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

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HOUSING REPORT
Urban residential buildings of the 19th century in the city of Basel

Report #	119
Report Date	26-05-2007
Country	SWITZERLAND
Housing Type	Stone Masonry House
Housing Sub-Type	Stone Masonry House : Rubble stone without/with mud/lime/cement mortar
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Reviewer(s)	

Summary

This building type was mainly constructed as residential buildings in the second half of the 19th century until the beginning of the 20th century in the vastly expanding city of Basel, but also in other Swiss cities. The buildings are made of unreinforced masonry with timber floors,

are four to five stories high and are attached to each other. The unreinforced masonry walls are usually made of simple stone (more or less regularly cut) or brick masonry, the thickness of the stone masonry walls being larger. The mortar used is usually lime mortar. In some cases, a mixed masonry was used, especially at the ground floors, with larger, well cut stones for the outer layer of the façade walls and simple stones or bricks arranged behind. The buildings are rather regular in plan and elevation. However, the timber floors are often not anchored to the masonry walls and the front and back façades usually have rather large openings for the windows whereas the side walls are solid walls used as fire division wall. The seismic performance of these buildings is expected to be rather poor.

1. General Information

Buildings of this construction type can be found in urban residential areas Basel and other cities in Switzerland, but also in German cities. This type of housing construction is commonly found in urban areas.

Only around 1850 a new law came out in Basel that allowed the construction of houses outside the old town wall. In the second half of the 19th century the town spread very rapidly and soon covered the area it covers today. Most of the buildings constructed at that time were residential buildings of unreinforced masonry with four to five stories. The floors are typically timber floors which are often not anchored to the masonry walls. The buildings are rather regular in plan and elevation and attached to each other. The front and back façades usually have rather large openings for the windows whereas the side walls are solid walls used as fire division wall.

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

Currently, this type of construction is not being built. Masonry buildings in Switzerland today are normally built with reinforced concrete floors.

Figure 1a: Typical Building

Figure 1b: Typical Building

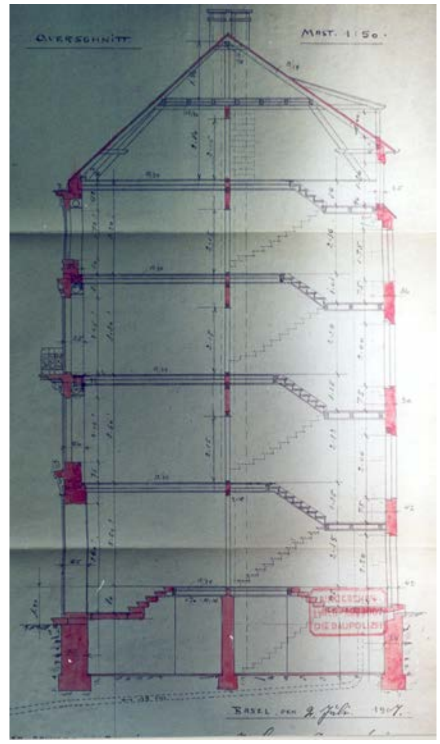

Figure 2: Perspective Drawing Showing Key Load-Bearing Elements

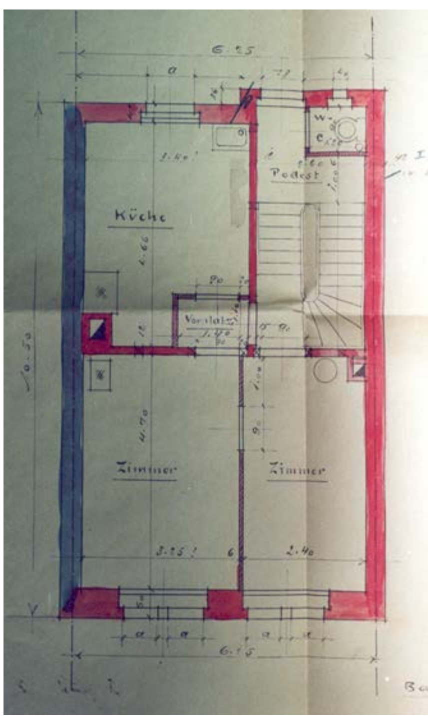

Figure 3: Plan of a Typical Building

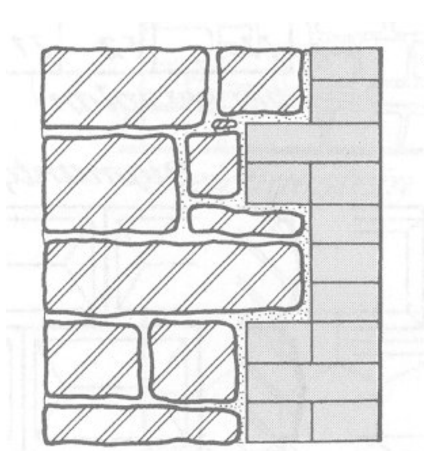

Figure 4: Wall section of mixed masonry walls

Figure 5: Illustration of Seismic Strengthening Techniques

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They share common walls with adjacent buildings. The buildings are typically joined together so there is no separation distance When separated from adjacent buildings, the typical distance from a neighboring building is 0 meters.

2.2 Building Configuration

The buildings are rather regular in plan with a rectangular shape. The openings for window and doors are positioned only at the front and back facades. At each floor there is typically a window every 2.5 to 2.8 meters. For typical building widths of 6 or 9 meters, there are two or three windows at the back and two or three windows at the front façade wall per story, with a total window area of about 20% of the façade walls (10% considering the overall wall surface area including the fire division walls between the buildings which have no openings).

2.3 Functional Planning

The main function of this building typology is multi-family housing. In most cases the buildings are pure residential buildings, and only in some cases the ground floor is used for a commercial purpose. In these cases the windows at the ground floor were often enhanced afterwards. In a typical building of this type, there are no elevators and no fire-protected exit staircases. Usually there is only one major stair case leading from the main entrance at the front to the apartment doors. But there is usually an additional entrance to the backyard.

2.4 Modification to Building

Usually, modernizations of kitchens and bathrooms have been introduced. In the case where the ground floor is used for a commercial purpose, the ground floor windows are often enlarged and interior walls are replaced by columns of steel or reinforced concrete.

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)	☐

Often a combination of different types of stones and brick was used. The mortar used is usually lime mortar.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). The unreinforced masonry walls also act as the gravity load-bearing structure to which the loads are transmitted by the timber floors.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). The lateral load-resisting system consists of unreinforced masonry walls. Various types of unreinforced masonry were used: Bricks, simple stone and rubble stone. Also a combination of different masonry was used. The type of masonry was used in specific buildings is generally not identifiable because of the plaster finish. Often for the outer layer of the façade walls, larger cut stones are used, especially at the lower floors, with simple stones (more or less regular) or bricks arranged behind. The mortar used is usually lime mortar.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 12 meters, and widths between 8 and 9 meters. The building has 4 to 5 storey(s). The typical span of the roofing/flooring system is 5 meters. Typical Story Height: Typical story heights range between 2.8 and 3.5 m. The story height of the ground floor is often bigger than the story height of the upper floors. Typical Span: Typical spans range from 4 to 6 m. The typical storey height in such buildings is 3 meters. The typical structural wall density is none. Ratio of the wall area to the plan area: Ground floor: Walls parallel to the façade=0.064; Walls orthogonal to the façade walls=0.064; Total wall area (sum of both directions)/plan area=0.128; Upper floors: Walls parallel to the façade=0.05; Walls orthogonal to the façade=0.055; Total wall area (sum of both directions)/plan area=0.105.

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	☑	☑

The floor above the basement consists sometimes of a vaulted system whereas for the upper floors and the roof, timber beam construction is used. The timber floors do not act as rigid diaphragms. In addition the timber beams are often not anchored to the masonry walls.

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	☐

The buildings usually have a basement. The walls from the upper floors rest on the basement walls which are made of brick or simple stone masonry with lime mortar; towards the end of the 19th century rammed concrete was also used. The basement walls rest on isolated or strip footings of masonry and later of rammed concrete. Rammed concrete started being used for foundation footings at the end of the 19th century. Instead of cement, often hydraulic limes were used as a matrix.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 5-10 housing unit(s). 4-5 units in each building. The number of units are given for a typical building with 4 to 5 stories and a building width of about 6 to 9 meters. For buildings with larger width the number of apartments increases respectively. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 11-20.

4.2 Patterns of Occupancy

There is typically one apartment per floor.

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 ratio of house price / annual income is given for one apartment. It ranges from 5/1 - 6/1. Economic Level: The ratio of price of housing price unit to the annual income can be 5:1 for middle class 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 4 bathroom(s) without toilet(s), no toilet(s) only and 4 bathroom(s) including toilet(s).

1 bathroom/apartment: 4 to 5 bathrooms per building. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) , individual ownership and ownership by a group or pool of persons.

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)	☐

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	Lateral load path: The load path from the walls to the ground is guaranteed. However, since the timber floors are generally not anchored to the walls, the load path from the floors to the walls may not be given. Building configuration: In the original configuration (as built) the buildings are regular with regards to both the plan and the elevation. However, in the cases where alterations were made at the ground floor in order to accommodate shops, the resulting ground floor is often less stiff then the upper stories. Wall proportions: the height to thickness ratio of the façade walls is always less than 13. However, for inner walls the ratio can be up to 26. Quality of building material: The use of lime mortar is no longer allowed by the codes in Switzerland.

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	--Low compressive strength due to the use of lime mortar. --Low level of bond between larger cut stones and less well cut stones or bricks in mixed masonry walls.	--High thicknesses of the outer walls (facades and fire division walls).	--Diagonal shear cracks. --In cases of poor bond: disintegration of the masonry wall.
Frame (Columns, beams)			
Roof and floors	--Floors are usually not anchored to the walls. --Flexible floor diaphragm.		--Slippage of the beams from their support leading to partial or total collapse of floors. --Out-of-plane failure of walls, leading also to collapse of floors.
Other		--Rather stiff basement allowing the forces to be transmitted to the ground.	

No damaging earthquake has occurred in Switzerland in recent decades which has damaged this specific building type. The damage patterns stated are typical damage patterns to be expected.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is A: HIGH VULNERABILITY (i.e., very 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 B: MEDIUM-HIGH VULNERABILITY (i.e., poor 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

No Earthquake has occurred in Switzerland in recent decades which has damaged this specific building type.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Unreinforced masonry with lime mortar	Brick: comp. 1.2 - 1.6 MPa; Simple stone: comp. 0.8 - 1.6 MPa	Lime mortar 1:3	
Foundation	Unreinforced masonry with lime mortar Unreinforced Concrete	Brick: comp. 1.2 - 1.6 MPa; Simple stone: comp. 0.8 - 1.6 MPa Comp. 5 - 20 MPa	Lime mortar 1:3 (matrix: sand) 1:3 - 1:10; since 1903 (first provisional code in Switzerland): 1:2:4	
Frames (beams & columns)				
Roof and floor(s)	Timber	Flexural tensile strength in the direction of the fibre: 40 - 50 MPa		Depends on type of timber

6.2 Builder

This type of building is not built anymore.

6.3 Construction Process, Problems and Phasing

This type of building is not built anymore. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. Some buildings would have undergone alterations at the ground floor to accommodate shops. Refurbishments usually concern the interior. Additional stories are usually not added.

6.4 Design and Construction Expertise

The buildings were built in the 19th century and the design was usually based on experience (i.e. thickness of walls required for a certain building height, etc.). The strengthening design would be done by an engineer. The architect would typically get involved if refurbishment is planned.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Swiss Standard SIA 266 "Masonry" (current standard). The year the first code/standard addressing this type of construction issued was 1943. The current Swiss Standard for unreinforced masonry is SIA 266 "Masonry", issued in 2003. However, the addressed building type was built before the first standard for masonry structures was issued in 1943 (Swiss Standard SIA 113). The type of masonry used at that time is no longer allowed. The most recent code/standard addressing this construction type issued was 2003. The current Swiss Standard for unreinforced masonry is SIA 266 "Masonry", issued in 2003. However, the addressed building type was built before the first standard for masonry structures was issued in 1943 (Swiss Standard SIA 113). The type of masonry used at that time is no longer allowed. recent code/standard addressing this construction was issued: 2003.

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).

6.8 Construction Economics

This type of building was built more than 100 years ago. An equivalent building in Switzerland (4-5 stories of unreinforced masonry) would cost today: 1000 - 1400 USD/m2 for structural system only 3000 - 4200 USD/m2 for entire building (with installations etc.). This type of building is no longer built. For an equivalent building the labor requirements would be: Ca. 10 weeks for the structural system (with 4-6 workers) Ca. 20-30 weeks for entire buildings (with installations etc.).

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. The ordinary building insurances in Switzerland do not include earthquakes. However, specific earthquake insurances are available. The premium discounts usually depends on the value of the building and the franchise. The basic earthquake insurance normally includes damages to the building (structural and nonstructural elements) including indirect damages due to water and fire. Additional coverage can be obtained for building content, lost rent, demolishing of heavily damaged buildings, etc.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Lack of Structural Integrity: --Floors are usually not anchored to the walls. --Flexible floor diaphragm.	--Anchoring of timber floor beams to the walls. --Introduction of ringbeams.
--Low compressive strength. --Inadequate bond	--Grouting. --Application of external reinforcement. --Application of CFK (carbon fibre plates) lamellae.

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?
So far, in Switzerland only the seismic strengthening using CFK lamellae (in some cases prestressed) has been used to increase the shear resistance of unreinforced masonry buildings (not necessarily the building type described).

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
The seismic strengthening was only applied on undamaged buildings.

8.3 Construction and Performance of Seismic Strengthening

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

The strengthening design is performed by an engineer.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
There is no experience, since no earthquake has occurred in Switzerland in recent times which has damaged the specific building type. Tests on masonry walls strengthened with CFK lamellae showed an improvement of the shear resistance of the walls. An important issue concerning this type of strengthening is the anchorage of the lamellae.

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