World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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HOUSING REPORT
Prefabricated metal construction of the Modern Movement

Report #	95
Report Date	04-07-2003
Country	GERMANY
Housing Type	Steel Moment Frame Building
Housing Sub-Type	Steel Moment Frame Building : Brick masonry infills
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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. 3,4), Frankfurt, Berlin, Stuttgart (1927 Weissenhof: Fig. 6), Kassel (1929 Rothenberg), Celle (1930 Blumlagerfeld) and others. Some 300,000 residential units (see "Weisse Vernunft", 1999). This type of housing construction is commonly found in sub-urban areas. This construction type has been in practice for less than 25 years.

Currently, this type of construction is not being built. This construction type had been practiced up to the world economy crisis.

Figure 1: Typical photo of a multistorey house of the type (in Karlsruhe; same type to be found in Kassel)

Figure 2: Low-rise building of this type (see an archiv 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)

Figure 3: Mid-rise building of this type in context - entry situation in Karlsruhe-Dammerstock

Figure 4: Low-rise building of this type in context (Karlsruhe).

Figure 5: Another mid-rise building of this type (in Stuttgart). Top: view from the back. Bottom: view from the front.

Figure 6: A renowned building of this type: Le Corbusier's building in Stuttgart Weissenhof (from 1927) - a mix of reinforced concrete and metal structure: free standing columns are out of metal.

Figure 7: View along the rows in a typical Siedlung (Karlsruhe).

Figure 8: View through the rows in a typical Siedlung (Karlsruhe).

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings. See figures 7 and 8 for typical views in a Siedlung

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 figure 17 (long facade of a typical building bar) and 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 12.

2.3 Functional Planning

Single family house and Multiple housing units. 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.

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.

Figure 9: Fig 9: The entry poster to such a Siedlung, including the plan with times of construction, an archive aerial view and description in German. 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).

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

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	☐
	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	☐
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 Table 10 on page 41.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Iron skeleton (fig. 11-13) 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. 16). The statics were computed for a 10cm thick brick-iron floor. Iron/steel frames are one story 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 skeleton serves as "Fachwerk" up to the cornice.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Lateral load resistance is provided by iron skeleton stiffened by brick infill walls (fig. 21) and by wind bracing within the staircase walls (fig. 20). The floor is the so called "Kleine" brick-iron-floor system with I-profile joists. The "Kleine" floor system was characterized through concrete reinforced with round iron bars at about 30cm 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 storey(s). The typical span of the roofing/flooring system is 3 meters. Typical Plan Dimensions: 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. 9 and 10). An aerial view today of a typical settlement 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). Typical Number of Stories: 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. 5), 4 (1 basement +GF+3 regular) in Kassel and in Karlsruhe (fig. 1) . The single family houses are 2 story (1 basement+GF+1 regular) in Celle and Karlsruhe (fig. 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 approximate 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 3.6m). 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.

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 joists. Ahnert (2002) shows the details of such a structure in Table 6 on page 36, Vol. III (with "Kleine" floor). More details are given in the "Kleine" floor in Table 18 on page 57 in Ahnert (2002), Vol. II. Here and in the adjacent Table 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, Table 22 on page 164) to the exterior walls and within these with higher density in the basement (Ahnert, 2002, vol. II, Table 23, page 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 Table 25 on page 78 and Table 26 on page 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, Table 31 on page 88.

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	☐

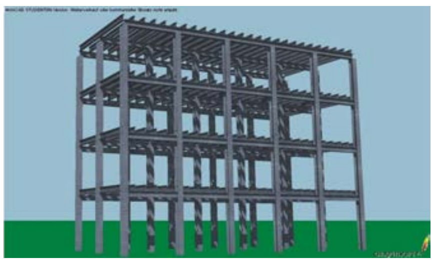

Figure 11: Perspective view of key load bearing elements: Variant 1 (for a structure of this type see Dammerstock Gruppe 3 by architect Otto Haesler in "Kunst und Handwerk" Heft 9. 1929. page 259)

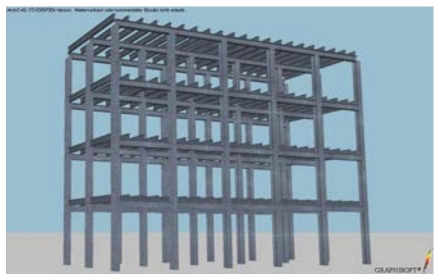

Figure 12: Key load bearing elements: Variant 2 (a structure of this type is to be seen in Kassel-Rothenberg by architect Otto Haesler in Haesler: "Mein Lebenswerk als Architekt". 1957. Page 32)

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

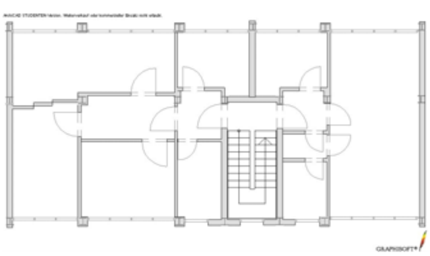

Figure 14: Plan of a typical building

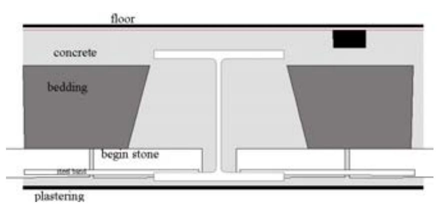

Figure 15: Critical structural floor detail ("Kleine" floor)

Figure 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 17: Facade detail from a mid-rise building of this type (Stuttgart).

Figure 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.

Figure 19: Corner detail for a mid-rise building of this type (Stuttgart).

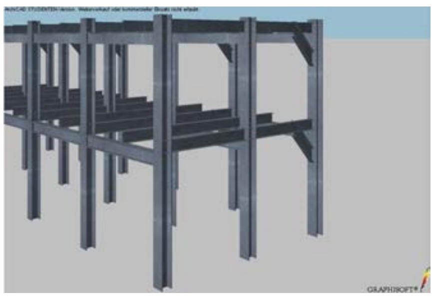

Figure 20: Key seismic features: Stiffening in the staircase area (an archive photo where such stiffening elements can be observed is found in N

Figure 21: Key seismic features: infill walls (an archive photo showing infilling of metal frame on the building site is found in N

Figure 22: Seismic feature (small openings in infill walls): Facade of a low-rise house (Karlsruhe)

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 21-50 housing unit(s). 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 others (as described below). The number of inhabitants during the evening and night is others (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.

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 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 Housing Unit Price 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	☐

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)	☑

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 corresponding legislative framework and different instruments (taxes and housing construction support programs 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 mortgage (=credit got by the investor) and the rest by the second mortgage (this followed an English model concerning the separation between capital and interest). After WWI, problems were encountered with the second mortgage. This model is still implemented in the Dammerstock Siedlung in Karlsruhe. The mortgage 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): [Wohnungsnot/Sozialpolitik] (="Housing shortage/Social politics") and [Finanzierung] (=Financing). In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting.

Type of ownership or occupancy?	Most appropriate type
Renting	☑
outright ownership	☐
Ownership with debt (mortgage or other)	☐
Individual ownership	☐

Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

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 appropriate type		
		Yes	No	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 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)	☐	☑	☐
Additional Comments				

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 oscillation	rigidity due to large concrete volume or reinforcement	curvature up to 5cm of the floor; the out of plane deformation of reinforcing iron (30cm).

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 occurred 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 (Table 6) and page 41 (Table 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/m²; 12cm thick - 1.5 kN/m². The "Kleine" floor (fig. 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: diameter 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 rationalization, typization and standardization. Industrial mounting methods aimed saving in time and costs. The construction flow had to be optimized 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 optimized 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 skeleton 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. 23-24) 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 addressing 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 information on standardization 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 optimization 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 rationalization were used more.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. The year the first code/standard addressing this type of construction issued was 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. The most recent code/standard addressing this construction type issued was 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. 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 an 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 rationalization 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 cost 64 (example with iron-concrete)-85 RM/m^3. RM = Reichsmark. Workmanship prices of the time were approx. 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). Realization in record speed owes to the optimized construction flow (see 7.3), the so-called Taylorization. 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, i.e. 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).

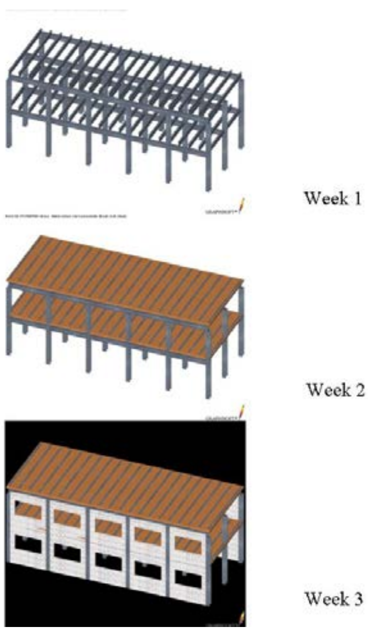

Figure 23: Building process (archive views of steps in building Dammerstock Gruppe 16, architect Otto Haesler, can be seen in Stein Holz Eisen. 1929. on page 769)

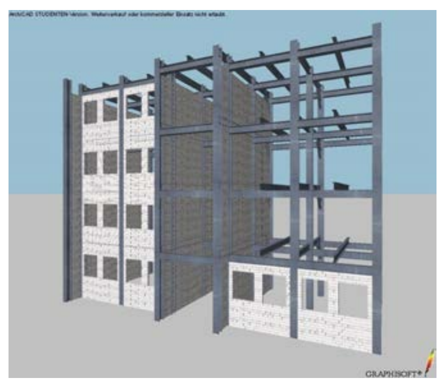

Figure 24: Highrise building of the type during the building process. (archive photo presenting such a succession in the construction process can be seen on the example of Kassel-Rothenberg, architect Otto Haesler, in Haesler: Mein Lebenswerk als Architect. 1957, on page 33)

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.

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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