Glossary for the GEM Building Taxonomy

GEM TECHNICAL REPORT
2013-03 V1.0.0

L. Allen, A.W. Charleson, S. Brzev, C. Scawthorn

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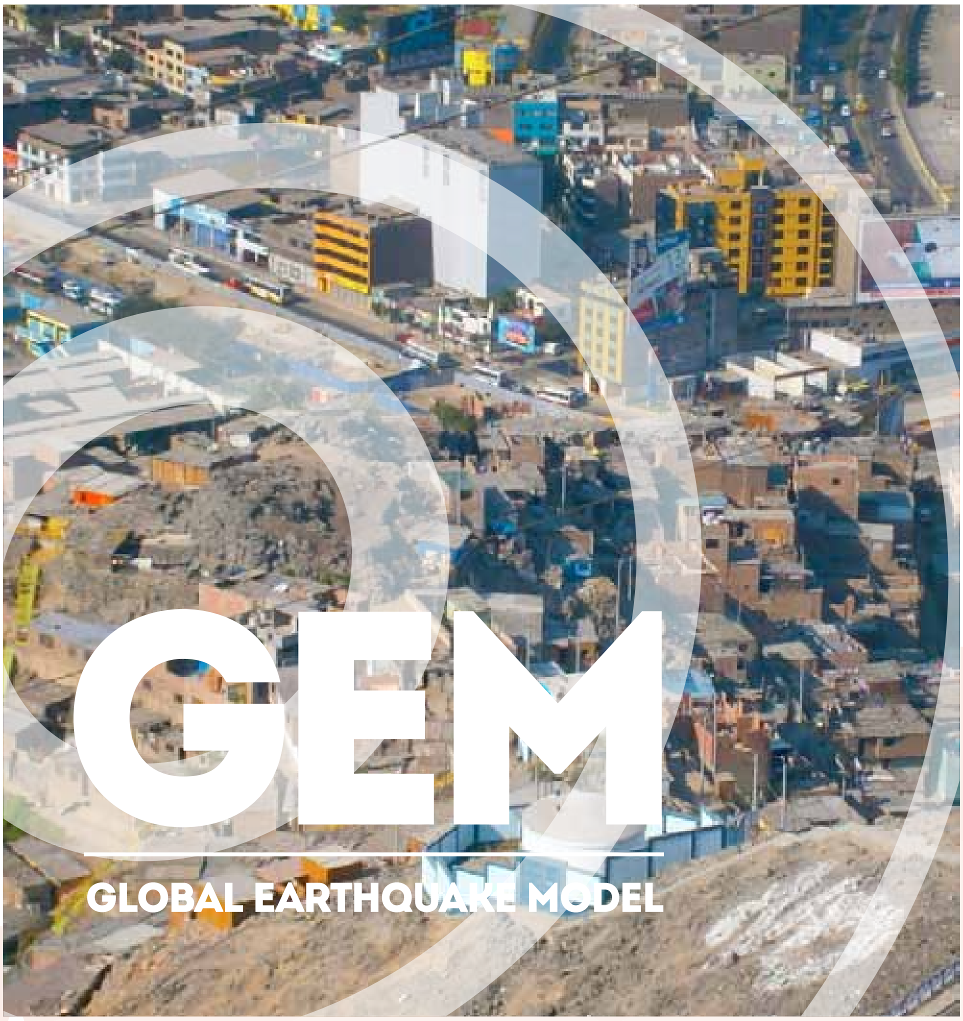

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GEM Technical Report 2013-03

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Graphical illustrations are critical for the effectiveness of the Glossary keeping in mind its diverse global audience. The authors have made an effort to contribute photographs from their own image collections, and numerous diagrams were drawn and adapted by Luke Allen. However, several individuals and organizations also contributed photographs and other illustrations included in the Glossary. The following 69 individuals from 27 countries have contributed photographs for the Glossary: A.Mahdizadeh (Iran); M.Yekrangnia (Iran); B.A.Bakshi (Iran); M.A.Ghanad (Iran); Alberto Cuevas Ramirez (Costa Rica); Amit Kumar (Tajikistan); Andrea Benedetti (Italy); Anna Lang (USA); Antonios Pomonis (Greece); Ayhan Irfanoglu (USA); Ben Benjamin (Canada); Bill McEwen (Canada); C.V.R. Murty (India); Cesar Loaiza (Peru); Gianfranco Ottazzi (Peru); Chitr Lilavivat (Thailand); David Bonowitz (USA); Durgesh Rai (India); Ja'far Niyazov (Tajikistan); Ljubisav Stamenic (Serbia); Mohammed Farsi (Algeria); Nebojsa Ojdrovic (Canada); Dustin Willms (Canada); Eric Lehmkuhl (USA); George C. Yao (Taiwan); M. S. Sheu (Taiwan); Hayley Dickson (USA); James K.W. Lee (Canada); Jitendra Bothara (New Zealand); John Adams (Canada); John Sherstobitoff (Canada); Jose Centeno (Canada); Junwu Dai (China); Keith Porter (USA); Ken Elwood (Canada); Kishor Jaiswal (USA); Luis Gonzalo Mejia (Colombia); Marcial Blondet (Peru); Maria Ofelia Moroni Yadlin (Chile); Cristian Gomez (Chile); Maximiliano Astroza (Chile); Marjana Lutman (Slovenia); Martijn Schildkamp (Netherlands); Mauro Sassu (Italy); Ignasio Ngoma (Malawi); Mehrdad Mehrain (USA); Farzad Naeim (USA); Miha Tomazevic (Slovenia); Muhammad Masood Rafi (Pakistan); Nicola Tarque (Peru); Polat Gulkan (Turkey); Mark Aschheim (USA); Robin Spence (United Kingdom); Masayoshi Nakashima (Japan); Radovan Dimitrijevic (Serbia); Sarosh H.Lodi (Pakistan); Sava Krstic (USA); Sinisa Mihaldzic (Canada); T. P. Tassios (Greece); Kostas Syrmakezis (Greece); Tom Abbuhl (Canada); Tom Schacher (Switzerland); Ulugbek T. Begaliev (Kyrgyzstan); Vivek Rawal (India); Win Clark (New Zealand); Yogeshwar K. Parajuli (Nepal); Bijay K. Upadhyay (Nepal); Kanat Kanbolotov (Kyrgyzstan); and Marija Brzev (Canada).

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ABSTRACT

The Glossary for the GEM Basic Building Taxonomy (the Glossary) has been developed as a companion to the GEM Building Taxonomy v2.0 (the Taxonomy). The purpose of the GEM Building Taxonomy is to describe and classify buildings in a uniform manner as key step toward assessing their seismic risk. The Glossary provides definitions for all attributes contained in the Taxonomy. The Glossary is intended to be referred to in conjunction with the Taxonomy, and its main purpose is to explain and clarify the meaning of attributes and their details for users. Each Glossary term contains a text description, and most terms contain one or more illustrations (photos and/or drawings). The Glossary includes more than 370 terms and 760 illustrations.

The Glossary is currently presented in two forms: an interactive online version and this report version. The online version is posted on the NEXUS platform and is suitable for alphabetical search[1]. All glossary terms are also hyperlinked from the attributes in the Taxonomy tables[2]. In the report version presented in this document, the Glossary definitions are listed in alphabetical order, followed by the Taxonomy tables, which are included in the appendix.

Members of the GEM community are invited to enrich the Glossary by contributing their photographs[3]. Feedback can be submitted in the Comments section of each web-based definition, and comments of a more general nature can be submitted directly to the authors via NEXUS platform.

Keywords

buildings, taxonomy, glossary, attributes, terminology, earthquakes

[1] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview/glossary
[2] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview
[3] http://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview/gem-building-taxonomy-photo-contribution-guideline

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	iii
ABSTRACT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xv
10-19 Units [RES2D]	1
2 Units (duplex) [RES2A]	2
20-49 Units [RES2E]	3
3-4 Units [RES2B]	4
5-9 Units [RES2C]	5
50+ Units [RES2F]	6
Adjoining building(s) on one side [BP1]	7
Adjoining buildings on three sides [BP3]	10
Adjoining buildings on two sides [BP2]	11
Adobe blocks [ADO]	14
Agricultural processing [AGR3]	17
Agriculture [AGR]	18
Agriculture, unknown type [AGR99]	19
Airport [COM10]	20
Animal shelter [AGR2]	21
Approximate date of construction or retrofit [YAPP]	22
Approximate height of ground floor level above grade [HFAPP]	23
Approximate number of storeys above ground [HAPP]	24
Approximate number of storeys below ground [HBAPP]	25
Arena [ASS2]	26
Assembly [ASS]	27
Assembly, unknown type [ASS99]	28
Bamboo [WBB]	29
Bamboo, cane or rope reinforced [RB]	30
Bamboo, straw or thatch roof [RWO5]	32
Basalt [SPBA]	33
Bolted connections [BOL]	35
Braced frame [LFBR]	36
Building occupancy class - detail	42
Building occupancy class - general	43
Building position within a block	44
Bus station [COM8]	45
Cast-in-place beam-supported reinforced concrete floor [FC2]	46
Cast-in-place beam-supported reinforced concrete roof [RC2]	48
Cast-in-place beamless reinforced concrete floor [FC1]	50
Cast-in-place beamless reinforced concrete roof [RC1]	52
Cast-in-place concrete [CIP]	54

Cast-in-place prestressed concrete [CIPPS] 56
Cement-based boards for exterior walls [EWCB] 58
Cement:lime mortar [MOCL] 59
Cement mortar [MOC] 60
Change in vertical structure (includes large overhangs) [CHV] 61
Cinema or concert hall [ASS3] 66
Clay or concrete tile roof covering [RMT1] 67
Cob or wet construction [ETC] 68
Cold-formed steel members [SL] 70
College/university, offices and/or classrooms [EDU3] 72
College/university, research facilities and/or labs [EDU4] 73
Commercial and public [COM] 74
Commercial and public, unknown type [COM99] 75
Complex irregular [RSH9] 76
Complex regular [RSH8] 77
Composite cast-in-place reinforced concrete and masonry floor system [FM3] 79
Composite masonry and concrete roof system [RM3] 80
Composite steel floor deck and concrete slab [FME3] 81
Composite steel roof deck and concrete slab [RME3] 82
Concrete blocks, hollow [CBH] 83
Concrete blocks, solid [CBS] 84
Concrete blocks, unknown type [CB99] 85
Concrete blocks 86
Concrete, composite with steel section [SRC] 87
Concrete exterior walls [EWC] 88
Concrete floor [FC] 90
Concrete floor, unknown [FC99] 91
Concrete, reinforced [CR] 92
Concrete roof [RC] 94
Concrete roof, unknown [RC99] 95
Concrete roof without additional covering [RMN] 96
Concrete, unknown reinforcement [C99] 97
Concrete, unreinforced [CU] 98
Concrete 99
Covered parking garage [COM7] 100
Cripple wall [CRW] 101
Curved [RSH7] 102
Curved, solid [PLFC] 104
Curved, with an opening in plan [PLFCO] 105
Date of construction or retrofit 106
Deep foundation, no lateral capacity [FOSDN] 107
Deep foundation, with lateral capacity [FOSDL] 108
Description of the direction 109
Detached building [BPD] 110
Direction of the building 112
Direction X 113
Direction Y 114

Direction	115
Dressed stone [STDRE]	117
Dual frame-wall system [LDUAL]	118
Ductile [DUC]	121
Ductility unknown [D99]	124
E-shape [PLFE]	126
Earth, reinforced [ER]	127
Earth technology, other [ETO]	128
Earth, unknown reinforcement [E99]	129
Earth, unreinforced [EU]	130
Earth	131
Earthen exterior walls [EWE]	132
Earthen floor [FE]	134
Earthen floor, unknown [FE99]	135
Earthen roof [RE]	136
Earthen roof covering [RMT9]	137
Earthen roof, unknown [RE99]	138
Education [EDU]	139
Education, unknown type [EDU99]	140
Entertainment [COM5]	141
Equipped with base isolation and/or energy dissipation devices [DBD]	142
Exact date of construction or retrofit [YEX]	146
Exact height of ground floor level above grade [HFEX]	147
Exact number of storeys above ground [HEX]	148
Exact number of storeys below ground [HBEX]	149
Exterior walls	150
Fabric [RFA]	151
Fabric roof, other [RFAO]	152
Fibre cement or metal tile roof covering [RMT2]	153
Fibre reinforcing mesh [RCM]	154
Fired clay hollow blocks or tiles [CLBLH]	156
Fired clay hollow bricks [CLBRH]	159
Fired clay solid bricks [CLBRS]	160
Fired clay unit, unknown type [CL99]	162
Fired clay	163
Flat [RSH1]	164
Flat slab/plate or waffle slab [LFLS]	165
Floor connections	172
Floor material, other [FO]	173
Floor material, unknown [F99]	174
Floor system material	175
Floor system type	176
Floor-wall diaphragm connection not provided [FWCN]	177
Floor-wall diaphragm connection present [FWCP]	181
Floor-wall diaphragm connection unknown [FWC99]	185
Floor	186
Foundation, other [FOSO]	187

Foundation System	188
Glass exterior walls [EWG]	189
Government [GOV]	191
Government emergency response [GOV2]	192
Government general services [GOV1]	193
Government, unknown type [GOV99]	194
Granite [SPGR]	195
Ground floor	197
H-shape [PLFH]	198
Heavy Industrial [IND1]	199
Heavy wood [WHE]	200
Height of ground floor level above grade [HF]	201
Height of ground floor level above grade unknown [HF99]	202
Height	203
Hospital/medical clinic [COM4]	204
Hot-rolled steel members [SR]	205
Hybrid lateral load-resisting system [LH]	207
Industrial [IND]	213
Industrial, unknown type [IND99]	214
Infilled flat slab/plate or infilled waffle slab [LFLSINF]	215
Infilled frame [LFINF]	217
Inflatable or tensile membrane roof [RFA1]	222
Informal housing [RES6]	223
Institutional housing [RES4]	224
Iron [MEIR]	225
Irregular plan shape [PLFI]	226
Irregular structure [IRIR]	227
L-shape [PLFL]	228
Lateral load-resisting system	229
Latest possible date of construction or retrofit [YPRE]	230
Light industrial [IND2]	231
Light wood members [WLI]	232
Lime mortar [MOL]	233
Limestone [SPLI]	234
Masonry, confined [MCF]	239
Masonry exterior walls [EWMA]	242
Masonry floor [FM]	248
Masonry floor, unknown [FM99]	249
Masonry, reinforced [MR]	250
Masonry reinforcement, unknown [MR99]	253
Masonry roof [RM]	254
Masonry roof, unknown [RM99]	255
Masonry unit, other [MO]	256
Masonry unit, unknown [MUN99]	257
Masonry, unknown reinforcement [M99]	258
Masonry, unreinforced [MUR]	259
Material of exterior wall, other [EWO]	262

Material of the lateral load-resisting system	263
Material properties	264
Material technology	265
Material type	266
Membrane roof covering [RMT3]	267
Metal beams or trusses supporting light roofing [RME1]	268
Metal beams, trusses or joists supporting light flooring [FME1]	270
Metal (except steel) [ME]	271
Metal exterior walls [EWME]	272
Metal floor [FME]	274
Metal floor beams supporting precast concrete slabs [FME2]	275
Metal floor, unknown [FME99]	276
Metal or asbestos sheets [RMT6]	277
Metal, other [MEO]	279
Metal roof [RME]	280
Metal roof beams supporting precast concrete slabs [RME2]	281
Metal roof, unknown [RME99]	282
Metal, Unknown [ME99]	283
Mixed, unknown type [MIX99]	284
Mixed use [MIX]	285
Mobile home [RES5]	286
Moment frame [LFM]	287
Monopitch [RSH5]	291
Mortar type unknown [MO99]	292
Mortar	293
Mostly commercial and industrial [MIX3]	294
Mostly commercial and residential [MIX2]	295
Mostly industrial and commercial [MIX5]	296
Mostly industrial and residential [MIX6]	297
Mostly residential and commercial [MIX1]	298
Mostly residential and industrial [MIX4]	299
Mud mortar [MOM]	300
Multi-unit, unknown type [RES2]	301
No elevated or suspended floor material [FN]	302
No irregularity [IRN]	303
No lateral load-resisting system [LN]	304
No mortar [MON]	306
Non-ductile [DNO]	307
Number of storeys above ground [H]	311
Number of storeys below ground [HB]	312
Number of storeys below ground unknown [HB99]	313
Number of storeys unknown [H99]	314
Number of storeys	315
Occupancy	316
Offices, professional/technical services [COM3]	317
Other gatherings [ASS4]	318
Other lateral load-resisting system [LO]	319

Other material [MATO] 320
Other occupancy type [OCO] 321
Other plan irregularity [IRHO] 322
Other vertical irregularity [IRVO] 323
Parallel to street [PF] 324
Perpendicular to street [OF] 325
Pitched and hipped [RSH3] 326
Pitched with dormers [RSH4] 327
Pitched with gable ends [RSH2] 328
Plan irregularity or vertical irregularity 329
Plan irregularity-primary [IRPP] 330
Plan irregularity-secondary [IRPS] 331
Plastic/vinyl exterior walls, various [EWPL] 332
Plywood panels or other light-weight panels for floor [FW4] 333
Plywood panels or other light-weight panels for roof [RWO4] 334
Polygonal, solid (e.g. trapezoid, pentagon, hexagon) [PLFP] 335
Polygonal, with an opening in plan [PLFPO] 336
Post and beam [LPB] 337
Pounding potential [POP] 338
Pre-school facility [EDU1] 345
Precast concrete [PC] 346
Precast concrete floor with reinforced concrete topping [FC3] 350
Precast concrete floor without reinforced concrete topping [FC4] 355
Precast concrete roof with reinforced concrete topping [RC3] 356
Precast concrete roof without reinforced concrete topping [RC4] 358
Precast prestressed concrete [PCPS] 359
Produce storage [AGR1] 360
Public building [COM6] 361
Railway station [COM9] 362
Rammed earth [ETR] 363
Range of height of ground floor level above grade [HFBET] 365
Range of number of storeys above ground [HBET] 366
Range of number of storeys below ground [HBBET] 367
Re-entrant corner [REC] 368
Recreation and leisure [COM11] 370
Rectangular, solid [PLFR] 371
Rectangular, with an opening in plan [PLFRO] 372
Regular or irregular 373
Regular structure [IRRE] 374
Reinforced concrete bands [RCB] 375
Religious gathering [ASS1] 376
Residential [RES] 377
Residential, unknown type [RES99] 378
Retail trade [COM1] 379
Riveted connections [RIV] 380
Roof connections 381
Roof covering, other [RMTO] 382

Roof covering 383
Roof material, other [RO] 384
Roof material, unknown [R99] 385
Roof shape, other [RSHO] 386
Roof shape 387
Roof system material 388
Roof system type 389
Roof tie-down not provided [RTDN] 390
Roof tie-down present [RTDP] 391
Roof tie-down unknown [RTD99] 393
Roof-wall diaphragm connection not provided [RWCN] 394
Roof-wall diaphragm connection present [RWCP] 397
Roof-wall diaphragm connection unknown [RWC99] 399
Roof 400
Rubble (field stone) or semi-dressed stone [STRUB] 401
S-shape [PLFS] 406
Sandstone [SPSA] 407
Sawtooth [RSH6] 411
School [EDU2] 412
Setback [SET] 413
Shallow-arched masonry floor [FM2] 415
Shallow-arched masonry roof [RM2] 416
Shallow foundation, no lateral capacity [FOSN] 417
Shallow foundation, with lateral capacity [FOSSL] 418
Shape of the building plan 420
Short column [SHC] 421
Single dwelling [RES1] 423
Slate [SPSL] 424
Slate roof covering [RMT4] 426
Slope of the ground [HD] 427
Slope of the ground - general 428
Slope of the ground unknown [HD99] 429
Soft storey [SOS] 430
Solar panelled roofs [RMT10] 435
Solid wood [WS] 437
Square, solid [PLFSQ] 439
Square, with an opening in plan [PLFSQO] 440
Steel [S] 441
Steel connections, unknown [SC99] 442
Steel, other [SO] 443
Steel-reinforced [RS] 444
Steel, unknown [S99] 445
Stone masonry 446
Stone, other type [SPO] 447
Stone slab roof covering [RMT5] 449
Stone, unknown technology [ST99] 450
Stone, unknown type [SP99] 451

Structural irregularity 452
Stucco finish on light framing for exterior walls [EWSL] 453
System ductility 454
T-shape [PLFT] 455
Temporary lodging [RES3] 456
Tensile membrane or fabric roof [RMT11] 457
Torsion eccentricity [TOR] 458
Triangular, solid [PLFD] 462
Triangular, with an opening in plan [PLFDO] 463
Tuff [SPTU] 464
Type of irregularity 466
Type of lateral load-resisting system 467
U- or C-shape [PLFU] 468
Unknown concrete technology [CT99] 469
Unknown earth technology [ET99] 470
Unknown foundation system [FOS99] 472
Unknown lateral load-resisting system [L99] 473
Unknown material [MAT99] 474
Unknown material of exterior walls [EW99] 475
Unknown occupancy type [OC99] 476
Unknown plan shape [PLF99] 477
Unknown roof covering [RMT99] 478
Unknown roof shape [RSH99] 479
Unknown structural irregularity [IR99] 480
Unspecified direction [D99] 481
Upper and lower bound for the date of construction or retrofit [YBET] 482
Vaulted earthen roofs [RE1] 483
Vaulted masonry floor [FM1] 484
Vaulted masonry roof [RM1] 485
Vegetative exterior walls [EWV] 487
Vegetative roof covering [RMT8] 488
Vertical structural irregularity - primary [IRVP] 489
Vertical structural irregularity - secondary [IRVS] 490
Wall [LWAL] 491
Wattle and daub [WWD] 497
Welded connections [WEL] 499
Wholesale trade and storage (warehouse) [COM2] 500
Wood [RWO] 501
Wood [W] 502
Wood-based sheets on joists or beams [FW3] 503
Wood-based sheets on rafters or purlins [RWO3] 504
Wood, other [WO] 505
Wood-reinforced [RW] 506
Wood, unknown [W99] 510
Wooden beams or trusses and joists supporting heavy flooring [FW2] 511
Wooden beams or trusses and joists supporting light flooring [FW1] 512
Wooden beams or trusses with heavy roof covering [RWO2] 513

Wooden exterior walls [EWW]	516
Wooden floor [FW]	518
Wooden floor, unknown [FW99]	519
Wooden or asphalt shingle roof covering [RMT7]	520
Wooden roof, unknown [RWO99]	521
Wooden structure with light roof covering [RWO1]	522
X-shape [PLFX]	527
Y-shape [FLPY]	528
Year unknown [Y99]	529
REFERENCES	531
APPENDIX A GEM Building Taxonomy Attributes	A.1

LIST OF TABLES

Table G1 GEM Building Taxonomy: Attributes A.1
Table 1: Direction A.3
Table 2: Material of the Lateral Load-Resisting System A.4
Table 3: Lateral Load-Resisting System A.7
Table 4: Height A.8
Table 5: Date of Construction or Retrofit A.11
Table 6: Occupancy A.12
Table 7: Building Position within a Block A.16
Table 8: Shape of the Building Plan A.17
Table 9: Structural Irregularity A.18
Table 10: Exterior Walls A.20
Table 11: Roof A.21
Table 12: Floor A.24
Table 13: Foundation System A.26

10-19 Units [RES2D]

Apartments, condominiums, townhouses of 10-19 units. Residential units are structurally connected.

2 Units (duplex) [RES2A]

Two residential units joined together. Can be stacked vertically, or joined horizontally as two semi-detached houses.

20-49 Units [RES2E]

Apartments, condominiums, townhouses of 20-49 units. Residential units are structurally connected.

3-4 Units [RES2B]

Apartments, condominiums, townhouses of 3-4 units. Residential units are structurally connected.

5-9 Units [RES2C]

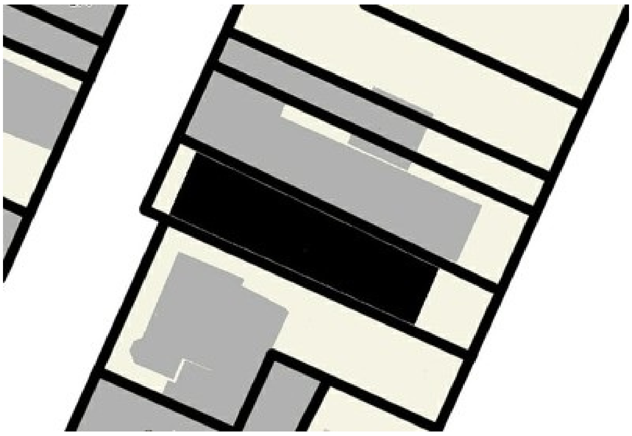
Apartments, condominiums, townhouses of 5-9 units. Residential units are structurally connected.

50+ Units [RES2F]

Apartments, condominiums, tow nhouses of 50+ units. Residential units are structurally connected.

Adjoining building(s) on one side [BP1]

The building has adjoining or attached building(s) **on one side**; this includes corner buildings (end buildings w ithin a block) and semi-detached buildings (w ith tw o housing units).



The building show n in black in this plan view has an adjoining building on one side.

An example of a building w ithin a block w ith adjoining buildings on one side, Vancouver, Canada (left photo: S. Brzev, right: Map data ©2013 Google, DigitalGlobe)

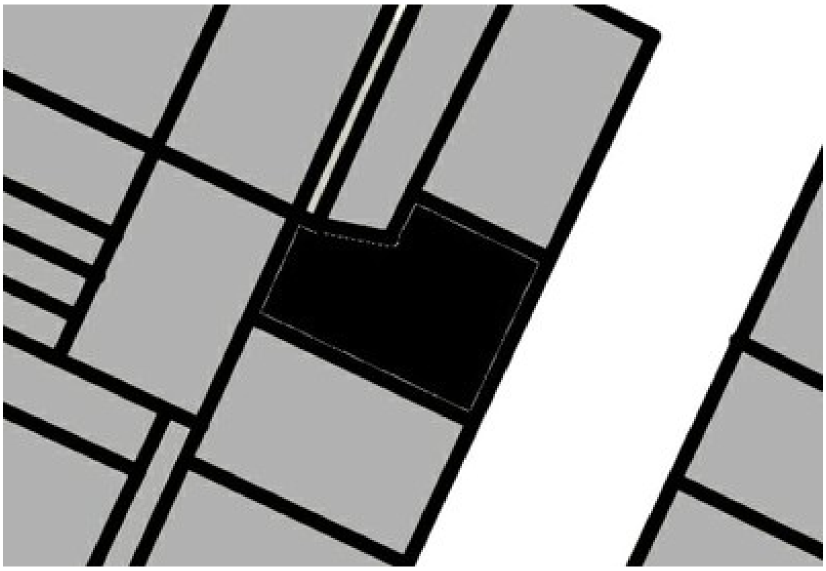
Semi-detached tow nhouse, adjoining building on one side, New Zealand (L. Allen).

Semi-detached house, adjoining building on one side, Constitution, Chile (S. Brzev).

A building on a corner, w ith an adjoining building on one side, Seattle, USA (S. Brzev).

Adjoining buildings on three sides [BP3]

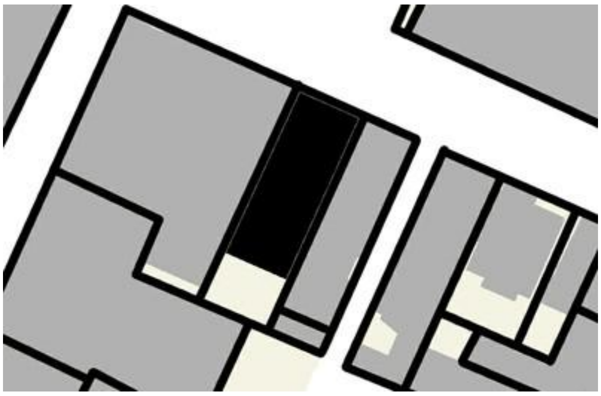
The building has adjoining or attached buildings on three sides (typically one building on each side, and one behind). An example is a building w ithin a block, that is also adjacent to a building in the back.



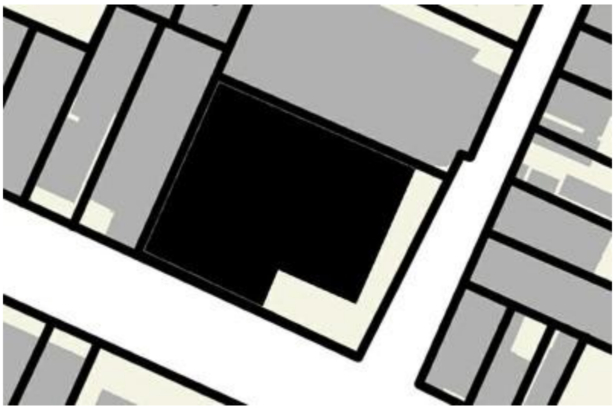
The building show n in black in this plan view has adjoining buildings on three sides.

Adjoining buildings on two sides [BP2]

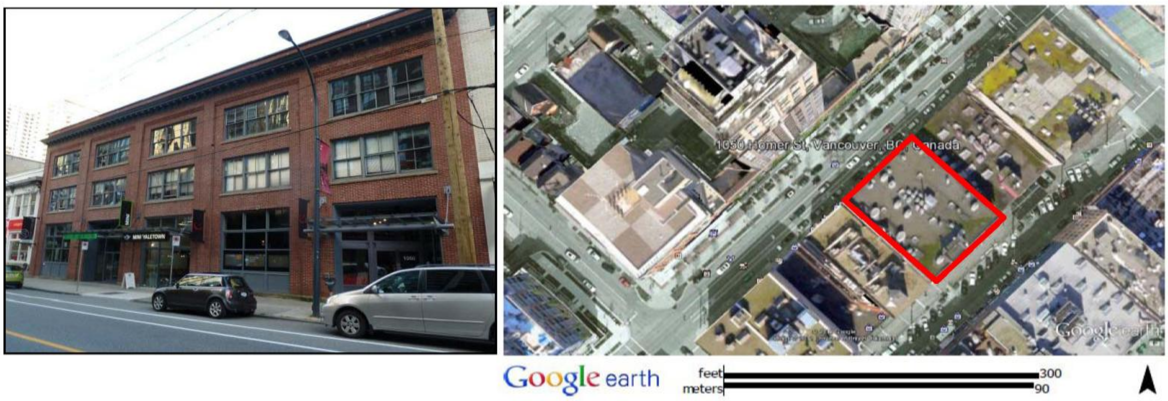
A building, usually located on a street corner, with adjoining or attached buildings **on two sides**. This includes mid-terrace buildings, buildings which are a part of the row of at least three buildings, or corner buildings with adjoining buildings on two perpendicular sides.



Example 1: the building shown in black in this plan is located within a block and it has adjoining buildings on two sides.



Example 2: the building shown in black in this plan view is located on a corner and has adjoining buildings on two perpendicular sides.



An example of a building within a block with adjoining buildings on two sides, Vancouver, Canada (left photo: S. Brzev, right: Map data ©2013 Google, Province of British Columbia, DigitalGlobe)

A corner building with adjoining buildings on two perpendicular sides, New Zealand (L. Allen).

A corner building with adjoining buildings on two perpendicular sides, Talca, Chile (S. Brzev).

Terrace housing with adjoining houses on two sides, New Zealand (L. Allen)

A midrise building in Santiago, Chile with adjoining low-rise buildings on two sides (S. Brzev)

Adobe blocks [ADO]

Sun-dried (or air-dried), unfired mud (clay) masonry, w here the clay is cast into blocks (and sometimes into bricks) and then laid, as opposed to w alls constructed in-place out of earth, as in earth construction (cob or rammed earth). Adobe blocks can be used both in unreinforced and reinforced masonry construction. Several types of reinforcement are available, including w ood, bamboo/cane, or fibre reinforcing mesh.

Adobe blocks are commonly used for single-family housing in Peru (N. Tarque)

Tw -storey adobe building in Cuzco, Peru (S. Brzev)

Adobe house, Iran (A. Bakshi, M.A.Ghannad, and M. Yekrangnia)

Adobe construction, Tajikistan (J. Niyazov)

Manufacturing of adobe blocks, Peru (left - M. Blondet) and different sizes of adobe blocks (right- S. Brzev)

Adobe blocks of different shapes and sizes, Peru (S. Brzev)

New adobe w all, Chile (S.Brzev)

Existing adobe buildings built in early 1900s in Chile (left) and a building damaged in the 2010 Maule earthquake (right) (S. Brzev)

Agricultural processing [AGR3]

A building used for any agricultural process. This includes sorting of produce, milking of cow s, abattoirs.

Agriculture [AGR]

The building is used for farming and produce grow ing purposes.

Agriculture, unknown type [AGR99]

The building is used for agriculture, but it is not know n w hat type of agricultural use.

Airport [COM10]

A building or group of buildings that accompany a landing strip for aircraft, for loading and unloading of passengers.

Animal shelter [AGR2]

A building in w hich animals are reared, or w here they take shelter.

Approximate date of construction or retrofit [YAPP]

This is the best estimate of construction date if it is not know n precisely. E.g. the construction likely took place betw een 1930 and 1940, so the year entered is 1935.

Approximate height of ground floor level above grade [HFAPP]

The approximate height of the ground floor above grade can be determined by the surveyor w here the exact height is not clear from survey or draw ing.
Units: metres

Example: HFAPP:0.5 (approximately 0.5 m)

Approximate number of storeys above ground [HAPP]

An approximate number of storeys above ground can be determined by the surveyor w here the exact number of storeys above ground is not clear from survey or draw ing. The number of the floors above ground includes the ground floor and floors above. It also includes storage and mechanical plant levels only if these cover over 50% of the plan area, but does not include basements below ground. If the building is stepped in height, then record the highest part.

HAPP:n
w here n = approximate number of storeys above ground level (integer)
Example: HAPP:2 (approximately tw o-storey high building)

This building in Manilla, Philippines is approximately 20 storeys high (C. Scaw thorn)

Approximate number of storeys below ground [HBAPP]

An approximate number of storeys below ground can be determined by the surveyor w here the exact number of storeys above ground is not clear from survey or draw ing. This does not include the ground floor. It includes storage and mechanical plant levels only if these cover over 50% of the plan area.

Arena [ASS2]

A large sporting venue w ith seating for more than 1000 spectators. Seating can be indoor or outdoors.

Refer also to Recreation and Leisure for sporting venues w ith few er spectators.

Assembly [ASS]

The building is a place of w orship, or a membership organisation such as a club or society.

Assembly, unknown type [ASS99]

It is clear that the building is a building used for religion or non-profit organisations, but the exact type of this use is unknown.

Bamboo [WBB]

Hollow -stemmed plant. Its stiff tubular stems, sometimes up to 150-200mm diameter, are used as a building material. It is commonly used as split and w oven construction, in the form of trusses and frames. Bamboo construction has been traditionally used in South-East Asia (India), East Asia (China), South Pacific, and to certain extent in Central and South America (e.g. Costa Rica).

Bamboo frame construction on stilts found in flood- and earthquake-prone areas such as Assam, India (People in Centre)

Bamboo frame construction, Assam, India (People in Centre)

Bamboo, cane or rope reinforced [RB]

The w all is bamboo-, cane-, or rope-reinforced, as sometimes used in adobe w alls.

Mud w all w ith bamboo reinforcement, Kenya (K. Jaisw al)

Adobe w all w ith vertical cane reinforcement, Peru (M. Blondet)

Adobe w all w ith cane reinforcement, Peru (S. Brzev)

Bamboo, straw or thatch roof [RWO5]

The surface of the roof is made from reed materials such as bamboo, straw or thatch; laid onto w ood battens, w ith a primary structure of w ood members. No sheet material is used for the roofing.

Thatch roof, Nepal (M. Schildkamp)

Straw roof, Chile (S. Mihaldzic)

Bamboo roof, Malaw i (Sassu and Ngoma, World Housing Encyclopedia Report 46)

Basalt [SPBA]

Basalt is a dark-colored, fine-grained, igneous volcanic rock which is hard and dense. Individual mineral crystals are typically hard to see with the naked eye, although some kinds can contain larger crystals, or it may have holes that are empty (bubbles) or filled with other minerals. Basalts are generally black or dark grey and polish well. As a result, they are not easily scratched by metal objects. Basalt is often used for paving and ocasionally for wall construction.

Stone masonry building - walls are likely to be a mix of basalt and trachyte stones with variation in block size and colour (J. Bothara)

A stone masonry building built in 1920s in Christchurch, New Zealand; exterior stonework is Halswell basalt with Oamaru limestone facings (W. Clark)

A 19th century stone masonry construction: exterior wall wythe is fine grained grey Halswell basalt, with facing stones and base course of pinkish-brown Port Hills trachyte and string courses of speckled Hoon Hay basalt; Canterbury Provincial Buildings complex, Christchurch, New Zealand (W. Clark)

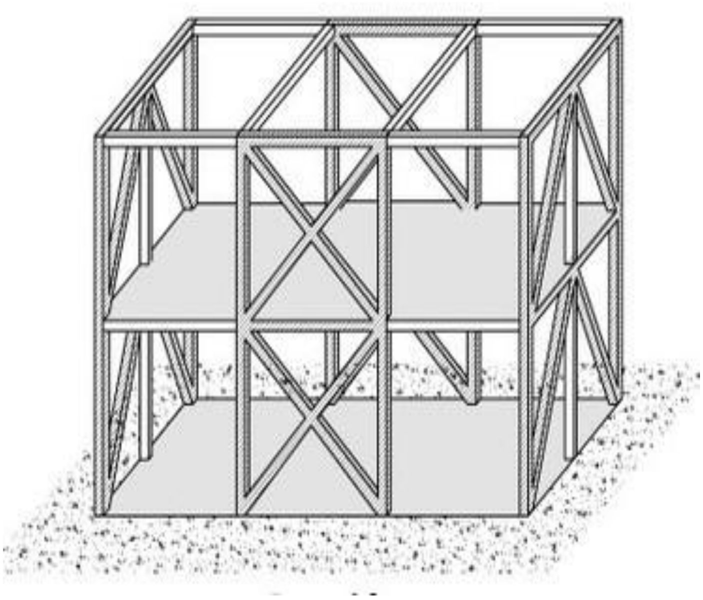
Bolted connections [BOL]

Structural steel or timber members are bolted together w ith steel bolts and nuts.

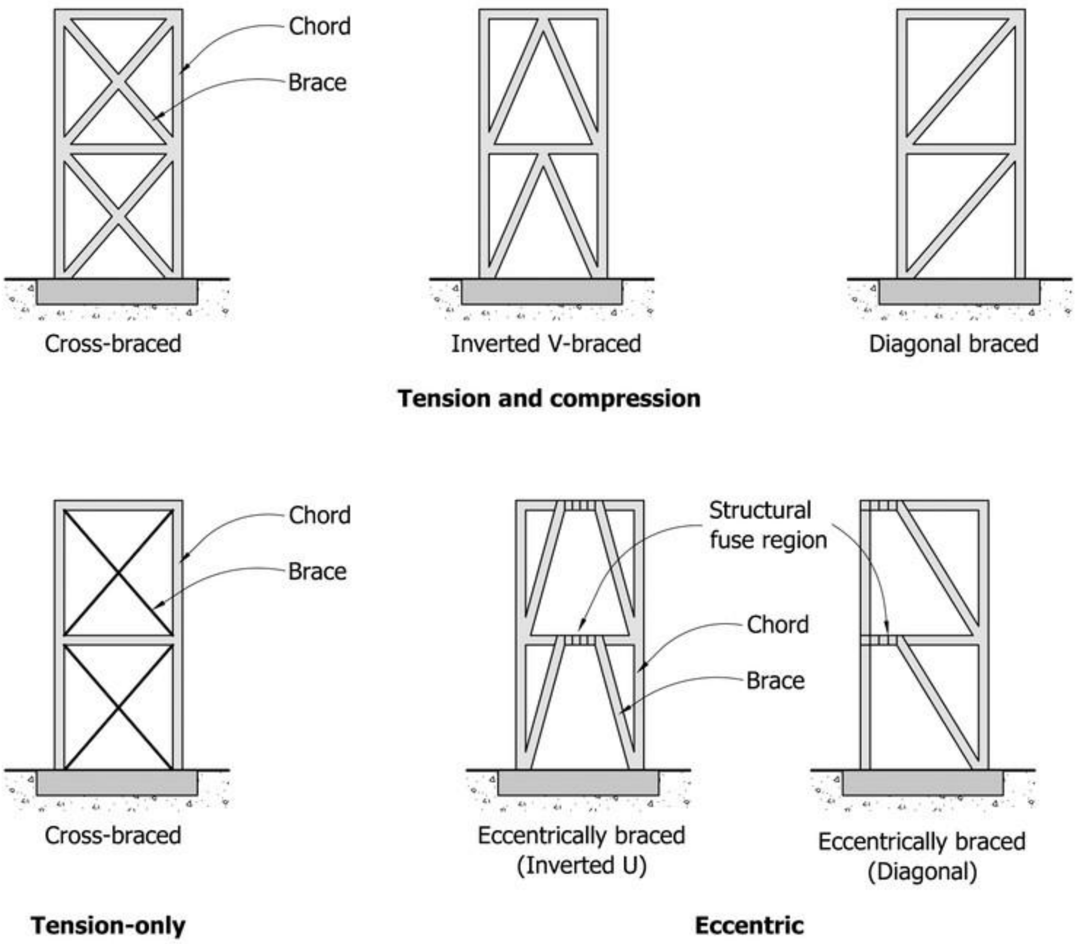
Bolted connection of three steel members joined at a column, Canada *S. Brzev)

Braced frame [LFBR]

A framework of beams and columns in which inclined, often diagonal, structural members brace the building and provide strength and rigidity. The bracing can take a variety of forms. If diagonal members are stocky they resist both tension and compression forces. However if slender, they resist tension forces only. Usually, braced frame members are triangulated and meet at joints (similar to a vertical truss). Eccentrically Braced Frames are the exception - their inclined members are deliberately offset at joints in order to create ductile fuse regions in the steel beams. Braced Frames may or may not be infilled.



A simplified drawing of a typical cross-braced frame structure (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 64, Fig. 5.2).



Examples of different types of braced frames (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 77, Fig. 5.23).

Exterior braced frame as a retrofit scheme for a reinforced concrete building, Mexico (C. Scawthorn)

Braced frame (Chevron braces), Seattle, USA (S. Brzev)

Eccentrically braced steel frame under construction, New Zealand (A. Charleson)

Concentrically braced steel frame under construction, Canada (S. Brzev)

Concentrically braced frame, India (A. Charleson)

Braced frame, Iran (A. Charleson)

Steel braced frame, Seattle, USA (S. Brzev)

Exterior steel braced frame as a retrofit solution, University Hall, University of Berkeley, California (S. Brzev)

Birds Nest Stadium in Beijing, China has a 3-D braced frame structural system (S. Brzev)

Variants

- Cross-braced Frame
- Tension-only Braced Frame
- Eccentrically Braced Frame
- Diagonally-braced Frame

Building occupancy class - detail

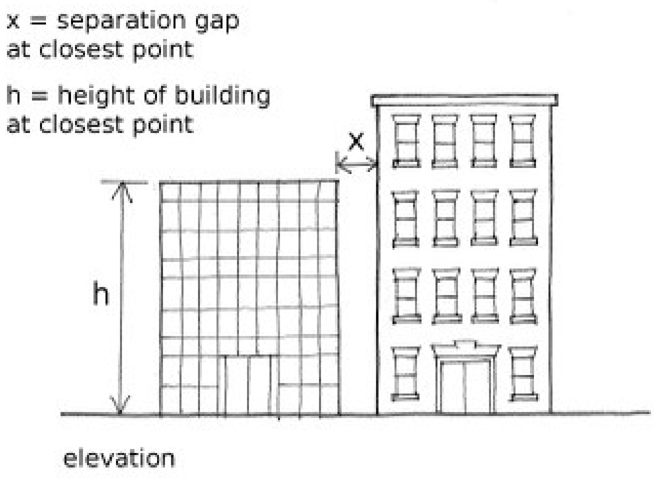
A more detailed occupancy description than the Building occupancy class - general

Building occupancy class - general

The main overall type of occupancy

Building position within a block

The position of a building in relation to other neighbouring buildings, in terms of the number of adjoining buildings and their location relative to the building under consideration. Adjoining is defined in this table as spaced apart a distance less than 4% of the height of the low er building.



If *x* is less than 4% of *h*, the buildings are considered to be adjacent.

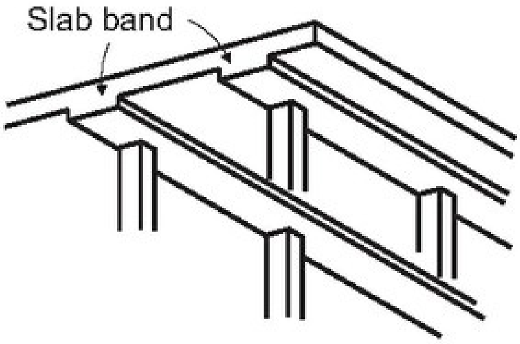
Bus station [COM8]

A building or group of buildings w here buses stop, for loading and unloading of passengers.

Cast-in-place beam-supported reinforced concrete floor [FC2]

Reinforced concrete slabs are supported by beams. This includes cast-in-place slabs with beams on all sides, waffle slabs with beams, slab band system (common in Canada), one-way joist system (common in North America), and clay tile coffered reinforced concrete slabs.

Reinforced concrete slab supported by beams, parking garage, Canada (S. Brzev)



Slab band floor system consisting of columns supported by wide beams and slabs is common in Western Canada (S. Brzev and J. Pao, Reinforced Concrete Design: A Practical Approach, Pearson Learning Solutions, 2013)

Reinforced concrete slab band floor system in a parking garage, Canada (S. Brzev)

Reinforced concrete slab on beams in a parking garage, Canada (S. Brzev)

Reinforced concrete w affle slab w ith beams, USA (S. Brzev)

Cast-in-place beam-supported reinforced concrete roof [RC2]

Reinforced concrete slabs are supported by beams. This includes cast-in-place slabs w ith beams on all sides, w affle slabs w ith beams, slab band system (common in Canada), one-w ay joist system (common in North America), and clay tile coffered reinforced concrete slabs. They are sometimes overlaid w ith light-w eight roofing.

Reinforced concrete slab supported by beams, Canada (S. Brzev)

Reinforced concrete slab band system, Canada (S. Brzev)

Reinforced concrete slab supported by beams, Canada (S. Brzev)

Reinforced concrete waffle slab system with beams, USA (S. Brzev)

Cast-in-place beamless reinforced concrete floor [FC1]

Reinforced concrete slabs are supported by columns or load-bearing walls. Flat slabs are supported by columns with capitals and/or drop panels, while flat plates are supported by columns without capitals. This floor system also includes waffle slabs without beams. Slabs or plates can be post-tensioned.

Waffle slab concrete construction, post office building, Canada (S. Brzev)

Flat plate concrete construction, parking garage, USA (S. Brzev)

Reinforced concrete flat slab system w ith capitals, UK (S. Brzev)

Floor slab system consisting of cast-in-place reinforced concrete voided w ith concrete blocks w as observed in Haiti after the 2010 earthquake (top photo - A. Irfanoglu and bottom photo - A. Lang)

Cast-in-place beamless reinforced concrete roof [RC1]

Reinforced concrete slabs are supported by columns or load-bearing walls. Flat slabs are supported by columns with capitals and/or drop panels, while flat plates are supported by columns without capitals. This floor system also includes waffle slabs without beams. Slabs or plates can be post-tensioned. They are sometimes overlaid with lightweight roofing.

Reinforced concrete waffle slab, Canada (S. Brzev)

Reinforced concrete flat plate supported by columns, USA (S. Brzev)

Reinforced concrete roof slab supported by w alls, Pakistan (J. Bothara)

Reinforced concrete flat slab system w ith capitals, UK (S. Brzev)

Cast-in-place concrete [CIP]

Concrete that has been cast on site in its final location in the structure.

Cast-in-place construction (columns), California (A. Charleson)

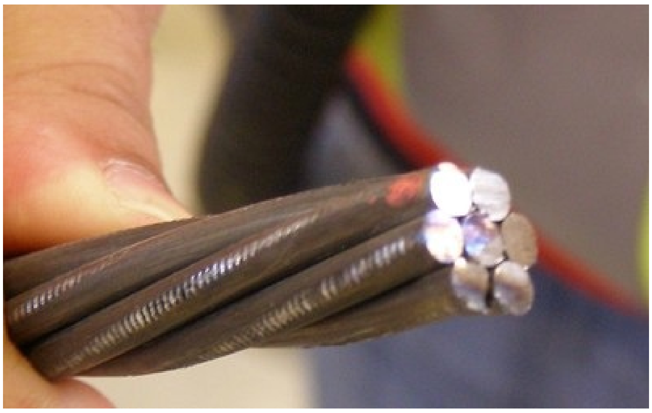
Cast-in-place concrete beam construction (note reinforcement and formw ork), Canada (S. Brzev)

Cast-in-place reinforced concrete slab reinforcement installation (left) and the slab supported by the shoring after the concrete has been cast (right), Canada (S. Brzev)

Cast-in-place concrete construction, India (note formw ork for the slab construction) (S. Brzev)

Cast-in-place prestressed concrete [CIPPS]

As per Cast-in-Place Concrete, but w here primary members of the Lateral Load-Resisting System are post-tensioned w ith steel cables or rods.



A typical prestressing cable (S. Brzev)

Prestressing cables laid out before the concrete pour (Canada, S. Brzev)

Anchorage of a prestressed concrete element, Canada (S. Brzev)

Cement-based boards for exterior walls [EWCB]

Fibre cement or asbestos boards, and fibre-reinforced concrete (FCR) and glass reinforced concrete (GRC) panels.

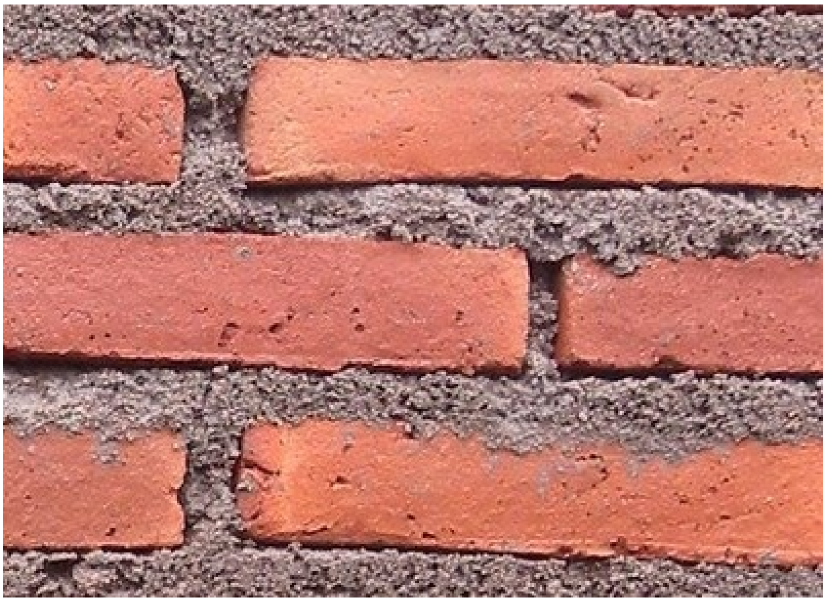
Exterior walls made of corrugated asbestos sheets, Canada (S. Brzev)

Cement:lime mortar [MOCL]

Mortar between masonry units consists of cement, lime, and sand. These materials are used in different mix proportions. For example, a lower strength mortar of this type would have a proportion 1:2:9 cement:lime:sand, and a higher strength mortar would have proportions of 1:1/2:3 1/2 cement:lime:sand. This mortar has a similar colour as cement:sand mortar. Lime is usually added to improve workability at the time of construction, but it does not improve strength.

Cement mortar [MOC]

Cement mortar betw een masonry units consists of a cement and sand mix. Cement mortar has a light grey colour (similar to concrete). It is considered a high-strength mortar, and it cannot be easily removed from the w all. How ever, mix proportions for cement mortar w idely range betw een countries, from 1:6 cement:sand to 1:3 cement:sand. Note that a larger amount of cement results in higher mortar strength and influences the strength of masonry construction. Cement mortar can be used for all types of masonry construction, except for adobe masonry.



Cement mortar (S. Brzev)

Change in vertical structure (includes large overhangs) [CHV]

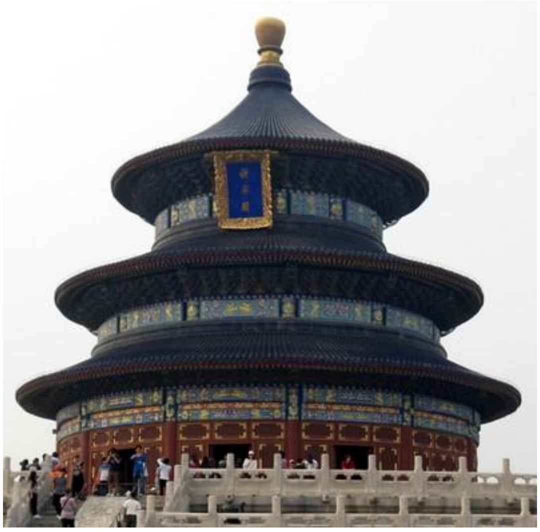
Changes in vertical structure when the structural system and/or structural material changes up the height of the building. This also covers the irregularity referred to as "Offset Structure" in some building codes. The Offset Structure refers to a case when the lateral load-resisting system is not vertically continuous from foundation to roof, but has a horizontal offset somewhere up its height. These buildings may have two different lateral load-resisting systems at some floor levels, but not across all levels (vertically), or across the entire plan (horizontally).

Change in vertical structure (FEMA 454, 2006)

Offset structure - discontinuous shear walls (FEMA 454, 2006)

Transamerica Pyramid, the tallest skyscraper in San Francisco, California is characterized by a change in vertical structure (S. Brzev)

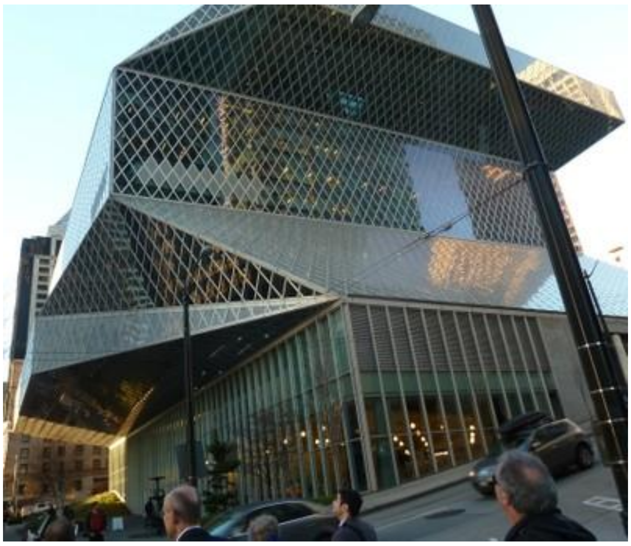
Change in vertical structure, Seattle, USA (S. Brzev)



Change in vertical structure, a temple in China (D. Willms)

This building in Rawalpindi, Pakistan is characterized by a change in vertical structure and it suffered damage in the 2005 Kashmir earthquake (C. Scawthorn)

A Kasbah in Tanger, Morocco with a large overhang (C. Scawthorn)



Change in vertical structure, Seattle Central Library, USA (S. Brzev)

A building with large overhangs, University of California Berkeley, USA (S. Brzev)

This building in India has large overhangs (People in Centre)

Cinema or concert hall [ASS3]

A venue for performance and view ing of films, including music and dance performances.

Clay or concrete tile roof covering [RMT1]

All types of clay tile and concrete tile roofing. Overlapping and sometimes fastened to wood battens. Also includes flat roofs that are covered with paving tiles (laid over some type of membrane), but does not include stone slabs.

Clay tiles, Cuba (S. Brzev)

Clay tile roof covering, Padang, Indonesia (J. Bothara)

Clay tiles (Mangalore tiles), India (People in Centre)

Cob or wet construction [ETC]

Stacked earthen construction that uses clay-based soil in the form of a cohesive paste. The material is first kneaded and then shaped into large balls, which are either stacked (piled) on top of one another or thrown forcefully onto the wall. A layer is left to dry before adding the next layer to build up walls. It is not rammed after placement, as with Rammed Earth. It is possible to build very thick walls (thickness varies from 40 to 200 cm) using this technique. The earthen mixture may contain fibres, usually straw, grass, or twigs, but that is not an universal practice. Straw is often used as an additive for cob wall construction in Europe.

A cob wall under construction, India (People in Centre)

Cob building under construction, India (People in Centre)

Cob building, India (People in Centre)

Variants

- Stacked Earth
- Bauge (French)
- Cob (Great Britain)

Cold-formed steel members [SL]

Steel members that are formed from folded (cold-formed) sheet steel. Typically used in steel framed house construction in conjunction w ith sheet materials that may provide bracing.

Cold-formed steel framing, Canada (S.Brzev)

Cold-formed steel framing detail, USA (S. Brzev)

Cold formed steel construction, Kyrgyzstan (K. Kanbolotov)

College/university, offices and/or classrooms [EDU3]

Buildings used for higher education and vocational training. Group housing, e.g. college residences, is not included in this category: refer to Institutional housing.

College/university, research facilities and/or labs [EDU4]

A building used for research, or laboratory buildings, w ithin a university or college.

Commercial and public [COM]

The building is mainly used for commercial and public purposes, including retail, storage, sports facilities, hospitals, libraries and museums.

Commercial and public, unknown type [COM99]

It is clear that the building is a commercial building, but the exact type of commercial use is unknow n.

Complex irregular [RSH9]

The roof is an irregular shape, consisting of forms that are not of regular configuration.

Irregular curved roof, Experience Music Project Museum, Seattle, USA (S. Brzev)

An irregular roof, an arrangement of multiple roof shapes and pitches on a single building, New Zealand (A. Charleson)

Complex regular [RSH8]

The roof is a complex combination of roof forms w ith a degree of regularity such as symmetry.

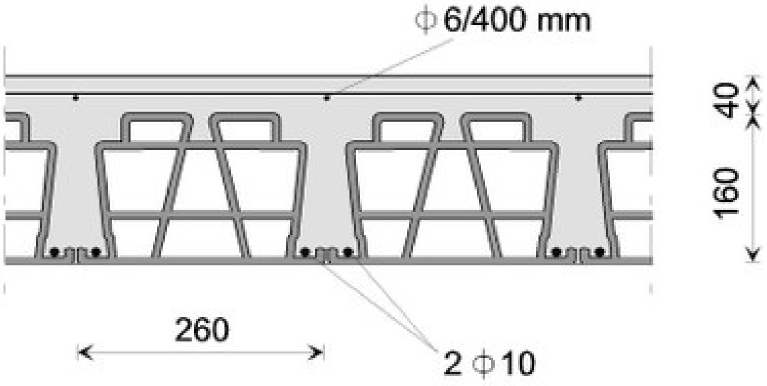
Complex regular roof, a symmetrical arrangement of multiple pitched gable roofs, New Zealand (A Charleson).

Complex regular roof, a repeating arrangement of multiple pitched gable roofs, New Zealand (A Charleson).

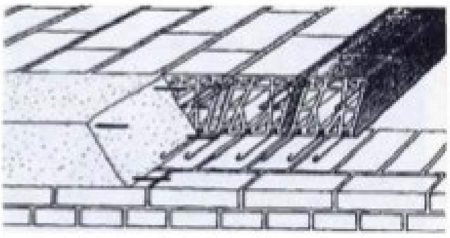
Complex regular roof, Phom Penh, Cambodia (C. Scaw thorn)

Composite cast-in-place reinforced concrete and masonry floor system [FM3]

Cast-in-place concrete joists with hollow clay tiles and cast-in-place reinforced concrete topping, sometimes overlaid with flooring. These floors may or may not have reinforced concrete ring beams at the perimeter.



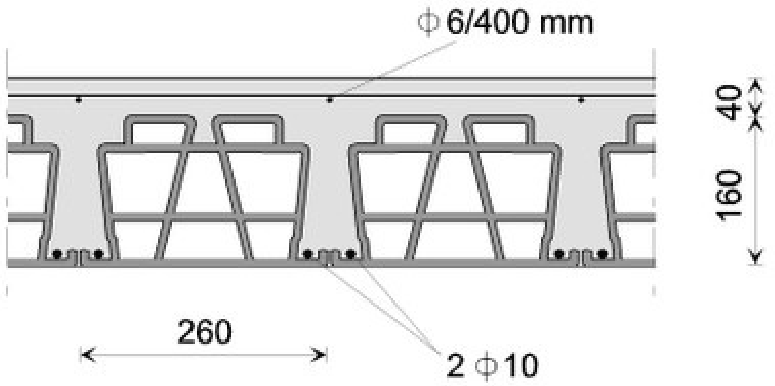
Hollow clay tiles with cast-in-place concrete joists and topping, Slovenia (World Housing Encyclopedia Report 73)



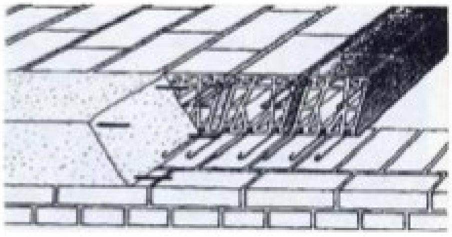
Prefabricated reinforced hollow clay tile beams, with reinforced concrete ring beams, Italy (Maffei et al., 2006)

Composite masonry and concrete roof system [RM3]

Cast-in-place concrete joists with hollow clay tiles and cast-in-place reinforced concrete topping, sometimes overlaid with roofing. These roofs may or may not have reinforced concrete ring beams at the perimeter.



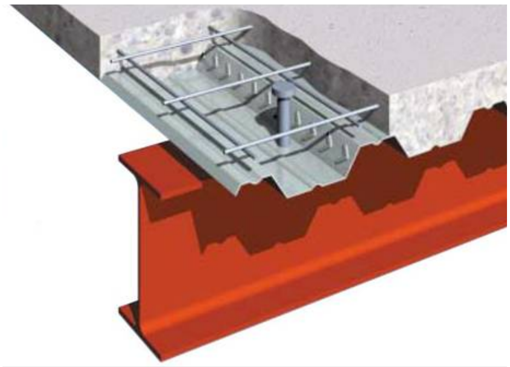
Hollow clay tiles with cast-in-place concrete joists and topping, Slovenia (World Housing Encyclopedia Report 73)



Prefabricated reinforced hollow clay tile beams, with reinforced concrete ring beams, Italy (Maffei et al., 2006)

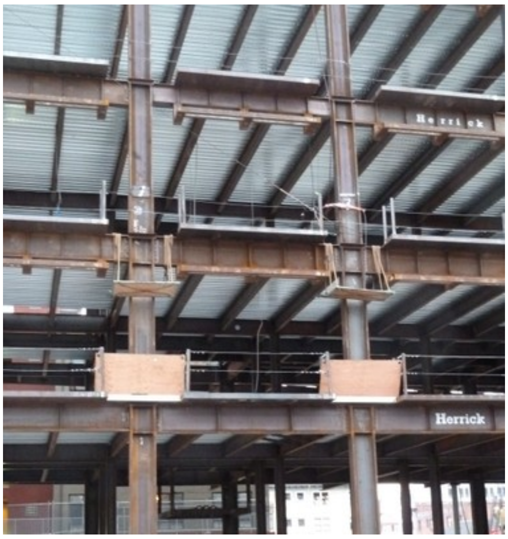
Composite steel floor deck and concrete slab [FME3]

Reinforced concrete cast onto steel decking, supported by beams or loadbearing walls.



Composite steel deck and concrete slab (SteelDecking, UK)

Steel trusses (open web steel joists) supporting composite steel and concrete floor system, Canada (S. Brzev)



Steel beams supporting composite steel and concrete deck floor, USA (S. Brzev)

Composite steel roof deck and concrete slab [RME3]

Reinforced concrete cast onto steel decking, supported by beams or load bearing walls. They are sometimes overlaid with light-weight roofing. This system is similar to the floor system called Composite Steel Floor Deck and Concrete Slab.

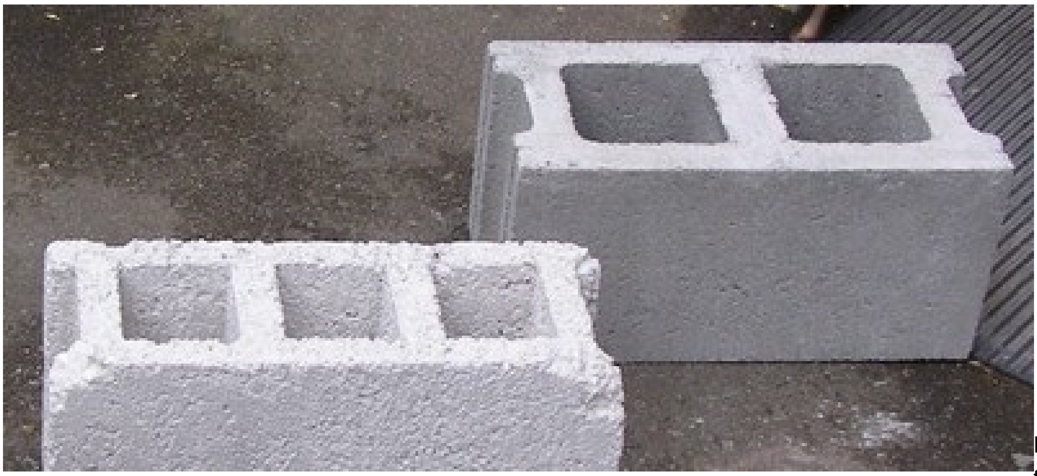
Steel trusses (open web steel joists) supporting composite steel and concrete floor system, Canada (S. Brzev)

Steel trusses (Open Web Steel Joists) supported by precast concrete tilt-up walls, Canada (S. Brzev)

Concrete blocks, hollow [CBH]

Concrete blocks with two or more cells (cavities) comprising more than 30% of the volume, which may be grouted and reinforced.

Hollow concrete blocks, Peru (S. Brzev)



Hollow concrete blocks with three cells, Haïti (front) and with two cells, Canada (rear), (S. Brzev)

Concrete blocks, solid [CBS]

Concrete blocks with less than 30% holes (cavities).

Concrete blocks, solid, Peru (A. Charleson)

Concrete blocks, unknown type [CB99]

It is clear that the masonry unit is concrete block, but the type of block is unknown. The blocks may be hidden, or it may not be possible to determine solid from hollow blockwork, or information about it is unavailable.

Various types of concrete blocks, Peru (S. Brzev)

Concrete block construction, Cuba (S. Brzev)

Concrete blocks

Concrete blocks are hollow or solid masonry units consisting of Portland cement and suitable aggregates combined with water. These blocks are usually laid in mortar. The following types of concrete blocks are included in the Taxonomy:

- Concrete blocks, unknown type
- Concrete blocks, solid
- Concrete blocks, hollow

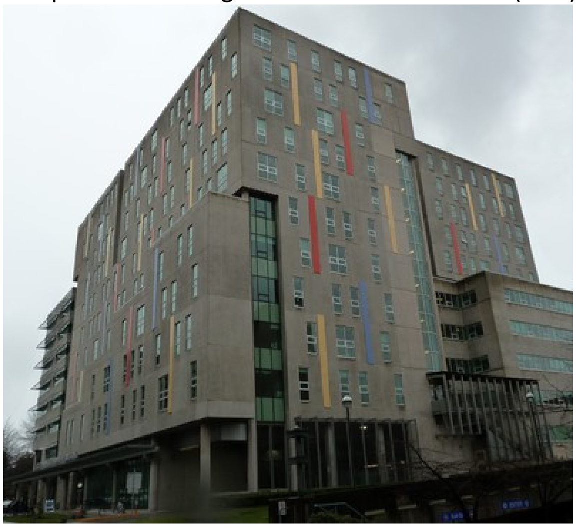
Concrete, composite with steel section [SRC]

Members of the lateral load-resisting system consist of large metal or steel sections filled with or encased in concrete to increase their strength rather than for fire-protection only.

Sometimes this composite structural material or steel reinforced concrete (SRC) is used in conjunction with other materials like reinforced concrete or steel construction. For example, a SRC frame might be constructed above or below some reinforced concrete frame stories, or a building might contain both SRC and reinforced concrete or steel frames. In these situations one has to assess whether the SRC frames or members will define the seismic performance of the overall structure. If that is not the case then the other structural material should be selected.

Concrete exterior walls [EWC]

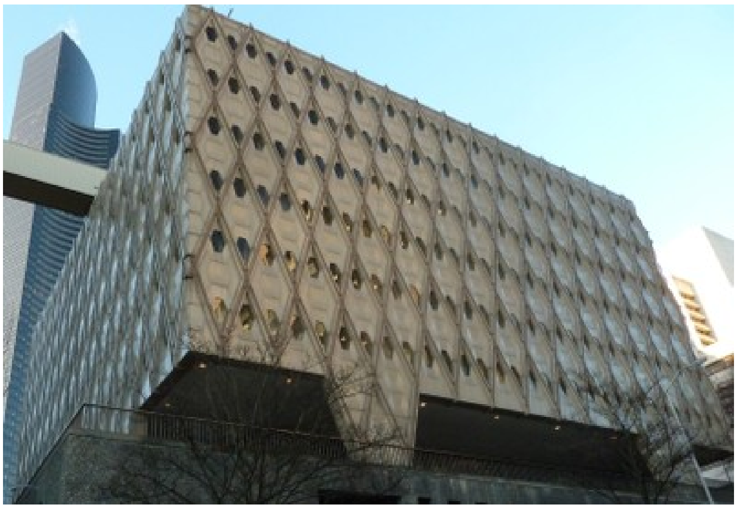
All types of concrete construction and cladding, reinforced or unreinforced, including where there is a plaster finish directly applied to the concrete. Includes cast-in-place or precast concrete panels, but not thin panels such as glass reinforced concrete (GRC) panels or fibre cement board.



Cast in-place reinforced concrete exterior walls, Vancouver, Canada (S. Brzev)

Exterior walls made of cast-in-place reinforced concrete, Vancouver, Canada (S. Brzev)

Reinforced concrete wall panels, USA (S. Brzev)



Exterior concrete wall panels, Seattle, USA (S. Brzev)

Concrete floor [FC]

The floor structure is constructed of concrete.

Concrete floor, unknown [FC99]

It is clear that the floor structure is made from concrete, but the type of concrete system is unknown. The system may be hidden, or information about it is unavailable.

Concrete, reinforced [CR]

Concrete that is reinforced by metal, usually steel rods or bars cast into the concrete, or by other reinforcement such as glass or metal fibres or natural materials that are strong in tension.

Includes prestressed concrete, and can be pre-cast or cast-in-place.

Reinforced concrete slab and columns under construction, Canada (S. Brzev)

Reinforced concrete building, New Zealand (A. Charleson)

Reinforced concrete w all and column retrofitted w ith carbon fibrew rap, USA (S. Brzev)

Concrete roof [RC]

The roof structure is constructed of concrete.

Concrete roof, unknown [FC99]

It is clear that the roof structure is made from concrete, but the type of concrete system is unknown. The system may be hidden, or information about it is unavailable.

Concrete roof without additional covering [RMN]

The roof structure is concrete slab and there is no other covering surface over the structure of the roof system, other than paint or a clear seal. This attribute does not apply to concrete tiles or fibre cement sheet.

Concrete roof w ithout additional covering, India (S. Brzev)

Concrete, unknown reinforcement [C99]

The structural material is concrete, but it is not know n if the concrete is reinforced or unreinforced.

Concrete, unreinforced [CU]

Concrete does not contain steel reinforcing, or reinforcing of any kind.

Concrete

Concrete is a composite material consisting of Portland cement, coarse aggregate (crushed stone), fine aggregate (sand), and w ater. It is usually grey in colour. The follow ing types of concrete are included in the GEM Building Taxonomy:

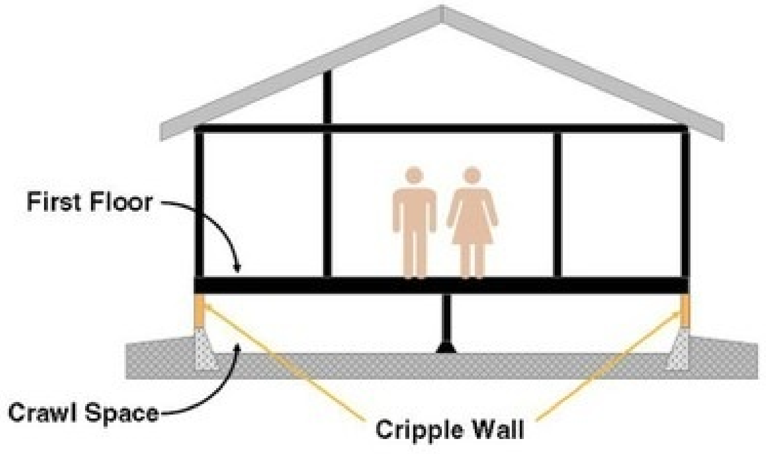
- Concrete, unknow n reinforcement
- Concrete, unreinforced
- Concrete, reinforced
- Concrete, composite w ith steel section

Covered parking garage [COM7]

Car parking facilities, covered and multi-storey. Does not include flat open lots.

Cripple wall [CRW]

A cripple w all is a w all that is less than a full storey high, and it usually occurs betw een a foundation and the ground floor in a light w ood frame building (thus creating a craw l space). These w alls are w eak because they are typically sheathed w ith only stucco or horizontal w ood siding on the exterior side of the w all. These sheathing materials are inadequate w all-bracing methods. Damage and collapse of older w ood frame buildings at the cripple-w all level w as observed in past earthquakes.



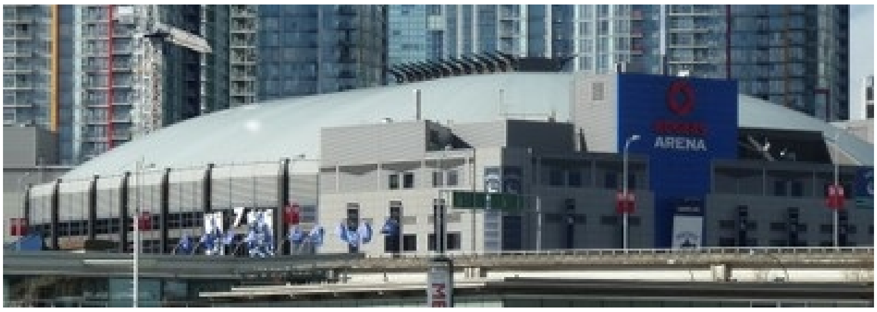
Cripple w all and craw l space (FEMA G225)

Collapse of a w ood-frame house w hich slid over the cripple w all, 1983 Coalinga, California earthquake (EERI)

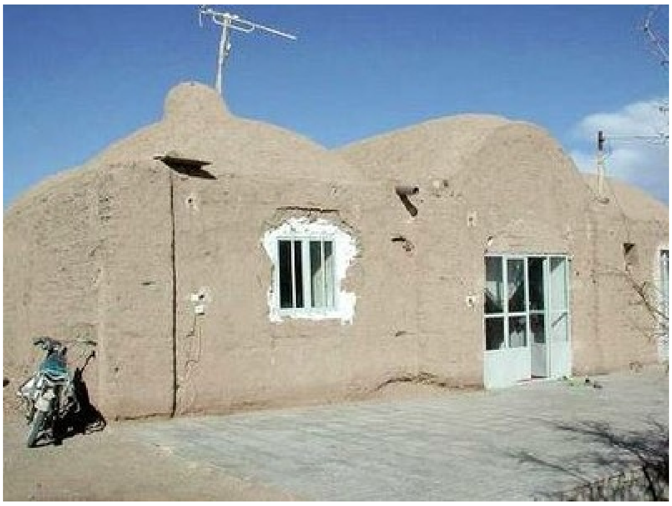
Cripple w all failure in the 1971 San Fernando, California earthquake (Courtesy of K.V. Steinbrugge and the NISEE, University of California, Berkeley)

Curved [RSH7]

The roof is curved. It may be of a regular round arched shape, or more irregularly curved w hen view ed in section.



Curved roof, Rogers Arena, Vancouver, Canada (S. Brzev)



Curved roof (earthen dome), Iran (F. Naeim)

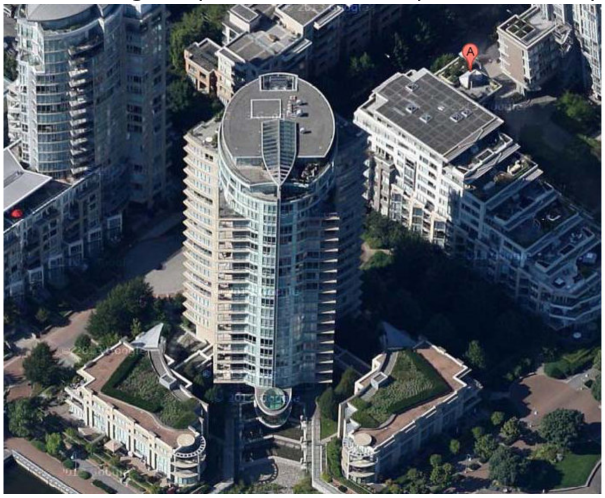
Irregular curved roof, Canada (S. Brzev)

Regular curved roof, Canada (S. Brzev)

Curved roof shape, Beijing Capital International Airport, China (S. Brzev)

Curved, solid [PLFC]

The building footprint is a round shape; circular, elliptical, or ovoid.



A building with a solid elliptical plan shape, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

Curved, with an opening in plan [PLFCO]

The building footprint is a round shape; circular, elliptical, or ovoid, and it has an interior open courtyard (whether roofed or not).

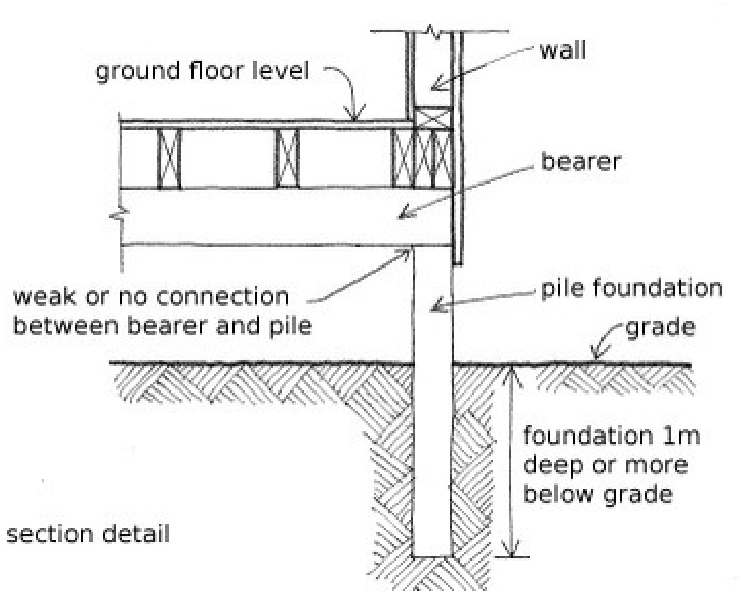
Beijing National Stadium (also known as the Bird's Nest) has a circular plan shape with an opening (Map data ©2013 Google, DigitalGlobe)

Date of construction or retrofit

Date of construction can be taken from when the building was completed. If the building consists of structures that vary in age, use the earliest date. If the structure of the building has been upgraded (retrofitted) in a manner that improves its seismic performance, enter the date of the retrofit instead of the date of construction.

Deep foundation, no lateral capacity [FOSDN]

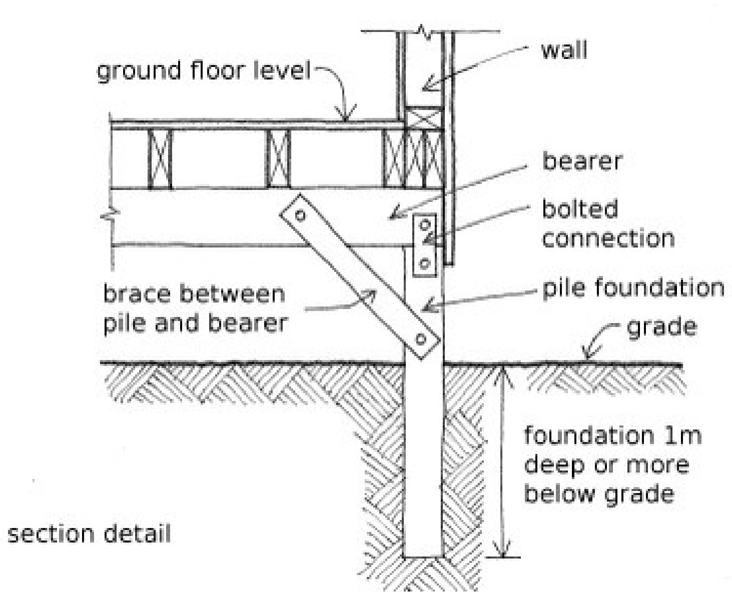
The foundations are 1m deep or more below grade, and they have no lateral capacity. Foundations w ith no lateral capacity include piles w ithout lateral bracing support.



An example of a timber pile deep foundation w ith no lateral capacity.

Deep foundation, with lateral capacity [FOSDL]

The foundations are 1m deep or more below grade, and they have lateral capacity. Foundations w ith lateral capacity include tie-beams, foundation w alls, inclined piles, piles or piers on w ide spread footings.



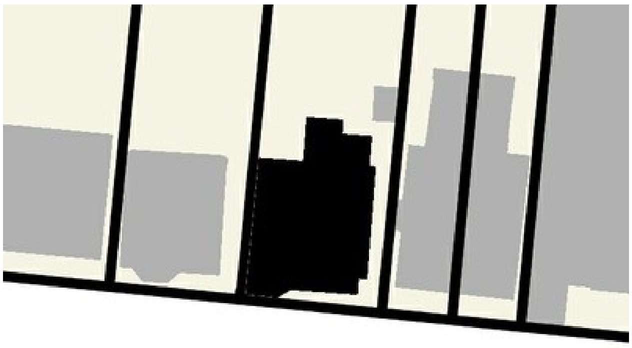
An example of a braced timber pile deep foundation w ith lateral capacity. This example is a deep foundation that is braced. Another option is for the deep pile not to be braced but to just act as a vertical cantilever provided the height of the pile is not too great above ground level.

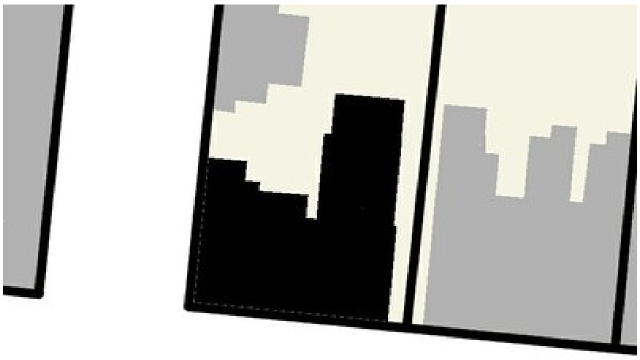
Description of the direction

Where it is possible to specify directions, Direction X is parallel to street, and Direction Y is perpendicular (orthogonal) to street. In some cases, it is not possible to identify Direction X and Direction Y - thus the user can select Unspecified Direction.

Detached building [BPD]

The building may be w ithin a block, but it is not attached to any other building. This applies to buildings w hose neighbouring buildings are spaced apart a distance equal to or more than 4% of the height of the low er building. Where buildings are spaced closer than this, but not attached, they are considered to be adjacent.





The buildings show n in black in this plan view are detached, as the tw o neighbouring buildings are too far aw ay to be considered adjacent.

An example of a detached building, Vancouver, Canada (Map data ©2013 Google, DigitalGlobe, IMTCAN)

Detached building on a corner, where the neighbouring buildings are too far away to be considered adjacent, New Zealand (L. Allen).

Detached building, where the neighbouring buildings are too far away to be considered adjacent. Putu, Chile (S. Brzev).

The building in the foreground is detached, as the neighbouring buildings are too far away to be considered adjacent. Santiago, Chile (S. Brzev).

Direction of the building

The Direction attribute is intended to identify two principal horizontal directions of the building plan.

Direction X

First principal horizontal direction of the building plan. It is listed as Parallel to Street if the building has a façade parallel to the street, or is listed as Unspecified Direction if the building does not. If there is more than one façade parallel to a street, consider Direction X as parallel to the façade w here the main entrance is located. See the Direction glossary term for an illustrative example.

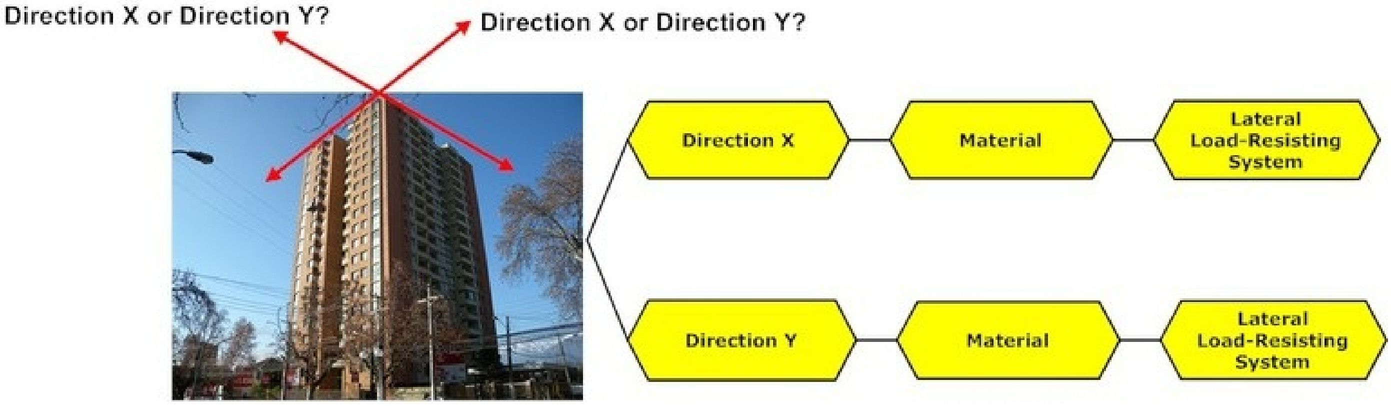
Direction Y

Second principal horizontal direction of the building plan. This direction is always perpendicular (orthogonal) to Direction X. It is defined as Perpendicular to Street if Direction X is listed as Parallel to Street. Alternatively, it is defined as Unspecified Direction when Direction X is defined as Unspecified Direction. See the Direction glossary term for an illustrative example.

Direction

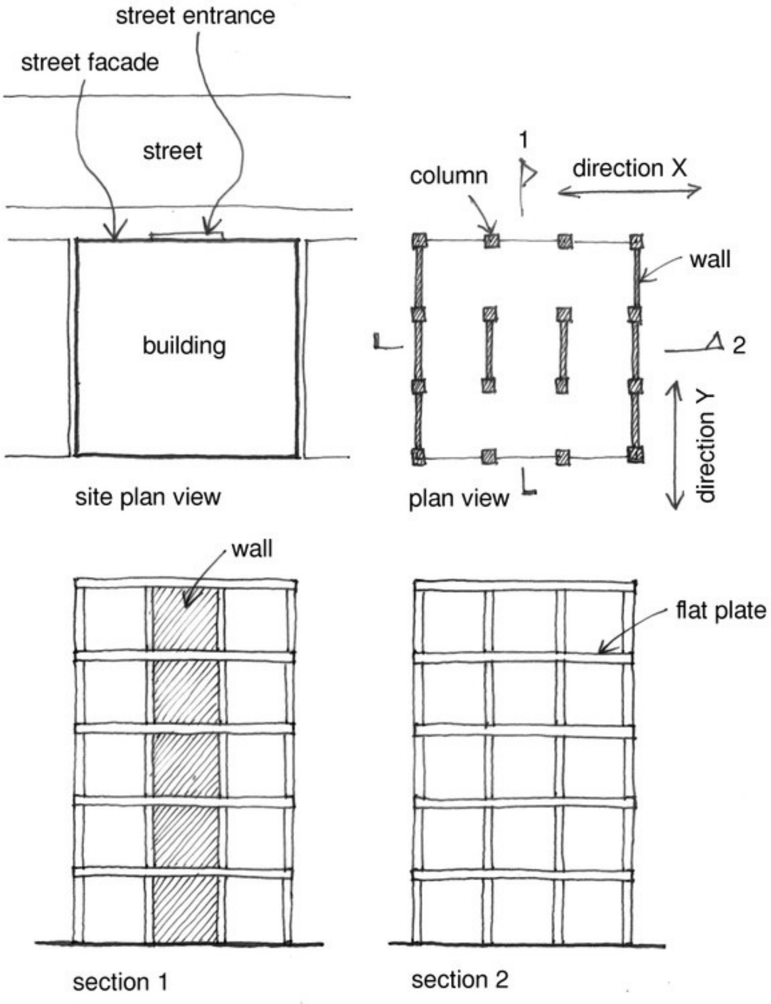
The Direction attribute is intended to identify two principal horizontal directions of the building plan. It is possible to specify different Lateral Load-Resisting System (LLRS) and the corresponding Material of the Lateral Load-Resisting System in two directions called Direction X and Direction Y; these systems are often referred to as Hybrid Systems or Mixed Systems. Where it is possible to specify directions, Direction X is parallel to street, and Direction Y is perpendicular (orthogonal) to street. In some cases, it is not possible to identify Direction X and Direction Y - thus the user can select Unspecified Direction.

Note that other types of hybrid systems can be described by the Hybrid Lateral Load-Resisting System attribute, which should be applied in one of the following cases: a) there is more than one LLRS in the building, but there is no clear distinction between LLRSs in directions X and Y, or b) there is only one LLRS, but two or more materials of the LLRS are used in different portions of the building.



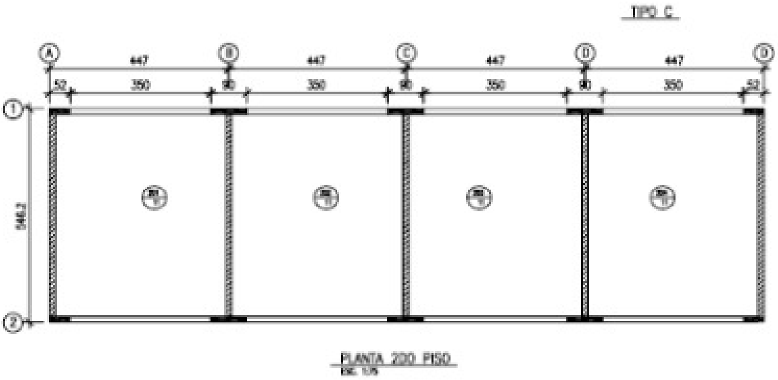
A building showing possible orientation for Directions X and Y

EXAMPLE 1: A building has two different LLRSs: reinforced concrete flat plate (slab and column system) parallel to street, and reinforced concrete wall system perpendicular to street, as shown below. In this case, Direction X (parallel to street) is associated with a flat plate system (LFLS) (see Section 2), and Direction Y (perpendicular to street) is associated with a wall system (LWAL) (see Section 1).

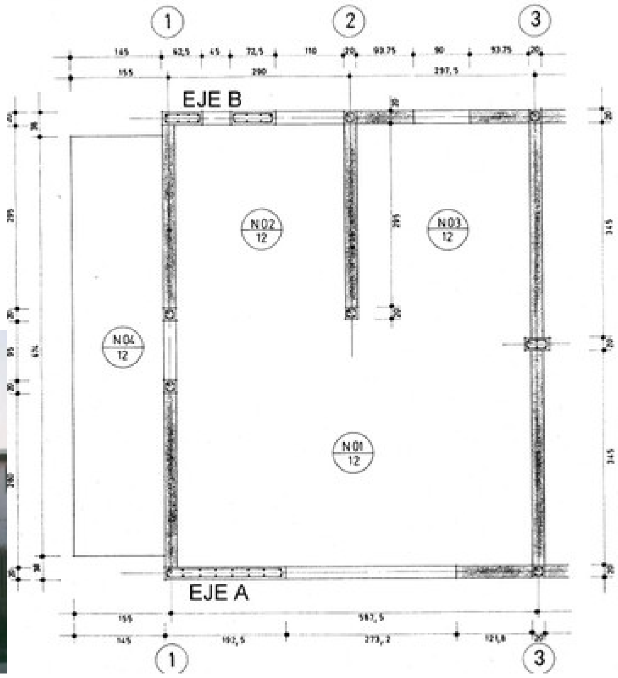


EXAMPLE 2: The Direction attribute can be used to describe a hybrid LLRS from Chile, with reinforced concrete frames in longitudinal

direction (Direction X) and confined masonry in transverse direction (Direction Y). It is assumed that Direction X (parellel to street) is longitudinal direction because entrance to individual housing units is in that direction (M. O. Moroni Yadlin).

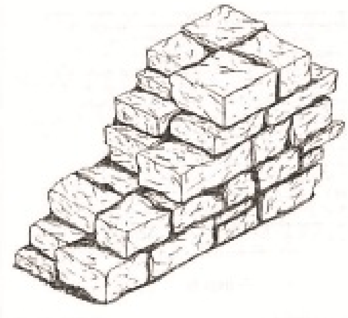


EXAMPLE 3: The Direction attribute can be used to describe a hybrid system from Chile, w here confined masonry is used in one direction and reinforced concrete shear w alls in other direction (Moroni, Gomez, and Astroza, World Housing Encyclopedia Report 8). The photo show s an earthquake-damaged building, and the draw ing show s a typical building plan (not related to the building show n on the photo).



Dressed stone [STDRE]

Square or rectangular-shaped prismatic stone blocks in bonded courses w ith narrow joints, w ith or w ithout mortar. Usually found in areas w here calcareous stones and tuffs (rocks formed from volcanic ash), w hich are relatively easy to shape, are available.

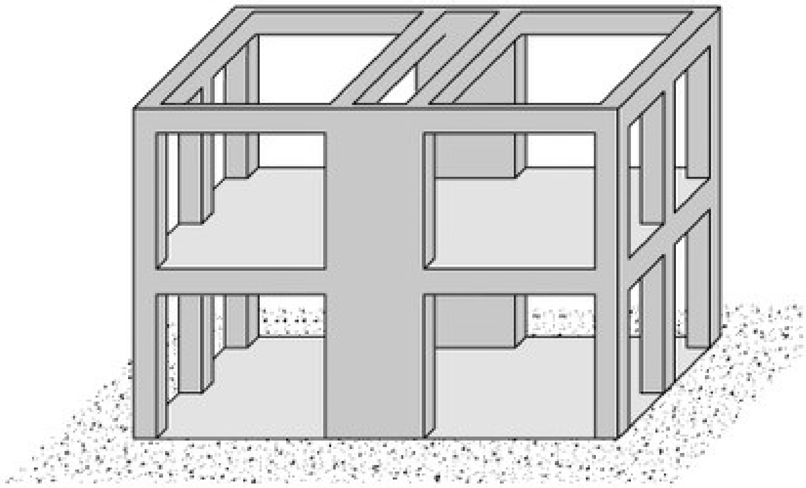


Dressed stone masonry w all, Italy (Maffei et al., 2006)

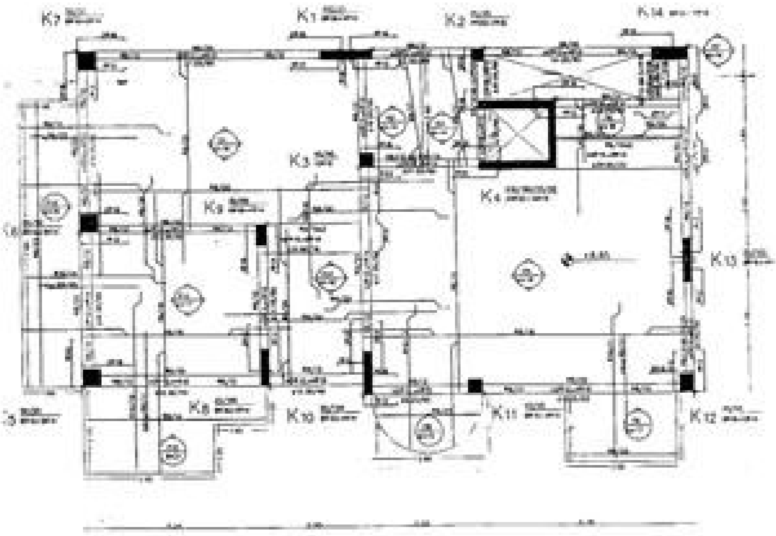
A stone masonry w all (exterior w all w ythe built using tuff stone) in San Giuliano damaged in the 2002 Molise earthquake, Italy (A. Benedetti)

Dual frame-wall system [LDUAL]

The lateral load-resisting structure comprises of moment frames and shear walls acting together in the same direction, and it is mostly applicable to reinforced concrete structures. Due to wall slenderness, the structural system cannot be classified as a Wall system; however shear walls interact with the moment frames and resist seismic effects. The walls are usually solid (not perforated by openings) and they can be found around the stairwells, elevator shafts, and/or at the perimeter of the building. The walls may have a positive effect on the performance of the frames such as by preventing a soft storey collapse. Very slender walls of a dual frame-wall system may or may not have been designed for the level of earthquake forces that could be imposed upon them. Note that the dual frame-wall system is a Hybrid Lateral Load-Resisting System, however it has been identified as a separate system in this taxonomy. It may be difficult to distinguish a Dual system from the Wall system in a reinforced concrete building. The user will need to have additional information related to the building design and local building codes and design practices.

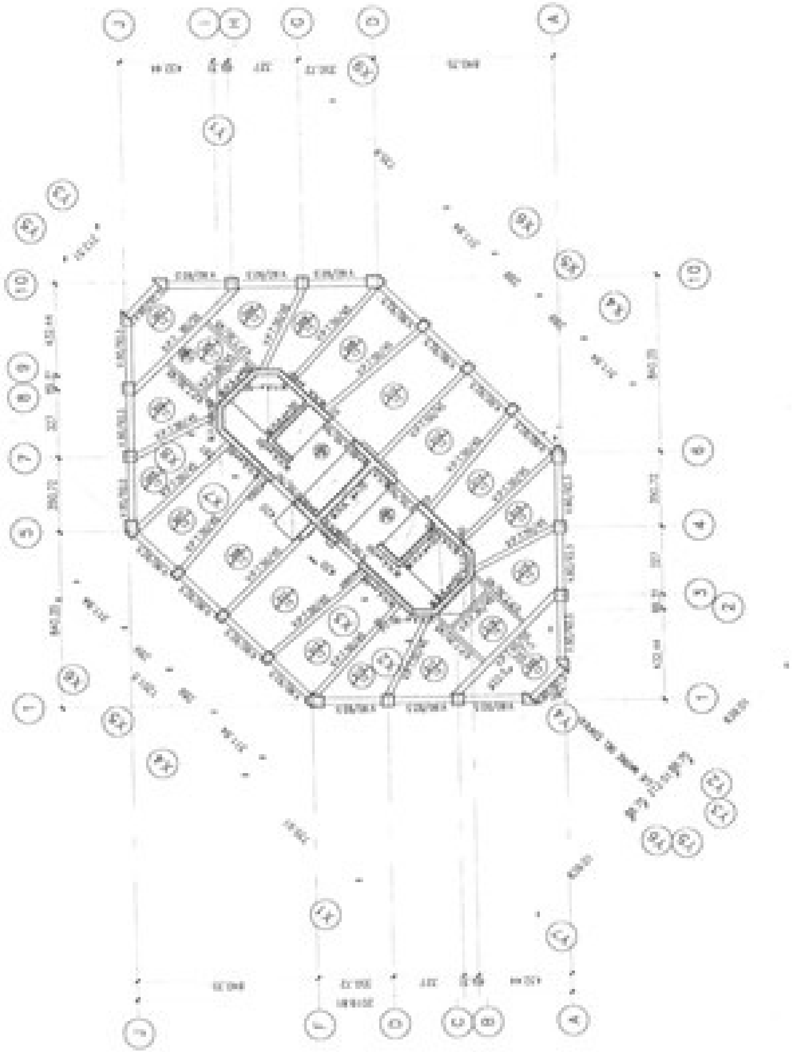


A simplified drawing of a dual frame-wall structure running in one direction (adapted from: A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p64 fig. 5.2). Beams must be present and not just slabs.



A typical reinforced concrete building with the frame-wall dual system, Greece (Tassios and Syrmakezis, World Housing Encyclopedia Report 15)

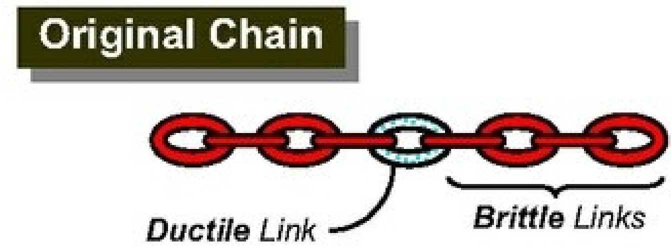
Dual frame-wall system is common for contemporary reinforced concrete building construction in Algeria (M. Farsi)

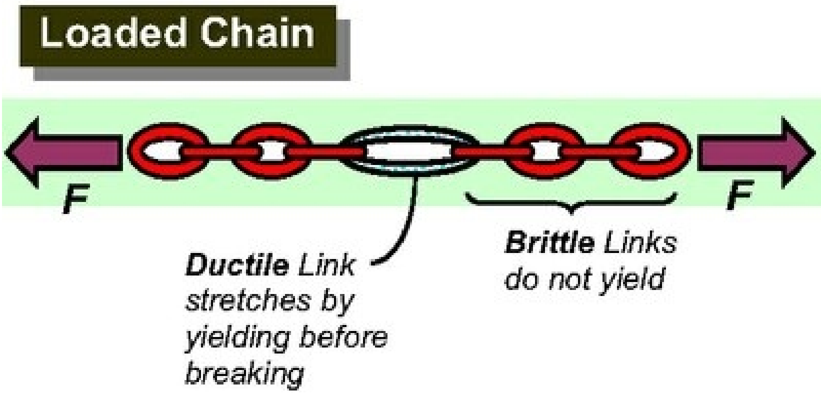



Reinforced concrete dual frame-w all construction, Chile (Moroni, Gomez, and Astroza, World Housing Encyclopedia Report 6)

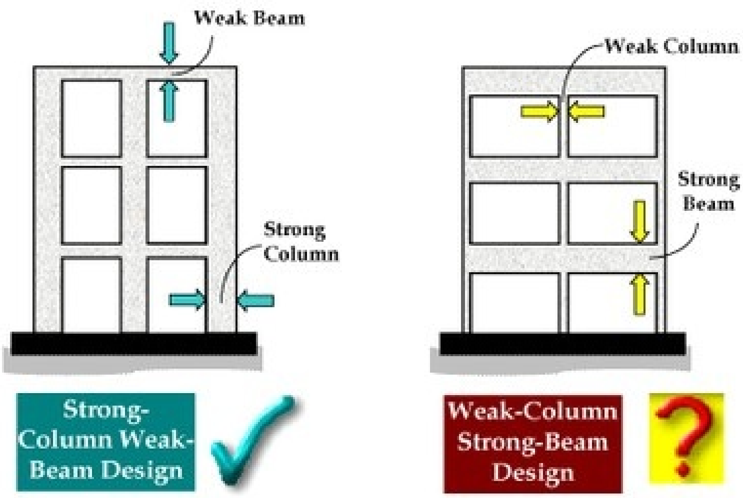
Ductile [DUC]

The structure incorporates ductile design, where steel members or reinforcing are designed to undergo plastic deformation in over-load situations before failure under earthquake loads occurs in structural members or their connections. Provision of ductility is achieved by both providing a hierarchy of member strengths in a structural system (known as Capacity Design Approach) as well as special member detailing. For example, ductile moment frames will have columns stronger than the beams and shear force detailing will prevent shear failures of both beams and columns occurring before flexural yielding.

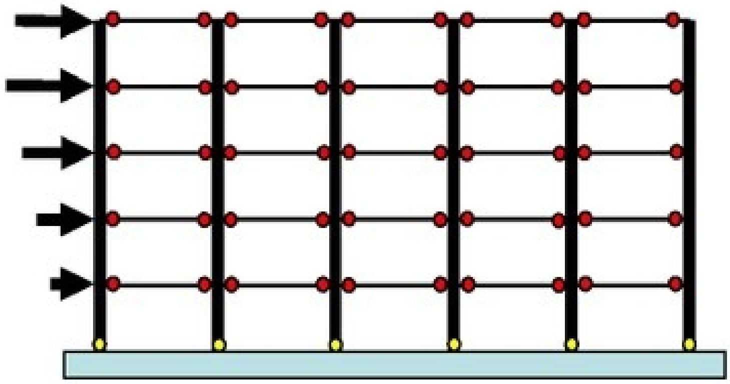




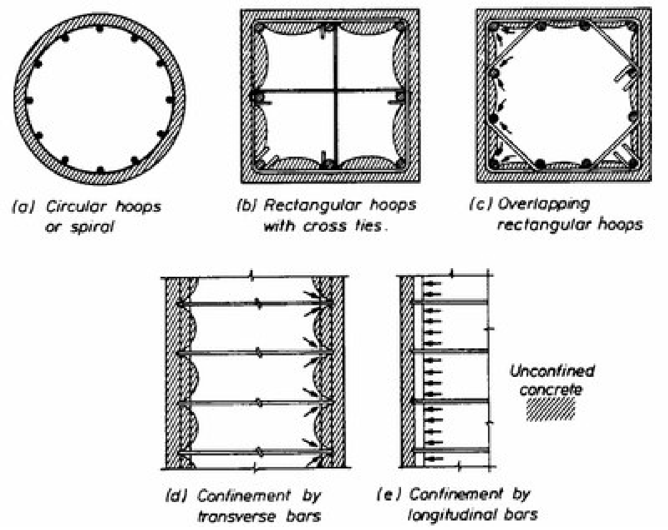
The main objective of the Capacity Design Approach is to ensure that buildings perform in a ductile manner, that is, to avoid brittle failure and collapse in earthquakes. The designer needs to select structural components in which extensive deformation and damage may be expected, while the remaining portion of the structure must remain strong enough, or flexible enough, to sustain these forces and deformations. This is can be explained on an example of a chain, where ductile links represent locations at which significant plastic deformations are expected (ductile links), while brittle links represent other structural components. For example, in a reinforced concrete frame extensive deformations are expected in the beams (analogous to ductile links), while columns need to remain strong (analogous to brittle links) (illustration by C.V.R. Murty, Earthquake Tip 9, NICEE, India)



One of the design requirements for ductile performance of reinforced concrete moment frames is to ensure Strong Column-Weak Beam design concept - beams must be the weakest links (C.V.R. Murty, Earthquake Tip 9, NICEE, India)

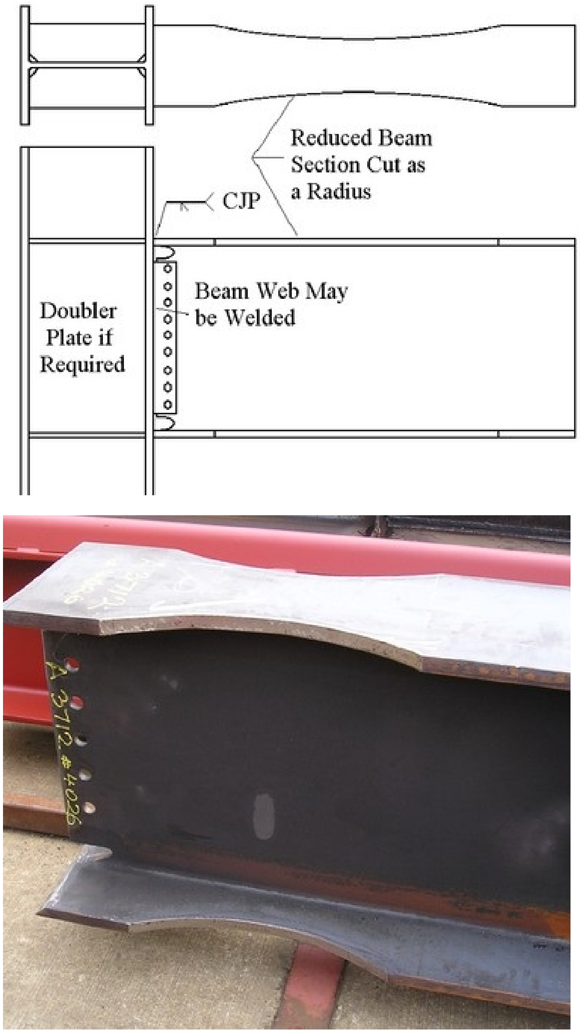


Plastic hinges (show n in red colour) are locations in a reinforced concrete or steel moment frame system w here significant deformations and damage are expected to take place during a major earthquake (FEMA 451B, 2006)

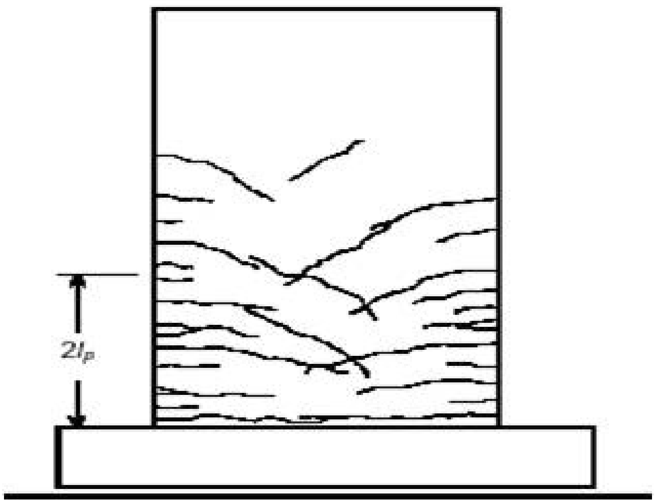


Olive View Hospital, 1971 San Fernando Valley earthquake

Special reinforcement detailing provisions are critical for ductile performance of reinforced concrete moment frame systems. Confinement is supplied by closely spaced reinforcement, usually in the form of hoops or ties. Reinforced concrete frames w ith adequately confined columns performed w ell in past earthquakes (illustrations: FEMA 451B)



Ductile behaviour of steel moment frame structures can be achieved using Reduced Beam Section (also known as dogbone connection). The dogbone connection consists of trimming a portion of the steel beam flange in the region adjacent to the beam-to-column connection; this type of connection acts as a ductile fuse, and it forces yielding to occur within the reduced section of the beam; see an I-shaped beam with dogbone connection ready for the construction, Canada (drawing: FEMA 355D, photo: S. Brzev)



Reinforced concrete and reinforced masonry walls with proper reinforcement amount and detailing are expected to show ductile seismic performance (FEMA 306, 1999)

Ductility unknown [D99]

It is unknown whether the structure is designed and constructed to be ductile. The structural components may be hidden, or information about them is unavailable. It is usually not obvious whether a building was designed to perform in a ductile manner, without additional information such as design calculations and construction drawings.

It is not clear whether this reinforced concrete frame building in Manila, Philippines was designed and constructed to perform in a ductile manner (C. Scawthorn)

It is not clear whether this building under construction in Bishkek, Kyrgyzstan was designed to perform in a ductile manner (C. Scawthorn)

E-shape [PLFE]

The footprint of the building when viewed in plan resembles the shape of the letter E.

A building with E-shaped plan, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

Earth, reinforced [ER]

Earthen construction that is reinforced by horizontal and or vertical bands or posts from wood or other materials capable of resisting bending and or tension. Examples of horizontal reinforcement are eaves or lintel bands. The reinforcement increases the strength of walls and/or functions to tie walls together.

Earth technology, other [ETO]

Any earthen construction type that is known but does not fit the descriptions of the other earth construction types in this table.

Earth, unknown reinforcement [E99]

It is clear that the structural material is earth, but whether or not it is reinforced is unknown. Examples of earthen construction include cob, rammed earth, etc. Note that adobe is not considered as earthen construction technology (it is a masonry construction).

Earth, unreinforced [EU]

Earthen construction, without any reinforcement. This includes rammed earth construction, cob, etc., but it doesn't include adobe construction, which is considered as a masonry construction practice.

Earth

Earthen construction includes a variety of techniques w here entire buildings or their components are built from earth, w ith or w ithout additives or reinforcement. Earthen construction does not include adobe w hich is considered to be masonry. The follow ing types of earthen construction are included in the GEM Building Taxonomy:

- Earth, unknow n reinforcement
- Earth, unreinforced
- Earth, reinforced

Earthen exterior walls [EWE]

All types of earthen construction, including cob, rammed earth, bajareque, quincha, sod, banco, wattle and daub.

Cob construction, India (overlaid by plaster) (People in Centre)

Mud walls reinforced with bamboo reinforcement, Kenya (K. Jaiswal)

Quincha construction, Peru - exposed at the lower level and overlaid with mud plaster above (S. Brzev)

Wattle and daub construction, India (People in Centre)

Earthen floor [FE]

The floor structure is of earthen construction.

Earthen floor, unknown [FE99]

It is clear that the floor structure is made from earthen construction, but the type of earthen construction system is unknown. The system may be hidden, or information about it is unavailable.

Earthen roof [RE]

The roof structure is of earthen construction.

Earthen roof covering [RMT9]

All roof types of earthen construction, including adobe-type covering with lathes. Includes 'green roof', 'sod roof', 'turf roof', where the roof is covered with a layer of soil on a waterproof membrane and planted with grass or plants.

Earthen roof covering, Iran (F. Naeim, World Housing Encyclopedia Report 104)

Earthen roof, unknown [RE99]

It is clear that the roof structure is made from earthen construction, but the type of earthen construction system is unknown. The system may be hidden, or information about it is unavailable.

Education [EDU]

The building is mainly used for education, including schools and universities.

Education, unknown type [EDU99]

It is clear that the building is used for education, but the exact type of educational use is unknown.

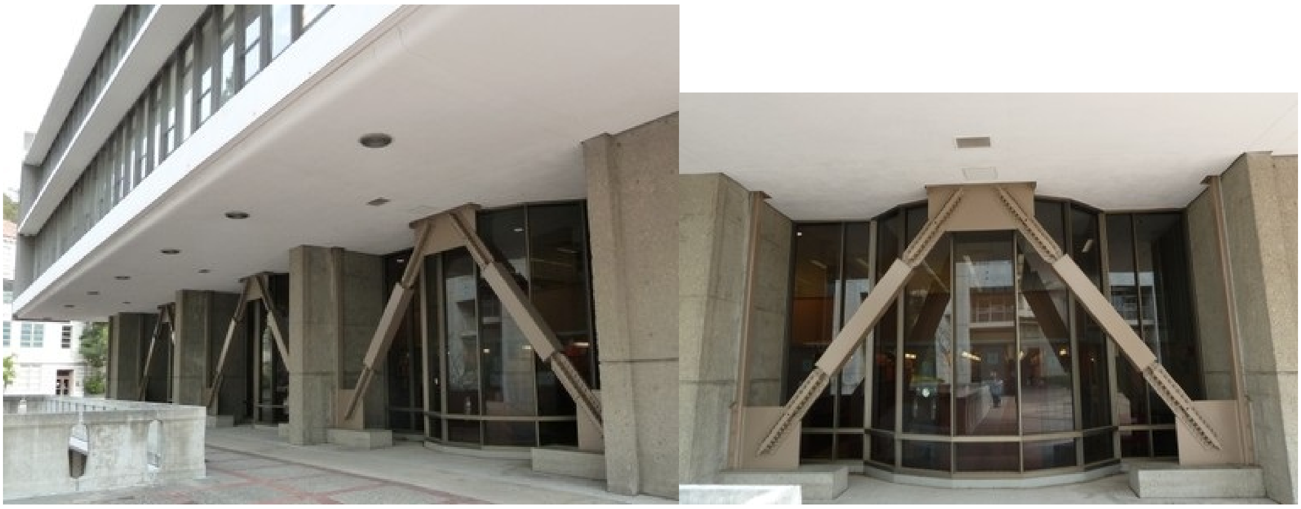
Entertainment [COM5]

Restaurants, bars, cafes

Equipped with base isolation and/or energy dissipation devices [DBD]

The building is equipped with base isolation and/or energy dissipation devices; this is an alternative to conventional seismic design approach, where buildings are designed for ductile performance. Base isolation reduces seismic effects in a building by "decoupling" it from the ground. This is achieved by installing isolation devices (isolators), usually at the base level of a building. In some cases, isolation devices are provided above the base. Base isolation devices are often not visible from the building exterior.

Energy dissipation devices (often called seismic dampers) reduce seismic effects in a building by providing supplemental damping. Energy dissipation devices act in a similar manner like shock absorbers (brakes) in cars. There are several types of devices and they are more often visible (particularly in retrofitted buildings) and look similar to diagonal steel braces.

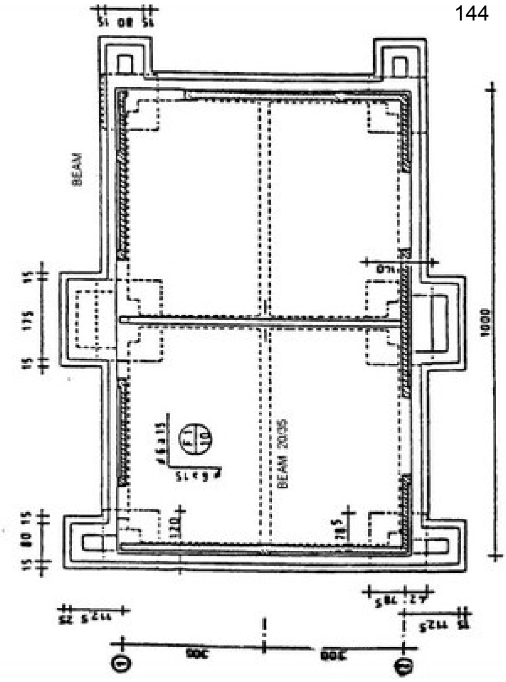


Unbonded braces (also known as Nippon braces) as a retrofit solution for the Hildebrand Hall, University of Berkeley, California (S.Brzev)

Energy dissipation devices were installed in the Union House, Auckland, New Zealand (S. Brzev)

Kyoto University Clock Tower (Japan) is a 1925 concrete building retrofitted in 2000s using base isolation (drawing by M. Nakashima and photos by C. Scawthorn)

The San Francisco International Airport (USA) is equipped with friction pendulum isolation devices (S. Brzev)



Edificio Comunidad Andalucía, a four-storey masonry building in Santiago, Chile w as built in 1992 and it is equipped w ith the high damping rubber isolation devices; an exterior view of the building is show n left (S. Brzev) and a floor plan show ing isolator locations is show n right (M. Moroni)

Edificio San Agustín (Catholic University of Chile) is concrete building in Santiago, Chile built in 2001 and equipped w ith lead core base isolation devices; the left photo show s the building and the right photo show s a typical isolation device located in the basement (S. Brzev)

Parque Araucano is a 22-storey concrete tow er in Santiago, Chile equipped w ith tw o tuned mass dampers at the roof level; the left photo show s the building and the right one show s a tuned mass damper suspended from the roof (S. Brzev)

Exact date of construction or retrofit [YEX]

Year during w hich the construction w as completed.

Exact height of ground floor level above grade [HFEX]

The exact height of the ground level above grade is clear from survey or drawings, and it does not vary more than 1m across the footprint of the building. The average height is defined to an accuracy of 0.1m.

Units: metres

Example: HFEX:0.7 (height is exactly 0.7 m)

Exact number of storeys above ground [HEX]

The exact number of storeys above ground is clear from survey or draw ings. The exact number of the floors above ground includes the ground floor and floors above. It also includes storage and mechanical plant levels only if these cover over 50% of the plan area, but does not include basements below ground. If the building is stepped in height, then record the highest part.

HEX:n
w here n= maximum number of storeys above ground level
Example: HEX:2 (exactly tw o-storey high building)

This is an eight storey building in Morocco (C. Scaw thorn)

Exact number of storeys below ground [HBEX]

The exact number of storeys below ground is clear from survey or drawings. This does not include the ground floor.

Fixed number (integer) e.g. HBEX:2 (two levels of basement)

Exterior walls

This term is related to the material that covers most of the exterior walls of the building. If two materials each cover equal areas of walls, choose the heavier material. Where there are multiple materials present on the exterior walls, choose the material that covers more of the walls by area than any other material.

In some cases this will be the same material as "Material of the lateral load resisting system" if the lateral loads are resisted by the exterior walls and if the structural material is exposed. However in many cases the material that covers the exterior walls will be a separate cladding material that does not resist lateral loads and is laid over the lateral load-resisting structure. In both cases, the material of exterior walls should still be defined if it is known, even if it is the same material that forms the lateral load-resisting structure.

Fabric [RFA]

The building has a fabric roof. Fabric is defined in this case as a textile material, woven or otherwise bonded into a thin flexible sheet. Examples of fabric roofs include tensile membranes, inflatable roofs, and other types of fabric roofs such as plastic sheet, tarpaulin, canvas sheeting.

Fabric, other [RFAO]

The type of fabric roof is know n, but it is not adequately described by the other attributes in this table. This includes any other type of fabric not inflatable or stretched like a tensile membrane, such as plastic sheet, tarpaulin, or canvas sheeting.

A tent-like storage facility w ith a fabric roof (S. Brzev)

Fibre cement or metal tile roof covering [RMT2]

Lightweight fibre cement/asbestos sheet tiles, or pressed metal tiles. Overlapping and usually fastened to wood battens.

Fibre reinforcing mesh [RCM]

This is an overlay of reinforcing mesh bonded or attached to a masonry w all to provide reinforcement. The reinforcement is usually in the form of fibre reinforced polymer (FRP) mesh or fabrics using glass or carbon fibres bonded to the w all w ith a resin, or polymer grid (geogrid) attached to the w all w ith plastic or nylon ties. Mesh is often also placed on the interior surfaces of w alls and to surfaces of interior w alls. The mesh is usually plastered over. Cement or mud plaster is used. This type of reinforcement is often installed in existing buildings as a seismic retrofit provision.

Adobe w alls reinforced w ith polymer mesh, construction phase; note the mesh overlaid w ith mud plaster on the right photo (N. Tarque)

Polymer mesh (geogrid) laid in form of horizontal and vertical bands, adobe w alls, Peru (left-S. Brzev and right-N. Tarque)

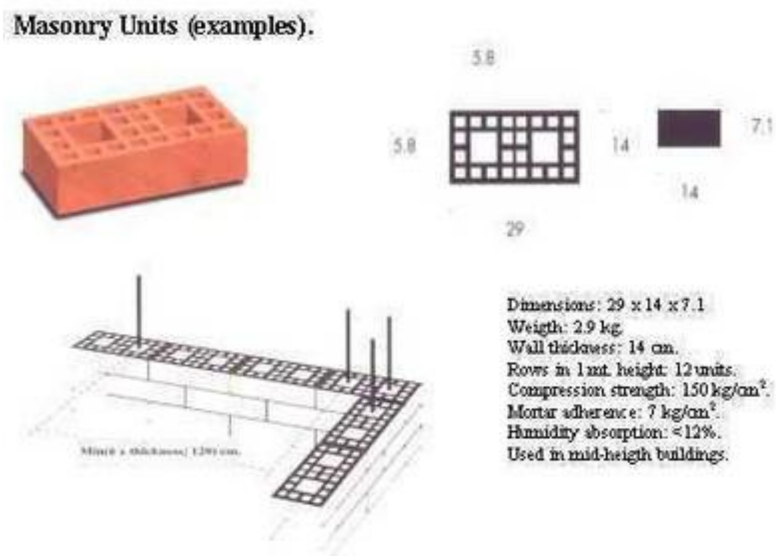
Concrete block masonry reinforced w ith fibre reinforced composite mesh, Canada (J. Sherstobitoff)

Fired clay hollow blocks or tiles [CLBLH]

Fired clay blocks, lightweight extruded type, with several small perforations. Volume of perforations may range from 25 to 70% of the gross block volume. The perforations are laid in the horizontal direction.

Fired hollow clay bricks with horizontally-laid perforations, Peru (S. Brzev)

Fired hollow clay blocks, Iran (A. Charleson)



Hollow clay masonry blocks and the reinforcing scheme, Chile (Moroni, Gomez, and Astroza, World Housing Encyclopedia Report 5)

Hollow clay tile masonry construction, Belgrade, Serbia (S. Brzev)

Fired clay tile masonry wall construction, Albania (C. Scawthorn)

Fired clay hollow blocks as a museum exhibit, Portugal (S. Brzev)

Variants

- Hollow Clay Tiles
- Clay Block
- Perforated Unit

Fired clay hollow bricks [CLBRH]

Fired perforated clay bricks w ith one or more holes (cavities) through the thickness of the brick w ith the area of cavities in excess of 25% of the volume. The holes can be seen from above after the brick has been laid.

Fired clay hollow bricks, Iran (A. Charleson)

Fired clay hollow bricks w ith vertical perforations, Peru (S. Brzev)

Fired clay solid bricks [CLBRS]

Fired or burnt solid clay bricks, usually formed in a shape of rectangular prism.

Fired clay solid bricks, Chile (S. Brzev)

Fired clay bricks (also known as burnt clay bricks) at a construction site, India (S. Brzev)

Clay brick masonry in cement:sand mortar, Christchurch, New Zealand (J. Bothara)

Fired clay unit, unknown type [CL99]

It is clear that the structural material is fired clay brick, but the type of brick is unknown. The bricks may be hidden, or it may not be possible to determine solid from hollow brickwork, or information about it is unavailable.

Fired clay brick wall, Chile (S. Brzev)

Fired clay

Fired clay masonry units are formed while plastic and burnt (low-fired) or fired (high-fired) in a kiln.

Flat [RSH1]

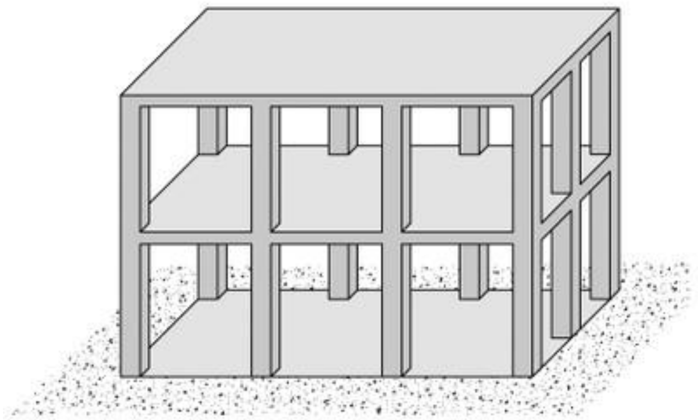
The roof is flat. Any roof with a slope of less than 7 degrees.

Flat concrete roof (waffle slab system), Vancouver, Canada (S. Brzev)

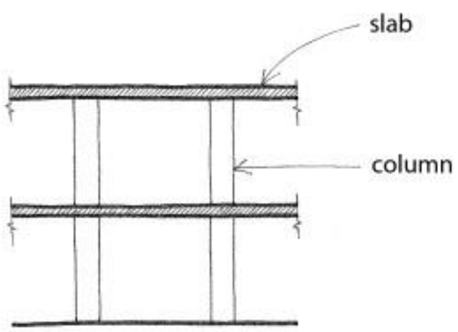
Flat concrete roofs, India (S. Brzev)

Flat slab/plate or waffle slab [LFLS]

Slabs and columns are constructed without beams. Unlike flat plates, flat slabs have capitals and/or drop panels at the tops of columns. (A capital is the upper portion of the column, which is usually of conical shape and larger in cross-section than the remaining portion of the column; a drop panel is a thickened portion of the slab in the area adjacent to a column.) Slab band systems, consisting of continuous wide beams spanning between the columns, also fall in this category due to specific beam-column connections (click here for more information). Primarily designed to resist gravity loads, these systems possess very limited ability to resist earthquake forces. If there are numerous walls *they* should be considered the lateral load-resisting system.



A simplified drawing of a flat slab / plate or waffle slab structure (adapted from: A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 64, Fig. 5.2)



Partial section of a flat plate structure

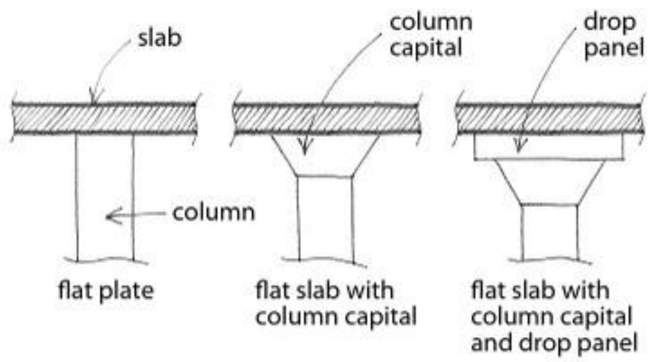


Diagram showing examples of flat plate and flat slabs

Reinforced concrete flat plate system, Eugene, USA (S. Brzev)

Flat slab structure, Canada - note column capitals (S. Brzev)

Reinforced concrete flat slab system (note column capitals), Vancouver, Canada (S. Brzev)

Reinforced concrete flat slab with a column capital, London, UK (S. Brzev)

Flat slab, Australia - note drop panels beneath the slab (A. Charleson)

Slab band system, Canada (S. Brzev)

A reinforced concrete building with flat plate system under construction, Kenya (K. Jaiswal)

Reinforced concrete flat slab under construction, Canada (S. Brzev)


Reinforced concrete parking garage with flat slab system, USA (S. Brzev)

This reinforced concrete building has a waffle slab system, Vancouver, Canada (S. Brzev)


A reinforced concrete waffle slab, Eugene, USA (S. Brzev)

Variants

- Mushroom Slab

Floor connections

Floor connections transfer in-plane forces of floor diaphragms to the lateral load-resisting structure of the building (e.g. w alls), and also restrain outw ard displacements of w alls. These connections apply to suspended floor diaphragms only, they do not apply to floors at ground floor level.

Floor material, other [FO]

The floor structure material is know n, but they do not fit w ithin any of the definitions in this table.

Floor material, unknown [F99]

The material of the floor is unknown. It has not been inspected sufficiently to determine the material, or information is unavailable. In some cases the material of the structure of the floor will not be visible due to overlay of floor covering materials and/or the presence of ceilings below the floor that may be a different material.

Floor system material

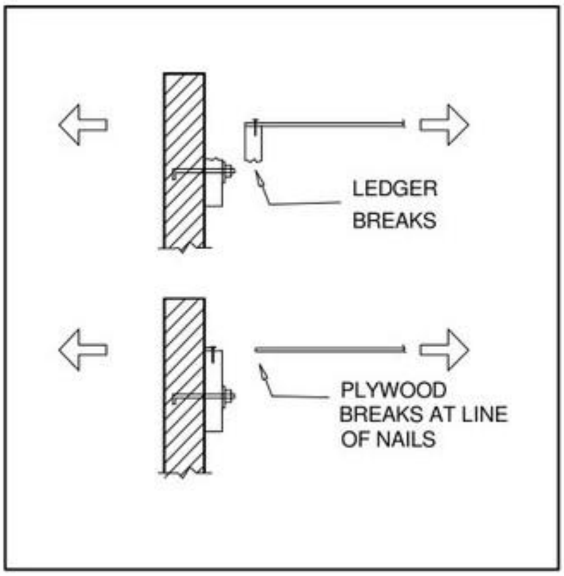
The material is that from which the floor is primarily constructed. Do not include materials that are non-structural or that are not part of the structure of the floor. In many cases floor structures can be overlaid with timber flooring or tiles etc., but it is the structure under that overlay material that should be listed as the material of the floor.

Floor system type

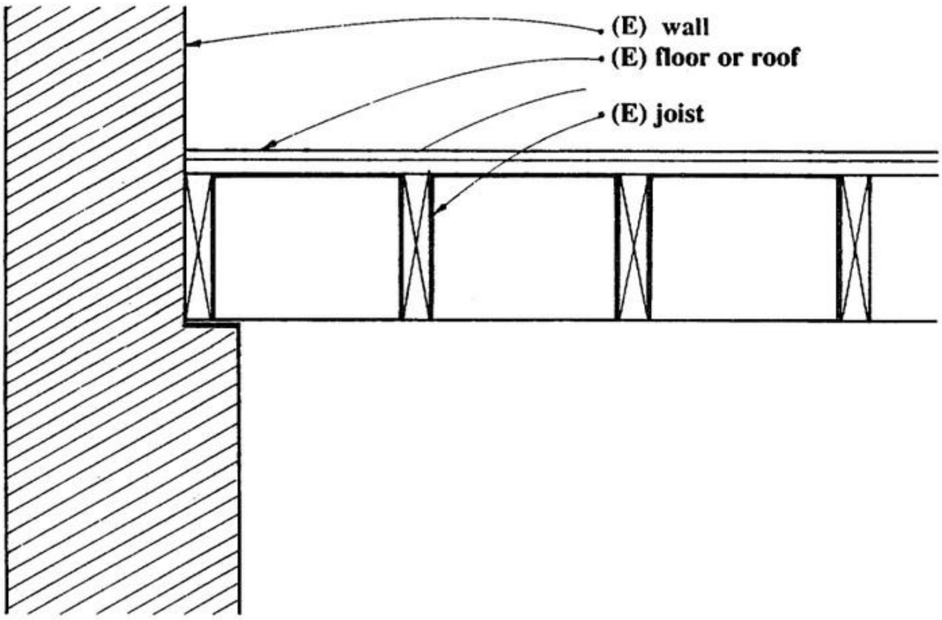
The floor type is the structural system of the floor. Floor types are grouped according to material and methods of construction. Do not include materials that are non-structural or that are not part of the floor structure. In many cases floor structures are overlaid with timber flooring or tiles etc., but it is the structure under that overlay material that should be listed as the floor type.

Floor-wall diaphragm connection not provided [FWCN]

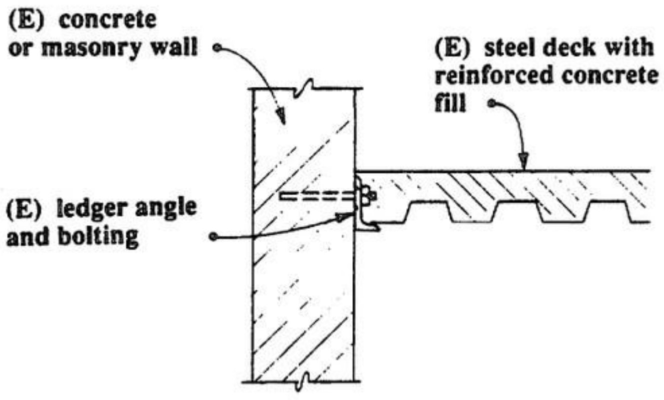
There are no connections between the floor diaphragm(s) and the walls that are capable of transferring in-plane forces from roof to wall and restraining outward displacements of walls.



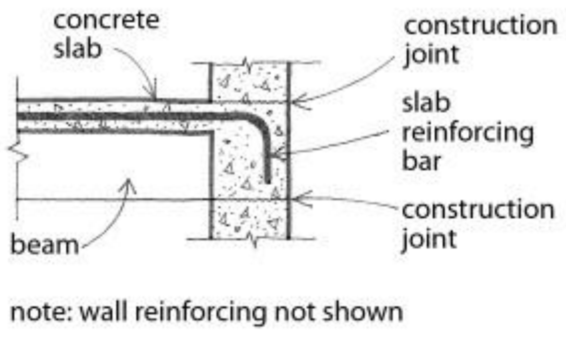
Inadequate wooden floor-to-wall connection (FEMA 310, 1998)



Example of wall-to-floor connections of a wood diaphragm, that may be inadequate (adapted from FEMA 172, 1992)

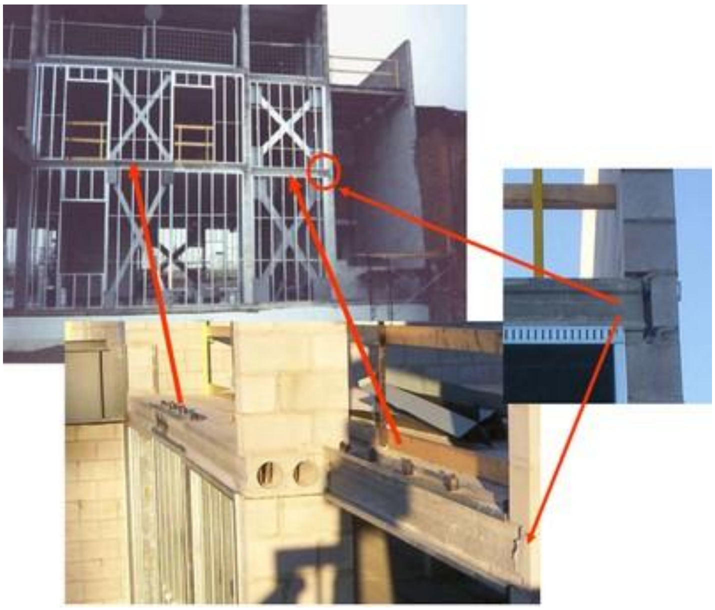


Example of connections of a composite concrete slab and steel deck diaphragm to a concrete or masonry wall, that may be inadequate (adapted from FEMA 172, 1992)



Cast-in-place reinforced concrete floor supported by concrete wall. The connection may not be adequate if construction joints are not able to transfer lateral loads across the interface.

Floor-wall diaphragm connections between steel trusses (known as Open Web Steel Joists in North America) and masonry walls may be inadequate if support provided by the wall is not adequately designed and/or constructed (J. Adams)



Support for hollow concrete slabs provided by masonry walls may be inadequate (J. Adams)

Inadequate support for precast concrete hollow floor slabs provided by supporting beams contributed to building collapse in the 2008 Wenchuan, China earthquake (J. Dai)

Out-of-plane wall collapse was reported in some unreinforced masonry buildings due to the 2011 Christchurch, New Zealand earthquake; the building shown on the photo had inadequate floor-wall connections (K. Elwood)

Floor-wall diaphragm connection present [FWCP]

There are connections betw een the floor diaphragm(s) and the w alls, capable of transferring in-plane forces from roof to w all and restraining outw ard displacements of w alls.

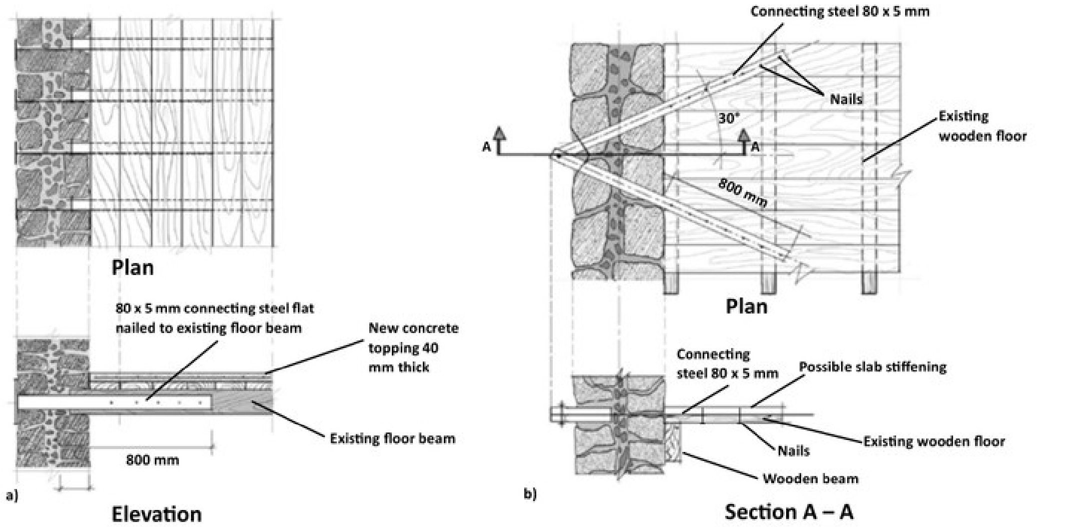


Figure 4.13 Steel straps for wall-to-floor anchorage: a) floor beams perpendicular to the wall, and b) floor beams parallel to the wall (source: UNIDO 1983)

Examples of retrofit methods to improve strength of existing w all-to-floor connections in stone masonry buildings w ith w ooden floors (Improving the Seismic Performance of Stone Masonry Buildings, Bothara and Brzev, EERI, 2011)

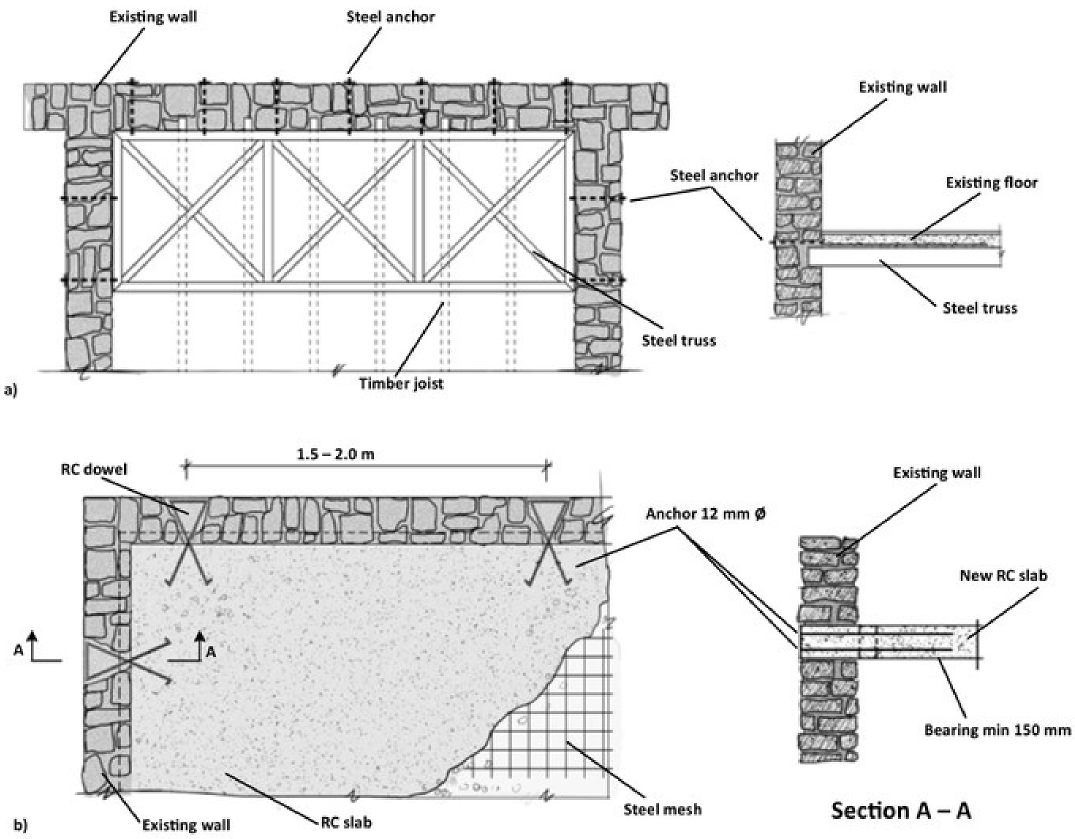
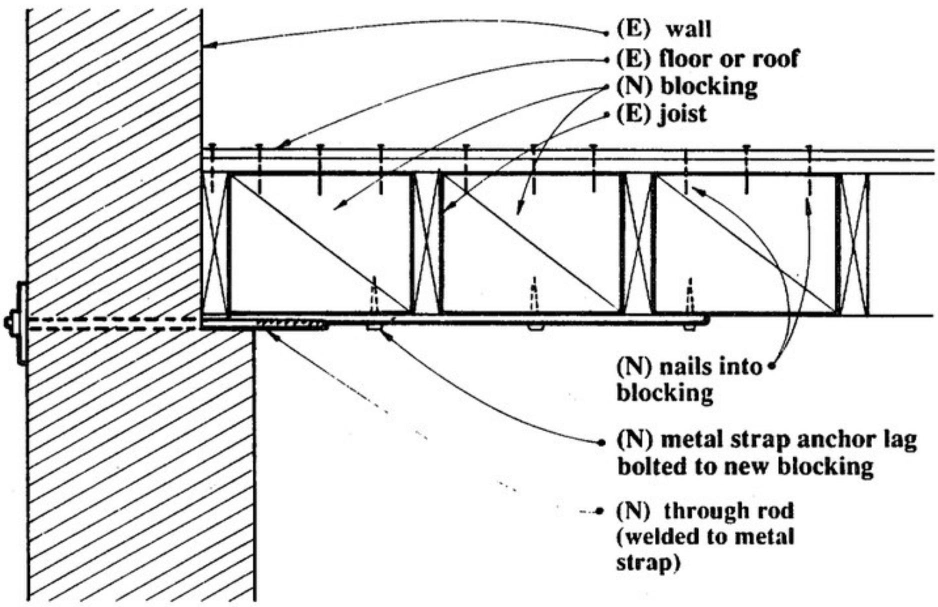
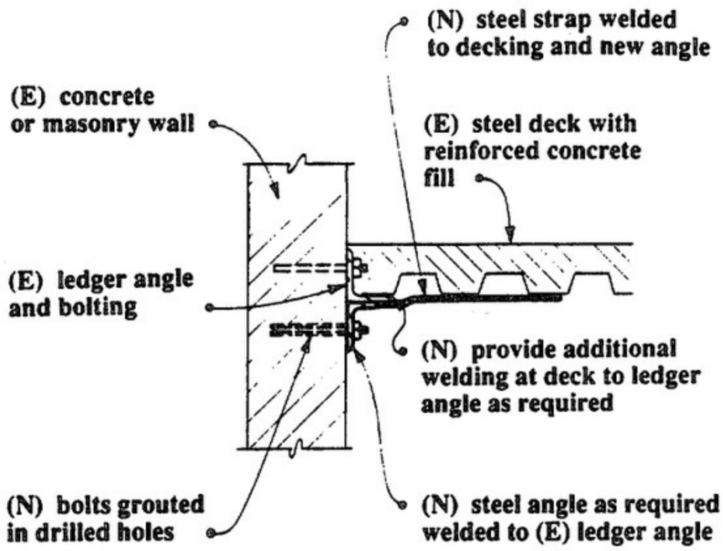


Figure 4.15 Retrofitting the floor and roof structures: a) diagonal braces, and b) a new RC slab (adapted from: Tomazevic 1999)

Examples of retrofit methods to improve strength of wall-to-floor connections in stone masonry buildings with reinforced concrete floors (Improving the Seismic Performance of Stone Masonry Buildings, Bothara and Brzev, EERI, 2011)



Example of retrofit method to improve strength of wall-to-floor connections of a wood diaphragm - note: N refers to New and E refers to Existing components (FEMA 172, 1992)



Example of retrofit method to improve strength of wall-to-floor connections of a composite concrete slab and steel deck diaphragm to a concrete or masonry wall; note: N refers to New and E refers to Existing components (FEMA 172, 1992)

A retrofitted unreinforced brick masonry building w ith floor-w all anchors visible at the exterior, Vancouver, Canada (S. Brzev)

A retrofitted unreinforced brick masonry building show ing exposed floor-w all and roof-w all anchors at the exterior, Seattle, USA (S. Brzev)

A typical w all anchor, consisting of a steel rod and an exterior steel plate exposed at the exterior; note that anchor plates are of different shapes and sizes (S. Brzev)

Floor-wall diaphragm connection unknown [FWC99]

It is not known if there are any connections between the floor diaphragm(s) and the walls that are capable of transfering in-plane forces from floors to wall and restraining outward displacements of walls. There is insufficient information available or the connections are not visible from a survey.

It is not clear if floor-wall diaphragm connections are present for this unreinforced brick masonry building (S. Brzev)

It is not clear if floor-wall diaphragm connections are present in this stone masonry building (S. Brzev)

Floor

This table only applies to intermediate floors above ground level that have a diaphragm action under lateral loads. The structure of ground floors is not included in this table. In the case of single storey buildings, this section should be left blank.

Foundation, other [FOSO]

The type of foundation system is known, but none of the foundation system types in this table adequately describe it.

Foundation System

The type of foundation system, clagssified according to depth and w hether it has lateral load-resisting capacity. A foundation system is the part of the building structure that is in contact w ith the ground and transfers the loads of the building structure into the ground.

Lateral capacity denotes some form of specific lateral support e.g. tie-beams, foundation w alls, inclined piles, piles or piers on w ide spread footings, and piles deeply embedded or braced w ith some type of diagonal bracing. It also applies to slabs on grade, in w hich the w hole slab or a major part of it is in contact w ith the ground.

Glass exterior walls [EWE]

Glass curtain walls, storefront glass systems, or any other exterior walls where glass windows cover more of the walls by area than any other material. Also includes solar panelled exterior walls, where photovoltaics modules are integrated directly into a building envelope by replacing curtain walls (Building Integrated Photovoltaics).

A highrise office building with glass curtain walls, Santiago, Chile (S. Brzev)

A building with glass curtain walls, Vancouver, Canada (S. Brzev)

Exterior walls in this building are mostly of glass and masonry, however glass is considered to be a prevalent material, Halifax, Canada (S. Brzev)

Solar (photovoltaic) modules as exterior walls, Vancouver, Canada (L. Stamenic)

Solar (photovoltaic) modules as exterior walls, United Kingdom (L. Stamenic)

Government [GOV]

The building is used by national or local government, and includes office buildings, and facilities involved in emergency management. Medical and educational facilities are not included in this category.

Government emergency response [GOV2]

Any local government or national government-ow ned building that has an essential post-disaster function. E.g. Police, fire station, emergency operations centre. For hospitals see COM5 Hospital / Medical clinic.

Government general services [GOV1]

Office buildings used for national government or local government purposes.

Government, unknown type [GOV99]

It is clear that the building is used by national or local government, but the exact type of government use is unknown.

Granite [SPGR]

Granite is a light-colored igneous rock with a random arrangement of minerals grains large enough to be visible with the unaided eye. Granite is a coarse-grained, light-colored igneous rock composed mainly of feldspars and quartz with minor amounts of mica and amphibole minerals. This mineral composition usually gives granite a red, pink, gray or white color with light and dark mineral grains scattered throughout the rock. Granite polishes well and resists weathering and acid rain. Granite is hard and difficult to shape into regular blocks; for that reason it is mostly used for random rubble or semi-dressed stone masonry construction. Granite is generally resistant to scratching by metal.

Granite is used for wall construction in Maharashtra, India (S. Brzev)

Granite stone boulders prepared for construction, Pakistan (T.Schacher)

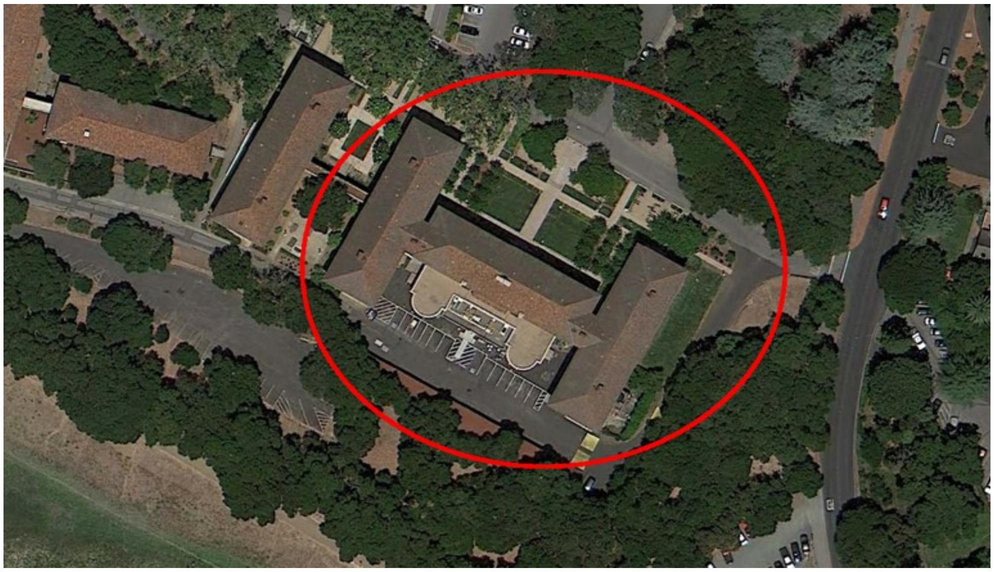
Granite w as used for the construction of Inca building complex, Macchu Picchu, Peru (S. Brzev)

Ground floor

The floor level of the building that is either on-grade, or the closest floor to outside ground level. Commonly called ground floor, but also called 'first floor' in American terminology. On sloping sites the low est floor level is called the ground floor.

H-shape [PLFH]

The footprint of the building when viewed in plan resembles the shape of the letter H.



A building with H-shaped plan, Stanford University, California, USA (Map data ©2013 Google, SIO, NOAA, U.S. Navy, NGA, GEBCO, LDEO-Columbia, NSF, Image Landsat)

Heavy Industrial [IND1]

Factories and facilities considered as heavy industry. E.g. Oil and petrochemical, pow er generation and distribution, pulp and paper.

Heavy wood [WHE]

Wood frame members of large cross-sections are used. They may form some type of frame or a Post and Beam system. Includes infilled heavy w ood frames such as Half-w ooded buildings.

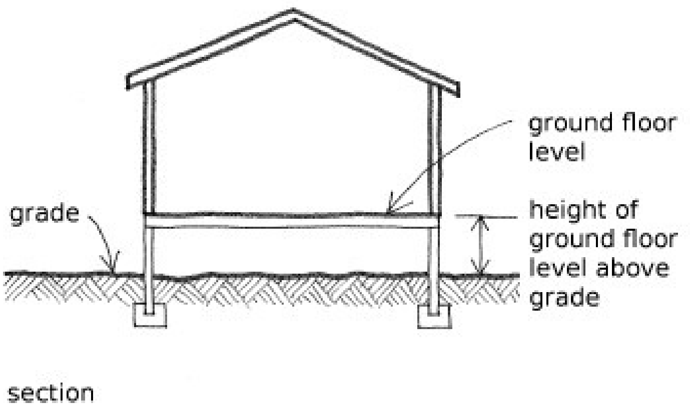

Heavy w ood, New Zealand (A. Charleson)

Height of ground floor level above grade [HF]

Grade is the level of the ground at the perimeter of the building. This attribute records the height of the ground floor level of the building above grade.

The height of ground floor level above grade can be recorded as an exact number, or as a range, or as an approximate number. It can also be recorded as unknown.

Grade is usually somewhat lower than the ground floor level, and this information is relevant for flood hazard and foundation seismic performance.



An example of how the height of the ground floor level above grade is measured on a flat site

Height of ground floor level above grade in this dwelling in Cambodia is at least 2 meters (C. Scawthorn)

Height of ground floor level above grade unknown [HF99]

The height of the ground floor above grade is unknown. It is impossible to determine this height within an estimated range, or give an exact or approximate height. Information is unavailable, or the building has not been inspected sufficiently to determine the height of the ground floor above grade.

Height

The height of the building is defined in this table, measured in storeys. The number of storeys below ground is also defined, as is the height of the ground floor level above grade, and the slope of the site.

Hospital/medical clinic [COM4]

All medical facilities, including hospitals and clinics.

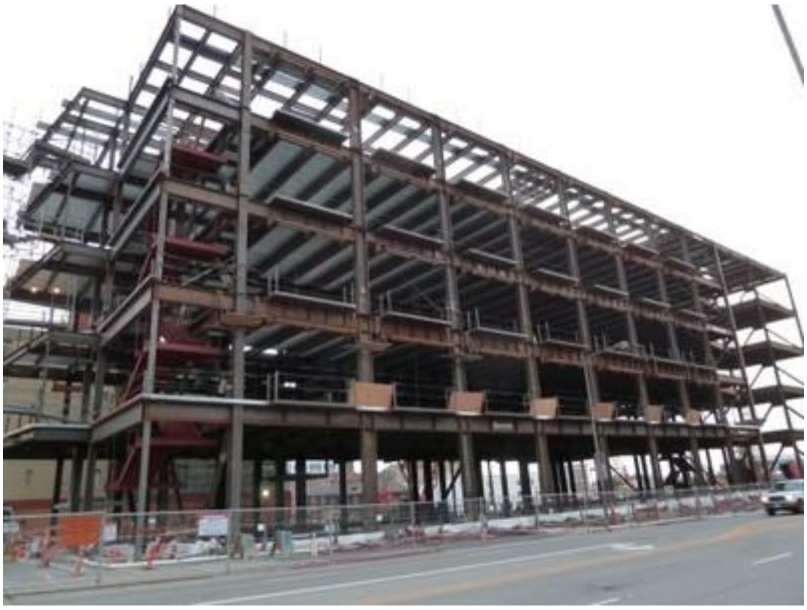
Hot-rolled steel members [SR]

Steel sections that have been hot rolled or fabricated from plates welded together and used as primary lateral load-resisting structure, welded or bolted together.

Hot-rolled steel sections at a construction site: I-shaped (called W sections in North America), channel sections (called C sections in North America, etc. (Canada - S. Brzev)

Hot-rolled hollow steel sections (HSS sections), Canada (S. Brzev)

Steel building construction, hot-rolled steel members, Wellington, New Zealand (A. Charleson)



Steel building under construction, hot-rolled steel members, California (S. Brzev)

Variants

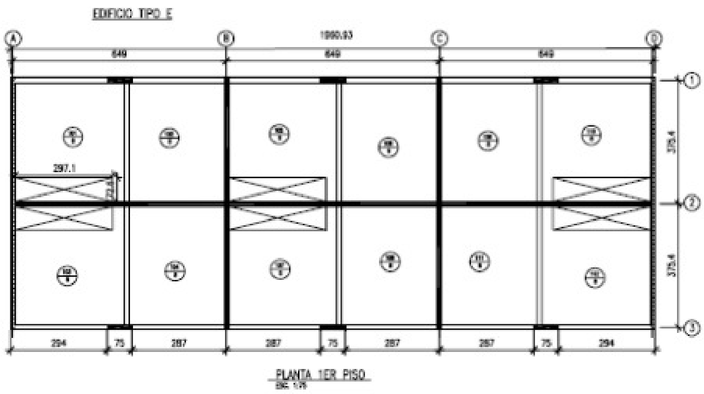
- Regular-weight steel sections

Hybrid lateral load-resisting system [LH]

Hybrid Lateral Load-Resisting System (LLRS) exists in one of the following two cases: a) there is more than one LLRS in the building, but there is no clear distinction between LLRSs in two principal directions (X and Y), or b) there is only one LLRS in the building, but two or more materials of the LLRS are used in different portions of the building. Note that Dual Frame-Wall System is also a hybrid system, however it has been classified as a separate LLRS in the taxonomy. It should be also noted that Direction attribute is intended to be used to describe buildings with two distinct LLRSs in principal directions of the building, which are also hybrid systems.

Different LLRSs could exist up the building height, or there could be more than one system in each principal direction of the building. For example, reinforced concrete moment frame exists in bottom one or two storeys and load-bearing masonry in the upper storeys in the same building.

An example of a hybrid LLRS where two different materials are used is Wall system, where load-bearing masonry exists in bottom one or two storeys supporting a wooden lateral load-resisting system (also classified as Wall) above.



An example of a hybrid system from Chile, where reinforced concrete columns exist in longitudinal direction (baylines 1 and 3) at the lower two floor levels, and there are reinforced masonry walls at upper levels (as shown on the floor plan above). Reinforced concrete walls along bayline 2 exist at the ground floor level, and there are reinforced masonry walls at upper levels. Walls in transverse direction (baylines A and C) are of reinforced masonry at all floor levels. Walls along bayline B are of reinforced concrete construction at the ground floor level, and reinforced masonry construction at upper levels (M.O. Moroni Yadlin).

An old loadbearing brick masonry building at the ground floor has been overlaid by new reinforced concrete frame construction above; the damage to the masonry part occurred during the Athens earthquake of Sept. 7, 1999; reinforced concrete frame extensions (in plan, or elevation, or both) to old masonry buildings are frequent in Greece w here they constitute around 5% of the existing building stock" (A. Pomonis)

Buildings w ith reinforced concrete frame used in the first storey and confined masonry above can be found in China; some buildings of this type w ere affected by the 2008 Wenchuan earthquake (J. Dai)

Buildings with a cast in-situ reinforced concrete frame at the ground floor level and brick masonry or concrete walls above can be found in Kyrgyzstan (K. Kanbolotov)

Collapse of the 6th storey of the 8-storey Kobe City Hall Annex building in the 1995 Kobe, Japan earthquake. The collapse was likely due to a hybrid lateral load-resisting system consisting of steel reinforced concrete (SRC) at lower floors and RC frame at upper floors (C. Scawthorn).


A six-storey building damaged in the February 2011 Christchurch, New Zealand earthquake has reinforced concrete w alls at the ground floor level and reinforced masonry construction above (in the form of interior reinforced concrete block w alls in the interior and cavity w alls at the exterior) (J. Centeno)

A hybrid system consisting of cast-in-place reinforced concrete frame construction at the ground floor level and w ood frame construction above can be found in California (USA) and British Columbia (Canada) (D. Bonow itz)

Reinforced concrete frames at the ground floor level and wood frame apartments above - ground floor usually used for parking, California (D. Bonowitz). A building with precast reinforced concrete frame at the ground floor level and wood frame above collapsed in the 1994 Northridge, California earthquake (the concrete frame collapsed and the building lost ground floor) (FEMA 454)

A building with the ground floor consisting of unreinforced stone and brick masonry construction, and the second storey with Dhajji Dewari construction, Kashmir, India (D. Rai)

A building with a hybrid lateral load-resisting system consisting of the confined masonry construction at the first storey and timber construction at the second storey, Constitution, Chile (S. Brzev)

An example of a hybrid system with reinforced concrete frame at the ground floor level and steel frame above, Athens, Greece (the left photo shows a building under construction and the right photo shows a similar building when completed) (A. Pomonis)

A hybrid building with stone masonry wall at the ground floor, brick masonry wall at the second floor, and Dhajji Dewari construction (note wooden posts) at the top floor level, Kashmir, India (D. Rai)

A hybrid system consisting of confined masonry at the bottom floor and reinforced clay block masonry above; this photo shows a building in Chile which suffered damage at the second floor in the 1985 Llolleo earthquake (M. Astroza)

Industrial [IND]

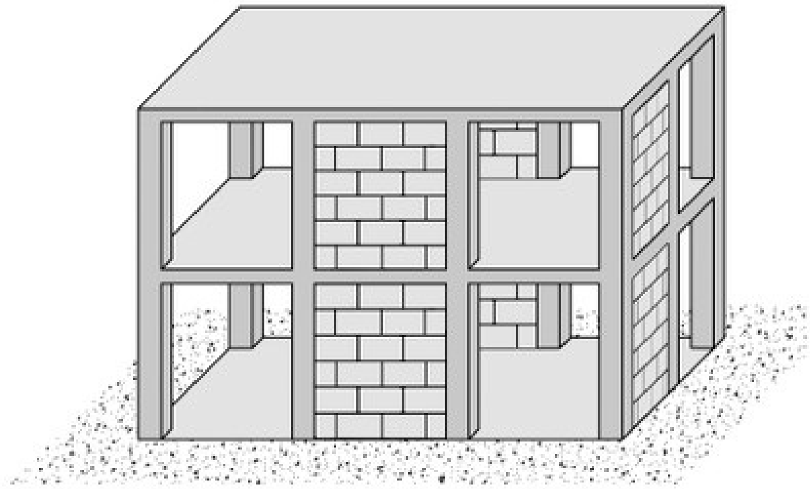
The building is used for industrial processes and manufacturing.

Industrial, unknown type [IND99]

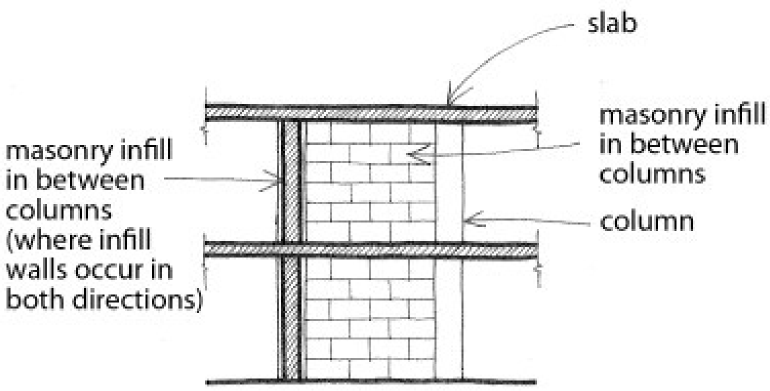
It is clear that the building is an industrial building, but the exact type of industrial use is unknow n.

Infilled flat slab/plate or infilled waffle slab [LFLSINF]

As per Flat Slab/Plate or Waffle Slab, but w here masonry or concrete infills provide lateral stability. For this type of lateral load-resisting system the infills are located betw een columns, otherw ise the system should be described as Wall.



A simplified draw ing of an infilled flat slab / plate or infilled w affle slab structure (adapted from: A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p64 fig. 5.2)



Partial section of an infilled flat plate structure

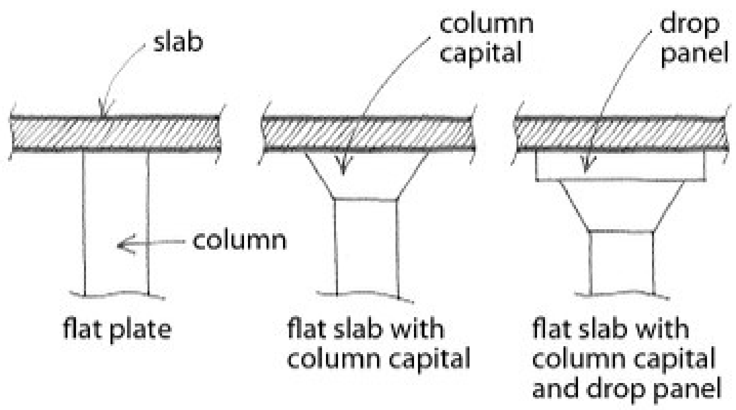
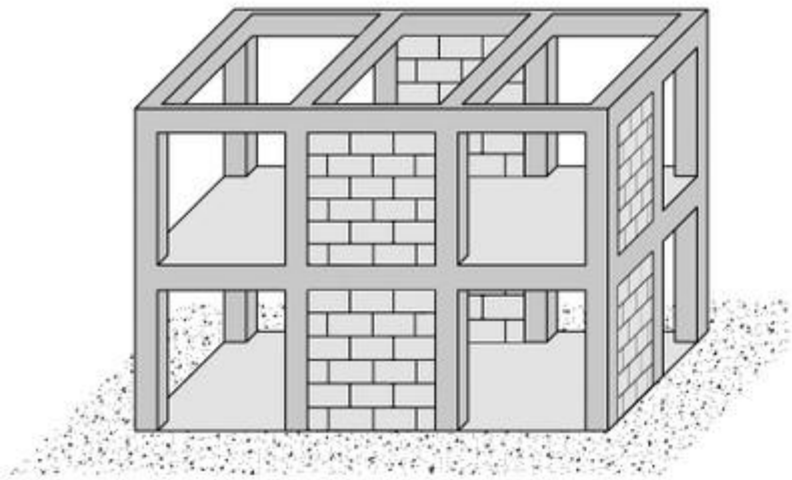


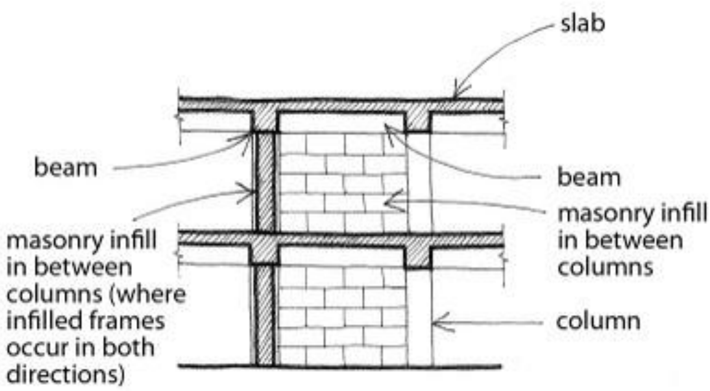
Diagram show ing examples of flat plate and flat slabs

Infilled frame [LFINF]

A framework of beams and columns in which some bays of frames are infilled with masonry walls that may or may not be mechanically connected to the frame. Due to great stiffness and strength in their planes, infill walls do not allow the beams and columns to bend under horizontal loading, changing the structural performance of the frame. During an earthquake, diagonal compression struts form in the infills so the structure behaves more like a Braced Frame rather than a Moment Frame. Infill walls can be part-height or completely fill the frame.



A simplified drawing of an infilled frame structure showing floor slabs supported by beams (adapted from: A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 64, Fig. 5.2)



Partial section of an infilled frame structure

Reinforced concrete frame with brick masonry infill walls, India (A. Charleson)

Reinforced concrete frame with brick masonry infills under construction, India (S. Brzev)

Reinforced concrete frame building with concrete block infill walls, Padang, Indonesia (J. Bothara)

Reinforced concrete frame building with brick infill walls under construction, Kathmandu, Nepal (J. Bothara)

Reinforced concrete frame infilled with stone masonry panels in M'Sila damaged in the 2010 Algeria earthquake (M. Farsi)

This reinforced concrete frame building with hollow clay tile infills in Algiers was under construction at the time of the 2003 Boumerdes, Algeria earthquake, and it suffered damage at the first storey level (S. Brzev)

Reinforced concrete frame building with hollow clay block infills, Uganda (E. Lemkuhl)

Reinforced concrete frame with masonry infills, Tangier, Morocco (C. Scawthorn)

Detail of a reinforced concrete frame with hollow clay tile infill, Rabbat, Morocco (C. Scawthorn)

Reinforced concrete frame with masonry infills under construction, Vietnam (C. Scawthorn)

Inflatable or tensile membrane roof [RFA1]

An inflatable roof uses fabric chambers pressurised w ith air to form a self-supporting structure.

A tensile membrane roof is made of stretched fabric, usually stretched in tw o directions to form a tensioned surface. Examples of tension membranes include polyester coated w ith PVC and glass fibre coated w ith Teflon.

BC Place Stadium in Vancouver, Canada has a tensile membrane roof; the roof is covered by a semi-transparent plastic material (ETFE) (S. Brzev)

Canada Place in Vancouver, Canada, a tent-like structure that resembles a sailing ship, has a tensile membrane roof (S. Brzev)

Informal housing [RES6]

Any form of shelter or settlement which is illegal, falls outside of government control or regulation, or is not afforded protection by the state.

Variants

- Slums
- Slum settlements
- Shanty towns

Institutional housing [RES4]

Group housing; including military, college, prisons, and nursing homes.

Iron [MEIR]

Generally cast iron, but includes all grades of iron.

Irregular plan shape [PLFI]

The building footprint is a shape that cannot be reasonably described by one of the shapes in this table. Buildings with A-, B-, F- or P-shaped plans are included in this class.


Guggenheim Museum in Bilbao, Spain has an irregular plan shape (Left:http://upload.wikimedia.org/wikipedia/commons/1/1d/Guggenheim_Museum,_Bilbao,_July_2010_%2806%29.JPG; Right: map data ©2013 Google, Eusco Jaurlaritza, Gobierno Vasco)


Supreme Court of Canada building in Ottawa has a B-shaped plan (Map data ©2013 Google, DigitalGlobe)

The West Block is a part of the building complex housing the Canadian Parliament (Parliament Hill, Ottawa, Canada); the building has a P-shaped plan (Map data ©2013 Google, DigitalGlobe)


Central Public Library in Vancouver, Canada has a circular plan shape with an opening, plus a free-standing elliptical wall, and an office tower (Map data ©2013 Google, DigitalGlobe)

Irregular structure [IRIR]

At least one structural irregularity (plan and/or vertical) listed in the table is present. A **primary** (plan or vertical) Irregularity is considered to increase the seismic vulnerability of the building more than the **Secondary** Irregularity.

L-shape [PLFL]

The footprint of the building when viewed in plan resembles the shape of the letter L; that is, the building is a single unit (no seismic gap) with two 'wings' near to or at right angles to each other.

This building in San Francisco, California has an L-shaped plan (Left: S. Brzev; right: Map data ©2013 Google, DigitalGlobe, U.S. Geological Survey)

Lateral load-resisting system

The structural system that provides resistance against horizontal earthquake forces through vertical and horizontal components.

It is possible to identify different lateral load-resisting systems in tw o principal directions of the building by using the Direction attribute. In some buildings, there is more than one lateral load-resisting system in each principal direction, or the system varies up the height of the building, in w hich case the Hybrid Lateral Load-Resisting System attribute is used.

Latest possible date of construction or retrofit [YPRE]

The construction w as completed before the World War II, thus the year entered is 1939.

Light industrial [IND2]

Factories and facilities considered as light industry. E.g. Factories, telecommunications, textiles, transportation services, utilities.

Light wood members [WLI]

Small w ood members typically w ith maximum dimensions in the order of 100 mm. Usually, they are closely-spaced. Light w ood framed house construction, w hich usually includes sheet linings or w ood boards that provide most of the bracing is classified as a Wall lateral load-resisting system.

Light Wood Framing, New Zealand (A.Charleson)

Lime mortar [MOL]

Mortar between masonry units consists of a mix of lime putty and sand. It is characterized by a light beige colour. Lime mortar is a low-strength (weak) mortar, and it can be easily scratched (removed) from the wall using a sharp tool (like a key). Lime mortar can be found in older buildings, mostly fired clay masonry construction.

Fired clay brick masonry in lime mortar, Canada (Ojdrovic Engineering)

Limestone [SPLI]

Limestone is a sedimentary rock made primarily of the mineral calcite (calcium carbonate). Limstones are usually white or grey, but maybe coloured brown, yellow, or red or blueish, grey, or black (due to iron oxides or carbon). Most limestones are usually fine grained and featureless, but may also be medium to coarse grained, or contain fossils. Because calcite is a not much harder than a fingernail, limestones are generally soft and can be scratched with metal easily. A diagnostic characteristic of limestone is that it effervesces (bubbles) when in contact with a solution of weak (5%) hydrochloric acid.

Limestone blocks used for stone masonry construction, Algeria (M. Farsi)

Loadbearing masonry walls built using limestone - note hewn stones in the corners and wooden lintels, Pylos, South West Peloponnese, Greece (A. Pomonis)

Limestone wall construction, school building, Nepal (M. Schildkamp)

Limestone masonry, multi-family housing, Kingston, Ontario, Canada (J. Lee)

Limestone masonry, single-family home, Kingston, Ontario, Canada (J. Lee)


Limestone masonry, single-family housing, Kingston, Ontario, Canada (J. Lee)


Limestone masonry construction, church, Kingston, Ontario, Canada (J. Lee)

Limestone masonry wall in Ben-Daoud damaged in the 2010 Algeria earthquake (M. Farsi)

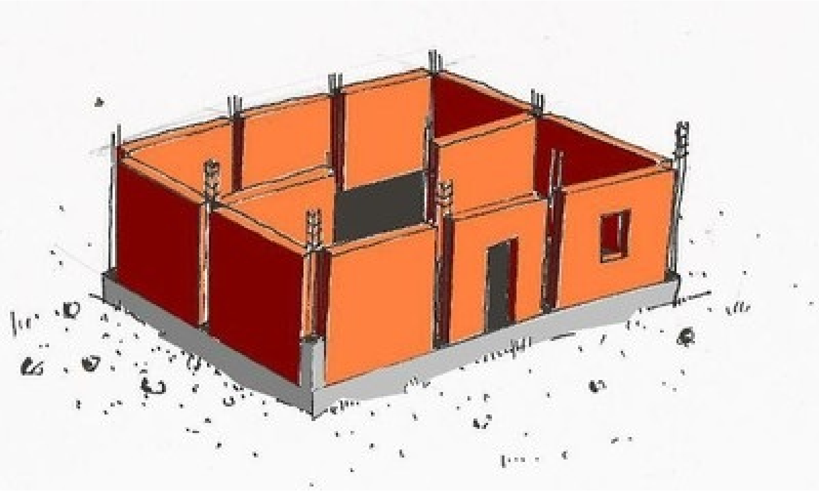
Limestone masonry wall in Beni-Ourtilane damaged in the 2000 earthquake (M. Farsi)

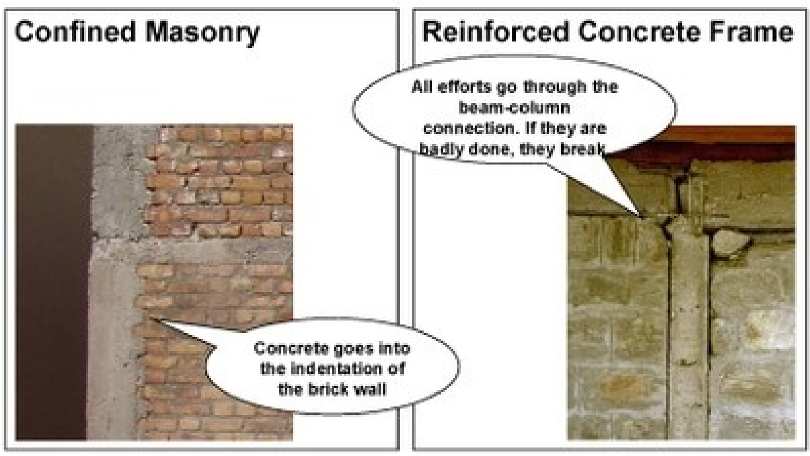
Limestone wall construction, Italy (S. Brzev)

Limestone masonry walls in a six-storey residential building, Nice, France (S. Brzev)

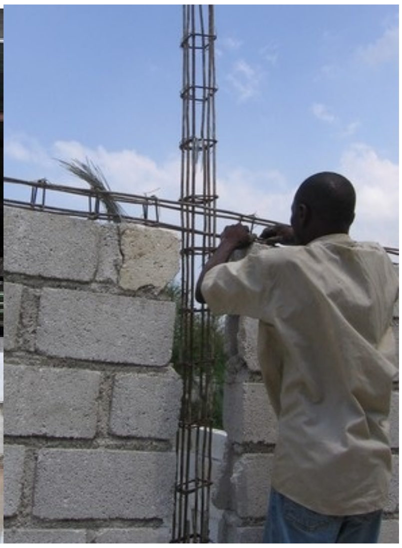
Masonry, confined [MCF]

Masonry construction w here masonry w alls are first laid and then reinforced columns and beams are cast. In this type of construction the concrete bonds to the masonry and the small-size columns and beams (called tie-columns and tie-beams) confine masonry w all panels. This material type is associated w ith the Wall lateral load-resisting system since the masonry bears gravity and lateral loads and the slender columns and beams do not constitute rigid frames but rather function as confining members. Construction w here columns and beams are constructed *before* the masonry w alls are laid is classified as an Infilled Frame or an Infilled Flat Slab/Plate.


Confined masonry construction, show ing that masonry w alls are constructed first, follow ed by reinforced concrete confining elements (T. Schacher)



A confined masonry building can be recognized by toothing, that is, interface betw een concrete and masonry w all as show n on the left photo; this is unlike reinforced concrete frame, w here frame is constructed first and there is no toothing. How ever, confined masonry in some countries (e.g. Argentina and Indonesia) is practiced w ithout toothing (T. Schacher)



Confined masonry under construction using concrete blocks, Haiti (B. Benjamin)

Confined masonry w all under construction using clay brick units, Chile (S. Brzev)

Confined masonry building, Mexico (S. Brzev)

Confined masonry construction, Indonesia (J. Bothara)

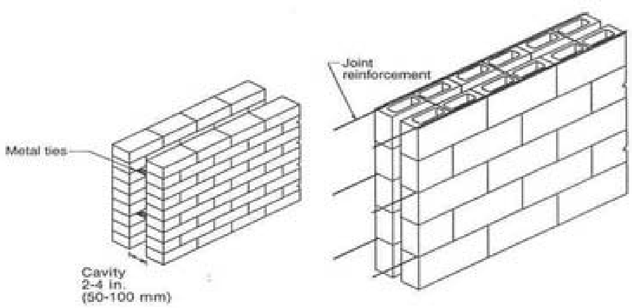
Confined stone masonry construction, Algeria (M. Farsi)

Masonry exterior walls [EWMA]

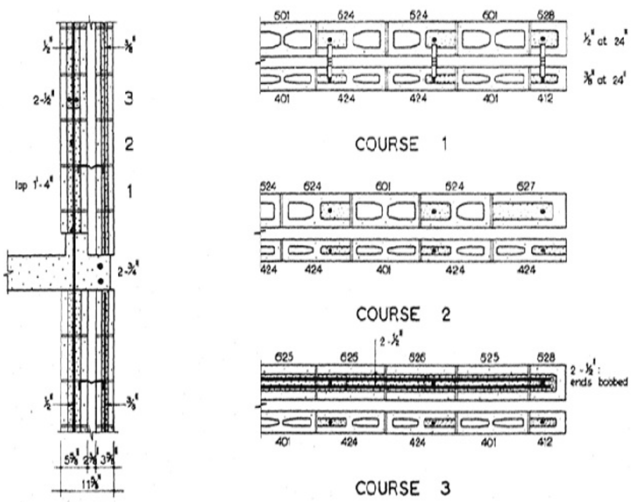
All types of masonry units used as cladding, infill, or exposed wall structure. Includes a variety of masonry units, including adobe bricks and blocks, burnt clay bricks and blocks, stone, ceramic tile. It is often difficult to identify type of masonry units once the walls have been covered by plaster. These walls can be in the form of veneers, cavity walls, infill walls, as well as all of these materials used as Wall structure (a part of the Lateral Load-Resisting System), and where they are not covered by another material.

Stone masonry at the ground floor level and brick masonry above, Berkeley, California (S. Brzev)

An older partially demolished multi-wythe brick masonry wall in Vancouver, Canada (B. McEwen)

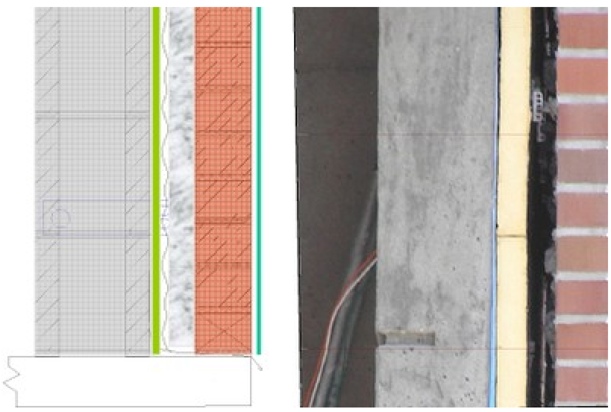


An exterior masonry wall may be a part of the cavity wall system, which consists of two masonry walls separated by an air gap; usually, one wall is load-bearing while the other is veneer (cladding). These walls may be connected by metal ties, and horizontal reinforcement may be provided (A. Charleson)

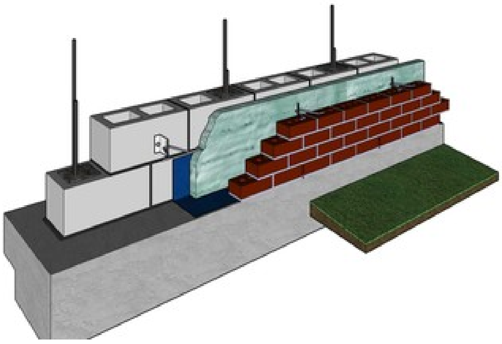


An illustration of cavity wall construction in New Zealand circa 1960 - note an interior (loadbearing) wythe and an exterior (veneer) wythe separated by a 50 mm air gap; the wythes are connected by galvanized wire ties (Holmes,I.L., Concrete Masonry Buildings in New Zealand, Proceedings of the 3rd World Conference on Earthquake Engineering, Session IV: 244-255,1965 - reproduced with the permission of the International Association for Earthquake Engineering)

Concrete block cavity walls damaged in the 2011 Christchurch, New Zealand earthquake: the photos show damage of both exterior and interior wall wythes (J. Centeno)

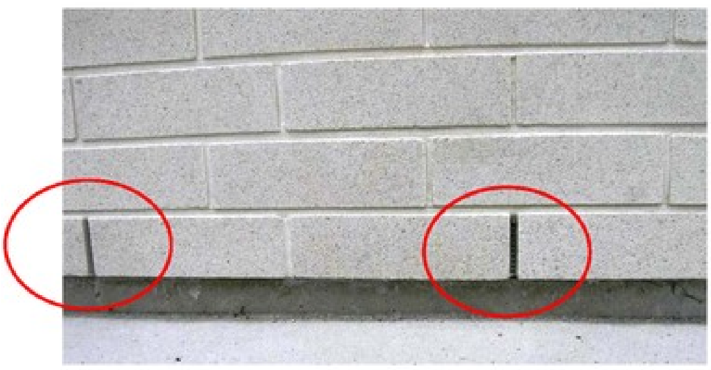


Masonry veneers are common exterior walls in Canada and the USA; a masonry veneer is a single-wythe brick masonry wall securely fastened to a structural backing (e.g. concrete masonry block wall, steel or wood stud framing). A veneer can be attached to structural backing by means of metal ties (B. McEwen, Canada; hyperlinked drawings courtesy of Masonry Institute of BC)

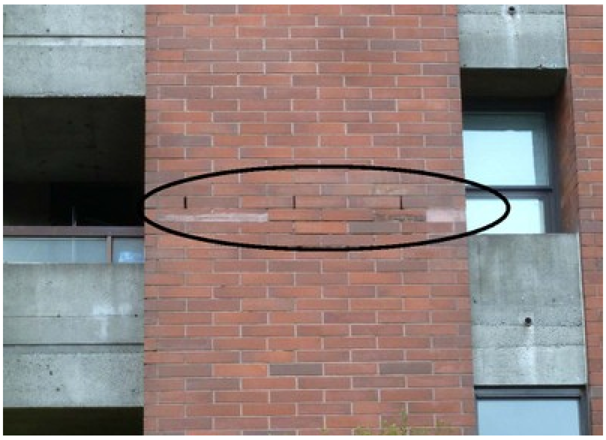


A diagram showing layered construction of a concrete block masonry backup wall with clay brick masonry veneer and insulation in between (web link permission courtesy of Masonry Institute of BC, Canada)

The exterior walls shown on the top photos look like loadbearing brick masonry construction. The photo on the left shows an older loadbearing brick masonry wall (built between 1900 and 1950), while the photo on the right shows a wall in a modern building (built between 1990 and 2010) which has similar masonry detailing like older buildings. However, the exterior brick masonry wall is a veneer and the loadbearing wall is likely a wood frame. The wall has weep holes characteristic of veneer construction (see detail on the bottom photo). The photos were taken in Vancouver, Canada (B. McEwen)



A concrete brick veneer wall with weep holes (B. McEwen)



An example of a masonry veneer in a reinforced concrete building in Vancouver, Canada; veneer can be identified by weep holes, as shown in the photo (S. Brzev)

Adobe masonry walls: exposed (during construction), Chile (S.Brzev)

Adobe masonry walls overlaid by plaster, Peru (C. Loaiza and M. Blondet, World Housing Encyclopedia Report 52)

Stone masonry walls: dressed stone at the front facade and uncoursed stone masonry in the perpendicular direction, France (S. Brzev)

Exposed brick masonry walls, Canada (S. Brzev)

Exterior stone masonry walls, Canada (S. Brzev)

Many buildings in Lisbon, Portugal have glazed ceramic tiles bonded to exterior walls (S. Brzev)

Masonry floor [FM]

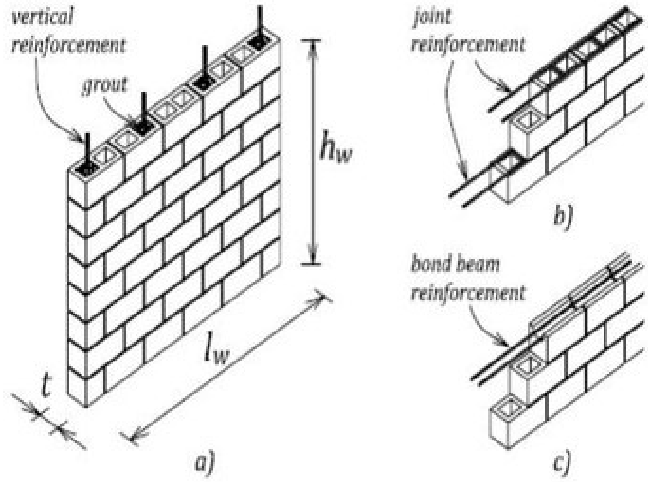
The floor structure is constructed of masonry.

Masonry floor, unknown [FM99]

It is clear that the floor structure is made from masonry, but the type of masonry system is unknown. The system may be hidden, or information about it is unavailable.

Masonry, reinforced [MR]

Masonry w all construction in w hich reinforcement is embedded in such a manner that tw o materials act together in resisting forces. The reinforcement resists tension w hile the masonry resists compression. Reinforcement can take various forms, such as internal steel or w ooden rods or bars grouted into masonry units or laid in horizontal mortar courses. Alternatively, vertical and/or horizontal w ood or reinforced concrete posts or bands can be provided to increase the strength of individual building elements like w alls and or tie them together. In some cases, textile reinforcing w hich is plastered over is used to reinforce masonry w alls.



Reinforced masonry construction using concrete block masonry and steel reinforcement, Canada (left: B. McEw en; right: Anderson and Brzev, 2009)

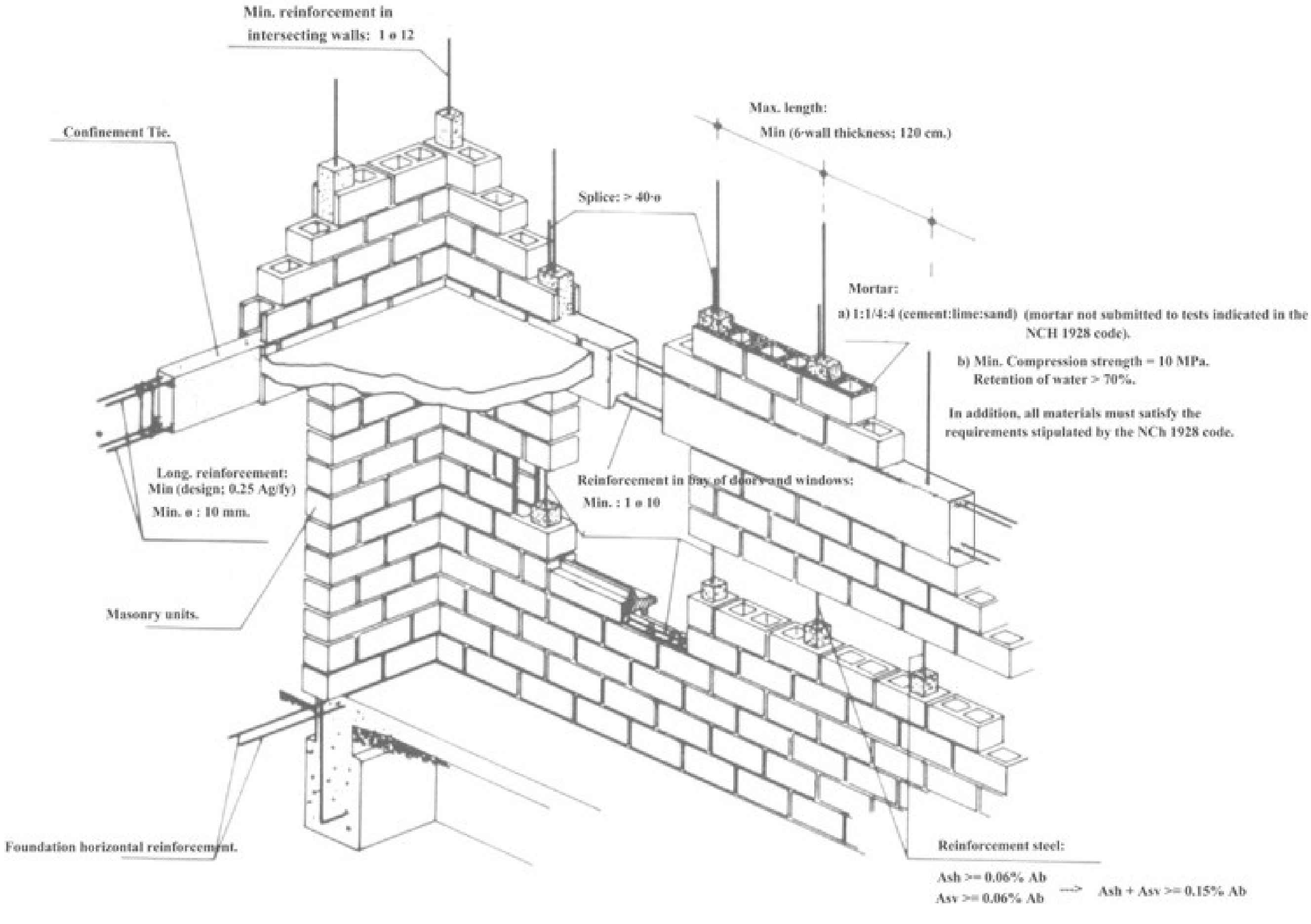
Wood-reinforced brick masonry know n as Dhaji Dhew ari in Kashmir, India (S. Brzev)

Adobe w alls reinforced w ith a polymer mesh (geogrid) attached to the w alls by plastic or nylon strings, Peru (N. Tarque)

Detail of an adobe w all reinforced w ith polymer mesh, Peru (A. Charleson)

Reinforced concrete block masonry, New Zealand - note vertical reinforcing bars placed in hollow cores (A. Charleson)

Reinforced clay block masonry, Chile (S. Brzev)



Typical reinforcement arrangement, Chile (Moroni, Gomez, and Astroza, World Housing Encyclopedia Report 5)

Masonry reinforcement, unknown [MR99]

It is know n that the masonry structure is reinforced, but the type of reinforcement is not know n.

Masonry roof [RM]

The roof structure is constructed of masonry.

Masonry roof, unknown [RM99]

It is clear that the roof structure is made from masonry, but the type of masonry system is unknown. The system may be hidden, or information about it is unavailable.

Masonry unit, other [MO]

Any masonry type that is know n but does not fit the descriptions of the other masonry types in this table.

Masonry unit, unknown [MUN99]

It is clear that the structural material is masonry, but the type of masonry is unknown. The build-up of the wall may be hidden, as in the case of a plastered wall, or information about it is unavailable.

Walls in masonry buildings are usually covered by plaster at the exterior and it is difficult to identify type of masonry unit used in such cases - like in the case of the masonry building in Constitution, Chile shown in the top photo; however, a closer inspection of the walls and the building interior revealed the adobe construction, as shown in the bottom photo (S. Brzev)

This is likely a masonry building, but the type of masonry unit is not known, Halifax, Canada (S. Brzev)

Masonry, unknown reinforcement [M99]

It is clear that the structural material is masonry, but the type of reinforcement is unknown. The reinforcing may be hidden, or information about it is unavailable.

These buildings in Lisbon, Portugal are likely of masonry construction, but it is not known whether reinforcement was provided (note exterior walls covered by glazed ceramic tiles typical of Portugal) (S. Brzev)

These buildings in Vroclaw, Poland are likely of masonry construction, but it is not known whether reinforcement was provided (C. Scawthorn)

Masonry, unreinforced [MUR]

Masonry w ithout any form of reinforcement.

Unreinforced brick masonry construction (covered by plaster), Indonesia (J. Bothara)

A typical unreinforced masonry building from the beginning of 20th century, Halifax, Canada (S. Brzev)

Unreinforced stone masonry, Sw itzerland (T. Schacher)

Unreinforced brick masonry damaged in the 2010 Maule, Chile earthquake (S. Brzev)

Unreinforced adobe masonry, Peru (left-N. Tarque and right-A. Charleson)

Unreinforced stone masonry building, Morocco (C. Scaw thorn)

Material of exterior wall, other [EWO]

The material covering the exterior w alls is know n, but it does not fit any of the definitions found in this table.

Exterior shell (w alls and the roof) of the National Sw imming Center in Beijing, China is made of a 0.2 mm thick plastic Teflon-like foil, w hich simulates bubbles (S. Brzev)

Material of the lateral load-resisting system

The material is that from w hich the Lateral Load-Resisting System is primarily constructed. If there is more than one Lateral Load-Resisting System, chose the material of the more seismically vulnerable system. Do not include materials that are non-structural or that are not part of the primary Lateral Load-resisting System. For example, if Unreinforced Masonry w alls resist the majority of the lateral load in a building w here most of the gravity loads are carried by say w ood or steel frames, the Material Type of the Lateral Load-resisting System should be listed as Masonry, Unreinforced.

Material properties

Detailed information related to material technology, such as steel connections, types of stone masonry and mortar

Material technology

A more detailed description of the material type

Material type

The material of the structural members that resist lateral loads and are the part of the Lateral Load-Resisting System.

Membrane roof covering [RMT3]

Sheet membrane or liquid-applied membrane roofing surface. Sheet membranes will typically be bituminous or synthetic rubber sheet. Examples of liquid-applied membranes are asphalt, and those that are fibreglass-reinforced. Sometimes a membrane system is covered with sand, small stones or stone chip. Most commonly used on a concrete or plywood sheet roof system.

Membrane roofing, Vancouver, Canada (S. Brzev)

Metal beams or trusses supporting light roofing [RME1]

Metal beams or trusses supporting light-weight roofing system e.g. corrugated metal or plywood sheets over steel rafters or purlins.

Curved steel beams supporting corrugated steel sheet roofing, Mumbai, India (S. Brzev)

Steel trusses (open web steel joists) supporting corrugated steel roofing, Canada (S. Brzev)

Detail of steel trusses (open web steel joists) supporting corrugated steel roofing, Canada (S. Brzev)

Metal beams, trusses or joists supporting light flooring [FME1]

Metal beams or trusses supporting light-w eight flooring system e.g. plyw ood sheets over steel rafters or purlins.

Metal beams or trusses supporting light flooring, Wellington, A W Charleson

Metal (except steel) [ME]

Metal (except steel) is a material like aluminium or iron used as structural elements.

Metal exterior walls [EWME]

All types of metal cladding and wall materials. Includes aluminum planks, corrugated steel sheets (CGI) or aluminium sheets, aluminium composite sheets, copper sheets, wire mesh and perforated sheet metal.

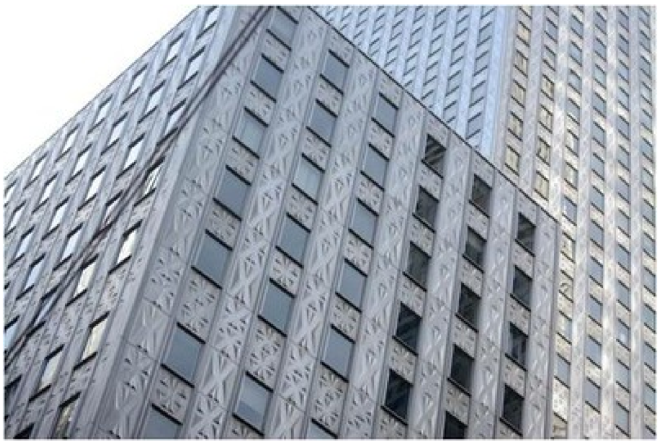
A building with exterior walls made of aluminum sheets, Vancouver, Canada (S. Brzev)

Corrugated steel sheets, Canada (S. Brzev)

Exterior wall made of corrugated metal sheets, Kenya (K. Jaiswal)

Corrugated metal sheets used as exterior cladding, India (S. Brzev)


HSB Turning Torso in Malmö, Sweden has aluminum exterior walls (C. Scawthorn)


Stainless steel exterior walls in a high-rise building, New York City, USA (C. Scawthorn)

Metal floor [FME]

The floor structure is constructed of metal. Note that this refers to the structure, and not any lightweight sheet flooring (such as plywood) that might be present.

Metal floor beams supporting precast concrete slabs [FME2]

Precast concrete slabs (e.g. hollow-core slabs) supported by steel beams.

Metal beams supporting precast concrete slabs, India (S. Brzev)

Metal floor, unknown [FME99]

It is clear that the floor structure is made from metal, but the type of metal structural system is unknown. The system may be hidden, or information about it is unavailable.

Metal or asbestos sheets [RMT6]

Sheet metal roofing, usually corrugated sheets or tray type. Typical metals include copper, lead, iron-zinc, corrugated galvanized iron (CGI), aluminum, and steel. This also includes asbestos sheets. Does not include metal roofing tiles.

Asbestos sheet roof covering, New Zealand (A. Charleson)

Metal sheet roofing, Canada (S. Brzev)

Steel decking joined by w elds at regular spacing, Canada (S. Brzev)

Metal roofing, Experience Music Project, Seattle, USA (S. Brzev)

Metal sheet roof covering, New Zealand (W. Clark)

Corrugated galvanized iron (CGI) roofing, India (D. Rai)

Metal, other [MEO]

Any metal construction type that is known (and is not steel) but does not fit the descriptions of the other metal construction types in this table.

Metal roof [RME]

The roof structure is constructed of metal. Note that this refers to the structure, and not any lightweight sheet metal roof covering that might be present.

Metal roof beams supporting precast concrete slabs [RME2]

Precast concrete slabs (e.g. hollow-core slabs) supported by steel beams.

Metal beams supporting precast concrete slabs, India (S. Brzev)

Metal roof, unknown [RME99]

It is clear that the roof structure is made from metal, but the type of metal structural system is unknown. The system may be hidden, or information about it is unavailable.

Metal, Unknown [ME99]

It is clear that the structural material of the Lateral Load Resisting System is metal (and is not steel), but the type of metal is unknown. The material may be hidden or coated, or information about it is unavailable.

Mixed, unknown type [MIX99]

The building is clearly mixed use, but the types of use are unknow n.

Mixed use [MIX]

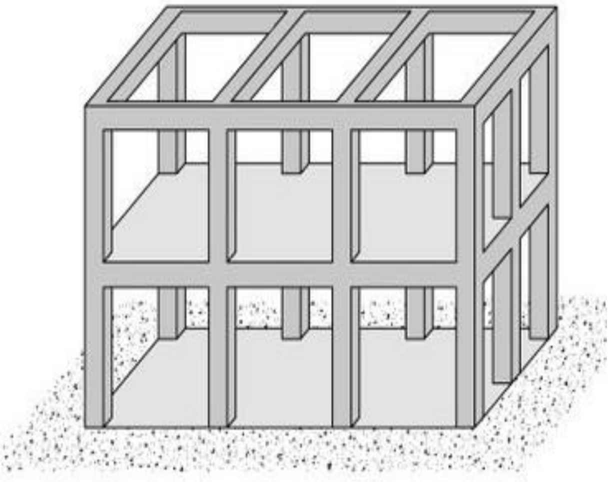
The building is used for commercial or retail at the ground floor, w ith residential or office accommodation above. Choose this attribute if the proportion of the commercial and residential occupancies are approximately equal. Otherw ise for mixed occupancy choose the dominant occupancy. For example, choose ‘mixed occupancy’ for a tw o story building w ith a single-family dw elling above a shop, but choose multi-family dw elling for a ten-story apartment building w ith shops at ground floor.

Mobile home [RES5]

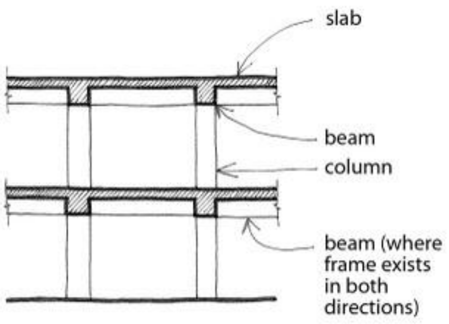
A lightweight wheeled trailer home that can be towed, and that provides temporary or permanent accommodation. This does not include motorised trucks or camper vans.

Moment frame [LFM]

This is a frame consisting of beams and columns, with strong and rigid beam-to-column connections. Includes frames with very slender walls, that do not resist a significant proportion of earthquake load. The frames can be single frames, or multiple bays repeated horizontally and/or vertically. These frames are not infilled with materials like masonry or concrete which would transform their behaviour to that of an infilled frame.



A simplified drawing of a moment-resisting frame structure showing floor slabs supported by beams (adapted from: A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 64, Fig. 5.2).



Partial section of a moment frame structure

Reinforced concrete frame building under construction, India (S. Brzev)

Reinforced concrete frame under construction, Thailand (C. Lilavivat)

Reinforced concrete buildings with a moment frame system have beams as a part of the floor system (Canada, S. Brzev)

Moment frame, concrete, New Zealand (A. Charleson)

A 1970s reinforced concrete frame, Wellington, New Zealand (J. Bothara)

Reinforced concrete frame building, Kyrgyzstan (K. Kanbolotov)

Reinforced concrete frame building under construction, Kyrgyzstan (U. Begaliev, A. Duishev, and R. Musakov)

Variants

- Portal Frame
- Moment-resisting Frame
- Open Frame
- Rigid Frame
- Bare Frame

Monopitch [RSH5]

The roof slopes in one direction. Lean-to-roof is a special case of monopitch roof - it has a single pitch that rests against a higher w all.

Monopitch roof, Mexico (S. Brzev)

Monopitch roof, Canada (S. Brzev)

Mortar type unknown [MO99]

It is clear that mortar is used in between masonry units, but the type of mortar is unknown. The mortar may be hidden, as in the case of a plastered wall, or information about it is unavailable.

Mortar

Mortar provides a uniform bed for laying the masonry units, and to bond the units together to produce a structurally sound and w eatherproof construction. The follow ing types of mortar are included in the GEM Building Taxonomy:

- Mud mortar
- Lime mortar
- Cement mortar
- Cement:lime mortar

Mostly commercial and industrial [MIX3]

The building is mixed use, a mixture of commercial and industrial. The majority of the floor area is for commercial use.

Mostly commercial and residential [MIX2]

The building is mixed use, a mixture of commercial and residential. The majority of the floor area is for commercial use.

Mostly industrial and commercial [MIX5]

The building is mixed use, a mixture of industrial and commercial. The majority of the floor area is for industrial use.

Mostly industrial and residential [MIX6]

The building is mixed use, a mixture of industrial and residential. The majority of the floor area is for industrial use.

Mostly residential and commercial [MIX1]

The building is mixed use, a mixture of residential and commercial. The majority of the floor area is for residential use.

Mostly residential and industrial [MIX4]

The building is mixed use, a mixture of residential and industrial. The majority of the floor area is for residential use.

Mud mortar [MOM]

Soil is mixed with water and used as mortar for various types of masonry construction. It is characterized by earthen colour, and it can be easily scratched (removed) from the wall using a sharp object (like a key).This type of mortar can be found mostly in adobe construction (e.g. Latin America and Asia), and stone masonry housing construction in remote rural areas where cement and/or lime are either unavailable or too expensive (e.g. south-east Asia). Mud mortar is a low-strength mortar, and it is the weakest of all mortar types.

Mud mortar and adobe blocks, Peru (S. Brzev)

Mud mortar and fired clay bricks, India (D. Rai)

Multi-unit, unknown type [RES2]

It is clear that the building is a multi-unit residential building, w ith structurally connected neighbouring units or apartments stacked vertically, but the number of dw ellings in the building is unknow n.

No elevated or suspended floor material [FN]

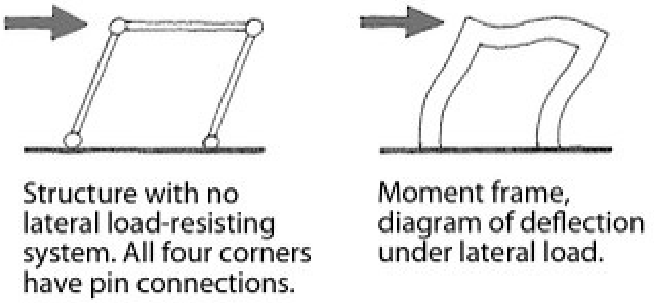
The building is a single storey building w ith no floors above ground floor level, and the ground floor level is not elevated above grade.

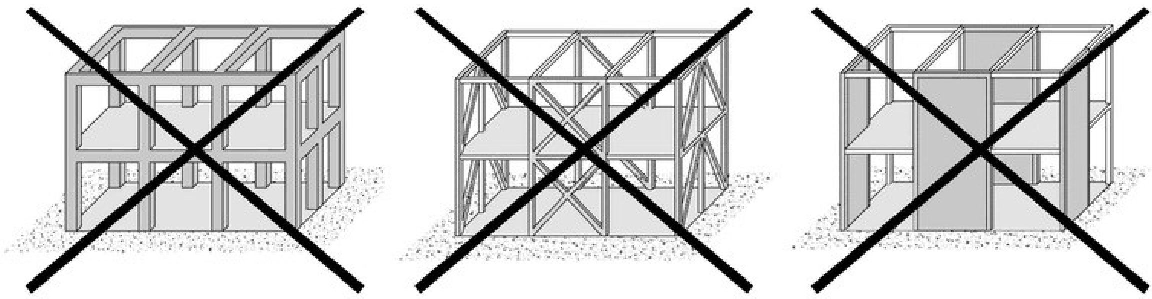
No irregularity [IRN]

There is no irregularity in this category.

No lateral load-resisting system [LN]

There is no identifiable structural system that is capable of resisting seismic loads, for example a post-and-beam structure w here columns are not cantilevered and the connections betw een column and beam are not moment-resisting.





Lateral load-resisting system of the ancient Greek temple Parthenon in Athens (construction completed in 432 BC) can be characterized as No Lateral Load-Resisting System, because there is no moment connection betw een columns and beams; the photos show the temple during the structural rehabilitation in 2007 (B. McEw en)

This building is a part of the Royal Palace complex in Phnom Penh, Cambodia. Its lateral load-resisting system can be characterized as No Lateral Load-Resisting System because it doesn't have any apparent lateral bracing (C. Scawthorn)

No mortar [MON]

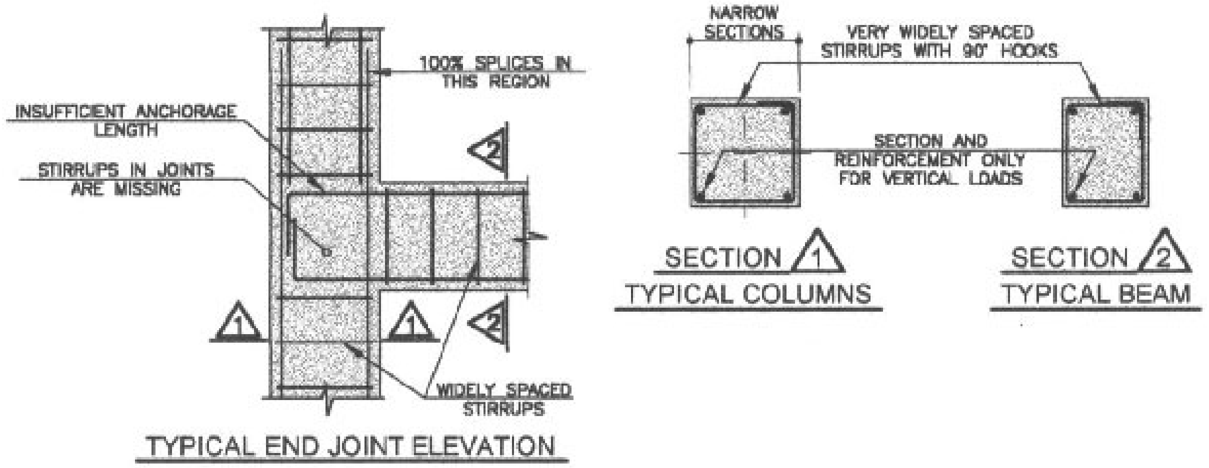
Dry laid masonry units w here no mortar has been used.

Masonry w alls w ithout mortar (also know n as dry masonry) w ere built by Inca civilization in Machu Picchu, Peru (S. Brzev)

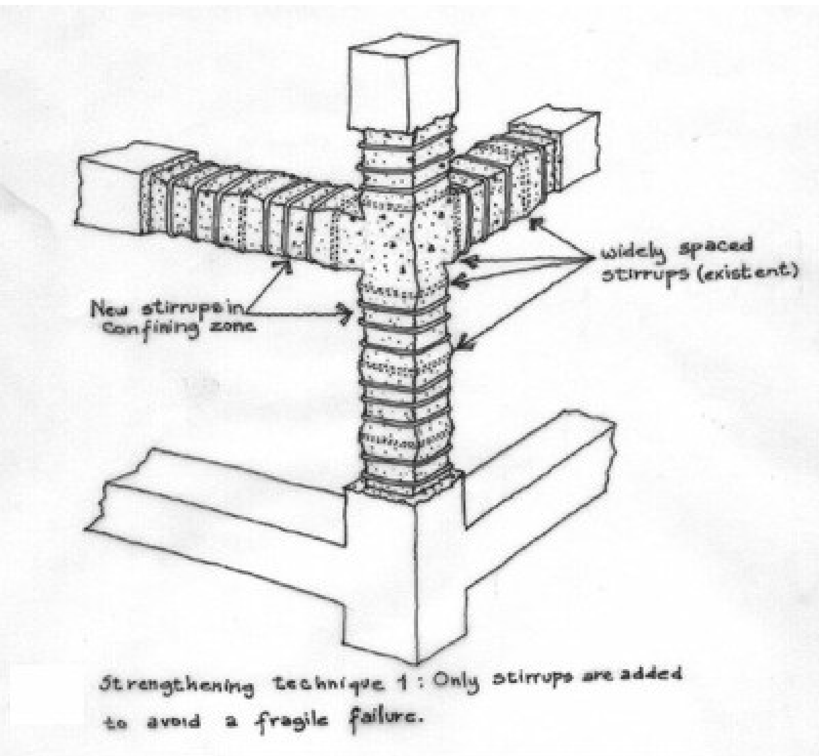
Non-ductile [DNO]

Steel members and steel reinforcing are not designed nor constructed to undergo plastic deformation before failure under earthquake loads. In the event of over-load during an earthquake structural members are expected to suffer brittle failure. For example, moment frames with weak columns and strong beams are non-ductile because once the columns are damaged they usually are unable to resist gravity loads. Reinforced concrete frames will also be classified as non-ductile if beam and column ties have 90 degree rather than 135 degree hooks, and if there is insufficient quantity and spacing of shear reinforcement to prevent shear failure before flexural failure.

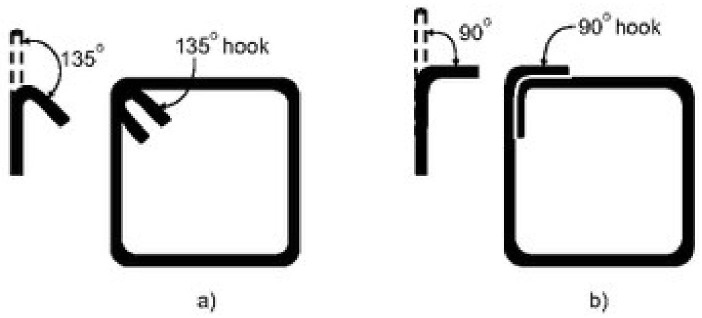
Unreinforced masonry buildings usually demonstrate non-ductile performance in earthquakes.



Details of a non-ductile reinforced concrete frame at critical locations: beam-column joint, beam and column (Colombia, World Housing Encyclopedia Report 11)

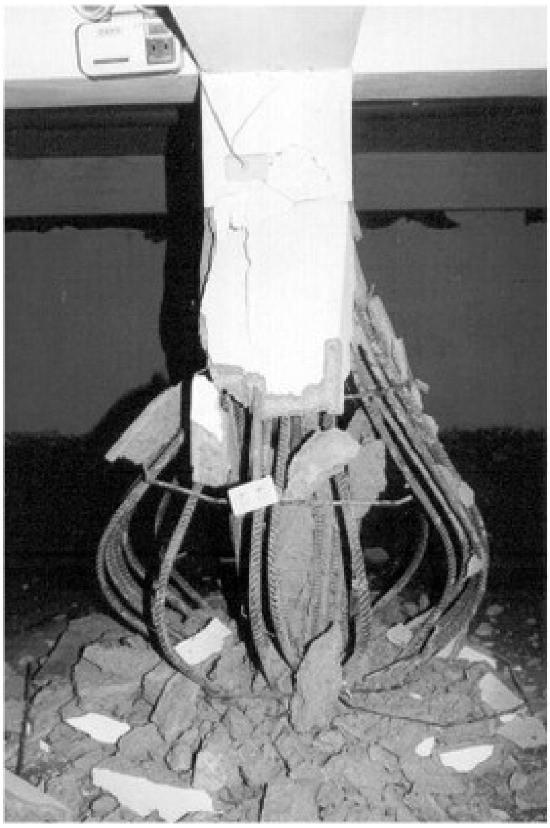


Widely spaced transverse reinforcement (ties in columns and stirrups in beams) are characteristic for non-ductile reinforced concrete frame; this isometric drawing shows a possible seismic strengthening technique (Colombia, World Housing Encyclopedia Report 11)

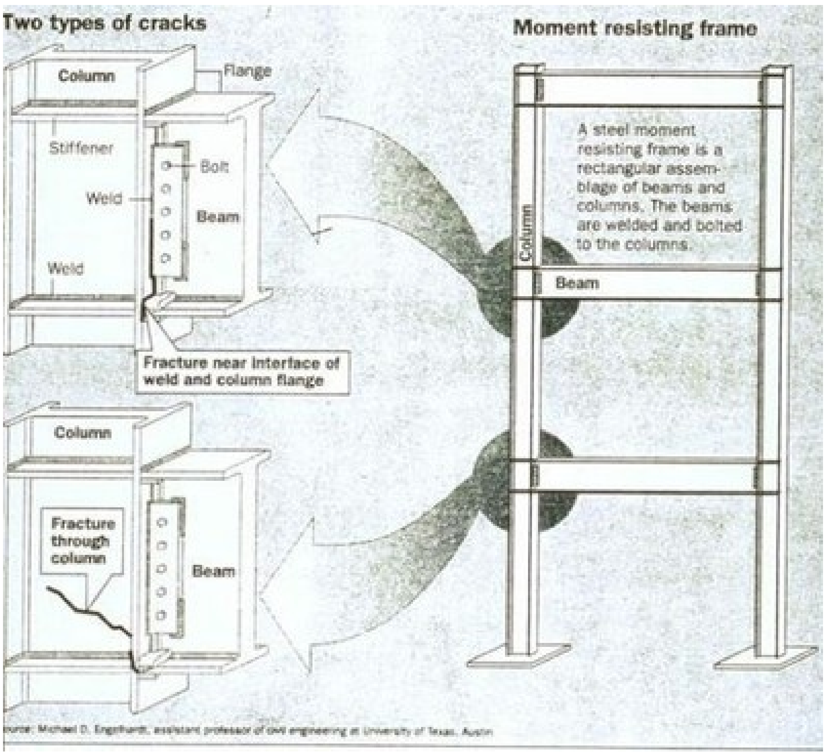


Ties in reinforced concrete columns: a) 135 degree hooks (ductile detailing), and b) 90 degree hooks (non-ductile detailing) (Brzev, S. and Pao, J. *Reinforced Concrete Design: A Practical Approach* , Pearson Learning Solutions, 2012)

Failure of reinforced concrete columns at the ground floor level of a building w ith the soft storey irregularity in the 2001 Bhuj, India earthquake; the columns w ere characterized by non-ductile details, such as w idely spaced ties and 90 degree hooks in ties (C.V.R. Murty, EERI)



Failure at the base of a reinforced concrete column due to 90 degree hooks and w idely spaced ties w as observed in the 1999 Chi Chi, Taiw an earthquake; use of 90 degree hooks is a feature of non-ductile concrete construction (EERI)



Older steel moment frame buildings w ere damaged in the 1994 Northridge, California earthquake due to non-ductile beam-column connections and w eld fractures (EERI and Bay Area Regional Earthquake Preparedness Project, CAL-OES)

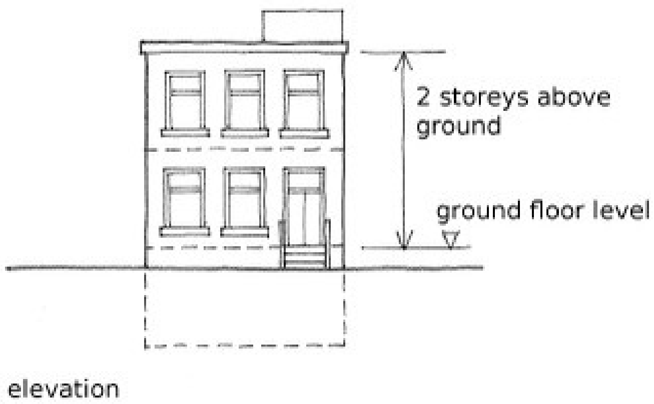
Damage of a poorly constructed confined masonry building in the 2010 Haiti earthquake; this is considered a non-ductile performance (A. Lang, EERI)

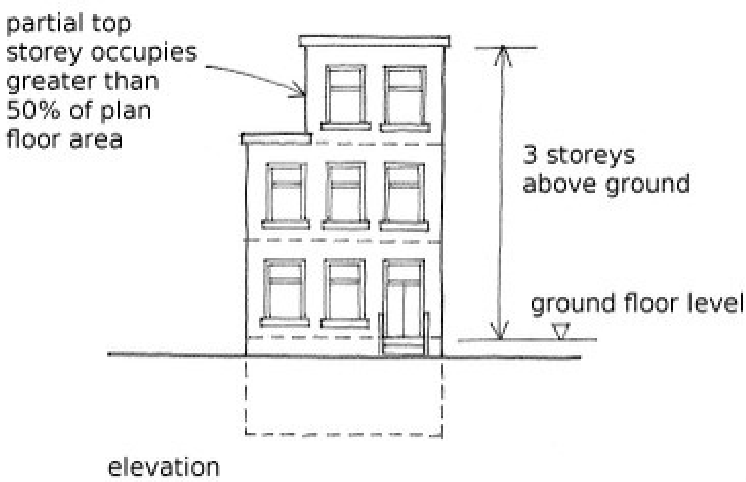
Unreinforced masonry buildings often show non-ductile performance and suffer damage in major earthquakes, such as the 2003 Boumerdes, Algeria earthquake (S. Brzev)

Number of storeys above ground [H]

Number of storeys or floors above ground, including the ground floor and floors above. Also includes storage and mechanical plant levels only if these cover over 50% of the plan area, but does not include basements below ground. If the building is stepped in height, then record the number of storeys of the highest part.

The number of storeys above ground can be recorded as an exact number, or as a range, or as an approximate number if the exact number is not known. It can also be recorded as unknown.

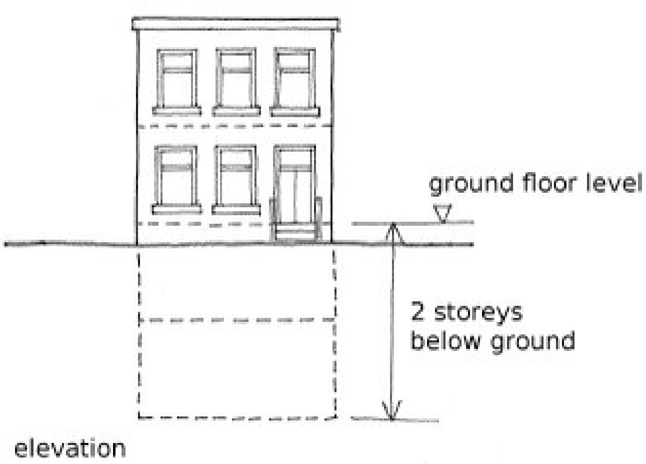




Number of storeys below ground [HB]

Number of storeys below the level of the primary entrance, otherwise described as the number of basements or basement levels. This does not include the ground floor. If it is known that there are no storeys below ground floor, the number is zero. It includes storage and mechanical plant levels only if these cover over 50% of the plan area.

The number of storeys below ground can be recorded as an exact number, or as a range, or as an approximate number if the exact number is not known. It can also be recorded as unknown.



Number of storeys below ground unknown [HB99]

The number of storeys of the building below ground is unknown. It is impossible to determine the number of storeys within an estimated range, or to an approximate number. Information is unavailable, or the building has not been inspected sufficiently to determine its number of storeys above ground.

Number of storeys unknown [H99]

The number of storeys in the building above ground level is unknow n. It is impossible to determine the number of storeys w ithin an estimated range, or an approximate number. Information is unavailable, or the building has not been inspected sufficiently to determine its number of storeys above ground.

It is difficult to determine number of storeys in the CCTV Headquarters building in Beijing, China based on the exterior view only (D. Willms)

A building w ith undefined number of storeys, Beijing, China (D. Willms)

Number of storeys

The total number of storeys of a building, both above and below ground-level

Occupancy

The type of activity (function) that the building is used for. This does not refer directly to the number of occupants.

Offices, professional/technical services [COM3]

All office buildings, including banks, but excluding national and local government office buildings. For government buildings refer to GOV1 Government General Services.

Other gatherings [ASS4]

A building used for social gatherings such as clubs (other than sports clubs), societies, political parties, function centres and conference centres, community halls, tow n halls.

Refer to Sports and Recreation for sports clubs.

Other lateral load-resisting system [LO]

A lateral load-resisting system that is known but does not fit into the other definitions in this table. Other systems include tension structures, shell structures, space-structures, folded plates, tubes and other complex structural systems for very tall buildings.

National Swimming Center in Beijing, China (also known as The Cube) is a space (3-D) frame assembled from 22,000 steel tubes welded to 12,000 nodes; this is a unique structure (D. Willms)

Space truss structure, Science World, Vancouver, Canada (S. Brzev)

Other material [MATO]

Materials such as reeds, plastics and fabrics. Any known material that does not fit into the other definitions in this table.

Other occupancy type [OCO]

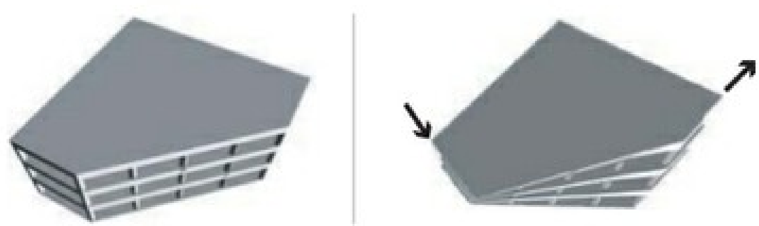
Use that is know n, but is not adequately described by any of the uses listed in this table.

Other plan irregularity [IRHO]

A plan irregularity, not defined as any of the other Plan Irregularity definitions in this table, that is likely to adversely affect the earthquake performance of the building.

Examples of such plan irregularities include discontinuous diaphragms, and vertical lateral load-resisting elements non-parallel to the major orthogonal axes of the lateral load-resisting system. Cantilevers supporting lateral load-resisting elements like infill walls that are likely to resist seismic forces that overhang the structure below are examples of out-of-plane offsets.

Discontinuous diaphragm (cutout) (FEMA 454)

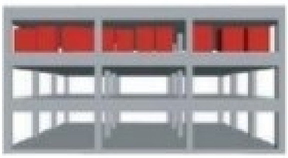


Non-parallel lateral load-resisting system (FEMA 454)

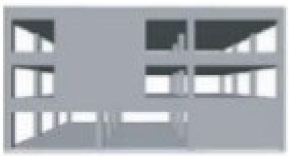
Other vertical irregularity [IRVO]

A Vertical Irregularity, not defined as any of the other Vertical Irregularity definitions in this table, that is likely to adversely affect the earthquake performance of the building.

Examples include w eight (mass) irregularity w here the w eight of one floor is greater than 150% of an adjacent floor, and in-plane discontinuity w here an in plane-offset of a vertical lateral load-resisting system causes greater overturning demands on the supporting structure. An example is w here, say a braced frame at ground level consists of tw o bays, but there are three bays above. Other vertical irregularities include non-concentric column-beam joints.



Weight (mass) irregularity (FEMA 454)



In-plane discontinuity (FEMA 454, 2006)

Parallel to street [PF]

Direction X is parallel to the building facade that is parallel to the street. If there is no building facade parallel to the street, define Direction X as 'Unspecified direction'.

Perpendicular to street [OF]

Direction Y is perpendicular (orthogonal) to the building facade that is parallel to the street. If there is no building facade parallel to the street, define Direction Y as 'Unspecified direction'.

Pitched and hipped [RSH3]

The roof is pitched (sloped) on all sides.

Pitched and hipped roof, Padang, Indonesia (J. Bothara)

Pitched and hipped roof, Assam, India (People in Centre)

Pitched and hipped roof, Indonesia (J. Bothara)

Pitched with dormers [RSH4]

A pitched roof w ith projecting vertical w indow s that have their ow n pitched roofs that intersect the main roof.

Pitched roof w ith dormers, New Zealand (A.Charleson)

Pitched with gable ends [RSH2]

The roof is pitched (sloped) on two sides up to a central ridge. At each end of the roof, i.e. the other two sides, there is a vertical gable. Gable is a triangular wall between the roof wedges.

Pitched roof with gable walls (shown in white colour), Chile (S. Brzev)

Pitched roofs, Nepal (M. Schildkamp)

Plan irregularity or vertical irregularity

An indication as to whether a plan structural irregularity and/or a vertical structural irregularity are present

Plan irregularity-primary [IRPP]

A structural irregularity that is observed in the plan (horizontal plane) of the building. If more than one plan irregularity is observed, the primary plan irregularity is that deemed to be the most significant in terms of affecting the building's seismic performance, and the secondary plan irregularity is that deemed to be the next most significant.

Plan irregularity-secondary [IRPS]

A structural irregularity that is observed in the plan (horizontal plane) of the building. If more than one plan irregularity is observed, the primary plan irregularity is that deemed to be the most significant in terms of affecting the building's seismic performance, and the secondary plan irregularity is that deemed to be the next most significant. If there is only one structural structural irregularity observed, the term "No Irregularity" will be used by default

Plastic/vinyl exterior walls, various [EWPL]

All types of plastic cladding. Includes plastic siding, corrugated plastic sheet.

Plywood panels or other light-weight panels for floor [FW4]

Panels are supported on beams or bearing w alls (possibly stressed-skin).

Plywood panels or other light-weight panels for roof [RWO4]

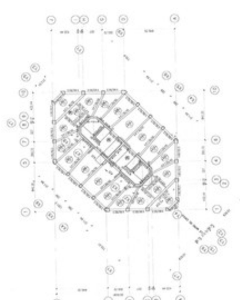
Panels are supported on beams or bearing w alls (possibly stressed-skin).

Polygonal, solid (e.g. trapezoid, pentagon, hexagon) [PLFP]

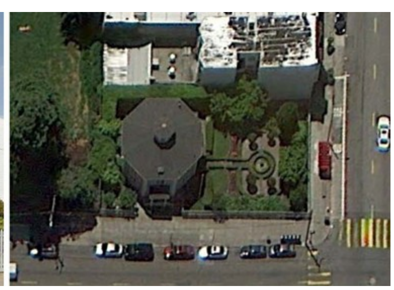
The shape of the building plan is approximately polygonal, with only minor variations from a polygonal shape. Polygon is a plane figure bounded by a finite number of straight lines (called sides), which connect up and form a closed shape. This term refers to shapes that can be approximated as regular convex polygons (see the drawing below for illustration). Polygon is regular when its side are of equal length. The following polygonal shapes are included in this category: trapezoid (4 sides), pentagon (5 sides), hexagon (6 sides), heptagon (7 sides), octagon (8 sides), etc. Note that square and triangle are also polygons, however they have been identified as separate items in the table.

Any line drawn through a regular convex polygon meets its boundary exactly twice - the example shows a pentagonal shape (adapted from Salix Alba for English Wikipedia)

A building with trapezoidal plan, Shiraikan Building, Kyoto University, Japan (left: Map data ©2013 Google, ZENRIN; right: C. Scawthorn)



A reinforced concrete high-rise building in Chile with hexagonal plan shape (O. Moroni, C. Gomez, and M. Astroza, Chile, World Housing Encyclopedia Report 6)



The Octagon House in San Francisco, California has octagonal plan shape (Map data ©2013 Google, DigitalGlobe, U.S. Geological Survey, USDA)

Polygonal, with an opening in plan [PLFPO]

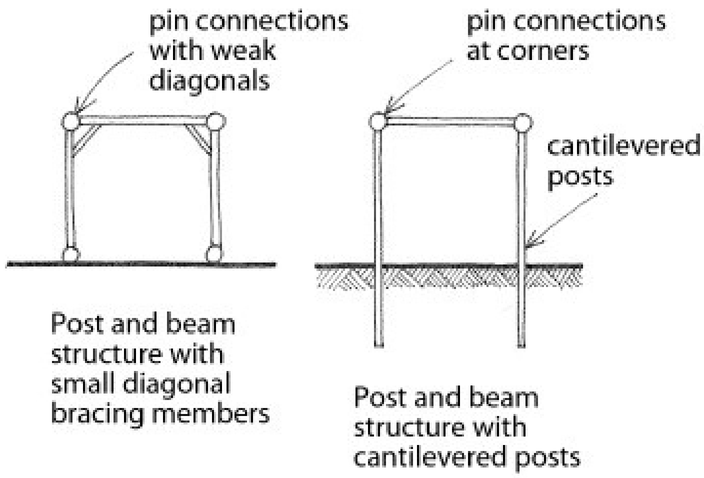
Same as PLFP but with an open internal courtyard or full height roofed atrium.

The Pentagon in Washington, D.C., USA has pentagonal plan shape with an interior courtyard (Map data ©2013 Google, Commonwealth of Virginia, DigitalGlobe)

Post and beam [LPB]

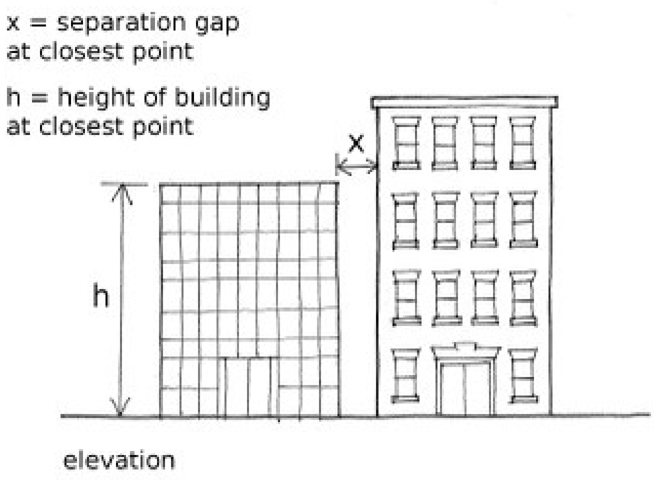
A framew ork of posts and beams w here posts are spaced several meters apart. If the posts do not cantilever from the foundations, lateral stability may be supplemented by infill w alls or by small diagonal bracing members at post and beam connections that provide some rigidity against horizontal forces. Includes systems comprised of cantilevered posts and trusses w ith simple pin-jointed connections betw een them. If most of the seismic resistance is provided by w alls or infill w alls then the lateral load-resisting system should be described as Wall.

Note that posts and beams include vertically cantilevered posts or columns w ithout rigidly connected beams that w ould otherw ise transform this structural system into a moment frame. If these vertical members have a height to depth or length (measured in the direction they resist horizontal load) less than 3.0 they should be considered as Walls.



Pounding potential [POP]

Insufficient or no seismic separation gap between buildings thus allowing them to pound and damage each other. A building can have pounding potential if the gap between buildings is less than 4% of the height (h) of the lower building, e.g. less than 400 mm for h = 10 m.



If x is less than 4% of h, the buildings can have pounding potential.

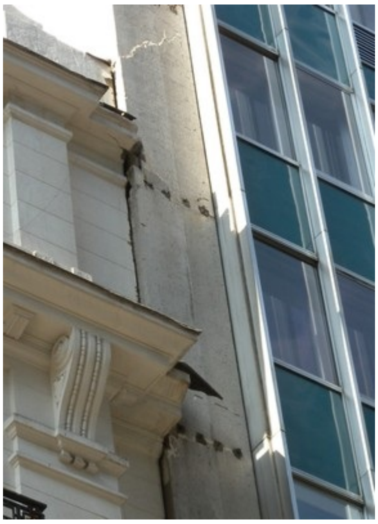
Many adjacent buildings in urban centres without a separation gap have pounding potential, Seattle, USA (S. Brzev)

Adjacent buildings of different height, pounding potential, Kathmandu, Nepal (K. Porter)

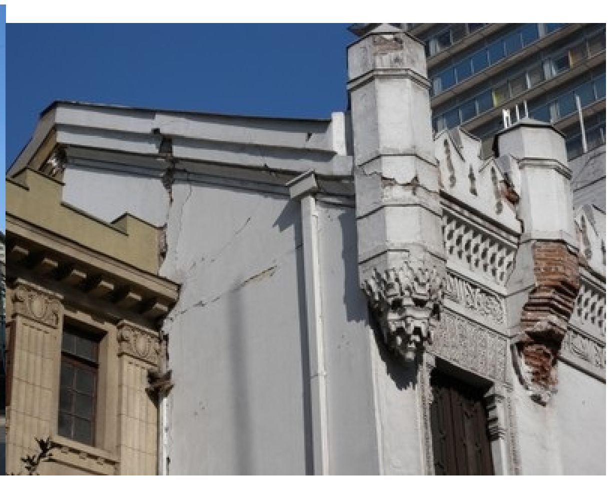
Two adjacent reinforced concrete buildings on a sloped ground suffered a major damage in the 2003 Boumerdes, Algeria earthquake; the buildings had an inadequate seismic gap, and the pounding effect was significant due to floor slabs at different elevations (S. Brzev)

Damage due to pounding in reinforced concrete buildings with floors at different elevations in the 1999 Athens earthquake (A. Pomonis)

Pounding damage in adjacent buildings of different heights affected by the 1999 Turkey earthquakes (Gulat, Ascheim, and Spence, World Housing Encyclopedia Report 64)



Pounding damage in Santiago due to the 2010 Chile earthquake (S. Brzev)



Damage to an unreinforced masonry building in Santiago due to the pounding effect in the 2010 Chile earthquake (S. Brzev)

Pounding damage due to the 2010 Chile earthquake (S. Brzev)

Adjacent buildings w ithout seismic gap, pounding potential, San Francisco, USA (C. Scaw thorn)

Adjacent buildings of different height w ithout seismic gap, pounding potential, San Francisco, USA (C. Scaw thorn)

Pre-school facility [EDU1]

Any pre-school educational centre. E.g. Child care centre, crèche.

Precast concrete [PC]

Prefabricated concrete structural elements that are moved into their final position in the structure after they have been cast. They can be tied together by protruding reinforcing bars and in-situ concrete at connections or by on-site welding of cast-in steel connections between elements. Connections to floor slabs are often made by reinforcing bars lapping with reinforcement in floor slab concrete topping. Typical precast elements, such as wall panels, beams and columns are manufactured off site, but they can also be cast on site before being erected, like tilt-up panels.

Erection of precast concrete wall panels, New Zealand (A. Charleson)

Precast concrete w all construction, Nepal (K. Porter)

Large panel precast concrete construction, Kyrgyzstan (K. Kanbolotov)

Precast concrete construction technology comprising horizontal w all panels and vertical posts and is used for one-storey housing, Costa Rica (A. Cuevas Ramirez)

Tilt-up w all panels are precast in horizontal position at the construction site and lifted to the final vertical position (Canada, T. Abbuhl)

Tilt-up w all construction, Canada (S. Brzev)

Precast concrete floor with reinforced concrete topping [FC3]

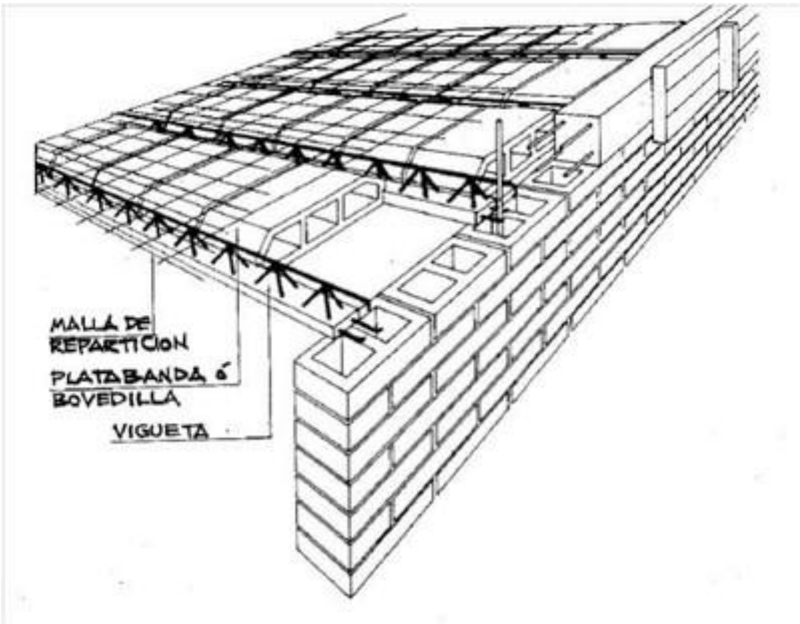
Precast concrete units with reinforced concrete topping. Precast units include hollow-core slabs, solid slabs, a system of precast concrete joists with timber or hollow masonry infill, and double-tee units.

Concrete floor system (Macedonian joists) found in Albania. Polystyrene or similar insulation blocks between concrete joists. A concrete form was constructed, above which concrete joists are laid between supporting concrete beams. In between the thus suspended joists, the blocks of insulation are placed on the formwork, spaced so as to create a void containing each joist. A topping slab is poured, which fills the voids, enclosing the joist in concrete. (C. Scawthorn)

Macedonian joists ready for the floor construction, Albania (C. Scawthorn)

Floor system consisting of concrete masonry units and reinforced concrete joists cast in-situ, Algeria (S. Brzev)

Floor system consisting of concrete masonry units and cast-in-situ reinforced concrete joists (known as "Tralix" system), Chile (S. Brzev)



"Tralix" system construction, Chile (M. Astroza)

Floor system consisting of concrete masonry units and cast-in-situ reinforced concrete joists, Haiti (A. Lang)


Precast concrete floor systems (double-tee units) are typically fabricated with a 50 mm flange and topped in the field with cast-in-place concrete (Canada, S. Brzev)


A typical double-tee element (left) and the end support (right) (S. Brzev)

Double-tee beam lifted by crane at the construction site, Denver, USA (K. Porter)

Wall corbels ready to support double-tees, Denver, USA (K. Porter)

Variants

- Tralix system (Chile)
- Macedonian joists (Albania)

Precast concrete floor without reinforced concrete topping [FC4]

Precast concrete units w ithout reinforced concrete topping. Precast units include hollow -core slabs, solid slabs, or a system of precast concrete joists w ith timber or hollow concrete infill.

Precast concrete hollow core slabs (tropicalconcrete.com)

Concrete floors consisting of hollow core slabs w ith inadequate connections collapsed in the 2008 Wenchuan, China earthquake (J. Dai)

Precast concrete hollow floor slab supported by concrete block masonry w alls, Canada (J. Adams)

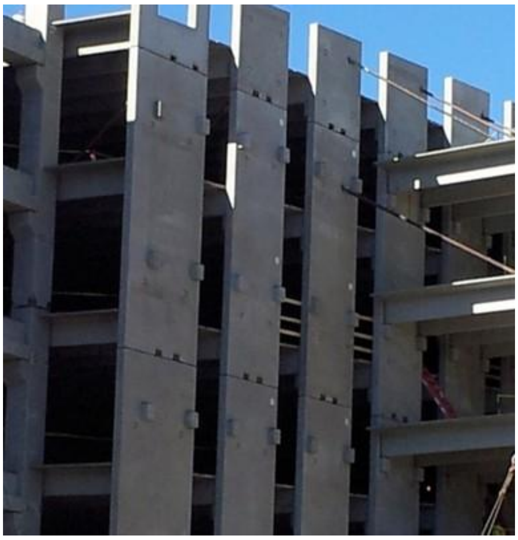
Precast concrete roof with reinforced concrete topping [RC3]

Precast concrete units with reinforced concrete topping. Precast units include hollow-core slabs, solid slabs, a system of precast concrete joists with timber or hollow masonry infill, double-tee units. Sometimes overlaid with light-weight roofing. This system is similar to Precast Concrete Floor with Reinforced Concrete Topping.

Roof/floor system consisting of cast-in-place reinforced concrete joists and precast concrete masonry units, Algeria (S. Brzev)

Roof/floor system consisting of concrete masonry units and cast-in-situ reinforced concrete joists (known as "Tralix" system), Chile (S. Brzev)

A double-tee beam lifted by the crane at the construction site, Denver, USA (K. Porter)



Wall corbels ready to support double-tees, Denver, USA (K. Porter)

Variants

- Tralix system (Chile)
- Macedonian joists (Albania)

Precast concrete roof without reinforced concrete topping [RC4]

Precast concrete units w ithout reinforced concrete topping. Precast units include hollow -core slabs, solid slabs, or a system of precast concrete joists w ith timber or hollow concrete infill. Sometimes overlaid w ith light-w eight roofing.

Precast concrete hollow core slabs (tropicalconcrete.com)

Precast prestressed concrete [PCPS]

As per Precast Concrete, but w here members of the Lateral Load-Resisting System are prestressed or post-tensioned w ith steel cables or rods.


Erection of precast concrete columns, Serbia (R. Dimitrijevic)

Precast prestressed concrete building under construction, show ing precast slabs and columns, Serbia (R. Dimitrijevic)


Anchorage of horizontal prestressing cables at the column-to-slab joint, Serbia (R. Dimitrijevic)

Produce storage [AGR1]

A building used for the storage of agricultural produce. It includes grain storage, hay, silage, fruit, vegetables.

Public building [COM6]

Examples: gallery, museum, monument building, library

Railway station [COM9]

A building or group of buildings w here trains stop, for loading and unloading of passengers, and buildings used for the loading and unloading of freight trains. This does not include covered sheds for storage and maintenance of trains.

Rammed earth [ETR]

Wall construction of earth which is compacted by hand or mechanically into formwork that is then removed and the wall allowed to dry. This technique makes it possible to build monolithic walls in compacted earth.

Rammed earth construction in Bamyan Province, Afghanistan (Aga Khan Development Network)

Rammed earth walls are constructed using local soil mixed with pebbles and water. The mix is compacted in wooden formwork (made of planks placed at regular intervals) to form monolithic walls (Aga Khan Development Network)

Rammed earth construction, Tajikistan (J. Niyazov)

Variants

- Taipa (Portuguese)
- Tapial (Spanish)
- Pisé (de terre) (French).

Range of height of ground floor level above grade [HFBET]

Recording the range of height of ground floor level above grade is used w here the exact height is uncertain but it is possible for the surveyor to determine a range, or w here the height varies more than 1m and the maximum and minimum height can be recorded.

Units: metres

HFBET:a,b
w here a= upper bound and b=low er bound

Example: HFBET: 1.5,0.5 (height ranges betw een 1.5 m and 0.5 m)

Range of number of storeys above ground [HBET]

Recording the number of storeys above ground as a range can be used to reflect either the surveyor’s lack of certainty for a single building, or w hen height ranges are used in regional surveys.

HBET:a,b
w here a=upper bound and b= low er bound for the range
Example: HBET:3,1 (height range from 1 to 3 storeys)

Height of buildings w ithin this block in Lisbon, Portugal ranges from 4 to 5 storeys (S. Brzev)

Range of number of storeys below ground [HBBET]

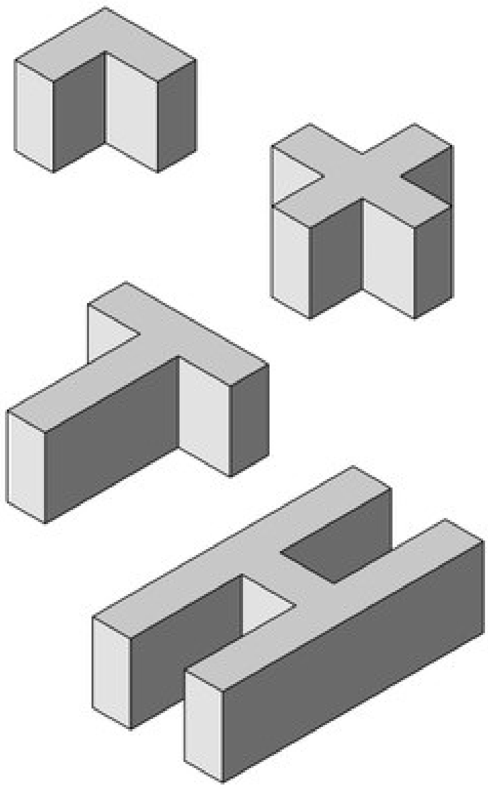
Recording the number of storeys below ground as a range can be used w here there is a lack of certainty about the exact number of storeys below ground but the surveyor is able to determine a range. This does not include the ground floor. It includes storage and mechanical plant levels only if these cover over 50% of the plan area.

HBBET:a,b
w here a=upper bound and b= low er bound for the range
Example: HBET:2,1
(betw een 1 and 2 levels of basement)

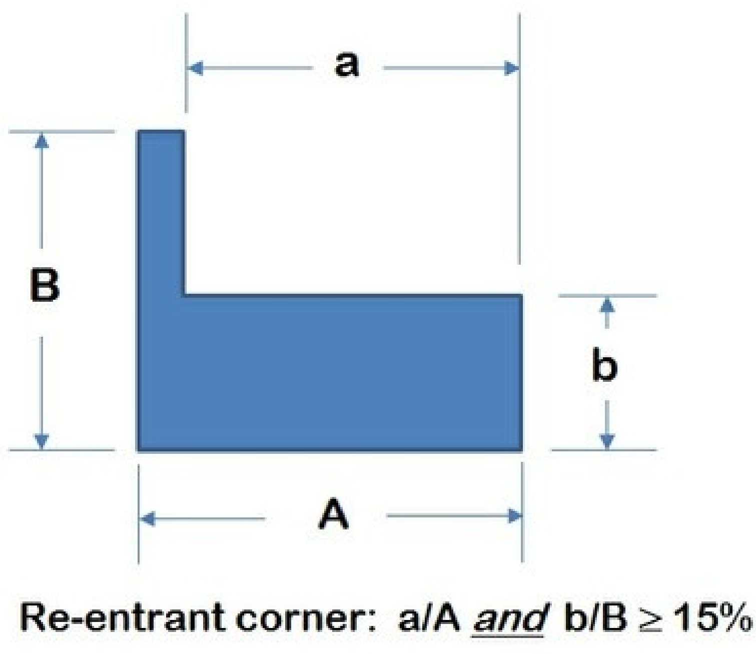
Re-entrant corner [REC]

An L-, U-, E- or other (in plan) shaped building w here tw o w ings may oscillate out-of-phase, leading to large shear stresses in floor and/or roof diaphragms.

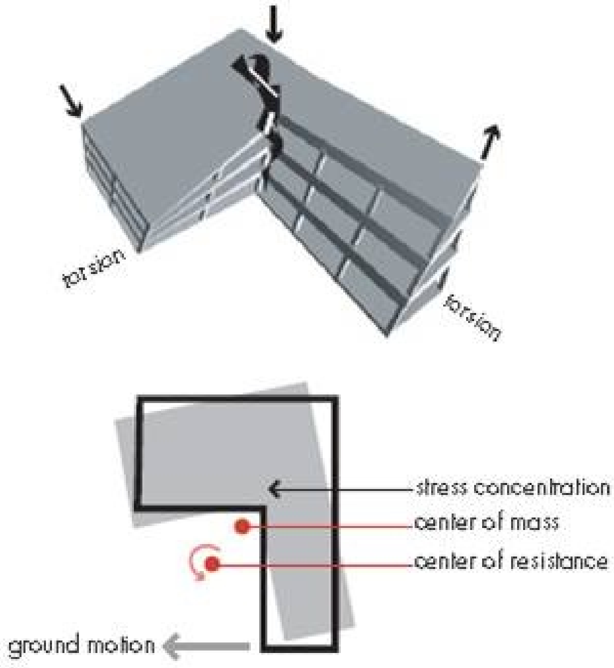
If the plan setback is at least 15% of both plan dimensions, then the setback is considered to form a re-entrant corner.



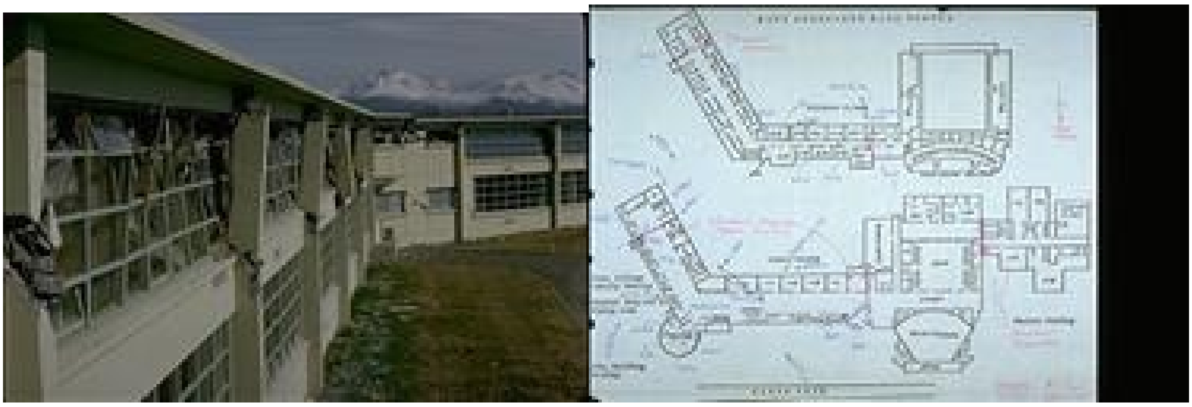
Examples of building shapes w ith re-entrant corners (A. Charleson, *Seismic Design for Architects* , Architectural Press 2008, p133 fig. 8.10)



This diagram illustrates the principle that a 15% plan setback is required in both directions for it to be considered a re-entrant corner.



Movement of the w ings of an L-shaped building during an earthquake results in high shear stresses combined w ith a stress concentration at the re-entrant corner; this is aggravated by torsional effects w hich develop since the center of mass and the center of rigidity cannot coincide in this form. (FEMA 454)



West Anchorage High School suffered extensive damage in the 1964 Alaska earthquake. Stress concentration at re-entrant corner caused damage in the concrete roof diaphragm of this reinforced concrete building. The left photo show s building damage, and floor plan draw ing is show n on the right (Courtesy of the NISEE, University of California, Berkeley)

An L-shaped building w ith re-entrant corner, India (S. Brzev)

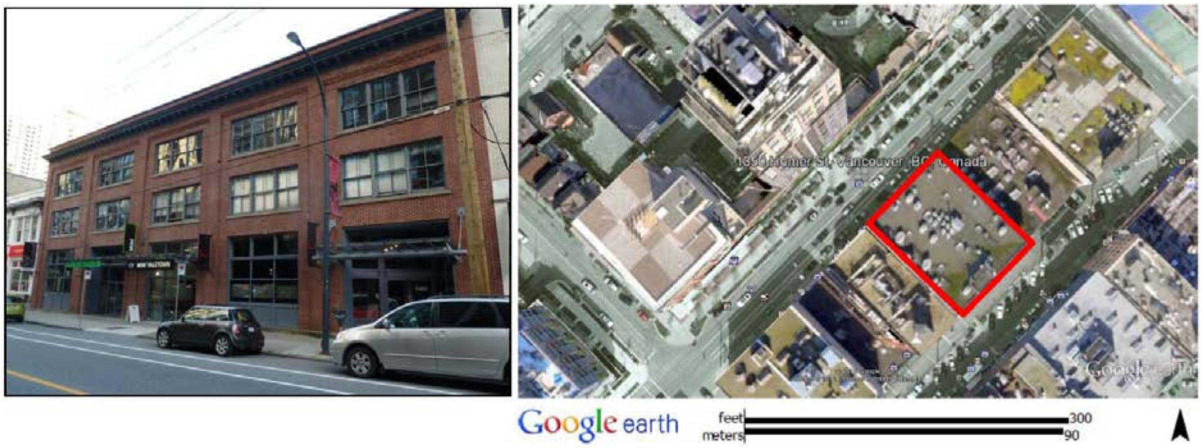
Recreation and leisure [COM11]

All sports and recreational facilities with seating for fewer than 1000 spectators.

Refer to 'Arena' for larger sporting venues with large numbers of spectators.

Rectangular, solid [PLFR]

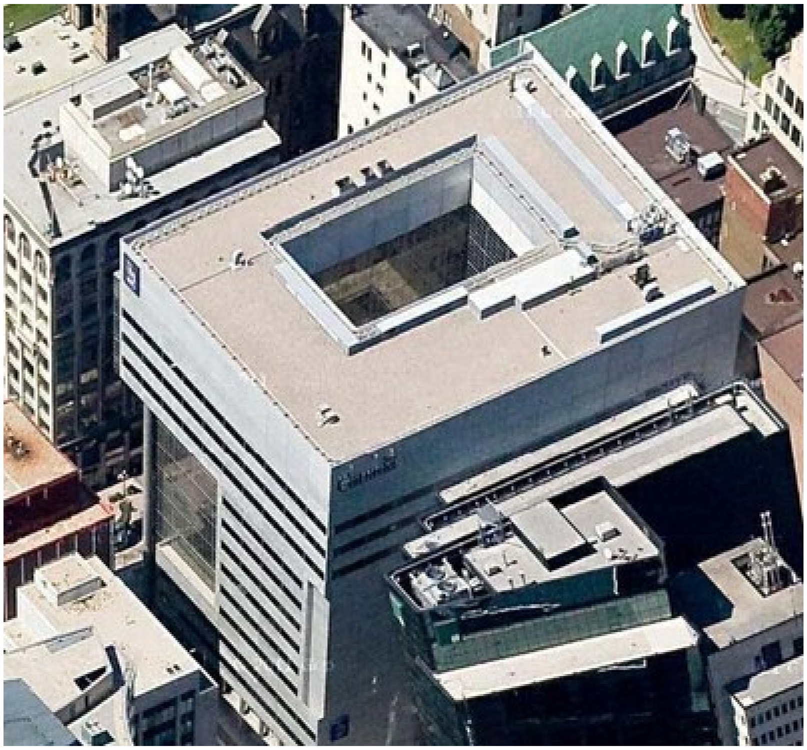
The shape of the building plan is approximately rectangular, with only minor variations from a rectangular shape. Two opposite sides are clearly longer than the other two sides.



A building with rectangular plan shape, Vancouver, Canada (left photo: S. Brzev, right: Map data ©2013 Google, Province of British Columbia, DigitalGlobe)

Rectangular, with an opening in plan [PLFRO]

Same as PLFR but with an open internal courtyard or full height roofed atrium.



This building in Ottawa, Canada has a rectangular-shaped plan with an interior opening (atrium) (Map data ©2013 Google, DigitalGlobe)

Regular or irregular

Does the building possess structural irregularities from a seismic perspective?

Regular structure [IRRE]

None of the structural irregularities listed in the table, and no other significant structural irregularities have been observed.

An example of a regular structure, Chile (S. Brzev)

Reinforced concrete bands [RCB]

There are horizontal bands of reinforced concrete w ithin a masonry w all. Usually at plinth, lintel or roof level.

Stone masonry buildings w ith reinforced concrete bands at the lintel level, India (S. Brzev)

Stone masonry bulding w ith a reinforced concrete band at lintel level, Nepal (M. Schildkamp)

Religious gathering [ASS1]

Place for religious gathering such as church, mosque, temple, synagogue, or monastery.

Residential [RES]

The building is mainly used as housing.

Residential, unknown type [RES99]

It is clear that the building is a residential building, but the format of the dwellings and number of dwellings in the building is unknown.

Retail trade [COM1]

All retail uses, including retail shops, supermarkets, shopping malls.

Riveted connections [RIV]

Structural steel members are connected together w ith steel rivets. Riveted connections are no longer used, how ever they can be found in buildings built before 1950s (this date may differ depending on the country).

Riveted connection, Canada (Ojdrovic Engineering)

Roof connections

These attributes define the follow ing tw o aspects of connections from the roof to the structure of the building:

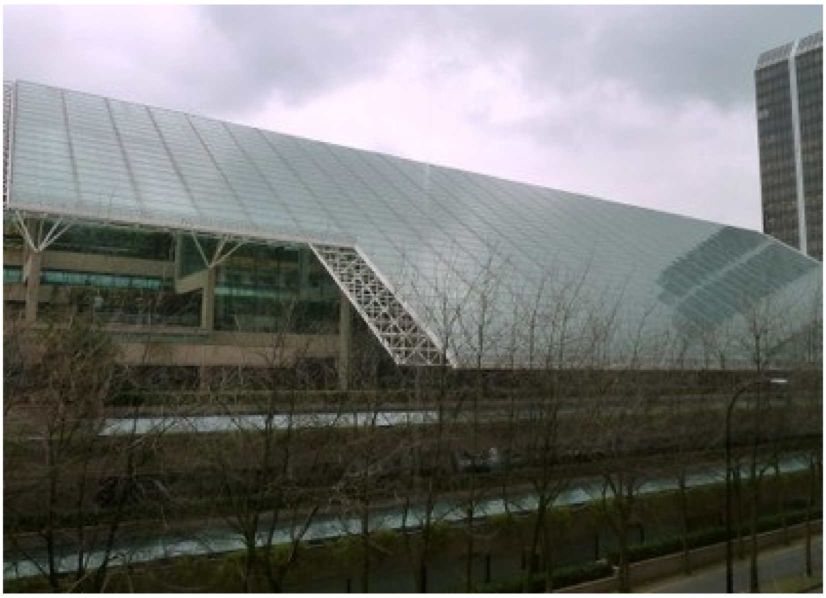
(a) Connections that enable the roof diaphragm to transfer horizontal shear forces induced by an earthquake or w ind to the lateral load-resisting structure of the building and to prevent w alls from falling aw ay from the diaphragm.

(b) Connections from the roof to the vertical structure of the building to prevent w ind uplift or lift-off.

Roof covering, other [RMTO]

The roof covering material is know n, but it is not adequately described by any of the roof covering types listed in this table.

For example: glass roof



Glass roof covering, Law Courts building, Vancouver, Canada (S. Brzev)

Roof covering

The material that covers the roof. In most cases this is different to the material of the roof system, but in some cases the roof covering will be the same as the roof system. In both cases, both the roof covering and the roof system should be defined where they are known. Where there are multiple covering materials present on the roof(s), choose the covering that covers more of the roof(s) by area than any other covering material.

Roof material, other [RO]

The roof structure material is know n, but they do not fit w ithin any of the definitions in this table.

Roof material, unknown [R99]

The material of the roof is unknown. It has not been inspected sufficiently to determine the material, or information is unavailable. In some cases the material of the structure of the roof will not be visible due to overlay of roofing materials and/or the presence of ceilings that may be a different material.

Roof shape, other [RSHO]

The shape of the roof is know n, but it cannot be described by any of the roof shapes in this table.

Conical roof shape, H.R. MacMillan Space Centre, Vancouver, Canada (S. Brzev)

Roof shape

The shape and angle of the roof on the building. If the building has more than one roof, describe the largest roof.

Roof system material

The general classification of the material of the roof system. Roof system is the structure that supports roof covering and environmental loading (such as rain and snow). Roof system is often not exposed from the exterior of the building. The material of roof system is usually different from the material of roof covering.

Roof system type

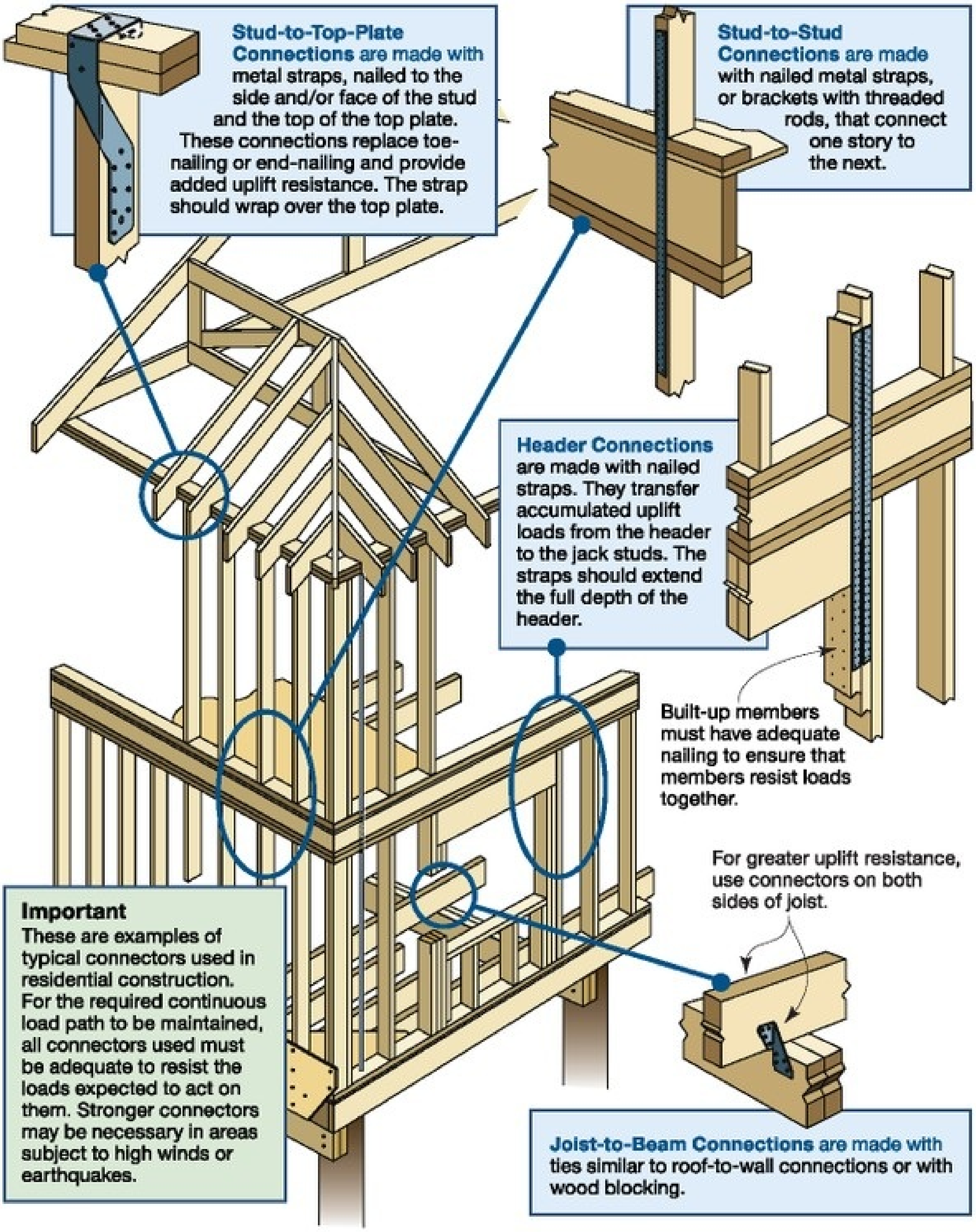
The detailed classification of the type of roofing system. This is the structural system of the roof. Roof covering material is a separate attribute and is classified as 'roof covering'.

Roof tie-down not provided [RTDN]

There are no connections that provide vertical attachment of roof to w alls in order to restrain roof from w ind lift-off, or the connections are considered to be inadequate.

Roof tie-down present [RTDP]

There are connections that provide vertical attachment of roof to w alls in order to restrain roof from w ind lift-off.



A diagram show ing roof-w all tie-dow n connections for resisting w ind loads (FEMA P-804, 2010)

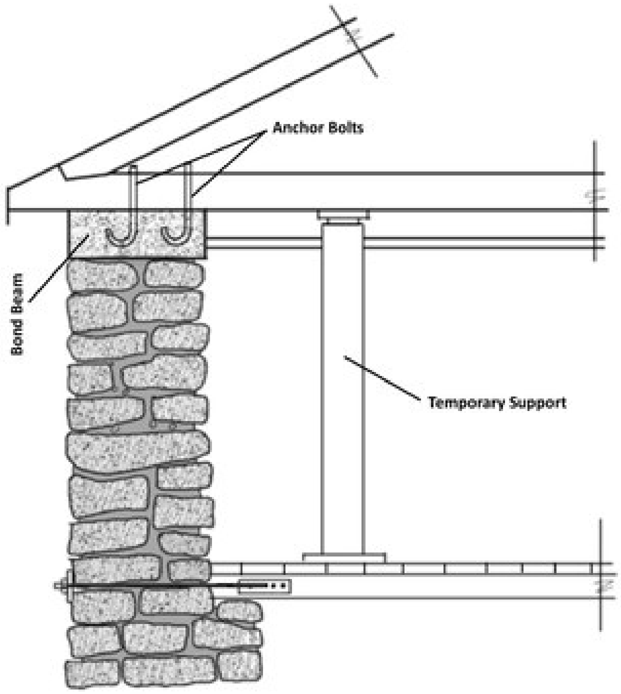


Figure 4.7 A new RC band must be anchored to the roof (adapted from: Tomazevic 1999)

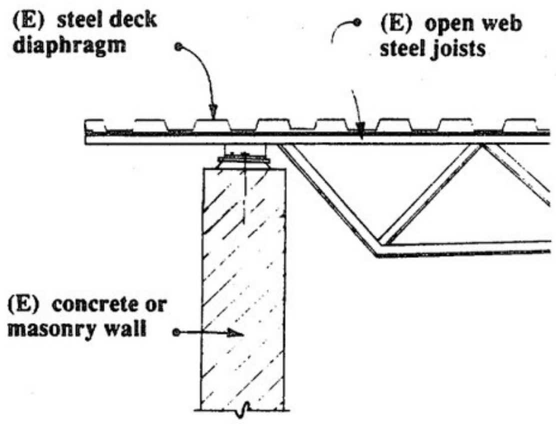
An example of a retrofit bond beam w ith roof tie-dow n anchor bolts ("J" bolts) (Improving Seismic Performance of Stone Masonry Buildings, Bothara and Brzev, EERI, 2011).

Roof tie-down unknown [RTD99]

It is not known whether connections are present that provide vertical attachment of roof to walls in order to restrain roof from wind lift-off. There is insufficient information available or the connections are not visible from a survey.

Roof-wall diaphragm connection not provided [RWCN]

There are no connections betw een the roof diaphragm and the w alls that are capable of transferring in-plane forces from roof to w all and restraining outw ard displacements of w alls.



Example of connections of a steel deck diaphragm to a concrete or masonry w all, that may be inadequate (adapted from FEMA 172, 1992)

An inadequate connection of a w ooden roof to the masonry w all in a building damaged in the 2011 Christchurch, New Zealand earthquake (W. Clark)

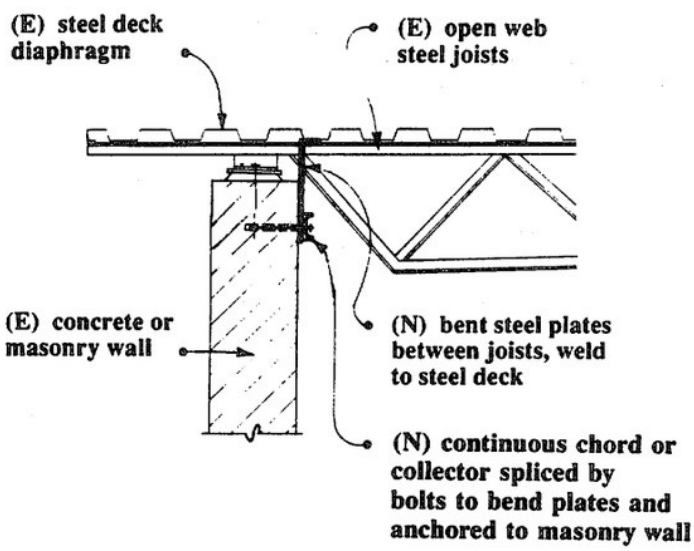
Out-of-plane collapse of masonry w alls at the top floor level in a building due to inadequate roof-w all connection, 1989 Loma Prieta, California earthquake (EERI)

Out-of-plane collapse of masonry w alls in a building damaged in the 1994 Northridge, California earthquake; note floor-w all anchors (EERI)

Roof-wall diaphragm connections between steel trusses (known as Open Web Steel Joists in North America) and masonry walls may be inadequate if support dimensions and attachment are not adequately designed and/or constructed (J. Adams)

Roof-wall diaphragm connection present [RWCP]

There are connections betw een the roof diaphragm and the w alls, capable of transferring in-plane forces from roof to w all and restraining outw ard displacements of w alls.



Example of retrofit method to improve strength of w all-to-roof connections of a steel deck diaphragm to a concrete or masonry w all; note that N refers to New and E refers to existing components (FEMA 172, 1992)

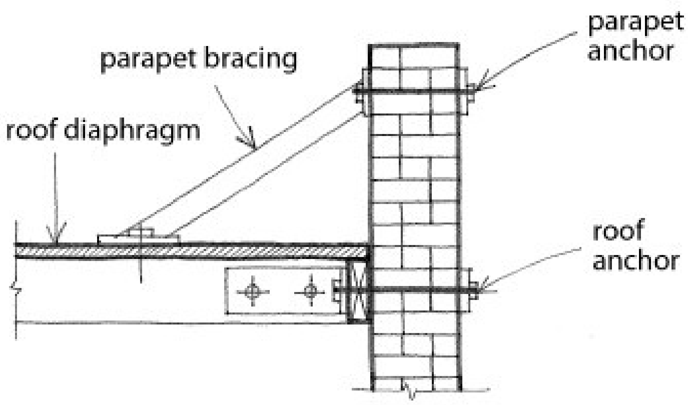


Diagram show ing a roof-w all connection for w ood diaphragm and masonry w all, and parapet bracing.

Roof-w all diaphragm connection in a retrofitted building in Seattle, USA achieved through steel anchors (S. Brzev)

A typical w all anchor, consisting of a steel rod and an exterior steel plate exposed at the exterior; note that anchor plates are of different shapes and sizes (S. Brzev)

Roof-wall diaphragm connection unknown [RWC99]

It is not known if there are any connections between the roof diaphragm and the walls that are capable of transferring in-plane forces from roof to wall and restraining outward displacements of walls. There is insufficient information available or the connections are not visible from a survey.

It is often difficult to assess whether floor-wall connections are present based on the exterior view alone - an interior inspection is required (S. Brzev)

Floor-wall and roof-wall connections in stone masonry buildings are usually not exposed at the exterior (S. Brzev)

Roof

The structural system supporting the roof cladding of the building. Lean-to roofs or smaller parts of the roof that differ in structural material to the main roof are not considered.

Rubble (field stone) or semi-dressed stone [STRUB]

Rubble/field stone masonry is composed of uncoursed rounded field stones or roughly-cut stones used for construction with or without mortar. There are two wall wythes and a core, usually filled with stone rubble and mud. Semi-dressed stone masonry is characterized by one wall wythe (usually exterior) built using shaped stones; usually only the exposed stone surface is shaped. In some cases, stone masonry can be reinforced, usually with wood elements (wood-reinforced).

Rubble stone masonry, Italy (T. Schacher)

Rubble stone masonry constructed using round river stones in lime or cement:lime mortar, usually 250 mm thick, West Sumatra, Indonesia (J. Bothara)

Random rubble stone masonry, Cambridge, United Kingdom (S. Brzev)

Stone masonry building in Algiers suffered damage in the 2003 Boumerdes, Algeria earthquake (M. Farsi)

Rubble stone masonry with timber bands, NWFP, Pakistan (J. Bothara)

Rubble stone masonry, Maharashtra, India (S. Brzev)

Semi-dressed stone masonry, Maharashtra, India (S. Brzev)

Semi-dressed stone masonry in mud mortar, Chile (S. Mihaldzic)

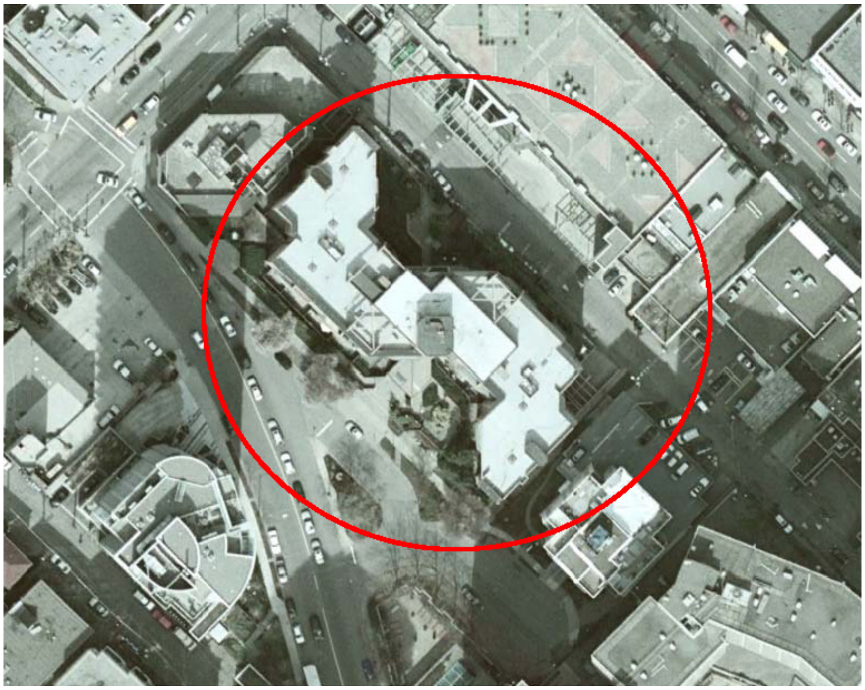
Rubble stone masonry, Marrakesh, Morocco (C. Scawthorn)

Variants

- Uncoursed Random Rubble Stone Masonry
- Ragstone
- Rubblestone

S-shape [PLFS]

The footprint of the building when viewed in plan resembles the shape of the letter S.

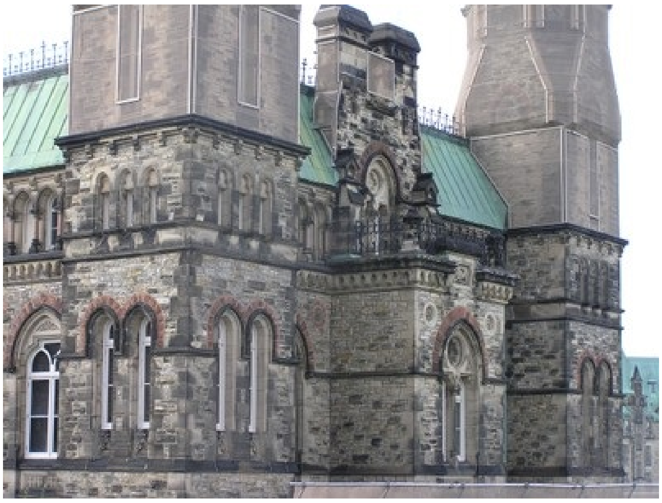


A building with S-shaped plan, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

Sandstone [SPSA]

Sandstone is a sedimentary rock formed of sand grains typically (1/16 to 2 mm in diameter) that are cemented together. Sand-sized particles are generally composed of other rocks and minerals, such as feldspar, quartz, rock fragments, and clay. The material cementing the sand grains can be silica, calcium carbonate, or iron oxides. Depending on the composition of the sands and cement, the hardness of sandstone can vary. Sandstone can be a variety of colours, but are typically grey, brow n, yellow, and sometimes red, green, or w hite.

A tw o-storey sandstone masonry building, West Cyprus (A. Pomonis)



Exterior w alls built in Nepean sandstone, National Parliament Building Complex, Ottaw a, Canada (Ojdrovic Engineering)

Sandstone masonry w alls in Ben-Daoud damaged in the 2010 earthquake, Algeria (M. Farsi)

Sandstone masonry w alls w ith timber reinforcement in Beni-Ourtilane damaged in the 2000 earthquake (M. Farsi)

Sandstone w alls under construction, Pakistan (M.M. Rafi)


Sandstone masonry construction, Bara Gumbad Mosque, New Delhi, India (S. Brzev)

Sandstone construction, Sun Temple, Modhera, Gujarat, India (S. Brzev)

Sandstone exterior w all, Chile (S. Brzev)

Sawtooth [RSH6]

A series of monopitch roofs all sloping in the same direction, giving the impression of a saw tooth in elevation. The vertical w alls that separate each roof from each other are typically glazed.

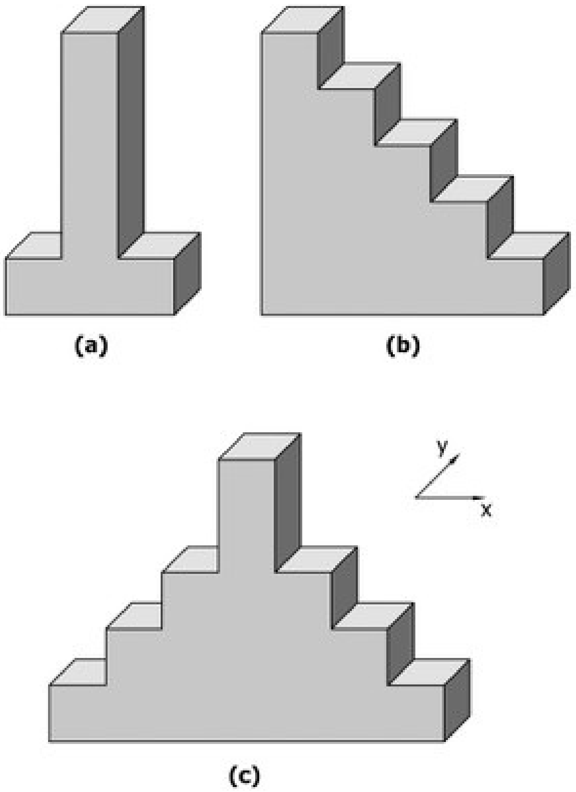
Saw tooth roof, Vancouver, Canada (S. Brzev)

School [EDU2]

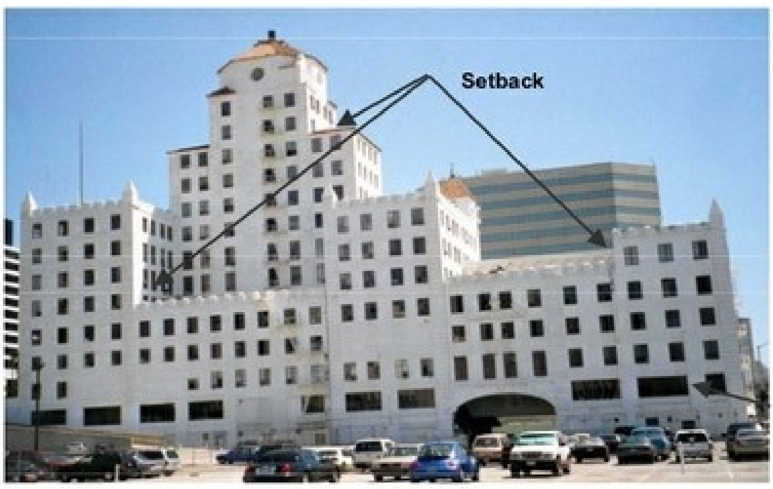
Any school-age educational centre. Includes government-owned and private schools.

Setback [SET]

Abrupt change in elevational profile, such as in a building w ith tow er and podium that creates a notch effect. A setback exists if the horizontal dimension of the seismic force-resisting system in any story is more than 130% of that in an adjacent story. Note that the Setback irregularity is a special albeit common case of Change in Vertical Structure, and therefore it has its ow n definition.



Simplified examples of typical building shapes that have setbacks (A. Charleson, *Seismic Design for Architects* , Architectural Press 2008, p154 fig. 9.21).



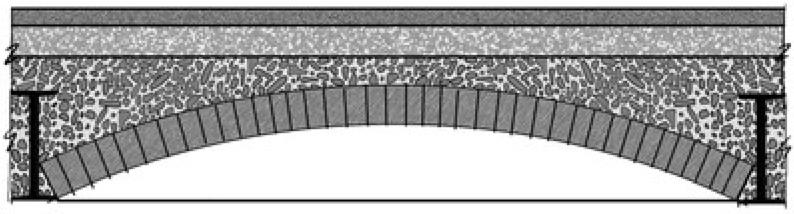
An example of a building w ith several setbacks (FEMA 154, 2002)

A building w ith a setback, Vancouver, Canada (S. Brzev)

A building w ith a setback, Fort Lauderdale, Florida, USA (S. Brzev)

Shallow-arched masonry floor [FM2]

Shallow-arched masonry floor spans between metal, timber or concrete joists, with ballast fill and overlaid with flooring.



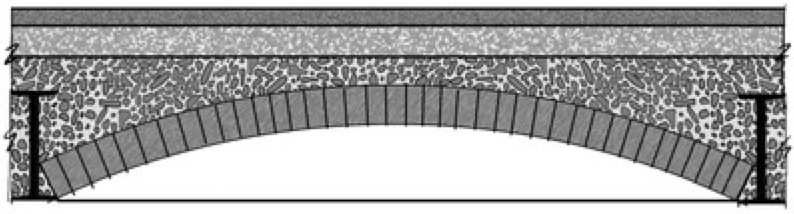
Masonry jack-arch construction (M. Lutman)

Variants

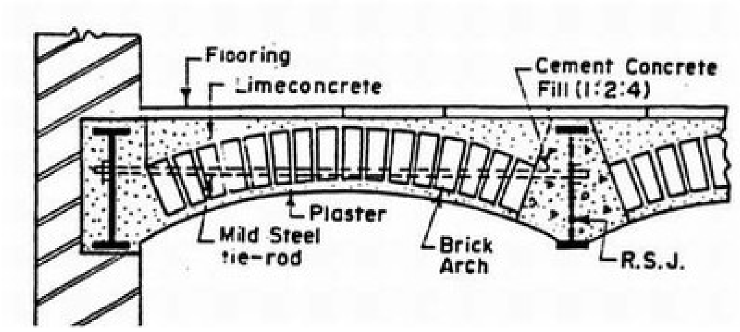
- Jack-arch construction

Shallow-arched masonry roof [RM2]

Shallow-arched masonry roof spans between metal, timber or concrete joists, with ballast fill and overlaid with roofing.



Masonry jack-arch construction (M. Lutman)



Masonry jack-arch construction (A. Pomonis)

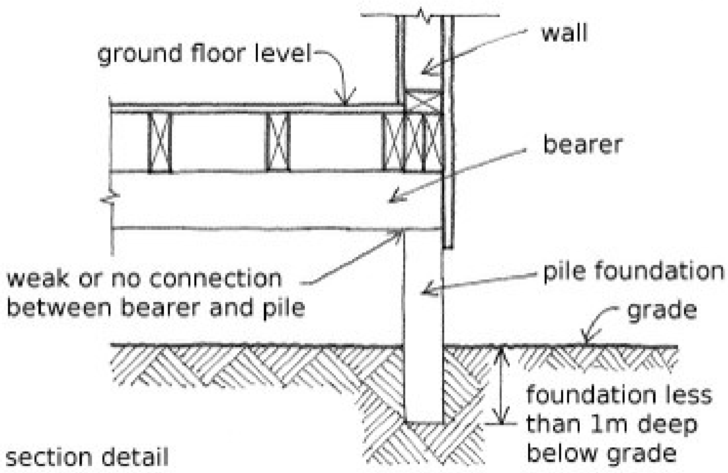
Brick masonry jack arch construction, Canada (Ojdrovic Engineering)

Variants

- Jack-arch construction

Shallow foundation, no lateral capacity [FOSN]

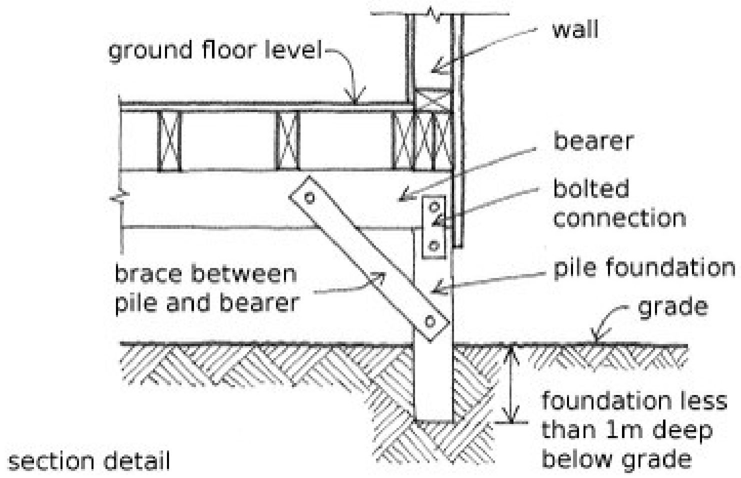
The foundations are less than 1m deep below grade, and they have no lateral capacity. Foundations with no lateral capacity include piles without lateral bracing support.



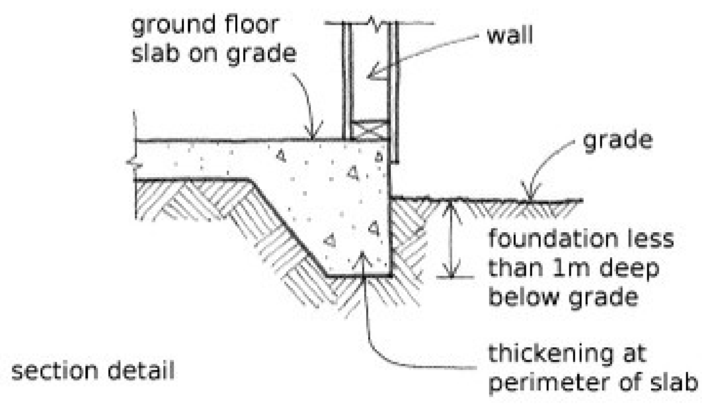
An example of a timber pile shallow foundation with no lateral capacity.

Shallow foundation, with lateral capacity [FOSSL]

The foundations are less than 1m deep below grade, and they have lateral capacity. Foundations with lateral capacity include tie-beams, foundation walls bracing in the direction of their lengths, inclined piles, piles or piers on wide spread footings, cantilevered or braced piles, and slabs on grade.



An example of a braced timber pile shallow foundation that has lateral capacity.



An example of a slab-on-grade shallow foundation that has lateral capacity.

Examples of braced timber pile foundations, New Zealand (Charleson).

Shape of the building plan

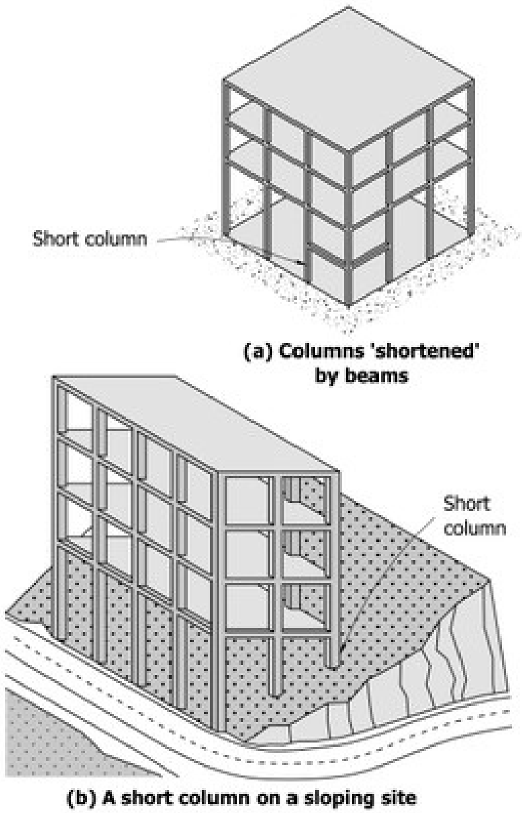
Shape of the building plan (building footprint) is the shape of the projection of the exterior edge of the building at grade onto the horizontal plane. To the extent possible, it is classified according to various simple shapes and letters of the alphabet. The shape from the table that most closely resembles the shape of the building footprint should be listed.

Where the building changes in plan cross-section (such as in the case of tow er and podium, or a setback) some judgment is called for – in general, the shape that the building conforms to for the majority of its height should be listed, and may differ from the footprint (plan cross-section) at ground floor level.

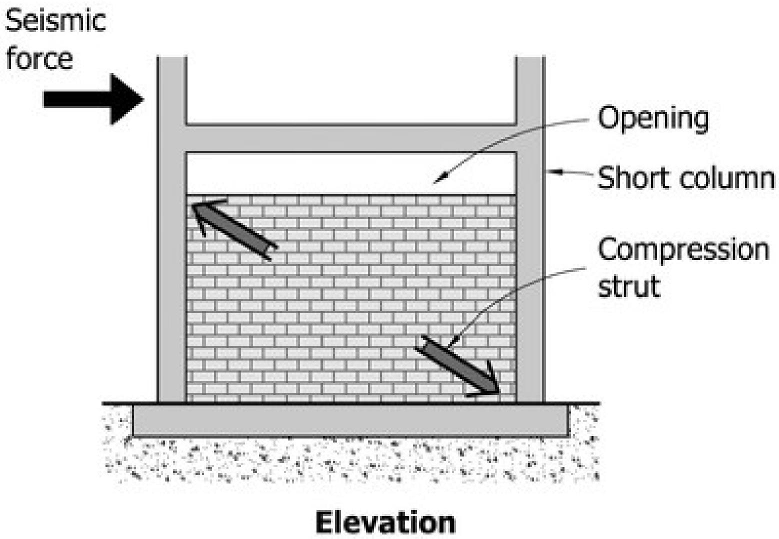
Short column [SHC]

A column of short length that will fail in shear rather than bend under lateral deformation when the column is overloaded during an earthquake. Includes captive columns, where wall elements (usually non-structural walls that are part of the enclosure system) effectively shorten some columns to less than the floor to beam height.

As a rule of thumb, a building has short columns if there are captive columns where the capturing non-structural walls reduce the height of unsupported length of the column by at least half, or where the capturing non-structural walls reduce the aspect ratio (height to depth ratio, where the depth of the column is measured parallel to the wall) of the column to less than 2:1.



Examples of short columns (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p148 fig. 9.8).



Example of short columns caused by part-height masonry infill (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p150 fig. 9.14).

Short Column in reinforced concrete construction, New Zealand (A. Charleson)

Captive columns in a reinforced concrete building damaged in the 2003 Boumerdes, Algeria earthquake (M. Farsi)

A building w ith captive columns suffered damage in the 2001 Bhuj, India earthquake (NICEE and IIT Kanpur)

Single dwelling [RES1]

House that is detached. A single residential unit, w hich w ould typically house one family. It is stand-alone and is not structurally joined to other residential units.

Slate [SPSL]

Slate is a very fine-grained metamorphic rock that easily splits into characteristic, thin slices, i.e. it is very cleavable. Slate is characteristically grey or grey-blue (but can also be black, green, purple, red, or brow n). Because it is composed mainly of fine-grained mica flakes and quartz, it is intermediate in hardness, but can still be scratched by metal. It has a dull luster and strong cleavage. Its nonabsorbent properties and durability make it a popular material for roof tiles and paving slabs, and in some cases it is used for w all construction.

Slate stone used for w all construction in coastal areas of Chile (S. Brzev)

Slate stone used for w all construction, Pakistan (S.H.Lodi)

Slate roof covering [RMT4]

Tiles of slate, foliated, homogeneous metamorphic rock derived from an original shale-type sedimentary rock composed of clay or volcanic ash. These tiles are usually thin and dark grey in colour. Overlapping and usually fastened to wood battens.

Slate roof tiles, Canada (Ojdrovic Engineering)

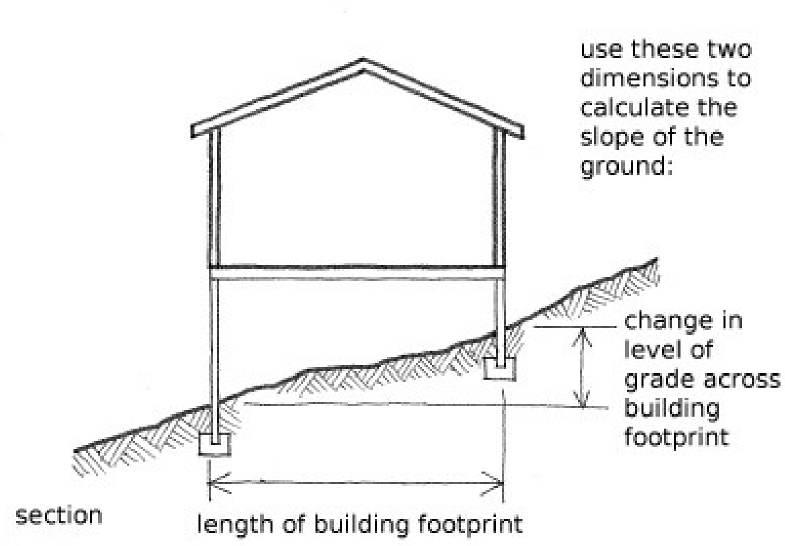
Slope of the ground [HD]

The slope of the ground is input w here the building is located on a sloping site, w here the height of the ground floor above grade varies by more than 1 m. The slope of the building is measured across the length of the building footprint, in the direction w here the greatest difference in level is observed. The slope is measured as an angle from horizontal (expressed in degrees), w here a flat site w ould be zero (0) degrees.

For flat sites, w here the variation of height of ground floor level above grade is less than 1m, the default value is zero (0) degrees.

Units: degrees

HD:a
w here a denotes slope (in degrees)
Example: HD:10 (the slope is 10 degrees)



The slope of the ground is calculated from the length of the building footprint (in the direction w here the greatest difference in level is observed), and the change in level of grade across this length.

Slope of the ground - general

The slope of the ground is input where the building is located on a sloping site, where the height of the ground floor above grade varies by more than 1 m.

Slope of the ground unknown [HD99]

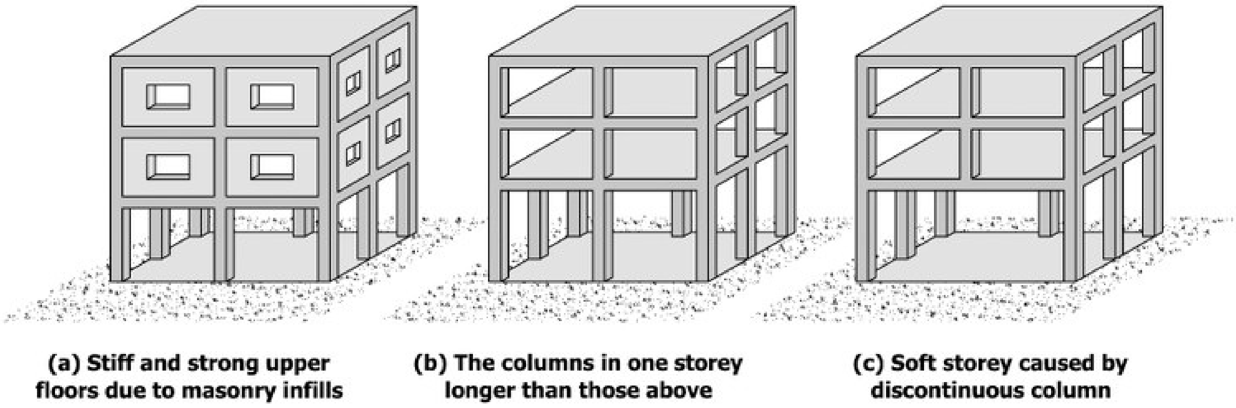
The slope of the ground is unknow n. It is impossible to determine the slope, as information is unavailable, or the building has not been inspected sufficiently to determine the slope of the ground.

This building in Vancouver, Canada w as built on a sloped ground, how ever the slope (in terms of number of degrees) is unknow n (S. Brzev)

Buildings in this street in Lisbon, Portugal w ere built on a sloped ground, how ever the slope information is not available (S. Brzev)

Soft storey [SOS]

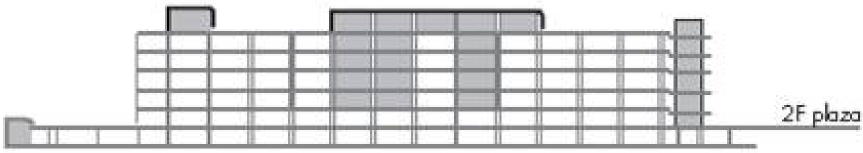
One storey is higher than others, or one storey is weaker than others. A soft or weak storey exists if the height of that storey is at least 15% greater than storeys above or below; or if it has at least 30% fewer columns in the case of a frame system, or at least 30% less full-height structural or infill wall length in the case of a wall or infill wall system, or if by other engineering calculation or approximation the storey appears to have 30% less lateral stiffness or strength. This irregularity is often found in buildings where open first (ground) storey is used to make space for parking, shops, or offices.



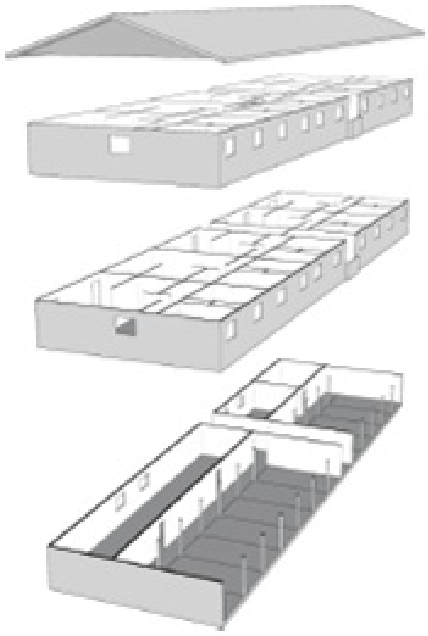
Examples of soft storey configurations (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p146, Figure 9.3).

Soft storey in a reinforced concrete building, New Zealand (A. Charleson)

Soft storey in reinforced concrete buildings, India (S. Brzev)

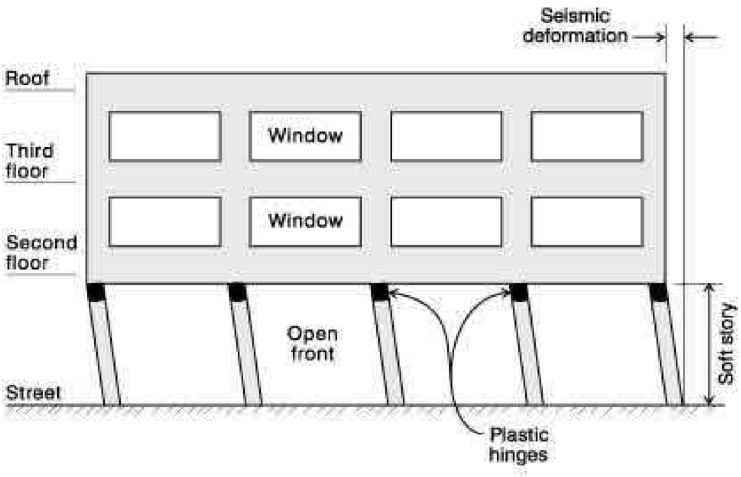


Olive View Hospital suffered severe damage in the 1971 San Fernando, California, due to discontinuous reinforced concrete shear walls shown shaded on the vertical section drawing. A soft two-storey layer of rigid reinforced concrete frames supported a stiff shear wall-frame structure above. Severe damage occurred in the soft storey portion, as shown in the photo (FEMA 454)



Soft storey w ood-frame buildings are common in suburban areas of California (such as Berkeley) and Pacific Northw est, USA. In most cases, these are residential apartment buildings and ground floor is used for parking, as show n on the photo (S. Brzev). An exploded view of a typical soft-storey w ood-frame building is show n on the draw ing (FEMA P-807).

Several soft-storey w ood-frame buildings w ere damaged in the 1994 Northridge earthquake and the 1989 Loma Prieta, California earthquake (left photo: Courtesy of the NICEE, University of California, Berkeley; right photo: EERI)



Several reinforced concrete frame buildings w ith open front suffered damage in the 1999 Chi Chi, Taiw an earthquake. These buildings had masonry infill w alls in the upper storeys. The rigid upper storeys caused significant lateral displacements in the columns at the low er level, as show n on the draw ing. The photo show s a typical damage observed in these buildings (Yao and Sheu, World Housing Encyclopedia Report 62)

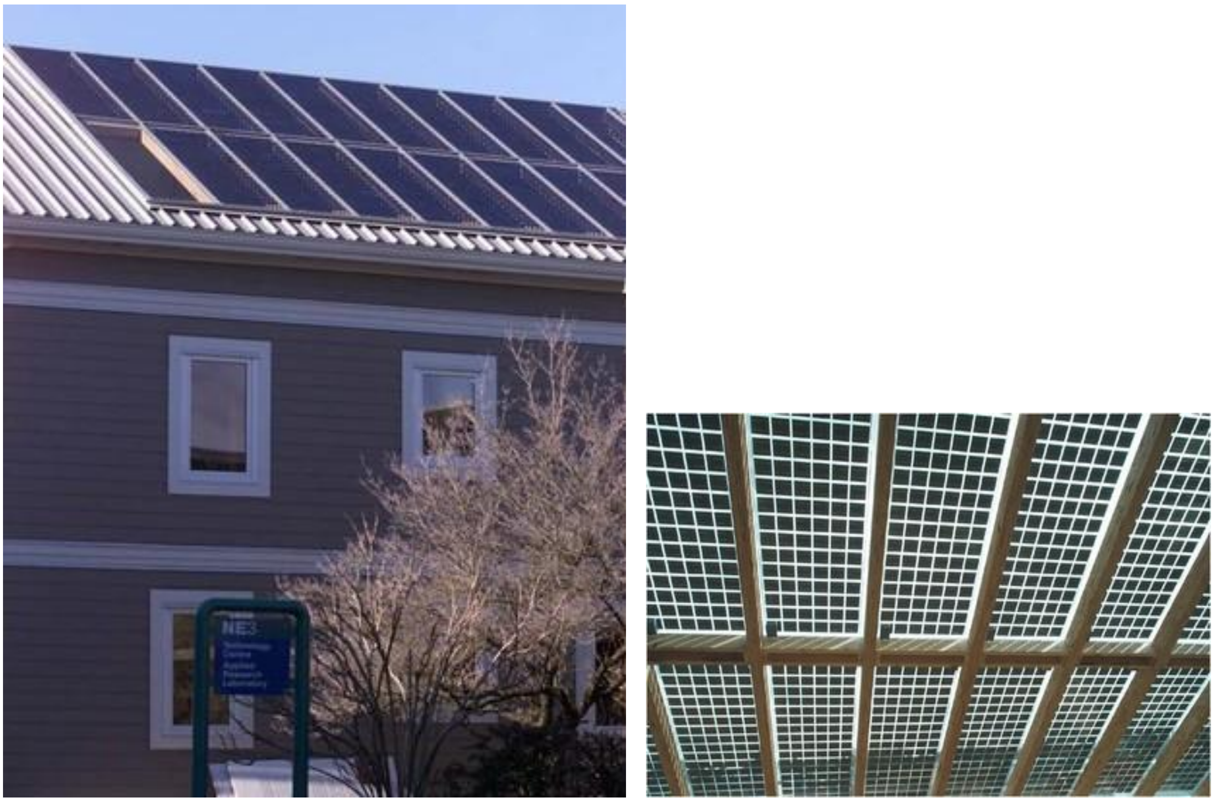
Several mixed occupancy buildings w ith stores at the ground floor w ere severely damaged or experienced collapse in the 2001 Bhuj, India earthquake (Indian Institute of Technology Bombay and EdM, 2001)

Ground floor is used for parking in many reinforced concrete framed buildings in Indian cities. Many buildings of this type experienced severe damage or collapse in the 2001 Bhuj earthquake. Left photo shows a building with open ground floor adjacent to a similar building that lost its ground floor due to the soft storey effect; right photo shows extensive damage in the columns at the ground floor level due to the earthquake, also due to the soft storey mechanism (Indian Institute of Technology Bombay and EdM, 2001)

Solar panelled roofs [RMT10]

Roofs where photovoltaic solar panels or solar hot water panels cover more of the roof area than any other roof covering material. There are two types of photovoltaic solar panelled roofs: Solar Photovoltaic Roofs and Building Integrated Photovoltaics. Solar photovoltaic roofs either completely displace conventional roof covering, or are installed over the existing conventional roof and attached to it via special mounting. Building Integrated Photovoltaics (BIPV) refer to photovoltaics modules which are directly incorporated into a building envelope by replacing conventional roof covering with photovoltaic elements.

Solar photovoltaic roof, Belgrade, Serbia (L. Stamenic)



Solar photovoltaic roof (exterior and interior view), Canada (L. Stamenic)

Building Integrated Photovoltaics in a fire hall, Germany (L. Stamenic)

Solar Photovoltaic Roof, California (S. Brzev)

Solid wood [WS]

Walls are made from solid wood. Includes hewn or unhewn log construction.

Log wood wall intersection, USA (S. Brzev)

Solid wood (log) construction, Canada (S. Brzev)

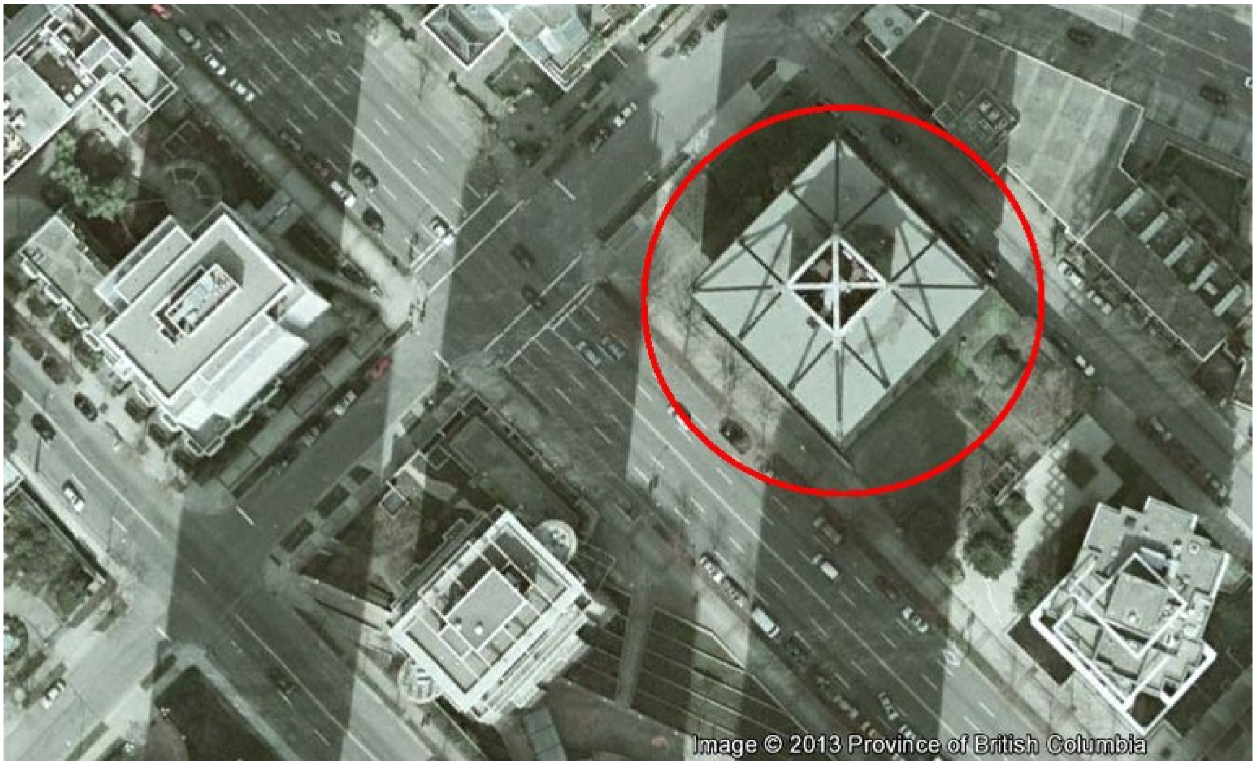
Solid wood construction, USA (S. Brzev)

Variants

- Log wood construction

Square, solid [PLFSQ]

The shape of the building is approximately square, with only minor variations from a square shape. It's sides are approximately equal in length.



A building with square plan shape, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

Square, with an opening in plan [PLFSQO]

Same as PLFSQ but with an open internal courtyard or full heigh roofed atrium.

A building with a square plan shape with an opening, Japan (left photo: C. Scawthorn, right: Map data ©2013 Google, ZENRIN)

Steel [S]

Steel is a strong and malleable material (alloy of iron and carbon) used for structural and non-structural purposes. Includes all grades and alloys of steel.

Steel building under construction, New Zealand (A. Charleson)

Steel connections, unknown [SC99]

It is clear that the structure is steel, but the type of steel connections is unknown. The connections are not visible or there is insufficient information to determine their type.

Steel, other [SO]

Any steel construction type that is know n but does not fit the descriptions of the other steel construction types in this table.

Steel-reinforced [RS]

Steel reinforcing bars can be used within the build-up of a concrete masonry wall, within cavities that are then filled with poured concrete. Alternatively, steel welded wire mesh overlaid with cement plaster can be attached to interior or exterior wall surfaces with steel dowels.

Concrete block masonry construction with steel reinforcement, Canada (B. McEwen)

An adobe building reinforced externally with steel wire mesh overlaid with cement plaster, Peru (N. Tarque)

Steel, unknown [S99]

It is clear that the structural material is steel, but the type of steel construction is unknow n. The steel structure may be hidden, or information about it is unavailable.

Stone masonry

Stone masonry construction is usually composed of stones and mortar. The stones range from unshaped field stones (rubble masonry construction) to shaped stone blocks (dressed stone masonry).

Stone, other type [SPO]

The type of stone is known, but its type is not listed in the table. For example, metamorphic rocks, e.g. gneiss, marble, quartzite, etc. Gneiss is a common type of metamorphic rock used for wall construction in Europe (e.g. Southern Switzerland, Italy, etc.).

Gneiss stone wall residential construction, Ticino, Southern Switzerland (T. Schacher)


Gneiss stone walls, a 12th century church, Ticino, Southern Switzerland (T. Schacher)

Heterogeneous (mixed) masonry w all uses a combination of limestone and limestone, as w ell as clay bricks for arching lintels, L'Aquila, Italy (A. Benedetti)

Stone slab roof covering [RMT5]

Flat roofs that are covered with stone slabs (other than slate).

Stone, unknown technology [ST99]

It is clear that the structural material is stone, but the type of stone masonry is unknow n. The build-up of the w all may be hidden, as in the case of a plastered w all, or information about it is unavailable.

This is a stone masonry building, but there is a mix of technologies - street facade w as built in dressed stone masonry and the other exterior w all is built using random rubble stone masonry (Halifax, Canada, S. Brzev)

Stone, unknown type [SP99]

It is clear that the structure is stone, but the type of stone is unknown. There is insufficient information or it is not possible to identify the exact type of stone.

Stone masonry building, Southern France (S. Brzev)

Stone masonry building, museum, Antibes, France (S. Brzev)

Structural irregularity

Structural irregularity is a feature of a building's structural arrangement, such as one storey significantly higher than other storeys, an irregular building shape or a change of structural system or material, that produces a known vulnerability during an earthquake. The user can choose a maximum of two vertical and two plan irregularities for a building. However, if a building has two irregularities of the same type (plan/vertical), the user needs to prioritize them by identifying the primary irregularity first and the secondary irregularity next.

Stucco finish on light framing for exterior walls [EWSL]

Plaster finish over sheet material such as fibre cement board or expanded polystyrene, fixed to metal or wood studs.

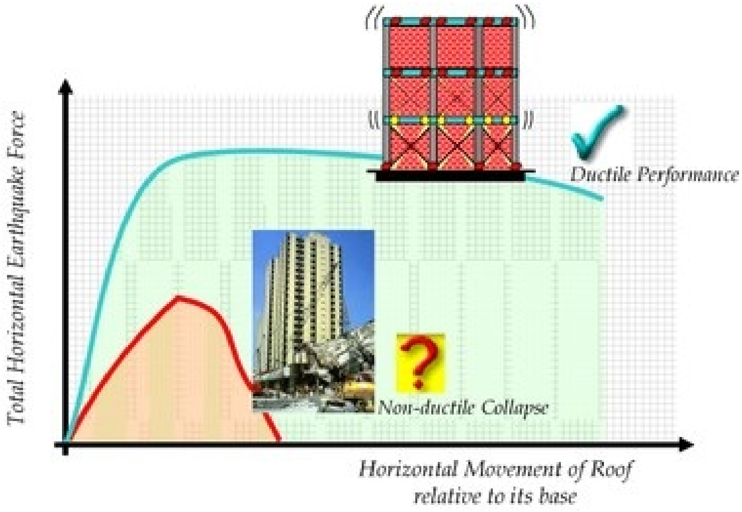
Stucco cladding over wood stud walls, Canada (S. Brzev)

System ductility

Ductility denotes an ability of a building structure to undergo significant deformations before the failure occurs in structural members or their connections. These large deformations (usually referred to as plastic or inelastic deformations) are accompanied by damage in some of the structural components. Structures w hich show ductile performance may experience permanent deformations after a major earthquake.

Ductility is one of the most important factors affecting building performance in an earthquake. In general, a building can be classified as ductile or non-ductile, depending on its expected seismic performance (based on the design and construction) before an earthquake, or its observed performance after an earthquake. It is difficult, if not impossible, to determine w hether a lateral load-resisting system should be classified as ductile or non-ductile based on visual information only. It is also difficult to determine w hether a system is ductile or non-ductile solely based on information about material of the lateral load-resisting system. For example, a reinforced concrete building can perform either in ductile or non-ductile manner, as explained in the related glossary terms. Unreinforced masonry buildings are generally expected to behave in a non-ductile manner, how ever reinforced or confined masonry buildings are expected to show ductile performance.

According to the conventional seismic design approach, buildings are designed for ductile performance. Alternatively, a building can be equipped w ith base isolation and/or energy dissipation devices. The objective of this approach is to avoid damage in structural components and building content in case of a major earthquake.



Ductile performance of a building is characterized by large horizontal deformations (lateral sw ay), as show n by the green curve, w hile non-ductile behaviour is characterized by smaller horizontal deformations and brittle damage or collapse of a building or its components, as show n by the red curve (C.V.R. Murty, Earthquake Tip 8, NICEE, India)

T-shape [PLFT]

The footprint of the building when viewed in plan resembles the shape of the letter T.

A building with T-shaped plan, San Francisco, California, USA (Map data ©2013 Google, SIO, NOAA, U.S. Navy, NGA, GEBCO, Image Landsat)

Temporary lodging [RES3]

Guest accommodation; including hotels, motels, guest lodges, cabins, and holiday accommodation.

Tensile membrane or fabric roof [RMT11]

The roof is made of fabric, including tensile membrane, inflatable fabric structures, and other types of fabric sheet roof.

A tensile membrane roof is made of stretched fabric, usually stretched in tw o directions to form a tensioned surface. Examples of tension membranes include polyester coated w ith PVC and glass fibre coated w ith teflon.

An inflatable roof uses fabric chambers pressurized w ith air to form a self-supporting structure.

Also included is any other type of fabric roof not inflatable or stretched like a tensile membrane, and includes plastic sheet, tarpaulin, canvas sheeting.

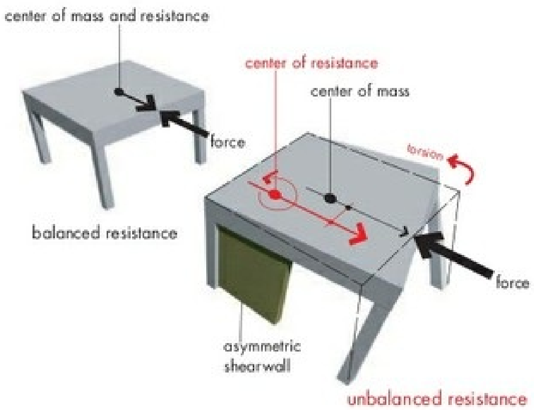
Canada Place in Vancouver, Canada is an example of tensile fabric roof structure (S. Brzev)

An example of a fabric roof (S. Brzev)

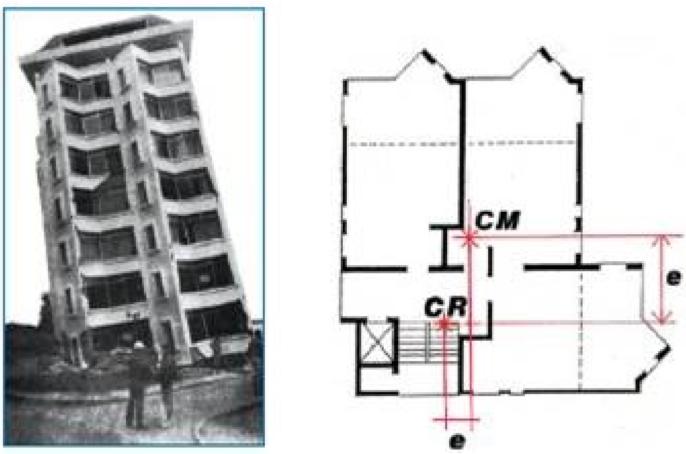
Torsion eccentricity [TOR]

For at least one direction (across or along the building) the centre of rigidity or resistance is located anywhere beyond the half-way point between the centre of a typical floor plan and the side of the building.

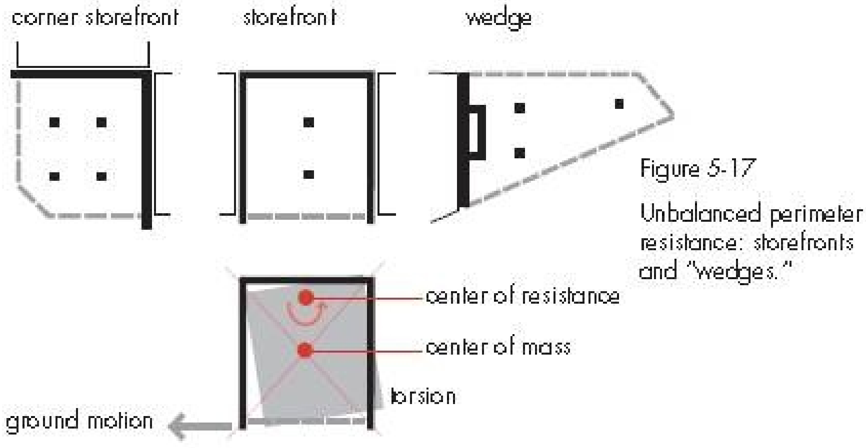
Torsion is created when the centre of mass (CM) and the centre of rigidity or resistance (CR) in the building do not coincide - the distance between these two points is referred to as torsion eccentricity. CM is usually the geometric centre of the floor (in plan). Location of the CR depends on the characteristics of components of lateral load-resisting system (shear walls, moment frames, braced frames, etc.). Torsional effects can develop only in buildings with rigid diaphragms. Also large torsion eccentricities may not lead to torsion irregularity if lateral load-resisting structure normal to the torsion generating structure is widely-spaced in plan and strong.



How torsional effects develop in a building (FEMA 454)

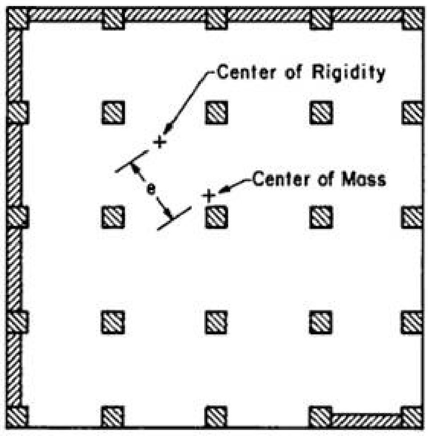


Torsional effects can develop in buildings whose configuration is regular and symmetrical, however stiff structural components such as strairwells or elevator cores are offset with regards to the centre of mass. The photo shows a building in Vina del Mar that was severely damaged in the 1985 Llolleo, Chile earthquake, and the drawing shows its floor plan (FEMA 454)



Torsional effects develop in corner buildings or open front buildings, such as show n on the draw ing (FEMA 454)

An open front building (fire station), Vancouver, Canada (S. Brzev)



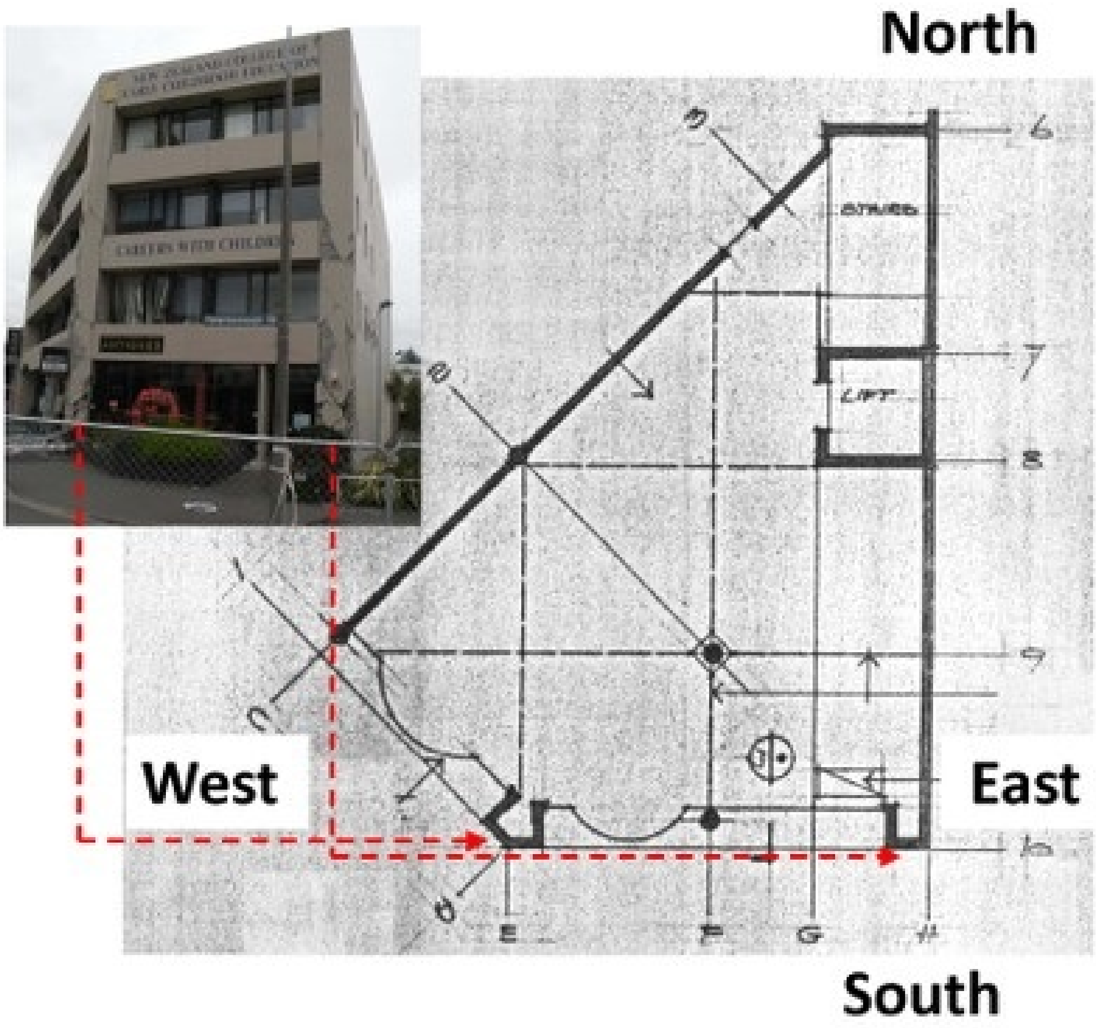
Collapse of the J.C. Penney building in the 1964 Anchorage, USA earthquake w as attributed to torsional effects. Shear w alls existed mostly along south and w est facade. There w ere no shear w alls in the north facade, w hich w as covered by precast concrete panels, and there w as a partial shear w all in the east facade. Torsional effects caused collapse of the east w all, and progressive collapse in the south and w est w alls. The photo show s east facade of the building after the earthquake, and the draw ing show s a building plan (Courtesy of the NISEE, University of California, Berkeley, and U.S. National Research Council)

1

2

3

A reinforced concrete frame building under construction w as damaged in the 2005 Kashmir earthquake in Pakistan (see Figure 1). Columns in upper storeys suffered severe damage and permanent displacements (Figure 3) due to a decrease in the stiffness at upper storeys; this w as caused by concrete block infill w alls at the ground floor level. The damage in the columns w as aggravated by the presence of a rigid stairw ell in one of the corners (see Figure 1) w hich collapsed (see Figure 3). The stairw ell caused torsional effects in the building due to eccentricity betw een the centre of mass and the centre of resistance (M. Tomazevic)

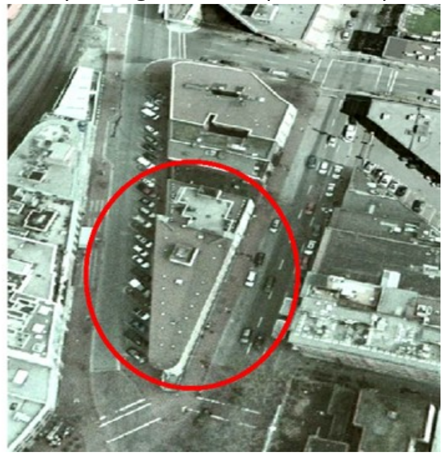


A reinforced concrete building w as damaged in the 2011 Christchurch, New Zealand earthquake due to torsional effects. Lateral load resisting system consisted of reinforced concrete shear w alls and elevator core along the east and north-w est direction and reinforced concrete and masonry columns at the south, as show n on the plan. The damage w as most pronounced in reinforced masonry and reinforced concrete columns located at the southern facade of the building, as show n in the photo (J. Centeno)

Building w ith an open first storey along street corner and w alls along other exterior faces collapsed in the 1999 Chi Chi, Taiw an earthquake. The building tilted due to collapse of first storey columns, creating apparent torsional w eakness (Courtesy of the NISEE, University of California, Berkeley, photo: J. Moehle)

Triangular, solid [PLFD]

The shape of the building footprint is approximately triangular in shape, or a tapered wedge shape.



A building with triangular plan shape, Hotel Europe, Vancouver, Canada (Left: S. Brzev; Right: map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

A building with triangular plan shape, San Francisco, California, USA (Map data ©2013 Google, SIO, NOAA, U.S. Navy, NGA, GEBCO, Image Landsat)

Triangular, with an opening in plan [PLFDO]

The building footprint is approximately triangular in shape, or a tapered wedge shape, and it has an open internal courtyard (Δ).

Tuff [SPTU]

Tuff is an igneous volcanic rock made up of rock and mineral fragments that are compacted w ith volcanic ash. In general, the grain size of the ash is below 4 mm (above 4 mm: volcanic breccia). The colour of tuff is variable (and strongly depends on its w eathering and chemical composition), but it is mostly greyish, brow n, or yellow It is a low -density, high-porosity rock that is often soft and porous and can therefore be scratched by metal objects. It is a relatively soft stone and it has been w idely used for masonry construction in regions w here it is available (e.g. Italy, Armenia, etc.).

Tuff stone blocks, Italy (A. Benedetti)

A view of Sovana, Italy - most buildings are built using tuff masonry and the city w as built on a tuff cliff (http://ilcasale1742.it/en/)

Tuff stone w as used for the construction of Bourbon del Monte Palace (16th century), Sovana, Italy (w w w .fototoscana.it)

Tuff stone used in modern w all construction, Italy (A. Benedetti)

A w all built using dressed tuff stone exterior w ythe over a rubble masonry in San Giuliano damaged in the 2002 Molise earthquake, Italy (A. Benedetti)

Tuff stone masonry in Algiers, Algeria w as affected by the 2003 Boumerdes earthquake (M. Farsi)

Type of irregularity

The detailed type of irregularities identified in plan irregularity or vertical irregularity

Type of lateral load-resisting system

Lateral load-resisting system is the structural system that provides resistance against horizontal earthquake forces through vertical and horizontal components. It is important to identify the most appropriate lateral load-resisting system. Please refer to the descriptions of relevant glossary terms before making the selection.

U- or C-shape [PLFU]

The footprint of the building when viewed in plan resembles the shape of the letter U.

Note that this also includes "C" shaped buildings (which look like a "U" when viewed from another direction).

Fairmont Chateau Laurier Hotel in Ottawa, Canada has a U-shaped plan (Map data ©2013 Google, DigitalGlobe)

City Hall in Toronto, Canada has two half-circle office towers, curving around a circular council chamber; the towers can be classified as U-shaped building plans (Map data ©2013 Google, DigitalGlobe)

A building with U-shaped plan (left photo: C. Scawthorn, right: Map data ©2013 Google, ZENRIN)

Unknown concrete technology [CT99]

It is clear that the structural material is concrete, but the type of concrete construction and w hether it w as precast, cast-in-place, pre-stressed etc is unknow n.

Unknown earth technology [ET99]

It is clear that the structural material is earth construction, but the type of construction is unknown. The structural material may be hidden, such as in the case of a plastered earth wall, or information about it is unavailable.

It is difficult to identify type of earthen construction when the walls are covered with plaster, like in this example of cob construction in India (People in Centre)

Older low-rise masonry buildings in Chile are of adobe construction (see the exposed portion of the wall); adobe is NOT considered to be an earthen construction (it is a masonry construction technology) (S. Brzev)

Many buildings in Peru are of adobe construction; adobe is NOT considered as earthen construction (it is a masonry construction technology) (S. Brzev)

Unknown foundation system [FOS99]

The type of foundation system is unknown. There is insufficient information available or it is not possible to determine the foundation type from a survey.

Unknown lateral load-resisting system [L99]

Lateral load-resisting system unknow n due to it being unclear w hich system is used. The system may be hidden, or information about it is unavailable.

Lateral load-resisting system for this building in Shanghai, China is unknow n (C. Scaw thorn)

Unknown material [MAT99]

The lateral load-resisting system material is unknown due to it being unclear which material is used. The material may be hidden, or information about it is unavailable.

Unknown material of exterior walls [EW99]

The material covering the exterior walls is unknown. There is insufficient information available or it is not possible to determine the material from a visual survey.

Unknown occupancy type [OC99]

The use of the building is unknow n.

Unknown plan shape [PLF99]

The shape of the building plan is unknow n. There is insufficient information available or the shape of the plan is not visible from a survey.

Unknown roof covering [RMT99]

The type of roof covering is unknown. There is insufficient information available or it is not visible from a survey.

Unknown roof shape [RSH99]

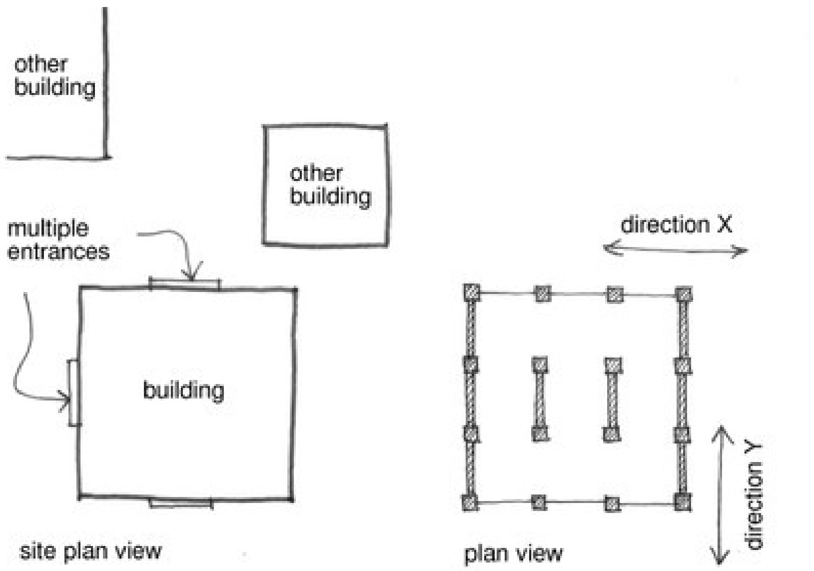
The roof shape is unknown. There is insufficient information available and the roof shape is not observable from the survey.

Unknown structural irregularity [IR99]

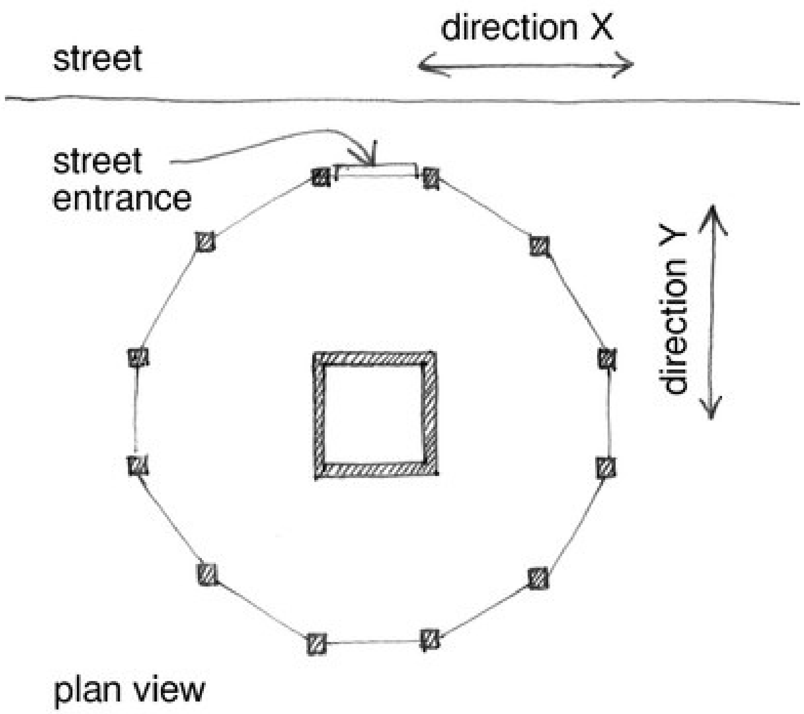
It is not known whether there are any structural irregularities, or what type of irregularities may exist. The building hasn't been inspected sufficiently to determine this, or this information about the building is unavailable.

Unspecified direction [D99]

Use this attribute if the building does not have a façade that is parallel to a street. Choose any other façade and define Direction X parallel to it. Direction Y w ill be perpendicular (orthogonal) to Direction X. This includes buildings that are not located next to a street or their orientation is not parallel to the street. It also applies to any building w here information about its direction is unavailable



Unspecified Direction - w hen street cannot be identified



Unspecified Direction - case of a building w ith a curved plan shape

Upper and lower bound for the date of construction or retrofit [YBET]

Low er bound and upper bound of the year in w hich the building w as first completed (e.g. 1930-1940). This is the best estimate of construction date if it is not know n precisely.

Vaulted earthen roofs [RE1]

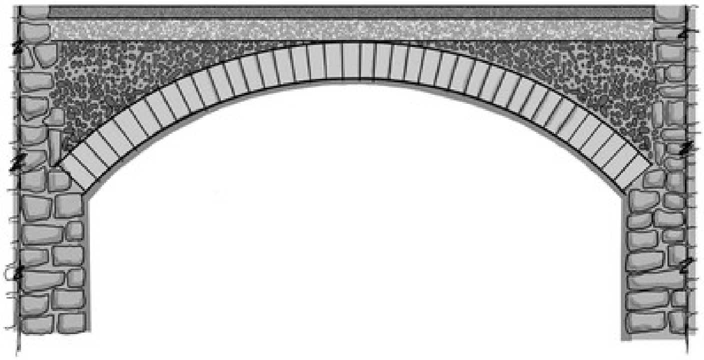
These systems include earthen domes and vaults.

Earthen masonry domes, Iran (F. Naeim)

Collapse of earthen buildings w ith domed roofs in the 2003 Bam, Iran earthquake (F. Naeim)

Vaulted masonry floor [FM1]

Masonry spans between bearing walls and is overlaid with fill. A flat floor surface is provided and is often overlaid with flooring. Includes two-way vaults and masonry domes.



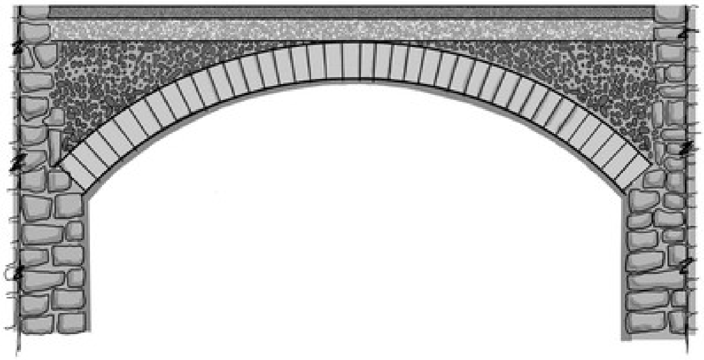
Brick masonry vault (M. Lutman)

Brick masonry double vault, Italy (S. Brzev)

Stone masonry double vault, Portugal (S. Brzev)

Vaulted masonry roof [RM1]

Masonry spans between bearing walls and is overlaid with fill. A flat roof surface is provided and is often overlaid with roofing. Includes two-way vaults and masonry domes.



Brick masonry vault (M. Lutman)

Brick masonry double vault, Italy (S. Brzev)

Double vaulted masonry roof, Peru (S. Brzev)

Vaulted masonry roof, Italy (S. Brzev)

Damage to masonry buildings with vaulted masonry roofs in L'Aquila earthquake, Italy (T. Schacher)

Vegetative exterior walls [EWV]

All types of plant-based wall materials. Includes matting, palm, thatch, straw.

Exterior walls made of matting (Ikra walls), Assam, India (People in Centre)

Vegetative roof covering [RMT8]

All types of roof covering made from lightweight vegetative material. Includes birch bark roof, split stem bamboo, thatched. Does not include planted 'green roofs' with soil and living plants.


Thatch roof covering, India (People in Centre)


Thatch roof covering, Cuba (S. Brzev)


Thatch roof covering, airport building, Dominican Republic (S. Brzev)

Vertical structural irregularity - primary [IRVP]

A structural irregularity that is observed in the elevation or section of the building (vertical plane). If more than one vertical irregularity is observed, the primary vertical irregularity is that deemed to be the most significant in terms of affecting the building's seismic performance, and the secondary vertical irregularity is that deemed to be the next most significant.

Example of a reinforced concrete building w ith a vertical irregularity, USA (S. Brzev)

Vertical structural irregularity - secondary [IRVS]

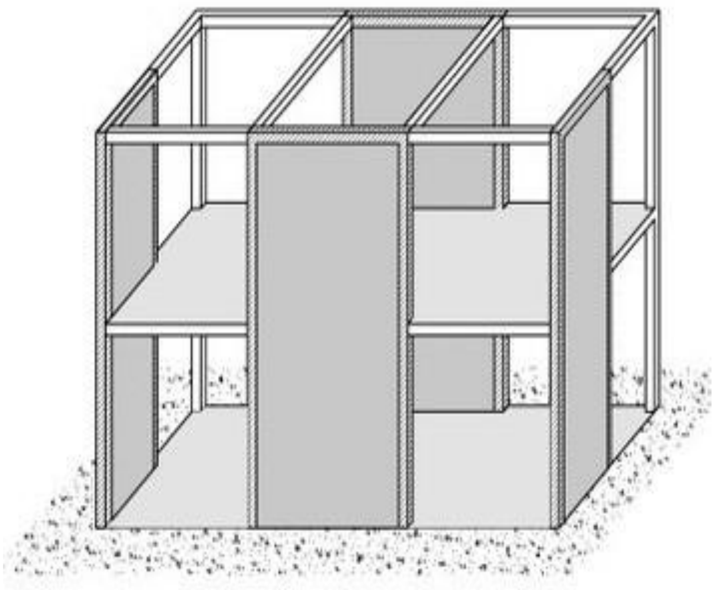
A structural irregularity that is observed in the elevation or section of the building (vertical plane). If more than one vertical irregularity is observed, the primary vertical irregularity is that deemed to be the most significant in terms of affecting the building's seismic performance, and the secondary vertical irregularity is that deemed to be the next most significant. If there is only one structural vertical structural irregularity observed, the term "No Irregularity" will be used by default.

Wall [LWAL]

A wall is a vertical planar building element which usually resists gravity loads, but also resists horizontal forces and provides stability to a building during an earthquake. Usually its length is greater than 6 times its thickness. Any vertical elements, like studs in light wood framed walls, are to be included in assessing the wall thickness.

Wall describes the lateral load-resisting structure comprising of walls and frames where the walls, due to their substantial lengths, resist the vast majority of the lateral load. Walls may be monolithic as in the case of reinforced concrete walls, or be of masonry construction. They can also comprise several materials as in the case of confined masonry construction with its system of masonry walls and reinforced concrete confining columns and beams, light wood framing with its sheet lining combining with the wood to provide earthquake bracing, or walls where mud has been applied to a light wood framework as in quincha construction.

Also within the definition of walls, coupled-walls or coupled-shear walls are to be included. These structures consist of two or more walls in the same plane (forming walls with openings up their heights) that are connected usually at every story by beams whose span-to-depth ratios are much smaller than for conventional beams.



A simplified drawing of a building with shear walls (A. Charleson, *Seismic Design for Architects*, Architectural Press 2008, p. 64, Fig. 5.2).

Walls, quincha construction, Peru (S. Brzev)

Wall, precast concrete, New Zealand (left - A. Charleson) and Denver, USA (right - K. Porter)

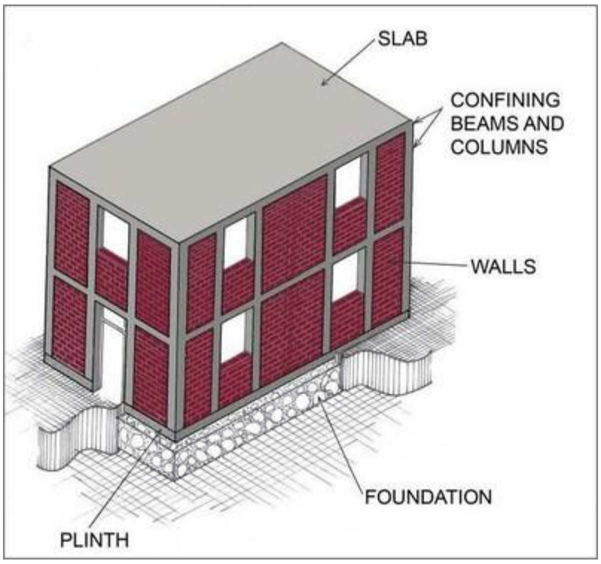
A cast-in-place reinforced concrete building with a Wall lateral load-resisting system, Oakland, California, USA (C. Scawthorn)

Reinforced concrete wall building under construction, Lima, Peru (S. Brzev)

Pre-1976 in-situ reinforced concrete wall construction, Christchurch, New Zealand (J. Bothara)

Wall, unreinforced masonry, New Zealand (A. Charleson)

Wood stud walls (left) and cold-formed steel stud wall (right) act as the Wall system for the purpose of Lateral Load-Resisting System classification; left photo shows a wood stud wall from New Zealand (A. Charleson), and the right photo shows a cold-formed steel stud wall from Canada (S. Brzev)



Confined masonry acts like a Wall system (Seismic Design Guide for Low-Rise Masonry Buildings, EERI and IAEE)

Assam type construction consists of small-sized wood columns and beams which are braced with ikra walls; this acts like a Wall system since connections between the wooden members are unable to transfer bending moments; this traditional construction in Assam, India has shown good performance in past earthquakes (People in Centre)

Dhaji Dhewari buildings in Kashmir, India consist of wood-reinforced brick masonry walls (D. Rai)

Cast-in place concrete wall construction, Kyrgyzstan (K. Kanbolotov)

Variants

- Shear Wall
- Load-bearing Wall
- Bracing Wall

Wattle and daub [WWD]

A w ooden frame around a lattice consisting of w oven tw igs (w attles that is filled or plastered w ith mud), reeds, grass, or bamboo. The earth is very clayey and mixed w ith straw or other vegetable fibres.

Wattle and daub construction, India (People in Centre)

Wattle and daub construction, India (People in Centre)

Wattle and daub w all detail (People in Centre)

Welded connections [WEL]

Structural steel members are welded together. This usually only applies to regular-weight steel members.

Welded connection of steel brace to gusset plate, New Zealand (A. Charleson)

Welded steel brace connection, USA (S. Brzev)

Wholesale trade and storage (warehouse) [COM2]

All w arehouses and storage facilities.

Wood [RWO]

The roof structure is constructed of w ood

Wood [W]

Wood construction may consist of posts or columns and beams as in Post and Beam construction, as light w ood framing consisting of closely-spaced posts as in light w ood-framed Walls, or as in solid w ood construction w here thick planks or logs are laid horizontally to create load-bearing Walls.

Wood-based sheets on joists or beams [FW3]

Plyw ood, particle board, or other sheet material fixed over w ooden members.

Wood based sheets on joists or beams, Wellington, New Zealand (A. Charleson)

Wood-based sheets on rafters or purlins [RWO3]

Plyw ood, particle board, or other sheet material fixed over w ooden members.

Wood-based sheets on rafters or purlins, California (A. Charleson)

Plyw ood sheets over w ood rafters or purlins - a roof under construction in Vancouver, Canada (S. Brzev)

Wood, other [WO]

Any w ood construction type that is know n but does not fit the descriptions of the other w ood construction types in this table.

Wood building, Padang, Indonesia (J. Bothara)

Wood-reinforced [RW]

Masonry walls that are reinforced against earthquake forces by horizontal, vertical, and/or diagonal wood members. The wood reinforcement might consist of wood bond beams at eaves level to tie walls together or may be vertical posts attached to walls to reduce the amount of earthquake damage.

Rubble stone masonry in mud mortar with timber bands (local name: Bhatar), NWFP, Pakistan (J. Bothara)

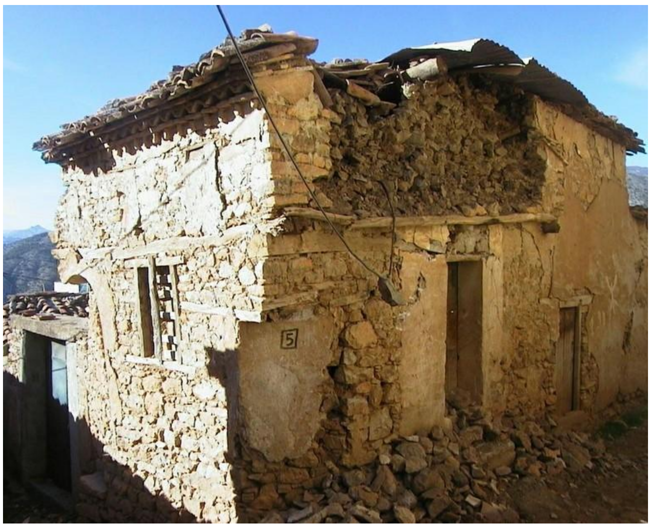
Taq is a timber-laced masonry construction where horizontal timbers are embedded in masonry walls at each floor level; this is a traditional construction found in Kashmir, India (D. Rai)

Adobe building with a wood bond beam at eaves level, Peru (M. Blondet)

Dhajji Dewari construction in Kashmir, India (D. Rai)

"Pombalino" buildings in Lisbon, Portugal are historic masonry buildings with wooden bracing members; these buildings were built after the devastating 1755 earthquake - refer to World Housing Encyclopedia Report 92 (Cardoso, Lopes, Bento, and D'Ayala) for more information

Wood reinforced adobe buildings can be found in Chile (tabiquería de madera rellena de adobe). The photo at the top shows a building in Santiago (note the exposed wall portion) and the bottom photos shows a building in Cauquenes damaged in the 2010 Maule earthquake (S. Brzev and M. Astroza)



Wood-reinforced stone masonry, Algeria (M. Farsi)

Variants

- Timber-reinforced
- Cator and cribbage (often used in British literature)
- Taq and Dhajji Dewari (Pakistan and Indian Kashmir)
- Bhatar (Pakistan)
- Gōz-Dolmaz and Hatil (Turkey)
- Gaiola Pombalina (in Portugal)
- Casa Baraccata (Calabria, Italy)
- Tabiquería de madera rellena de adobe (Chile)

Wood, unknown [W99]

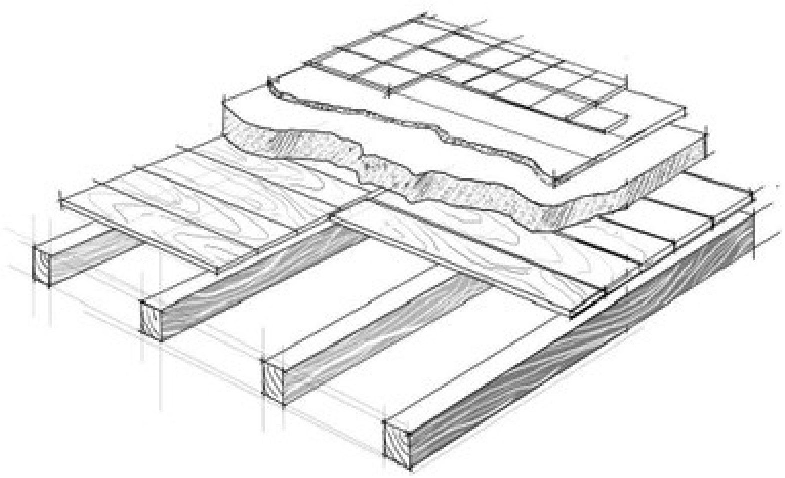
It is clear that the structural material resisting lateral loads is w ood, but the type of w ood construction is unknow n. The w ood structure may be hidden, or information about it is unavailable.

Wood house, Christchurch, New Zealand (W. Clark)

Wood house, Tajikistan (J. Niyazov)

Wooden beams or trusses and joists supporting heavy flooring [FW2]

Examples include a w ooden floor w ith a balast fill (earth or other material) covered by clay tiles, found in high precipitation regions around the w orld. Another example of heavy covering is stone tiles, w hich are used for roofing and flooring.

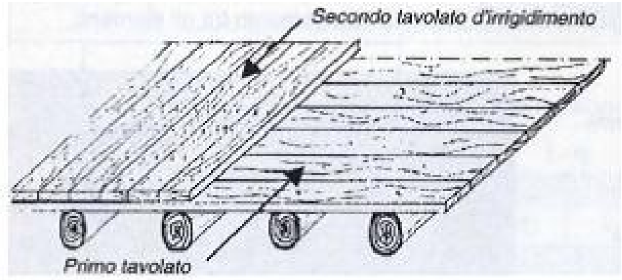


Floor structure w ith w ooden beams and planks, balast fill, and tile flooring (Improving Seismic Performance of Stone Masonry Buildings, Bothara and Brzev, EERI, 2011)

Wood floor w ith heavy overlay, India (S. Brzev)

Wooden beams or trusses and joists supporting light flooring [FW1]

Wooden beams or trusses and joists, supporting light flooring, e.g. w ooden planks.



Wooden beams w ith tw o perpendicular layers of w ood-plank flooring, Italy (Maffei et al. 2006)

Wooden floor structure overlaid by planks and bamboo strips, Nepal (World Housing Encyclopedia Report 74)

Wooden joists supporting light flooring, Portugal (S. Brzev)

Wooden beams or trusses with heavy roof covering [RWO2]

Wooden beams or trusses and joists, supporting heavy roof covering. Examples include a sloped wooden roof with a layer of earth covered by clay roof tiles, found in high precipitation regions around the world. Another example of heavy covering is stone tiles, which are used for roofing.

This also includes flat roofs with heavy roof covering made from mixture of clay, straw and tamped earth. New layers are added annually to the roof as a protection against rain and snow percolation. These roofs are predominantly found in single-storey buildings in rural areas of Eastern Turkey, Iran, Afghanistan, Pakistan, India, China, as well as in the Andean highlands and other regions.

Flat wooden roof with heavy mud and straw overlay, Iran (A. Mahdizadeh, M. Yekrangnia)

Unreinforced masonry building in Baghlia City experienced roof collapse in the 2003 Boumerdes, Algeria earthquake; the timber roof structure supported clay tile roof covering (M. Farsi)

Typical flat roof found in adobe buildings in Peru made of w ooden (or bamboo) beams overlaid w ith straw , mud, and in some cases tiles or metal sheets (N. Tarque)

Wooden roof structure w ith stone slate tiles, Nepal (M. Schildkamp)

Wooden roof supporting clay tiles, Chile (S. Brzev)

Flat w ooden roof structure supporting heavy mud covering, India (S. Brzev)

Wooden roof w ith a heavy mud overlay caused many fatalities in the 1993 Maharashtra, India earthquake (S. Brzev)

Wooden exterior walls [EWW]

All types of wood cladding, including wood planks, wood shingles, plywood sheets. Also includes wood construction where it also forms the exterior wall surface, such as solid wood or log construction.

Wood plank cladding (lower level) and wood shingles (upper level), Canada (S. Brzev)

Wood plank siding, Cuba (S. Brzev)

Wood shingles cladding, Saint Martin (Caribbean) (S. Brzev)

Log wood walls, USA (S. Brzev)

Wood shingles, California, USA (S. Brzev)

Wooden floor [FW]

The floor structure is constructed of wood. Note that this refers to the structure, and not wood overlay flooring or plywood sheet laid over a different structural material.

Wooden floor, unknown [FW99]

It is clear that the floor structure is made from wood, but the type of wooden structural system is unknown. The system may be hidden, or information about it is unavailable.

Wooden or asphalt shingle roof covering [RMT7]

Wooden shingles are usually split wood, overlapping and fastened to wood battens. Wooden shingles are usually made of cedar, redwood, hardwood etc. Asphalt shingles are small overlapping sheets of asphalt, usually fastened to a plywood sheet substrate. An alternative form is made of glass fiber or polyester fleece impregnated with bituminous material (tar, asphaltic bitumen).

Wooden shingle roof covering, USA (S. Krstic)

A roof with asphalt shingle covering, Canada (S. Brzev)

Variants

- Felt
- Bitumen sheets

Wooden roof, unknown [RWO99]

It is clear that the roof structure is made from wood, but the type of wooden structural system is unknown. The system may be hidden, or information about it is unavailable.

Wooden structure with light roof covering [RWO1]

Wooden beams or trusses and joists, supporting light roof covering, e.g. corrugated sheets. Also includes curved roof structures e.g. vaulted roofs.

Timber beams and joists supporting light roofing, New Zealand (W. Clark)

Wooden roof truss structure, Cuba (S. Brzev)

Wooden roof truss, California, USA (S. Brzev)

Wooden structure supporting wooden planks and steel sheet roofing, Chile (S. Brzev)

Wooden truss structure supporting light metal roofing, Chile (S. Brzev)

Wooden roof structure supporting light metal roofing, Indonesia (J. Bothara)

Wooden beam and joist roof, Peru (S. Brzev)

A church with a vaulted wooden roof in Curico, Chile damaged in the 2010 Maule, Chile earthquake (M.O. Moroni)

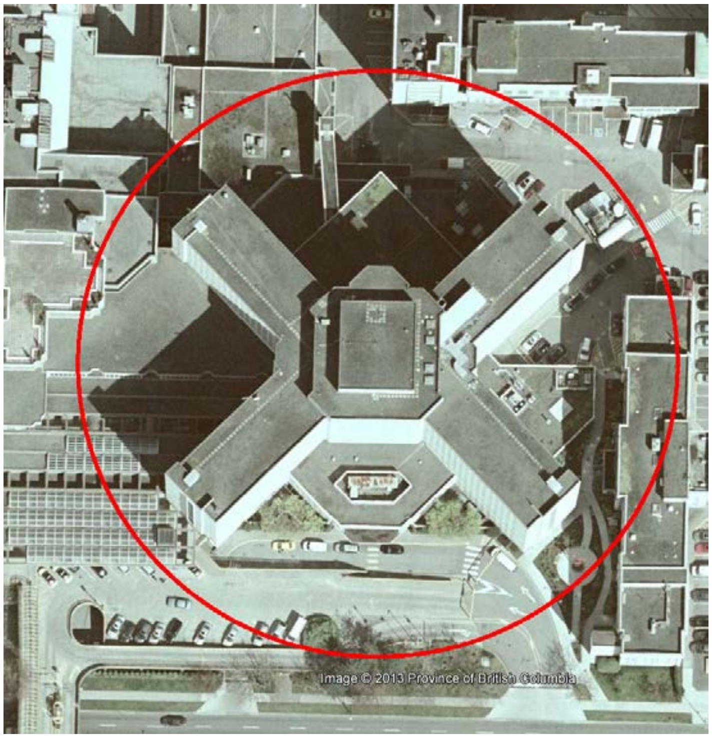
Curved wooden glulam beams supporting light metal roof covering, Canada (S. Brzev)

A roof structure consisting of steel decking supported by wooden glulam beams, Vancouver, Canada (S. Brzev)

X-shape [PLFX]

The footprint of the building when viewed in plan resembles the shape of the letter X.

Note that this also includes crucifom-shaped plans (resembling the "+" sign).



A building with X-shaped plan, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

A building with cruciform-shaped plan, Clock Tower Building, Kyoto University, Japan (left: Map data ©2013 Google, ZENRIN; right: C. Scawthorn)

Y-shape [PLFY]

The footprint of the building when viewed in plan resembles the shape of the letter Y.

A building with Y-shaped plan, Vancouver, Canada (Map data ©2013 Google, Province of British Columbia, DigitalGlobe, IMTCAN)

Year unknown [Y99]

The year of construction is unknow n. It is impossible to determine in w hich decade the building w as built, information is unavailable, or the building has not been inspected sufficiently to determine its age.

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APPENDIX A GEM Building Taxonomy Attributes

Table G1 GEM Building Taxonomy: Attributes

TaxT Attribute Group	#	Attribute	Reference	Attribute levels	Type	Example
Structural System	1	Direction	Table 1	Direction of the building		
	2	Material of the Lateral Load-Resisting System	Table 2	Material type (Level 1)	Text	Steel
				Material technology (Level 2)		
				Material properties (Level 3)		
	3	Lateral Load-Resisting System	Table 3	Type of lateral load-resisting system (Level 1)	Text	Braced frame
				System ductility (Level 2)		
Building Information	4	Height	Table 4	Height	Integer	4
	5	Date of Construction or Retrofit	Table 5	Construction completed (year)	Integer	1925
	6	Occupancy	Table 6	Building occupancy class - general (Level 1)	Text	Residential
				Building occupancy class - detail (Level 2)		
Exterior Attributes	7	Building Position within a Block	Table 7		Text	
	8	Shape of the Building Plan	Table 8	Plan shape (footprint)	Text	
	9	Structural Irregularity	Table 9	Regular or irregular (Level 1)	Text	Re-entrant corner
				Plan irregularity or vertical irregularity (Level 2)		
				Type of irregularity (Level 3)		
	10	Exterior Walls	Table 10	Exterior walls	Text	Wood

TaxT Attribute Group	#	Attribute	Reference	Attribute levels	Type	Example
Roof/Floor/ Foundation	11	Roof	Table 12	Roof shape (Level 1)	Text	Tile (clay, concrete)
				Roof covering (Level 2)		
				Roof system material (Level 3)		
				Roof system type (Level 4)		
				Roof connections (Level 5)		
	12	Floor	Table 11	Floor system material (Level 1)	Text	Concrete
				Floor system type (Level 2)		
				Floor connections (Level 3)		
	13	Foundation System	Table 13	Foundation system	Text	Shallow foundation, with lateral capacity

Table 1: Direction

ID	Level 1 (L1)	ID	Level 2 (L2)
	Direction of building under consideration		**Description of the direction**
DX	Direction X		
		D99	Unspecified direction
		PF	Parallel to street
DY	Direction Y		
		D99	Unspecified direction
		OF	Perpendicular to street

Table 2: Material of the Lateral Load-Resisting System

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
Attribute_ Type_Code	MAT_TYPE		MAT_TECH		
MAT99	Unknown material				
C99	Concrete, unknown reinforcement	CT99	Unknown concrete technology		
CU	Concrete, unreinforced	CIP	Cast-in-place concrete		
CR	Concrete, reinforced	PC	Precast concrete		
SRC	Concrete, composite with steel section	CIPPS	Cast-in-place prestressed concrete		
		PCPS	Precast prestressed concrete		
S	Steel			STEEL_CONN	
		S99	Steel, unknown	SC99	Steel connections, unknown
		SL	Cold-formed steel members	WEL	Welded connections
		SR	Hot-rolled steel members	RIV	Riveted connections
		SO	Steel, other	BOL	Bolted connections
ME	Metal (except steel)				
		ME99	Metal, unknown		
		MEIR	Iron		
		MEO	Metal, other		

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
Attribute_Type_Code	MAT_TYPE	MAT_TECH		MAS_MORT	
M99	Masonry, unknown reinforcement	MUN99	Masonry unit, unknown	MO99	Mortar type unknown
MUR	Masonry, unreinforced	ADO	Adobe blocks	MON	No mortar
MCF	Masonry, confined	ST99	Stone, unknown technology	MOM	Mud mortar
MR	Masonry, reinforced	STRUB	Rubble (field stone) or semi-dressed stone	MOL	Lime mortar
		STDRE	Dressed stone	MOC	Cement mortar
		CL99	Fired clay unit, unknown type	MOCL	Cement:lime mortar
		CLBRS	Fired clay solid bricks	SP99	Stone, unknown type
		CLBRH	Fired clay hollow bricks	SPLI	Limestone
		CLBLH	Fired clay hollow blocks or tiles	SPSA	Sandstone
		CB99	Concrete blocks, unknown type	SPTU	Tuff
		CBS	Concrete blocks, solid	SPSL	Slate
		CBH	Concrete blocks, hollow	SPGR	Granite
		MO	Masonry unit, other	SPBA	Basalt
		MASS_REIN		SPO	Stone, other type
		MR99	Masonry reinforcement, unknown		
		RS	Steel-reinforced		
		RW	Wood-reinforced		
		RB	Bamboo-, cane- or rope-reinforced		
		RCM	Fibre reinforcing mesh		
		RCB	Reinforced concrete bands		

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Material type		**Material technology**		**Material properties**
Attribute_Type _Code	**MAT_TYPE**		**MAT_TECH**		
E99	Earth, unknown reinforcement	ET99	Unknown earth technology		
EU	Earth, unreinforced	ETR	Rammed earth		
ER	Earth, reinforced	ETC	Cob or wet construction		
		ETO	Earth technology, other		
W	Wood				
		W99	Wood, unknown		
		WHE	Heavy wood		
		WLI	Light wood members		
		WS	Solid wood		
		WWD	Wattle and daub		
		WBB	Bamboo		
		WO	Wood, other		
MATO	Other material				

Table 3: Lateral Load-Resisting System

ID	Level 1 (L2)	ID	Level 2 (L2)
	Type of lateral load-resisting system		**System ductility**
Attribute_Type _Code	**LLRS**		**LLRS_DUCT**
L99	Unknown lateral load-resisting system	DU99	Ductility unknown
LN	No lateral load-resisting system	DUC	Ductile
LFM	Moment frame	DNO	Non-ductile
LFINF	Infilled frame	DBD	Equipped with base isolation and/or energy dissipation devices
LFBR	Braced frame		
LPB	Post and beam		
LWAL	Wall		
LDUAL	Dual frame-wall system		
LFLS	Flat slab/plate or waffle slab		
LFLSINF	Infilled flat slab/plate or infilled waffle slab		
LH	Hybrid lateral load-resisting system		
LO	Other lateral load-resisting system		

Table 4: Height

ID	Level 1 (L1)	ID		Definition	Examples
	Height				
Attribute_Type_Code					
H99	Number of storeys unknown				
Attribute_Type_Code	**STORY_AG**				
H	Number of storeys above ground				
		HBET	Range of number of storeys above ground	HBET:a,b = range of number of storeys (a=upper bound and b= lower bound)	Range HBET:3,1 (height range from 1 to 3 storeys)
		HEX	Exact number of storeys above ground	HEX:n = maximum number of storeys above ground level	Fixed number (integer) HEX:2 (two storeys)
		HAPP	Approximate number of storeys above ground	HAPP:n = approximate number of storeys above ground level	Fixed number (integer) HAPP:2 (two storeys)

ID	Level 1 (L1)	ID		Definition	Examples
	Height				
Attribute_Type_Code	**STORY_BG**				
HB	Number of storeys below ground				
		HB99	Number of storeys below ground unknown		
		HBBET	Range of number of storeys below ground		Range (meters) HBBET: 3,1 (between 1 and 3 levels of basement)
		HBEX	Exact number of storeys below ground		Fixed number (integer) e.g. HBEX:2 (two levels of basement)
		HBAPP	Approximate number of storeys below ground		
Attribute_Type_Code	**HT_GR_GF**				
HF	Height of ground floor level above grade				
		HF99	Height of ground floor level above grade unknown		
		HFBET	Range of height of ground floor level above grade	HFBET:a,b (a= upper bound and b=lower bound)	Range (meters) HFBET: 1.0,0.5 (between 0.5 m and 1.0 m)
		HFEX	Exact height of ground floor level above grade		HFEX:0.75 (exactly 0.75 m)

ID	Level 1 (L1)	ID		Definition	Examples
	Height				
		HFAPP	Approximate height of ground floor level above grade		HFAPP:0.5 (approximately 0.5 m)
Attribute_Type_Code	**SLOPE**				
	Slope of the ground				
		HD99	Slope of the ground unknown		
		HD	Slope of the ground	HD:a	Integer (degrees) e.g. HD :10 (10 degrees)

Table 5: Date of Construction or Retrofit

ID	Level 1 (L1)	Definition	Examples
	Date of construction or retrofit		
Attribute_Type_Code	**YR_BUILT**		
Y99	Year unknown		
YEX	Exact date of construction or retrofit	Year during which the construction was completed or retrofitted.	YEX:1936
YBET	Upper and lower bound for the date of construction or retrofit	The construction likely took place between 1930 and 1940.	YBET:1940,1930
YPRE	Latest possible date of construction or retrofit	The construction was completed before the World War II, thus the year entered is 1939.	YPRE:1939
YAPP	Approximate date of construction or retrofit	The construction was completed approximately in 1935	YAPP:1935

Note: There is a possibility of entering information related either to the date of original construction or the retrofit - whichever occurs later. For example, if a building was constructed in 1936 and it was retrofitted in 1991, the user should enter 1991.

Table 6: Occupancy

ID	Level 1 (L1)		ID	Level 2 (L2)
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**
Attribute_ Type_Code	OCCUPCY			OCCUPCY_DT
OC99	Unknown occupancy type			
RES	Residential			
			RES99	Residential, unknown type
			RES1	Single dwelling
			RES2	Multi-unit, unknown type
			RES2A	2 Units (duplex)
			RES2B	3-4 Units
			RES2C	5-9 Units
			RES2D	10-19 Units
			RES2E	20-49 Units
			RES2F	50+ Units
			RES3	Temporary lodging
			RES4	Institutional housing
			RES5	Mobile home
			RES6	Informal housing
COM	Commercial and public			
			COM99	Commercial and public, unknown type

ID	Level 1 (L1)		ID	Level 2 (L2)
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**
			COM1	Retail trade
			COM2	Wholesale trade and storage (warehouse)
Attribute_Type_Code	OCCUPCY			OCCUPCY_DT
			COM3	Offices, professional/technical services
			COM4	Hospital/medical clinic
			COM5	Entertainment
			COM6	Public building
			COM7	Covered parking garage
			COM8	Bus station
			COM9	Railway station
			COM10	Airport
			COM11	Recreation and leisure
MIX	Mixed use			
			MIX99	Mixed, unknown type
			MIX1	Mostly residential and commercial
			MIX2	Mostly commercial and residential
			MIX3	Mostly commercial and industrial
			MIX4	Mostly residential and industrial

ID	Level 1 (L1)		ID	Level 2 (L2)
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**
			MIX5	Mostly industrial and commercial
			MIX6	Mostly industrial and residential
IND	Industrial			
			IND99	Industrial, unknown type
			IND1	Heavy industrial
			IND2	Light industrial
AGR	Agriculture			
			AGR99	Agriculture, unknown type
			AGR1	Produce storage
			AGR2	Animal shelter
			AGR3	Agricultural processing
ASS	Assembly			
			ASS99	Assembly, unknown type
			ASS1	Religious gathering
			ASS2	Arena
			ASS3	Cinema or concert hall
			ASS4	Other gatherings
GOV	Government			
			GOV99	Government, unknown type
			GOV1	Government, general services

ID	Level 1 (L1)		ID	Level 2 (L2)
	Building occupancy class - general	**Definition**		**Building occupancy class - detail**
			GOV2	Government, emergency response
EDU	Education			
			EDU99	Education, unknown type
			EDU1	Pre-school facility
			EDU2	School
			EDU3	College/university, offices and/or classrooms
			EDU4	College/university, research facilities and/or labs
OCO	Other occupancy type			

Table 7: Building Position within a Block

ID	Level 1 (L1)
	Building Position within a Block
Attribute_Type_Code	**POSITION**
BP99	Unknown building position
BPD	Detached building
BP1	Adjoining building(s) on one side
BP2	Adjoining buildings on two sides
BP3	Adjoining buildings on three sides

Table 8: Shape of the Building Plan

ID	Level 1 (L1)
	Shape of the Building Plan
Attribute_Type_Code	**PLAN_SHAPE**
PLF99	Unknown plan shape
PLFSQ	Square, solid
PLFSQO	Square, with an opening in plan
PLFR	Rectangular, solid
PLFRO	Rectangular, with an opening in plan
PLFL	L-shape
PLFC	Curved, solid (e.g. circular, elliptical, ovoid)
PLFCO	Curved, with an opening in plan
PLFD	Triangular, solid
PLFDO	Triangular, with an opening in plan
PLFP	Polygonal, solid (e.g. trapezoid, pentagon, hexagon)
PLFPO	Polygonal, with an opening in plan
PLFE	E-shape
PLFH	H-shape
PLFS	S-shape
PLFT	T-shape
PLFU	U- or C-shape
PLFX	X-shape
PLFY	Y-shape
PLFI	Irregular plan shape

Table 9: Structural Irregularity

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Regular or irregular		**Plan irregularity or vertical irregularity**		**Type of irregularity**
Attribute_Type_Code	**STR_IRREG**				
IR99	Unknown structural irregularity				
IRRE	Regular structure				
IRIR	Irregular structure				
		Attribute_Type_Code	**STR_HZIR_P**		
		IRPP	Plan irregularity-primary	IRN	No irregularity
				TOR	Torsion eccentricity
				REC	Re-entrant corner
				IRHO	Other plan irregularity
		Attribute_Type_Code	**STR_HZIR_S**		
		IRPS	Plan irregularity-secondary	IRN	No irregularity
				TOR	Torsion eccentricity
				REC	Re-entrant corner
				IRHO	Other plan irregularity

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Regular or irregular		Plan irregularity or vertical irregularity		Type of irregularity
		Attribute_Type_Code	STR_VEIR_P		
		IRVP	Vertical structural irregularity - primary	IRN	No irregularity
				SOS	Soft storey
				CRW	Cripple wall
				SHC	Short column
				POP	Pounding potential
				SET	Setback
				CHV	Change in vertical structure (includes large overhangs)
				IRVO	Other vertical irregularity
		Attribute_Type_Code	STR_VEIR_S		
		IRVS	Vertical structural irregularity - secondary	IRN	No irregularity
				SOS	Soft storey
				CRW	Cripple wall
				SHC	Short column
				POP	Pounding potential
				SET	Setback
				CHV	Change in vertical structure (includes large overhangs)
				IRVO	Other vertical irregularity

Table 10: Exterior Walls

ID	Level 1 (L1)
	Exterior Walls
Attribute_Type_Code	**NONSTRCEXW**
EW99	Unknown material of exterior walls
EWC	Concrete exterior walls
EWG	Glass exterior walls
EWE	Earthen exterior walls
EWMA	Masonry exterior walls
EWME	Metal exterior walls
EWV	Vegetative exterior walls
EWW	Wooden exterior walls
EWSL	Stucco finish on light framing for exterior walls
EWPL	Plastic/vinyl exterior walls, various
EWCB	Cement-based boards for exterior walls
EWO	Material of exterior walls, other

Table 11: Roof

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
	Roof shape		**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
Attribute_Type_Code	**ROOF_SHAPE**		**ROOFCOVMAT**		**ROOFSYSMAT**		**ROOFSYSTYP**		**ROOF_CONN**
RSH99	Unknown roof shape	RMT99	Unknown roof covering	R99	Roof material, unknown			RWC99	Roof-wall diaphragm connection unknown
RSH1	Flat	RMN	Concrete roof without additional covering					RWCN	Roof-wall diaphragm connection not provided
RSH2	Pitched with gable ends	RMT1	Clay or concrete tile roof covering	RM	Masonry roof			RWCP	Roof-wall diaphragm connection present
RSH3	Pitched and hipped	RMT2	Fibre cement or metal tile roof covering			RM99	Masonry roof, unknown	RTD99	Roof tie-down unknown
RSH4	Pitched with dormers					RM1	Vaulted masonry roof	RTDN	Roof tie-down not provided
RSH5	Monopitch	RMT3	Membrane roof covering			RM2	Shallow-arched masonry roof	RTDP	Roof tie-down present
RSH6	Sawtooth	RMT4	Slate roof covering			RM3	Composite masonry and concrete roof system		
RSH7	Curved	RMT5	Stone slab roof covering	RE	Earthen roof				
RSH8	Complex regular	RMT6	Metal or asbestos sheet roof covering			RE99	Earthen roof, unknown		
RSH9	Complex irregular	RMT7	Wooden or asphalt shingle roof covering			RE1	Vaulted earthen roof		
RSHO	Roof shape, other	RMT8	Vegetative roof covering	RC	Concrete roof				

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
	Roof shape		**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
		RMT9	Earthen roof covering			RC99	Concrete roof, unknown		
		RMT10	Solar panelled roofs			RC1	Cast-in-place beamless reinforced concrete roof		
		RMT11	Tensile membrane or fabric roof			RC2	Cast-in-place beam-supported reinforced concrete roof		
		RMTO	Roof covering, other			RC3	Precast concrete roof with reinforced concrete topping		
						RC4	Precast concrete roof without reinforced concrete topping		
				RME	Metal roof				
						RME99	Metal roof, unknown		
						RME1	Metal beams or trusses supporting light roofing		
						RME2	Metal roof beams supporting precast concrete slabs		
						RME3	Composite steel roof deck and concrete slab		
				RWO	Wooden roof				
						RWO99	Wooden roof, unknown		
						RWO1	Wooden structure with light roof covering		

ID	Level 1	ID	Level 2	ID	Level 3 (L3)	ID	Level 4 (L4)	ID	Level 5 (L5)
	Roof shape		**Roof covering**		**Roof system material**		**Roof system type**		**Roof connections**[1]
						RWO2	Wooden beams or trusses with heavy roof covering		
						RWO3	Wood-based sheets on rafters or purlins		
						RWO4	Plywood panels or other light-weight panels for roof		
						RWO5	Bamboo, straw or thatch roof		
				RFA	Fabric roof				
						RFA1	Inflatable or tensile membrane roof		
						RFAO	Fabric roof, other		
				RO	Roof material, other				

Table 12: Floor

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Floor system material		**Floor system type**		**Floor connections**
Attribute_Type_Code	**FLOOR_MAT**		**FLOOR_TYPE**		**FLOOR_CONN**
FN	No elevated or suspended floor material (single-storey building)				
F99	Floor material, unknown			FWC99	Floor-wall diaphragm connection unknown
FM	Masonry floor			FWCN	Floor-wall diaphragm connection not provided
		FM99	Masonry floor, unknown	FWCP	Floor-wall diaphragm connection present
		FM1	Vaulted masonry floor		
		FM2	Shallow-arched masonry floor		
		FM3	Composite cast-in-place reinforced concrete and masonry floor system		
FE	Earthen floor				
		FE99	Earthen floor, unknown		
FC	Concrete floor				
		FC99	Concrete floor, unknown		
		FC1	Cast-in-place beamless reinforced concrete floor		
		FC2	Cast-in-place beam-supported reinforced concrete floor		

ID	Level 1 (L1)	ID	Level 2 (L2)	ID	Level 3 (L3)
	Floor system material		**Floor system type**		**Floor connections**
		FC3	Precast concrete floor with reinforced concrete topping		
		FC4	Precast concrete floor without reinforced concrete topping		
FME	Metal floor				
		FME99	Metal floor, unknown		
		FME1	Metal beams, trusses, or joists supporting light flooring		
		FME2	Metal floor beams supporting precast concrete slabs		
		FME3	Composite steel deck and concrete slab		
FW	Wooden floor				
		FW99	Wooden floor, unknown		
		FW1	Wooden beams or trusses and joists supporting light flooring		
		FW2	Wooden beams or trusses and joists supporting heavy flooring		
		FW3	Wood-based sheets on joists or beams		
		FW4	Plywood panels or other light-weight panels for floor		
FO	Floor material, other				

Table 13: Foundation System

ID	Level 1 (L1)
	Foundation System
Attribute_Type_Code	**FOUNDN_SYS**
FOS99	Unknown foundation system
FOSSL	Shallow foundation, with lateral capacity
FOSN	Shallow foundation, no lateral capacity
FOSDL	Deep foundation, with lateral capacity
FOSDN	Deep foundation, no lateral capacity
FOSO	Foundation, other

THE GLOBAL EARTHQUAKE MODEL

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