, P. 394) Reinforcement with round smooth steel of the quality OBOO (Bălan et al, 1982, P. 382).	Columns: The distribution of re-bars in the colum section was governed by geometrical principles rather than by structural ones (more bars on the long side). Reinforcement degree has been often under 0,5%. There weren't provided enough stirups at columns and the ones provided were simple, connecting only the corner rebars, not all of them. (according to Bălan et al, 1982) The reinforcement had insufficient lap splicing. 100-120kg steel/m^3 concrete (accroding to Prager, 1979) Prefered diametres at stirups: 6-8mm. Maximum distance between longitudinal bars: 25-30cm, medium distance between stirups: 25-35cm (in badly executed constructions up to 1m) (Bălan et al, 1982, P. 382) Beams: 1906: 1,5m3 gravel at 1,0m^3 mortar (out of 1000/700 kg cement and 1m^3 sand). This leaded to 215 kgf after 28 days (Prager, 1979) 1890: pure cement had 45.30 kgf/cm^2 in tension and 408.23	Cement with rapid hardening was often used in order to spare costs (short times). Such one is the Fieni cement, where only 10 days for concrete hardening is needed. (Prager, 1979) Due to maintenance problems sometimes concrete was spalling after reinforcement corrosion before the earthquake. See figures 5-13 – 5-15 for reinforcement details.

Structural element	Building material	Characteristic strength	Mix proportions/ dimensions	Comments
			kgf/cm^2 in compression. The mortar 1:3 had 21.62 kgf/cm^2 in tension and 206.78 kgf/cm^2 in compression (after Prager, 1979). No data for reinforcement distribution. 100-120kg steel/m^3 concrete.	
Roof and floor(s)	reinforced concrete		For the model building considered it was usually 10 cm thick (also 8, 9, 11, 12 cm), but where the slab surface was smaller due to secondary beams, especially over the basement it was as thin as 6cm. For alternative floor slab solutions see 4.4. 100-120kg steeel/m^3 concrete	

6.2 Builder

According to Prager (1979): Some buildings have been constructed with money gathered from the future owners, but some are simply money investments in central blocks of flats for speculation. Urban population has grown and rent was high. Thus, many people wanted to own housing and this encouraged speculation. During the increased construction activity 1936-1940 speculation characteristics grew. The construction enterprises had a technic commercial organisation based on large bank means or own fonds. The competition leaded to economies at cement and steel. Sometimes works did not get finished. Especially betwen 1918 and 1932 the housing construction activity has been accentuated by important capital investments attracted by imobil speculations.

6.3 Construction Process, Problems and Phasing

According to Prager (1979): The building site organisation includes terms for material delivery, scaffolding, casting, removing scaffolding and co-ordination with contractual obligations. Construction machinery was especially used for foundation works, concrete and reinforced concrete, masonry. Thus the construction time has been shortened. Till 1912 concrete had been prepared manually. 14 workers needed 10-12h/m^3. Concrete preparation was mechanised 120. Mobile "betoniere" 150-250l, with termal engines, were imported. After 1929 the "betoniere" were generally used. Concrete was prepared on the building site, with "betoniere" up to 1 cubic metre and special cups for transportation, manevrated by a crane. Also used were "bob"s, "paternoster" for lifting bricks, mud and so on, and a few 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 a block of flats building site. The transport of concrete to the work point has been usually made with wagons having the capacity of 0,5-0,75 cubic metre, circulating on metalic rails of 500-600mm, as well as "bob" and lifts with friction troleys. Through a good organisation of delivery and transport castings of 25-30m^3/day could be achieved. Many building sites made the concrete casting over night, especially on warm summer days. An instalation to cast fluid 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 some building sites uses electricity like:

- "Torkret" for shotcrete out of concrete and cement mortar
- "jony" - pneumatic transporter for the transport of concrete of French fabrication.
- "injection pump" for cement mortar
- "electrical circulars, pneumatic hammer, perforator"
- "ecluze pneumatice" for Wolfholz pilots manually diggen through tubes in foundation works on sandy ground under water.

Some enterprises did not use any machinery and had no technical organisation. 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 specialised construction companies had teams of qualified workers able to assure the technical realisation obligations. A typical building site of the time for this structural type 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, that when the RC members were finished at lower floors the masonry works could start at these while casting the concrete for the upper floors and when masonry works were ready at lower floors the finishing works could start at these while doing the casting for the uppest floors and the masonry works for the middle ones. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

Prager (1979) p. 184-185 provides a list of the publications used 1907-1918 for the design of reinforced concrete buildings. That time there were no tables or similar to make computations easier. The methods for elastic computation 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 are used. 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 armé et ses applications] = "The reinforced concrete and its use" – in French (1899)
- Prof. E. Mörsch: [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 statical calculation" - in German (1907)

- Ing. C. Kersten: [Der Eisenbetonbau] = "The Iron-Concrete-Construction" - in German (1908)
- Ing. Ejner Björnstad: [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 by particular "antreprize" like: "ing. Constantin M. Vasilescu", "Societatea de Beton si Fier" (founded 1906), "Antrepriza ing. Tiberiu Eremia", "Societatea Edilitatea", "Societatea Unirea", "Societatea Constructia Moderna" etc. They were organised for such works. Some owned modern specialised machinery, personal for technical leading, for steel, iron, scaffolding, wood works, repairing. They employed well formed maisters for different working branches, on salary or hour 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 "Legea Contabilității Publice" stated the rules for getting contracts, making payments and receiving ("recepție") the work. The general conditions were updated 1894. On the building sites there were technical control methods for the quality of aggregates, water, cement. Strength trials are made for compression on concrete cubes. Trials for break of reinforced concrete beams are also made. 1932 building site laboratories appeared, which monitored the quality of concrete and aggregates but only at public works. Further data about the progress in reinforced concrete design of the time are described by Prager (1979), p. 481-483. For a list of publications see 4.2. To the authors knowledge as frames are defined as a beam supported directly by two columns, which was very rarely the case in such constructions due to beams outside the axis and/or reduced section of the elements (see fig. 5-5, also pointed out in Bălan et al, 1982, P. 234). Bălan et al (1982) additionally points out that the node reinforcement was designed for gravitational loads only, theoretically follwoing the German circular from 1925 (P. 234 Bălan et al, 1982, 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 been considered in computations until recently. Infill walls arranged as one single brace are mention ed in the contenmporary code (P100-92). More even, it is known that the constructions of the time were designed as much more flexible as they proved as the masonry infill was not taken into consideration (see Bălan et al, 1982, P. 235). A huge number of this kind of buildings have been designed by renowned architects. They are characteristic for Bucharest's today's face, and most of them are to be found along the main N-S boulevard in the city. Emil Prager writes extensivelly in his book about the history of reinforced concrete in Romania about the co-operation between engineers and architects in that time (see reference). 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 be employed by building site organisation companies. Usually one or two architects (and their employees) made the architecture project. The reinforced concrete projects were made by an engineer. The supervison of conctruction work may be made again by the same or another engineer, or by an architect. Construction works were carried out by particular "antreprize", leaded by engineers or architects employed by the benefitors 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 RC members, which started after the control of the scaffolding and supports and at the "reception" through "proces verbal" of the metal reinforcement mounted according to the project. In the honorary prices for the Architects Corps was included in 1934 that for a technical control on the building site the payment will be 30-50% higher. This occured after noticing several deffects in execution, like deformation of scaffolding for the slabs at upper floors after height differences of supports, not vertical columns, beams with obliques walls, especially when the technical control of the "diriginte de şantier" was missing. Later the building permits required for reinforced concrete works to be signed by a diploma engineer, acredited by the avisation service. Civil engineers were there to assure the quality of work. They had to assure through their computings the strength and stability of the structure for the most difficult life conditions and use of the chosen site and to expose the safety coefficients prescribed to realise these conditions. Also the civil engineer had to prepare the technical data and necessary indications to prepare the aggregates necessary for the concrete, the quality of cement, the working conditions, the duration of execution and removing of formwork, and to follow the quality of execution on building sited in the corresponding time.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Title of the code or standard: - control methods - Year the first code/standard addressing this type of construction issued: 1932 prescriptions, 1941 precode National building code, material codes and seismic codes/standards: 1932 - prescriptions which spread fast: - granulometric study of the aggregates: a/c relation; - probes on cubes at 28 days (160kgf/cm^2); - vibrating concrete till 2500kg/m^3 characteristic weight is achieved. These were applied only at public works (they were included there in the functional specifications). (after Prager, 1979) When was the most recent code/standard addressing this construction type issued? This type of buildings nearly stopped to be constructed in the "pre-code" period (Lungu et al., 2000b) after the HAZUS methodology), after the 1940 earthquake. The codes issued after that earthquake were P.I. - 1941 and I.-1945. Within that a seismic design coefficietnt of 5% has been adopted for shear walls and frames. Not that today practice prescribes 10% for flexible frame buildings and 12.5% for rigid shear wall buildings. see also 7.10.

As described by Prager (1979) in the boom time (1933-1942) the dimensioning was made following the German prescriptions from 1916 and 1932 as well as [Prima lecție de beton armat] = "The first reinforced concrete lesson" in Romanian (1903) transformed in 1914 into [Curs de beton armat] = "Reinforced concrete course" in Romanian and 1930 into [Conferința de beton armat] = "Reinforced concrete conference" (in Romanian). Until the 1940 earthquake the 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 numberous buildings throughout the country, the Ministry of Public Works made a comission with the duty to elaborate the obligatory prescriptions for the computation 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 of constructions with reinforced concrete structure, obligatory for the design engineers which had to sign the permit projects. 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 the Public Works Ministery) the "Instrucțiuni pentru prevenirea deteriorării construcțiilor din cauza cutremurelor" (Instructions for preventing the deterioration of constructions due to earthquakes) was published in "Monitorul Oficial" no. 120 from May 1945. After that this type of buildings has been continued in a slightly different manner, as described in report #71.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules.

1934 the Master Plan of Bucharest, one of the most innovatives from that time appeared and this has presribed the building rules. 1,2m recesses above a certain height were prescribed in those regulations, for example, in order to lower street shadowing by high buildings. The height itself has been also prescribed, and there were prescriptions permitting relativelly high ground floor occupancy. The commercial ground floors have been supported by the regulation. Prager (1979) P. 90-96: After 1908 the main problem was the division of legal responsability for the success of the works for which the owner has employed the architect as general designer and which had the responsibility of choice of the specific designer and of the supervison of works. This initial phase was influenced by the honorary quote for the reinforced concrete works design, which had to be stated by the architect. At that stage collegial agreements were made. After 1918 the signature of an engineer on the authorisation (permit) plans was required by the municipal services. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s).

6.8 Construction Economics

This type of multiple housing units are not build any more. After Prager (1979): The reinforced concrete schelet did cost 12-15% of the complete construction cost. This is why prefabrication of metal parts after western model has not been practiced so much. The cast in place system was also chosen due to the low cost of the timber for scaffolding works and the lower cost of working force due to the mechanisation of casting works. No data are available about the absolute cost of such a building. However, Prager (1979) gives some figures about the costs variation: Average costs indices: - a block of flats at 1000 cubic metre 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 single family 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 1926-1927 material prices increased, transportation means were lacking and inflation leaded to variation in the price of working force. After Prager (1979): A well organised construction enterprise had clear advantages. The high cost of the machinery described at 7.3 as well as the missing continuity of work on building site and the maintenance and use expenses determined that the "small mecahnisation" developped only in special works, where their necessity was obvious. Some buildings have been constructed with great spead. An example: at a block of flats with 6 floors: 2 weeks for a floor of 600 sqm, the whole building being finished between June and November 1925. Availability of technology after Prager (1979) p. 456: For scaffolding antique means of wooden works were used. Bending and binding with wire of reinforcement bars was fast learned by the workers. It also did not need extensive work, since there were less than 100-120 kg steel/m^3 concrete. Preparing of concrete out of local aggregates was fast learned by the constructors, 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 succes was the quality of works, all details regarding 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 and specialised. The Romanian engineers were quite well informed about the technical progress in the Occident. After 1910 they were almost exclusively educated in Romania.Technical construction work force was well qualified and available in sufficient number for wooden works, masonry works, concrete works. The sezonal unqualified work force was insufficient. The reputation of the construction enterprize was definitory for the engineers working for, which in many cases could organise on the building sites without prescriptions or mandatory normes the succession ofconstruction, the mix and casting of concrete, and to respect the deadlines which were generally sufficient for hardening during the specific climatic conditions of the year.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction:

Seismic Deficiency	Description of Seismic Strengthening provisions used
damaged RC columns	local repairing after (fracture)+crush+spall+(yield)+crack (see Bălan et al, 1982: figure VIII.8.a., quoting ONU, on page 417) 1. Breaking up masonry around the column; 2. Taking over loads from the 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 stirups; 9. Anchoring of stirups to the re-bars; 10. Scaffolding (Scaffolding for repairing a damaged zone in a concrete member: 1 - existing concrete,; 2 – felt (Romanian: "pâsla") band fixed to scaffolding; 3 - scaffolding; 4 - new concrete; 5 - distancing tensor; 6 - casting opening and cover to produce presure. (see Bălan et al, 1982: figure VIII.5. quoting ONU, on page 414); 11. Casting concrete; 12. Removing scaffolding; 13. Plastering inside and outside. (from Bostenaru, 2004)
deeply damaged RC beams	local repairing after (fracture)+crush+spall+(yield)+crack (see Bălan et al, 1982: figure VIII.8.b., after ONU, on page 417) 1. Removing plastering; 2. Removing floor finishing; 3. Reducing the curvature; 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. Mounting new 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)
superficially damaged RC beams	Reparing with plating with woven glass embeded in epoxy resins. (see Bălan et al, 1982: figure VIII.18. on page 423 and figure VIII.19.a. and b. on page 424): 1. Removing plastering; 2. Mechanical hole bore; 3. Injection of rifts; 4. Plating with weaving; 5. New plastering. INCERC

Seismic Deficiency	Description of Seismic Strengthening provisions used
	(2000) further documents following details: injection of rifts up to 3mm opening with epoxy resins on 15cm depth, 2cm bore holes and Rooving type weaving.
Rifts in masonry infill 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)
Reduced column section	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 masonry wall around columns; 5R. "Spițuire" 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 joint columns not just bars but also L profiles 40x40x4mm); 9G/10R. Formwork; 10G/11R. Casting B300 concrete; 11G. Removing formwork and pins; 12aR. Interior plastering; 12bR. Exterior plastering; 13R. Repair of floor finishing; evtl. 14R. Filling the joint. R= provisions as described by INCERC (2000) for typical Romanian buildings while G= provisions as developed with Bourlotos (2001) for typical Greek buildings. See RC Column retrofit through jacketing (Bălan et al, 1982: figure VIII.9.a. on page 418 and figure VIII.11. on page 419) for this measure. See Jacketing of a column with metal profiles (Bălan et al, 1980: figure VIII.10.a. on page 418 and VIII.12.a. and b. on page 420) for an alternative measure with rigid reinforcement. See figures 5-20 – 5-26 for position of jacketed columns in the model building retrofit solution.
Reduced beam section	beam jacketing in different ways: RC jacket (see Bălan et al, 1982: figure VIII.9.b. on page 418 and figure VIII.13.a. and b. on page 420); concrete plating (with concrete mark B500, see Bălan et al, 1982: figure VIII.16. on page 423); jacketing with stiff profiles (see Bălan et al, 1982: figure VIII.10.b. on page 418); plating with steel fixed with epoxy resins (see Bălan et al, 1982: figure VIII.17. on page 423).

Strengthening of New Construction:

Seismic Deficiency	Description of Seismic Strengthening provisions used
Insufficient stiffness	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. "Spiţuire" 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. Binding anchors between masonry walls and shear walls; 10R. Mounting the binding anchors; 10G/11R. Casting concrete in shear walls and evtl. columns; 12aR. Interior plastering; 12bR. Exterior plastering; 13R. Repair of masonry. (see Notes) See figures 5-20 – 5-26 for position of new walls (either in existing frames as in the Greek provisions or with new boundary elements as in the Romanian provision) in the model building retrofit solution.

For measures 4, 5 and 7: R = provisions as described by INCERC (2000) for typical Romanian buildings while G = provisions as developed with Bourlotos (2001) for typical Greek buildings. The highly irregular structures without proper stiffening elements of highest vulnerability (see 4.11.) are mainly repaired, not strengthened. Retrofit works are being carried out (fig. 5-27). After the 1977 the main retrofit method has been jacketing of beams and columns. The rest of the interventions was reduced to repairing of masonry (mainly with mortar injections), of RC members (mainly with epoxy resin injections) and of finishings.

8.2 Seismic Strengthening Adopted

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

Yes. The exact number of retrofitted buildings is unknown, but from the ones (110) today listed for the first category of risk 92 have been retrofitted totally after the 1977 earthquake, and 43 of them are purely residential. The retrofit methods used at the residential buildings were: masonry repairs, jacketing of columns and beams, mortar injections, finishes, epoxy resins injections. Some of them have been previously retrofitted after the 1940 earthquake. Retrofitting after the 1940 earthquake or after bombing was usually local reinforced concrete jacketing. Emil Prager (1979) describes such a measure at p. 426-427. At a block of flats with 7 floors in the city centre the perimetre columns and the ones at the corner suffered permanent displacements of 8.5-11cm vertically. The proves made afterwards showed some dimensioning errors of the project. The retrofit was made through replacing some of the damaged columns through metalic columns supported by RC "cuzinet", through jacketing and confinement of the rifted ones and through the retrofit of rifted beams with metalic profiles welded to the reinforcement. The works were performed between November 1940 and March 1941. To perform the retrofit the building has been lifted by 8 hydraulic presses of 100 and 200 tf. According to Bălan et al (1982) P. 235 the main measures taken after the 1940 earthquake have been repairing measures, which haven't even reestablish the state before the earthquake.

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

Most works until today have been made following earthquake damage. The srengthening prescribed today is thought to be a mitigation effort.

8.3 Construction and Performance of Seismic Strengthening

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

No, but the inspection determining the risk class today is thought so.

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

Contractor.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

After the repair measures following the 1940 earthquake buildings performed rather poorly in the 1977 one, as there were only small scale reparations. In the case analysed by Prager (1979) described above 60% of the permanent displacement was reduced and the building was considered to be brought to the initial state. There are no data about the performance of this particular building in the 1977 earthquake. In the earthquake from 1940 one building with commercial occupancy collapsed and further 8 of this construction type, some with commercial occupancy, some without have been severly damaged. The damages were rifts and breaks in the columns of the ground floor and sometimes of first and second floor. Some of them have been partially retrofited and many of them collapsed partially or totally in the 1977 earthquake. (Balan, 1980, P. 237, further reference Beles, 1941). The behaviour of such buildings with commercial ground floor is not object of this report.

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Figure 5-20: Perspective view after retrofit

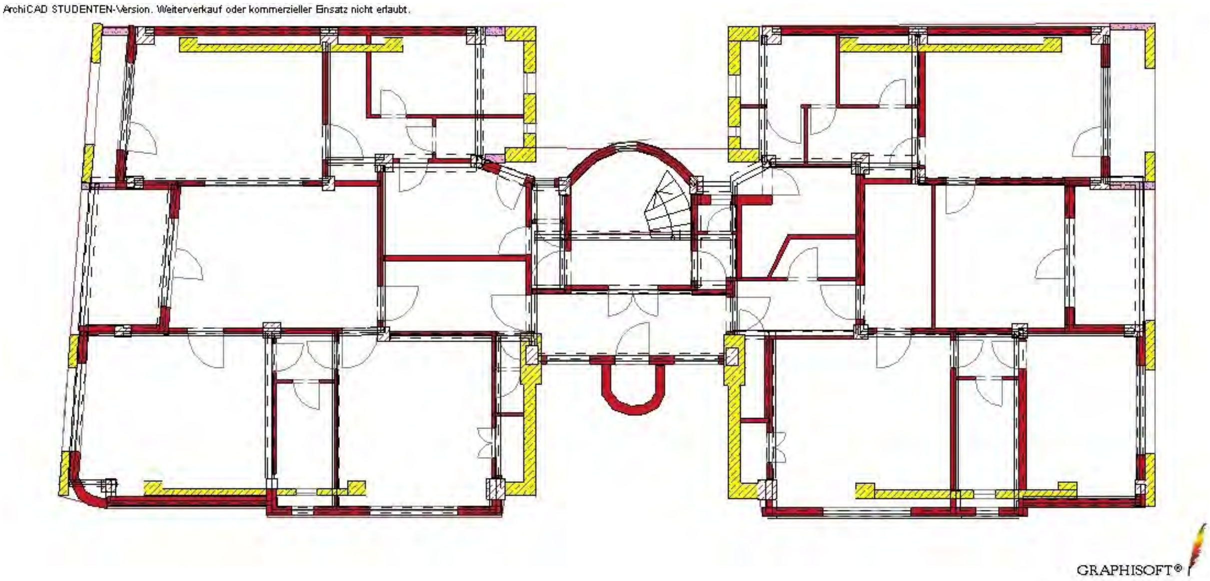

Figure 5-21: Retrofit plan for the typical building considered, using shear walls and column jacketing. The retrofit elements are highlighted. (from Bostenaru, 2004)

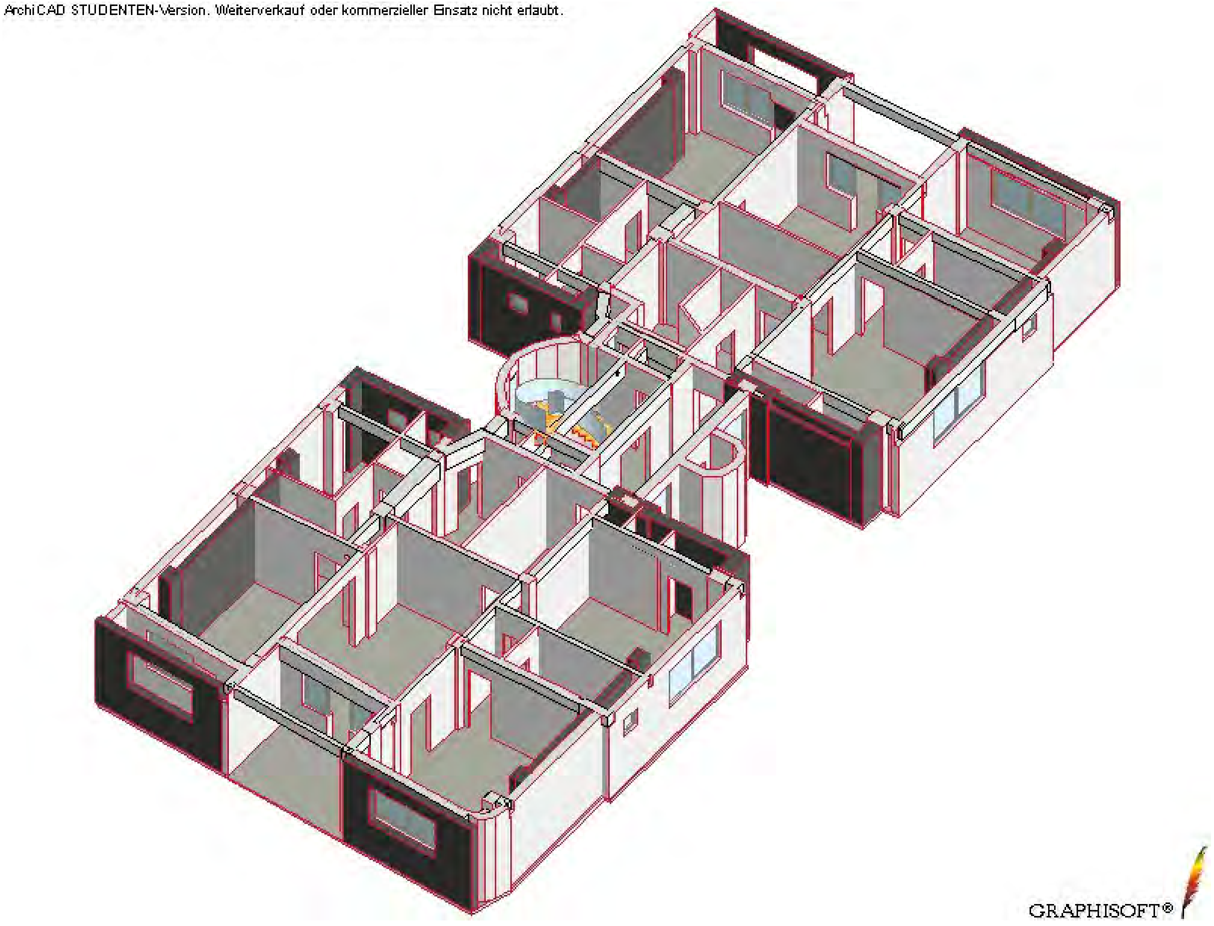

Figure 5-22: Axonometric view of a typical floor after retrofitting

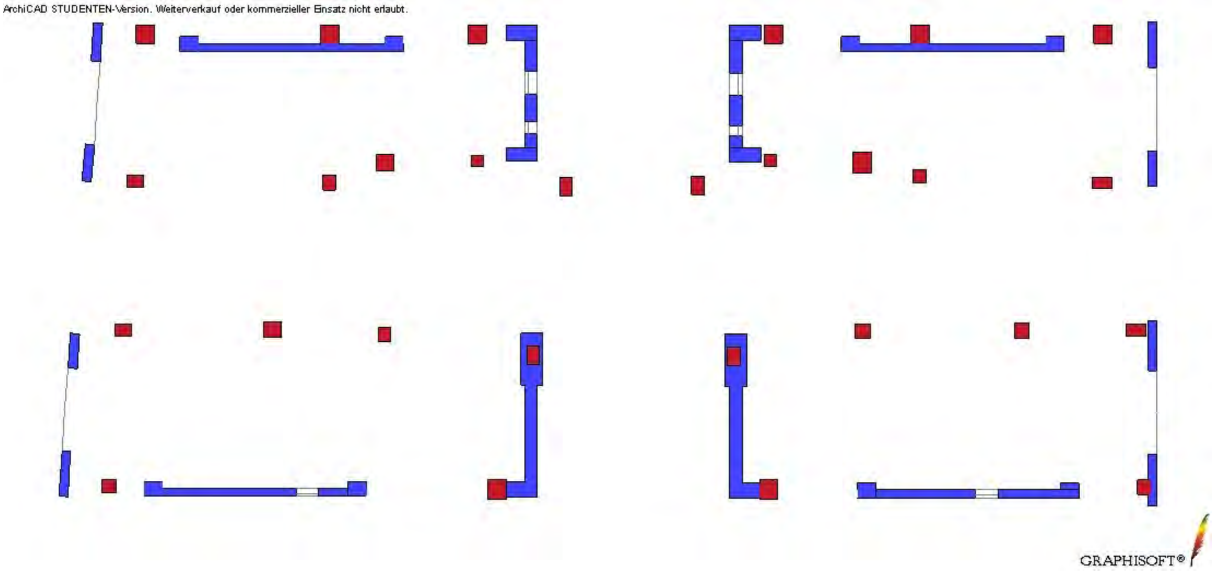

Figure 5-23: Layout of vertical load bearing elements after retrofit

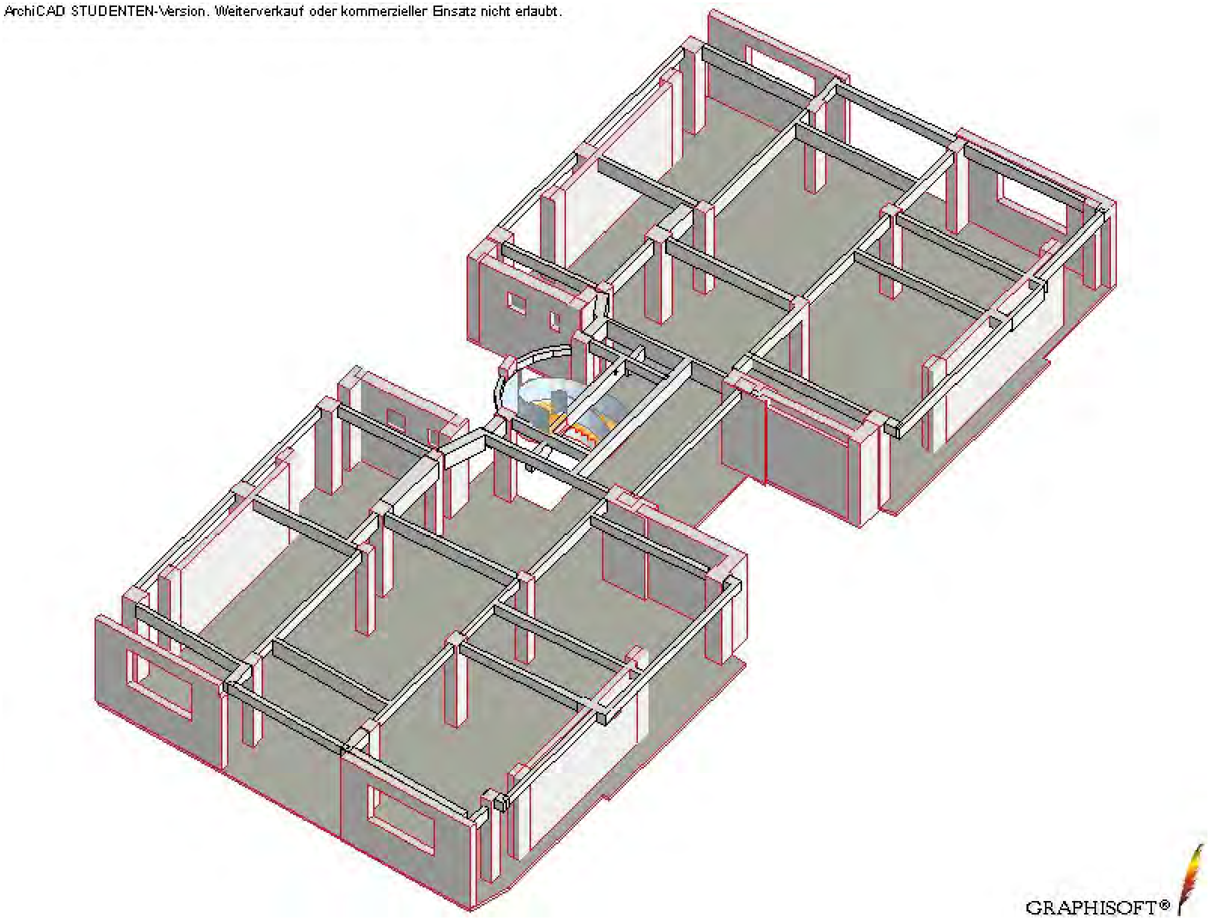

Figure 5-24: Axonometric view of the load bearing parts on a current retrofitted floor

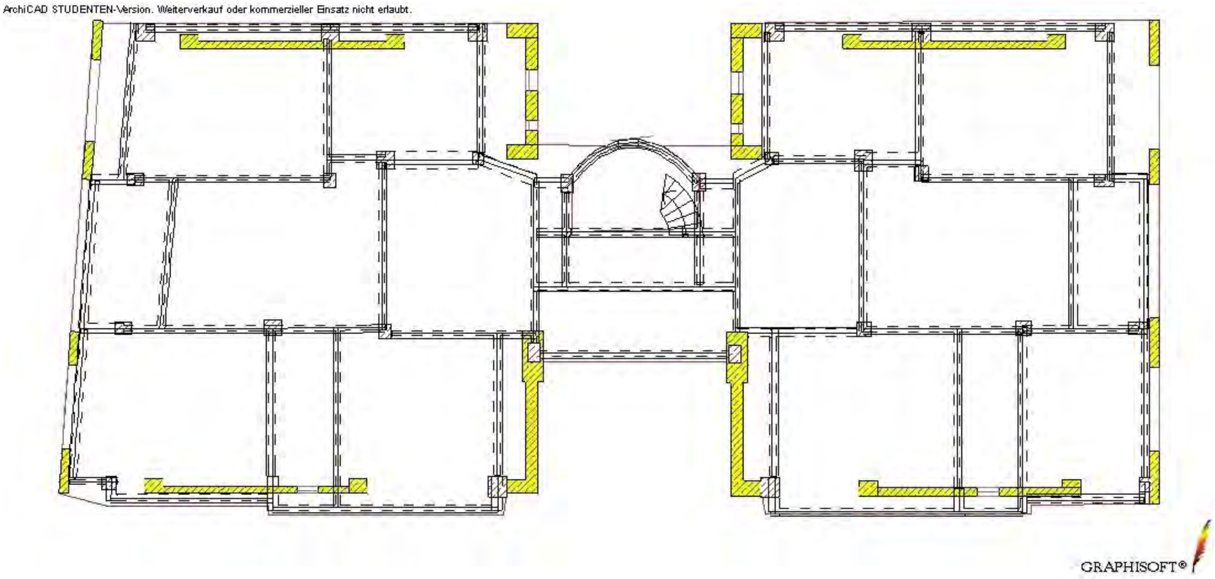

Figure 5-25: Load bearing elements after retrofitting, with highlighting on the retrofit parts

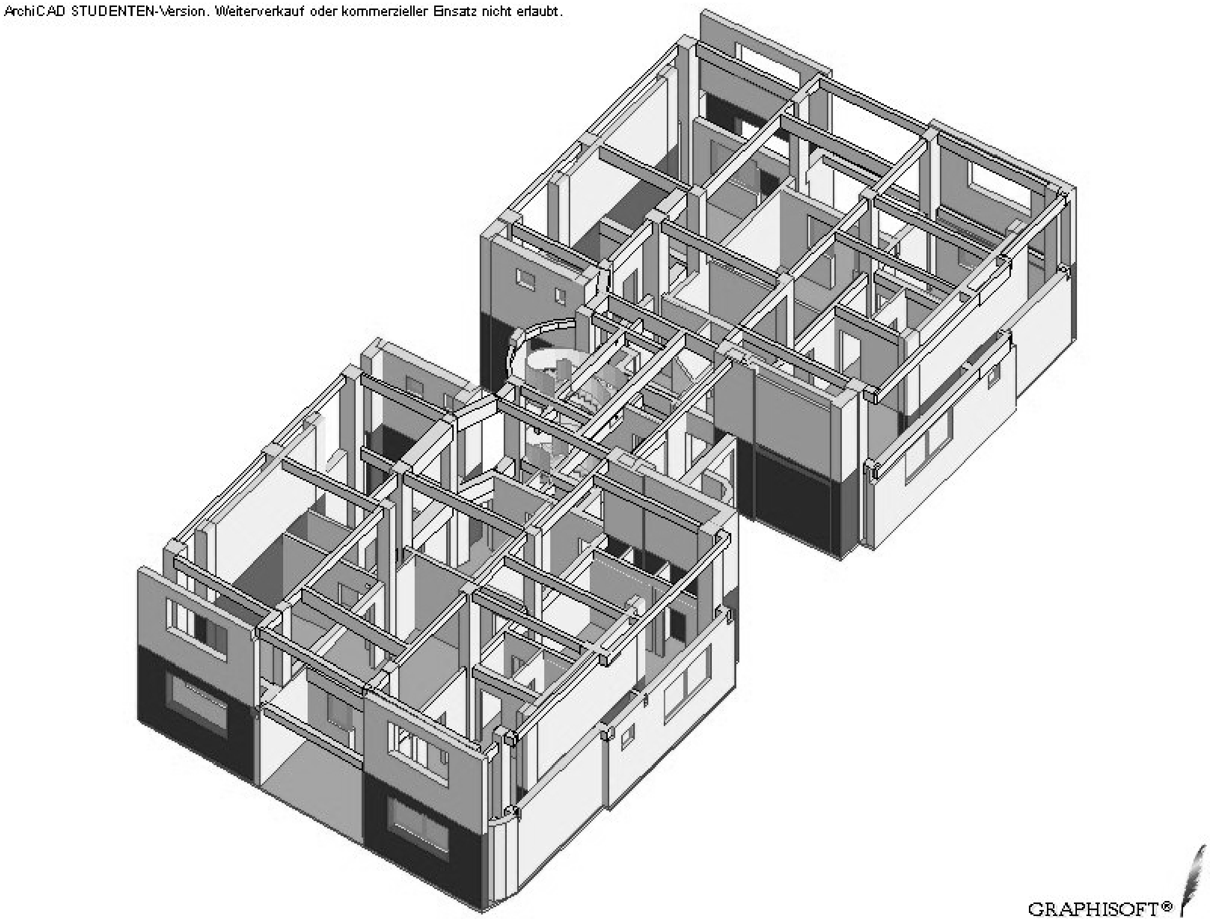

Figure 5-26: Axonometric view of the relationship between load bearing elements and masonry walls in the structure of the retrofitted building. (from Bostenaru, 2004)

Figure 5-27: Retrofit of such a block of flats. Photo: M. Bostenaru, 2002.

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Traditional German housing in Romania: Swabian House

(Report # 106 in the "World Housing Encyclopedia" http://www.world-housing.net/)

Summary

This is a rural type of popular housing practiced by the German (Swabian) colonists in the Austrio-Hungarian Empire of the time. The villages founded by them were located in three different regions of moderate seismicity: the one affected by the Banat earthquakes (encompassing today territories in Romania: Banat, Serbia: Bacska, and Hungary: Bács), the one affected by the earthquakes around lake Balaton (today in Hungary: Dunántul) and the one affected by the Crişana earthquakes or the Maramureş earthquakes (today in Romania: Komithat Sathmar). Historically two variations of this type regarding the functional conformation can be seen: one with the short side to the road and a long wall with no windows on the parcel line (earlier type) and one with long side to the road with windows from the main rooms to it (turn-of-the-century type for wealthy families). The second one could be found in urban environments as well. Contemporary variations of this housing type are still practiced. A functional particularity is that there is a second kitchen, open to the courtyard, at the end of the house to yard and garden. This one, called "summer kitchen" has only one entrance, from the yard. There is a "winter kitchen" in the main part of the building, forming an ansemble with the other rooms. The "summer kitchen" was sometimes added later on. The load bearing structure consists of masonry walls and timber floors.

1. General Information

This kind of buildings can be found in zones inhabited by the so-called "Danube Swabians", a population which immigrated from south-west Germany to the Eastern limit of the Habsburg Empire around 1700. Today they are spread in Western Romania, West and South Hungary and Nothern Serbia, in "Banat", "Bács" and "Dunántul" and "Bacska" respectively and affected by the Romanian Banat earthquakes. This type of housing construction is commonly found in rural areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built.

Figure 6-1: Street view of a typical building of this type. Photo by Ágota Heinrich, 2009

Figure 6-2: Axonometric view of the variation of the building

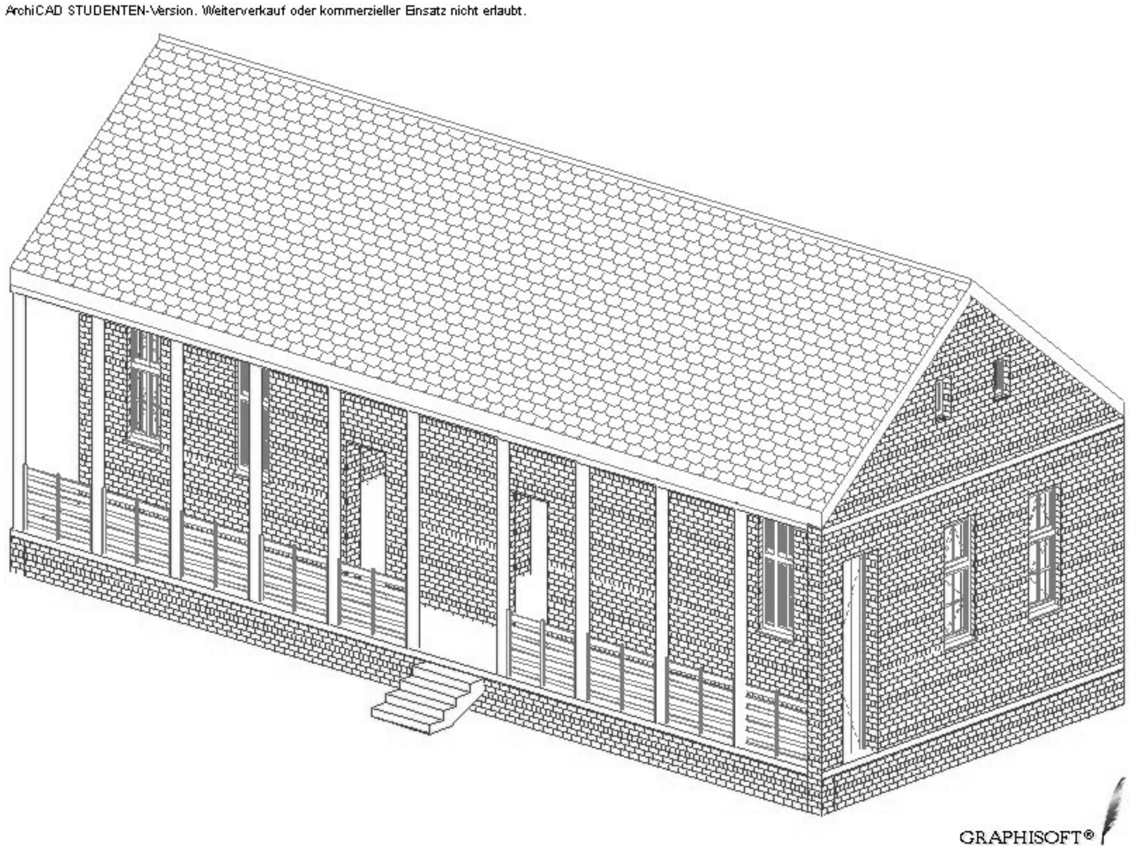

Figure 6-3: Axonometric view of a typical house

Figure 6-4: Another axonometric view of coupled buildings

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings.

2.2 Building Configuration

rectangular.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and no fire-protected exit staircases.

2.4 Modification to Building

Figure 6-5: Entrance. Photo by Ágota Heinrich, 2009

Figure 6-6: Street view of the door to the loggia of such a building. Photo by Ágota Heinrich, 2009

Figure 6-7: Loggia of a typical building. Photo by Ágota Heinrich, 2009

Figure 6-8: Entrance portico. Photo by Ágota Heinrich, 2009

Figure 6-9: Entrance portico. Photo by Ágota Heinrich, 2009

Figure 6-10: Service building. Photo by Ágota Heinrich, 2009

Figure 6-11: Typical courtyard. Photo by Ágota Heinrich, 2009

Figure 6-12: Variation of the house type with long side to the street

Figure 6-13: Street facade of a typical building

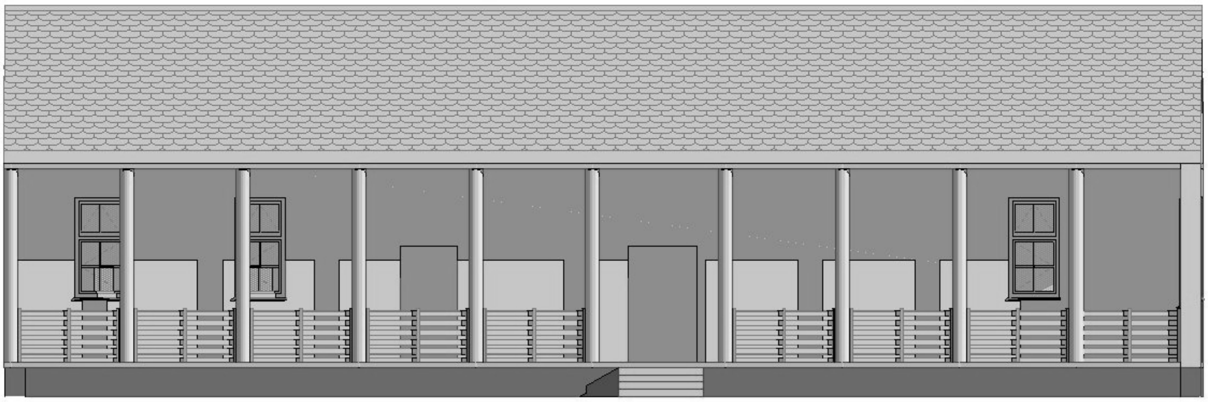

Figure 6-14: Courtyard facade of a typical house

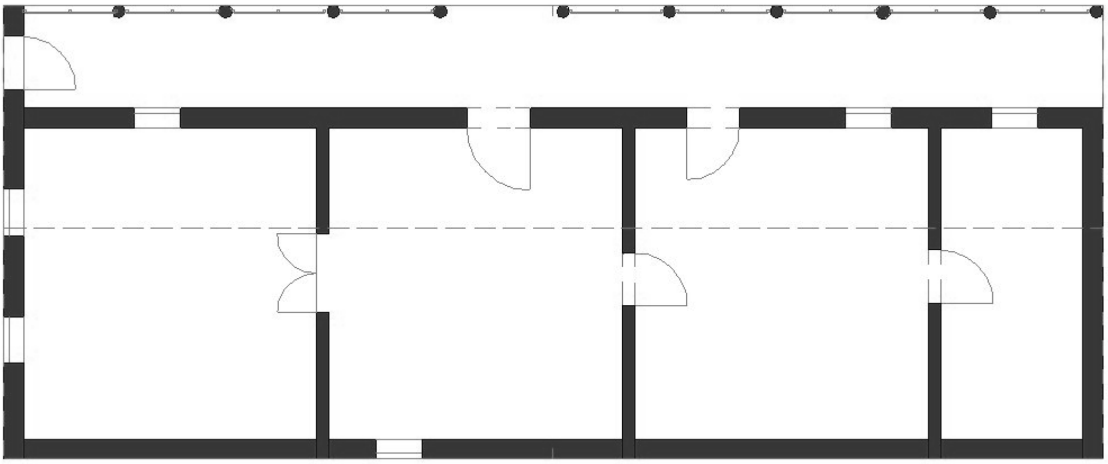

Figure 6-15: Floor plan of a typical building

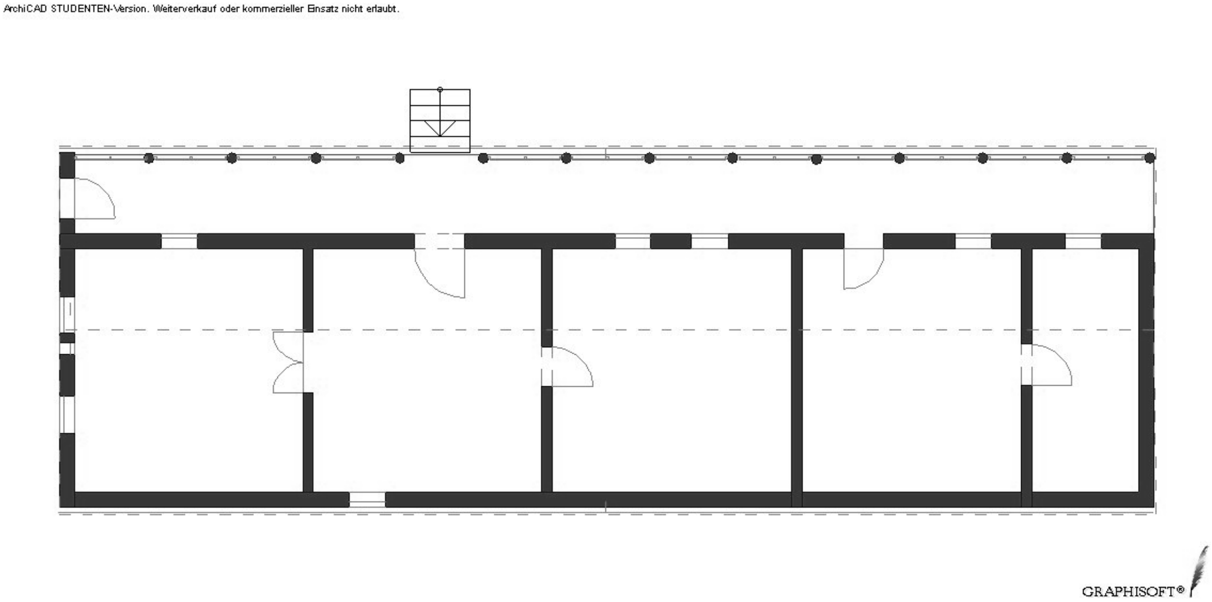

Figure 6-16: Floor plan of a building with extension

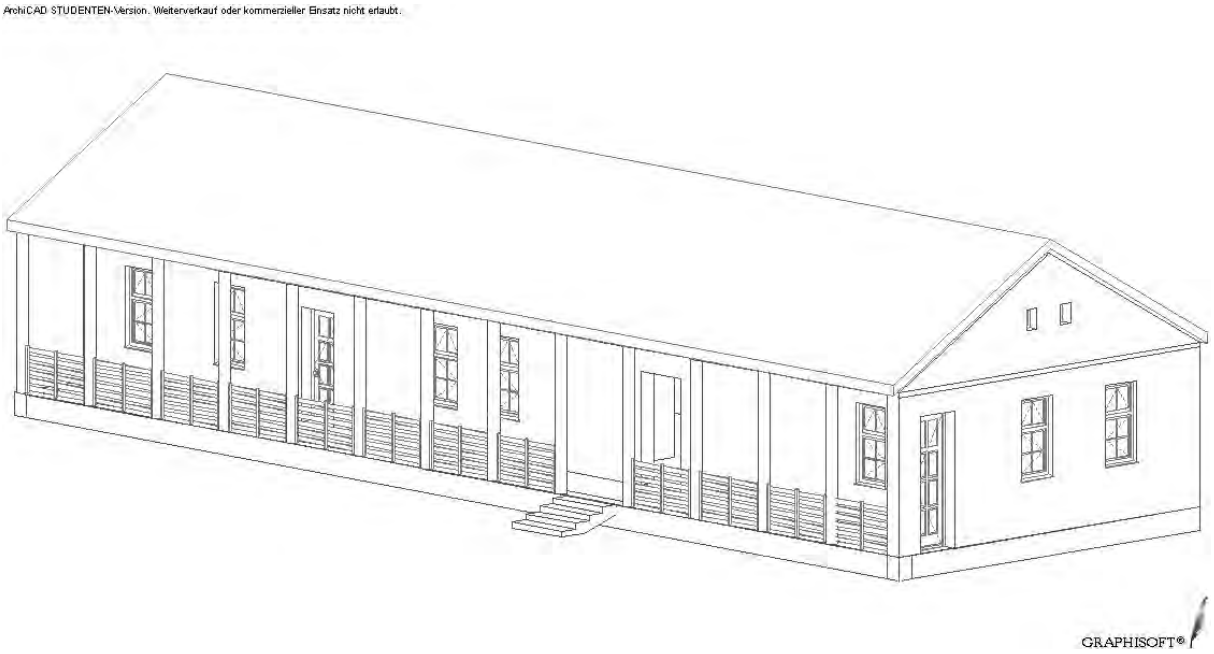

Figure 6-17: Axonometric view of a building with extension

Figure 6-18: Rendered axonometric view of a building with extension

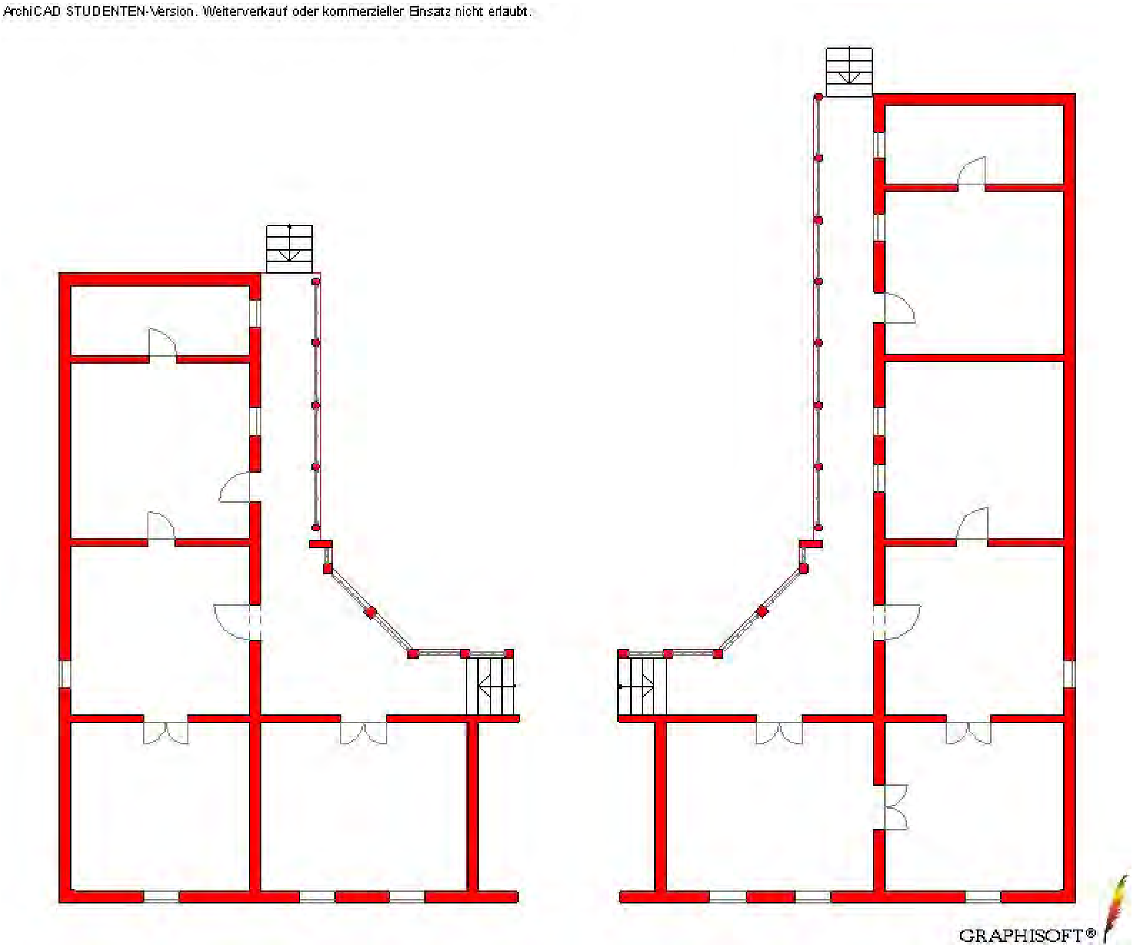

Figure 6-19: Floor plan of coupled buildings

3. Structural Details

3.1 Structural System

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Dressed stone masonry (in lime/cement mortar)	
	Adobe/ Earthen Walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block walls	
		6	Rammed earth/Pise construction	
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	
		8	Brick masonry in mud/lime mortar with vertical posts	
		9	Brick masonry in lime/cement mortar	
		10	Concrete block masonry in cement mortar	
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	
		12	Clay brick masonry, with concrete posts/tie columns and beams	
		13	Concrete blocks, tie columns and beams	
	Reinforced masonry	14	Stone masonry in cement mortar	
		15	Clay brick masonry in cement mortar	
		16	Concrete block masonry in cement mortar	
Structural concrete	Moment resisting frame	17	Flat slab structure	
		18	Designed for gravity loads only, with URM infill walls	
		19	Designed for seismic effects, with URM infill walls	
		20	Designed for seismic effects, with structural infill walls	
		21	Dual system – Frame with shear wall	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
	Structural wall	22	Moment frame with in-situ shear walls	
		23	Moment frame with precast shear walls	
	Precast concrete	24	Moment frame	
		25	Prestressed moment frame with shear walls	
		26	Large panel precast walls	
		27	Shear wall structure with walls cast-in-situ	
		28	Shear wall structure with precast wall panel structure	
Steel	Moment-resisting frame	29	With brick masonry partitions	
		30	With cast in-situ concrete walls	
		31	With lightweight partitions	
	Braced frame	32	Concentric connections in all panels	
		33	Eccentric connections in a few panels	
	Structural wall	34	Bolted plate	
		35	Welded plate	
Timber	Load-bearing timber frame	36	Thatch	
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	
		38	Masonry with horizontal beams/planks at intermediate levels	
		39	Post and beam frame (no special connections)	
		40	Wood frame (with special connections)	
		41	Stud-wall frame with plywood/gypsum board sheathing	
		42	Wooden panel walls	

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Other	Seismic protection systems	43	Building protected with base-isolation systems	
		44	Building protected with seismic dampers	
	Hybrid systems	45	other (described below)	

3.2 Gravity Load-Resisting System

The vertical load-resisting system is un-reinforced masonry walls. The floor structure is formed by timber slabs with joists. The roof consists of wood framework.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. There are two longitudinal and several transversal unreinforced brick masonry walls in hydraulic lime mortar. All walls have sufficient stiffness to contribute to resisting lateral loads, both in terms of load capacity and deformation. The back longitudinal wall is not common for two neighbouring buildings, which are completely separate structural units. Most of the time two neighbouring buildings are not adjacent, but having their yard-windows to the same cardinal direction. The horizontal structure is made of timber joists overlaid by timber planks and a suspended ceiling made out of mud mortar on slat and cane. The girders are supported by the longitudinal walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 14 and 22 meters, and widths between 6.6 and 8.6 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 6.6 meters.

Typical Span: up to 7m. The typical storey height in such buildings is 3.9 meters. The typical structural wall density is none.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted		
	Composite system of concrete joists and masonry panels		
Structural concrete	Solid slabs (cast-in-place)		
	Waffle slabs (cast-in-place)		
	Flat slabs (cast-in-place)		
	Precast joist system		
	Hollow core slab (precast)		
	Solid slabs (precast)		
	Beams and planks (precast) with concrete topping (cast-in-situ)		
	Slabs (post-tensioned)		
Steel	Composite steel deck with concrete slab (cast-in-situ)		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood shingle roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams supporting natural stones slates		
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other	Described below		

3.6 Foundation

Type	**Description**	**Most appropriate type**
Shallow foundation	Wall or column embedded in soil, without footing	
	Rubble stone, fieldstone isolated footing	
	Rubble stone, fieldstone strip footing	
	Reinforced-concrete isolated footing	
	Reinforced-concrete strip footing	
	Mat foundation	
	No foundation	
Deep foundation	Reinforced-concrete bearing piles	
	Reinforced-concrete skin friction piles	
	Steel bearing piles	
	Steel skin friction piles	
	Wood piles	
	Cast-in-place concrete piers	
	Caissons	
Other	Described below	

Figure 6-20: End of the roof. Photo by Ágota Heinrich, 2009

Figure 6-21: Masonry. Photo: Ágota Heinrich, 2009

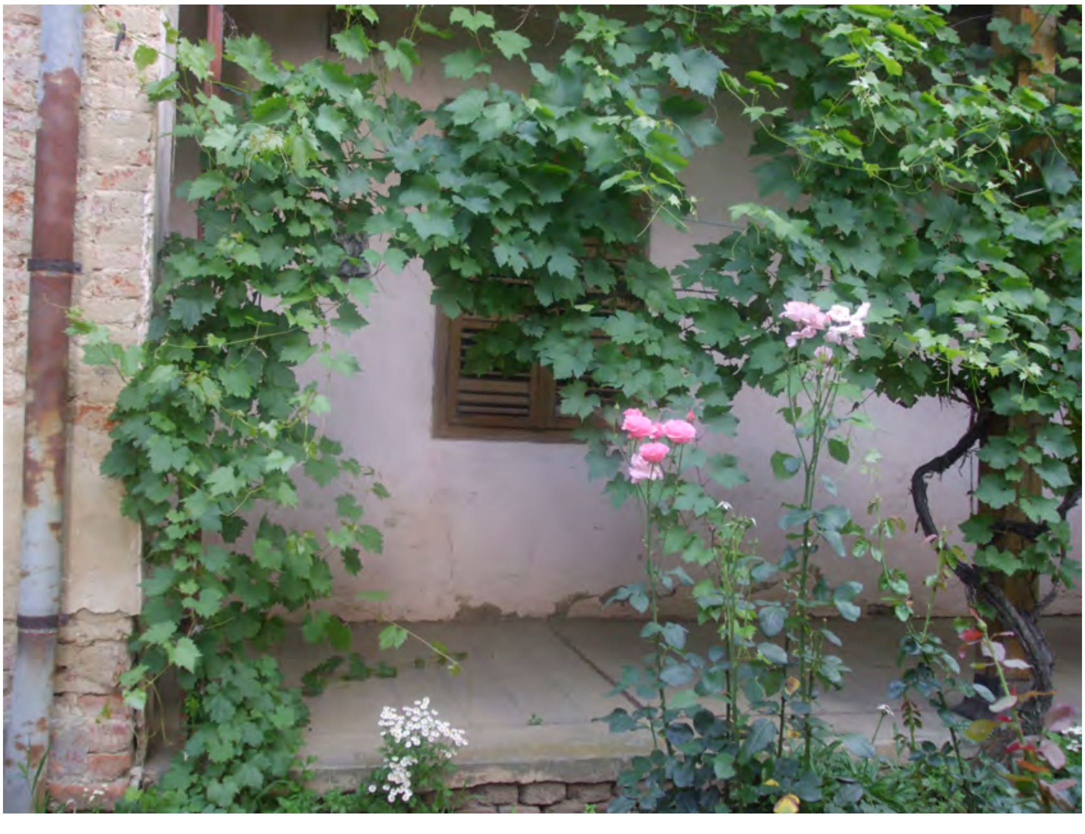

Figure 6-22: End of the wall to the street. Photo: Ágota Heinrich, 2009

Figure 6-23: Entrance openings. Photo: Ágota Heinrich, 2009.

Figure 6-24: Connection oft he entrance tot he loggia

Figure 6-25: Window and door opening. Photo by Ágota Heinrich, 2009.

Figure 6-26: Openings. Photo by Ágota Heinrich, 2009

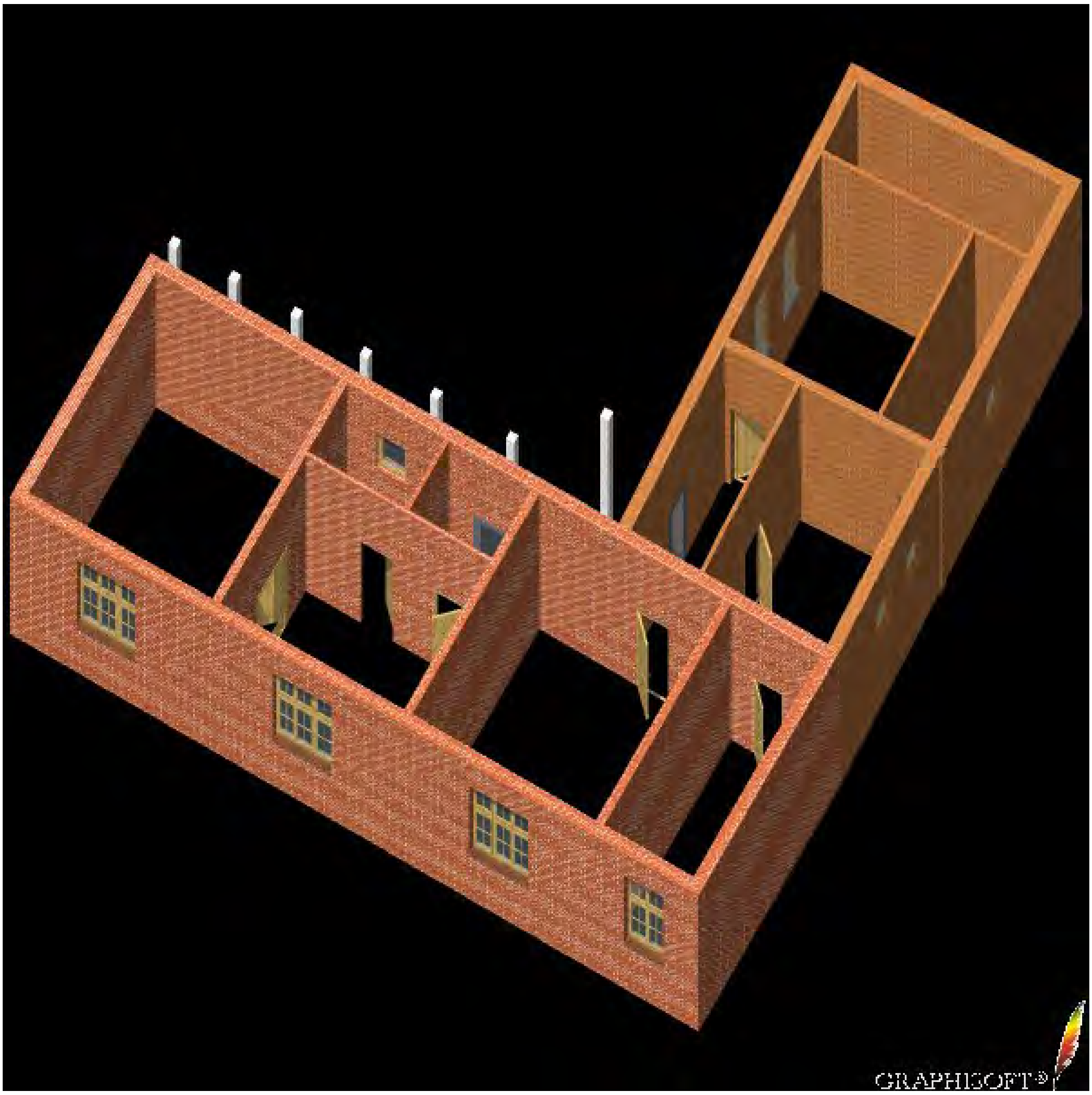

Figure 6-27: Wall structure for the long side variant, extension is marked.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing units. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is less than 5.

4.2 Patterns of Occupancy

During the day inhabitants are usually away for work, there are maybe the elderly at home, 1-2 persons.

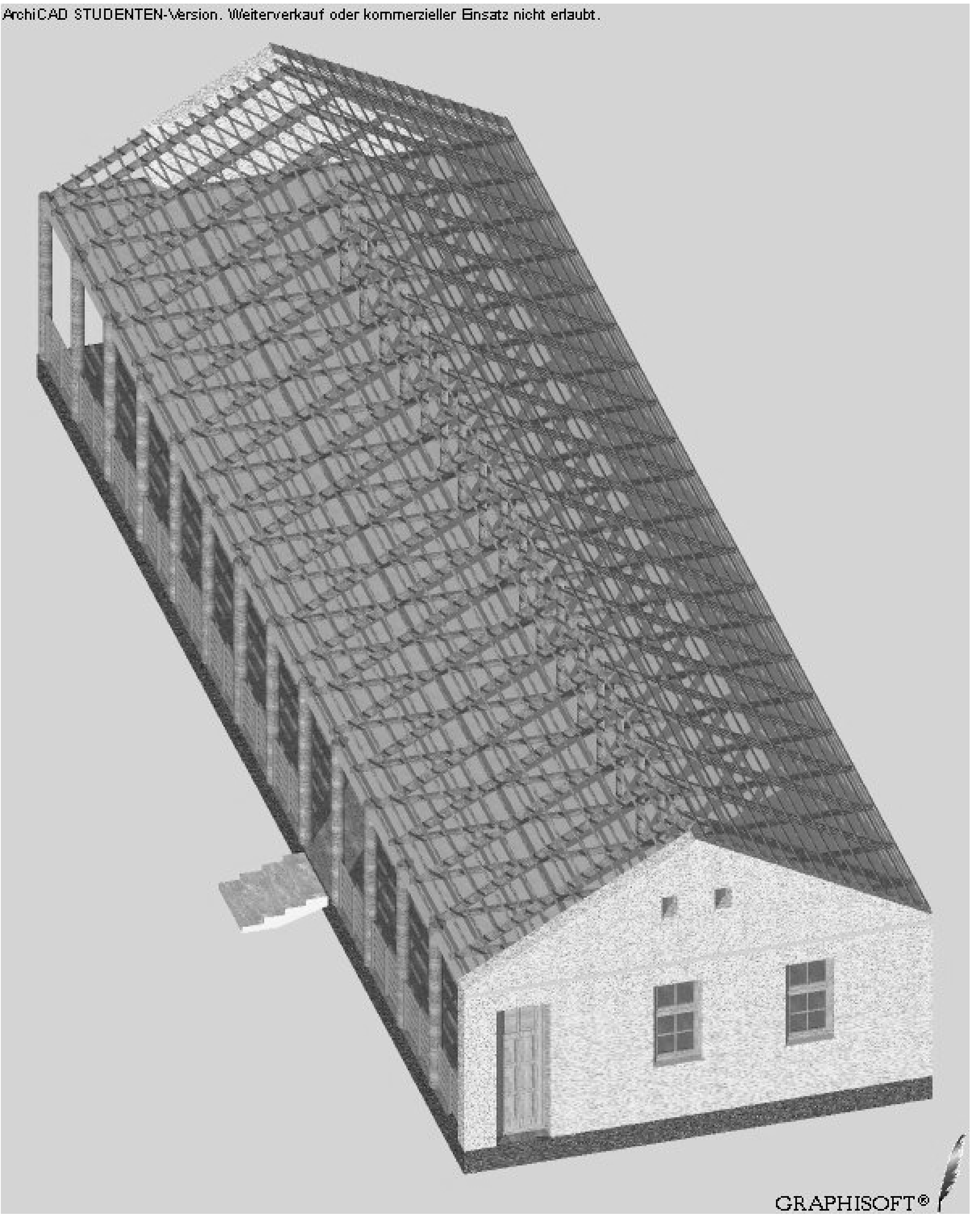

Figure 6-28: Structure of the roof

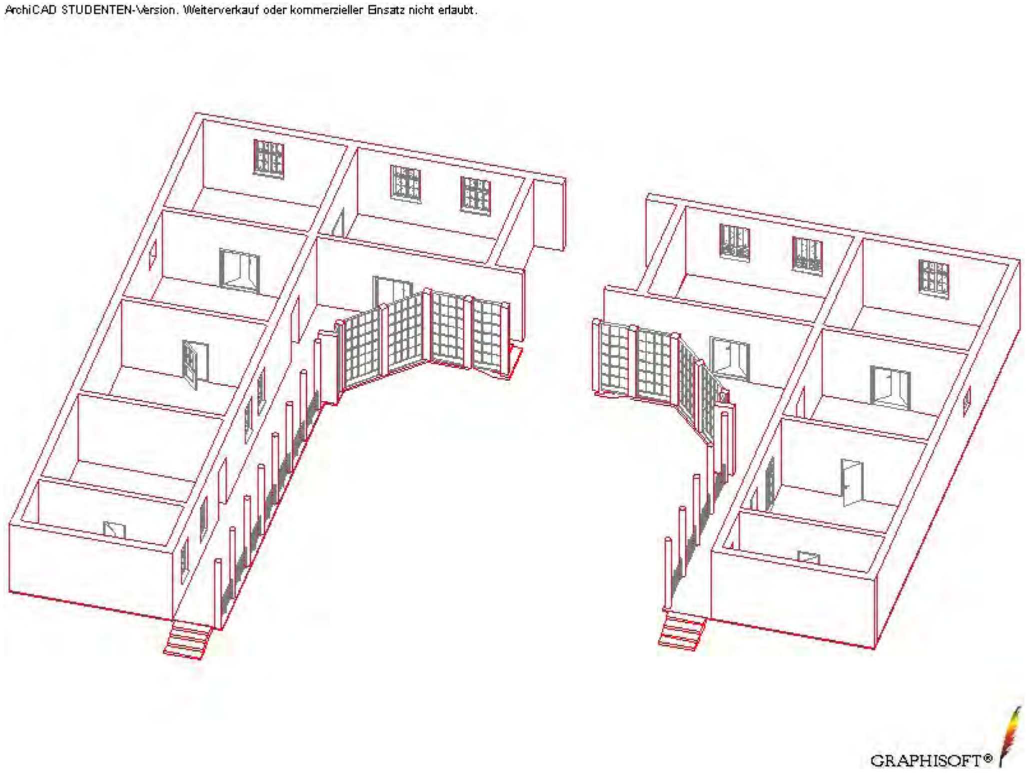

Figure 6-29: Wall structure of coupled buildings

Figure 6-30: Wall structure of coupled buildings

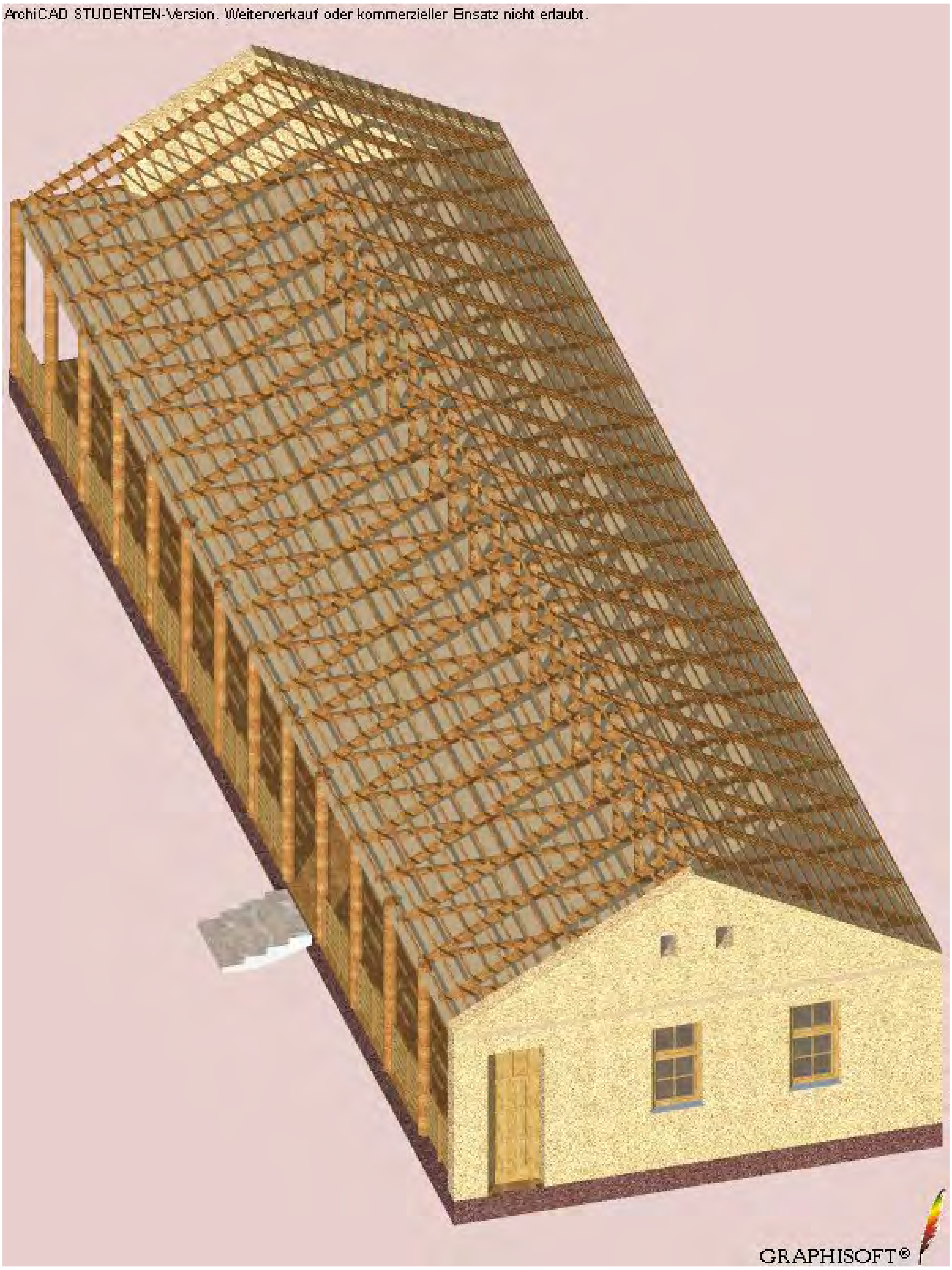

Figure 6-31: Structure of extended building - emphasys on street side

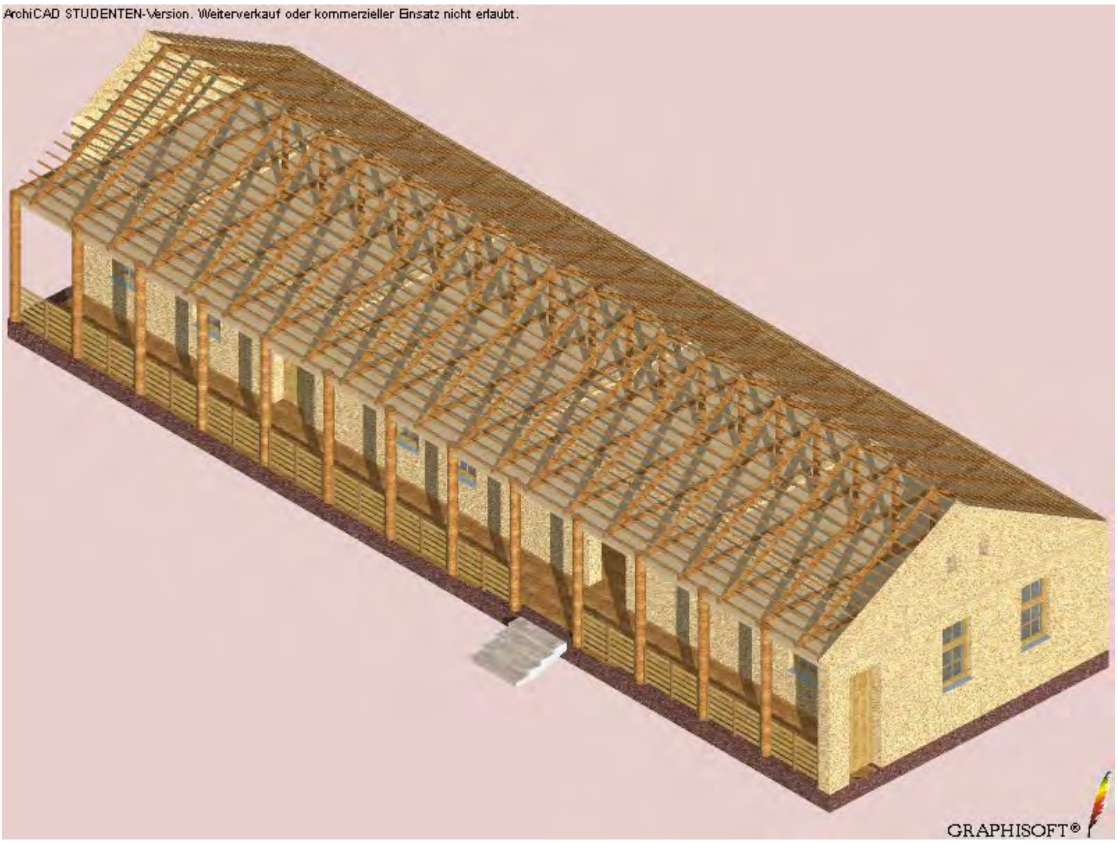

Figure 6-32: Structure of extended version - emphasys on courtyard side

Figure 6-33: Axonometric view of a typical house.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	
b) low-income class (poor)	
c) middle-income class	
d) high-income class (rich)	

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	
4:1	
3:1	
1:1 or better	

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	
Personal savings	
Informal network: friends and relatives	
Small lending institutions / micro-finance institutions	
Commercial banks/mortgages	
Employers	
Investment pools	
Government-owned housing	
Combination (explain below)	
other (explain below)	

In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).
It depends on the house, some have bathrooms with toilets, some have only running (cold) water and toilets in the yard, some none of them.

4.4 Ownership

The type of ownership or occupancy is outright ownership.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.			
Building Configuration	The building is regular with regards to both the plan and the elevation.			
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.			
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.			
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.			
Wall and frame structures- redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.			
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);			
Foundation-wall	Vertical load-bearing elements (columns, walls) are attached to the foundations;			

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	N/A
connection	concrete columns and walls are doweled into the foundation.			
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps			
Wall openings	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).			
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).			
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)			
Other				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	The disposition of walls sometimes does not respect rules concerning uniform distribution of mass and stiffness. Brickwork can be extensively worn out (poor maintenance, decay) No reinforced concrete vertical posts. Height differences to adjacent buildings possible. Use of mortars with moderate strength.	Good quality (hydraulic) lime mortar. Because of the wall-roof connection, which do not assure the spatial co-operation of the structures, the appeared dissimetries don't cause significant general torsion effects under the action of seismic forces.	Some cracks in the plaster Vulnerability to pounding In some buildings: diagonal cracks on the facades and on the party wall. Corner damage
Roof and floors	No stiff floors so no co-operation of load bearing walls and floors, so eventual capacity deficiencies of walls cannot be compensated by a uniform distribution of loads through the floors to walls with higher capacity. Linear load bearing elements with one direction load transmission, not anchored to the walls. No tie beams.	Timber floors with joists every 70cm assure an uniform distribution of rigidities in the plane avaoiding torsional effects. Timber joists are sustained by the longitudinal walls. Roof support on these girders leads to the fact that horizontal forces from earthquakes are absorbed without causing significant damages.	UAIM (2000) classifies small rifts in the ceiling plastering as being characteristic for both not affected and light affected buildings, while in affected buildings the floor joists might move from their supports. The movement and collapse of the roof is also characteristic for affected buildings.
Openings	Not always respecting the actual prescriptions regarding the dimensions and the areas of openings in walls. Piers (between windows) of reduced sections compared to the loads to be supported. Lintels are usually brick vaults, timber or metal joists.		In some buildings: X shaped cracks above the openings; Z shaped cracks on the "parapet" (under the window); cracks in the lintels over the entry door; cracks in the piers of the facade.
Foundation	Foundations are clay brick masonry as well, and rarely stone masonry or concrete.	-	-

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance)*, the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance).*

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1784	Maramures	4.4	VI-VII
1786	Transilvania	4.1	VI
1797	Banat	4.7	VII
1829	Crisana	4.7	VII

All earthquakes listed above and bellow except the last one are taken from the database compiled by Bălan et al (1982) and found place on Romanian territory that formerly belonged to the Austro-Hungarian Empire (where this kind of buildings can be found). In 1847, 1859, 1879, 1894, 1900 earthquakes of similar intensity with the 1797 one occured in Banat. In 1823 an earthquake with intensity VII and MI 4.7 occured with the epicentre in Maramures, while in 1830 one with intensity VI and MI 4.1 occured there. 1831 an earthquake with intensity VI occured in Maramures, but, different from the previously recorded ones it was of intermediate depth and thus MI was computed to be 5.5. In 1870 again an earthquake of normal depth occured in Maramureş, intensity being VI-VII and MI 4.1. 1893 a normal depth earthquake in Maramures of intensity VII resulted in a computed MI of 4.7. An earthquake from 1834 has affected the church of Nagykároly (Carei), a locality situated today in Western Romania, surrounded by villages with houses of this type. The church tower collapsed, as recorded in the church archives. It must have been the 1834 earthquake with epicentre in Crişana, of intensity VIII and computed MI 5.3. Earthquakes with epicentre in Transilvania were found by Bălan et al (1982) in historical records from 1523 and 1550, but by that time this kind of buildings did not exist. 1786 was the first one to affect this type of constructions. 1880 another earthquake with epicentre in Transylvania occured; this one had an intensity of VII and a computed MI of 4.7. No strong motion records list earthquakes after 1900 in either of this regions in Bălan et al (1982) nor in the European Strong Motion Database on Romanian territory. On Hungarian territory this kind of constructions has been affected by the 1995 Várpalota earthquake, with M 5.1.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/ dimensions
Walls	The construction material used is clay brick.	No data was available.	Usual are 37.5cm exterior walls and 25cm thick interior walls.
Foundation	There are no data.	No data was available.	
Roof and floor(s)	The building material for roofs and floors was timber.		

6.2 Builder

The builder typically lives in this construction type.

6.3 Construction Process, Problems and Phasing

Usually it is built by the future owner together with relatives, neighbours. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size.

6.4 Design and Construction Expertise

This is a vernacular type of housing. Architects are now increasingly preoccupied for conserving this type of vernacular architecture.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. A new version of the Eurocode has been adapted 2007 for Romania and also addresses this type of building. The historic buildings are not addressed.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by owners.

6.8 Construction Economics

Information not available.

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

8.2 Seismic Strengthening Adopted

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

No.

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

Not applicable.

8.3 Construction and Performance of Seismic Strengthening

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

Not applicable.

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

Not applicable.
What was the performance of retrofitted buildings of this type in subsequent earthquakes?
Not applicable.

Reference(s)

Danube Swabians http://en.wikipedia.org/wiki/Danube_Swabians

Typical village in Hungary, with archive photos of such houses
http://www.falvak.hu/vallaj

Monuments in German villages
http://www.csatolna.hu/hu/tolnamegye/muemlek/aparaszt.shtmlsee also linked page
http://www.csatolna.hu/hu/tolnamegye/muemlek/svab.shtml
collective author (CsaTolna)

Typical houses and decorations in Hungary
http://tudos.virtus.hu/index.php?id=detailed_article&aid=45144&recommend=1

Typical house on a stamp
http://de.wikipedia.org/w/index.php?title=Datei:Stamp_1998_Nikolaus_Lenau.jpg&filetimestamp=20091220230838

Typical house
http://commons.wikimedia.org/wiki/File:Casa_Svabeasca_Jimbolia.jpg

Example of renovated house
http://picasaweb.google.com/lh/photo/rqEgBYInbs82kelS49rwOw

Typical house, adobe variation, in Hungary
http://www.ipari.vein.hu/index.php?q=node/126

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Comparison and conclusions

Between Romania and Germany there exists a link, regarding traditional housing. German settlements started on the territory of today's Romania in the 12th century, with Transylvanian Saxons; in the 17th century and till the second half of the 19th century the Danube Swabians came. The typical vernacular house of the Danube Swabians can be found in three countries: Romania, Hungary and Serbia, where these settlers found a home. Such a typical house in three countries is also the vernacular housing of Southern Germany about which a report in this book is: the southern German half timbered house can be found in Germany, France and Switzerland. The house typologies are different, regarding construction material, structural system and architectural details, especially typical height. Vernacular housing in Romania is single storey, with large courtyards, since it was especially typical for rural settings. The German half timbered house (Fachwerkhouse) is a multistory skeleton construction typical for urban settings, exploiting the space by consoles in the upper storeys. The rural/urban setting influenced more the typology of the houses than the cultural background of the immigrants. The local geography influenced less, since villages of Saxon or Swabian immigrants in Transsylvania differ from Romanian villages. Interestingly, the earthquake hazard in the two zones is rather close, considering that more than half of Romania is affected by the intermediate depth strong Vrancea earthquakes, and the Swabian houses are in Banat, where shallow earthquakes shape the hazard. Germany, even the southern part, is a low seismicity region, where no severe damages to earthquakes have been noticed since the 1356 Basel earthquake. However, the typology of the Fachwerk is seismically resistant, being introduced in codes after earthquakes such as 1755 Lisbon (Marques de Pombal) or 1783 Calabria (Bourbon government), as "gaiola pombalina" and respectively "casa baraccata" (Tobriner, 1983), and considered to express the local seismic culture in other countries where present, from Turkey and Italy (Pompei) to Nepal and Peru. The vernacular house in Romania is from the point of view of structural typology close to those practices outside the Carpathians, the "wagon" house: elongated rectangular in shape, with entrance in the middle of the long side, arrayed rooms, single storey, with massive masonry walls and timber floors. For the conditions of Bucharest, where the other two investigated typologies are situated, this type was seismically resistant. The intermediate depth Vrancea earthquakes affect, given the local site conditions of alluvial soil, especially middle to high rise buildings, and these single storey buildings were safe. Theories are that the buildings of the Saxons display local seismic culture being lower and thicker the closer to the Vrancea region (Sever Georgescu, personal communication). If the materials and structural type are different for the vernacular housing, the more differences are at the Modernist housing. In fact, construction materials used in Germany are substantially different of those in Romania. For Germany wood, stone and, in Modern times, metal are common, while in Romania burned and unburned clay and, in Modern times, reinforced concrete, are the rule. Like in case of vernacular housing, it is not so much a question of local seismic culture as it is a question of geography. These materials were local resources. Germany has been rich in forests, and iron was a cheaper material than reinforced concrete with the industrial revolution. Even landmarks such as the Einstein tower in Potsdam (fig. 7-1) were done to their largest part in mixed structure with iron, not in reinforced concrete (Huse, 2000), despite the architectural shape demanding for concrete. Other experimental buildings, such as the coupled house of Le Corbusier at the Weissenhof Siedlung in Stuttgart, were also mixed structures of iron and concrete. Metal was the structural material also for multistory housing buildings, like the type described in the report included in this book, a situation found in other countries covered by the "World Housing Encyclopedia" only in Iran, but in contemporary times. Metal skeleton is rather uncommon for housing buildings. In Romania we find it in two buildings of the Modern times, the Telephone Palace (fig. 7-2) and the Adriatica building (fig. 7-3), both office buildings, while the Adriatica is the work of a German immigrant of the Modern times, Rudolf Fränkel. In Romania the building material with which was innovated in housing building of the Modernism was reinforced concrete. The structural type which proved most vulnerable, from which already in the 1940 earthquake the Carlton Building of G.M.

Cantacuzino collapsed, and in 1977 about 30 buildings collapsed or were damaged was reinforced concrete skeleton. The structural layout was dictated by the architectural layout, thus the elements of the skeleton were not forming moment resistant frames, but there was no clear division between primary and secondary load bearing elements. Exceptions (Bostenaru, 2005) are notable, but few. Also the Master Plan of Bucharest from 1934 was stipulating that the streets' importance is defined by their facades and thus the maximum height was raised, it was allowed for commercial functions in the ground floor leading to soft storeys and the street intersections were marked by corner towers, which moved the moment centre of the buildings. These all happened because, despite implementing the Athens Charter and the separation of functions in the Master Plan of 1934, in Bucharest the Modernist housing was done in the city centre, especially on the North South boulevard traced at the end of the 19th century following the Haussmanian model. It was because the housing programme, on which Modernism proved particularly innovative, was dictated by the market, and the middle class demanded for this condominium housing in the city centre. This was a situation not unique in Europe, in Greece Modernist housing was dictated by the same middle class, but in Greece the insertions were done in rectangular extensions of the street grid, with buildings of 5-6 storeys and no marked corners, like in the city of Tony Garnier. Also in Greece, another seismically prone country, the construction material was concrete, as steel would have been an imported material and thus more expensive. And in both countries the calculations, as shown also in the report included in this book, were done following the German model, while in architectural typology Romania followed a French model, both being low seismicity countries. Condominium housing is also typical for another reinforced concrete housing building in urban tissue of the interwar time, namely that in Italy. But even more must be remarked that this urban block of flats was a European and Northern American phenomenon (Sonne, 2009), which proves to be a model for today's sustainable development. It was a fundamentally different approach of that in Germany, of the "Neues Bauen", which promoted building on the periphery, the social minimal housing on "the green field", in so-called "Zeilenbau", long rows middle in green in the negative urban space shape of Le Corbusier. On the other hand, regarding the sustainability of the vernacular housing shown, the one in Germany experiences these times a revival, while the one in Romania is in danger, like also modernist low rise buildings (fig. 7-4) due to speculation with the high cost parcels.

This book provided a comparison of two rather different approaches to both vernacular and modernist housing, as it is difficult to find two countries which approached more differently the two, despite being open to influences by the immigration, first massive, then of architects. The geographic conditions, especially the availability of materials proved stronger and had greater impact than the local seismic culture as well. Actually the typologies in low seismicity Germany prove more earthquake resistant than those in Romania, as they have been tested in strong earthquakes in other countries, as other reports in the "World Housing Encyclopedia" prove. Therefore an enlarged comparison in the context of the whole Encyclopedia, as it is growing, is demanded.

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Figure 7-1: Einstein Tower, Postdam (1919-1921). Architect: Erich Mendelsohn. Photo by Maria Bostenaru, 2002.

Figure 7-2: Bucharest Telephone palace (1929-1934). Architect: Edmond Van Saanen Algi. Photo by Maria Bostenaru, 2009.

Figure 7-3: Adriatica building, Bucharest (1933). Architect: Rudolf Fränkel. Photo by Maria Bostenaru, 2002.

Figure 7-4. “Prager” villa, Bucharest. Architect Henrietta Delavrancea-Gibory (1936). Photos by Maria Bostenaru, 2009.

Author‘s CV

Dipl.-Ing. M. Bostenaru Dan obtained an engineering degree in architecture, specialisation in urbanism, from the Universität Karlsruhe, Germany, in 1999. She was involved, with the Collaborative Research Centre 315 "Preservation of historically relevant constructions" in a building survey in Poland and employed as research assistant at the CRC 461 "Strong earthquakes", both at the Universität Karlsruhe. With a DFG scholarship in the Research Training Group "Natural Disasters" in Karlsruhe and a Marie Curie Early Stage Research Fellowship in Pavia, Italy, research was done on "Applicability and economic efficiency of seismic retrofit measures on existing buildings". She was experienced researcher on the project "Preservation of historic reinforced concrete housing buildings across Europe" (CA'REDIVIVUS), a Marie Curie Intra-European Fellowship in Pavia. She returned to Romania with a Marie Curie Reintegration Grant on "The innovation in the plan of the current floor: Zoning in blocks of flats for the middle class in the first half of the 20th century" (PIANO). Since 2008 she is also employed as researcher at the "Ion Mincu" University of Architecture and Urbanism, permanent position. There she was involved in CNCSIS funded research on "Arts, Urban Communities, Mobilisation - The social reinsertion of the artistic and architectural project" and in a Union of Romanian architects co-funded project: Tzigara-Samurcaş archive. She keeps doing earthquake engineering in a CNMP project lead by the University of Bucharest: "Multihazard and vulnerability in the seismic context of Bucharest city" (since 2007) and the "World Housing Encyclopedia" (since 2001, editorial board member 2003-2006) and co-teaching the course "Risks" at the Urbanism Department, the "Ion Mincu" University (since 2009). She is MC member at the COST action TU0801 "Semantic enrichment of 3D city models for sustainable urban development". She has been journal guest editor and reviewer and conference session organizer. She has more than 100 publications, including 3 books and 2 journal special issues and is in the scientific committee of conferences.