

World Housing Encyclopedia

A Resource on Construction in Earthquake Regions



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Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Prefabricated metal construction of the Modern Movement

Report#	95
Last Updated	
Country	Germany
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Important

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General Information

Building Type:	Prefabricated metal construction of the Modern Movement
Country:	Germany
Author(s):	Maria D. Bostenaru
Last Updated:	
Regions Where Found:	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.
Summary:	<p>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.</p>
Length of time practiced:	Less than 25 years
Still Practiced:	No
In practice as of:	
Building Occupancy:	Single dwelling Residential, 20-49 units
Typical number of stories:	2-4
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	See figures 7 and 8 for typical views in a Siedlung. This construction type was both used for single family housing and multiple ho

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	20-160
Typical plan width (meters)	5.5-8.5
Typical story height (meters)	2.8
Type of Structural System	Steel: Moment Resisting Frame: With brick masonry partitions
Additional comments on structural system	<p>The vertical load-resisting system is 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. 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.</p>
Gravity load-bearing & lateral load-resisting systems	Typical skeleton with I shaped members is shown in Ahnert (2002) Vol. III in Table 10 on page 41.
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on typical wall densities	The typical structural wall density is 5 - 8% This density is given for infill walls.
Wall Openings	<p>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</p>

the distribution of windows in a typical low-rise building can be seen in figure 12.

<p>Is it typical for buildings of this type to have common walls with adjacent buildings?</p>	<p>Yes</p>
<p>Modifications of buildings</p>	<p>The original light walls were later replaced by the masonry partition walls. The empty rooms were later used for residential occupancy.</p>
<p>Type of Foundation</p>	<p>Shallow Foundation: Reinforced concrete isolated footing</p>
<p>Additional comments on foundation</p>	
<p>Type of Floor System</p>	<p>Composite steel deck and concrete slab</p>
<p>Additional comments on floor system</p>	<p>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", "Frster", "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 DIN1046. Later cross reinforcing of such floors was possible, as documented by Ahnert (2002), Vol. II, Table 31 on page 88.</p>
<p>Type of Roof System</p>	<p>Composite steel roof deck and concrete slab</p>
<p>Additional comments on</p>	<p>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", "Frster", "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</p>

roof system

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Additional comments section 2

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 2story (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.



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

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/pos>

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	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 "stau" bricks and frames)
Foundations	concrete	
Floors	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)	10cm thick - 1,25 kN/m ² ; 12cm thick - 1.5 kN/m ² . 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
Roof	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. 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

Other	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)
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Design Process

Who is involved with the design process?	Engineer Architect
Roles of those involved in the design process	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.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	
Expertise of those involved in building process	

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 planning 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

Construction process and phasing

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 inhabited 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.

Construction issues

Building Codes and Standards

Is this construction type address by codes/standards?

Yes

Applicable codes or standards

The year the first code/standard addressing this type of construction issued was in 1917, the first code (DIN = [Deutsche Industrie Norm] = "German Industrial Standard") for the construction industry appeared. The board was initiated 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, Bemessung und Ausführung blicker Hochbauten] = "Building in German earthquake regions - loading assumptions, dimensioning and execution of common buildings" was issued in 1981. This then became a technical prescription.

Process for building code enforcement

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

enforcement

is foreseen that this will appear in the Eurocode 8. For details see: http://www.lgrb.uni-freiburg.de/d/akt/lgrb_n0202.pdf.

Building Permits and Development Control Rules

Are building permits required?

Yes

Is this typically informal construction?

No

Is this construction typically authorized as per development control rules?

Yes

Additional comments on building permits and development control rules

Building Maintenance and Condition

Typical problems associated with this type of construction

Who typically maintains buildings of this type?

Other

Additional comments on maintenance and building condition

Construction Economics

Unit construction cost

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; and for dry mounting example is 80RM/m. Other buildings of innovative type cost 64 (example with iron-concrete)-85 RM/m. RM = Reichsmark. Workmanship prices of the time were approx. 1.5 RM/h, while material prices looked like: ~50RM/1 t cement, ~70RM/1m gravel, ~200RM/1t steel (after Ahnert, 2002, vol. I, P. 13).

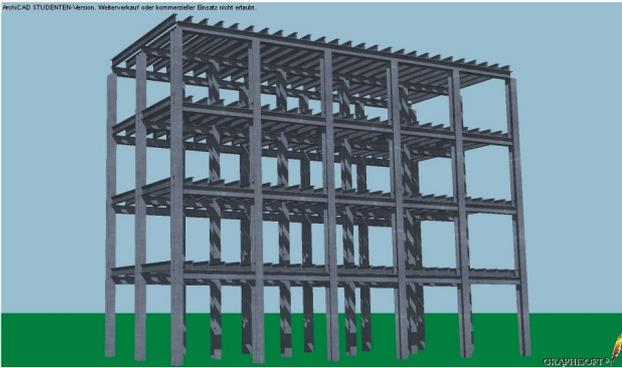
Realization in record speed owes to the optimized construction flow, the so-called Taylorization. Most of the construction is based on the extensive prefabrication of parts. The size of prefabricated parts was dictated by the lifting force of the machinery or eventually of a worker, although manual work had been tried to be avoided. The construction site management becomes almost like

Labor requirements

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 buildingsite in Dessau-Trten 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 "Bauhtte". For details see "Weisse Vernunft" (1999).

Additional comments section 3

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 DIN 4114 released in 1952. Joists for this type of building have been addressed by standards since 1876 and by norms since 1934. The DIN 1050 was updated in 1937 and 1947 retained its name. This construction type was typically built as social housing.



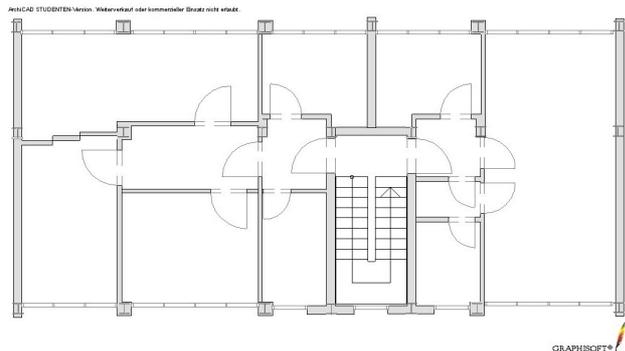
Perspective view of key load bearing elements: Variant 1 (for a structure of this type see Dammerstock Gruppe 3 by architect Otto Haesler in "Kunst und Handwerk" Heft 9, 1929, page 259)



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)

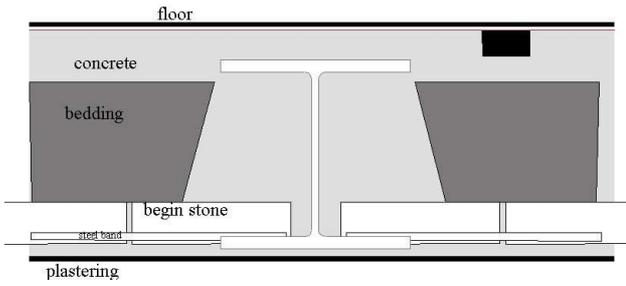


Axonometric view of key load



Plan of a typical building

bearingelements in variant 1



Critical structural floor detail ("Kleine" floor)



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



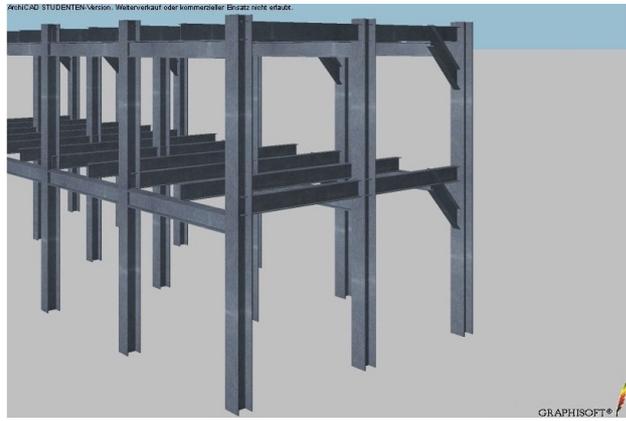
Facade detail from a mid-rise building of this type (Stuttgart).



Details showing the way horizontal and vertical (iron) reinforced concrete and vertical metal elements are combined in Le Corbusier's building in Stuttgart Weissenhof.



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



Key seismic features: Stiffening in the staircase area



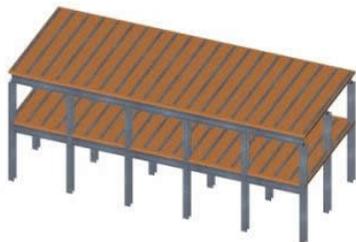
Key seismic features: infill walls



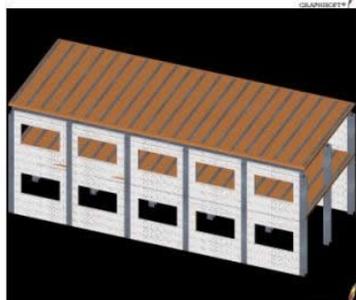
Seismic feature (small openings in infill walls): Facade of a low-rise house (Karlsruhe)



Week 1



Week 2



Week 3



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 pa

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)

Socio-Economic Issues

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 (32-34m ²) to 8 (60-78m ²) 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). Each building typically has 24 housing unit(s).
Number of inhabitants in a typical building of this construction type during the day	>20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	The average number of inhabitants in a typical building depends on the number of units. Approximately 96 inhabitants reside in a typical building.
Economic level of inhabitants	Low-income class (poor)
Additional comments on economic level of inhabitants	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.
Typical Source of Financing	Government-owned housing Other

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

Additional comments on financing

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 Karlsruhe 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).

Type of Ownership

Rent

Additional comments on ownership

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.

Is earthquake insurance for this construction type typically available?

Yes

What does earthquake insurance typically cover/cost

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. 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>.

Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?

No

Additional comments on premium discounts

Additional

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1970	Albstadt, Sw abian Jura
1977	Sigmaringen
1978	Tailfingen-Onstmettingen (Albstadt)
1980	Onstmettingen (Albstadt, Sw abian Jura)

Past Earthquakes

<p>Damage patterns observed in past earthquakes for this construction type</p>	<p>For further details on the earthquake in 1978 see: http://www.iaag.geo.unimuenchen.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 Wutschingen (north of the Rhein and south of Donaueschingen, west from Bodensee in the Black Forest; earthquakes from there registered in Basel, Zrich and many other locations with both rock and stiff soil; Magnitude 3.9 ML); 1996 - Gottmadingen (close to Wutschingen, west from Bodensee, between Singen and Zrich; 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 Rheinfeldern, 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.unimuenchen.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 Gro-Gerau (north of Basel on the Rhein) followed. A new earthquake map for Baden-Wrttemberg 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</p>
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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.

Additional comments on earthquake damage patterns

Curvature up to 5cm of the floor; the out of plane deformation of reinforcing iron (30cm).

Structural and Architectural Features for Seismic Resistance

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

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than 1/2 of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.

Structural/Architectural Feature	Statement	Seismic Resistance
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
Roof Construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this	TRUE

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.	FALSE
Foundation Performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	FALSE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
Wall Proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	N/A
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few	FALSE

	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).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	hollow bricks, large window openings
Earthquake-resilient features in walls	fills the frame
Seismic deficiency in frames	especially the column bases oxydates, as it lays without protection in the concrete
Earthquake-resilient features in frame	presence of stiffening elements
Seismic deficiency in roof and floors	heavier than computed and thus inducing additional loads into the structure; sensitive to oscillation
Earthquake resilient features in roof and floors	rigidity through large concrete volume or reinforcement
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

High

Medium

Low

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

Retrofit Information

Description of Seismic Strengthening Provisions

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

Additional comments on seismic strengthening provisions	These measures were applied because of general structural system problems, not necessarily due to seismic deficiencies.
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Has seismic strengthening described in the above table been performed?	It was performed in practice, in Stuttgart, see Ngele (1992), P. 112-114.
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Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	The building was damaged but not by an earthquake.
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Was the construction inspected in the same manner as new construction?	Yes.
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Who performed the construction: 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".
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What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

No data is available on this.

Additional comments section 6

References

Typical Constructions from 1860 till 1960/ Vol. I. Foundations, Isolations, load bearing massive walls, corniches, smokestacks, load bearing walls out of wood, old units of measure (in German) Ahnert, R., and Krause, K.H. CD-ROM; ISBN 3-345-00622-7 2000

Typical Constructions from 1860 till 1960/ Vol. II. Wooden joist floors, massive floors, floor index, floorings, bays and balconies, overview of live loads (in German) Ahnert, R. and Krause, K.H. CD-ROM, ISBN 3-345-00623-5 2001

Typical Constructions from 1860 till 1960/ Vol. III. Beams and masonry belt arches, piers and columns, stairs, roofs and roof structures, wooden roof buildings, loading assumptions for the roof (in German) Ahnert, R. and Krause, K.H. CD-ROM, ISBN 3-345-00624-3 2002

Internet-Site for European Strong-Motion Data, European Commission, Research-Directorate General Ambraseys, N., Smit P., Sigbjornsson, R., and Suhadolc, P., and Margaris, B. Environment and Climate Programme. Geo. - Hamburg : Gruner + Jahr ISSN 0342-8311, 1980 2002

My Lifework as Architect Haesler, O.P. 30, 32, 33, XVIII. Images 34, 42, 44 and 47 1957

Art and Handcraft Kunst and Handw erk Zeitschr. f 1929

Perception of Risks from Nature's Catastrophes - An Empirical Study in Six Endangered Zones of Southern and Western Germany Plapp, T. PhD Dissertation, University of Karlsruhe, Online at: <http://www.wubka.uni-karlsruhe.de/cgi-bin/psview?document=2003/wiw/i/10> 2003

Wahrnehmung von Risiken aus Naturkatastrophen. Eine empirische Untersuchung in sechs gefl. Plapp, T. Reihe II - Risikoforschung und Versicherungsmanagement Vol 2, Ed. Prof. Dr. U. Werner, Verlag f 2004

Stone Wood Iron Stein, H.E. Frankfurt, M. P.769 1929

Stone Wood Iron Stein, H.E. Frankfurt, M. P.536, Page 18 1930

Die Suche nach einer Wohnreform Ungers, L.P.149 1983

Gruner + Jahr Geo. - Hamburg, ISSN 0342-8311 1980

The Restoration of the Wein Stuttgart: Karl Kr 1992

White Ration. Siedlung Construction in the 20th CDROM f. MacOS 7.5x u. Windows 95. Prestel, March 1999

www.weissenhof2002.de/

www.baukosten.de/

www.iaag.geo.uni-muenchen.de/sammlung/Zollerngraben.html

www.iaag.geo.uni-muenchen.de/sammlung/Stockach.html

www.lgrb.uni-freiburg.de/d/akt/lgrb_n0202.pdf

www.lgrb.uni-freiburg.de/d/akt/lgrb_n0202.pdf

www.diw.de/deutsch/produkte/publikationen/wochenberichte/docs/02-35-2.html#HDR2

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